Fishery Data Series No. 12-40

Steelhead studies from the Situk River in Southeast Alaska, 2002-2008

by

Brian H. Marston,

Robert E. Johnson

and

Sarah Power

August 2012

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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

FISHERY DATA SERIES NO. 12-40

STEELHEAD STUDIES FROM THE SITUK RIVER IN SOUTHEAST ALASKA, 2002-2008

By
Brian H. Marston
Alaska Department of Fish and Game, Division of Sport Fish, Yakutat

Robert E. Johnson
Alaska Department of Fish and Game, Division of Sport Fish, retired

and

Sarah Power
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

August 2012

This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Projects F-10-18 – F-10-24.

ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.adfg.alaska.gov/sf/publications/. This publication has undergone editorial and peer review.

Brian H. Marston[a],
Alaska Department of Fish and Game, Division of Sport Fish,
P. O. Box 49, Yakutat, AK 99689-0049

Robert E. Johnson,
Alaska Department of Fish and Game, Division of Sport Fish (retired)

and

Sarah Power
Alaska Department of Fish and Game, Division of Sport Fish,
P. O. Box 110024, Juneau, AK 99811-0024

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

This document should be cited as:
Marston, B. H., R. E. Johnson, and S. Power. 2012. Steelhead studies from the Situk River in Southeast Alaska, 2002-2008. Alaska Department of Fish and Game, Fishery Data Series No. 12-40, Anchorage.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

In 2002–2008, a bipod and picket weir with a resistance board section was used to count steelhead kelts emigrating from the Situk River in Southeast Alaska. Counts averaged 10,494 and ranged from 6,113 to 15,003. Mean length of kelts did not decline in samples taken during this time period. Males averaged 763 mm (SE = 8) and females 773 mm (SE = 7). The sex ratio of kelts sampled at the weir was skewed to females, but male fish made up the majority of fish that were found dead and washed up on the weir. The repeat spawning rate, as measured with PIT-tagged fish, was 9% for fish that returned a second time, and 1% for fish that returned a third. PIT-tagged fish that were recaptured multiple times showed considerable consistency in date of emigration across years (mean = 9 days). Run timing of the emigration varied with midpoint dates that ranged from May 18 to June 14. Emigration timing appeared to be triggered by water temperatures above 6°C. Kelt abundance the following year was positively correlated to the previous year's water temperature in May. The sport catch during the study years averaged 12,600 and did not track the abundance trend of kelts. The sport harvest of steelhead, which was restricted to trophy-length fish (>36 inches or 914 mm TL) and limited to 2 per year, averaged 18 fish. The average percentage of trophy-length fish in a weir site sample was 3%. The largest fish sampled was 1,100 mm and the smallest was 400 mm.

Key words: steelhead, *Oncorhynchus mykiss*, kelt, resistance board weir, Situk River, Alaska, angling, remote video

INTRODUCTION

The Situk River (Figure 1), near the village of Yakutat in Southeast Alaska, originates in tributaries of Mountain Lake at approximately 600 m, flows via Mountain Stream into Situk Lake, and then flows 29 km as the mainstem Situk River into Situk-Ahrnklin Lagoon. Two larger tributaries, the West Fork Situk River and The Old Situk River, flow into the mainstem, along with several lesser waters. The mainstem Situk River below Situk Lake at 69 m elevation and the lower portions of its larger tributaries, are slow flowing, meandering, and of slight slope (<1.5 m/km). The Ahrnklin River, Seal Creek, and the Lost River, along with several small streams, join Situk River waters in the Situk-Ahrnklin Lagoon before emptying into the Gulf of Alaska. The drainage encompasses 397 ha.

The Situk River sustains the largest steelhead *Onchorhynchus mykiss* sport fishery in Alaska, and also has significant fisheries for sockeye *O. nerka*, pink *O. gorbuscha*, and coho salmon *O. kisutch*, as well as smaller fisheries for Chinook *O. tshawytscha* salmon, Dolly Varden *Salvelinus malma*, and resident rainbow trout. Angler catches of steelhead on the Situk River averaged 12,600 from 2002 to 2008, and that of other salmonids averaged in excess of 50,000. Additionally, commercial fishery harvests exceeded 100,000 Pacific salmon, primarily sockeye and coho salmon. Steelhead cannot be targeted for commercial harvest, but the incidental harvest in commercial fisheries is not known. The subsistence take of steelhead in Alaska is also not well understood, although they are not relatively as important as salmon species for subsistence use.

Past studies have shown that steelhead exhibit 2 spawning strategies in the Situk drainage (Glynn and Elliot 1993; Johnson 1990, 1991, 1996; Johnson and Jones 1998-2001, 2003). Steelhead adults enter the Situk River in 2 separate groups. A smaller "fall" component or river-maturing fish enters the Situk drainage mainly in late October-November, although some fish enter in late summer. These "fall" fish migrate to the upper lakes, or remain inriver until the next spring when the majority of the run enters the river in April as a second "spring" component or ocean-maturing. Spawning of both components occurs in April-May, but it is not known if or how the two components are genetically related, or if they spawn separately. Spawning behaviors of resident rainbow trout, which may spawn with either component, may also add further complexity to spawning strategies seen in Situk River steelhead. A small sport fishery

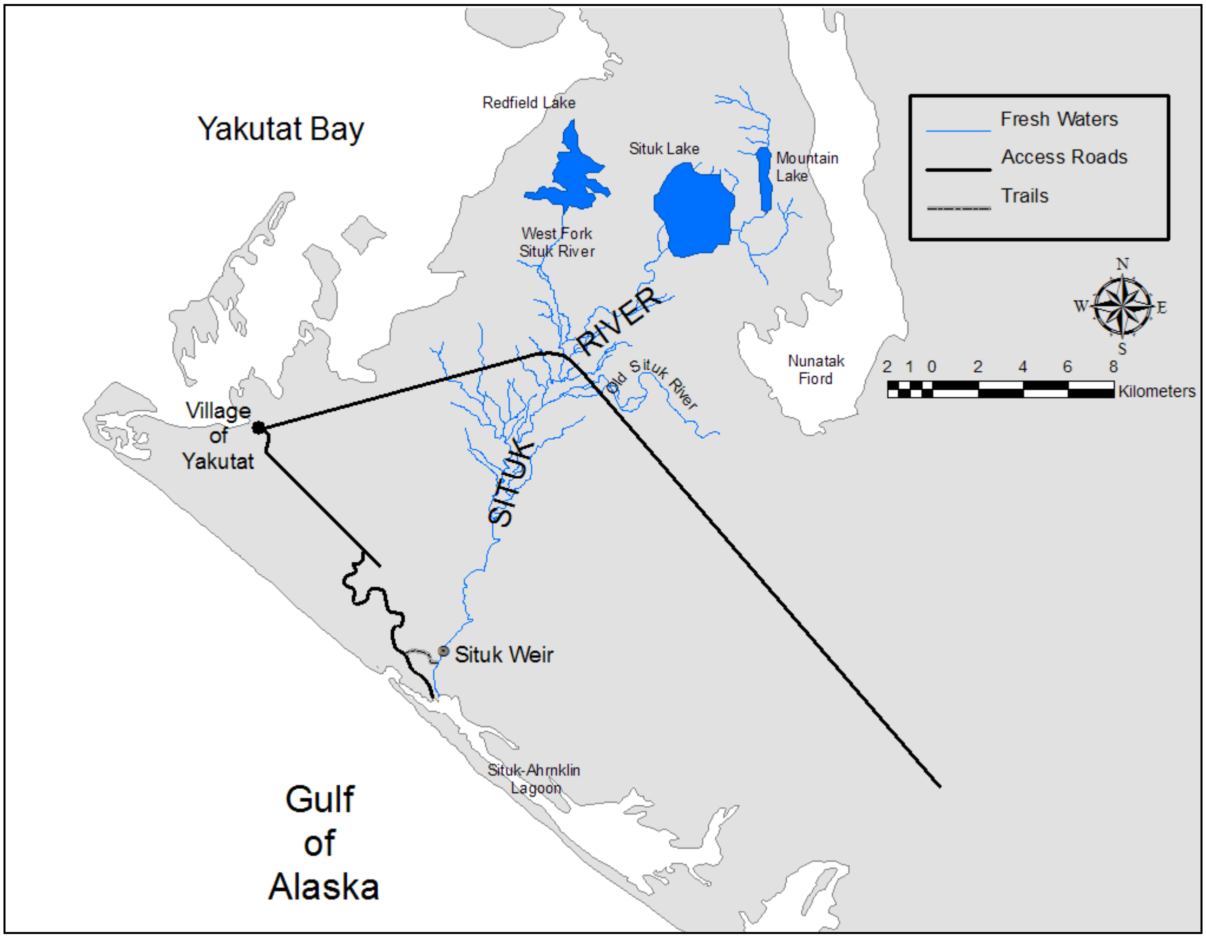


Figure 1.–The Situk River drainage and the location of the Situk River weir for kelt studies, 2002–2008.

exists for fall fish, but seasonal high water conditions and the smaller number of fish limits this fishery. The main sport fishery for Situk steelhead is in April and May. The emigration of adult steelhead "kelts" (fish that emigrate after spawning) is typically over by mid June.

Although steelhead populations in the southern parts of its range have declined, steelhead are still a major part of freshwater sport fisheries in Southeast Alaska. Maintenance of the quality fisheries generated by the wild populations of steelhead in Alaska require continued population monitoring, critical habitat conservation, and effective strategic management planning to sustain steelhead populations. Kelt steelhead abundance data collected at the Situk River weir is used along with index counts in other Alaskan systems to monitor abundance over time and stock status. Other steelhead systems in Southeast Alaska that have had steelhead weirs are Sitkoh Creek, Peterson Creek, Karta River, Sashin Creek, and Ratz Creek, while smaller streams have been assessed with snorkel surveys (Harding et al. 2009). Sport fishery management for steelhead in Alaska, including the Situk River, has restricted harvest to 1 fish over 36 inches per day, 2 per year, in most streams.

Counts of Situk River steelhead have been collected by various agencies since 1947 (see review in Bain et al. 2003). Since 1995, the current configuration of the Situk River steelhead weir has been operated by the Alaska Department of Fish and Game (ADF&G) Division of Sport Fish (DSF) in order to index total adult abundance by counting emigrating steelhead kelts. In 1999, an objective to estimate sex/length characteristics of the run was begun. Most recently, another objective was added in 2002 to assess scale-growth characteristics of known-age increments of steelhead adults by tagging kelts, recapturing these fish in later years, and obtaining scales at each capture. An archive of scale samples has also been created. Steelhead kelt weir operations are now begun in late April-May of each year. This document reports on steelhead kelt abundance and biological attribute data for the Situk River steelhead studies for the years 2002-2008.

OBJECTIVES

The primary objectives in this study were:

1. Count steelhead kelts emigrating past a weir on the Situk River.
2. Estimate the sex and length composition of steelhead kelts emigrating past a weir on the Situk River.
3. Insert passive integrated transponder tags into adult steelhead meeting specific criteria to facilitate determining the age of repeat-spawning fish.

An additional task was collection of scales for archiving from fish sampled for sex and length composition.

