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Steelhead Trout Production Studies at Sitkoh Creek, Alaska, 2003–2004

by

David C. Love

and

Roger D. Harding

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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 Department of Fish and Game	ADF&G
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)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

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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David C. Love
Alaska Department of Fish and Game, Division of Sport Fish, Douglas
and
Roger D. Harding
Alaska Department of Fish and Game, Division of Sport Fish, Douglas

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

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David C. Love[a]
Alaska Department of Fish and Game, Division of Sport Fish
802 3rd St., Douglas, AK 99824, P.O. Box 110024, Juneau, AK 99811, USA

and
Roger D. Harding
Alaska Department of Fish and Game, Division of Sport Fish
802 3rd St., Douglas, AK 99824, P.O. Box 110024, Juneau, AK 99811, USA

[a] Author to whom all correspondence should be addressed: david.love@alaska.gov

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

The need for life history information on steelhead trout *Oncorhynchus mykiss* 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, i.e., smolt per spawner. This information will be combined with data from a steelhead carrying capacity project to lay the foundation for estimating escapement targets. This report summarizes the first 2 years of the multi-year project at Sitkoh Creek (2003 and 2004). A bi-directional immigrant/emigrant weir was operated on Sitkoh Creek from 10 April to 20 June 2003, and from 10 April to 25 June 2004. A total of 679 and 764 adult steelhead trout were counted in 2003 and 2004, respectively (historical range 520–1,108). All immigrating steelhead captured in 2003 and all untagged adult steelhead captured in 2004 were given passive integrative transponder (PIT) tags. The emigrant weir trap captured 3,162 steelhead smolt, 4,588 sea-run cutthroat trout, and 52,884 sea-run Dolly Varden during 2003. During 2004, a total of 3,742 steelhead smolt, 4,095 sea-run cutthroat trout, and 62,409 sea-run Dolly Varden emigrated downstream. Approximately 68% (460) post-spawning adult steelhead trout (kelts) survived spawning during 2003 and were successfully passed downstream through the weir. During 2004, 75% (573) survived and returned to saltwater. During 2003 and 2004, all untagged emigrating adult steelhead were PIT-tagged and released downstream. Additionally, 2,995 and 3,608 steelhead smolt were PIT-tagged and released downstream in 2003 and 2004, respectively. Scales collected from smolt and adult steelhead were imaged with electronic imaging software, and the images archived for future aging and reference.

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

INTRODUCTION

Steelhead *Oncorhynchus mykiss* in Alaska are found in coastal streams from Dixon Entrance to the Alaska Peninsula, but the largest number of streams supporting populations are located in Southeast Alaska. Southeast Alaska has 271 uniquely identified steelhead systems and an additional 60 tributaries that flow into these systems, for a total of 331 known water bodies containing steelhead (Harding 2005). Most systems are thought to support populations of 200 or fewer adults, but some, like the Thorne River, probably produce annual runs in excess of 1,000 adults. The small populations of steelhead in Southeast Alaska may be vulnerable to overexploitation if recreational or subsistence harvests significantly increase. Thus, there is a need to conservatively manage these relatively small populations. This project is designed to collect the data necessary to develop and support management options for ensuring adequate escapement to seed the available freshwater habitat. The specific research emphasis of this project is to collect demographic parameters 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 et al. *In prep*), will provide the information necessary to establish escapement targets.

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 invaluable in guiding management actions. This report summarizes the first two years (2003 and 2004) of a planned 7-year study and presents information on the steelhead immigration and emigration, length distributions, tagging, and preliminary scale-aging methodology. Emigrant counts and length frequency distributions of sea-run cutthroat trout and Dolly Varden char are also summarized.

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, and is a steelhead index stream, and supports a valued 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 about 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 6 times prior to 2003 with weirs operated in 1936, 1937, 1982, 1990, 1993, and 1996 (Chipperfield 1938; Jones 1983; Jones et al. 1991; Harding and Jones 1994; Yanusz 1997). Escapement counts ranged from 520 to 1,108 and averaged approximately 780 fish (Table 1). The Sitkoh system (creek and lake) ranked third highest in catch during 1999–2004 for all freshwater steelhead systems in Southeast Alaska, and CPUE estimates (steelhead caught, but not harvested, per days fished) ranked second only to the Situk River (Howe et al. 2001a-b; Jennings et al. 2004, 2006a-b, 2007; Walker et al. 2003). Current angling regulations permit retention of steelhead ≥36 in (914 mm) TL, thus effectively protecting 96% of the fish in Sitkoh Creek.

METHODS

An aluminum bipod weir was installed on Sitkoh Creek in 2003 and 2004. The weir contained separate emigrant-immigrant traps (2.5-m square) and was located approximately 400 m upstream from tidewater. This was the same site used during previous studies in 1982, 1990, 1993 and 1996. 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 by 1.8-m frames covered with vinyl-coated wire mesh (10 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 plastic fencing (18.75-mm square openings) and covered with sandbags. Both the wire mesh and plastic fencing 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. Plastic fencing was overlaid on both traps to create a barrier for fish ≥150 mm. The weir was scheduled to be operated from early April to the last week of June during each sample year. During both years, no adjustments were 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 09:00 each day during 2003 and 2004 and in addition, rainfall was recorded in 2004.

ADULT STEELHEAD

All immigrating adult steelhead were counted and measured to the nearest 1.0 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, and tagged with either 125 kHz (2003) or 134 kHz (2004) 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. In 2004, all immigrating adult steelhead were checked for adipose clips and previously-implanted PIT tags, measured, and passed upstream through the weir.

A systematic subsample of scales was collected from immigrating adult steelhead each year. Scales were removed from an area approximately

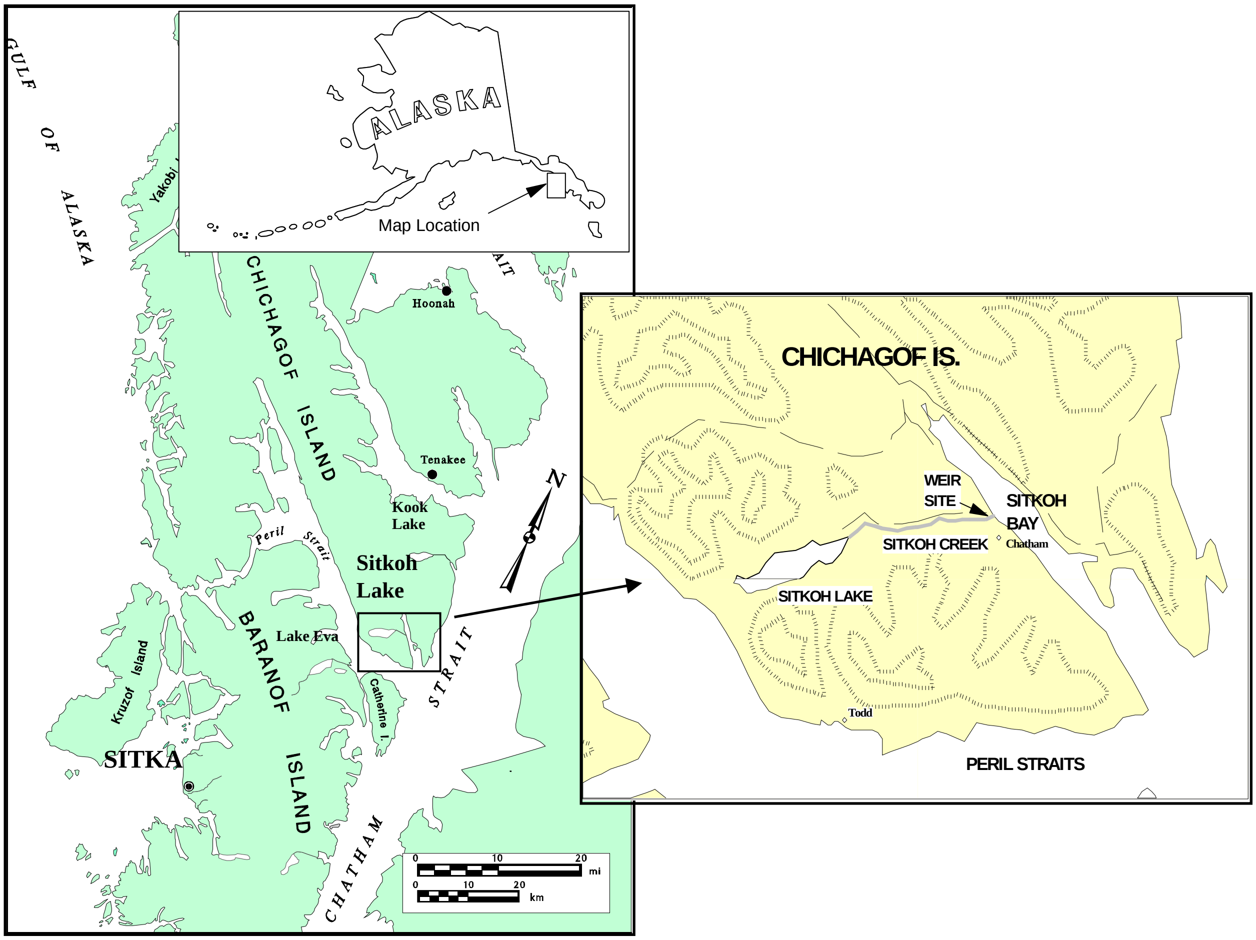


Figure 1.–Location of Sitkoh Lake, Sitkoh Creek, and weir site on Sitkoh Creek**.**

4–6 scale rows below and behind the dorsal fin, but above the lateral line. Untagged fish had 4 to 5 scales removed from the left side, while scales from previously tagged fish were removed from the right side. Scale samples were placed on labeled gum cards and pressed flat in sequential order for storage. Detached adipose fins were collected from 50 adults and preserved in 70% ethanol for later genetic sequencing by the U.S. Fish and Wildlife Service Genetics Laboratory in Anchorage.

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 finclip, measured, and sexed. If a fish had a PIT tag but was not finclipped, the adipose fin was removed and this was noted on the data forms accordingly.

Daily and cumulative numbers of adult fish passing through the weir were recorded for 2003 and 2004. Since all adult steelhead were measured during the period the weir was operable, the length composition of immigrant steelhead passed through the weir was known for both years. The weir was fish tight and was not breached during the sample period in 2003 and 2004, thus immigrant and emigrant counts were considered to be a census. Had the weir been breached or a portion of the immigration occurred prior to installing the weir, the immigration could have been estimated using Chapman's modified Petersen estimator for a closed population (Seber 1982).

A regression model ($R^2 = 0.98$, $P = 3.72e\text{-}41$) was developed using length data from 11 different streams in Southeast Alaska and across years between 1994 and 2006 (unpublished data) to estimate TL from FL for all steelhead in Sitkoh Creek during 2003 and 2004:

$$\text{TL (mm)} = 24.459689 + 1.0033394 * \text{FL (mm)} \quad (1)$$

The model was used to determine the number of adult steelhead of legal harvestable size, and lengths of harvestable male and female steelhead.

Table 1.–Historical escapements (based on weir counts) and sex composition of steelhead at Sitkoh Creek. Data for 1936 and 1937 from Chipperfield (1938); 1982 data from Jones (1983); 1990 data from Jones et al. (1991); 1993 data from Harding and Jones (1994); 1996 data from Yanusz (1997).

Year	Escapement (weir count)	Proportion Female	Proportion Male
1936	760		
1937	1,108		
1982	690	0.5	0.5
1990	661	0.61	0.39
1993	520	0.63	0.37
1996	926	0.62	0.38
Average	778		
2003	679	0.62	0.38
2004	764	0.60	0.40

STEELHEAD SMOLT

All emigrant steelhead smolt ≥150 mm were counted, examined for PIT tags, measured to the nearest 1 mm FL, PIT-tagged if untagged, and adipose-finclipped. Steelhead smolt were anesthetized using a buffered MS-222 solution prior to sampling. In 2003, 125 kHz PIT tags were implanted in all steelhead smolt. In 2004, the improved 134 kHz PIT tags were used, as these tags have a greater read range. Both tag types were "recaptured" during subsequent years. PIT tags were implanted into the left side of the fish just under the skin and just 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. In 2004, all emigrating juvenile steelhead were checked for adipose clips and previously implanted PIT tags prior to sampling.

Scales were collected from a systematic subsample of emigrant steelhead smolt. Scales were removed from an area approximately 4–6 scale rows below and behind the dorsal fin, but above the lateral line. Untagged fish were sampled on the left side, while previously-tagged fish were sampled on the right. About 15–20 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.

Smolt were held for varying periods of time to evaluate tag retention and mortality. A subsample was used if crowding became a problem. Fish were held inside custom-made, wire mesh boxes (10-mm square openings) that were placed in large plastic fish totes. The totes were filled with water continuously pumped from the stream to maintain a consistent temperature and dissolved oxygen level. Fish were released during low light conditions to mitigate predation. All smolt mortalities were counted, measured to the nearest 1 mm FL, and sampled for scales and otoliths. If they were PIT-tagged, mortalities were necropsied to assess tagging techniques.

We assumed that all steelhead smolt >150 mm FL were retained by the vinyl-coated wire mesh used to cover the face of the weir. A Petersen estimate was not calculated, as counts for both 2003 and 2004 were considered a census. Emigrant steelhead juveniles <150 mm FL could pass through the weir without being captured. These smaller fish represented an unknown percentage of the total emigration and were not considered as smolt for this project. All juvenile steelhead <150 mm FL were counted, measured to the nearest 1 mm FL, subsampled for scales, and released. Otoliths were collected from mortalities.

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 Jones (*Undated/Unpublished*) for steelhead trout. As described in Erickson (1999), scale ages were determined primarily from the area of the scale lying 45° off either side of an imaginary reference line drawn along the longest axis of the

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

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. Not having known-aged samples, scale ages were considered to be estimated, not determined (Ericksen 1999). Scale-aging technicians made 2 independent readings of scale samples to estimate the initial age of each fish. Prior to each reading, the scale images were "shuffled," or other measures were taken to ensure no information from previous readings was available. Disagreements between the replicate readings were tallied following the second reading, and those scales not in agreement were read a third time (after being randomized to prevent access to previous readings). The modal age of the 2 to 3 readings were taken as the estimated age. If all 3 readings disagreed, the sample was rejected.

Paired scale-otolith samples collected from smolt mortalities in 2003 have not been analyzed. Scale and otolith samples will be read 3 times by 3 separate technicians.

