Fishery Data Series No. 16-21

Steelhead Studies from the Situk River in Southeast Alaska, 2009–2011

by

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and

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June 2016

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

As a continuation of a monitoring project begun in 1994, a bipod and picket weir was used to count and sample steelhead *Oncorhynchus mykiss* kelts emigrating from the Situk River in Southeast Alaska from 2009 to 2011. Counts were 7,302, 5,335, and 7,458, emigrating kelts for 2009–2011 respectively. The 2009–2011 counts were below the long-term (18 years: 1994-2011) average of 8,487 (-21%), and represent a 60% drop off the recent peak counts (10–15,000) seen within the last decade, but they were similar or above the previous low counts recorded historically (< 5,000 observed 1988-1992). For 2009 to 2011, male total length averaged 821, 754, and 755 mm respectively, and females averaged 825, 749, and 760 mm respectively. Mean total length in 2009 was largest on record for female fish and the second largest for male fish. Mean total length of kelts varied but did not show a consistent up or down trend in samples taken during this study period, or as compared to a long-term dataset from the drainage. For 2009–2011, the date of first emigrant ranged from 7 May to 12 May, and the date of midpoint of emigration varied from 17 May to 3 June, whereas the date of the last emigrant ranged from 27 June to 26 July. Each year the onset of high daily kelt emigration numbers was associated with river temperatures that reached 6° Celsius. A total of 207 Passive Integrated Transponder tags were inserted in steelhead kelts from 2009 to 2011, bringing the total tags at liberty to 829 from past years' tagging efforts occurring between 2000–2011. Passive Integrated Transponder tag recaptures fell from 11.3% in 2009 to 10.6% in 2011. The average return rate of PIT tagged fish was 11% across years.

Key words: Steelhead, Oncorhynchus mykiss, weir, salmonid, anadromous, iteroparous, trout, sport fishery, Situk River, Southeast Alaska

INTRODUCTION

The Situk River (Figure 1), near the village of Yakutat in Southeast Alaska, originates in tributaries of Mountain Lake at approximately 600 m elevation, 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 ~17,000 ha.

The Situk River sustains the largest steelhead *Oncorhynchus mykiss* sport fishery in Alaska accounting for greater than 40% of the statewide catch (http://www.adfg.alaska.gov/sf/sportfishingsurvey/). The Situk River also has regionally significant fisheries for sockeye *O. nerka*, pink *O. gorbuscha*, and coho salmon *O. kisutch*, as well as smaller fisheries for Chinook salmon *O. tshawytscha*, Dolly Varden *Salvelinus malma*, and resident rainbow trout *O. mykiss*. Angler catches of steelhead on the Situk River averaged 11,228 for the years 2000–2010, and that of other salmonids averaged in excess of 50,000. Angler harvest of steelhead was typically small averaging 26 fish/year from 2000–2010. Steelhead cannot be targeted for commercial harvest in Alaska, and the incidental harvest in commercial fisheries is estimated to be low (<25 per year). Commercial fishery harvests targeting other salmon species conducted with gillnets in the Situk estuary exceeded 100,000 fish, consisting primarily of sockeye and coho salmon. The subsistence take of steelhead in Alaska is not well understood, although they are not as important as other salmon species for subsistence use. The permit system for subsistence steelhead has not recorded more than 10 fish in any year for the Situk River Drainage.

Figure 1.–The Situk River drainage near Yakutat in Southeast Alaska, showing the location of the Situk River steelhead weir.

Past studies have shown that steelhead exhibit 2 spawning strategies in the Situk drainage (Glynn and Elliot 1993; Johnson 1991, 1996; Johnson and Jones 1998-2001, 2003) and anglers target both strategies to varying extent. Steelhead adults enter the Situk River in two 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 remainder (and majority) of the entire run enters the river in April as the second component, referred to as “spring” or ocean-maturing fish. 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 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” (emigrating fish after spawning) and the fishery is typically over by mid-June.