METHODS

STUDY SITE, WEIR CONSTRUCTION, AND INSTALLATION

A 40 m long bipod and picket weir with a 10 m wide "resistance board" section was installed on the Situk River 1.9 km upstream of the Lower Landing (Figures 1 and 2), and was fish tight in the first week of May each year. The resistance board section allowed high water forces to bypass the main weir structure, and allowed anglers in boats to safely cross the weir at any time. The weir site was above mean high tide influence, although the monthly highest tides often slowed river flows slightly at the site. Access to the site was via water from the Lower Landing boat ramp at tidewater, or two 2 km trails. A small cabin for housing of personnel that doubled as a counting structure was also on site, and 2 smaller sheds were used for storage of gear and power generators. Steelhead kelts were counted (see method below) each year as they passed downstream through an opening gate in the weir, and a set proportion of kelts was captured with a weir trap for sampling of biological information and passive integrated transponder (PIT) tag implantation or recapture (see method below).

The weir installation date (fish-tight date) was evaluated each year in reference to immigrating fish, and periodic boat surveys of the upper river to access spawning activity. Installation was delayed slightly if spawning activity was not occurring, indicating the emigration was yet to start. Installation may have also been expedited if periodic observations done with float counts on the upper river prior to installation showed the onset of spawning behavior, indicating the emigration may begin soon. This typically also signified the cessation of major immigrations. At all times, the pool below the weir was also observed after installation and immigrating fish were allowed to pass through by removing a few pickets, or by passing the fish upstream through the kelt counting gate; this was typically only a small number of fish (the 2002–2006 mean was <5% of the total kelt abundance).

KELT COUNTING PROCEDURES

Kelts were counted during late night hours, primarily between 2200 and 0300 hours, when fish typically emigrated downstream. These hours matched peak emigration timing seen in past years (Johnson and Jones 1998, 1999). The weir was kept closed at other hours unless unusual fish buildup was noted by the weir crew. Kelts were counted as they passed through a weir gate by utilizing an underwater video system (Figure 2). During normal counting (non-capture sampling) of kelts, a trap below the upper weir gate functioned as a chute, the upper and a lower gate on the trap were both open, and fish passed through freely.

The gate at the upper opening in the weir was viewed remotely with the underwater video system and a LCD screen in the nearby cabin so that the presence of personnel on the weir did not hinder fish passage. The underwater video system also eliminated poor visibility associated with weather conditions. Nightly counts of kelts were recorded on data forms and also relayed via VHF radio to the main office each morning for archiving.

The video system utilized for counting consisted of a Seaview™[1] waterproof camera mounted to the weir gate, a LCD display screen and DVD recorder located in the cabin, plus Seaview™ LED lighting and power sources. Wires ran the length of the weir and lead to the cabin. The video picture encompassed the entire weir gate at all times and fish could not pass the weir in any other location. The light provided minimal illumination to view the gate. Technicians monitored camera lighting, focus, and angle at all times so if the camera picture began to fail, the gate could be shut and the camera repositioned. The technicians were able to close the weir gate by remote trigger at any time if needed. The video screen was viewed within the counting cabin on the eastern shore. Fish were tallied by technicians at the appropriate hours each night in shifts. In some cases (<5% of the time) when total video failure or atypical fish congregations occurred, the weir technicians directly counted fish without video by removing pickets and allowing fish to pass, or by submerging a resistance board section.

CAPTURE, MEASUREMENT, AND SAMPLING PROCEDURES

When a sample was needed, the lower gate on the trap (Figure 2) was closed and fish were allowed to accumulate after being counted. When the trap filled with fish the upper gate was closed and fish were processed or held in a holding pen while more fish were trapped to achieve sample size goals. Sample size goals changed over time. In years 2002–2006 when scale sampling was the focus, a 10% sampling goal was desired. In subsequent years when the focus was length estimation and PIT tagging, a smaller sample of 3% was targeted. A fixed proportion was targeted each sampling night in order to achieve the yearly sample size goal, and samples were collected 2 nights per week. Nightly sampling goals were calculated by subtracting the cumulative weir count at the completion of the previous sampling event from the current cumulative count, and multiplying by the fixed proportion. Fish were sampled late (after midnight) the first night, and early (prior to midnight) the second night to account for diel variations in emigration found in past studies (Johnson and Jones 1998, 1999).

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

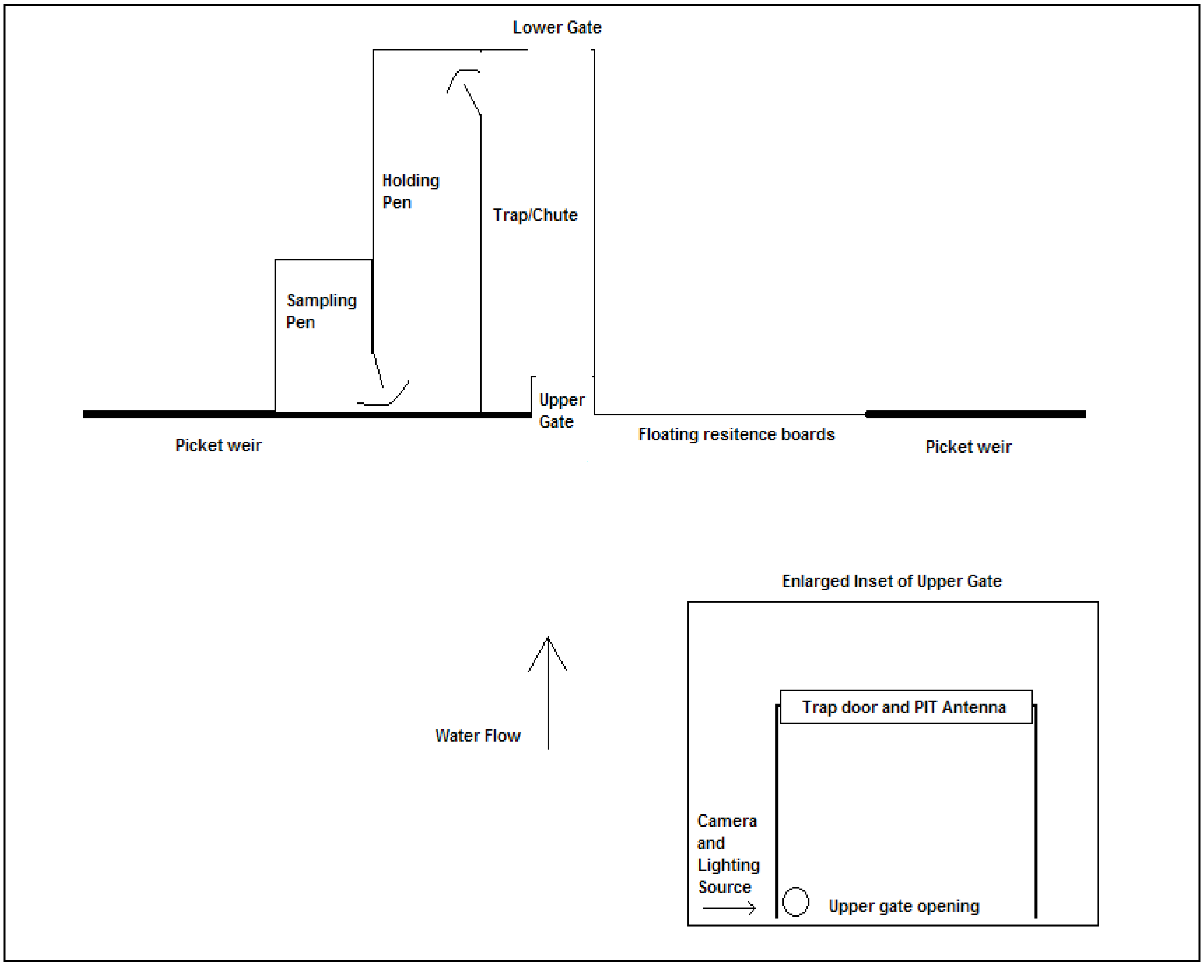


Figure 2.–Diagram of the Situk weir and fish trap including inset of camera placement and PIT tag antenna location.

All fish sampled for age, sex and length (ASL) were checked by hand (Biomark ™ pocket reader) for PIT tags. Sex, length to the nearest 5 mm TL (tip of snout to tip of tail), incidence of wounds, and color classification were recorded from sampled fish. Color classifications included bright, medium, or dark (recorded as 1, 2, or 3 respectively). Scale samples were also obtained from each fish. Four scales were taken from the "preferred" area on both sides of the fish (Welander 1940) for archiving. Scale rings were analyzed as in Love and Harding (2008 and 2009).

PIT Tagging and Recapture Procedures

PIT tags (Biomark ™) were implanted in selected kelts in 2002–2008. These fish were selected from the ASL sample by a length, color, and health classification. Presence or absence of fungus was also noted on each fish, and any wounds or scars were described. Fish selected for PIT tags were color classed as bright, displayed an absence of potentially life-threatening injuries or body fungus, and had a total length of 750 mm or less. The 750 mm maximum length limit was used to maximize the accuracy of initial age determination (2-ocean age or less and initial spawning cycle). The color and condition criteria were likewise selected to maximize the probability of at-sea survival, and subsequent likelihood of future recapture. PIT tagging was planned to take place annually so that subsequent recaptures of these fish at the weir, along with scales collected on both occasions, could be used to calibrate age readings from scales and observe scale patterns in multiple spawning individuals. The 20 mm PIT tags (model 1411 SST Biomark™) were placed beneath the skin near the pelvic fin using an 8-gauge veterinary syringe and needle. The pelvic area tag placement was selected to minimize the likelihood of anyone ingesting the tag if the fish was harvested. The injection wound was sealed with an application of Super Glue™. PIT tags were initially test scanned, labeled by unique identification number in a tag holder, and then applied.

Subsequent recapture of PIT tagged fish was possible because the upper weir trap gate was constructed with a PIT antenna (Biomark ™ flat plate antenna) attached so that all fish passed through the reception field while being counted (Figure 2). The antenna was wired to a PIT tag reader so that every fish that passed through the gate was scanned by the reader. If a tagged fish was detected an audible tone was emitted by the PIT tag reader and amplified via a speaker system in the counting cabin. Weir personnel would then pull a mechanical trigger to automatically close the weir trap gate(s) and capture that fish. The tagged fish was then netted out of the trap and sampled as a recapture. If more than one fish was in the trap at that time, all fish were netted and a hand held PIT tag Pocket Reader (Biomark ™) was used to locate the PIT-tagged fish. Recaptured fish were measured and processed as an ASL fish, except that 8 scales were taken so that a readable scale was assured. Scales from recaptured fish will be compared to scales from those fish taken in previous years when sufficient sample sizes have been obtained.