Aging of scales collected from immigrant adults will be completed, pending age validation comparisons to return tag data for 2004–2007. Ocean ages of repeat spawning and skip spawning adults, as well as "known ocean age" at initial spawn of previously-tagged smolt, will be obtained during subsequent years of this study. The "scale read" ocean age will then be compared to "known ocean age" based on PIT tag capture history. Tallies of the differences between true and estimated ocean ages will be compiled over time to determine bias in readings. Functionally significant differences between the 2 measures of ocean age (i.e., more that 0.5 years different on average) will be investigated to determine if the ocean-age reading criteria based on scales can be modified to improve reading accuracy. Scale-based age estimates for both adult and smolt steelhead sampled in 2003 and 2004, electronic imaging, and aging methodology will be summarized in FDS reports to be completed in 2008 and 2009

CUTTHROAT TROUT AND DOLLY VARDEN CHAR

All downstream-migrating Dolly Varden char and cutthroat trout were counted and checked for the presence of tags or marks applied during studies in Sitkoh Creek in 1996. Length to the nearest 1 mm FL was collected from a subsample of Dolly Varden char and cutthroat trout captured on a daily basis. Scales were not collected from either species.

Size composition of migrant Dolly Varden char and cutthroat trout were estimated using the following equation:

$$\hat{p}_a = \frac{n_a}{n} \qquad (2)$$

$$\hat{var}[\hat{p}_a] = \left(1 - \frac{n}{N}\right)\frac{\hat{p}_a(1-\hat{p}_a)}{n-1} \qquad (3)$$

where $\hat{p}_a$ = estimated proportion of group a (size group), n_a = number of sampled fish in group a, N = total number of fish in the emigrating population, and n = number of fish successfully measured for length.

RESULTS

2003

Adult Steelhead-Immigration

The Sitkoh Creek weir was continuously operated from 10 April through 19 June, 2003. A total of 673 adult steelhead were passed upstream through the Sitkoh Creek weir during 2003. Every adult immigrant received a PIT tag and an adipose finclip. One fish was released without a tag, despite having an adipose fin clipped and lengths taken (the tag was found in the needle after release). Six additional untagged emigrant fish were also captured. Adding these to the immigrant count gives a minimum total known census of 679 fish. Scale samples were taken from 224 immigrant steelhead, or 33% of the total adult escapement. Electronic scale images were created and archived for future analysis.

The first adult was captured in the upstream trap on 11 April, and the last on 6 June. The peak daily count (76) occurred on 25 April, and the midpoint of the run, on 29 April. Most of the immigration occurred prior to 15 May, while water temperature was still below 10°C. Upstream migration seemed to follow periods of increased stream discharge and presumed increased precipitation (Figure 2).

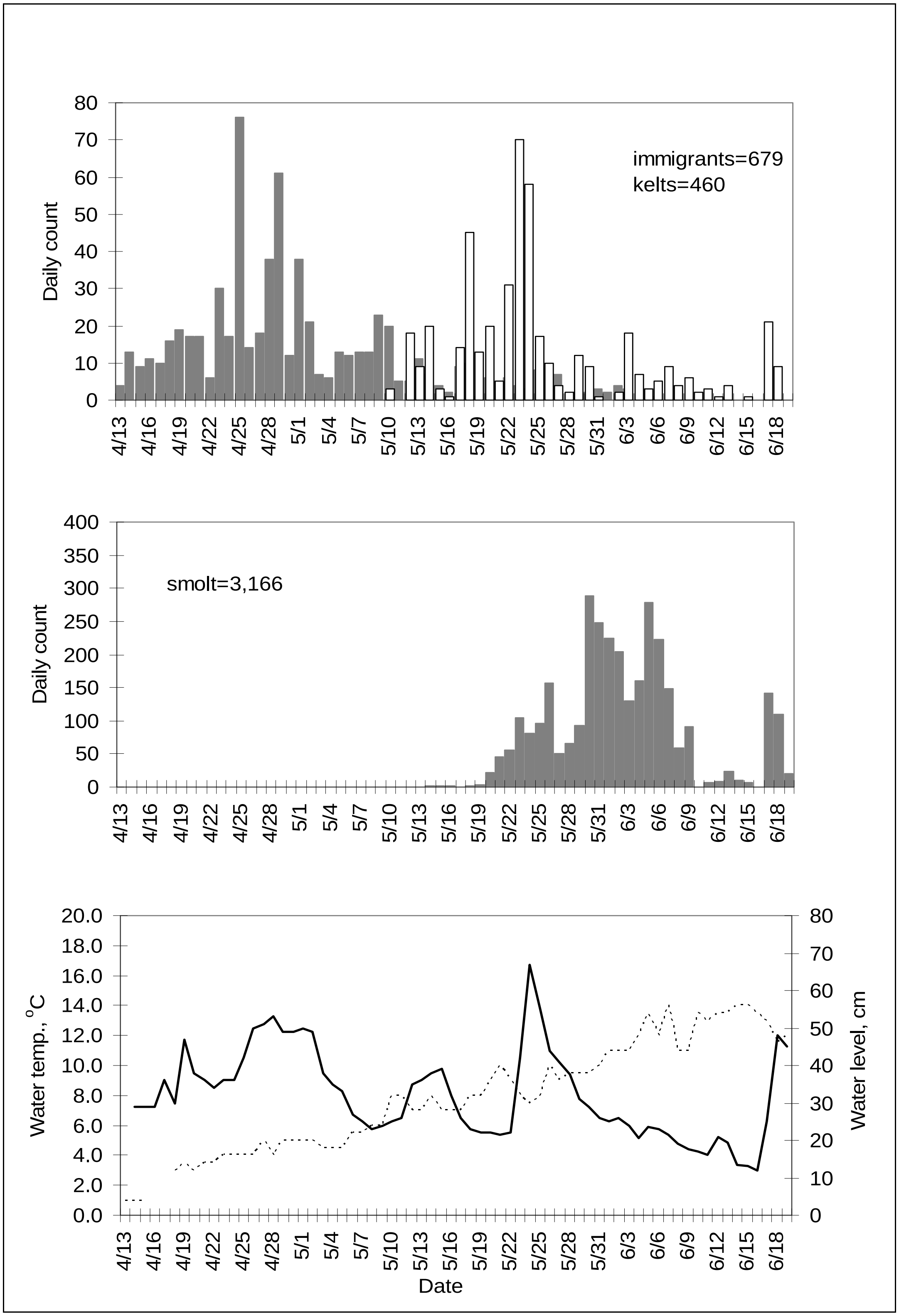


Figure 2.–Daily counts of immigrant steelhead (top panel solid bar graph) and downstream kelts (top panel clear bar graph), emigrant steelhead smolt (center panel), and daily measurements of water level in cm (solid line), and water temperature in °C (stippled line) at Sitkoh Creek, 2003 (bottom panel).

Females made up the majority of the run at 62% (415 fish), while males represented 38% (257 fish); 1 adult steelhead was not sexed. Although female immigrants were more abundant overall, an equal number of males and females moved upstream through the weir prior to 28 April. After 28 April, proportionately more females than males immigrated into Sitkoh Creek (Figure 3). The spawning immigration was largely complete by 26 May, when the cumulative proportion of females to males was 1.6:1.

The fork length measurements of all immigrant steelhead passed through the weir averaged 751 mm FL and had SD = 74.7 mm; the range was 555 to 910 mm (N = 673). Proportionately more fish >750 mm FL were females and fish <750 mm were predominately males (Figure 4). The length for all males averaged 728 mm FL and had SD = 89.3 mm (N = 257); for females, length averaged 766 mm FL and had SD = 59.6 mm (N = 415). In addition to fork length, total length was measured on 427 fish. These data were included in the Southeast regionwide regression model described above (equation 1). In 2003, 16 fish (2.4 % of the total immigrant steelhead run) met the minimum length requirements for sport fish retention.

Adult Steelhead-Emigration

There were 460 adult steelhead captured emigrating from Sitkoh Creek in 2003. Of these, 454 had been previously marked during their upstream migration, and 6 were untagged kelts. The first fish was captured leaving the system on 10 May, the last was captured on 18 June, and the midpoint of the emigration was on 23 May. The peak daily downstream count (70) occurred on 23 May (Figure 2). From May 11 to June 20, more females (67%) emigrated from the system following spawning than did males, although this was similar to the sex ratio of the spawners entering the system. The adipose-clipped fish captured in the upstream trap and unintentionally released without a PIT tag was recaptured and tagged. All untagged emigrant fish were PIT-tagged, sexed, and measured. Post-spawning survival was approximately 67.7% (460 emigrants/679 immigrants) in 2003.

Steelhead Smolt

A total of 3,162 steelhead smolt and 4 juvenile (parr) steelhead were captured emigrating through the weir during 2003. Of those, 3,004 were released alive and 2,995 received a PIT tag. There were 13 fish released without a tag: the 4 juvenile (parr) steelhead that did not meet the minimum size requirement of ≥150 mm FL for tagging, 7 smolt that had lost a significant amount of scales and were visibly stressed, and 2 smolt that lost their tags in the holding tank and were not re-tagged prior to release. There were 158 smolt steelhead mortalities, or about 5% (of 3,162 smolt captured). Paired scale and otoliths samples were collected from 80% of the sample mortalities.

The first smolt was captured at the weir on 14 May, the last on 19 June, and the midpoint of the run was 1 June. The peak daily count (288) occurred on 30 May (Figure 2). Initially, PIT-tagged smolt were held until darkness before release. This resulted in high mortality due to excessive descaling in their attempts to escape from the holding pen. We reduced the holding time following PIT-tagging and released fish after they recovered from the anesthetic. This appeared to allow recovery, resulted in less scale loss and abrasion, and lowered mortality. These methods were adopted for all subsequent years. Prior to making this change on 24 May, there were 63 mortalities (19%) out of 339 smolt. Once the new procedure was implemented, there were only 95 additional mortalities among the next 2,827 smolt. This resulted in a survival rate of 96.7% after 24 May and an overall survival rate of about 95%.

Fork length was measured on 3,158 smolt, or about 99.7% of the run. The mean FL for steelhead smolt sampled was 196 mm and had SD = 24.6 mm (range = 140 mm to 385 mm FL); the mode of the length frequency distribution was centered at 178 mm. Emigrant smolt that left Sitkoh Creek later in the season were smaller than earlier emigrants (Figure 5).

Scale samples were collected from 234 steelhead smolt (7.4%). Preliminary age analysis indicated that most smolt (78%) were approximately 3 and 4 years old. Ages ranged from age 2 to age 6 (Table 2). Typical age-3 and -4 scale ages are depicted in Figure 6a and 6b. Note the winter growth and "crossing over" of circuli on the outer margin of the age-3 scale. About 5% of the scale samples collected could not be read due to large, regenerated foci, dirty scales, or an insufficient number of scales in the sample. About 1% of all

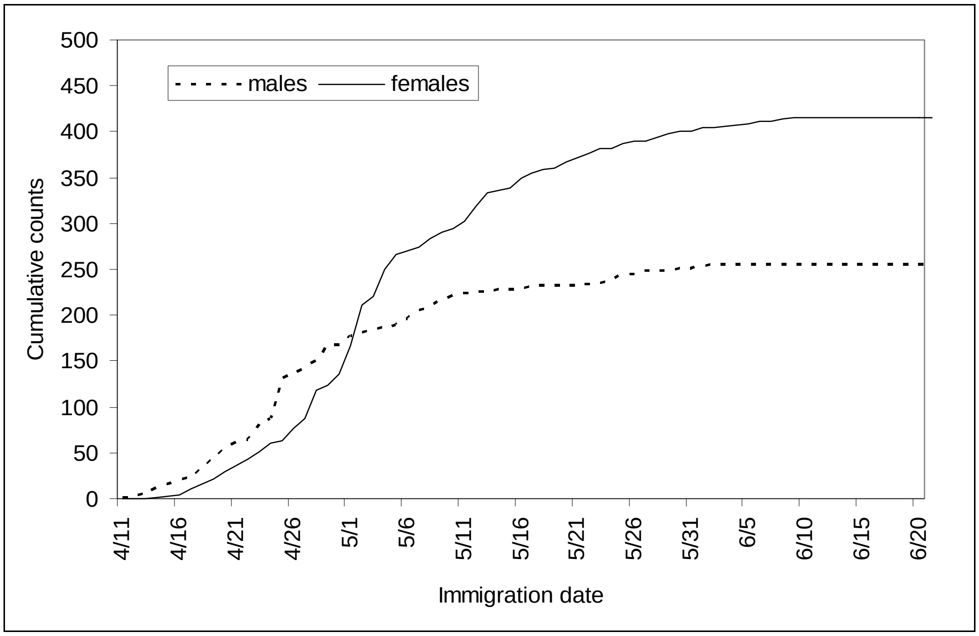


Figure 3.–Cumulative counts of adult male (stippled line) and female (solid line) steelhead immigrating through the Sitkoh Creek weir from April 11 to June 20, 2003.

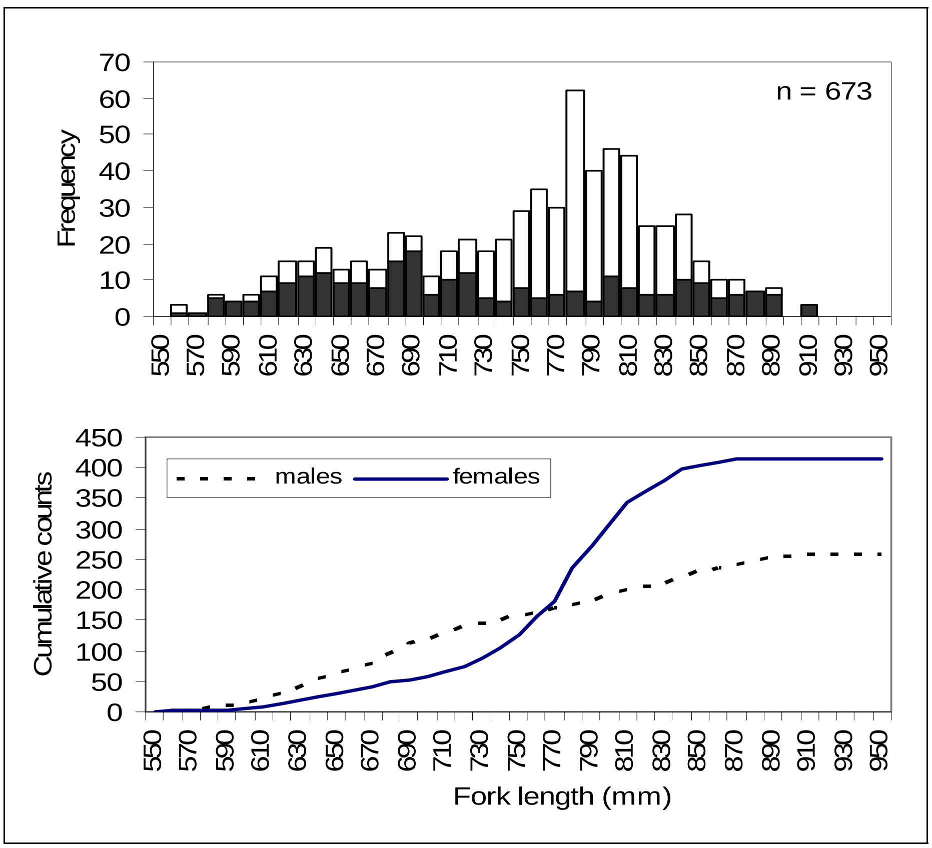


Figure 4.–Length-frequency distributions for male (filled bars) and female (clear bars) steelhead (top panel) and cumulative numbers by sex and length of adult male (stippled line) and female (solid line) steelhead immigrating into Sitkoh Creek during 2003 (bottom panel)**.**