Recent work monitoring the steelhead emigration has continued on the Situk River (Marston et al. 2012, Johnson 1991) and the data set, begun in 1988, now contains 24 years of weir counts from a consistent weir location on the lower Situk River, and 10 years of counts with an identical weir count methodology (a video camera was added in 2002). This document reports the results of steelhead kelt counts on the Situk River from 2009–2011. Additionally, a summarization and reporting of all historic length data from the Situk River weir is included, as is a reporting of Passive Integrated Transponder (PIT) tagging.

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 made 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, up- or downstream, at any time. The weir site was above mean high tide influence, although the highest tides occurring each month often slowed river flows slightly at the site. Access to the site was via river boat from the Lower Landing boat ramp at tidewater, or through two 2 km trails. A small cabin for housing of personnel that doubled as a counting structure was also on site, and two smaller sheds were used for storage of gear and power generators. Steelhead kelts were counted (see kelt counting procedures) 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 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. Installation was delayed slightly if spawning activity was not occurring, as seen in the boat survey, indicating the emigration was yet to start. Installation may have also been expedited if observations obtained through boat surveys showed the onset of spawning behavior, indicating the emigration was beginning or would occur soon. 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). The weir was run each year specifically to count steelhead until June 9, by which time the majority of steelhead have left the river, as observed in past years. However, the weir remained in place until August 10 to count other species of salmon. Any remaining kelts that passed after June 9 were also tallied as they moved downriver through the salmon weir.

KELT COUNTING PROCEDURES

Kelts were counted during late night hours, primarily between 22:00 and 03:00, 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. Kelts were counted as they passed through a weir gate by utilizing an underwater video system (Figure 2). During normal kelt counting operations (no capture or handling needed), a trap below the upper weir gate functioned as a chute, where 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 via the underwater video system linked to an 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 problems with above-surface visibility of fish associated with poor 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.