ANCILLARY DATA

Ancillary information on steelhead, the steelhead fishery, and environmental information was also gathered. Environmental data gathered daily on site for this project included water temperature and stream stage-height recordings. Additionally, daily river flow statistics were obtained. The weir site data were recorded by weir personnel at 10 am. Temperature recordings were gathered immediately above the weir at 0.6 m of depth with a hand held thermometer. Stage height was measured with a permanent stadia rod incorporated into the weir structure. The stage height readings from the weir were not relative to any other geographic elevation, and were only designed to depict daily change at the site. Daily river flow statistics (cubic feet per second and temperature) collected at Nine Mile Bridge by an automated National Oceanographic and Atmospheric Administration (NOAA) recording station (available at http://nwis.waterdata.usgs.gov/ak) were also obtained at year's end to compare against weir recordings. Ancillary steelhead morphological data included otolith extraction, scale sampling, total length measurement, and sex determination of all mortalities found washed up on the weir. Calculations of interparty rates were also done with data from fish that were recaptured with PIT tags. Yearly sport fishery steelhead catch/harvest data for the Situk River, compiled from the ADF&G Statewide Harvest Survey (Jennings et al. 2010) were also compared to kelt abundance.

ANALYSIS

Summary statistics generated from biological sampling included estimates of sex and length composition. The length and sex composition of emigrants was estimated:

$$\hat{p}_a = \frac{n_a}{n} \tag{1}$$

$$\hat{\text{var}}(\hat{p}_a) = \left(1 - \frac{n}{N}\right) \frac{\hat{p}_a(1-\hat{p}_a)}{n-1} \tag{2}$$

Where $\hat{p}_a$ = the estimated proportion of the population in length or sex group *a*, *n* = number of fish sampled for length or sex, n_a = subset of *n* that belongs to group *a*, and *N* = number of fish counted at the weir. Because all (or nearly all) emigrants were enumerated, a finite population correction factor (fpc) = (1-*n*/*N*) was included in the estimator. The standard error of $\hat{p}_a$ was $\sqrt{\hat{\text{var}}(\hat{p}_a)}$.

The mean length $(\bar{y})$ of emigrants was estimated:

$$\bar{y} = \frac{1}{n}\sum_i y_i \tag{3}$$

$$\hat{\text{var}}(\bar{y}) = \left(1 - \frac{n}{N}\right) \frac{\sum_i (y_i - \bar{y})^2}{n\,(n-1)} \tag{4}$$

where *i* denotes an individual fish. A fpc was again used because all fish were counted at the weir. The standard error $= \sqrt{\hat{\text{var}}(\bar{y})}$. The standard deviation $SD(\bar{y})$ as also calculated as a measure of the dispersion of the *y* values:

$$SD(\bar{y}) = \sum (y_i - \bar{y})^{1/2} n\,(n-1)^{1/2} \tag{5}$$

Temporally (e.g., weekly) stratified estimators were not used to estimate compositions or mean length because such estimates were neither statistically (α = 0.1) different or as precise as estimates based on the usual estimators (equations 3 and 4).

Various statistical tests are noted in the text when used in comparative analysis.

RESULTS

KELT ABUNDANCE AND TIMING

Year-end kelt counts ranged from 6,113 to 15,003 between 2002 and 2008, and peaked in 2006 (Figure 3, Table 1). Four successive years were above average beginning in 2004 (Figure 3). The yearly abundance of kelts that passed the weir was highly correlated with average May water temperatures the previous year ($r^{2 =}$ 0.79, P = 0.01); higher temperatures in May predicted higher kelt abundance the next year. The yearly abundance of kelts was not correlated to the sport catch of that year (r^2 = 0.26, P = 0.23), or lagged by 1 year (r^2 = 0.06, P = 0.65). May 7 was the average date that the first kelt passed through the weir and this ranged from April 29 to May 12

(13 days; Table 1). The average date that 50% of the kelt emigration had passed the weir was May 29 and ranged from May 18 to June 14 (27 days; Table 1). The average date that the last fish passed the weir was July 17 and ranged from June 26 to July 28 (33 days; Table 1). The distributions of daily counts were different between years (Kruskal-Wallis $H_c = 15.35$ $P = 0.02$) (Figures 4 and 5, Table 2). The early run year of 2005 and the late run year of 2007 were significantly different from years 2002 and 2008, which were both years of low abundance, short duration, and more uniform daily counts (Figures 4 and 5, Table 2). The maximum number of mortalities found at the weir site was 29 in year 2007.

Table 1.–Yearly kelt counts and emigration timing at the Situk River weir, 2002–2008.

Year	2002	2003	2004	2005	2006	2007	2008	Average
Total count	6,113	7,936	12,462	12,196	15,003	12,438	7,312	10,494
Date of first migrant	5/11	4/29	5/8	4/29	5/11	5/10	5/12	5/7
Date of 50% migrant	6/1	5/21	5/22	5/18	5/31	6/14	6/9	5/29
Date of last migrant	7/23	6/26	7/28	7/17	7/26	7/22	7/8	7/17

Table 2.–Kruskal-Wallis pairwise comparison test statistics for daily run distribution tests of kelts at the Situk River weir, 2002–2008. Bold indicates statistically significant differences.

Year	2002	2003	2004	2005	2006	2007	2008
2002	0.0000	0.4893	0.0781	**0.0081**	0.0861	**0.0140**	0.8374
2003		0.0000	0.2823	0.0712	0.2901	0.0856	0.6770
2004			0.0000	0.3924	0.9455	0.5126	0.1021
2005				0.0000	0.2812	0.6225	**0.0104**
2006					0.0000	0.4650	0.0991
2007						0.0000	**0.0138**
2008							0.0000

SEX, AND LENGTH SAMPLING

A total of 4,449 fish were sampled for length measurements from 2002–2008 (Table 3). Female steelhead were more abundant in the ASL samples. The average ratio was 67% female and ranged from 61% to 71% during the study years.

Yearly sampling goals changed after 2006 creating variable yearly samples sizes that ranged from 164 to 1,061 kelts. Samples collected from 2002 through 2006 exceeded 640 fish each year.

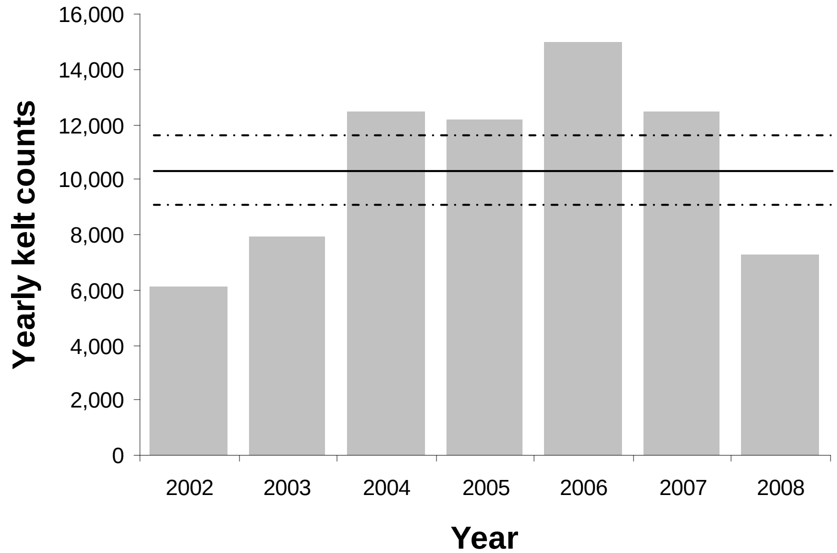


Figure 3.–Yearly kelt counts and overall average (solid line is average, dashed lines are ± 1 SD) at the Situk River weir, 2002–2008.

Table 3.–Total length (mm) of kelts in samples from the Situk River weir, 2002–2008.

	2002			2003		
	Female	Male	All	Female	Male	All
Average	807	774	795	767	722	751
SE	3	6	3	3	6	3
n	413	232	645	489	267	756
	2004			2005		
	Female	Male	All	Female	Male	All
Average	780	774	778	765	761	764
SE	3	6	3	3	6	3
n	520	237	757	540	203	743
	2006			2007		
	Female	Male	All	Female	Male	All
Average	745	762	751	773	787	777
SE	3	4	2	4	11	4
n	648	413	1,061	238	85	323
	2008			Average of all years		
	Female	Male	All	Female	Male	All
Average	777	761	772	773	763	770
SE	6	12	5	7	8	6
n	117	47	164	7	7	7

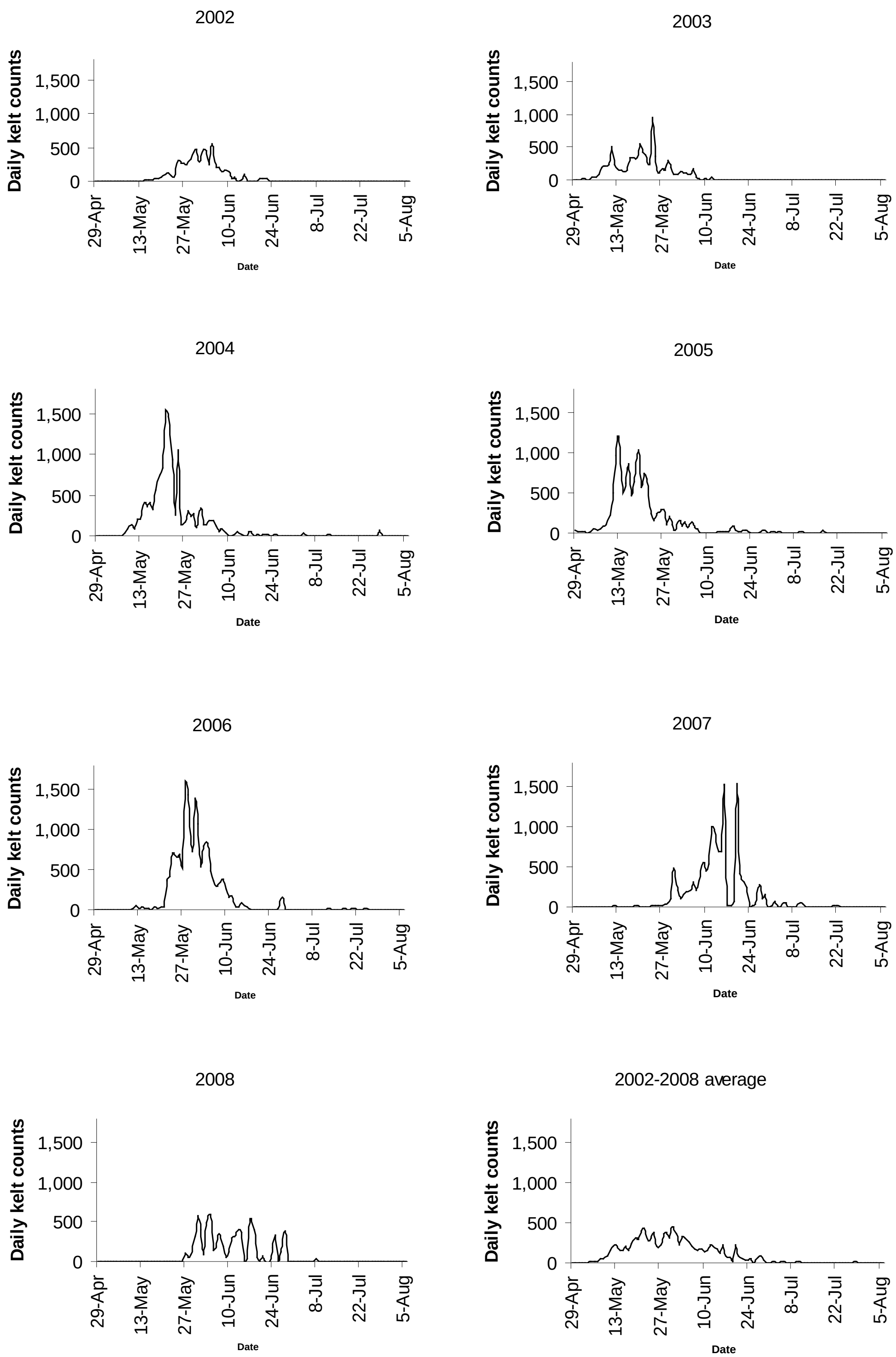


Figure 4.–Distribution of daily counts of steelhead kelts at the Situk River weir, 2002–2008.