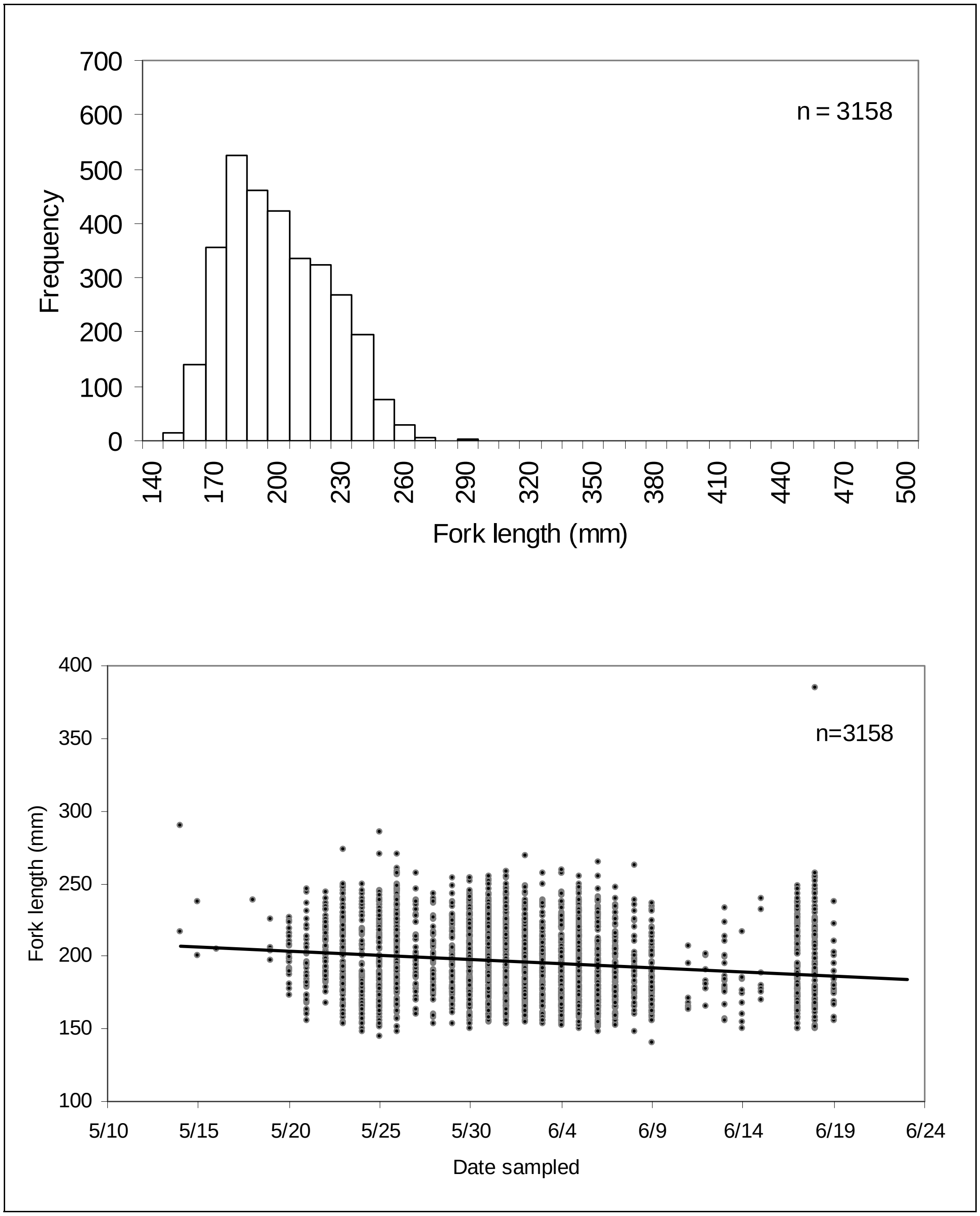
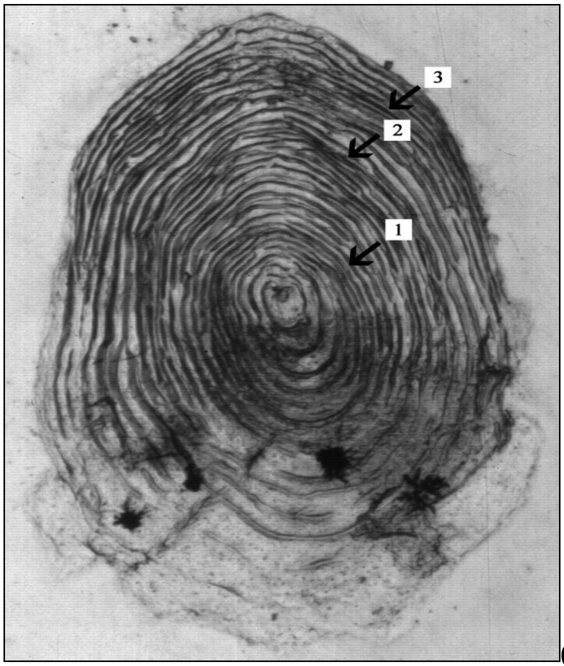


Figure 5.–Length-frequency distribution for steelhead smolt sampled emigrating out of Sitkoh Creek (top panel) and size (mm FL) of steelhead smolt by date captured at the weir during 2003 (bottom panel). Depicted trendline is best fit linear trendline (y=mx+b) of smolt size by sample date.

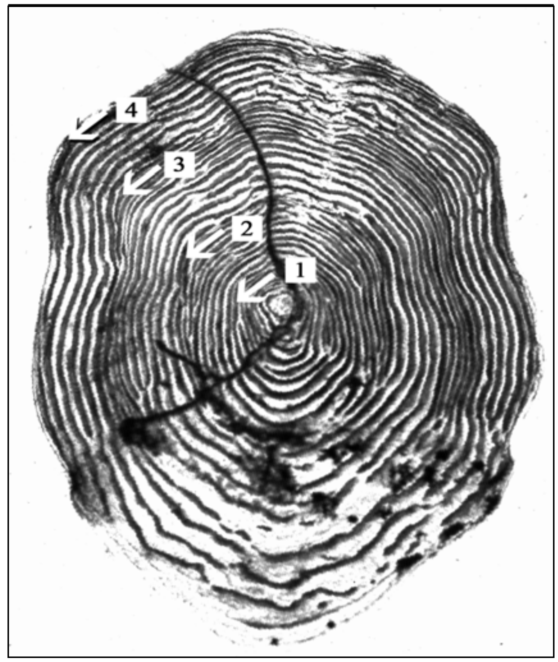
scales sampled could not be aged because there was not agreement between readings. An exceptionally large steelhead smolt measuring 385 mm FL was captured on 18 June, 2003. This emigrant fish exhibited all the physical characteristics of a smolt, but was between 6 and 7 years old, which is more typical for rainbow trout (Figure 6c). This scale was rejected as an unreadable scale due to the large, regenerated focus.

Dolly Varden Char

There were 52,884 Dolly Varden counted and passed downstream through the weir. The first fish was counted on 20 April and the peak daily count (8,239) was on 17 May. The midpoint of the



(a)



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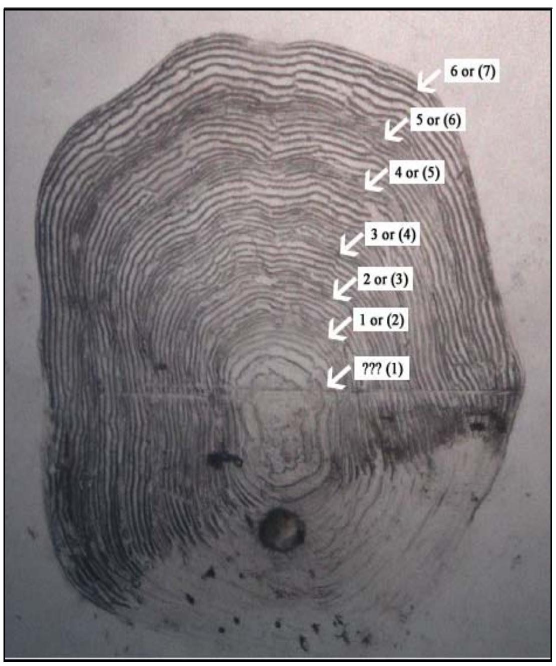


(c)

Figure 6.–Typical electronic scale images from scales sampled from steelhead smolt estimated to be 3-yrs old (a); 4-yrs old (b); and from an exceptionally large fish measuring 385 mm FL, captured in 2003 at Sitkoh Creek weir (c). Note the large, regenerated focus, and uncertainty of age-1 annuli.

run also occurred on 17 May (Figure 7). The length of those measured (n = 526) averaged 279 mm FL (SE = 2.7) and had SD of 62.8 mm. The range was 100 to 471 mm. The length distribution of emigrant Dolly Varden was essentially unimodal; the highest peak occurred within the 231–240 mm FL category, and the mode was at 228 mm FL. Fork length generally decreased as the run progressed (Figure 8).

Cutthroat Trout

A total of 4,588 emigrant cutthroat trout were enumerated through the weir. The first trout was captured on 19 April and the midpoint occurred on 23 May. The peak daily count (491) occurred on 17 June, just 3 days before the removal of the weir. Fish continued to be caught until the day before the weir was removed on June 19 (Figure

Table 2.–Proportion of the total steelhead escapement >914 mm TL and proportion by sex for all fish >914 mm TL for all years during which a weir was operated. Data from Chipperfield (1938), Jones et al. (1991), Harding and Jones (1994), and Yanusz (1997).

			Sex composition of steelhead >914 mm TL	
Year	No. of fish >914 mm TL[a]	Proportion of escapement >914 mm TL[a]	Proportion male (of fish >914 mm TL)	Proportion female (of fish >914 mm TL)
1982	48	0.070 [b]	0.380	0.620
1990	19	0.029 [b]	0.210	0.790
1993	29	0.056 [c]	0.530	0.470
1996	28	0.030 [b]	0.500	0.500
2003	16	0.024 [b]	0.875	0.125
2004	17	0.022 [b]	0.647	0.353

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

[b] All fish examined.

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

7). The length of those measured (n = 442) averaged 290 mm FL (SE = 2.8) and had SD = 59.4 mm. The range was 125 to 465 mm. The length distribution of emigrant cutthroat trout was somewhat bimodal, the highest peak occurred within the 331–340 mm FL size category and another strong mode occurred at 201–220 mm FL. Many of the larger fish were in spawning condition and left the Sitkoh system early in the outmigration. Overall size varied throughout the run, but generally fish size decreased through time (Figure 9).

Other Migrants

Rainbow trout, rainbow/cutthroat hybrids and returning sockeye salmon were also passed through the Sitkoh Creek weir during 2003. There were 28 rainbow trout passed downstream and 4 passed upstream that were not classified as steelhead. Two trout captured in the downstream box that displayed strong characteristics of both rainbow and cutthroat trout were classified as hybrids. There were also 81 returning sockeye salmon that passed through the weir between 29 May and 18 June. No pink salmon were observed in 2003.

2004

Adult Steelhead-Immigration

The weir was continuously operated from 10 April to 25 June, 2004. A total of 764 adult steelhead immigrated into Sitkoh Creek in 2004. Of this total, 654 untagged fish and 105 previously-tagged fish were passed upstream through the weir, and 5 were untagged kelts. Untagged fish were measured, sexed, and PIT tagged. Tagged fish were measured and sexed and the tag number was recorded. Females made up the majority of the total immigrant run at 60.3% (461 fish), while males represented 39.7% (303 fish, Table 1).

The first adult steelhead was caught on 10 April, the day after the weir was fish tight (1 fish was seen during weir installation on 8 April). The last fish was captured on 17 June. The peak daily count (52) occurred on 5 May. The midpoint of the run was on 2 May (Figure 10). Most of the immigration occurred prior to 23 May, when water temperatures were less than 10°C. Water temperatures increased steadily from 12°C around 12 June to almost 18 °C by 25 June

The length of immigrating steelhead averaged 740 mm FL and had SD = 69.5 mm (range = 576 to 930mm). Proportionately fewer females than males immigrated into Sitkoh Creek prior to 5 May (Figure 11) and proportionately more fish >750 mm FL were females (Figure 12). The length of males averaged 732 mm FL and had SD = 55.9 mm (N=303), and the length of females averaged 779 mm FL and had SD = 58.5 mm (N = 461).