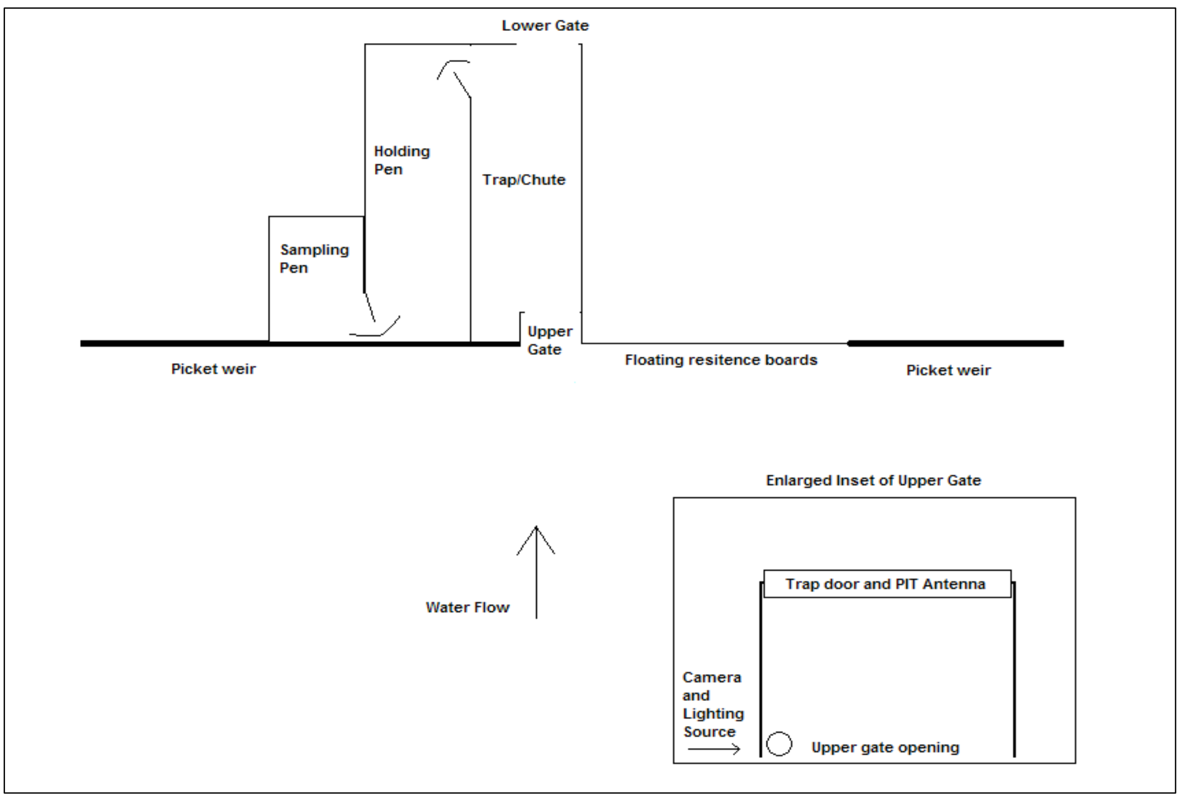


Figure 2.–Diagram of the Situk River steelhead weir and fish capture trap. Lower right inset shows the weir trap gate, PIT tag antenna, and video camera placement.

The video system utilized for counting steelhead kelt emigration consisted of an Ocean Systems[1] (model: Deep Blue Pro) waterproof camera mounted to the weir gate and an LCD display screen and DVD recorder located in the cabin, plus Ocean Systems LED lighting and power sources. Wires ran the length of the weir and led 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, thus eliminating concerns about non-detection. 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 would 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 to form additional openings or by submerging a resistance board section and allowing fish to pass.

CAPTURE, MEASUREMENT, AND SAMPLING PROCEDURES

A steelhead trap is used below the weir to capture fish for measurement and PIT tag implantation or evaluation. When a capture sample was taken, 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. A proportion of 3–5% was targeted each sampling night (for measurement and sex identification) in order to achieve the overall yearly sample size goal (223 fish minimum), while proportionally sampling the entire run. Samples were collected two nights per week (Mondays and Thursdays). 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 proportion target. Fish were sampled late (after midnight) the first night, and early (prior to midnight) the second night to account for diel variations in emigration observed in past studies (Johnson and Jones 1998, 1999). All fish sampled for sex and length (SL) were also checked by hand (Biomark pocket reader) for PIT tags. Total lengths (tip of snout to tip of tail) to the nearest 5 mm, sex, presence of wounds or fungus, and color classification were recorded from each sampled fish. Color classifications included bright, medium, or dark (recorded as 1, 2, or 3 respectively).

PIT TAGGING AND RECAPTURE PROCEDURES

Biomark PIT tags were also implanted in selected kelts in 2009–2011. These fish were selected from the SL sample by a length, color, and health classification. 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 (ocean-age-2 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. Tagging with PIT tags 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

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

scale patterns in multiple spawning individuals. The 20 mm PIT tags (Biomark model 1411 SST) 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. All PIT tags were initially test scanned, labeled by unique identification number in a tag holder, and then applied.

Beginning in 2004, recaptures of PIT tagged fish were observed with a Biomark PIT antenna mounted to the weir trap gate and attached so that all fish passed through the reception field while being counted (Figure 2). This process was developed in 2002 and 2003, and then fully utilized consistently beginning in 2004. Tagged fish were recorded and saved to memory in a PIT reader housed on the weir. Additionally, as 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 the fish. The tagged fish was then netted out of the trap and sampled as a recapture. Recaptured fish were measured and processed as age, sex, and length (ASL) fish, similar to SL fish except that 8 scales were taken so that a readable scale was assured. Scales were taken from the "preferred" area on both sides of the fish (Welander 1940) for archiving. Scales' rings were analyzed as in Love and Harding (2008-2009). Scales from recaptured fish will be compared to scales from those fish taken in previous years when staffing time allows.