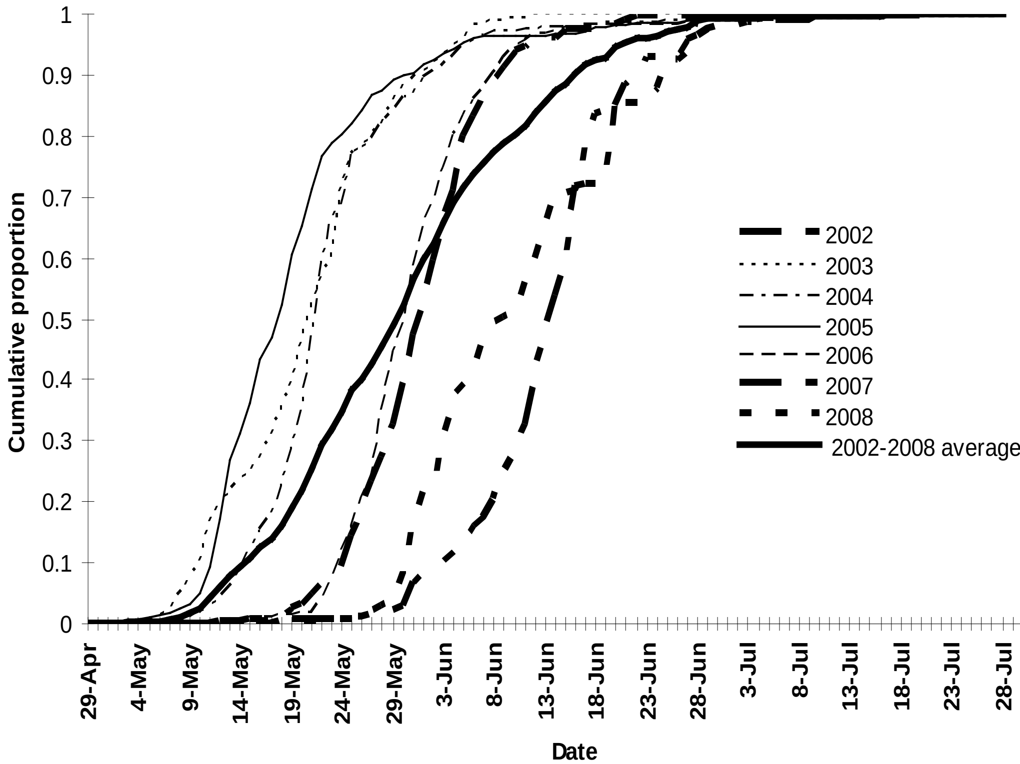


Figure 5.–Cumulative run distributions for kelts from the Situk River, 2002–2008.

The 2008 sample did not meet sample size goals. Yearly average length of all steelhead ranged from 751 to 795 mm TL, and the all year average was 770 mm. Average length of males ranged from 722 to 787 mm, and the all year male average was 763 mm; the average length of females ranged from 745 to 807 mm, and the all year average was 773 mm. Female steelhead were significantly longer than males in 2002 and 2003, and males were longer in 2006 (Table 4).

Mean length was not associated with abundance for females (r^2 = 0.4, F = 5.61, P = .06) or males (r^2 = 0.09, F = .51, P = 0.51). Length distributions were different across years for male (F = 11.5, P < 0.0001) and female fish (F = 36.1, P < 0.0001), but average length of either sex did not show a consistent up or downward trend across years (Figure 6).

Fish designated as trophy fish (>36 inches or 914 mm TL) made up 3% of the samples taken at the weir ranging yearly from 0 to 5% (Table 5). Mean length of trophy fish ranged from 927 to 957 mm across all study years.

PIT TAGS

A total of 641 fish were PIT tagged (Table 6), of which 173 were male and 468 were female. The length range of all PIT-tagged fish was 420 to 945 mm. Males ranged from 420 to 915 mm, and females ranged from 520 to 945mm. In the following years a total of 59 fish were recaptured once (51 females and 8 males), and 7 were recaptured twice (all female). Nine percent of the fish that were tagged were recaptured, and 13% of those returned a third time (all female). Third time returners were 1% of the total tagged fish sample. There did not appear to be differences in total length of fish that were tagged and later recaptured compared to those that were tagged but not recaptured (Table 6), indicating that fish length at tagging did not influence subsequent recapture rate, but sample size was too small to test adequately. The date of recapture across years for fish that were captured multiple times was consistent within an average of 9 calendar days for individual fish (Table 7).

Preliminary analysis of kelt scales collected from fish that spawned multiple times showed that yearly circuli patterns were consistent with the known-age increments, and freshwater growth could also be accurately calculated across years (Figure 7). However, obtaining scales is difficult and scale quality from kelts is often low due to scale re-absorption and the deteriorated skin quality of post-spawn steelhead.

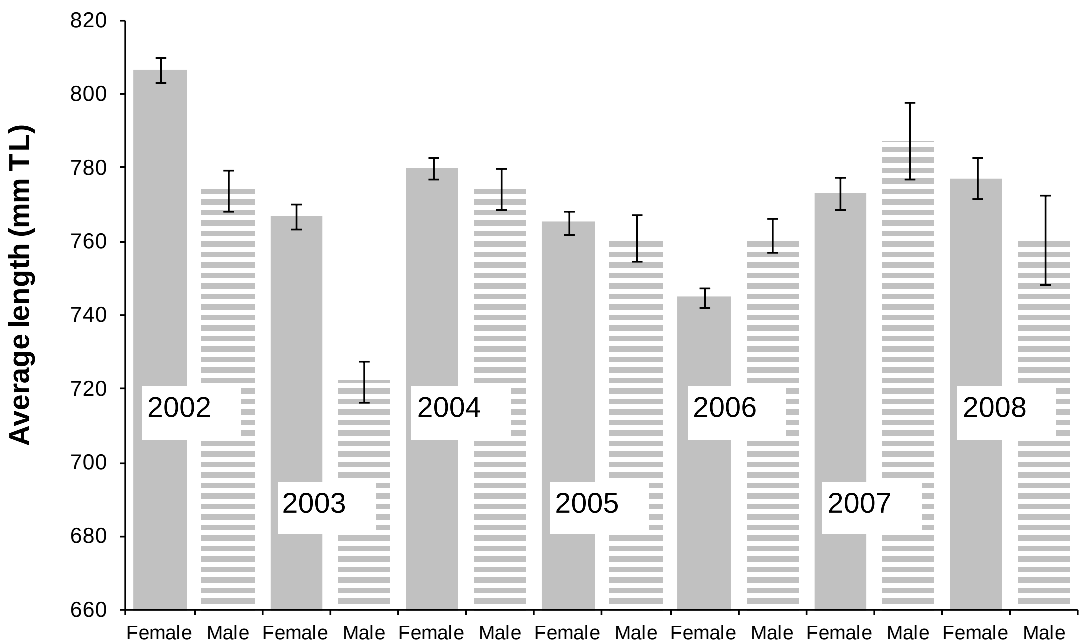
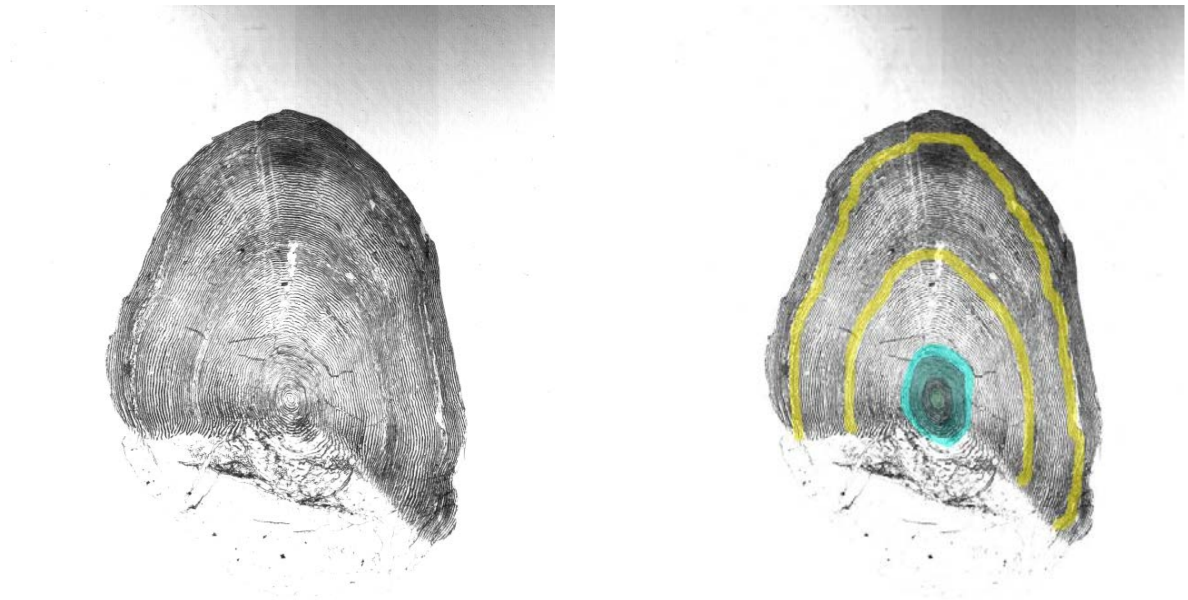


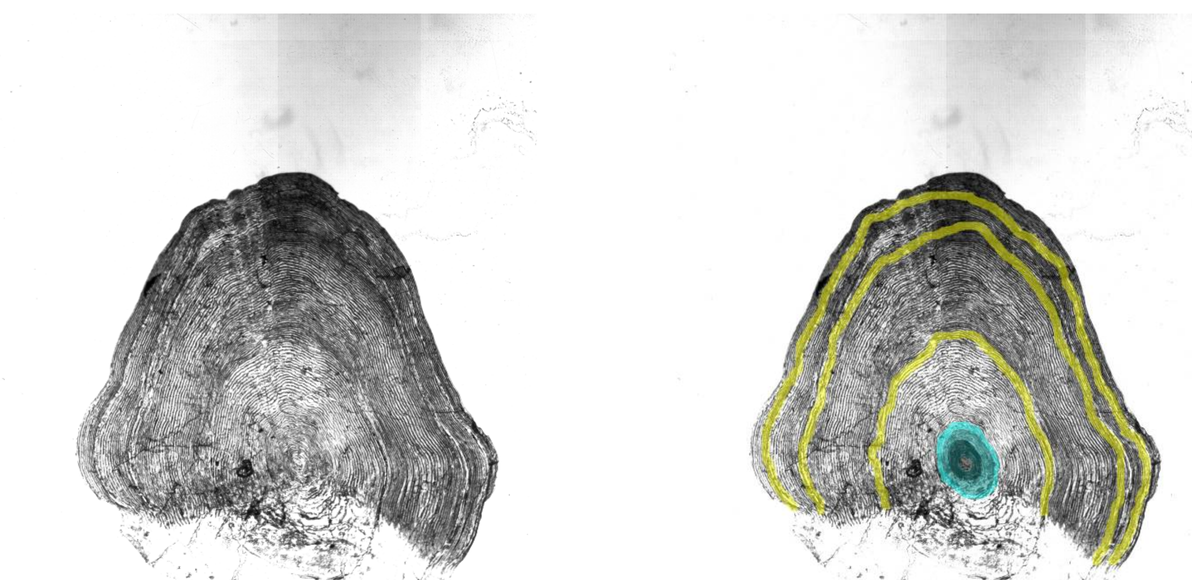
Figure 6.–Average total length of kelts by sex and year at Situk River weir, 2002–2008.