Total length measurements from 291 fish were taken for inclusion in the regionwide regression model (equation 1) and evaluation of current size-based regulations. In 2004, 17 fish (2.2 % of the

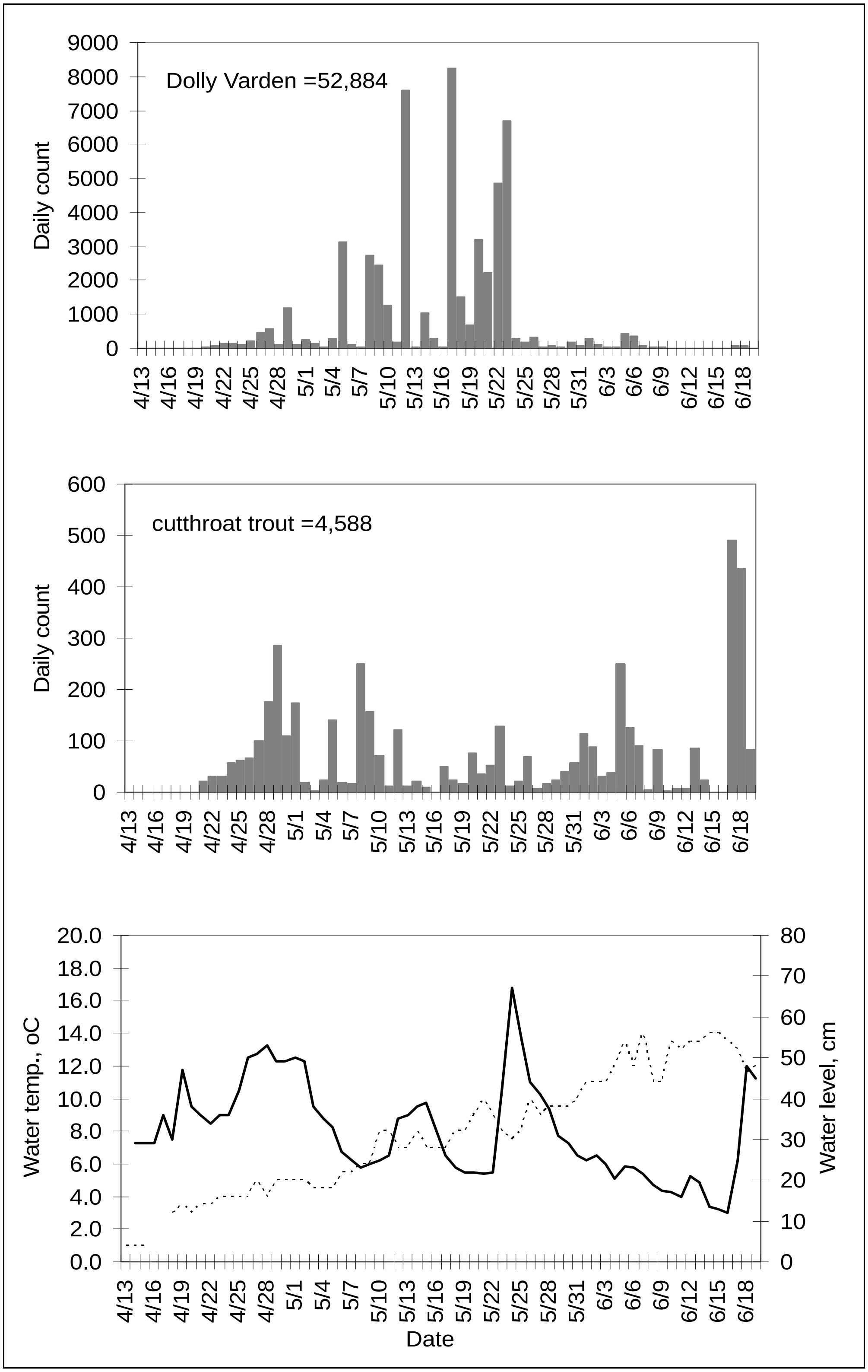


Figure 7.–Daily counts of emigrant Dolly Varden char (top panel) and emigrant cutthroat trout (center panel), and daily measurements of water level in cm (solid line) and water temperature in °C (stippled line) at Sitkoh Creek, 2003 (bottom panel).

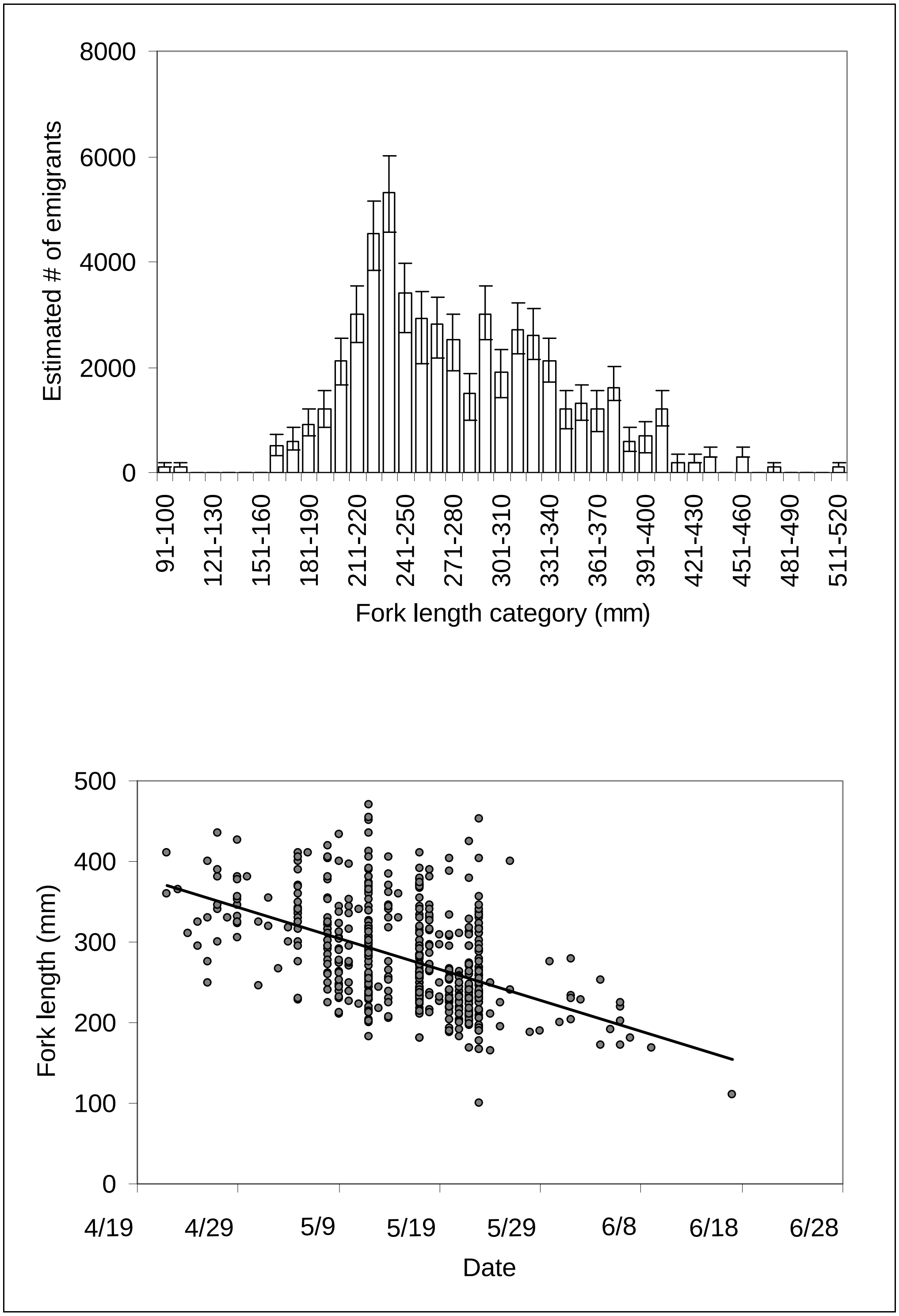


Figure 8.–Length-frequency distribution (top panel) and size at emigration (bottom panel) date for Dolly Varden char emigrating from Sitkoh Creek during 2003. Numbers are based on estimated proportions of emigrants by size category. Sample standard error bars are ± one SE (526 Dolly Varden measured, 52,884 passed downstream through weir). Linear trendline (y=mx+b) of Dolly Varden size by sample date depicted (bottom panel).

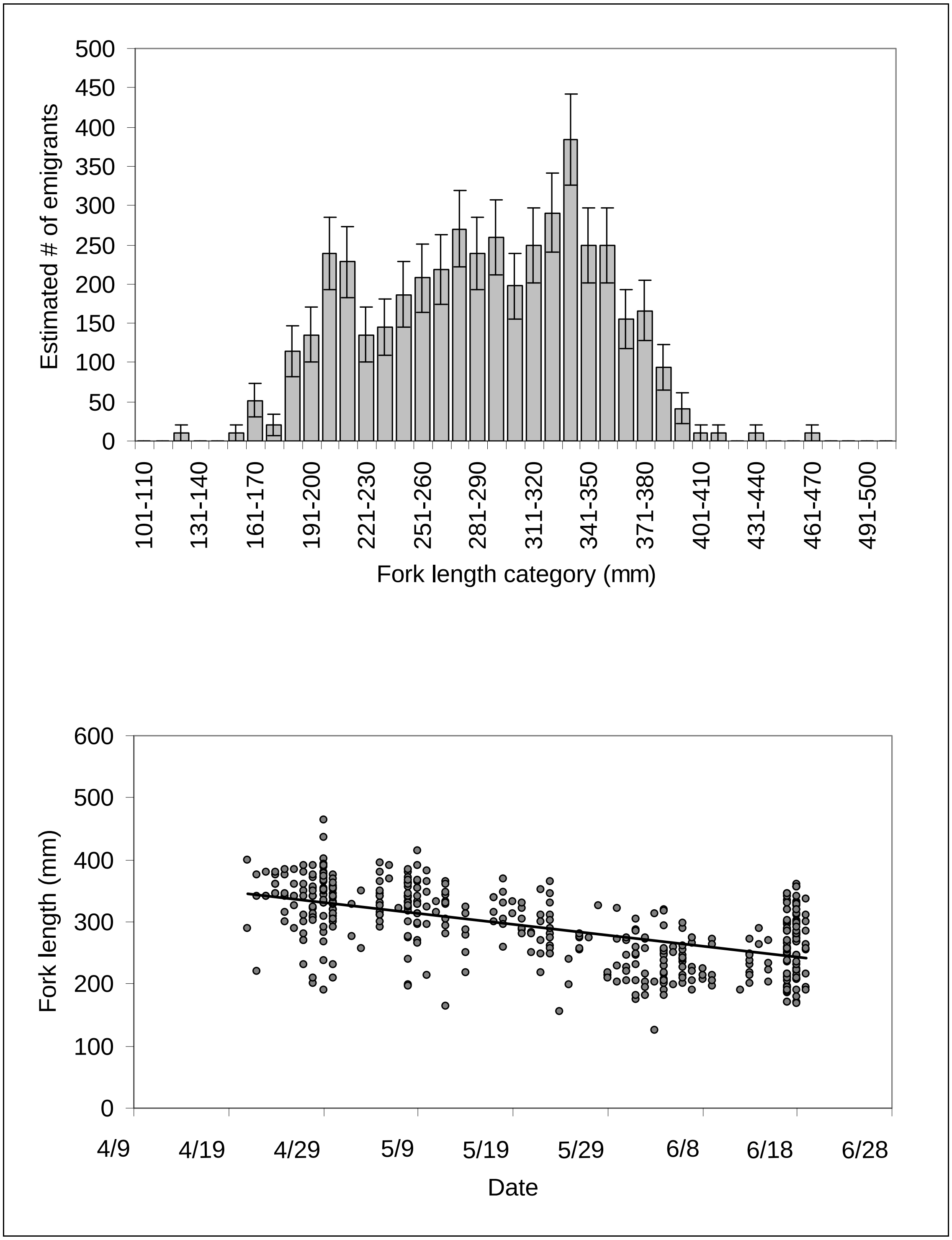


Figure 9.–Length-frequency distribution (top panel error bars are ± one SE) and size at emigration date (bottom panel) for cutthroat trout emigrating from Sitkoh Creek during 2003. Numbers are based on estimated proportions of emigrants by size category (442 cutthroat trout measured, 4,588 passed downstream through weir). Linear trendline (y=mx+b) of cutthroat trout size by sample date is depicted**.**

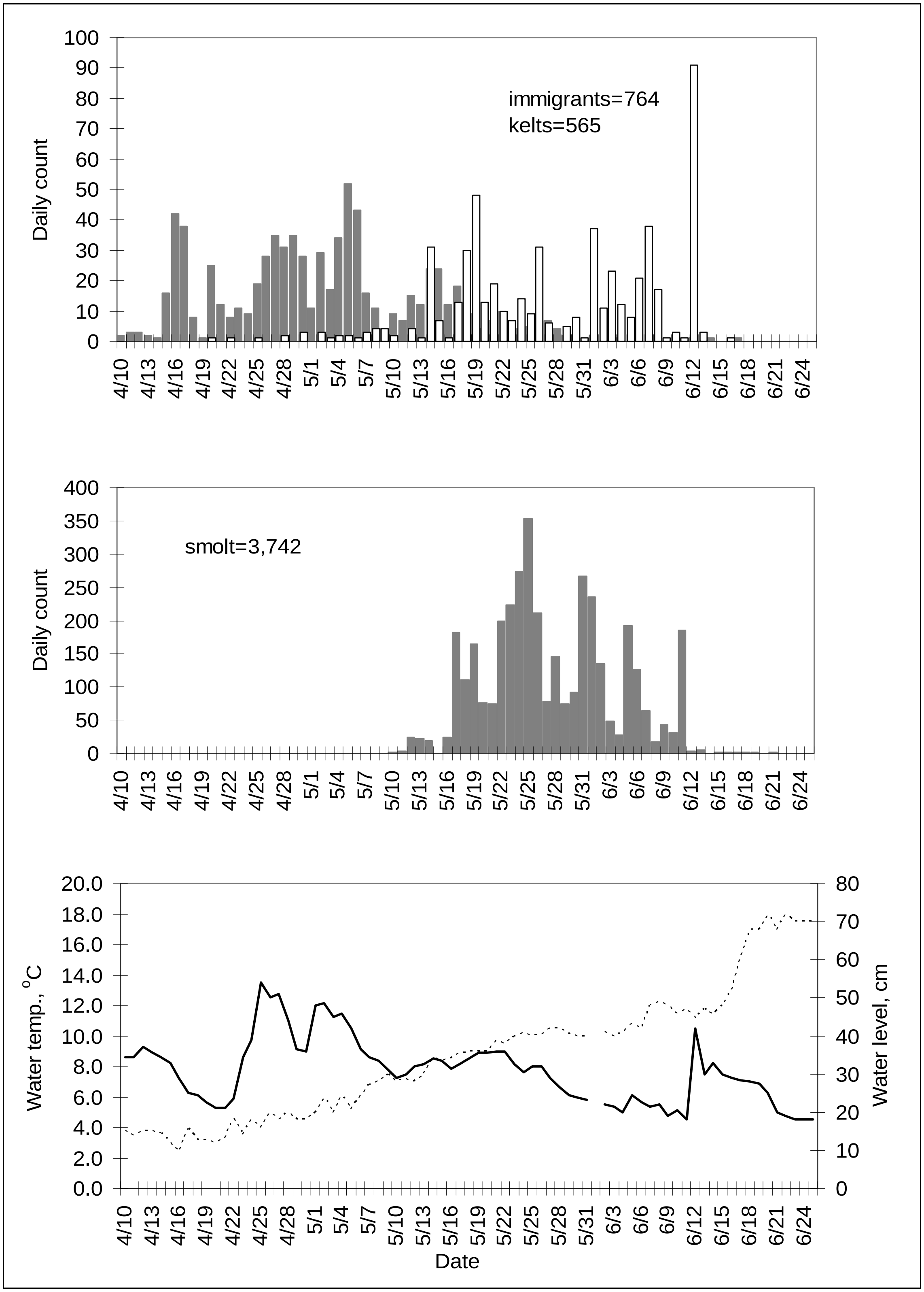


Figure 10.–Daily counts of adult upstream immigrant steelhead (top panel solid bar graph) and downstream kelts (top panel clear bar graph), emigrant steelhead smolt (center panel), and daily measurements of water level in cm (solid line), and water temperature in °C (stippled line) at Sitkoh Creek, 2004 (bottom panel).

