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Steelhead Trout Production Studies at Big Ratz Creek, Alaska, 2010–2011

by

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and

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February 2013

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

Limited quantitative information exists about production of adult and smolt steelhead *Oncorhynchus mykiss* from Prince of Wales Island (POW), Southeast Alaska streams. In 2010, an assessment of a steelhead population in Big Ratz creek, on the eastern side of POW, was initiated by the Alaska Department of Fish and Game to evaluate adult and smolt production. During 2010–2011, standardized weir counts were obtained and all captured smolt and adult steelhead were tagged with Passive Integrated Transponder (PIT) tags. Production estimates generated from weir census were provided to a concurrent habitat suitability modeling project on Big Ratz creek to estimate habitat area-based carrying capacity. Adult escapement, based on weir census of immigrant and emigrant fish, was 377 in 2010 and 549 in 2011. Approximately 63% of the adult immigrants survived spawning in 2010, and 80% survived in 2011. A total of 1,820 emigrant steelhead smolt were counted through the weir in 2011, and 1,328 were counted in 2011. The predominant estimated scale ages of randomly-selected subsampled smolt were 3-, 4-, and 5-freshwater (89.2% of the sample in 2010, and 86.6% in 2011). Adult and smolt counts through the weir were considered minimums, thus habitat-based carrying capacity estimates were conservative. Other species counted emigrating through the weir in the spring of 2010 and 2011 included rainbow trout *O. mykiss*, cutthroat trout *O. clarki clarki*, and Dolly Varden char *Salvelinus malma*.

Keywords: Steelhead trout, *Oncorhynchus mykiss*, Big Ratz creek, weir census, scale sampling, PIT tagging, smolt and adult production, Petersen model, smolt-per-spawner, habitat-based carrying capacity, Dolly Varden char, *Salvelinus malma*, rainbow trout, cutthroat trout, *Oncorhynchus clarki clarki*

INTRODUCTION

Steelhead trout *Oncorhynchus mykiss* in Alaska are found in coastal streams from Dixon Entrance to the Alaska Peninsula, but the majority of streams that support populations are located in Southeast Alaska. Southeast Alaska has 309 watersheds known to support annual escapements of steelhead. Most of the systems in Southeast Alaska are thought to support populations of 200 or fewer adults, but some like the Thorne River on Prince of Wales Island (POW) and Naha River north of Ketchikan may produce runs in excess of 1,000 adults. Big Ratz Creek, on POW, supports a population of steelhead trout of about 400 adults (Table 1). Since 1994, the Southeast Alaska sport fishing region-wide minimum size limit has been very restrictive, allowing harvest of only one fish per day and two fish annually over 36 inches. An analysis of sport fishing length data collected at numerous weir sites throughout Southeast Alaska substantiates that in any given year or system approximately 3% to 5% of adult steelhead are available for harvest (Harding et al. 2009). Under these restrictive regulations Big Ratz Creek supports what is essentially a catch-and-release sport fishery. Because so few adults are available to harvest, ADF&G believes that the current conservative sport fishing regulations sustain steelhead stocks in Southeast Alaska. However, fishery managers remain concerned about incomplete accounting of subsistence harvest and incidental harvest by commercial fishing, especially from populations of steelhead in Southeast Alaska such as those on POW that may be vulnerable to overexploitation. Thus, there is a need to conservatively manage these small to medium sized populations of steelhead in Southeast Alaska.

A limited amount of biological data has been collected on a small number of steelhead systems on POW, including Harris River, Cable Creek, 12-Mile Creek, Natzuhini Creek, and Eagle Creek/Luck Lake. Steelhead trout in the Big Ratz Creek system have been investigated two other times: weirs were operated in 2005 and 2007 (Tables 1 and 2; Piazza et al. 2008; Piazza 2009). No smolt emigration estimates have been made anywhere on POW. A multi-year assessment of the Big Ratz Creek steelhead population was initiated in 2010 by the Alaska Department of Fish and Game (ADF&G), Division of Sport Fish to estimate adult and smolt production for use with a habitat suitability model being developed for Big Ratz Creek (Schroeder and Nichols 2012). The information collected also provided insight on steelhead ecology in POW streams compared to other systems within the distributional range of this species. These northern, relatively pristine, oligotrophic systems appear to support slower growing steelhead whose populations may be more sensitive to harvest, hooking mortality, and other perturbations that could affect sustained production and sport fishing opportunity.

Table 1.–Steelhead trout immigrant counts, peak of immigration, and number of emigrants recorded at the Big Ratz Creek weir, 2005, 2007, 2010, and 2011.

	Adult steelhead				
Year	Escapement	Peak of immigration	Number of emigrants	Date weir installed	Date weir was pulled
2005	399	26 Apr	122[a]	11 Mar	31 May
2007	284	21 Apr	135[a]	19 Mar	29 May
2010	377	24 Apr	278	30 Mar	15 Jun
2011	549	29 Apr	458	23 Mar	20 Jun

[a] Emigrant counts likely incomplete due to early removal of weir.

Big Ratz Creek was chosen as a site for this project because of past successful operation of weir projects at this creek, productive habitat for steelhead smolt, and a moderately high production of adults relative to stream size. As outlined in "Strategic Plan for Southeast Alaska Steelhead Research and Monitoring Program" (unpublished ADF&G, Division of Sport Fish manuscript, available at the Southeast Regional Office, Douglas, Alaska), the planned duration of this study was 2010 to 2016, but the project was terminated following the spring of 2011, due to lack of funding. This report summarizes the two years (2010–2011) of this project and presents estimates of steelhead immigration and emigration, length distributions, and adult and smolt ages. Emigrant counts of rainbow trout *O. mykiss*, cutthroat trout *O. clarki clarki*, and Dolly Varden char *Salvelinus malma* through the weir are also presented.

OBJECTIVES

The objectives for this project during 2010–2011 were to:

1. Enumerate and tag with passive integrative transponder (PIT) tags all downstream migrating steelhead smolt.
2. Estimate the length and 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 adult steelhead passed through the weir.
5. Determine the length composition and sex ratio of all immigrant adult steelhead.
6. Determine the age composition of all immigrant adult steelhead.
7. Enumerate all rainbow trout, cutthroat trout, and Dolly Varden passing the weir.

STUDY AREA

Prince of Wales Island is the largest island of the Alexander Archipelago in Southeast Alaska. The island is 217 km long, 72 km wide and has an area of 6,674 km^2. There are 70 identified steelhead streams on the island and most systems (43) have at least one lake in their watershed. The Big Ratz Creek system (Anadromous Stream Catalog No. 106-10-10100) is located on northeastern POW (Figure 1), and empties into Ratz Harbor. Big Ratz Creek is about 6.4 km long and drains Big Lake, Trumpeter Lake, and Little Lake, which have a combined surface area of 1.31 km^2. The Big Ratz Creek weir site is accessible by United States Forest Service logging road # 30 north of Thorne Bay, and the creek mouth is accessible by boat via Clarence Strait. The Big Ratz Creek weir site is approximately 400 m upstream from salt water (Figure 1).

METHODS

An aluminum bipod weir was installed and operated on Big Ratz Creek in 2010 and 2011. The weir consisted of separate emigrant-immigrant traps (2.5 m^2) and was located at the same site used during previous studies in 2005 and 2007. 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 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

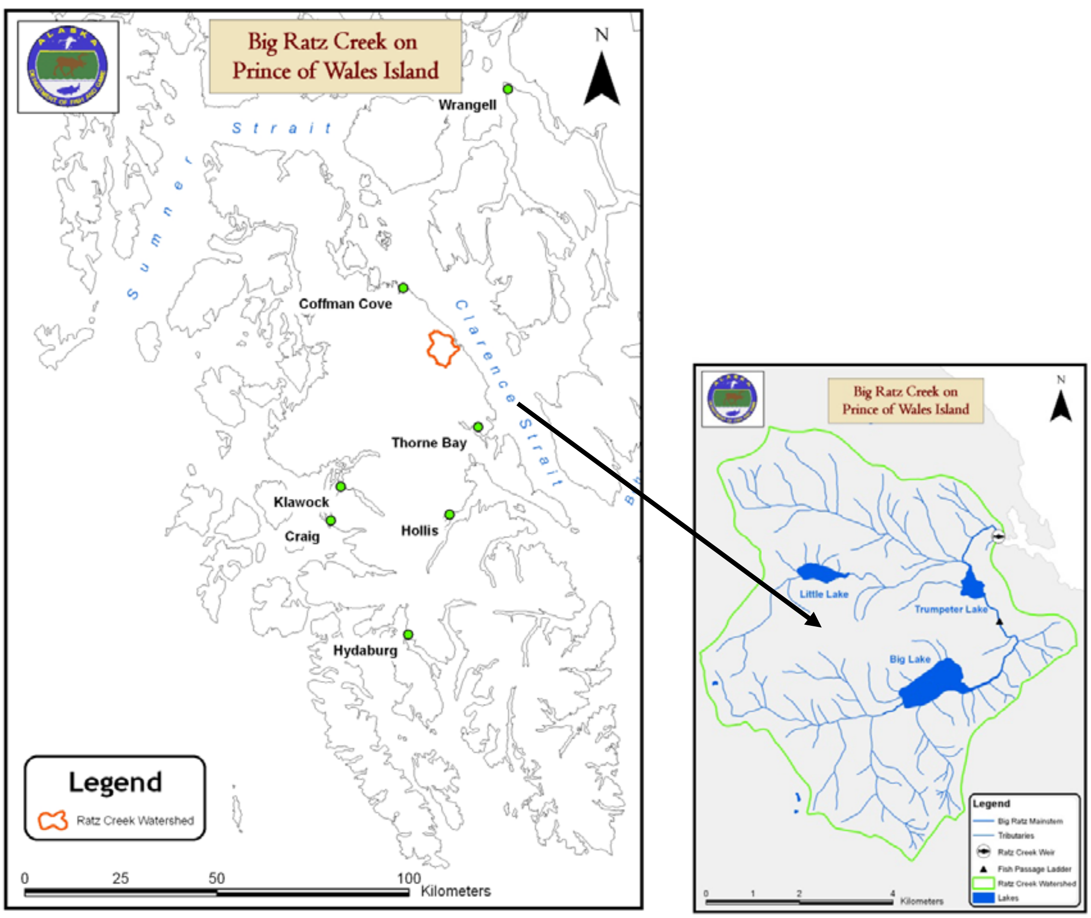

Figure 1.–Location of Big Ratz Creek, and the weir site on Big Ratz Creek.

streambed was skirted with Vexar®[1] (18.75 mm^2 openings) and covered with sandbags. A picket and channel trap and a 2.4 m^2 welded aluminum cage, both overlain with vinyl-coated wire mesh, were placed on the upstream and downstream sides of the weir to hold captured fish entering and exiting the system. The vinyl-coated wire mesh and Vexar® had been used effectively during 2003–2009 on the steelhead weir operated on Sitkoh Creek, Chichigof Island (Love and Harding 2008, 2009; Love et al. 2012a, 2012b). This weir and trap configuration appeared to safely block the passage of all fish >150 mm FL. Weir integrity was checked several times daily, and water temperatures and depth were recorded at approximately 12:00 a.m. each day. The weir was scheduled to be operated from mid-March until about the last week of June during each sample year. Due to high water during most of late March and the first few days of April 2010, the upstream trap was not fishing until 3 April. Once installed, no adjustments were made to the structure of the weir or its position in the creek during any period of its operation in 2010. In 2011, heavy snowpack on the road to the weir required it to be plowed and prevented installation of the weir until 26 March; the first immigrant adult was captured on 1 April. In 2011, five consecutive days of heavy rain and snowmelt forced the weir crew to pull the vinyl-coated wire panels during the evening of 5 May and day of 6 May. Panels were replaced the morning of 7 May.

ADULT STEELHEAD

Captured immigrant and emigrant adult steelhead were processed promptly to avoid crowding and minimize stress. All immigrating adults 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 immigrant and emigrant adults were categorized by sex using secondary sexual characteristics as described by Morrow (1980) and Hart (1988), and tagged with 134 kHz PIT tags. PIT tags were implanted into the left side of the fish just under the skin and posterior to the cleithrum. Entrance wounds caused by PIT tag insertion were treated with iodophore and sealed with a drop of cyanoacrylate glue. Newly tagged fish were also secondarily marked by removing the adipose fin. If any previously adipose fin-clipped adults did not appear to have a PIT tag, the fish was re-tagged, 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. Detached adipose fins were collected from 100 untagged adults and preserved in 70% ethanol for later genetic sequencing by the U.S. Fish and Wildlife Service Genetics Laboratory in Anchorage. During 2010 and 2011, all immigrant and emigrant adult steelhead were checked for adipose clips and previously implanted PIT tags, measured, and passed upstream through the weir.

Scale samples were collected from all immigrating adult steelhead each year. Scales were removed from an area approximately four to six scale rows below and behind the dorsal fin, but above the lateral line. Untagged fish had four to six scales taken from the preferred area two rows above the lateral line and along a line from the posterior end of the dorsal fin to the anterior end of the anal fin. Scales from previously tagged fish were removed from the right side to avoid sampling regenerated scales resulting from prior sampling. Scale samples were placed on labeled gum cards and pressed flat in sequential order for storage.

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[1] This and subsequent product names are provided for completeness and do not constitute product endorsement.