Table 4.–*Z* test statistics for total length comparisons by sex of kelts sampled at Situk River weir, 2002–2008. Bold indicates statistically significant differences.

	2002		2003	
	Male	Female	Male	Female
Average	774	807	722	767
Variance	7,650	4,832	8,182	4,891
Observations	232	413	267	489
Hypothesized mean difference	0		0	
z	4.88009		-7.02610	
P (Z ≤ z), 2-tail	1.1E-06		2.1E-12	
Z critical, 2-tail	1.95996		1.95996	
	2004		2005	
	Male	Female	Male	Female
Average	774	780	761	765
Variance	7,510	4,603	8,471	5,190
Observations	237	520	203	540
Hypothesized mean difference	0		0	
z	-0.86780		-0.57150	
P (Z ≤ z), 2-tail	0.38551		0.56768	
Z critical, 2-tail	1.95996		1.95996	
	2006		2007	
	Male	Female	Male	Female
Average	762	745	787	773
Variance	8,177	4,873	9,450	4,326
Observations	413	648	85	238
Hypothesized mean difference	0		0	
z	3.22017		1.25569	
P (Z ≤z), 2-tail	0.00128		0.20923	
Z critical, 2-tail	1.95996		1.95996	
	2008			
	Male	Female		
Average	761	777		
Variance	7,094	3,734		
Observations	47	117		
Hypothesized mean difference	0			
z	-1.22640			
P (Z ≤ z), 2-tail	0.22004			
Z critical, 2-tail	1.95996			



(a)



(b)

Figure 7.–Kelt scale images from 2005 (left, a) and 2006 (left, b) from fish number 19995300 captured on multiple occasions at the Situk River weir and kelt scale images from 2005 (right, a) and 2006 (right, b) from fish number 19995300 with yearly growth highlighted (lines mark saltwater growth and interior circles mark freshwater growth).

Table 5.–Percent of trophy length (>36 inches or 914 mm TL) kelts in yearly samples collected at the Situk River weir, 2002–2008.

Year	2002	2003	2004	2005	2006	2007	2008	All years
Number of steelhead	31	16	12	14	13	13	1	100
Percent of total	4.8	2.1	1.6	1.9	1.2	4.0	0.6	2.6
Maximum length	1,020	1,100	1,020	1,025	940	1,090	925	1,100

Table 6.–Numbers of PIT-tagged kelts captured at the Situk River weir, and total length of kelts that were recaptured and those that were not, 2002–2008. TL = total length in mm, values in parentheses = SD.

	Female	Male	All
Number of fish tagged	468	173	641
Number of fish recaptured once	51	8	59
% of tagged fish recaptured once	11	5	9
Number of fish recaptured twice	7	0	7
% of tagged fish recaptured twice	1	0	1
Average initial TL sampled	763 (1)	756 (3)	761 (1)
Average initial TL tagged	700 (2)	671 (4)	693 (2)
Average initial TL of recaptures	695 (6)	676 (17)	693 (5)
Average initial TL of non-recaptures	701 (2)	671 (4)	693 (2)

Table 7.–Date that PIT-tagged kelts were passed through the Situk River weir for fish recaptured more than one time, 2002–2008.

Fish number	Tag date	First recapture	Second recapture	Third recapture
5901436	6/8/2002	5/22/2004	5/19/2005	
5911619	6/6/2002	5/18/2004	5/14/2005	
5912483	5/19/2003	5/25/2004	5/18/2005	
5973462	5/22/2003	5/25/2004	5/20/2005	
17983792	5/29/2003	5/25/2004	5/17/2005	
17991605	5/29/2003	5/22/2004	5/11/2005	
19995300	5/31/2004	5/18/2005	6/2/2006	6/14/2007

DISCUSSION

ABUNDANCE

Recent kelt counts in the Situk River peaked at a near record in 2006, and returned to a more typical level in 2008. Historical counts within the drainage have been as low as 1,200 fish (see review in Bain et al. 2003). Historical kelt counts in the Situk River show that a general upturn in abundance began in 1992. Fishery management policies designed to counter putative steelhead declines in the area were instigated in 1994 (Harding and Love 2008). These included lower sport fishery limits, bait restrictions, and restrictions on commercial sale. The recent Situk weir peak counts in 2004–2007 do not however, represent the highest historical counts of adult fish for this system, and it is unknown what the steelhead carrying capacity is for this drainage. Historical peak counts of kelts in the Situk River have exceeded 20,000, but these numbers have not been recorded consistently or in recent times.

Specific methodologies in the counting procedures changed prior to 1995, but generally a weir in the same location has been used since 1995. Cyclic abundance in salmonids is commonly reported, but few long-term data sets exist for steelhead adults. As the counts of adult fish in the Situk River were emigrant adults (kelts) and not immigrant adults, it is not clear what total adult abundance was in this drainage. The variable upstream run timing of fall and spring migrants and harsh winter conditions made immigrant abundance counts impossible on the Situk River. The kelting rate (survival of immigrants to emigration) of all spawners has been reported to be 68–75% by several studies in other Alaskan drainages (Love and Harding 2008). As such, if similar kelting rates occurred on the Situk River from 2002 to 2008, the total in-stream abundance of spawning adults likely exceeded 20,000 fish in some years of this study.

Steelhead management in Alaska is often driven by angler attitudes and the reported number of fish caught by those anglers affects those attitudes. Evidence suggests that reported catch rates may not be an accurate predictor of steelhead abundance. High steelhead abundance years generally correspond with high sport fishery catch rates in steelhead fisheries (Ward and Wightman 1989). However, the recent highest kelt counts have not corresponded to high catch rates in the Situk River. Catch rates were more variable than kelt abundance. Steelhead angler effort has been shown to be associated with river flow (Ward and Wightman 1989). Climatic and river conditions during the steelhead runs likely influence catch rates, as well as overall use by anglers. High water conditions in April on the Situk river that favor easier fish immigration to the upper portions of the watershed likely influenced angler catch rates negatively because the upper portions of the river are less accessible and have seasonal fishing closures. Conversely, low water conditions may have made fish more visible to anglers while also concentrating fish in the lower river where angling pressure was highest, which may have increased steelhead catch rates in some years. Many factors likely influence angler catch rates and attitudes that are not associated with steelhead abundance.

Abundance of steelhead in the Situk River exceeds any other assessed water body in Alaska, but the abundance trends seen here are similar to other streams in Southeast Alaska (Harding et al. 2009). Similar to the Situk River, trends in steelhead abundance in most Southeast Alaska streams peaked between year 2000 and 2006 then fell back closer to average, although the exact years of peak abundance counts have varied among streams. Conversely, recent steelhead counts in a different region, Southcentral Alaska, have remained above average into 2008, (D. Tracy, ADF&G DSF biologist, Kodiak; unpublished data). The Copper River and other large rivers, some of which extend into Canada, undoubtedly have large steelhead populations (Savereide 2008), but no effective assessments are undertaken in such water bodies, and no significant fisheries exist on those remote and turbid rivers.

RUN TIMING

Run timing of the Situk River emigration varied during the years of this report and throughout its historical data set (see review in Bain et al. 2003). Spring river conditions in Southeast Alaska are highly variable, and are associated with winter snow pack, spring temperature progression, rainfall, and larger climatic regimes, as well as complex associations among these factors. Migration behavior in steelhead adults and juveniles has been shown to be associated with river temperature in other areas (High et al. 2006). Steelhead spawning in Southeast Alaska generally occurs at 6–9°C (Harding and Love 2008; Richter and Holmes 2005) Although there were some years when river temperatures were in excess of 6ºC prior to the start of the emigration, the onset of emigration at the Situk River weir appeared to be linked with spring temperatures approaching and staying above 6°C (Figure 8). In most years the emigration began only after the river temperature reached and stayed above 6ºC. In years when warming to 6ºC was delayed, the emigration occurred later (Table 1, Figures 5 and 8). The 2004 and 2005 emigrations, when this was not observed due to very early high river temperatures prior to weir installation, were years that the total run was short in duration. This indicates steelhead were responding to the warmer water temperatures by spawning and emigrating sooner in 2004 and 2005. However, there was no indication that fish were missed in 2004 and 2005 because the counts were low early in the migrations, but subsequently peaked in later days, indicating significant emigration had not begun prior to weir installation. Fundamentally, the spawning event must occur prior to emigration. Steelhead that encountered high temperatures in early spring thus spawned and moved out earlier, while steelhead that encountered cooler temperatures delayed spawning and moved out later.

The majority of the kelt emigration occurred in May during the study years. Higher kelt abundances the following year appeared to be associated with temperatures >8°C earlier and throughout May the previous year (Figure 9). Cooler temperatures typically increase energy demands and decrease swim efficiency in steelhead (Brett 1956). This could have lead to the observation of abundance increases following years of warmer May temperatures in that warmer temperatures lowered the energy demands for spawning and emigration and increased kelt survival. Higher temperatures throughout May were associated with a spring flush of river flow in late April-May from rapid snow melt and normal warming spring conditions (Figure 10). There is also some evidence in more recent runs that an upper threshold of May temperatures exists above which increased kelt survival to the following year does not occur (B. Marston ADF&G DSF biologist, Yakutat; unpublished data). The associations between temperature and flow rate likely influence kelt behavior and/or survival in complex ways each year. Observations of temperature at the Situk weir site were only a correlate to the overall river conditions that steelhead may have evolved to exploit. The true causative mechanisms of emigration or survival to return spawning may not be known, and those specific mechanisms may not be appropriate in other river systems.