ANCILLARY DATA

Ancillary information on steelhead, the steelhead fishery, and the surrounding environment was also gathered during 2009–2011. Environmental data gathered daily on site for this project included water temperature and stream stage-height recordings collected at the weir site. Additionally, daily river flow statistics and temperature were obtained from a United States Geological Survey (USGS) gauging station located at 9 Mile Bridge. The weir site environmental data were recorded by weir personnel at 10 AM. Temperature recordings were gathered immediately above the weir at a depth of 0.6 m 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 9 Mile Bridge by an automated USGS recording station (available at http://waterdata.usgs.gov/usa/nwis/uv?site_no=15129500) 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 iteroparity 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 (http://www.adfg.alaska.gov/sf/sportfishingsurvey/), 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 $\sqrt{\hat{\text{var}}(\hat{p}_a)}$ (Thompson 2002).

The mean length $(\bar{y})$ of emigrants and associated variance ($\hat{\text{var}}$) 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. The fpc was again used because all fish were counted at the weir. The standard error is $\sqrt{\hat{\text{var}}(\bar{y})}$ (Thompson 2002).

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

Various statistical procedures are noted when used in descriptive or comparative analysis.

RESULTS

KELT ABUNDANCE

Abundance of steelhead kelts in 2009-2012 was not consistent across the study years and showed large variations from the longer-term dataset. Abundance of steelhead kelts in the initial 2009 study year was 7,302 fish, declining to 5,335 in 2010 and then increasing to 7,458 in 2011 (Figure 3). The relatively low count in 2010 represented a >60% drop from the highest historical count observed in 2006. The low count of 2010 was not the lowest recorded in the system and was similar to several other low counts in the late 1990s and early 2000s (Bain et al. 2003).