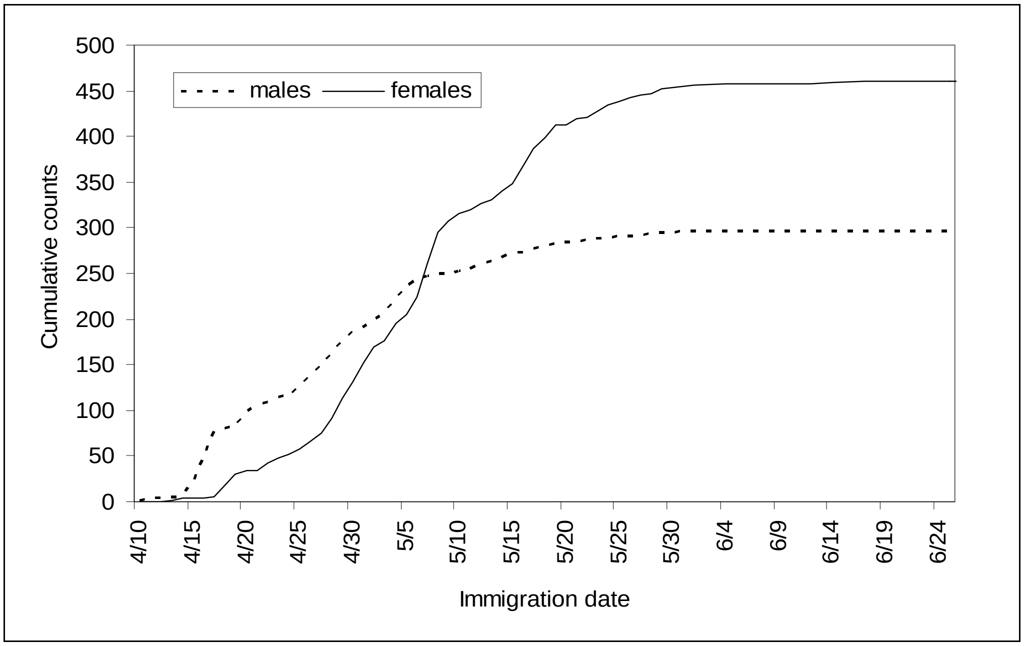


Figure 11.–Cumulative counts of adult male and female steelhead immigrating through the Sitkoh Creek weir from April 10 to June 25, 2004.

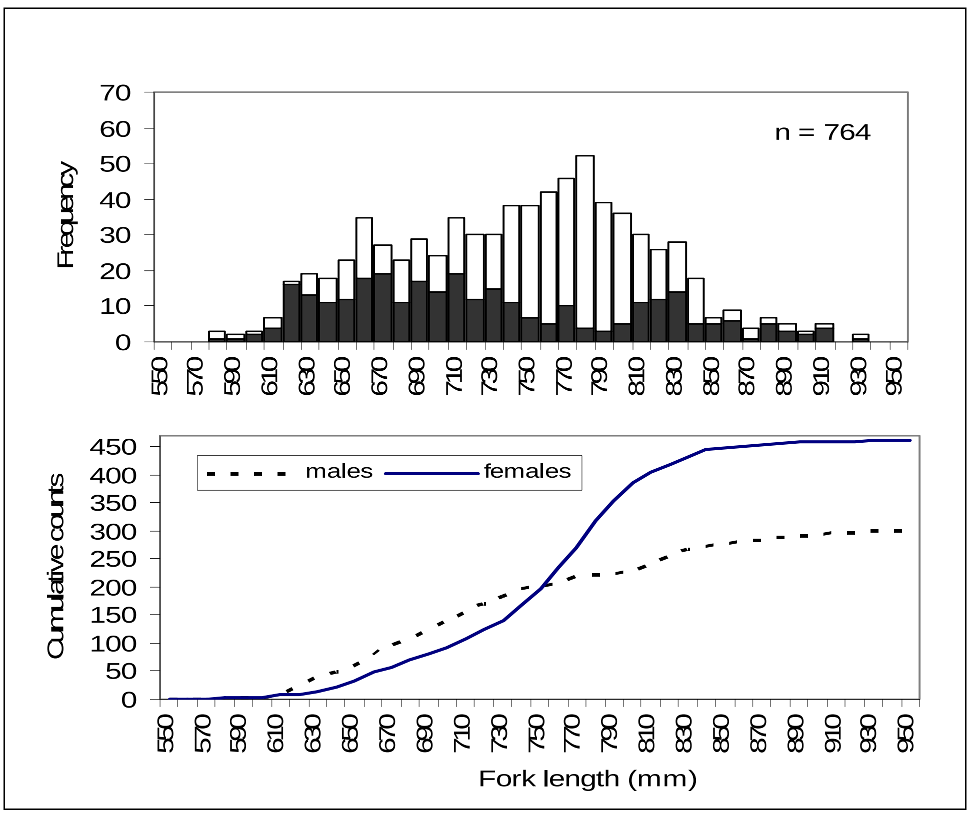


Figure 12.–Length-frequency distributions for male (filled bars) and female (clear bars) steelhead (top panel) and cumulative proportion by sex and length of adult male (stippled line) and female (solid line) steelhead immigrating into Sitkoh Creek during 2004 (bottom panel).

total immigrant steelhead run) met the minimum length requirements for sport fish retention. Although more of the large fish in this population were females than in 2003, proportionately more of the fish of legal size or greater (>914 mm FL or >36 in TL) were males (64.7%, Table 2). In addition to length frequency measurements, spawning condition of 757 adult steelhead was recorded and categorized as bright (27%), semi-bright (41%), and blush fish (32%). Scale samples were taken from 325 adults.

Of the total run of 764 fish, 105 adult steelhead (13.7%) were repeat spawners initially tagged in 2003. Because 2003 adults were first to be tagged, this number does not represent all possible repeat spawners. However, of these repeat spawners, proportionately more females (70.3%) returned than were counted in the total escapement (60.3%). The ratio of female to male repeat spawners was 2.4:1 as compared to a sex ratio of 1.5:1 for all fish combined.

The length of all known repeat spawners averaged 768 mm FL and had SD = 60.5 mm. The range was 586 to 900 mm. These fish grew an average of 45 mm and had a standard deviation in growth of 23 mm since initial tagging in 2003. The length of known repeat-spawning males measured during 2004 averaged 733 mm FL and had SD = 52.0 mm (N = 31). Known repeat-spawning females averaged 782 mm FL and had SD = 58.4 mm (N = 74).

Adult Steelhead-Emigration

There were 565 adult steelhead captured emigrating from Sitkoh Creek in 2004. Of these, 560 had been previously marked during their upstream migration during either 2003 or 2004. There were 5 untagged fish exiting the system that must have immigrated prior to the weir being installed. All untagged fish were measured, sexed, PIT tagged and adipose finclipped prior to being released downstream. All untagged fish were males.

The first kelt was captured on 20 April, the last was captured on 16 June, and the midpoint of the run was about 5 June. The peak daily downstream count (91) occurred on 12 June, following a rain event (Figure 10). The length of all emigrant steelhead averaged 737 mm FL and had a SD of 66.8 mm. The range was 580 to 930 mm (N=564). Females varied less in size and were generally larger than males. The length of females averaged 750 mm FL and had a SD of 57.7 mm, versus the length of males, which averaged 711 mm FL and had a SD of 76.1 mm. Proportionately more females (68%) emigrated from the system following spawning than did males. Females appeared to survive spawning slightly better than did males at 60.3% and 39.7%, respectively.

A snorkel survey conducted on 20 June revealed an additional 8 fish above the weir. All appeared to have fresh adipose finclips. Adding these to the emigrant total of 565 fish passed through the weir resulted in a post-spawning survival rate of 75% for the total immigration (764 fish) in 2004.

Steelhead Smolt

A total of 3,742 steelhead smolt ≥150 mm FL emigrated through the weir in 2004, of which 3,608 were PIT-tagged, measured, and released downstream. The remaining 134 passed downstream were either too small (<150 mm FL) to tag, too heavily descaled, or were mortalities. The overall mortality rate was slightly less than 1% (37 fish). All juvenile steelhead <150 mm FL were measured and released alive. The first steelhead smolt was captured passing through the weir on 11 May, and the last on 22 June. The midpoint of the emigration and peak daily count (354 smolt), occurred on 26 May, about a week earlier than in 2003 (Figure 10).

The length of steelhead smolt ≥150 mm averaged 200 mm FL and had SD = 24.7 mm (range = 150 to 346 mm). Emigrating steelhead smolt were slightly smaller in length later in the run (Figure 13). Scale samples were collected from 306 fish (8.2% of the fish encountered). Preliminary scale analysis indicated that most smolt (88%) were estimated to be age 3 and 4, and ages ranged from age 2 to 6 (Table 3). About 3% of the scale samples collected could not be read due to large, regenerated foci, dirty scales, or an insufficient number of scales in the sample, and 1% of all scales sampled could not be aged because there was not agreement between readings.

Two "re-emigrant" smolt initially tagged in 2003 were recaptured in late May of 2004. One fish measured 255 mm FL and the other was 346 mm. The smaller of these 2 fish grew 80 mm, while the other grew 89 mm since initial capture in early

Table 3.–Freshwater ages based on scale analysis for Sitkoh Creek steelhead, 2003 and 2004. Estimated unbiased ages based on the equivalent 2 out of 3 independent readings of the same scale by the same scale aging technician.

	2003		2004		2003–2004	
Scale Age	# sampled	%	# sampled	%	total #	avg %
sample of total emigration	234 (3,162)	7.4	306 (3,742)	8.2	540 (6,904)	7.8
2	9	3.8	5	1.6	14	2.6
3	89	38.0	146	47.7	235	43.5
4	93	39.7	122	39.9	215	39.8
5	26	11.1	19	6.2	45	8.3
6	3	1.3	0	0.0	3	0.6
ngs[a]	12	5.1	9	2.9	21	3.9
no match	2	0.9	3	1.0	5	0.9
recaptures	--	--	2	0.7	2	0.4

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

June 2003. The smaller fish was estimated to be 4 to 5 years old, while the larger fish was 6 to 7. Scale samples revealed that both fish appeared to show estuarine growth as indicated by widely spaced annuli on the outer margin of the scale (Figure 14).

Dolly Varden Char

There were 62,409 Dolly Varden passed downstream through the weir in 2004. The first fish was counted on 11 April, and the peak daily count (8,288) occurred on 6 May (Figure 15). The midpoint of the run occurred on 8 May. The length of those measured (n = 595) averaged 283 mm FL (SE = 2.3) and had a SD of 55.8 mm. Fish ranged in size from 123 to 514 mm FL. The length distribution of emigrant Dolly Varden was essentially unimodal. The mode was at 256 mm and the median at 267 mm FL. Fork length generally decreased as the run progressed, with fewer large fish caught in the downstream trap later in the season (Figure 16).

Cutthroat Trout

A total of 4,095 emigrant cutthroat trout were enumerated through the weir. The first trout was captured on 11 April, and the midpoint of the weir count occurred on 10 May. The peak daily count (282) occurred on 22 April, almost a month earlier than in previous years (Figures 7 and 15). The length for those trout measured averaged 292 mm FL (SE =3.0) and had SD = 61.3 mm. Fish ranged in size from 118 to 502 mm FL. As in 2003, many of the larger fish were in spawning condition and left the Sitkoh system earlier in the spring. Average size generally decreased with time (Figure 17).

Other Migrants

During weir operations in 2004, 40 rainbow trout were passed downstream. These fish were believed to be sea-run rainbow trout, which migrate within the freshwater and estuarine systems throughout the summer. Five of these trout, captured in the downstream box, displayed strong characteristics of both rainbow and cutthroat trout, and were classified as hybrids. Although representing an incomplete count of the entire run, 2,257 sockeye salmon were captured migrating upstream from June 9 to June 25 and 436 pink salmon were passed between June 15 and June 25 (prior to the weir being removed for the season).

DISCUSSION

The demographic parameters defined during this study provide resource managers a snapshot of a steelhead system that supports normal sport fishing pressure. Resulting information provides general insight into average adult and smolt production, migration timing, sex ratio, survival rates, and freshwater and ocean ages. These parameters can be used to determine when and if management action is needed.

Few long-term (10 years or greater) steelhead out-migrant escapement time series have been collected from streams on the west coast. Previous long term studies include the Keogh River on Vancouver Island (Ward and Slaney 1988),

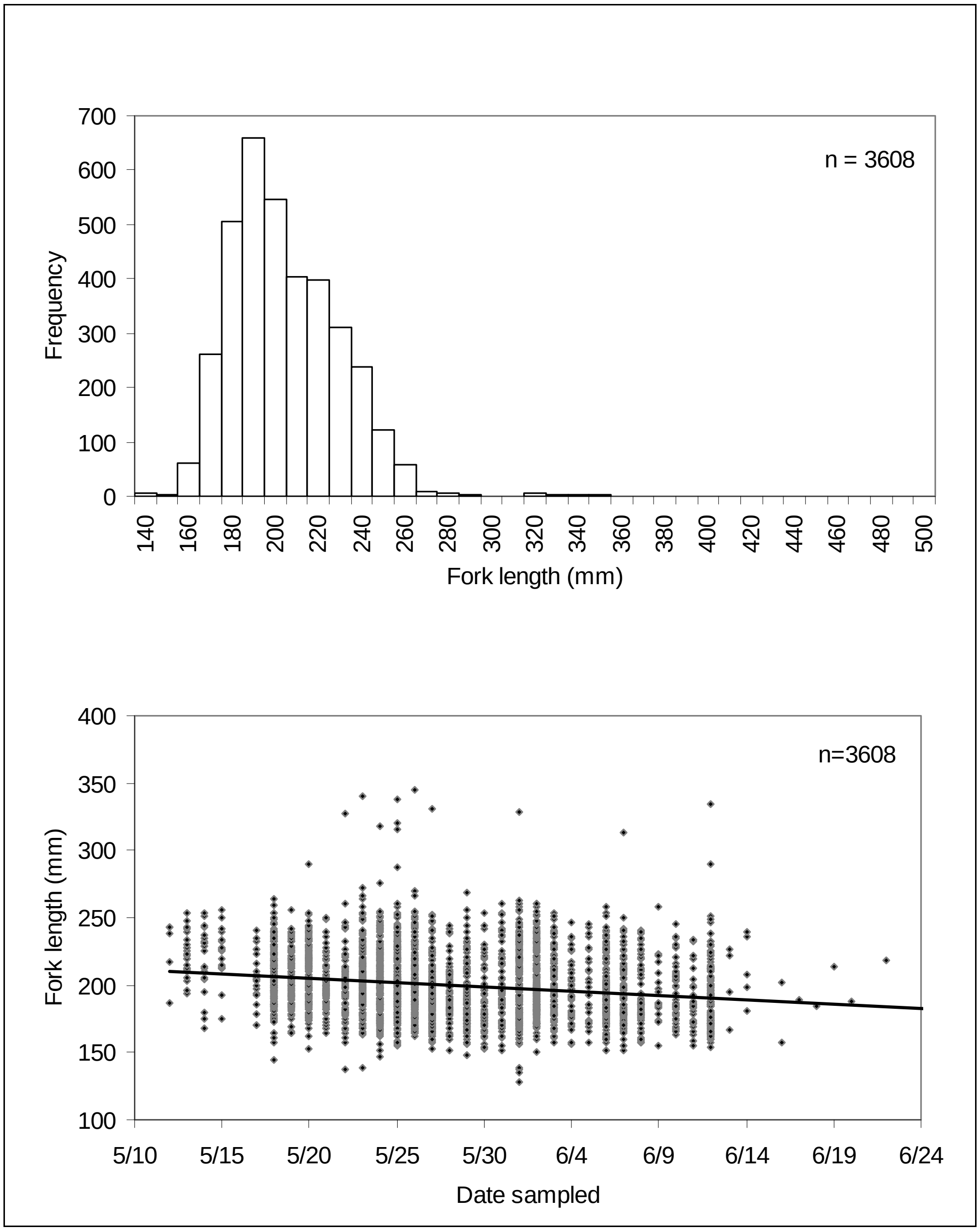


Figure 13.–Length-frequency distribution for steelhead smolt sampled emigrating out of Sitkoh Creek (top panel) and size (mm FL) of steelhead smolt by date captured at the weir during 2004. Linear trendline (y = mx + b) of smolt size by sample date depicted (bottom panel).