Daily and cumulative numbers of adult fish passing through the weir were recorded in 2010 and 2011. Because all adult steelhead were measured during the period the weir was in place, the length composition of immigrant steelhead passed through the weir was known. The weir was considered fish tight throughout the sample period for adults; however, it was operational later in the spring (April) in 2010 than in 2011. The total abundance of immigrant steelhead was estimated using the Chapman modification of the Petersen estimator (Seber 1982):

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

where:

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

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

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

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

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

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

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

R: the number of 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 passing either upstream or downstream through the weir.

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

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

$$\hat{Var}(\hat{N}') = \frac{\sum_{b=1}^{200,000}(\hat{N}_{(b)} - \overline{N})^2}{200,000 - 1}, \quad (3)$$

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

Conditions that must be met for use of Chapman's modification of the Petersen estimator (Seber 1982) include:

(a) every fish had an equal probability of being marked in the first sample, or that every fish had an equal probability of being captured in the second sample, or that marked fish mixed completely with unmarked fish; and

(b) recruitment and mortality did not occur between samples; and

(c) marking did not affect the catchability of a fish during the second sampling event; and

(d) fish did not lose their marks in the time between the two samples; and

(e) all marks were reported on recovery in the second sample; and

(f) repeat sampling did not occur.

Condition (a) was evaluated by time, area, size, and sex. The procedures used to analyze sex and length data for statistical bias, as well as remedial measures (stratification) if bias is detected, are described in Appendix A1. The consistency tests described by Seber (1982) and in Appendix A2 were used to test for temporal violations of condition (a) when appropriate data were available. Failure to reject at least one of these three hypothesis tests was sufficient to conclude that at least one of the conditions in (a) was satisfied, and a Petersen-type model was appropriate to estimate abundance.

The experiments were not closed to recruitment (condition b) because we expected that some steelhead had immigrated to the spawning area prior to the weir being installed. We also know that some portion of the spawning steelhead suffered mortality and were not available for second event sampling during downstream emigration. If marked fish mixed completely with unmarked fish prior to second event sampling and if mortality was similar for marked and unmarked fish, then the Chapman model was germane to first event sampling and was used to estimate the number of spawners that entered the system.

Condition (c) could not be evaluated, however, gentle and careful handling of all fish sampled ensured that this condition could be met and that fish sampled during the first event suffered no greater mortality during spawning due to handling than fish that were not sampled.

The use of multiple marks during the first event and careful inspection of all fish captured during second event sampling helped to insure that conditions (d) and (e) were met. Sampling during fish passage through the weir ensured that condition (f) was met.

STEELHEAD SMOLT

All steelhead smolt $\geq$150 mm were counted, examined for PIT tags, measured to the nearest 1 mm FL, and scale sampled. Steelhead smolts were anesthetized using a buffered MS-222 solution prior to sampling. 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 2010 and 2011. 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 and were not considered to be completely enumerated. 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 were captured and appeared to have undergone smoltification were counted, measured to the nearest 1 mm FL, subsampled for scales, and released.

Scales were collected from all steelhead smolt. Scales were removed from an area approximately four to six scale rows below and behind the dorsal fin, but above the lateral line. All untagged fish were scale sampled on the left side. About 15 to 20 scales were removed from each sampled fish and were evenly spaced on clear glass slides. A second glass slide was secured over the first to protect the samples. Slides were stored inside a coin envelope inscribed with the sample number. Coin envelopes were stacked in sequential order and stored for subsequent aging. Length and age composition of subsampled steelhead smolt were estimated using:

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

and

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

where n is the number of fish selected for aging, n_a is the subset of n that belong to age group a, and N is the population size. Length frequencies were calculated for the entire enumerated smolt outmigration and standard sample summary statistics were calculated using Cochran (1977).

STEELHEAD SCALE AGING AND ELECTRONIC IMAGING

Scale samples were taken from all emigrant steelhead smolt passed through the weir in 2010 and in 2011. Postseason, a subsample of 1 in 6 smolt scales from 2010 and 1 in 3 from 2011 were imaged using a Leica DMD108 imaging microscope. Electronic images of scales sampled in 2010 and 2011 were archived for later scale aging. Methodology used to estimate ages from electronic scale images was similar to that used by Ericksen (1999) for cutthroat trout, and by Love and Harding (2008, 2009) and Love et al. (2012a, 2012b). Scale ages were determined primarily from the area of the scale lying 45^{o} off either side of an imaginary reference line drawn along the longest axis of the scale, from the focus to the anterior edge. Patterns were often more evident in this area of the scale. Ideal scales were clean, mucus-free, and did not have a regenerated focus. Scale ages were considered to be estimated, not determined, because a known-aged freshwater reference collection was not available for comparison. To minimize error associated with variability between readers, only one scale aging technician was employed to estimate ages of steelhead smolt during 2010–2011. This scale-aging technician made three independent readings of each sampled scale to estimate age. If none of the three reads agreed, the sample was considered unreadable and was omitted from the age composition estimation. The modal age of three successful scale age readings from each scale was assumed to be the most consistent age and was reported. Assuming that a matching scale age, if not accurate, was the most consistent (precise) estimate, it was concluded that this was the best estimate. Between independent readings, the scale images were randomized by the project biologist and scale aging results from the previous reading(s) were not known. All reads were archived for assessing aging errors, if any were later determined to be errors. Criteria for aging juvenile and smolt scales included: rejection of latinucleate scales, consistent overall scale size, average number of annual circuli relative to year of growth, identification of annuli, and identification of "plus growth." These criteria were used in a previous project on Sitkoh Creek (Love and Harding 2008, 2009, Love et al. 2012a, 2012b) to develop aging "rules," which were incorporated into a scale aging methodology that was used for aging scales from Big Ratz Creek.

The age designation used was from the discussion by Koo (1962). For example, a scale sample from a smolt sampled in the spring might be estimated to be age 3.0, indicating that it had three annular marks or had spent three years in fresh water, and had not yet spent time in salt water. By comparison, an immigrant adult sampled in the spring might be designated as age 3.2S1 indicating its total age was six years. Scale aging would have estimated that it had spent three summers in fresh water before migrating to the ocean, where it spent two winters before reentering the stream on its first spawning migration (S denoting the reabsorption of annuli in a "spawning check"), followed by an additional year in the ocean before being captured in the spring of its second migration into fresh water prior to spawning.

Aging of scales samples collected from immigrant adults and emigrant smolts in 2010 and 2011 was completed in the fall of 2011. Reproducibility of scale reading techniques (i.e., precision) of these scale aging estimates for adult and smolt scales were calculated using coefficient of variation (CV), expressed as the ratio of the standard deviation over the mean (Campana 2001) using:

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

where CV_j was the age precision estimate for the *j*th fish, X_{ij} was the *i*th age determination of the *j*th fish, X_j was the mean age estimate of the *j*th fish, and *R* was the number of times each fish was aged. Averaging CV_j across all fish gave a mean CV for the method used. Mean CV was calculated for adult and smolt scales. The observed variability in scale readings was recorded and archived to support future research efforts where modeling uncertainty in steelhead ages, and thus age structure of different populations, is critical.

Cutthroat Trout, Rainbow Trout, and Dolly Varden Char

All emigrant Dolly Varden char, rainbow trout, and cutthroat trout were counted and released below the weir during 2010 and 2011. No immigrants of these species were expected because they overwinter in the lakes of this drainage and typically return to salt water in the spring.

RESULTS

2010

Adult Steelhead-Immigration

The weir was continuously operated from 3 April to 14 June. The first adult was captured in the upstream trap on 8 April, and the last on 6 June. The peak daily count (23) occurred on 24 April, and the midpoint of the run was 26 April (Figure 2). Water temperatures increased steadily from 4.0^{o}C on 3 April to a peak of 16.5^{o}C on 31 May, before cooling off again to about 11^{o}C by 14 June.

A total of 270 adult steelhead were passed upstream through the weir. All fish were sexed and PIT tagged, and all but two fish were measured. Females composed the majority of the immigration at 59% (Table 2). Approximately equal numbers of males and females immigrated into Big Ratz Creek prior to 1 May (51%), whereas more females than males immigrated after May 1 (70%) (Figure 3).

The average and maximum lengths of males and females were very similar (Figure 4). The length of immigrant steelhead (both sexes combined) averaged 681 mm FL (SD = 61.7 mm), and ranged from 505 to 860 FL mm (N = 268). Two immigrants were not measured. The length of males averaged 682 mm FL and had a SD = 55.1 mm (N = 112); for females, length averaged 680 mm FL and had a SD = 66.1 mm (N = 158). In addition to fork length, total length was measured. None of the fish were large enough to be legally retained during sport fishing (Table 2).

Scale samples were taken from 267 of 270 untagged immigrant steelhead, and 177 (66%) were successfully aged (Table 3). Unreadable scales did not have a readable freshwater or saltwater portion, were damaged, or could not be assigned replicate ages in triplicate readings. Electronic images created from the readable scale samples were used for aging and were archived. Estimated ages were compiled for the freshwater and saltwater portions from each of the scale images to obtain total age. Freshwater ages ranged from two to five and averaged three years. Adult steelhead ocean ages ranged from two to four years and averaged three years for first-time and repeat spawners combined.

Adult Steelhead-Emigration

The adult steelhead emigration totaled 278, and was composed of 171 previously PIT-tagged fish and 107 untagged fish. Combining the 270 immigrant upstream count with the 107 untagged downstream emigrant count gives an escapement through the weir of 377 (Figure 2). The first adult emigrant was captured on 23 April, the last was captured on 12 June, and the midpoint of the emigration was on 18 May. The peak daily downstream count (27) occurred on 12 May (Figure 2).

The length of all emigrant steelhead averaged 676 mm FL (SD = 60.0 mm) and ranged from 505 to 835 mm FL (N = 276). Two fish were released downstream without being measured due to injuries and weakened condition. Emigrant males and females were similar in length: females averaged 680 mm FL (SD = 68.6 mm), and males, averaged 669 mm FL (SD = 47.7 mm).

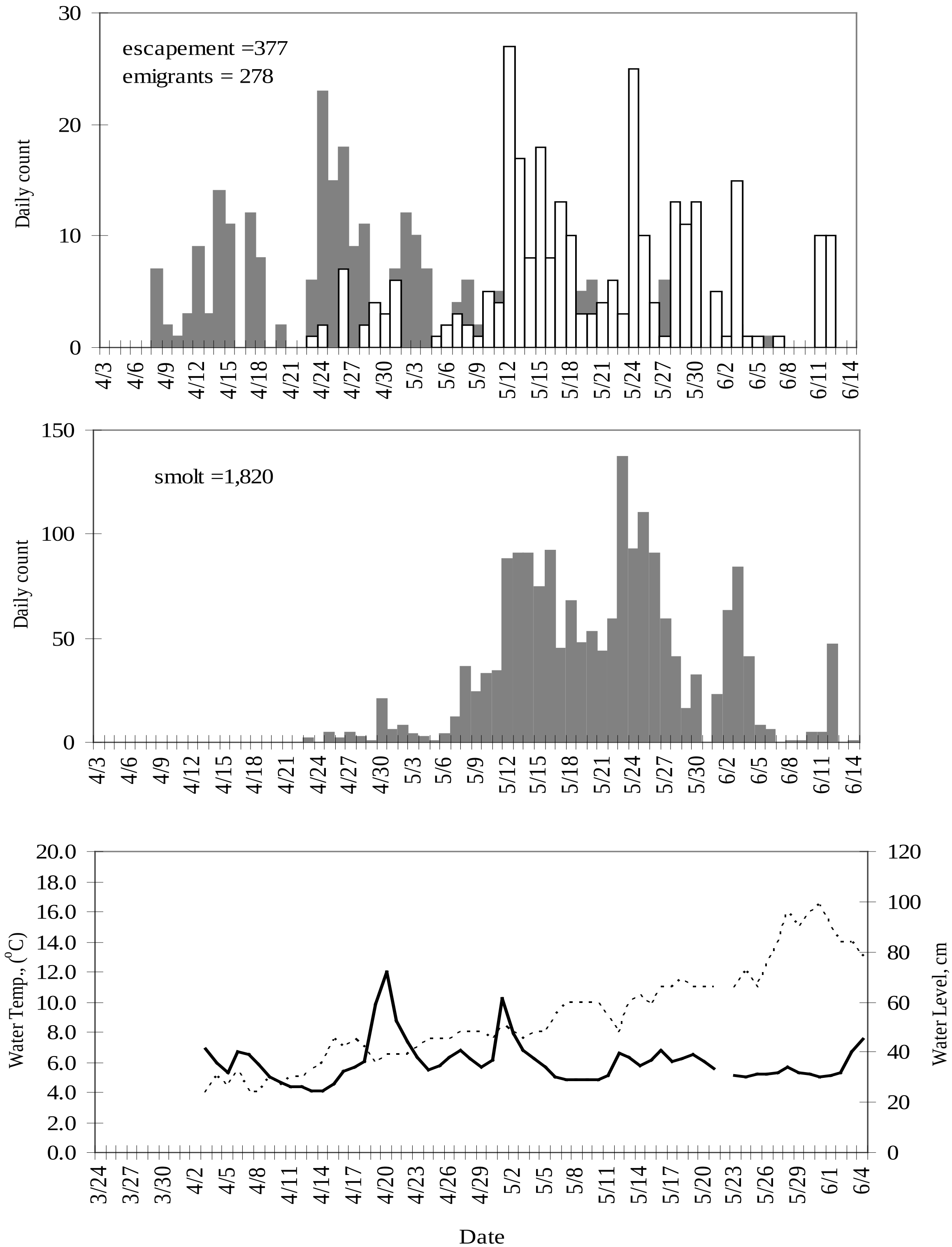

Figure 2.–Daily counts of total steelhead escapement (top panel solid bar graph) and kelts (top panel clear bar graph), steelhead smolt (center panel), and daily measurements of water level in cm (solid line), and water temperature in °C (stippled line) at Big Ratz Creek, 2010 (bottom panel).