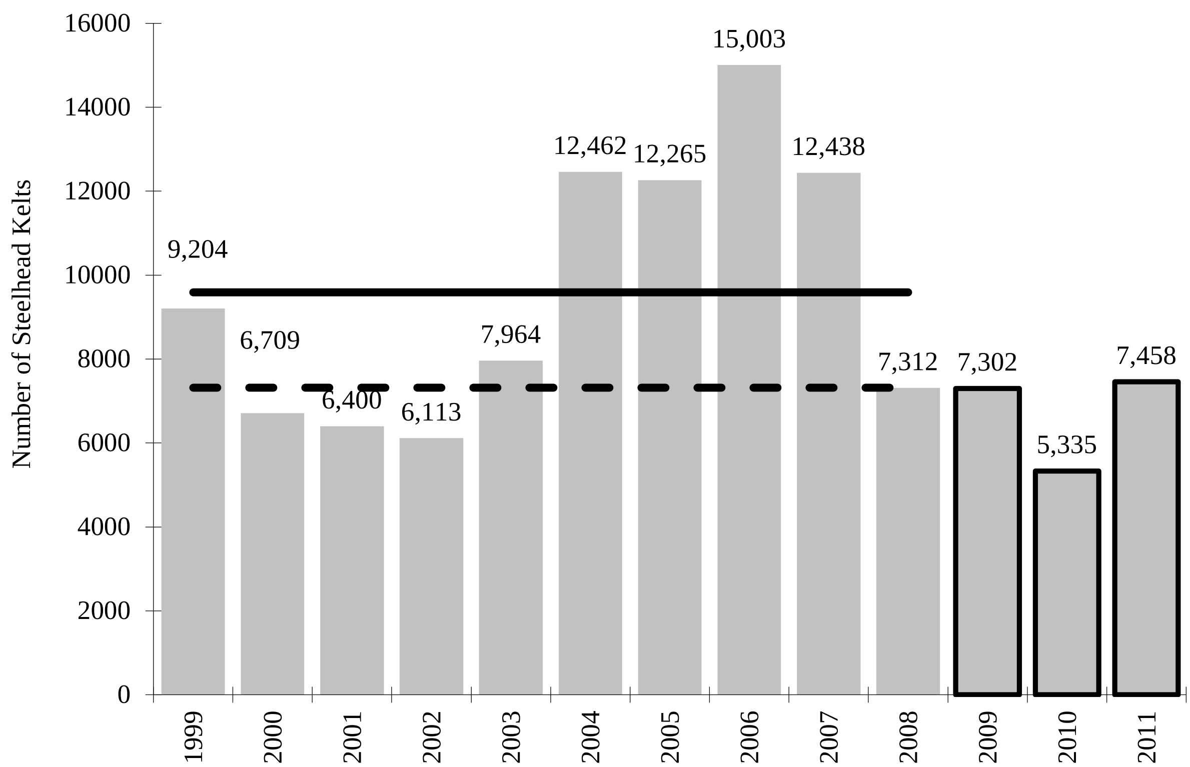


Figure 3.–Steelhead kelt counts from the Situk River Weir for the current study years of 2009–2011 (bold bordered bars), compared to those of the preceding decade 1999–2008 (non-bordered bars). The solid line shows the mean count of the preceding decade, and the dashed line shows the long term median of all steelhead counts since 1995.

KELT EMIGRATION TIMING

Emigration timing during the 2009 to 2011 study period began late all 3 years, compared to the previous 10-year average (Figure 4). The weir was made fish tight on the 9th, 8th, and 6th of May for years 2009 to 2011 respectively. In 2009, significant kelt passage did not occur until May 27, but the emigration progressed quickly and ended during mid-June as is typical. In 2010, emigration timing mirrored average historic patterns, with an early May start date and a late June end. In 2011 emigration timing started in mid-May but was extended in time with late and large pulses of fish emigrating into July. Two days in 2011 had counts over 100 fish occur after June 9, and a total of 1,201 fish passed the weir after that date.

KELT SIZE ATTRIBUTES

Size attributes per sex (SL) of Situk River steelhead kelts that were recorded during this study period varied, but the largest lengths ever seen for this system were observed during the study period (Figure 5). In 2009, the average total length of female kelts was the largest ever observed and male average total length was the second largest. Conversely, average lengths of both sexes were slightly below average in 2010 and 2011. In 2009, a paucity of small fish of both sexes was observed, and large fish dominated the sample, producing length histograms that were skewed without many fish less than 850 mm (Figure 6), whereas the other two years showed partially bimodal (2010) or bell-shaped (2011) size distributions, with relatively more abundant small fish. Compared to the other two years, 2010 had the highest proportions of fish smaller than 850 mm. The number of fish in the trophy class (>36 inches or 914 mm) was 8%, 3%, and 1% for each study year respectively. Attributes of SL from a larger dataset dating back to 1999 (Appendix A1) varied, and size tended to increase during the low abundance years.

KELT PIT TAGGING

A total of 829 PIT tags have been inserted into selected kelts, beginning in the year 2000 and up to and including tagging efforts in 2011. During this study period (2009–2011), 207 kelts were PIT tagged. Since 2001 (the first year a tagged fish could be recaptured), the cumulative number of recaptured-tagged fish was 77, inclusive of 12 that occurred during the 2009–2011 study period. The yearly recapture rate declined slightly from 11.25% in 2009 to 10.74% in 2010, and was 10.62% in 2011. The average recapture rate was 10.96 % across all years of the data set. The fine scale changes in recapture rates were associated with kelt abundance and a corresponding 2-year lag (Figure 7); higher kelt abundance tended to predict higher recapture rates 2 years later.

ENVIRONMENTAL DATA

During 2009–2011, Situk River conditions generally consisted of warm water temperatures and low flows. River conditions in the spring of 2009–2011 included some of the warmest water temperatures and lowest flows on record for the Situk River during the steelhead spawning season (May and June). The years 2009–2011 had temperatures that were mostly above average, especially during 2010. The flow depths of all 3 study years were below average for the majority of the spring, although 2009 had a late pulse of flow that was above average (Figure 8). The 2011 year was below normal in flow depth during the entire spawning season and varied the least inseason. The abundance of kelts was positively correlated with river temperatures of the previous spring (Figure 9). The onset of high kelt emigration counts occurred after the river temperatures reached 6 °C each year of this report (Figure 10).