Waddell Creek in California (Shapovalof and Taft 1954), Snow Creek in Washington (Johnson and Cooper *in* Bley and Moring 1988), and in the Columbia and Snake river drainages. Within coastal Alaska, multi-year escapement and/or creel studies (5 years or less) have been conducted on the Anchor, Karluk, Karta, and Situk rivers, as well as on Petersburg, Petersen and Sitkoh creeks (Lohr and Bryant 1999; Freeman and Hoffman 1989, 1990, 1991; Harding and Jones 1990, 1991, 1992, 1993, 1994). Long-term tagging data from a relatively unperturbed stream system in Southeast Alaska were not available. Most previous PIT-tag research was only related to movement of smolt through the hydroelectric dams in the Columbia River Basin, or ocean migrations of hatchery smolt and adults in and around the Pacific. As originally conceived, this project was designed to

Table 4.–Freshwater ages of Sitkoh Creek steelhead smolt by adult brood year. Based on scale aging for 2003 and 2004, age classes 2-5+ comprise 94% of all outmigrants on average. Adult-to-smolt production (i.e.- smolt-per-spawner) could be tabulated here based on scale aging results and age-attributed smolt numbers for outmigrant years 2005–2012.

		Smolt outmigrant year									
Brood year	Escapement	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
2003	679			2	3	4	5				
2004	764				2	3	4	5			
2005						2	3	4	5		
2006							2	3	4	5	
2007								2	3	4	5
2008									2	3	4
2009										2	3
2010											2

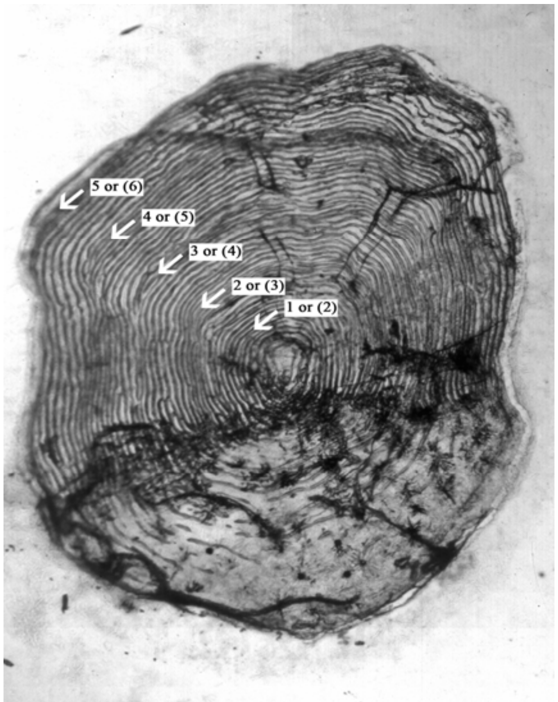
continue for 10 years of study, ending in 2012. This project is unique in Alaska, and possibly throughout their native range, in that no other long-term studies of a wild steelhead population have used PIT-tagging techniques to estimate adult and smolt production, migration timing, survival rates, and freshwater and ocean ages. Preliminary analysis suggests that freshwater ages of parr and smolt sampled in Sitkoh Creek can be estimated with relatively good precision from scale samples. Comparison to paired otolith samples should allow an estimate of accuracy. Continued study at Sitkoh Creek may enable researchers to estimate smolt-to-adult ocean ages and survival and adult-to-smolt production (Tables 4 and 5).

Estimates of average adult egg production can be obtained from the literature (eggs per length is likely a physiological constant). Estimates of density by habitat type and survival of critical life history stages, such as fry (Elliott 1989), can also be estimated. Identification of useable spawning areas as well as total rearing areas can be estimated using the habitat research currently being conducted (Crupi et al. *In prep*). Estimates of escapement based on calibration of snorkel surveys to known instream abundance above the weir can be determined. Census of steelhead adults through the Sitkoh weir is the most accurate method for estimating expansion factors of snorkel survey to escapement and outmigration enumeration provides the smolt abundance needed to extrapolate habitat utilization by juvenile steelhead. Snorkel survey expansions factors have been estimated (Harding 2008) and habitat studies will be reported in a separate FDS report (Crupi et al. *In prep*). Combined, these components provide preliminary estimation of stock recruit parameters that can be used in a general model for Sitkoh Creek. This information may be of use for the management of other steelhead populations throughout Southeast Alaska.

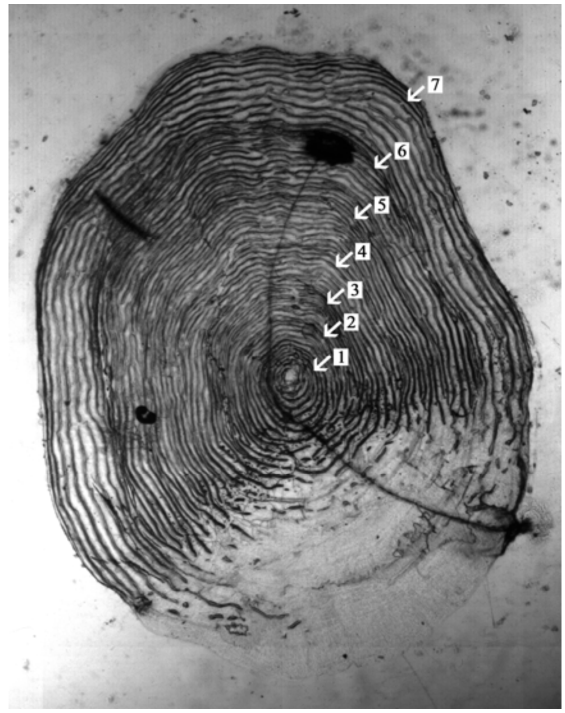
ADULT PRODUCTION, SIZES, SEX RATIOS AND SURVIVAL

The numbers of adult steelhead that returned during 2003 and 2004 were below the historical average of all weir counts conducted since 1936 (Table 1). Weir integrity was not compromised during the course of the 2 years of study, thus counts were considered a census of spring steelhead in Sitkoh Creek. Based on these 2 years of data, overall production of steelhead adults from Sitkoh Creek appears to be stable, in comparison to previous weir data, but lower than the average of all previous years. Subsequent escapement counts on Sitkoh Creek will indicate whether interannual abundance continues to remain stable, and whether weir projects consistently predict abundance in line with other abundance indices (snorkel surveys) used.

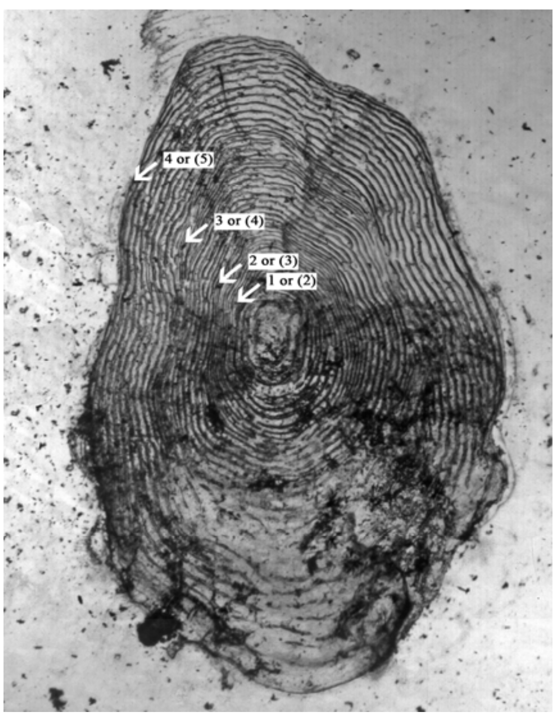
Immigrant female steelhead were more abundant during 2003 and 2004 and were generally larger in size than males. Proportionally more of the total immigration was composed of females: 62% in 2003 and 60% in 2004. Although female-biased sex ratios are not necessarily the norm, more females than males have been reported in the spawning runs of 9 other Alaskan systems: Karta



a) 2003, fish # 183



b) 2004, fish # 183



c) 2004, fish # 139

Figure 14.–Multiple scale images of "re-emigrant" steelhead smolt #183 that was initially tagged outmigrating in 2003, with regenerated focus (a), and recaptured outmigrating in 2004 (b). Note wide spacing of circuli (estuarine growth pattern) between annuli 6 and 7 as compared to previous years' growth patterns and more consistent, evenly spaced circuli evident in fish #183 and fish #139 which was 4-5 yrs old (c).

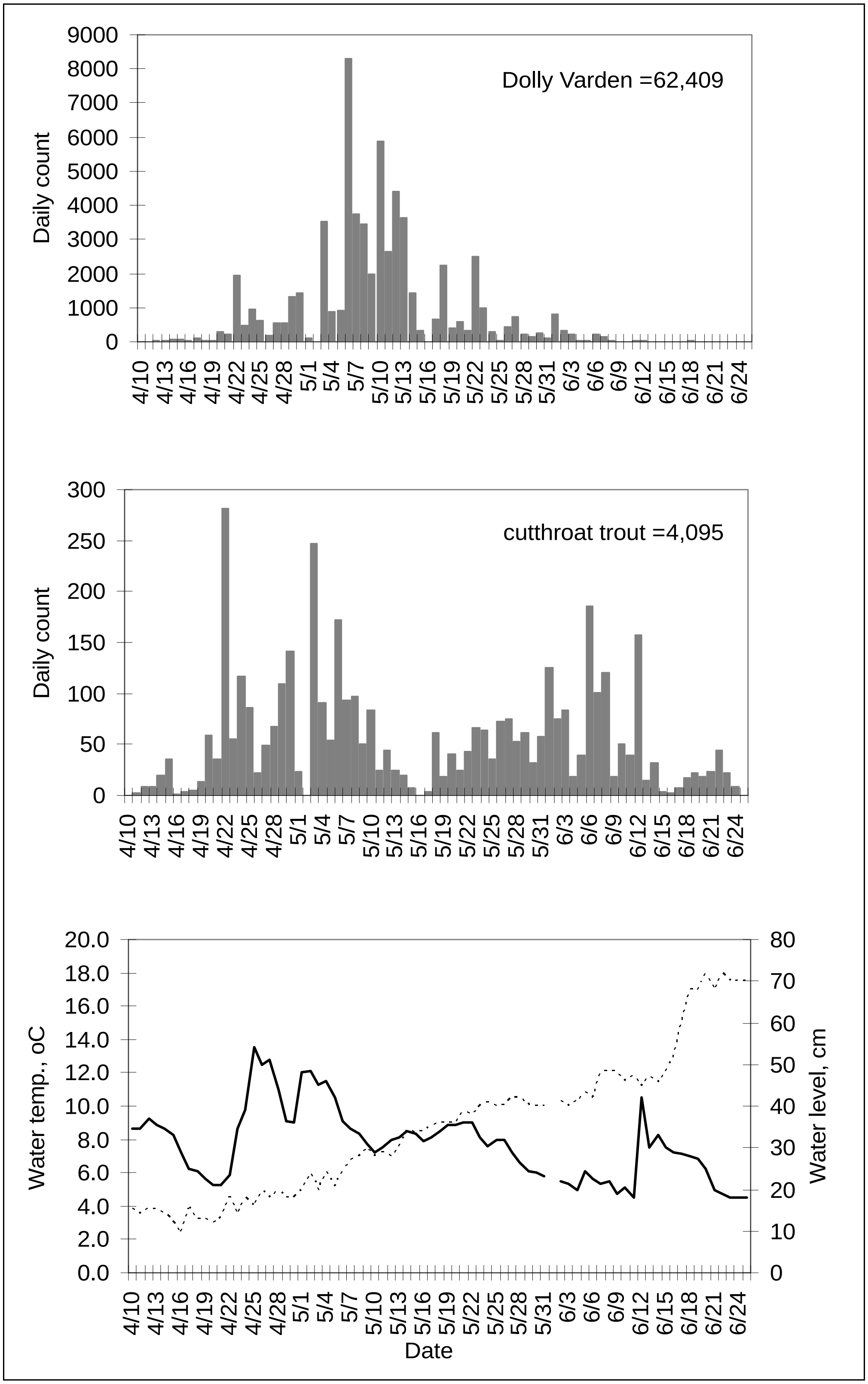


Figure 15.–Daily counts of emigrant Dolly Varden char (top panel) and emigrant cutthroat trout (center panel), and daily measurements of water level in cm (solid line), and water temperature in °C (stippled line) at Sitkoh Creek, 2004 (bottom panel).