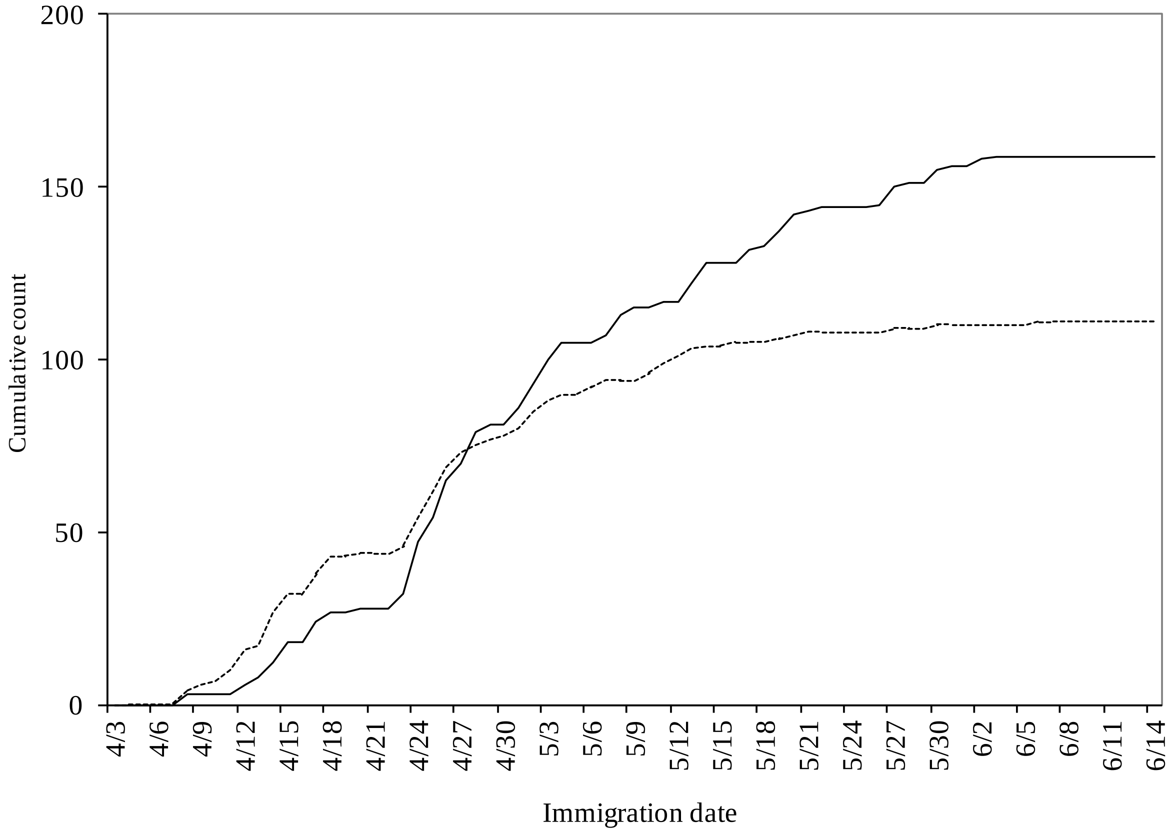

Figure 3.–Cumulative counts of adult male (stippled line) and female (solid line) steelhead (N = 270) immigrating through the Big Ratz Creek weir from 3 April to 14 June 2010.

Table 2.–Escapement counts, mean lengths (mm FL), range of lengths (mm FL), proportion of the total steelhead escapement >914 mm TL (> 36 in),[a] and proportion of females in the escapement recorded at the Big Ratz Creek weir, 2005, 2007, 2010, and 2011.

	Year sampled			
Adult immigration	2005[b]	2007[c]	2010	2011
Escapement count	399	284	377	549
Mean length, mm FL	751	760	681	692
Length range, mm FL	600–950	475–920	505–860	440–850
≥914 mm FL, %	1.7	0.6	0.0	0.0
Female, %	64	62	59	59

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

[b] From Piazza et al. (2008).

[c] From Piazza (2009).

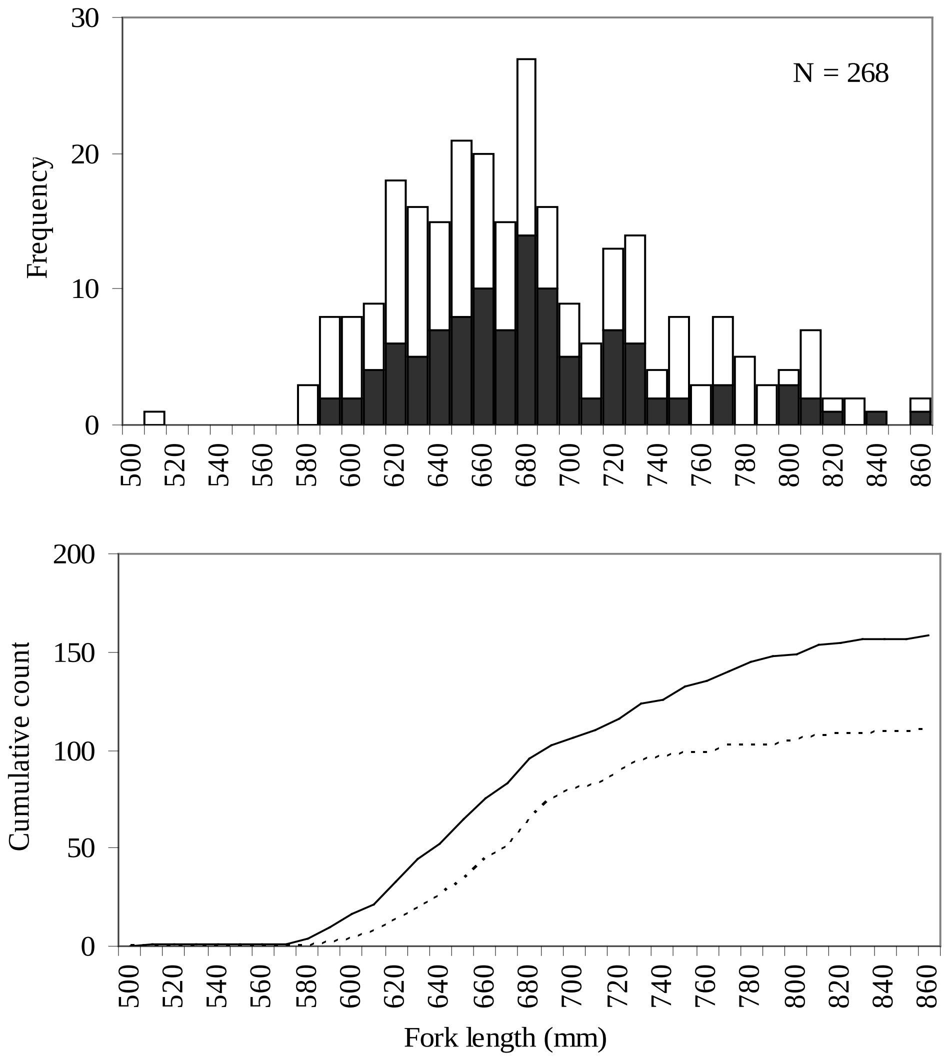

Figure 4.–Length frequency distributions for male (filled bars) and female (clear bars) steelhead (top panel) and cumulative numbers by sex and length of adult male (stippled line) and female (solid line) steelhead immigrating into Big Ratz Creek, 2010 (bottom panel).

Table 3.–Age composition, number (*n*), and proportion by age class $(\hat{p}_a)$ of all first-time and repeat steelhead spawners for which age estimates were made, Big Ratz Creek, 2010. Estimated ages are based on 3 independent readings of each scale sample by the same scale-aging technician. Total first-time and repeat spawners, fish that were not sampled, scale readings that did not match in 2 of 3 replicates, and unreadable scales are summarized for the immigrant (N = 270) and emigrant (N = 107) adults passed upstream and down through the weir in 2010.

	Immigrant adults		Emigrant adults	
Age class	*n*	$\hat{p}_a$	*n*	$\hat{p}_a$
2.2	5	0.028	0	0.000
3.1	1	0.006	0	0.000
3.2	79	0.446	26	0.317
3.3	9	0.051	6	0.073
4.2	33	0.186	17	0.207
4.3	11	0.062	8	0.098
5.2	1	0.006	1	0.012
5.3	0	0.000	1	0.012
2.2s1	1	0.006	0	0.000
2.3s	1	0.006	0	0.000
3.2s	1	0.006	4	0.049
3.2s1	12	0.068	2	0.024
3.2s1s	0	0.000	1	0.012
3.2s1s1	4	0.023	1	0.012
3.3s1	0	0.000	1	0.012
3.3s1s	1	0.006	0	0.000
4.2s	6	0.034	3	0.037
4.2s1	5	0.028	5	0.061
4.2s1s	1	0.006	5	0.061
4.2s1s1	2	0.011	0	0.000
4.3s1	3	0.017	1	0.012
6.2s1	1	0.006	0	0.000
First-time spawners	147		66	
Repeat spawners	30		16	
Not sampled	3		0	
No match	13		4	
Unreadable	77		21	
Total	270		107	
Successfully aged	177		82	

The proportion of emigrant females (65%) was slightly higher than the immigrant proportion (59%), indicating somewhat better survival of females. Prior to the midpoint of the emigration (18 May), more females (70%) emigrated from the system than males. Males appeared to stay in the stream longer (about 40% of the emigration after the midpoint was male). Overall, postspawning survival for both sexes combined was approximately 63%. About 52% of all males passed upstream survived spawning and were passed downstream, and female survival was about 70%.

Scale samples were taken from all of the 107 untagged emigrant adults. Readable scales were collected from 82 fish and successfully aged (Table 3). Estimated ages were compiled for the freshwater and saltwater portions from each of the scale images to obtain total age. Freshwater ages averaged three years, and ocean ages averaged three years for first-time and repeat spawners combined. For both immigrant and emigrant samples, first-time spawning adults outnumbered repeat spawners better than 4:1 (Table 4).

Adult Steelhead-Abundance

Evidence of size-selective sampling during the first and second sampling events was evaluated using the Kolmogorov-Smirnov two-sample test (Conover 1980; see Appendix A1). Size bias sampling was not evident during the first ($P = 0.98$) or second ($P = 0.95$) sampling events.

Contingency table analyses were used to detect evidence that sex-selective sampling occurred during the first and/or second sampling events Results indicated that there was equal probability of sampling males and females during the immigration ($P = 0.92$), but an unequal probability of sampling males or females during the emigration ($P = 0.15$). This result corroborates the higher proportion of females seen as emigrants.

Temporal bias could only be tested for the first event sampling. The marked: unmarked ratio observed early in the immigration (23 April–11 May) was significantly lower ($P < 0.001$) than the ratio observed later (31 May–12 June). This result suggests that there was an unequal probability of capture over time during the immigration. Based on the capture of a relatively large number of untagged emigrants, adult steelhead were evidently upstream of the site prior to installation of the weir. Although no emigrant steelhead were captured for four days prior to removal of the weir, it is possible that the weir was removed prior to the completion of emigration. Thus, it is possible that all emigrant steelhead did not have a similar probability of capture during the second event. Clearly, complete mixing did not occur based on the test for first event sampling.

These results suggest that a temporally-stratified model as described by Darroch (1961) should be used to estimate steelhead abundance. Unfortunately, sufficiently detailed data were not collected to allow a Darroch-type model to be used. Although likely biased, the Chapman modified Peterson estimate was 439 (SE = 12.6).

The minimum escapement, based on weir counts of immigrant and emigrant fish, was 377. This count was comprised of the sum of 270 untagged adults passed upstream and 107 untagged adults passed downstream.

Table 4.–Age composition, number (*n*), proportion by age class $(\hat{p}_a)$, and standard error for all untagged immigrant and emigrant first-time and repeat steelhead spawners combined for which age estimates were made (*n* = 259), Big Ratz Creek, 2010. Estimated ages are based on three independent readings of each scale sample by the same scale-aging technician. Total first-time and repeat spawners, fish that were not sampled, scale readings that did not match in 2 of 3 replicates, and unreadable scales are summarized for the entire escapement of 377 adults passed upstream and down through the weir in 2010.