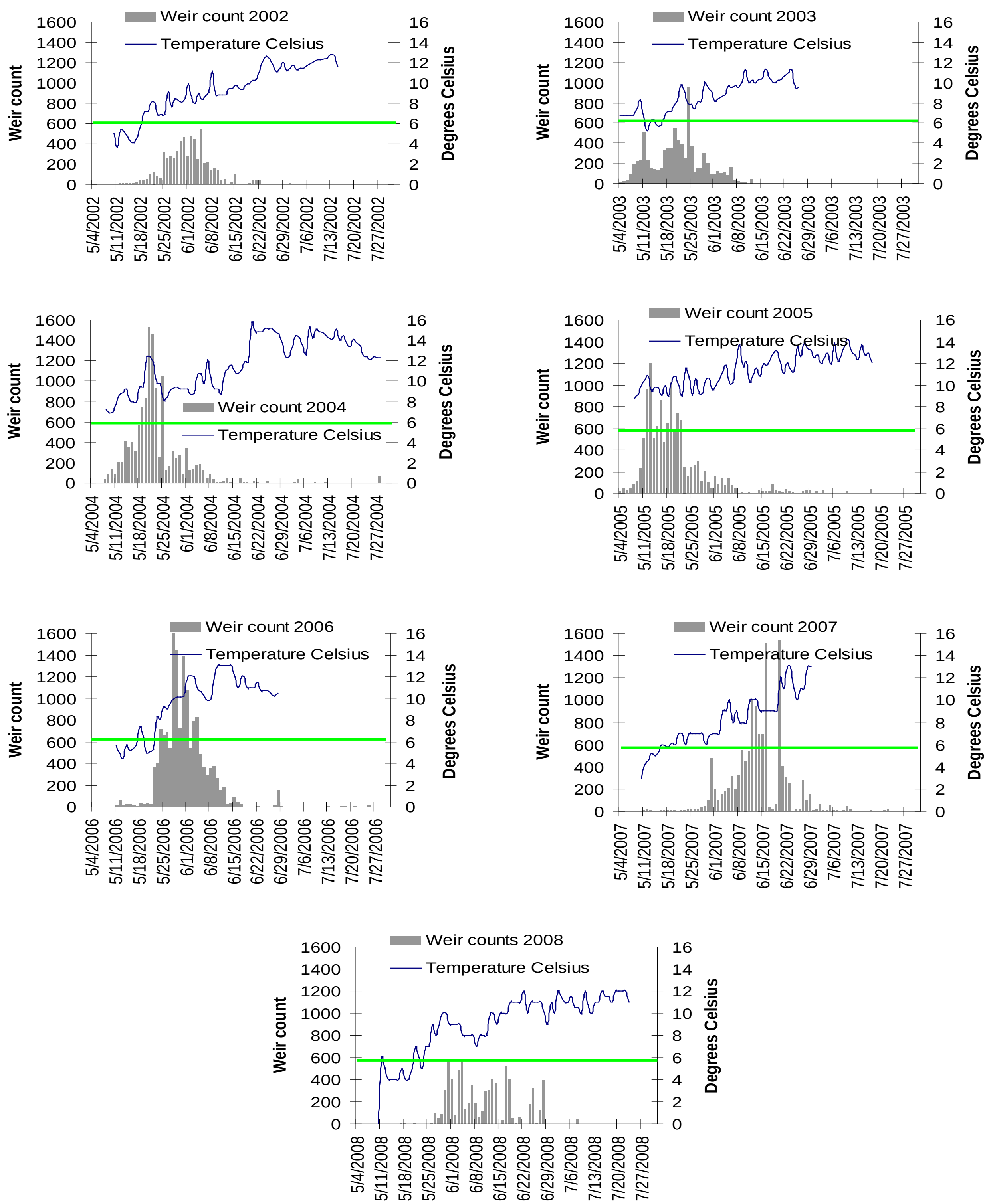


Figure 8.–Temperature at weir site and daily abundance of kelts passed through the Situk River weir, 2002–2008 (Horizontal line marks 6ºC).

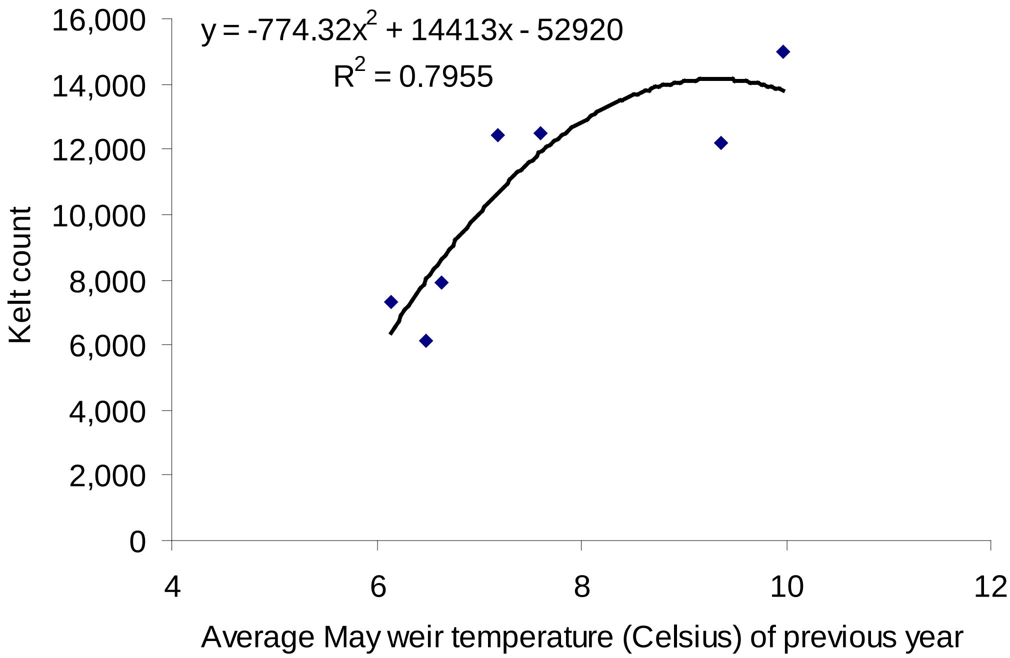


Figure 9.–Relationship of total annual steelhead kelt counts to the previous year's average May water temperature at the Situk River weir, 2002–2008.

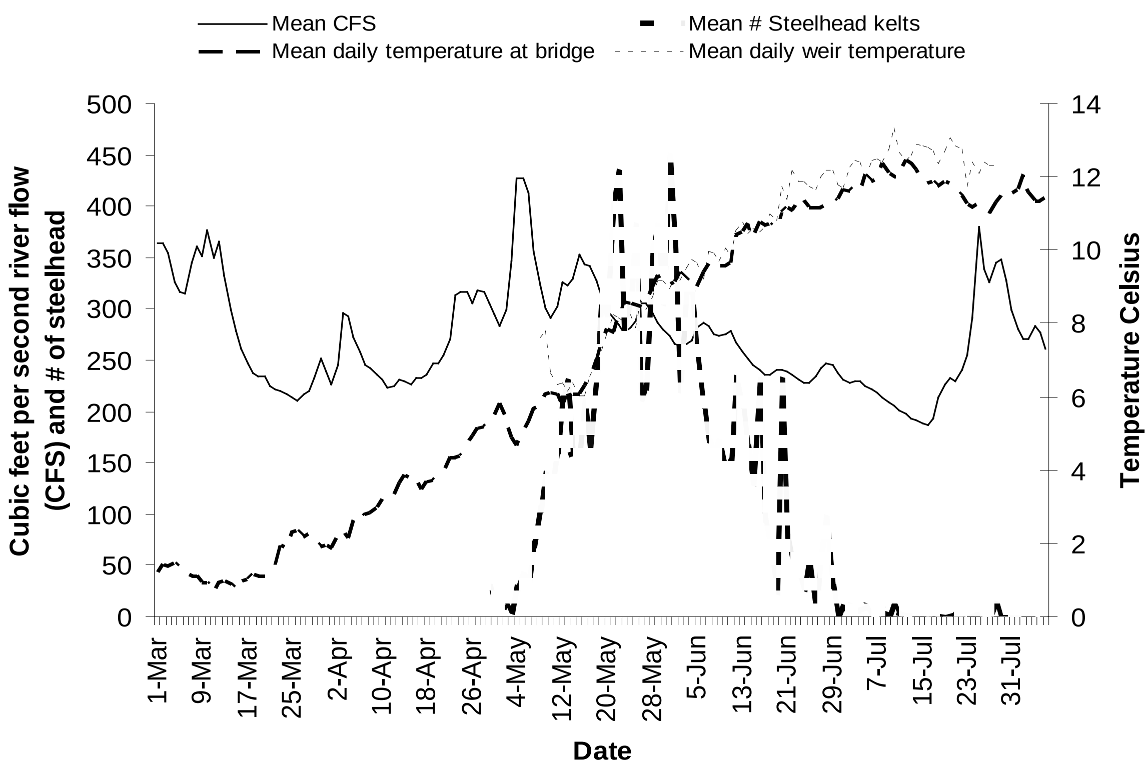


Figure 10.–Average across all years of daily kelt counts, temperatures at the weir, upriver temperatures, and upriver cubic feet per second of river flow fin the Situk River, 2002–2008.

A portion of the Situk steelhead population enters the river in fall and matures inriver. The abundance of the fall portion of the Situk steelhead population is not known. It is also unknown if these fish interbreed with spring ocean-maturing fish that immigrate in spring. Spawning and emigration prior to spring have not been observed in any Alaskan system, although late fall and winter spawning does occur in the most southerly populations within the range of steelhead. Boat surveys for other salmonids done throughout the fall by DSF on the Situk River and many tributaries have not recorded fall or winter steelhead spawning. The lack of a fall or winter emigration in the Situk River is likely a result of the available incubation and rearing conditions. Egg-to-fry incubation survival was not studied in this project, but the preferred range for optimum survival has been shown to be 5 to 10ºC (Myrich and Cech 2005). These temperatures occur in late spring or summer in the Situk River drainage, (Figure 11) so that eggs that are deposited in the spring hatch when ideal rearing temperatures are reached in the summer (11–19ºC) (Myrich and Cech 2005; Wurtsbaugh and Davis 1977). Fall temperatures in the Situk River also reach 5–10ºC, but during the subsequent months of winter, temperatures that eggs would hatch into are very low (Figure 11), which limits the potential for successful rearing after a fall or winter spawning event and subsequent emigrations prior to spring.