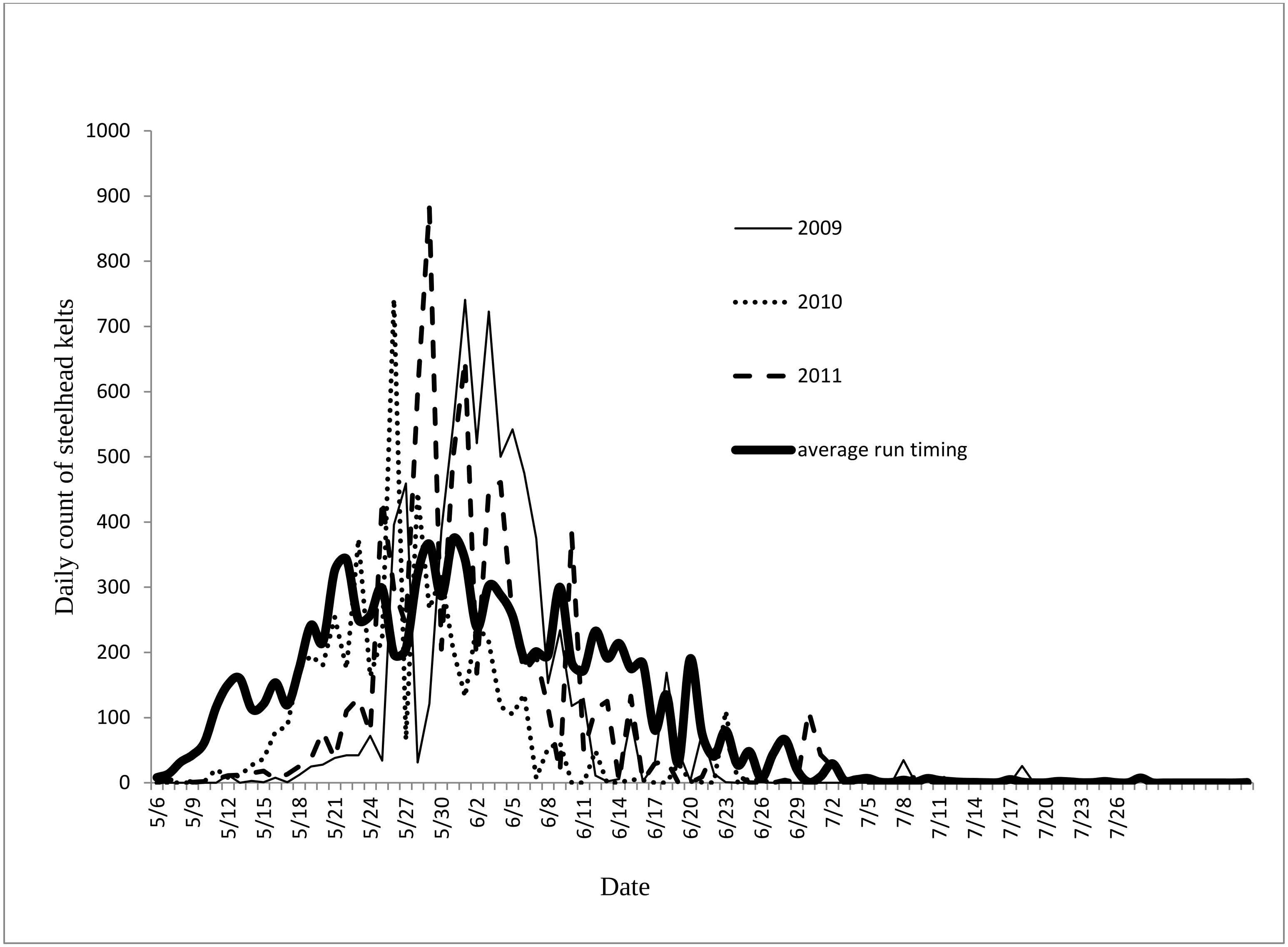


Figure 4.–Daily kelt counts from the Situk River Weir during 2009–2011, compared to the average daily counts from the preceding decade.