	Immigrant and emigrant adults		
Age class	*n*	$\hat{p}_a$	SE($\hat{p}_a$)
2.2	5	0.019	0.0086
3.1	1	0.004	0.0039
3.2	105	0.405	0.0306
3.3	15	0.058	0.0145
4.2	50	0.193	0.0246
4.3	19	0.073	0.0162
5.2	2	0.008	0.0054
5.3	1	0.004	0.0039
2.2s1	1	0.004	0.0039
2.3s	1	0.004	0.0039
3.2s	5	0.019	0.0086
3.2s1	14	0.054	0.0141
3.2s1s	1	0.004	0.0039
3.2s1s1	5	0.019	0.0086
3.3s1	1	0.004	0.0039
3.3s1s	1	0.004	0.0039
4.2s	9	0.035	0.0114
4.2s1	10	0.039	0.0120
4.2s1s	6	0.023	0.0094
4.2s1s1	2	0.008	0.0054
4.3s1	4	0.015	0.0077
6.2s1	1	0.004	0.0039
First-time spawners	213	0.565	0.0309
Repeat spawners	46	0.122	0.0204
Not sampled	3		
No match	17		
Unreadable	98		
Total escapement	377		
Successfully aged	259	0.687	

Steelhead Smolt

A total of 1,820 steelhead smolt and 31 juvenile (parr) steelhead were captured as they emigrated through the weir. The first smolt emigrant was captured at the weir on 23 April, the last on 14 June, and the midpoint of the emigration occurred on 21 May. The peak daily count (137) occurred on 23 May (Figure 2). Of the total smolt, 1,815 were PIT-tagged and released downstream, one was not tagged due to excessive scale loss, and there were four mortalities (0.3%). All mortalities were measured to the nearest 1 mm FL, and sampled for scales and otoliths. No previously tagged smolt were passed through the weir. The 31 parr were too small to be safely PIT tagged without injuring them, but they were measured and scale samples were taken before being released downstream.

All smolt were measured for fork length. The length of smolt averaged 202 mm FL (SD = 25.1 mm), and ranged from 150 mm to 380 mm FL; the mode of the length frequency distribution was centered at 190 mm FL (Table 5, Figure 5). Smolt >350 mm FL had all the physical characteristics of average-sized smolt, so these fish were regarded to be steelhead and not rainbow trout and were thus PIT tagged. Smaller smolt left later in the season, but the range in sizes was similar to earlier emigrants (Figure 5).

Scale samples were collected from 1,815 smolt. Five smolts were not scale sampled. A systematic sample of 483 scales (26.6%, or a subsampling rate of about 1 in 4) were selected for aging. Freshwater ages ranged from 2 to 8 years; age 2 (22%) and age 3 (50%) were the predominant age classes (Table 6). Ages could not be estimated for approximately 8% of the subsample because they were either damaged or dirty, had regenerated foci, or could not be assigned replicate ages in triplicate readings. The mean CV across all ages for all smolt scales aged was 5% (Table 6).

Dolly Varden Char

A total of 10,326 Dolly Varden emigrants were captured and passed downstream through the weir. The first fish was captured on 22 April. The midpoint of the run occurred on 6 May (Figure 6), and emigrant Dolly Varden were still being captured on 14 June. No emigrant Dolly Varden were measured for length frequency analysis. Fork length was generally observed to decrease as the run progressed; greater numbers of larger fish left the system earlier in the emigration. Between 11 June and 14 June (when the weir was removed) a total of 17 large adult Dolly Varden (450–500 mm FL) were captured moving upstream.

Cutthroat Trout

A total of 643 emigrant cutthroat trout were counted through the weir. The first cutthroat trout was captured on 22 April and the midpoint occurred about 14 May. Emigrant cutthroat trout were still being caught until two days before the weir was removed (14 June). The peak daily count (65) occurred on 27 April, and another high count (50) occurred on 30 April (Figure 6). No cutthroat trout were measured for length frequency analysis. As observed for Dolly Varden, the length of emigrants appeared to vary throughout the run, but generally fish length decreased through time.

Rainbow Trout and Other Migrants

A total of 287 emigrant rainbow trout were captured between 23 April and 14 June, and the midpoint of the emigration occurred on 16 May (Figure 6). Adult salmon were captured and passed upstream through the weir and included: six sockeye salmon *O. nerka* between 7 June and 14 June, one chum salmon *O. keta* on 25 April, and one Coho salmon *O. kisutch* on 9 June.

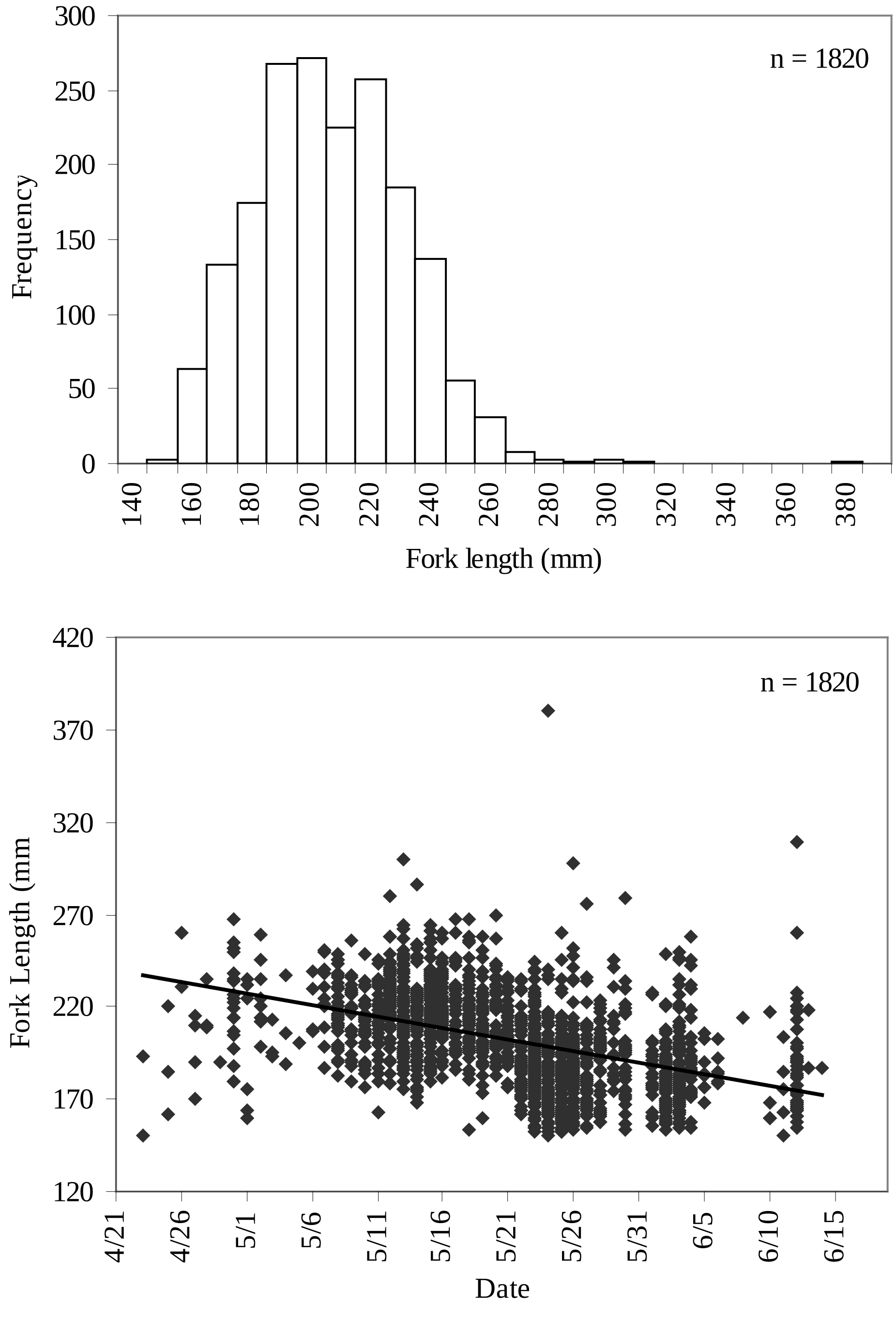

Figure 5.–Length frequency distribution for all steelhead smolt that emigrated out of Big Ratz Creek (top panel) and size (mm FL) of sampled steelhead smolt by date captured at the weir (bottom panel) from 3 April to 14 June 2010. The first smolt emigrant was captured 23 April. The depicted trend line is the best fit linear trend line (y = mx + b) of smolt size by sample date (bottom panel), $r^2 = 0.201$.

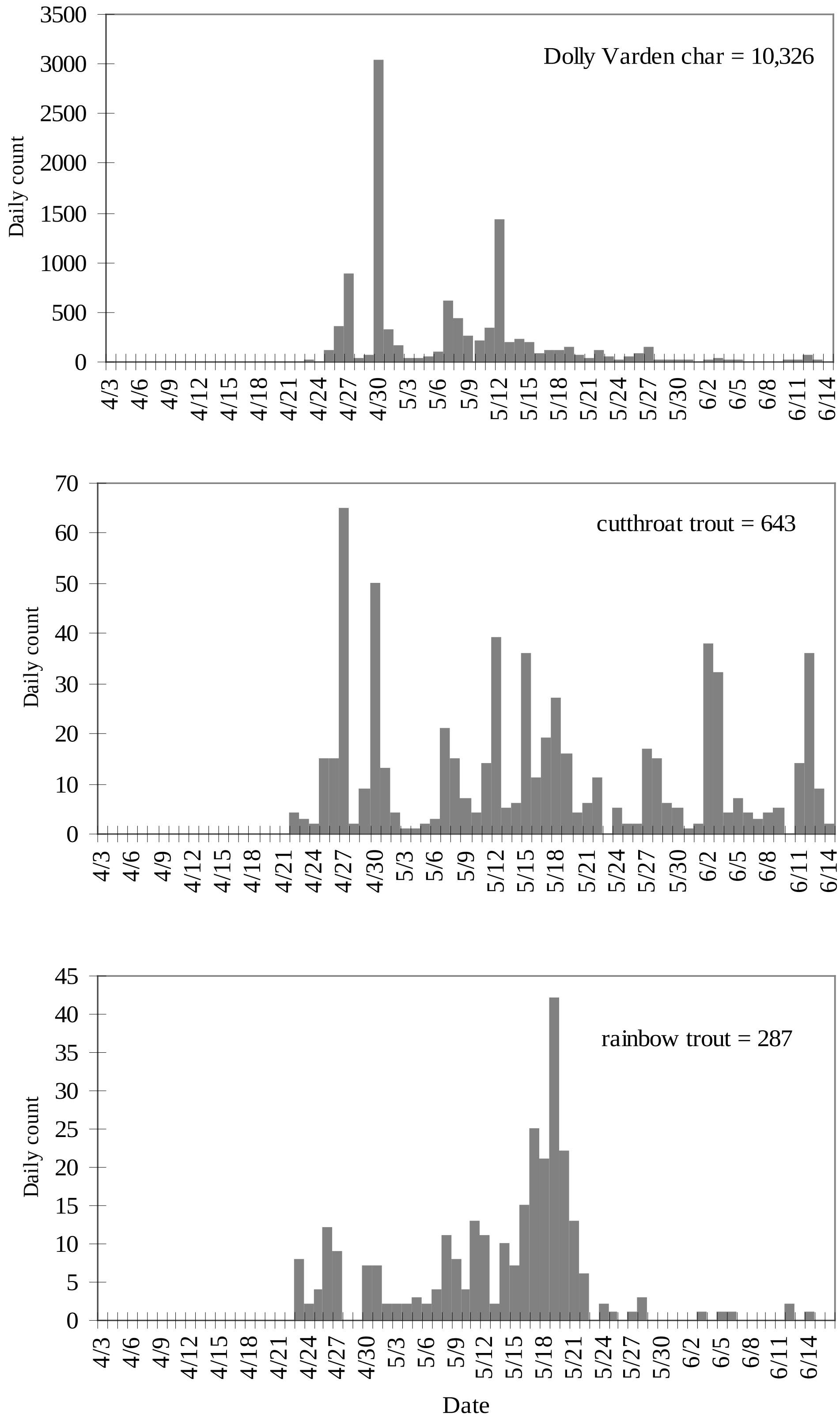

Figure 6.–Daily counts of emigrant Dolly Varden char, emigrant cutthroat trout, and emigrant rainbow trout at Big Ratz Creek, 2010.

Table 5.–Length frequencies of Big Ratz Creek steelhead smolt passed downstream through the weir in 2010.

Length class (mm FL)	Number of steelhead sampled (*n*)
140	0
150	3
160	64
170	133
180	175
190	268
200	271
210	225
220	257
230	185
240	137
250	55
260	31
270	8
280	3
290	1
300	2
310	1
320	0
330	0
340	0
350	0
360	0
370	0
380	1
390	0
Total	1,820

2011

Adult Steelhead-Immigration

The weir was continuously operated from 23 March to 20 June. The first adult was captured in the upstream trap on 1 April, and the last on 12 June. The peak daily count (24) occurred on 29 April, and the midpoint of the immigration was 2 May (Figure 7). Water temperatures increased steadily from 2.0°C on 26 March to about 14°C by 20 June.

A total of 449 adult steelhead were passed upstream through the weir: 407 were untagged and 42 had been tagged in 2010. Females composed the majority of the immigration at 59% (Table 2). Approximately equal numbers of males and females immigrated into Big Ratz Creek prior to 29 April, whereas more females than males immigrated after 29 April (Figure 8).

Table 6.–Freshwater ages based on scale analysis for Big Ratz Creek steelhead smolt, 2010. Scale samples were subsampled at a rate of 1 in 4 (total emigrant count for 2010 was 1,820 smolt). About 92% of subsampled scales were successfully aged and not rejected due to regeneration, damage or unmatched reads. Estimated ages were based on three independent readings of each scale by the same scale-aging technician. Mean CV was calculated for CVs of all triplicate reads of successfully aged smolt scales.