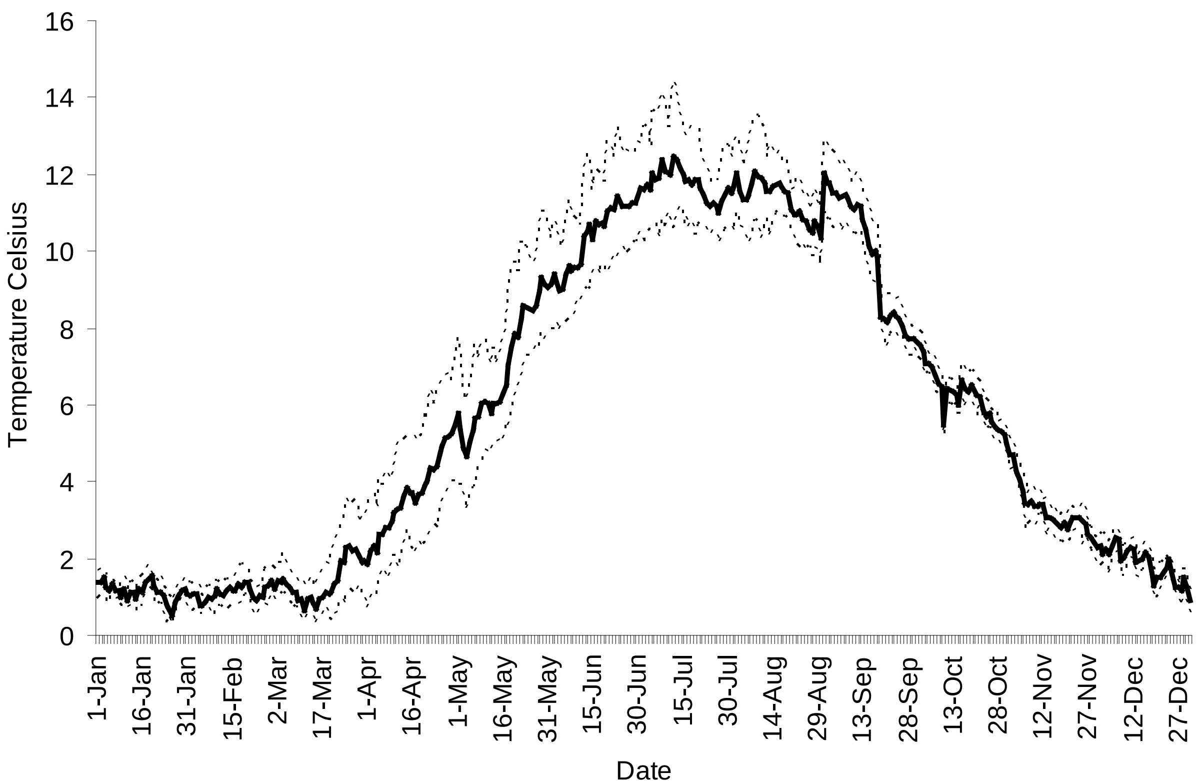


Figure 11.–Average (bold line = daily average, upper dotted line = daily high, and lower dotted line = daily low) daily water temperatures in the Situk River at Nine Mile Bridge, 2002–2008.

The Situk River is one of the most northerly streams known to have a predominantly spring immigration event (Harding and Love 2008). Immigration timing in Southcentral Alaska streams tends to be slightly later than in Southeast Alaska streams, and more southerly populations in Southeast Alaska immigrate earlier than the Situk River stock (Harding and Love 2008). Although immigration timing was not specifically studied here, the onset of spring immigration is partially recorded by the placement of the Situk River kelt weir. Generally the weir is placed after immigration occurs because the focus of the study is kelt abundance. However, some proportion of immigrant fish is still passing upstream after the weir is installed each year. These fish are passed and counted up through the weir during the first days of kelt emigration by the weir crew. Higher numbers of steelhead were still immigrating in years of lower temperatures (B. Marston ADF&G DSF biologist, Yakutat; unpublished data) and late spring conditions, indicating run timing had been delayed by local conditions.

SEX, AND LENGTH

Length attributes of the Situk kelt population varied from 2002 to 2006 (Figure 6). The length of steelhead in the sample collected at the weir appeared to change slightly through time in accordance with abundance, as the large abundance years of 2005–2007 showed a slight decrease in length driven mostly by smaller female fish (Figure 6, Table 4). Year 2006, the peak abundance year, was also the only year male fish were significantly longer than females, whereas in the lower abundance years of 2002 and 2003, females were significantly longer. In 2008, a low abundance year, the length of females may have also been shown to be significantly longer if the sample size target had been met. High kelt abundance years appear to have resulted from an influx of relatively more small female fish. This likely resulted from high survival of a particular year class. No significant sport fishery harvest of steelhead occurs in the Situk River. Regulations limit the harvest to 2 fish per year over 36 inches and most anglers do not harvest any fish at all, regardless of length. Harvest of Situk steelhead averaged 18 fish from 2002 to 2008 (Jennings et al. 2010) and the average rate of harvest was <1% (as a percentage of kelt abundance). It does not appear that the sport fishery is affecting fish length on the Situk River.

Skewed female sex ratios in kelts have been reported in other Southeast Alaska streams (Love and Harding 2008, 2009). In the Situk River samples, female fish also made up a larger proportion of returning tagged fish, suggesting that female fish survive to kelting at a higher rate. Mortalities that washed up on the weir were typically male fish with excessive fungus infection and wounds (B. Marston ADF&G DSF biologist, Yakutat; unpublished data). High male mortality rates may be driven by redd/mate defense behaviors that result in excessive wounding and subsequent fungal infection and death, thus resulting in higher female kelting rates, which is consistent with several other studies on steelhead, as well as Atlantic salmon (Fleming 1998; Keefer et al. 2008; Niemela et al. 2000; Withler 1966). Alternatively, the female skew in kelt samples on Situk River and other areas may be true for the spawning population at large as shown in other Alaskan steelhead studies (Love and Harding 2008). The association of the sex ratio of resident *O. mykiss* in combination with the anadromous population is also not well understood.

PIT TAGS

Repeat spawning behaviors complicate the process of using scales for aging salmonids. Multiple recaptures of repeat-spawning fish on the Situk River have shown that scale aging of steelhead can be difficult, but is possible. A similar study with more complete results also showed that scale aging is possible and accurate with steelhead (Love and Harding 2008; 2009). Scale aging in drainages like the Situk River could be complicated further by fish with both fall and spring migration behaviors, i.e., higher incidence of scale absorption. Assessments of multiple spawning checks in steelhead scales may be more effective by utilizing techniques that sample immigrant fish.

PIT tag returns have shown that repeat-spawning fish can make up a considerable fraction of the spawning population in some years in the Situk River. Up to 9% of the tagged fish returned as spawners that had reached kelting phase the previous year. This equates to over 1,300 fish in some years. Other streams in Alaska have shown higher repeat spawning rates (Love and Harding 2008, 2009). The observed low rate of return spawning in the Situk River was likely influenced by the fact that only kelts were tagged so that the true number of returns (inclusive of returns prior to tagging) is unknown. Conversely, fish were chosen and tagged based on the perception that bright fish were healthier, which may have biased our survival estimate high. Variation in successful repeat spawning can be another reason why abundance varies considerably across years. The Situk River is longer than most other studied steelhead streams in Alaska, which may also be why it has lower observed survival of kelts compared to other Alaskan streams.

The sample size of recaptured fish was very low, but the PIT tag data seems to suggest steelhead may be utilizing instinctive behaviors for emigration timing. Similar to observations in another study (Leider 1985), the PIT tagging data appeared to show that individual emigrant steelhead kelts were exiting the river at similar calendar dates across years in certain circumstances. The calendar date of recapture for PIT-tagged fish that had been captured multiple times was often similar (i.e., see Table 7), and varied by an average of only 9 days, ranging from 3 to 19 days. Furthermore, fish that were initially tagged in 2003 were recaptured within only 3–9 days of the initial calendar date of capture (Table 7). Across all years of study, the variation observed in overall run timing appeared to follow water temperature conditions based on the 50% point in the run, and date of first migrant (Table 1). However, in 2003–2005 overall run timing also ranged from 3 to 9 days, similar to recapture dates of individual fish. Repetitive spawning behaviors such as migration speed, location choice, and spawn timing should result in similar subsequent recapture dates at emigration if river conditions do not vary substantially across years, but this was not the case on the Situk River during this study. The temperature conditions in 2003–2005 were consistent and warmer early in May (Figure 8). Tagged fish exited the river at very similar dates during those years. Other years were cooler earlier and more varied in run time dates. This observation, linked to the other observation that warmer temperatures in May predicts greater overall kelt abundance the following year (Figure 10), may be responsible for the population peak in 2006 after 3 successive years of consistent and warm temperatures in 2003–2005. Large population peaks like those seen in 2006 on the Situk River may require both favorable environmental conditions and successive years of occurrence.

FURTHER RESEARCH AND MANAGEMENT

The Situk River lies at the northern extreme of the range of *O. mykiss*, which creates special management challenges in light of its popularity with anglers and the importance of protecting peripheral populations of trout because of their potential to maximize within-species biodiversity (Haak et al. 2010). Organisms at the far geographical extents of their range can be more vulnerable to habitat disturbance and population decline. Large annual variation in kelt counts has occurred in the Situk River, and the run timing observed in steelhead spawners, although not well understood, includes both fall and spring components, as well as resident fish. Complex life history behaviors have likely evolved in light of variable climatic conditions that promote generalist behaviors in organisms like the steelhead that have broad geographical ranges. Unfavorable changes in habitat conditions at the extremes of an organism's range can lead to marked abundance variations and more generalist behaviors to exploit good conditions, and weather periods of poor conditions. Low steelhead abundance in the Situk River may require changes in fishery regulation to safeguard the steelhead population if harvest is not held low, and sustained low abundance occurs.

Similar to the Situk River, multiple and complex adult *O. mykiss* behaviors for spawning and residency have been noted in other streams (Araki et al. 2007; Docker and Heath 2003; McMillan et al. 2007; Olsen et al. 2006; Zimmerman et al. 2009), and have also been observed in cutthroat trout (*O. clarkia*; Behnke 1992), a closely related and sympatric species. Competitive advantages either in egg survival or juvenile hatch timing from spawning earliest in the spring may drive the fall immigration behavior in Situk River steelhead. Fall immigration may result in adult fish accessing the spawning areas earlier in spring to some advantage over later spring-immigrating fish (Seamons et al. 2004). Conversely, the occurrence of this fall immigration on the Situk River may be limited by increased over-winter mortalities when winter temperatures are harshly low, and result in cold-temperature stress (Brett 1956; Robards and Quinn 2002; Thompson et al. 1958). Multiple spawning behaviors, inclusive of spring and fall immigrants, allow the overall population to exploit ephemeral early-season spawning conditions in light of climatic uncertainties. The specifics of spawning success or the interrelationships of the two anadromous run-time behaviors in the Situk River have not been studied. Additionally, the association between resident rainbow trout and anadromous-form spawning behaviors has not been explored. These life history associations are in need of further study. It is important to note that the spring immigrant population is the focus of our current management strategy and it is believed that this provides adequate protection for all forms of steelhead/rainbow in the Situk River.

Reproductive links among divergent *O. mykiss* spawning behaviors, both anadromous and resident, have been observed in recent studies in other areas (Araki et al. 2007; Docker and Heath 2003; Olsen et al. 2006; Satterthwaite et al. 2009). Along with continued conservative harvest management, the long-term sustainability of steelhead fishery in the Situk watershed will likely require broad habitat preservation including comprehensive water quality and flow preservation goals, as well as maintaining connectivity of habitat types to preserve the suite of *O. mykiss* life history forms. Additionally, adequate restoration of impacted steelhead habitats in the Situk River watershed, although limited in scope currently, also require broad goals for restoration that repair and reconnect habitats for the complete reestablishment of all *O. mykiss* life histories. Portions of the west-side drainages, including the West Fork Situk River (Figure 1) were logged in the recent past. Several small tributaries are now dry and are crossed by road developments. The larger tributary waters of the West Fork Situk River have had stream buffer failures[2] that resulted in areas of extensive blow-down timber deposited in the stream channel that appear to have altered salmonid habitat suitability. Bed load movements in the channel appear to have been altered by blow-down timber and hydraulic actions at high flows that have deposited gravel mounds, which then became dry during low flows. A full understanding of the influence of deposited trees on bed load movements, as well as the effects of the potential mitigation action of removing or notching those trees, will be needed to fully restore the natural connectivity of the West Fork Situk River drainage.