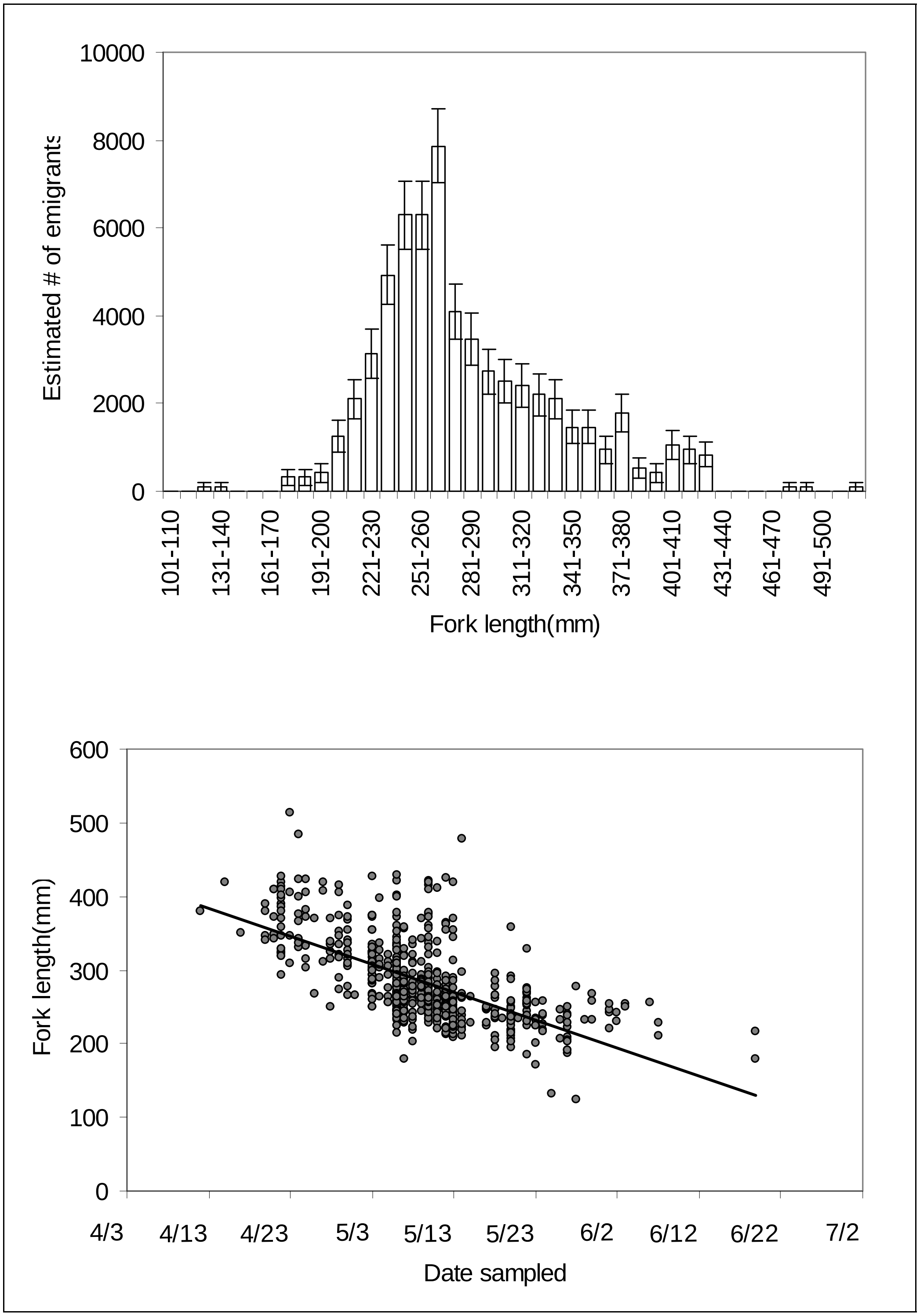


Figure 16.–Length-frequency distribution (top panel error bars are ± one SE) and size at emigration date for Dolly Varden char (bottom panel) emigrating from Sitkoh Creek during 2004. Linear trendline (y-mx+b) of Dolly Varden size by sample date is depicted. Numbers are based on estimated proportions of emigrants by size category (595 Dolly Varden measured, 62,409 passed downstream through weir)**.**

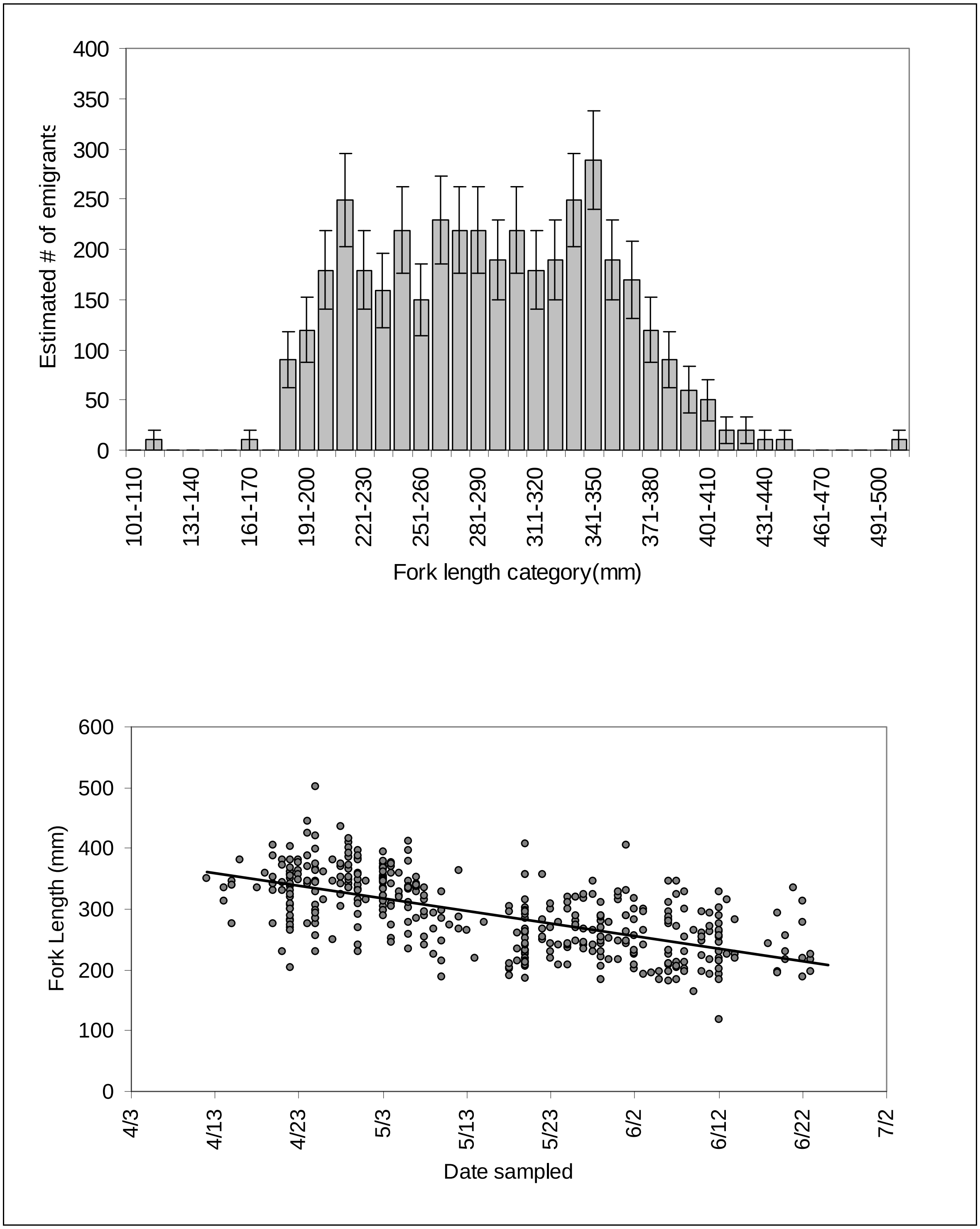


Figure 17.–Length-frequency distribution (top panel error bars are ± one SE) and size at emigration date for cutthroat trout emigrating from Sitkoh Creek during 2004 (bottom panel). Numbers are based on estimated proportions of emigrants by size category (411 cutthroat trout measured, 4,095 passed downstream through weir). Linear trendline (y = mx + b) of cutthroat trout size by sample date depicted in lower panel.

Table 5.–Years that PIT-tagged, outmigrant steelhead smolt will return as adults for the first time to Sitkoh Creek. Ocean ages at return are shown. Note that the 2-ocean smolt returning in 2007 would be the first returns from the 2003 adult brood class, for which we have escapements. Smolt-to-adult production could be tabulated here from PIT tag returns. Only initial spawners would be tabulated. Repeat spawners would be included in the smolt-per-spawner production estimates in Table 4.

		Return year									
Smolt outmigration Year	Smolt abundance	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
2003	3,162			2	3	4					
2004	3,742				2	3	4				
2005						2	3	4			
2006							2	3	4		
2007								2	3	4	
2008									2	3	4
2009										2	3
2010											2

River, Petersburg Creek, Peterson Creek, Situk River, Anchor River, Karluk River, Copper River, Crooked Creek and Nikolai Creeks (Lohr and Bryant 1999; Begich 1999; Gates and Palmer 2006a, b; Wuttig et al. 2004) and in the Columbia River Basin (Holubetz 1995). Males were slightly more abundant earlier in the run in 2004 (Figures 3 and 11). The length frequency distributions in 2003 and 2004 could be considered bimodal with males centered around the smaller mode, and larger females predominant at the larger mode (Figures 4 and 12). Females were also 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 (Lohr and Bryant 1999; Gates and Palmer 2006a, b). Female steelhead in Sitkoh Creek also grew faster than males. PIT-tagged females recaptured in 2004 had grown an average of 13 mm FL, while males grew only 5 mm.

Female steelhead appeared to survive spawning better than males. Post-spawning survival in Sitkoh Creek for both sexes combined was 67% in 2003 and 75% in 2004. Emigrant females comprised 67% of all kelts in 2003 and 68% in 2004, more than their immigration sex ratios. 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 the 1971 to 1993 period (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). The mean fork length of emigrating females was also larger at 750 mm compared to 711 mm for males.

Repeat spawning female steelhead were also more abundant than males. Adult steelhead that were PIT-tagged during their immigration in 2003 and recaptured as immigrants in 2004 comprised 13.7% of the entire escapement of steelhead to Sitkoh Creek. This is an incomplete estimate of total repeat spawning as it only measures repeat spawning across 2 years. Repeat spawning rates based solely on scale analysis in other Southeast Alaska systems are reported to range from 32 to 59% (Jones 1983; Hoffman et al. 1990; Jones et al. 1991), and a maximum of about 20% in the Keogh River in British Columbia (Ward 1989). Higher survival rates for female steelhead appear to bias sex ratios towards females in trout populations with high incidence of repeat spawning. This may be attributed to females leaving the system soon after spawning, whereas males remain longer to engage in multiple spawning attempts (Shapovalof and Taft 1954; Withler 1966). This appears also to be the case for Sitkoh Creek. It may be that female evolutionary fitness favors larger size, which results in higher fecundity, better redd defense, lower mortality due to predation, and higher attractiveness to males (Fleming and Gross 1991; van den Berghe and Gross 1989; Jonsson and Jonsson 1993).

IMMIGRATION TIMING

Run timing of steelhead at Sitkoh Creek during 2003 and 2004 was very similar to previous observations in the 1990s (Jones et al. 1991; Harding and Jones 1994; Yanusz 1997). The midpoint of the immigration occurred on 29 April in 2003 and on 2 May in 2004. This was slightly later than the 1982 run, but was about 2 weeks earlier than the historical data from 1936 and 1937 (Jones et al. 1991; Chipperfield 1938; Yanusz 1997; Figure 18). Immigration timing at Sitkoh Creek appears to be intermediate between steelhead systems to the north and south. In southern Southeast Alaska, the midpoint of steelhead immigration in 12-Mile Creek on Prince of Wales Island occurred on 22 April, 2004 (Steve McCurdy, ADG&G, Division of Sport Fish, personal communication). Farther to the north in the Situk River, immigration timing has been similar to that observed for Sitkoh Creek, with the midpoint occurring on 22 May in 2004 and 16 May in 2005 (Bob Johnson, ADG&G, Division of Sport Fish, personal communication).

Adult immigration timing seems to be related to water flow and temperature and may be influenced by the weir itself. During both 2003 and 2004, daily peaks in adult immigration appeared to follow high flow events (Figures 2 and 10). Increasing stream levels from spring rains and snow melt in April and May attracted the adults upstream. They remained in the system about a month during both years and then left as water temperatures rose and flows began to decrease. Jones et al. (1991) reported immigrant as well as emigrant movements primarily from 11:00 am until 2:00 pm. This was the general time frame during which most immigrant fish moved through the weir during 2003 and 2004. Higher flows qualitatively appeared to correspond to decreases in water temperature. In both years, most of the immigration occurred while water temperature was below 10°C. Emigration was

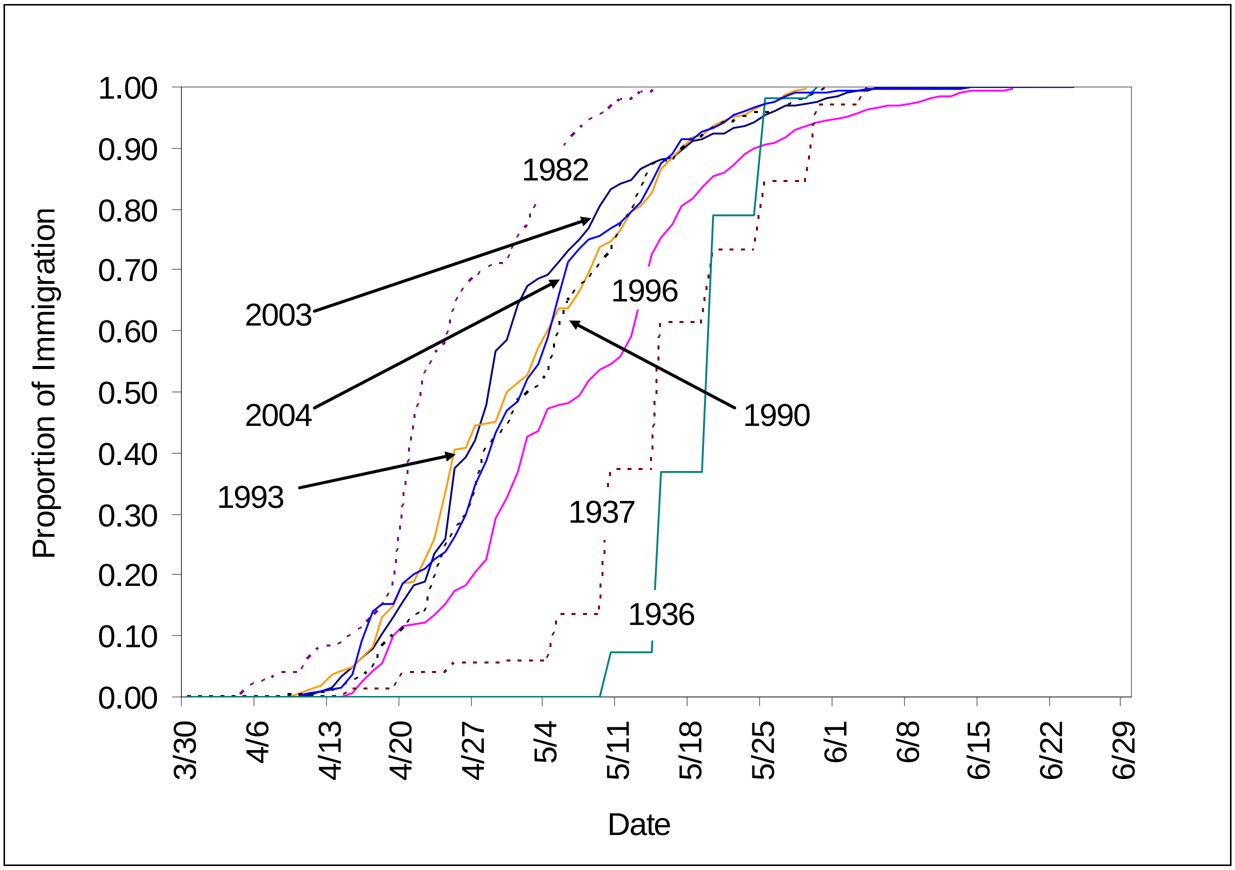


Figure 18.–Immigration timing of steelhead at Sitkoh Creek for all years during which a weir was operated. Data from Chipperfield (1938), Jones (1983), Jones et al. (1991), Harding and Jones (1994), and Yanusz (1997).

essentially complete before temperatures reached 12 to 13°C. Neither immigrants nor emigrants were observed when temperatures climbed above 15°C (Figures 2 and 10). Although water temperature and flow data were unavailable for the 1936 and 1937 weir projects on Sitkoh Creek, the 1936 summary indicated slow snow melt and little rainfall. This may indicate that the spring season was colder and drier possibly resulting in a protracted immigration period (Banta 1936; 1937). Such conditions may help explain why the immigration timing during 1936 and 1937 occurred almost a month later than during subsequent years (Figure 18). Finally, the weir itself may also affect migration into and out of the creek. For example, during the period of low water and higher temperatures in mid-June 2004, kelts appeared reluctant to leave the deeper pool immediately upstream from the weir. These fish did not move downstream through the weir until the entrance to the downstream trap was covered by an overhead tarp to create lower light conditions, and plastic placed on the upstream side of the pickets to create a deeper pool was removed, creating riffle-type flow.