Scale age	# Sampled	$\hat{p}_a$	SE($\hat{p}_a$)
Sample	483		
# Successfully aged	445		
Total emigration	1,820		
2	2	0.004	0.0000
3	105	0.217	0.0002
4	240	0.497	0.0002
5	86	0.178	0.0001
6	11	0.023	0.0000
7	0	0.000	0.0000
8	1	0.002	0.0000
Unreadable	36	0.075	0.0001
No match	2	0.004	0.0000
Mean CV(all triplicate reads), %	5.049		
Successfully aged, %	92		

The average and maximum lengths of males and females were similar, although minimum size of males was smaller than for females (Figure 9). The length of immigrant steelhead (both sexes combined) averaged 692 mm FL (SD = 68.3 mm) and ranged from 440 to 850 FL mm (N = 449). The length of males averaged 668 mm FL and had a SD = 72.4 mm (N = 182); for females, length averaged 709 mm FL and had a SD = 60.1 mm (N = 267). The smallest male was 440 mm FL and the largest was 845 mm FL. The smallest immigrant female was 565 mm FL and largest was 850 mm FL. In addition to fork length, total length was measured. None of the fish were large enough to be legally retained during sport fishing (Table 2).

Scale samples were taken from all 407 untagged and all 42 previously-tagged steelhead. Ages were estimated from a subsample of 244 untagged immigrant adults, and all previously tagged immigrant adults; 167 samples from untagged immigrants (41%) and 30 from previously-tagged fish (71%) were successfully aged (Table 7). Unreadable scales were those for which all scales in the sample either did not have a readable freshwater or saltwater portion, were damaged, or could not be assigned replicate ages in triplicate readings. Electronic images created from the readable scale samples were aged and archived. Estimated ages were compiled for the freshwater and saltwater portions from each of the scale images to obtain total age. Freshwater ages ranged from two to six and averaged four years. Adult steelhead ocean ages ranged from one to four years and averaged two years for first-time and repeat spawners combined.

Adult Steelhead-Emigration

The adult steelhead emigration totaled 458. Of these, 358 had PIT tags from 2010 or were PIT tagged during their upstream migration in 2011, and 100 were untagged downstream migrants. Combining the 449 immigrant upstream count with the 100 untagged downstream emigrant count gives an escapement through the weir of 549 (Figure 7). The first adult emigrant was captured on 27 April, the last was captured on 19 June, and the midpoint of the emigration was on 25 May. The peak daily downstream count (49) occurred on 27 May (Figure 7).

Table 7.–Age composition, number (*n*), and proportion by age class ($\hat{p}_a$) for all untagged and recaptured immigrant first-time and repeat steelhead spawners for which age estimates were made (*n* = 286), Big Ratz Creek, 2011. Estimated ages are based on three independent readings of each scale sample by the same scale-aging technician. Total first-time and repeat spawners, fish that were not sampled, scale readings that did not match in two of three replicates, and unreadable scales are summarized for the entire immigration of 449 adults passed upstream through the weir in 2011.

	Untagged immigrants		Recaptured immigrants		All immigrants combined	
Age class	*n*	$\hat{p}_a$	*n*	$\hat{p}_a$	*n*	$\hat{p}_a$
3.2	23	0.138	0	0.000	23	0.117
3.3	9	0.054	0	0.000	9	0.046
4.1	2	0.012	1	0.033	3	0.015
4.2	45	0.269	0	0.000	45	0.228
4.3	8	0.048	0	0.000	8	0.041
5.1	0	0.000	1	0.033	1	0.005
5.2	4	0.024	0	0.000	4	0.20
5.3	1	0.006	0	0.000	1	0.005
6.2	1	0.006	0	0.000	1	0.005
3.2s	6	0.036	0	0.000	6	0.30
3.2s1	29	0.174	11	0.367	40	0.203
3.2s1s	2	0.012	1	0.033	3	0.015
3.2s1s1	1	0.006	1	0.033	2	0.010
3.2s1s1s1	1	0.006	0	0.000	1	0.005
3.3s1	0	0.000	2	0.067	2	0.10
4.2s	5	0.030	0	0.000	5	0.25
4.2s1	22	0.132	11	0.367	33	0.168
4.2s1s	5	0.30	0	0.000	5	0.025
4.3s1	1	0.006	1	0.033	2	0.10
5.2s	1	0.006	0	0.000	1	0.005
5.2s1	0	0.000	1	0.033	1	0.005
6.2s1	1	0.006	0	0.000	1	0.005
First-time spawners	105		2		107	
Repeat spawners	62		28		90	
Not sampled	0		1		1	
No match	11		1		12	
Unreadable	66		10		76	
Total sampled	244		42		286	
Successfully aged	167		30		197	

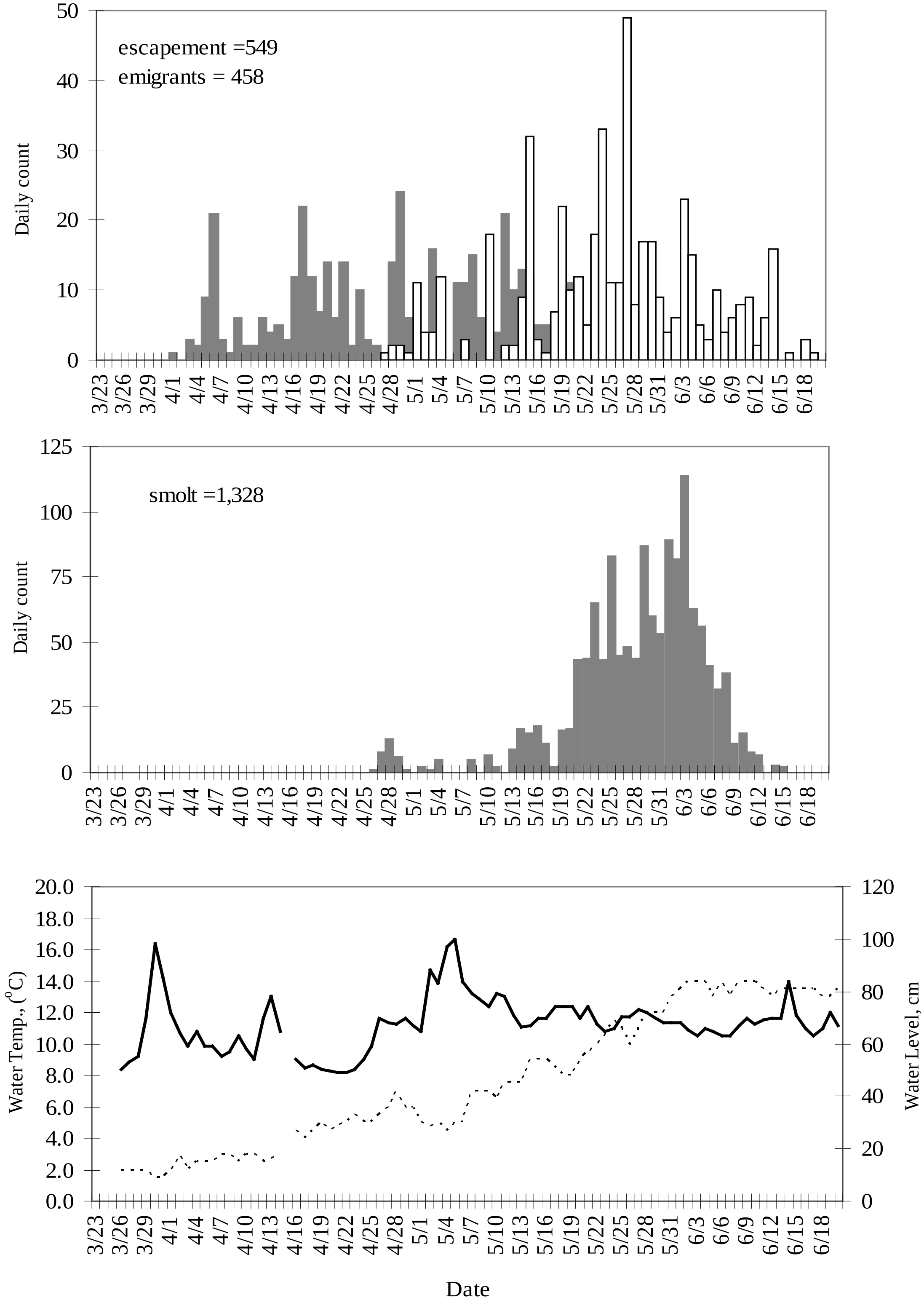

Figure 7.–Daily counts of total steelhead escapement (top panel solid bar graph) and kelts (top panel clear bar graph), steelhead smolt (center panel), and daily measurements of water level in cm (solid line), and water temperature in °C (stippled line) at Big Ratz Creek, 2011 (bottom panel).

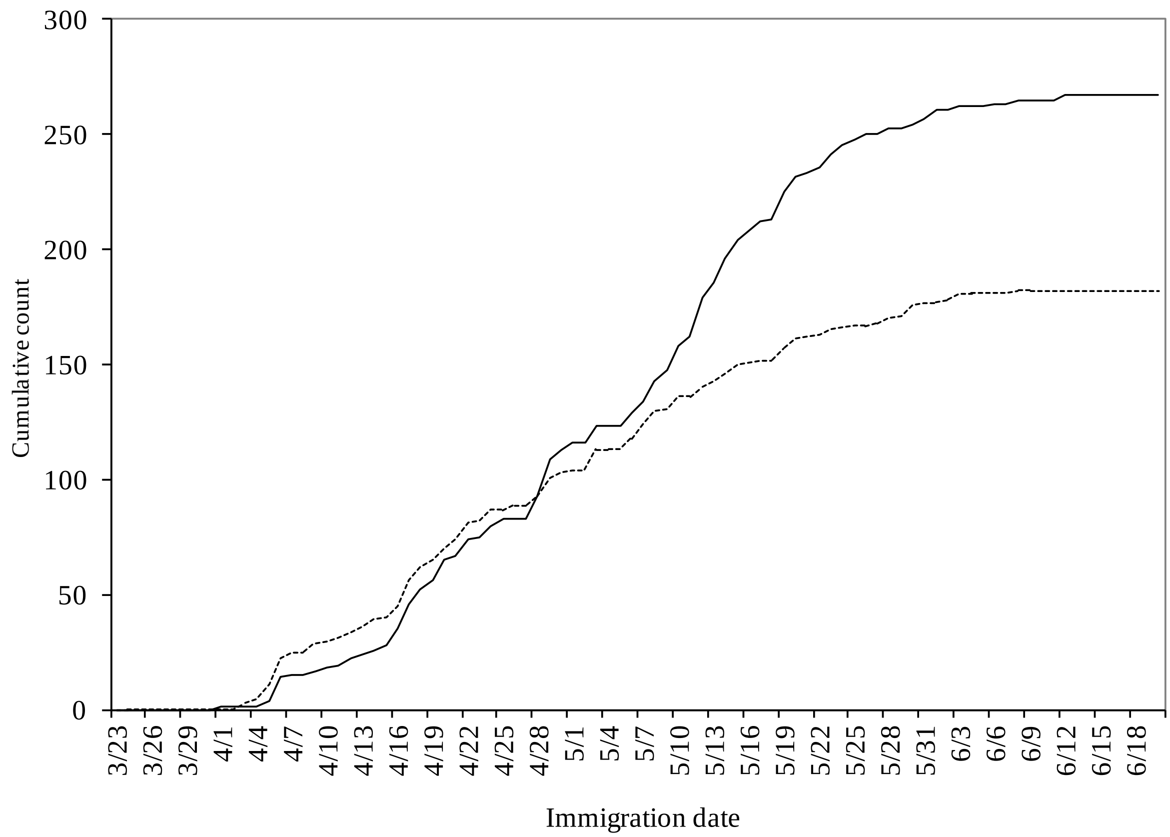

Figure 8.–Cumulative counts of adult male (stippled line) and female (solid line) steelhead (*N* = 449) immigrating through the Big Ratz Creek weir from 23 March to 20 June 2011.

The length of all emigrant steelhead averaged 701 mm FL (SD = 68.0 mm), and ranged from 440 to 860 mm FL (N = 458). Emigrant males and females were similar in length: females averaged 702 mm FL (SD of 66.8 mm), and males averaged 695 mm FL (SD of 88.4 mm).

The proportion of emigrant females (63%) was similar to the immigrant proportion (59%), indicating a slightly better survival of females. Prior to the midpoint of the emigration (25 May), approximately equal numbers of females (58%) emigrated from the system as did males. Overall, postspawning survival for both sexes combined was approximately 80%. About 71% of all males passed upstream survived spawning and were passed downstream, and female survival was about 85%.

Of the 100 untagged adults passed downstream, all but one was sampled for scales. Readable scales were collected from 55 fish and successfully aged (Table 8). For both immigrant and emigrant samples, first-time spawning adults were similar in number to repeat spawners; the first-time: repeat ratio was 1.25:1 (Table 8).

Table 8.–Age composition, number (*n*), and proportion by age class ($\hat{p}_a$) of all first-time and repeat spawning immigrant and emigrant adult steelhead for which age estimates were made, Big Ratz Creek, 2011. Estimated ages based on three independent readings of each scale sample by the same scale-aging technician. Total first-time and repeat spawners, fish that were not sampled, or did not match in two of three reads, and un-readable scales are summarized for the immigrant (*n* = 286) and emigrant (*n* = 99) adults passed upstream and down through the weir in 2011.