Angler management in the Situk River has also been an area of interest of both anglers and resource managers. Issues of high angler use of the river during peak steelhead fishing have

---

[2] Yakutat Ranger District West Forelands Landscape Assessment, June 2005. Patricia O Connor, USDA Forest Service District Ranger, Yakutat Alaska 99689, unpublished report.

created negative perceptions that the fishery may at times be too large. These perceptions include: 1) the potential vulnerability of fish to snagging or hooking injury while on redds; 2) fishing in areas of active steelhead spawning that could disrupt successful spawning; 3) angler foot traffic in steelhead spawning sites that may harm eggs; 4) jet boat use that may harm fish habitats; 5) sanitation at high use camping areas that could impact habitats; and 6) multiple landings of individual fish by anglers that could decrease individual survival. High recent steelhead counts on the Situk River along with high use, and the lack of any negative association between angler catch and subsequent abundance, appears to suggest that current angler use levels do not have a negative effect on the steelhead population. However, if fish abundance decreases significantly for any reason and fishing pressure remains high, the risk of a negative effect would increase. Persistent low fish abundance drove anglers and managers to alter angling regulations in the past for the Situk River, and throughout the region. The perception that limiting angler use would increase fish abundance, or that high angler harvest was responsible for declines, drove these changes. The current success and stability of fishery regulations requires continued angler catch/harvest information in order to fully describe the potential effects of angler use levels on fish population biology. Potential areas of study that could help more fully assess the issue of angler-use management are assessments of the spatial distribution of angling and catch within the Situk River watershed, along with the spatial distribution of spawning sites to identify angling use in relation to important spawning areas. Additionally, the potential effects of jet boat use on spawning fish behavior or habitat, especially during low flow periods or low fish abundance years, should be explored.

ACKNOWLEDGMENTS

Chet Woods provided crew leadership and technical field work for the project for the majority of years of this report. Nicole Miller, Anne Crane, Mike Freeman, and Alfredo Munoz provided technical field work at some time. Their diligence in counting kelts, weir construction and repair, plus motivation in the late night cold water sampling was critical to the success of the project. M. Sparkman provided helpful comments to the original draft of the manuscript. Stacey Poulson prepared the manuscript for publication.

REFERENCES CITED

Araki, H., R. S. Waples, W. R. Arden, B. Cooper, and M. S. Blouin. 2007. Effective population length of steelhead trout: influence of variance in reproductive success, hatchery programs, and genetic compensation between life history forms. Molecular Ecology 16:953–966.

Bain, C., S. T. Elliott, R. E. Johnson, and G. Woods. 2003. Situk River steelhead: A review of historical data through 1996. Alaska Department of Fish and Game, Fishery Manuscript No. 03-01, Anchorage.

Behnke, R. J. 1992. Native trout of western North America. American Fisheries Society Monograph 6.

Brett, J. R. 1956. Some principles in the thermal requirements of fish. Quarterly Review of Biology 31:75–87.

Docker, M. F., and D. D. Heath. 2003. Genetic comparison between sympatric anadromous steelhead and freshwater resident rainbow trout in British Columbia, Canada. Conservation Genetics 4:227–231.

Fleming, I. A. 1998. Pattern and variability in the breeding systems of Atlantic salmon (*Salmo salar*), with comparisons to other salmonids. Canadian Journal of Fisheries and Aquatic Sciences 55:59–76.

Glynn, B., and S. Elliott. 1993. Situk River steelhead trout counts, 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-29, Anchorage.

Haak, A. L., J. E. Williams, H. M. Neville, D. C. Dauwalter, and W. T. Colyer. 2010. Conserving peripheral trout populations: the values and risks of life on the edge. Fisheries 35(11)530-549.

Harding, R. D., and D. C. Love. 2008. Southeast Alaska steelhead snorkel surveys of regional index streams, 2004 and 2005. Alaska Department of Fish and Game, Fishery Data Series No. 08-19, Anchorage.

Harding, R. D., K. A. Kondzela, and R. P. Marshall. 2009. Survey of anglers using Southeast Alaska recreational cabins during 2006. Alaska Department of Fish and Game, Fishery Data Series No. 09-60, Anchorage.

High B. C., A. Peery, and D. H. Bennett. 2006. Temporary straying of Columbia River summer steelhead in coolwater areas and its effect on migration rates. Transactions of the American Fisheries Society 135:519–528.

Jennings, G. B., K. Sundet, and A. E. Bingham. 2010. Estimates of participation, catch, and harvest in Alaska sport fisheries during 2008. Alaska Department of Fish and Game, Fishery Data Series No. 10-02, Anchorage.

Johnson, R. E. 1990. Steelhead studies: Situk River, 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-47, Anchorage.

Johnson, R. E. 1991. Situk river steelhead studies, 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-49, Anchorage.

Johnson, R. E. 1996. Situk River steelhead trout studies, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 96-1, Anchorage.

Johnson, R. E., and J. D. Jones. 1998. Southeast Alaska steelhead studies, 1997: Situk River weir and surveys of index streams. Alaska Department of Fish and Game, Fishery Data Series No. 98-45, Anchorage.

Johnson, R. E., and J. D. Jones. 1999. Southeast Alaska steelhead studies, 1998: Situk River weir and surveys of regional index streams. Alaska Department of Fish and Game, Fishery Data Series No. 99-33, Anchorage.

Johnson, R. E., and J. D. Jones. 2000. Alaska steelhead studies, 1999: Situk River weir and surveys of regional index streams. Alaska Department of Fish and Game, Fishery Data Series No. 00-16, Anchorage.

Johnson, R. E., and J. D. Jones. 2001. Southeast Alaska steelhead studies, 2000: Situk River weir and surveys of regional index streams. Alaska Department of Fish and Game, Fishery Data Series No. 01-20, Anchorage.

Johnson, R. E., and J. D. Jones. 2003. Southeast Alaska steelhead studies, 2001: Situk River weir and surveys of regional index streams. Alaska Department of Fish and Game, Fishery Data Series No. 03-18, Anchorage.

Keefer M. L., R. H. Wertheimer, A. F. Evans, C. T. Boggs, and C. A. Peery. 2008. Iteroparity in Columbia River summer-run steelhead (*Oncorhynchus mykiss*): implications for conservation. Canadian Journal of Fisheries and Aquatic Science 65(12): 2592–2605.

REFERENCES CITED (continued)

Leider, S. A. 1985. Precise timing of upstream migrations by repeat steelhead spawners. Transactions of the American Fisheries Society 114:906–908.

Love, D. C., and R. D. Harding. 2008. Steelhead trout production studies at Sitkoh Creek Alaska, 2003–2004. Alaska Department of Fish and Game, Fishery Data Series No. 08-44, Anchorage.

Love, D. C., and R. D. Harding. 2009. Steelhead trout production studies at Sitkoh Creek Alaska, 2005–2006. Alaska Department of Fish and Game, Fishery Data Series No. 09-68, Anchorage.

McMillan J. R., S. L. Katz, and G. R. Pess. 2007. Observational evidence of spatial and temporal structure in a sympatric anadromous (winter steelhead) and resident rainbow trout mating system on the Olympic Peninsula, Washington. Transactions of the American Fisheries Society 136:736–748.

Myrich, C. A., and J. J. Cech. 2005. Effects of temperature on the growth, food consumption, and thermal tolerance of age-0 Nimbus-Strain steelhead. North American Journal of Aquaculture 67:324–330.

Niemela, E., T. S. Makinen, K. Moen, J. Erkinaro, M. Lansman, and M. Julkunen. 2000. Age, sex ratio and timing of the catch of kelts and ascending Atlantic salmon in the subarctic River Teno. Journal of Fish Biology 56: 974–985.

Olsen, J. B., K. Wuttig, D. Fleming, E. J. Kretschmer, and J. K. Wenburg. 2006. Evidence of partial anadromy and resident form dispersal bias on a fine scale in populations of *Oncorhynchus mykiss*. Conservation Genetics 7:613–619.

Robards, M. D., and T. P. Quinn. 2002. The migratory timing of adult summer-run steelhead in the Columbia River over six decades of environmental change. Transactions of the American Fisheries Society 131:523–536.

Richter, A., and S. A. Holmes. 2005. Maximum temperature limits for Chinook, coho, and chum salmon, and steelhead trout in the Pacific Northwest. Reviews in Fisheries Science 13(1):23–49.

Satterthwaite, W. H., M. P. Beaks, E. M. Collins, D. R. Swank, J. E. Merz, R. G. Titus, S. M. Sogard, and M. Mangel. 2009. Steelhead life history on California's central coast: insights from a state-dependent model. Transactions of the American Fisheries Society 138:532–548.

Savereide, J. W. 2008. Relative abundance, migratory timing, overwintering, and spawning distribution of steelhead in the Copper River drainage. Alaska Department of Fish and Game, Fishery Data Series No. 08-56, Anchorage.

Seamons, T. R., P. Bentzen, and T. P. Quinn. 2004. The mating system of steelhead (*Onchorhynchus mykiss*) inferred by molecular analysis of parents and progeny. Environmental Biology of Fishes 69:333–334.

Thompson, R. N., J. B. Haas, L. M. Woodall, and E. K. Holmberg. 1958. Results of a tagging program to enumerate the numbers and to determine the seasonal occurrence of anadromous fish in the Snake River and its tributaries. Fish Commission of Oregon, Portland.

Ward, B. R., and J. C. Wightman. 1989. Monitoring steelhead trout at the Keogh River as an index of stock status and smolt-to-adult survival: correlations with other data sources. Providence of British Columbia, Fisheries Management Report No. 95.

Welander, A. D. 1940. A study of the development of the scale of the Chinook salmon (*Oncorhynchus tschawytscha*). Master's Thesis. University of Washington.

Withler I. L. 1966. Variability in life history characteristics of steelhead trout (*Salmo gairdneri*) along the Pacific coast of North America. Journal of Fisheries Research Board of Canada 23:365–393.

Wurtsbaugh, W. A., and G. E. Davis. 1977. Effects of temperature and ration level on the growth and food conversion efficiency of *Salmo gairdneri*, Richardson. Journal of Fish Biology 11:87–98.

Zimmerman, C. E., G. W. Edwards, and K. Perry. 2009. Material origin and migratory history of steelhead and rainbow trout captured in rivers of central California. Transactions of the American Fishery Society 138:280–291.

APPENDIX A:
DATA FILES

Appendix A1.–Data files in archive for Situk River steelhead studies, 2002–2008.

File	Description
Situk steelhead data 2002–2008 9 mile CFS readings.xls	Data from USGS gauging station of river flows in cubic feet per second for Situk River at 9 Mile Bridge, 2002–2008
Situk steelhead data 2002–2008 kelt counts.xls	Situk River weir kelt abundance counts, temperature and river stage height at weir site
Situk steelhead data 2002–2008 length data.xls	Situk River weir steelhead kelt length and age data, 2002–2008
Situk steelhead data 2002–2008 9 mile river temp readings.xls	Situk River water temperatures at 9 Mile Bridge, 2002–2008
Situk steelhead data 2002–2008 paper figures.xls	Figures for Situk River steelhead studies manuscript, 2002–2008