LEGAL SPORT FISH SIZES AND MANAGEMENT ISSUES

Although females were proportionately more abundant overall, the sex composition of very large steelhead (>914 mm TL or ≥36 in TL) was mostly males (88% in 2003 and 65% in 2004). Prior to 2003, sex ratios of legal-sized fish were more equal or skewed somewhat towards large females. Nonetheless, only 16 to 17 fish (2.3% of the escapement on average) were available for harvest during the 2 years of study. The conservative sportfishing regulations currently in place seem to be protecting most of the steelhead in Sitkoh Creek and informal interviews with sport anglers indicate little interest in harvesting steelhead.

Steelhead are taken incidentally in commercial salmon fisheries and are important subsistence species throughout Alaska. Commercial harvest of steelhead in Alaska has ranged from 849 to 11,540 fish since 1989. Fewer have been reported in recent years due to changes in commercial regulations in 1994 prohibiting the sale of commercially caught steelhead by purse seine and gillnet permit holders (Lohr and Bryant 1999; Harding et al. 2006). These are conservative estimates as reported by fish buyers, they do not include steelhead caught but not reported or sold. Current incidental harvest in the Southeast Alaska commercial seine and gillnet fisheries is not known. The proportion of steelhead originating from Alaska in commercial catches prior to 1994 is also unknown. Captured steelhead marked with coded wire tags from California, Oregon, Washington, Idaho, and British Columbia have been recovered (Jones 1994). It is not known whether Sitkoh Creek steelhead are also captured in any commercial fisheries, as no tags have been recovered. Regardless of future use of this resource, monitoring harvest, escapement, and smolt production is necessary for the conservative management of populations of steelhead in Southeast Alaska.

STEELHEAD SMOLT PRODUCTION, LENGTH, AND LIFE HISTORY

The 2003 and 2004 steelhead smolt counts (3,162 and 3,742, respectively) were comparable but less than the 1996 count of 3,883 (Yanusz 1997); the 1996 count is the only other smolt count conducted in Sitkoh Creek. The 2003 and 2004 smolt length distributions and emigration timing were remarkably similar. Both years' length distributions were unimodal, averaged about 190–200 mm FL, and ranged from 140 to 385 mm. Sitkoh Creek smolt were larger in size and had a greater range than reported for the Keogh River in British Columbia (173 mm FL, range 160 to 187) in 1993. Subsequent smolt sizes for the Keogh averaged 171 mm in 2002 and 180 mm in 2003, smaller than in Sitkoh Creek (McCubbing 2002; McCubbing and Ward 2003). As suggested by decade-long Keogh River research, adult 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; Ward et al. 1989). Tagging-related ocean survival estimates of initial, repeat, and skip spawning rates for Sitkoh Creek steelhead will become available as PIT-tagged smolt return to spawn during subsequent years of this project. This will allow comparison to the Keogh system and estimates for Sitkoh adult returns as related to smolt emigrant size and run strength.

The midpoints of smolt emigration during 2003 and 2004 were 23 May and 26 May, respectively.

Emigration pulses did not seem to be strongly correlated with stage of flow during 2003 and 2004, occurring throughout a range of water levels. Smolt appeared to move downstream following rain events, with completion of emigration by the time stream temperature reached 12° C. During mid to late May, Dolly Varden char and cutthroat trout were observed feeding on emigrant salmon fry in the pool immediately below the weir. The midpoint of the Dolly Varden char emigration in 2003 and 2004 occurred 1 to almost 3 weeks earlier than the steelhead smolt emigration. The midpoint of the cutthroat trout emigration was similar to the smolt emigration in 2003, but 2 weeks earlier than smolt emigration in 2004.

A high proportion of steelhead smolt (83% of all sampled) in Sitkoh Creek appear to be ages 3 and 4+ (Table 3). Precision of scale analysis is considered good with more than 90% of 2 out of 3 reads matching; accuracy cannot be verified until paired scale/otolith samples collected from steelhead smolt mortalities in 2003 are aged. The same scale age technician was employed to read scales collected during each year of the study and he used similar techniques year to year. Compared to smolt ages estimated from the Keogh River from 1977 to 1983, Sitkoh Creek smolt were older (Lohr and Bryant 1999). Approximately 89% of Keogh River smolt averaged 2 to 3+ freshwater age and fewer (11%) were aged 4+ (Ward and Slaney 1988). This is not unexpected as steelhead spend more years in freshwater before smolting in northern streams (Withler 1966). Assuming that scale morphology is indicative of true age, subsequent years' data should indicate which smolt age class belong to which adult brood year. Adult-to-smolt production estimates can then be calculated from the total number of smolt counted, their freshwater age based on scale analysis, and assignment to the brood year from which they were produced. As a crude first estimate using only 2003 and 2004 data, approximately 600 adults in Sitkoh Creek produce about 3,000 smolt each year, or approximately 5 smolt per adult. This crude estimate of course assumes all years have approximately the same age structure, and smolt and adult production are consistent year after year; we acknowledge that neither assumption is true. However, this crude analysis allows us to compare smolt production in Sitkoh with the Keogh River, which produces an average of 5.6 smolt-per-adult, and where smolt production appears to be dependent on environmental conditions (McCubbing 2002; McCubbing and Ward 2003).

Marine survival estimates of smolts-to-adult from the Keogh River ranged from 4.5% to 7.8% in 2002 and 2003 (McCubbing 2002; McCubbing and Ward 2003). At Sitkoh Creek, known marine survival will be obtained as more PIT-tagged smolt are recovered as adults in coming years. Beverton-Holt recruitment curve analysis on the Keogh River, wherein large numbers of fry experience density dependent competition, indicated that fry survival may determine smolt production. Associated survival of adults produced from these fry/smolt outmigrant classes would indicate whether adult replacement is sustainable. Oceanic and freshwater conditions may also determine survival (Ward 2000). Coupled with other techniques such as snorkel survey of area index streams, use of electronic, sonar or video counters, and quantification of habitat-based juvenile carrying capacity, this information may be very useful for estimating minimum escapement levels.

RAINBOW TROUT LIFE HISTORY AND EMIGRATION

Small numbers of rainbow trout emigrated through the Sitkoh weir during 2003 and 2004. Early in the season, many of these fish 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 from Sitkoh Creek (Yanusz 1997), or migrating within the system. No rainbow trout were captured by weir technicians with sport gear downstream from the weir despite almost daily efforts, although a systematic sampling was not conducted. Interestingly, some of the later rainbow emigrants appeared to be in post-spawning condition (fungus, abraded pelvic and caudal fins). These fish may have been moving into the estuary to recover and possibly to feed. Two "re-emigrant" smolt initially tagged in 2003 were recaptured in late May of 2004, indicating that a small percentage (0.1%) of steelhead smolt in Sitkoh Creek make repeated migrations between fresh and salt waters before maturing as adults, similar to the behavior of sea-run cutthroat trout. Rainbows may also be hybridizing with resident cutthroat as indicated by the rainbow/cutthroat hybrids captured during both years which appeared to have intermediate physical characteristics.

In Sitkoh Creek it appears that rainbow trout and steelhead life history strategies may include several different forms other than classic resident and ocean-going steelhead. One life history form observed (n = 2) resembles the "half-pounder" form described by Behnke (2002) where smolts may enter marine waters during the spring months, return to freshwater during late summer and fall, and smolt again the following spring to reside in the ocean and grow into adult steelhead. The other life history form observed is best described as sea-run rainbow trout and mirror the classic sea-run cutthroat trout form i.e., spring and summer migrations between fresh and estuarine waters, or possibly to other stream systems to spawn, followed by overwintering in freshwater. Male and female rainbow trout emigrants were observed at the weir that were classified in pre- (dripping gametes) and post- spawning (fungus, abraded pelvic and caudal fins) condition. The pre-spawning fish tended to emigrate earlier than the post-spawning fish. Because spawning habitat between the weir and saltwater is minimal, it is assumed these ripe fish were migrating to other systems to spawn. This life history polymorphism of rainbow trout observed at Sitkoh 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). Two rainbow trout examined at the weir suggested that hybridizing with cutthroat trout may be occurring as noted by the intermediate physical characteristics; this naturally occurring hybridization is also noted by Behnke (2002).

DOLLY VARDEN CHAR PRODUCTION, EMIGRATION, AND LENGTH

The number of Dolly Varden that emigrated through the weir in 2003 (52,884 fish) and 2004 (62,409 fish) both exceeded the 1996 count of 48,252. Historical counts prior to 1996 were found to have limitations that rendered them unreliable for comparison (Yanusz 1997). The daily emigration was marked by enormous pulses of downstream moving schools of Dolly Varden, including daily peak counts of 8,239 fish in 2003 and 8,288 in 2004 (Figures 7 and 15). Emigration timing in 2003 appeared to be similar to that observed in 1996, but the timing in 2004 was earlier. Although further quantitative analysis is needed, qualitatively it may be that higher rainfall and stream flows during 2003 resulted in low water temperature, whereas warmer air temperatures, lower flows, and less rainfall in 2004 resulted in warmer water temperatures early in the season, which prompted early emigration.

The mean fork length of Dolly Varden in 2004 (283 mm FL) was larger than in 2003 (279 mm FL), although ranges in size were comparable. Increasing abundance and size as compared to 1996 (266 mm FL), may indicate good overwintering survival and growth. Many of the Dolly Varden emigrants were observed to be parasitized by tapeworms and roundworms in the intestines and flesh, and several different types of copepods were observed on the gills, mouth and fins. The effect of this parasitism on the population health as a whole is not known, but the external parasites are likely killed once the fish emigrates to salt water (Post 1987).

CUTTHROAT TROUT PRODUCTION, EMIGRATION, AND LENGTH

The cutthroat trout emigration in Sitkoh Creek during 2003 (4,588) was the 13% higher than the 1996 count of 3,955 and 10% higher than the emigration in 2004 (4,095). The timing of cutthroat trout emigration from Sitkoh Creek in 2003 appeared to be similar to that observed in 1996 as roughly 22% of the entire cutthroat trout emigration (1,010 fish) passed in the 72-hour period preceding the deconstruction of the weir in late June (Figure 7). The emigration in 2004 was completed almost two weeks earlier.

The 2003 and 2004 emigrant weir count supports historical data showing abundance levels of over-wintering cutthroat trout at Sitkoh Creek to be relatively high in comparison to other Southeast Alaska systems (Yanusz 1997). The mean lengths of cutthroat sampled in 2003 and 2004 were comparable to the 1996 mean length (Yanusz 1997).

Little or no emigration of cutthroat trout occurred in either 2003 or 2004 as water temperatures in

Sitkoh Creek rose above 12°C (Figure 15). Water temperatures above 14°C were recorded for only 3 days during 2003 when only 4 cutthroat trout emigrated (Figure 7). During 2004, water temperature increased from 12 to 18°C between 16 June and 25 June and again there was minimal emigration. Downstream movement of cutthroat trout did not appear to be strongly influenced by water levels during either 2003 or 2004.

OTHER SPECIES

Immigrant sockeye and pink salmon were counted into Sitkoh Creek during June 2003 and 2004. Eighty-one (81) adult sockeye were observed migrating upstream in 2003, but 3,701 were counted during 2004; the 2004 count may been nearly the entire annual escapement (Jan Conitz, ADF&G, Division of Commercial Fisheries, personal communication). Almost 450 pink salmon passed through the Sitkoh weir in 2004; no pink salmon were counted during 2003.

The presence of these species may confer an advantage to newly-emergent steelhead fry by providing a ready food supply in the form of salmon eggs. Differences in steelhead smolt production in odd versus even years in the Keogh River may be a function of pink salmon egg deposition during critical freshwater rearing stages of steelhead juveniles (Ward et al. 1989), but has not been determined for Sitkoh Creek as pink salmon production is not known. Other salmon species co-occurring in the same stream system may also benefit steelhead juveniles, e.g., abundant and healthy stocks of sockeye may contribute to supporting consistently healthy, genetically diverse populations of steelhead, as well as cutthroat trout and Dolly Varden char (Wright 2004). Higher steelhead production in lake verses stream systems in Southeast Alaska may be due to better salmon production in these systems.

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APPENDIX A
FILE DESCRIPTIONS

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

FILE NAME	SOFTWARE	CONTENTS
03-04Sitkoh steelhead FDS.doc	Word 2003	This report
0304FDS_Tables & Figs.xls	Excel 2003	Figures and tables and associated data and Appendices used to generate them for this report
03-04Sitkoh 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 2003 and 2004
03Sitkoh DV,CT lengths.xls	Excel 2003	Cutthroat trout and Dolly Varden char lengths at Sitkoh Creek weir collected in 2003
04Sitkoh DV,CT lengths.xls	Excel 2003	Cutthroat trout and Dolly Varden char lengths at Sitkoh Creek weir collected in 2004
03Daily&Cumm counts.xls	Excel 2003	Daily weir counts in 2003 for all species at Sitkoh Creek
04Daily&Cumm counts.xls	Excel 2003	Daily weir counts in 2004 for all species at Sitkoh Creek
daily temp and level 2003.xls	Excel 2003	Daily temp and stage gauge at Sitkoh Creek in 2003
daily temp and level 2004.xls	Excel 2003	Daily temp and stage gauge at Sitkoh Creek in 2004