	All immigrants combined		Untagged emigrants		Combined immigrant and emigrant adults		
Age class	*n*	$\hat{p}_a$	*n*	$\hat{p}_a$	*n*	$\hat{p}_a$	SE
2.3	0	0.000	3	0.055	3	0.012	0.0068
3.2	23	0.117	4	0.073	27	0.107	0.0195
3.3	9	0.046	8	0.145	17	0.067	0.0158
3.4	0	0.000	1	0.018	1	0.004	0.0040
4.1	3	0.015	0	0.000	3	0.012	0.0068
4.2	45	0.228	5	0.091	50	0.198	0.0252
4.3	8	0.041	6	0.109	14	0.056	0.0145
4.4	0	0.000	1	0.018	1	0.004	0.0040
5.1	1	0.005	0	0.000	1	0.004	0.0040
5.2	4	0.020	0	0.000	4	0.016	0.0079
5.3	1	0.005	0	0.000	1	0.004	0.0040
6.2	1	0.005	0	0.000	1	0.004	0.0040
2.2s1	0	0.000	1	0.018	1	0.004	0.0040
3.2s	6	0.030	1	0.018	7	0.028	0.0104
3.2s1	40	0.203	8	0.145	48	0.190	0.0248
3.2s1s	3	0.015	0	0.000	3	0.012	0.0068
3.2s1s1	2	0.010	0	0.000	2	0.008	0.0056
3.2s1s1s1	1	0.005	0	0.000	1	0.004	0.0040
3.3s	0	0.000	1	0.018	1	0.004	0.0040
3.3s1	2	0.010	2	0.036	4	0.016	0.0079
4.2s	5	0.025	2	0.036	7	0.028	0.0104
4.2s1	33	0.168	10	0.182	43	0.171	0.0237
4.2s1s	5	0.025	0	0.000	5	0.020	0.0088
4.2s1s1	0	0.000	1	0.018	1	0.004	0.0040
4.3s	0	0.000	1	0.018	1	0.004	0.0040
4.3s1	2	0.010	0	0.000	2	0.008	0.0056
5.2s	1	0.005	0	0.000	1	0.004	0.0040
5.2s1	1	0.005	0	0.000	1	0.004	0.0040
6.2s1	1	0.005	0	0.000	1	0.004	0.0040
First-time spawners	107		33		140	0.255	0.0275
Repeat spawners	90		22		112	0.204	0.0254
Not sampled	1		0		1		
No match	12		15		27		
Unreadable	76		29		105		
Total sampled	286		99		385		
Successfully aged	197		55		252		

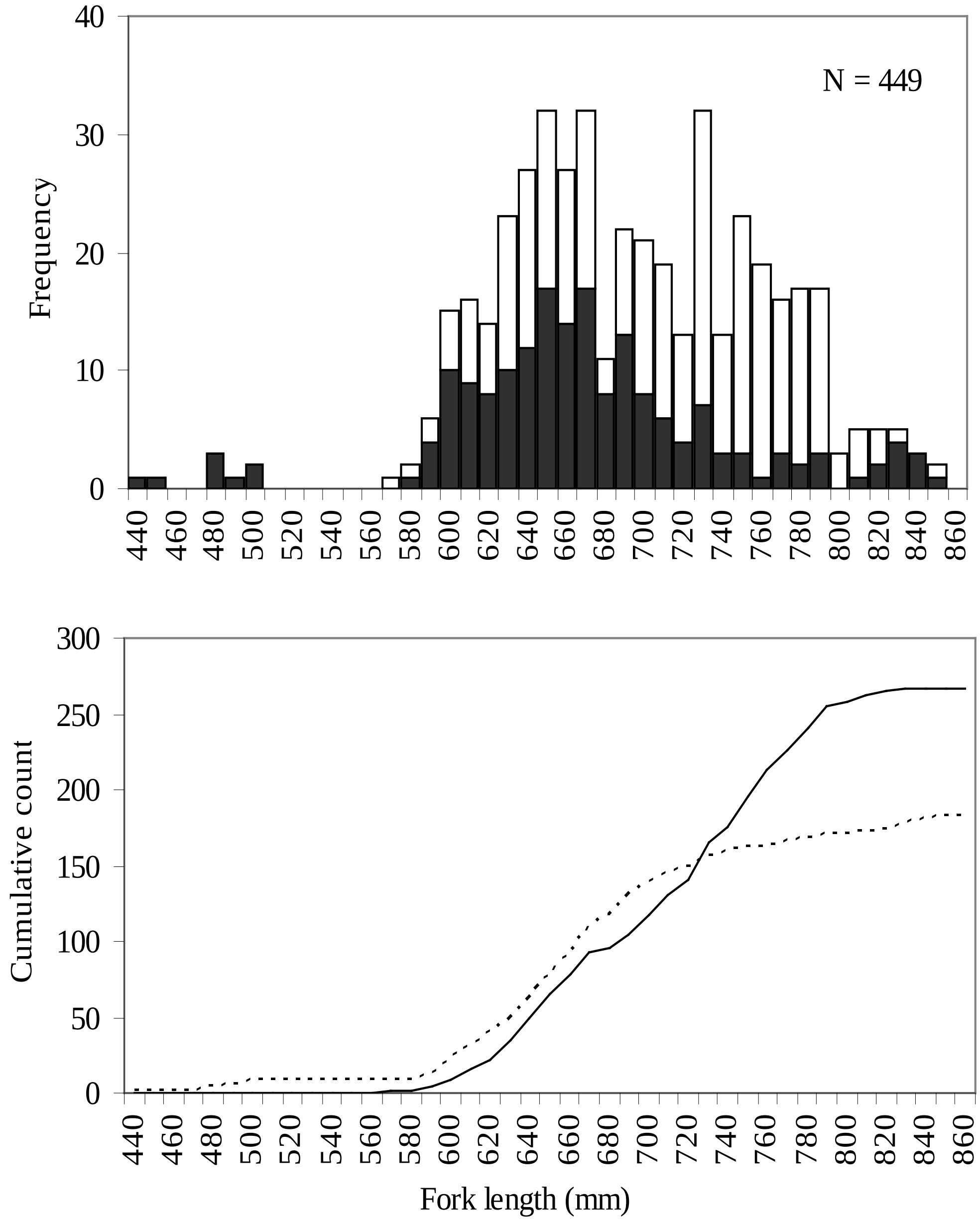

Figure 9.–Length frequency distributions for male (filled bars) and female (clear bars) steelhead (top panel) and cumulative numbers by sex and length of adult male (stippled line) and female (solid line) steelhead immigrating into Big Ratz Creek, 2011 (bottom panel).

Adult Steelhead-Abundance

Size-selective sampling was not evident during the first (P = 0.75) or second (P = 0.99) sampling events. Contingency table analyses indicated that there were equal probabilities of sampling males and females during the immigration (P = 0.75), but there was some evidence of an unequal probability of sampling males or females during emigration (P = 0.18). Similar to 2010, this result corroborates the higher proportion of females seen as emigrants. Neither size nor gender stratification was necessary to eliminate bias prior to estimating abundance.

There appeared to be significant evidence of temporal bias for both the first event (P < 0.001) and second event (P < 0.001), and incomplete mixing of marked to unmarked fish (P < 0.001). Attempts to use a Darroch (1961) model to estimate steelhead abundance after temporally stratifying first and second event data did not result in any admissible estimates. The biased Chapman modified Peterson estimate was 579 (SE = 6.6).

The minimum escapement, based on weir counts of immigrant and emigrant fish, was 549. This count was comprised of the sum of 449 adults (tagged and untagged) passed upstream and 100 untagged adults passed downstream.

Steelhead Smolt

A total of 1,328 steelhead smolt and 10 juvenile (parr) steelhead were captured as they emigrated through the weir. The first smolt was captured at the weir on 26 April, the last on 15 June, and the midpoint of the emigration occurred on 29 May. The peak (116) daily count occurred on 2 June (Figure 7). Of the total smolt, 1,306 were PIT-tagged and released downstream, 17 were released downstream without being measured, sampled for scales, or tagged, two were tagging mortalities (0.15%), and three were released without being tagged because of extensive scale loss or injury. All mortalities were measured to the nearest 1 mm FL, and sampled for scales and otoliths. No previously tagged smolt were passed through the weir in 2011. The 10 parr were too small to be safely PIT tagged without injuring them, but they were measured and scale samples were taken before they were released downstream.

Of the total emigration, 1,311 were measured for fork length. The length of smolt averaged 190 mm FL (SD = 22.5 mm), And ranged from 150 mm to 356 mm FL; the mode of the length frequency distribution was centered at 190 mm FL (Table 9, Figure 10). Smolt >350 mm FL had all the physical characteristics of average-sized smolt, so were regarded to be steelhead and not rainbow trout and were thus PIT tagged. The larger smolt emigrated earlier in the season, but the range in smolt sizes were similar throughout the emigration. (Figure 10).

Scale samples were collected from 1,311 smolt captured. Seventeen smolts were not sampled. A systematic sample of 440 scales (33.5%, or a subsampling rate of about 1 in 3) were selected for aging. Freshwater ages ranged from two to six years; age 3 (38%) and age 4 (45%) were the predominant age classes. Ages could not be estimated for about 12% of the subsample because they were either damaged or dirty, or had regenerated foci. The mean CV across all ages for all smolt scales aged was 6% (Table 10).

Dolly Varden Char

A total of 13,130 Dolly Varden emigrants were captured and passed downstream through the weir. The first fish was captured on 26 April and the midpoint of the run occurred on 13 May (Figure 11). The peak daily count (1,422) occurred on 15 May. Dolly Varden were still being captured until the weir was removed on 20 June. No emigrant Dolly Varden char were measured for length frequency analysis. Fork length was generally observed to decrease as the run progressed; greater numbers of larger fish left the system earlier in the emigration.

Table 9.–Length frequencies of Big Ratz Creek steelhead smolt passed downstream through the weir in 2011

Length class (mm FL)	Number of steelhead sampled (*n*)
140	0
150	4
160	64
170	140
180	244
190	295
200	239
210	138
220	89
230	48
240	15
250	10
260	7
270	7
280	2
290	1
300	1
310	1
320	4
330	1
340	0
350	0
360	1
Total	1,328

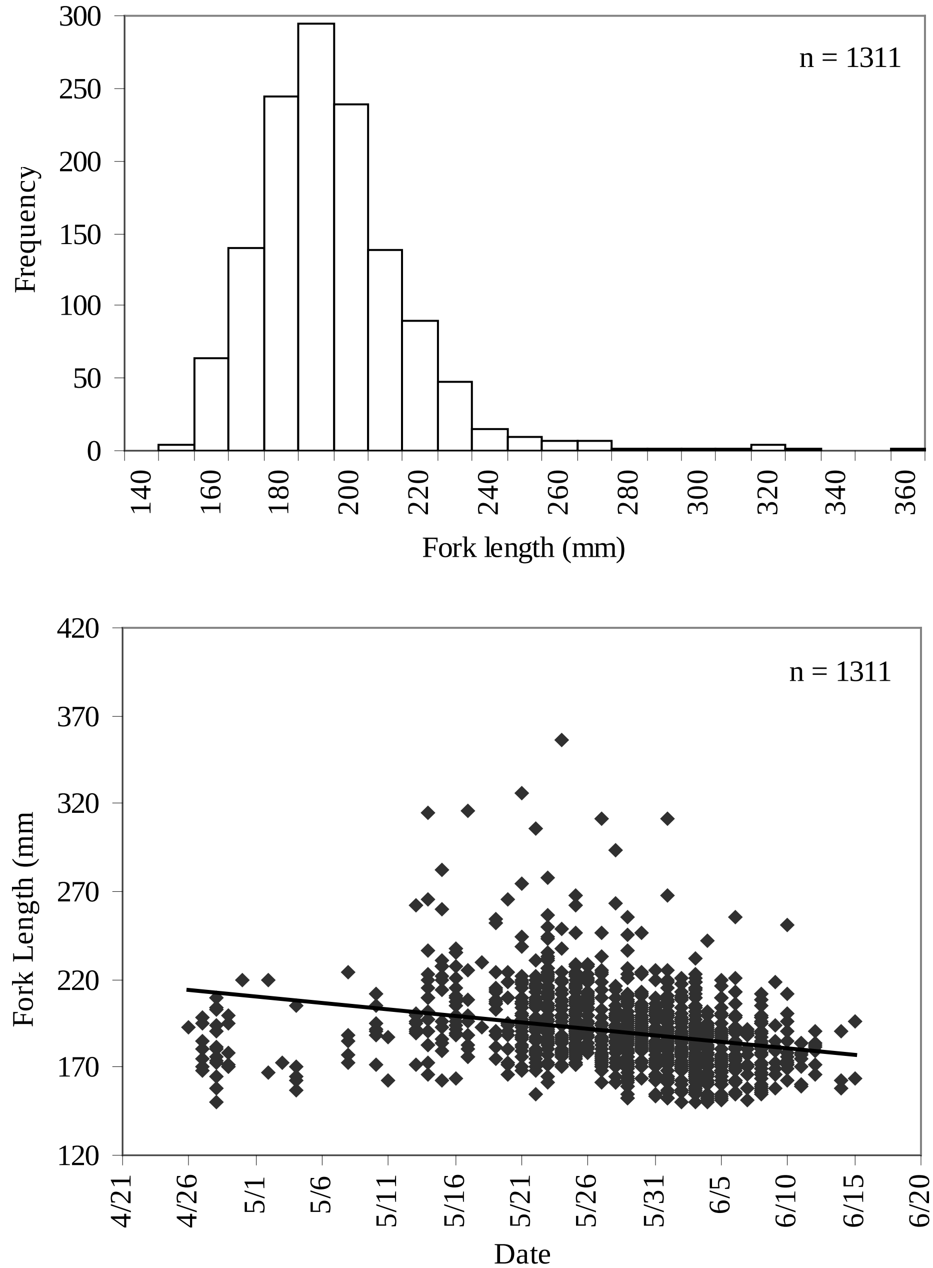

Figure 10.–Length-frequency distribution for all steelhead smolt that emigrated out of Big Ratz Creek (top panel) and size (mm FL) of sampled steelhead smolt by date captured at the weir (bottom panel) from 23 March to 20 June 2011. The first smolt emigrant was captured 26 April. The depicted trend line is the best fit linear trend line (y = mx + b) of smolt size by sample date (bottom panel), $r^2 = 0.071$.

Cutthroat Trout

A total of 617 emigrant cutthroat trout were counted through the weir. The first trout was captured on 26 April and the midpoint occurred about 13 May. Emigrant cutthroat trout were caught until the week before (14 June) the weir was removed. The peak daily count (50) occurred on 1 May, and another high count (50) occurred a few days earlier on 28 April (Figure 11). No cutthroat trout were measured for length frequency analysis. As was observed for Dolly Varden, the length of emigrants appeared to vary throughout the run, but generally fish length decreased through time.

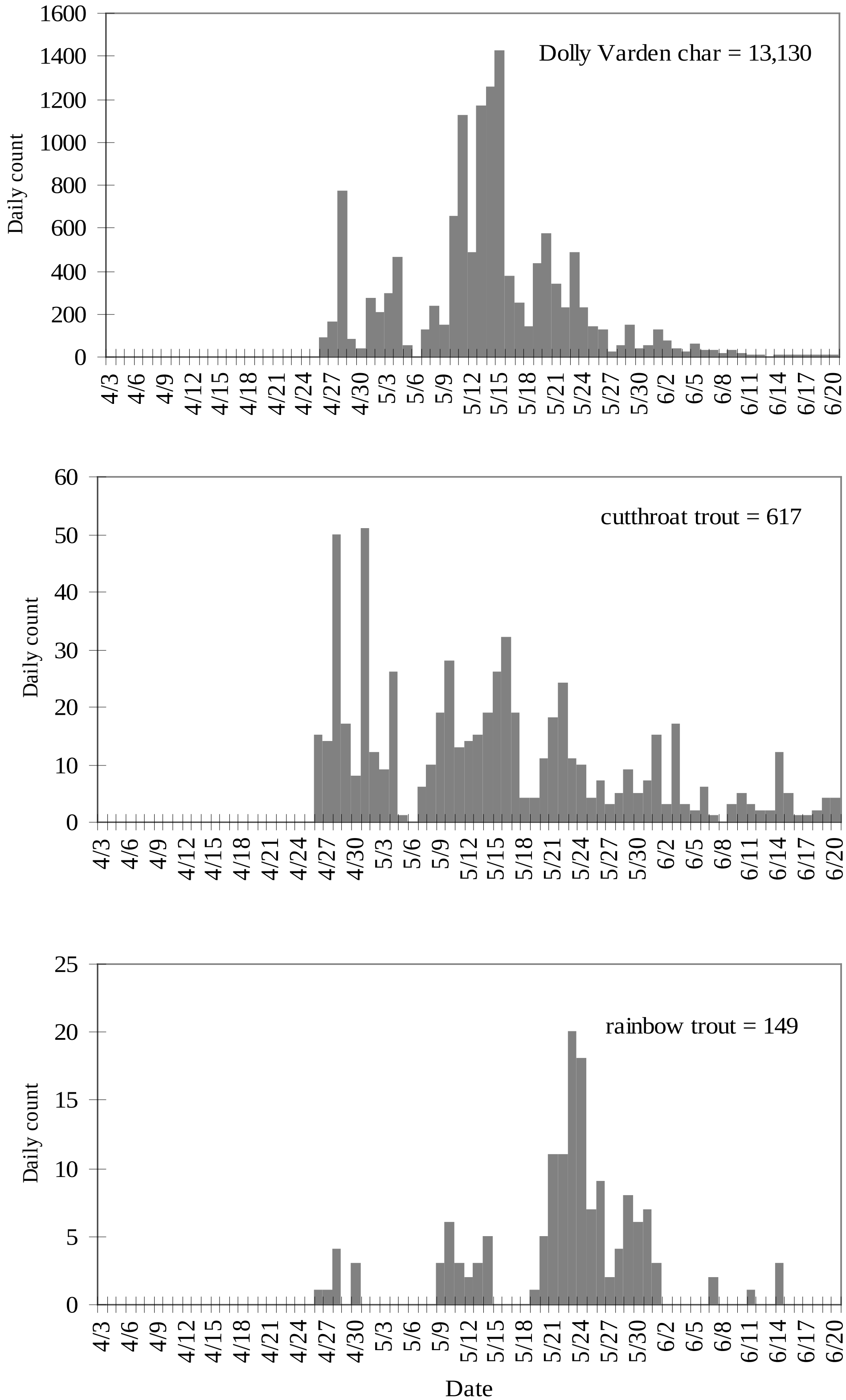

Figure 11.–Daily counts of emigrant Dolly Varden char, emigrant cutthroat trout, and emigrant rainbow trout at Big Ratz Creek, 2011.

Table 10.–Freshwater ages based on scale analysis for Big Ratz Creek steelhead smolt, 2011. Scale samples were subsampled at a rate of about 1 in 3 (total emigrant count for 2011 was 1,328 smolt). About 88% of subsampled scales were successfully aged and were not rejected due to regeneration, damage or unmatched reads. Estimated ages are based on three independent readings of each scale by the same scale-aging technician. Mean CV was calculated for CVs of all triplicate reads of successfully aged smolt scales.

Scale age	# Sampled	$\hat{p}_a$	SE($\hat{p}_a$)
Sample	440		
# Successfully aged	388		
2	5	0.011	0.0000
3	166	0.377	0.0003
4	197	0.448	0.0003
5	18	0.041	0.0000
6	2	0.005	0.0000
Unreadable	51	0.116	0.0001
No match	1	0.002	0.0000
Mean CV (all triplicate reads), %	5.638		
Successfully aged, %	88		

Rainbow Trout and Other Migrants

A total of 149 rainbow trout emigrants were passed downstream between 26 April and 14 June. The first rainbow trout was captured on 26 April, the last on 14 June, and the midpoint of the emigration was 23 May (Figure 11). There were also two immigrant sockeye salmon that passed through the weir between 28 May and 7 June.

DISCUSSION

As originally conceived, this project was to provide resource managers with a short time series of smolt and adult production data (seven years: 2010 to 2016) from a steelhead system in southern Southeast Alaska. These production data were to be combined with a previous steelhead production time series on Sitkoh Creek, Chichigof Island (Love and Harding 2008, 2009; Love et al. 2012a, 2012b), and detailed habitat mapping (Schroeder and Nichols 2012*;* Crupi and Nichols 2012) to estimate adult and smolt production per useable habitat area. The design of this project was unique in Southeast Alaska because use of standardized weir methods coupled with individual tagging histories would have allowed comparable estimates of adult and smolt production, marine survival, first-time and repeat spawning rates, and an understanding of life history variation essential for habitat production modeling. Unfortunately, this project was ended after only two years. Resultant incomplete sampling of adult and smolt steelhead may not provide sufficient information necessary for assigning production to steelhead habitat estimates provided in Schroeder and Nichols (2012). This foreshortened data set only allows an incomplete estimate of the total number of steelhead smolts produced from the 2007 brood year (freshwater ages 3 and 4, but not 2 or 5), and may be of limited usefulness to state and federal managers interested in assessing or monitoring changes in steelhead streams across the region. Baseline information from projects such as this is generally lacking for steelhead and is invaluable for informed management decisions.

Adult Steelhead Counts, Evaluation of Peterson Estimates

Previous weir counts in 2005 and 2007 were likely incomplete because the weir was removed before the end of the emigration (Table 1). Weir counts were reported for 2005 (n = 399), but Petersen estimates of the immigration were not calculated (Piazza et al. 2008). In 2007, a Chapman's modified Peterson estimate of 331 (SE = 12) was generated, but it was believed to be biased because of failure to meet model assumptions (Piazza 2009). The weir counts in 2005 and 2007 were considered to be minimum estimates. Census in 2010 and 2011 based on standardized weir methodology resulted in minimum adult escapement counts for 2010 and 2011 of 377 and 549, respectively (Table 11).

Due to high water conditions during both 2010 and 2011, the weir was installed about 10 days to two weeks later than weir operations in 2005 and 2007. Although late installation may have resulted in some early immigrants being missed, extended operation through mid to late June allowed more untagged emigrant kelts to be counted. However, it was unclear if the adult emigration counts were complete during either year: no fish were captured at the weir during the four days prior to weir removal in 2010, and emigrants were captured up until the day before the weir was removed in 2011. Diagnostic test results for size and gender bias indicated that stratification by length or sex was not necessary. However, field observations and tests for temporal bias indicated that the Chapman model was inappropriate, and the partially stratified model described by Darroch (1961) would be necessary to minimize bias due to heterogeneity in probability of capture over time. Unfortunately, data were not available to fit a Darroch model for 2010, and the 2011 data did not yield an admissible estimate. Because the equal probability of capture condition (condition a) was not satisfied, the Chapman estimator provided biased estimates of abundance. Although the direction of bias is unclear when temporal and/or geographic variability in probability of capture occurs during both sampling events, simple simulations were conducted to evaluate the direction of bias. The first event probability of capture was assumed to be lower during early immigration than during late immigration, and the second event probability of capture was assumed to be higher during early emigration than during late emigration. These assumptions were consistent with how sampling occurred in the field. If it was also assumed that the earliest immigrants to the system tended to emigrate earlier than later immigrants, then the simulations showed that the modified Peterson estimates would be biased high. The Chapman modified Peterson estimates were 439 for 2010, and 579 for 2011 compared to minimum escapement counts through the weirs of 377 and 549 for 2010 and 2011, respectively.

Adult Age, Sex and Length Composition

Distributions between successfully-aged immigrants and emigrants were not significantly different, so combining both groups allowed inference about the population of adult spawners. Freshwater and ocean ages were similar to the steelhead population sampled at Sitkoh Creek during 2003–2009, except that more ocean-age 1 adults were sampled in Big Ratz Creek than were observed in all years combined at Sitkoh Creek (Love and Harding 2008, 2009; Love et al. 2012a, 2012b). In 2010, first-time spawning adults were more numerous than observed at Sitkoh Creek, but in 2011 they were similar in relative abundance.

Table 11.–Summary of immigrant and emigrant steelhead counts, lengths, sex ratio and percent scale sampled and PIT tagged at Big Ratz Creek weir, 2010–2011.

	Sample year			
	2005[a]	2007[b]	2010	2011
Adult immigration				
Total immigration	399	284	377	549
Petersen Estimate (SE)	Not estimated	Not estimated	439(12.6)	579(6.6)
Mean length (SD)	751(78.2)	760(76.0)	681(61.7)	692(68.3)
Length range	600–950	475–920	505–860	440–850
Legal, %	1.7	0.6	0.0	0.0
Female, %	64	62	59	59
# Scales successfully aged	352	144	259	252
First-time spawners, %	75	64	82	56
Repeat spawners, %	25	36	18	44
Adult emigration				
Total emigration	122[c]	135[c]	278	458
Mean length (SD)	ND	ND	676 (60.0)	701(68.0)
Length range	ND	ND	505–835	440–860
Female, %	ND	ND	65	63
# Scale sampled	ND	ND	107	99
Kelt survival, %	ND	ND	63	80
Smolt emigration				
Total emigration	ND	ND	1,820	1,328
Mean length (SD)	ND	ND	202 (25.1)	190 (22.5)
Length range	ND	ND	150–380	150–356
# Scale sampled	ND	ND	483	440
Emigration of other species				
Cutthroat trout	ND	ND	643	617
Rainbow trout	ND	ND	287	149
Dolly Varden	ND	ND	10,326	13,130

[a] From Piazza et al. (2008).

[b] From Piazza (2009).

[c] Weir pulled 31 May 2005 and 29 May 29 2007; emigration count likely low.

Female steelhead composed the majority of the escapement both years. Even as smolt, females appear to be more abundant. Recently completed analysis of genetic samples collected from Big Ratz Creek steelhead smolt in 2011 indicate that the sex ratio was also skewed (60%) towards females (Haley Ohms, Assistant Research Biologist, Oregon State University, personal communication). This may indicate that smolt marine survival does not favor females and that females are typically more abundant in the steelhead population in Big Ratz Creek. Based on PIT tag recaptures, adult steelhead males appeared to spend more time in fresh water during spawning than females. More of the females appeared to enter the creek after the peak of the immigration, and emigrated prior to the peak of the emigration, thus spending less total time in fresh water. On average, males spent more time in fresh water, and were predominantly first-time spawners that did not survive spawning as well as older, larger females.

Average length and SD of both sexes combined were not significantly different between years. Immigrant and emigrant females were larger in average fork length than males in 2011 by about 20–30 mm, and in 2010 emigrant females were larger by about 10 mm. Tagged and untagged fish were about the same average size during both years. However, large fish were less abundant in 2010–2011 compared to 2005 and 2007. Average fork length in 2010–2011 was about 40 mm shorter, and the range in sizes was smaller. During 2005 and 2007, an average of about 1.2% of the escapements were large enough to be harvested under sport fishing regulations (Table 2); while no fish of harvestable size were observed in 2010 or 2011.

SMOLT AGES, LENGTHS, AND SMOLT-PER-SPAWNER

Outmigrant smolt size appeared to be relatively similar between 2010 and 2011, and were essentially unimodal. These length frequencies and modes were remarkably consistent and similar to those observed at Sitkoh Creek during 2003–2009 (Love and Harding 2008, 2009; Love et al. 2012a, 2012b). Smolt sizes and range in sizes for the Keogh River, British Columbia (McCubbing 2002, 2010; McCubbing and Ward 2003, 2007) have consistently been smaller than Sitkoh Creek, and thus were also smaller than the smolt sizes at Big Ratz Creek.

Estimated scale ages of smolt from Big Ratz Creek were similar to Sitkoh Creek, except that more age-2 smolt were observed than in all years of study at Sitkoh Creek. The proportion of steelhead smolts assigned age 3 and 4 from Big Ratz Creek (71.4% in 2010 and 82.5% in 2011) was similar to that reported for more recent years in Sitkoh Creek (78% in 2007 and 2008, 91% in 2009; Love et al. 2012a, 2012b). Ages 3 and 4 were also the most abundant age classes reported for five other steelhead populations in Southeast Alaska, each having at least two years of data (Lohr and Bryant 1999). Collectively, the predominant freshwater ages of smolts reported for Southeast Alaska streams differs from the Keogh River where ages 2 and 3 were the most prevalent ages, with age 2 composing 48% (McCubbing 2010).

A preliminary estimate of smolt-per-spawner (SPS) can be generated for Big Ratz Creek by dividing the estimated number of adults that spawned during 2007 with the smolt counts from 2010 (age 3) and 2011 (age 4). This SPS estimate would have to be considered conservative because it does not include smolts classified as age 2 and 5 that would have emigrated during a time outside of the scope of this project. Dividing the minimum escapement of 284 adult steelhead estimated for Big Ratz Creek in 2007 by the number of age 3 and 4 smolt (989) yields an estimate of about 3.5 SPS. Although conservative, this estimate is comparable to the estimate for the 2003 brood year at Sitkoh Creek (Love et al. 2012b).

Although SPS estimates may be similar between Big Ratz and Sitkoh creeks, steelhead smolt may also have emigrated from these systems at times other than when the weirs were in place, which would have resulted in higher estimates. Recognizing that the estimate of the spawning population obtained during 2007 was a minimum, a rough estimate of how many adults may have been missed can be obtained by comparing average adult emigrant to immigrant proportions. For example, leaving the weir in place into June captured an average of 368 emigrant adults during in 2010 and 2011, or about 79.5% of the immigrant count. This compares to an average emigrant-to-immigrant proportion for 2005 and 2007 of 37.6% during the years in which the weir was pulled early at the end of May (Piazza et al. 2008; Piazza 2009); thus approximately 42% of the 2007 escapement was possibly missed. Sitkoh and Ratz creeks SPS estimates are low compared to the Keogh River, which produced an average of about 5.0 SPS for 1986–1995 under natural conditions (Ward et al. 2002, 2003, McCubbing 2002). Although estimates of SPS in Southeast Alaska may be a useful measure for freshwater production, longer duration studies would allow more complete estimates of marine survival, repeat spawning rates, and life history strategies, and provide production estimates during variable abiotic events that could alter available habitat.

Smolt outmigration counts on the Keogh River below 1,500 in 2008 and 2009 were cause for conservation concern, especially because marine survival was less than 5% (McCubbing 2010). Verifying that marine survival is better than 5%, as was possible on Sitkoh Creek, is not possible for Big Ratz Creek because the weir was not operated after 2011 (Love et al. 2012a, 2012b). Small adult runs in the Keogh River appear to be related to low marine survival. In combination with freshwater production, estimates of marine survival would also be very useful for monitoring sustained production of steelhead populations in areas such as Southeast Alaska that have relatively undisturbed freshwater habitats (Ward 2000; Welch et al. 2000; Smith and Ward 2000). This argues for continued long-term tagging and freshwater production studies of steelhead populations, as well as the need to better understand the influence of marine conditions on maintaining stocks.

HABITAT AND SMOLT PRODUCTION

The 2010 (N = 1,820) and 2011 (N = 1,328) smolt counts are the only counts made to date on POW (Table 11). Big Ratz Creek counts for 2010–2011 were similar to the smolt counts from Sitkoh Creek during 2007 (N = 1,704) and 2008 (N = 1,751), but higher than the Sitkoh Creek count in 2009 of 893 (Love et al. 2012a; Love et al. 2012b). The known life history of steelhead in Southeast Alaska implies that most steelhead smolt emigrate before 30 June (Lohr and Bryant 1999; Love and Harding 2008, 2009; Love et al. 2012a, 2012b). Although both the Big Ratz and Sitkoh creek projects had the same objective of enumerating steelhead smolt from March to June, these counts may not represent the entire smolt production for either creek as an unknown number of smolt may have passed downstream during other times of the year. Nevertheless, snorkel surveys conducted each year just prior to removal of the Big Ratz Creek weir indicated that few smolt were in the creek, and emigration was largely complete. Therefore, it seems that the majority of the emigration was accounted for and that the census could be considered a minimum count.

Smolt production per usable habitat area for Big Ratz Creek has been estimated at 126 smolt/ha (considered a minimum) as compared to 158 smolt/ha in Sitkoh Creek (Crupi and Nichols 2012; Schroeder and Nichols 2012). These habitat-based abundance estimates fall into the lower end of the range of 100–600 smolt/ha reported for six Oregon steelhead streams (Cramer and Ackerman 2009). However, changes to stream habitat due to extreme rain-on-snow events, seasonal flooding, affects of marine derived nutrients from immigrant salmon, and a host of other factors should also be taken into account when developing production-by-area estimates. Big Ratz Creek and Sitkoh Creek are, for the most part, clearwater streams (not heavily tannin-stained) with active stream channels, variable flows, low primary productivity, and cold water temperatures that may all contribute to lower production of smolt per area in comparison to more southern stocks. Sympatric populations of rainbow/steelhead trout in Southeast Alaska streams have variable life history strategies (life history polymorphism) that may enable them to persist and utilize lower quality, available habitat when conditions change. This plasticity in behavior may allow persistence of the species in the oligotrophic, dynamic stream systems in Southeast Alaska as long as habitat remains intact, marine survival is good, and overfishing of adults throughout the metapopulation range is minimized.

TROUT AND DOLLY VARDEN PRODUCTION

Timing of the emigration of rainbow trout, cutthroat trout, and Dolly Varden char at Big Ratz Creek was similar between 2010 and 2011, but no trends in numbers of emigrant rainbow trout, cutthroat trout and Dolly Varden char can be discerned with the two years of data collected (Table 11). Comparing the numbers of cutthroat trout and Dolly Varden emigrants from Big Ratz Creek to counts from other systems in Southeast Alaska provides an insight into the Big Ratz Creek system (stream and lakes) as an overwintering site for these species. Emigrant counts of Big Ratz Creek cutthroat trout and Dolly Varden are approximately twice the average emigrant count at Auke Creek (John Joyce, National Marine Fisheries Service, Auke Bay Laboratory, personal communication). The cutthroat trout emigration from the Big Ratz Creek system was similar in scope (500–1,000) to Kook, Petersburg, Windfall and Chilkat lakes, but approximately 40–80% less than emigrant counts from Eva and Sitkoh lakes (Harding and Coyle 2011). The Big Ratz Creek emigrant Dolly Varden count was less than half of the emigrant counts from systems known to host substantial overwintering populations, such as Eva, Sitkoh and Windfall lakes.

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APPENDIX A: TESTS OF SELECTIVE SAMPLING AND CONSISTENCY FOR THE PETERSEN ESTIMATOR

Appendix A1.–Detection of size and/or sex selective sampling during a two-sample mark recapture experiment and its effects on estimation of population size and population composition.

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conovor 1980) is used to detect significant evidence that size selective sampling occurred during the first and/or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R) by using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. A third test that compares M and C is then conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling: Contingency table analysis (Chi^2-test) is generally used to detect significant evidence that sex selective sampling occurred during the first and/or second sampling events. The counts of observed males to females are compared between M&R, C&R, and M&C using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. If the proportions by gender are estimated for a sample (usually C), rather than observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are then compared between samples using a two sample test (e.g., Student's t-test).

M vs. R	**C vs. R**	**M vs. C**

Case I:

Fail to reject H_o	Fail to reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during either sampling event.

Case II:

Reject H_o	Fail to reject H_o	Reject H_o

There is no size/sex selectivity detected during the first event but there is during the second event sampling.

Case III:

Fail to reject H_o	Reject H_o	Reject H_o

There is no size/sex selectivity detected during the second event but there is during the first event sampling.

Case IV:

Reject H_o	Reject H_o	Either result possible

There is size/sex selectivity detected during both the first and second sampling events.

Evaluation Required:

Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test is likely detecting small differences which have little potential to result in bias during estimation. *Case I* is appropriate.

B. If a) sample sizes for M vs. R are small, b) the M vs. R p-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the second event which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

-continued-

C. If a) sample sizes for C vs. R are small, b) the C vs. R p-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the first event which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R p-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

Case I. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

If stratification by sex or length is necessary prior to estimating composition parameters, then an overall composition parameters (p_k) is estimated by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \hat{p}_{ik} \text{ ; and,} \tag{1}$$

$$\hat{V}\left[\hat{p}_k\right] \approx \frac{1}{\hat{N}_\Sigma^2} \sum_{i=1}^{j} \left(\hat{N}_i^2 \hat{V}\left[\hat{p}_{ik}\right] + \left(\hat{p}_{ik} - \hat{p}_k\right)^2 \hat{V}\left[\hat{N}_i\right] \right). \tag{2}$$

where: j = the number of sex/size strata;

$\hat{p}_{ik}$ = the estimated proportion of fish that were age or size *k* among fish in stratum *i*;

$\hat{N}_i$ = the estimated abundance in stratum *i*; and,

$\hat{N}_\Sigma$ = sum of the $\hat{N}_i$ across strata.

Appendix A2.-Tests of consistency for the Petersen estimator (from Seber 1982, page 438).

Tests of consistency for Petersen estimator

Of the following conditions, at least one must be fulfilled to meet assumptions of a Petersen estimator:

1. Marked fish mix completely with unmarked fish between events;
2. Every fish has an equal probability of being captured and marked during event 1; or,
3. Every fish has an equal probability of being captured and examined during event 2.

To evaluate these three assumptions, the chi-square statistic will be used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis needs to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests are rejected, a temporally or geographically stratified estimator (Darroch 1961) should be used to estimate abundance.

I.-Test For Complete Mixing[a]

Area/Time	Area/Time Where Recaptured				Not Recaptured
Where Marked	1	2	…	t	(n_1-m_2)
1					
2					
…					
s					

II.-Test For Equal Probability of capture during the first event[b]

	Area/Time Where Examined			
	1	2	…	t
Marked (m_2)				
Unmarked (n_2-m_2)				

III.-Test for equal probability of capture during the second event[c]

	Area/Time Where Marked			
	1	2	…	s
Recaptured (m_2)				
Not Recaptured (n_1-m_2)				

[a] This tests the hypothesis that movement probabilities (θ) from time or area i (i = 1, 2, ...s) to section j (j = 1, 2, ...t) are the same among sections: H_0: $\theta_{ij} = \theta_j$.

[b] This tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among time or area designations: H_0: $\Sigma_i a_i \theta_{ij} = kU_j$, where k = total marks released/total unmarked in the population, U_j = total unmarked fish in stratum j at the time of sampling, and a_i = number of marked fish released in stratum i.

[c] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among time or area designations: H_0: $\Sigma_j \theta_{ij} p_j$ = d, where p_j is the probability of capturing a fish in section j during the second event, and d is a constant.

APPENDIX B: FILE DESCRIPTIONS

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

FILE NAME	SOFTWARE	CONTENTS
20102011FDS_Tables_Figs.xls	Excel 2007	Figures and tables and associated data and Appendices used to generate them for this report
2010Big Ratz_Data.xls	Excel 2007	Sample and tag numbers, lengths, scale sample and genetic sample numbers, otolith sample number, dates samples collected for steelhead adults and juveniles at Big Ratz Creek weir during 2010
2011Big Ratz_Data.xls	Excel 2007	Sample and tag numbers, lengths, scale sample and genetic sample numbers, otolith sample number, dates samples collected for steelhead adults and juveniles at Big Ratz Creek weir during 2011
2010Daily_Cum_Counts.xls	Excel 2007	Daily weir counts in 2010 for all species at Big Ratz Creek
2011Daily_Cum_Counts.xls	Excel 2007	Daily weir counts in 2011 for all species at Big Ratz Creek
2010Big Ratz_Temp_Level.xls	Excel 2007	Daily temp and stage gauge at Big Ratz Creek in 2010
2011Big Ratz_Temp_Level.xls	Excel 2007	Daily temp and stage gauge at Big Ratz Creek in 2011