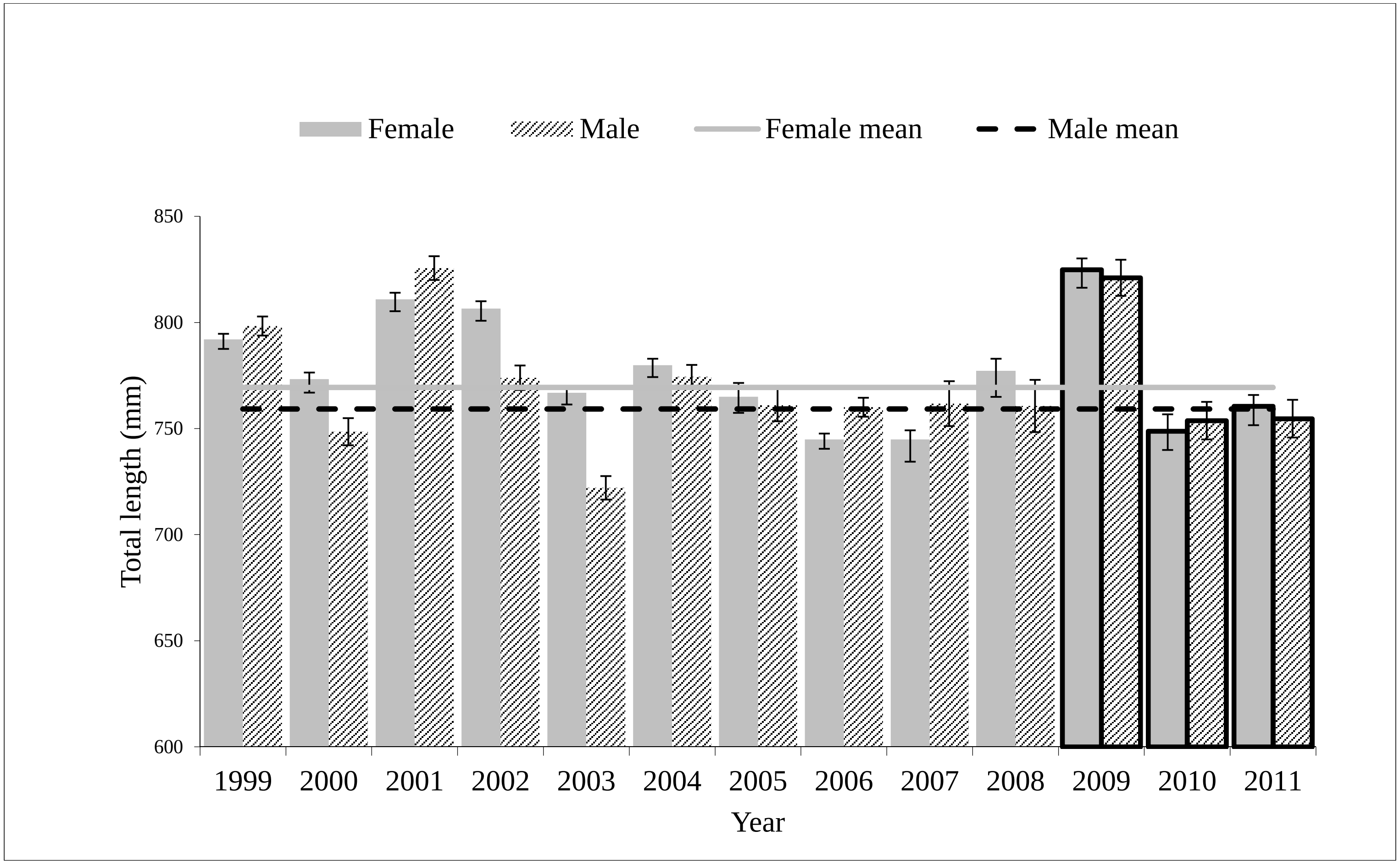


Figure 5.–Mean total length (mm) of steelhead sampled from the Situk River during the current study years of 2009–2011 (bold bordered bars) compared to those of the preceding decade 1999–2008 (non-bordered bars). The dotted and dashed lines depict the mean female and male total length (mm) for the preceding decade respectively.

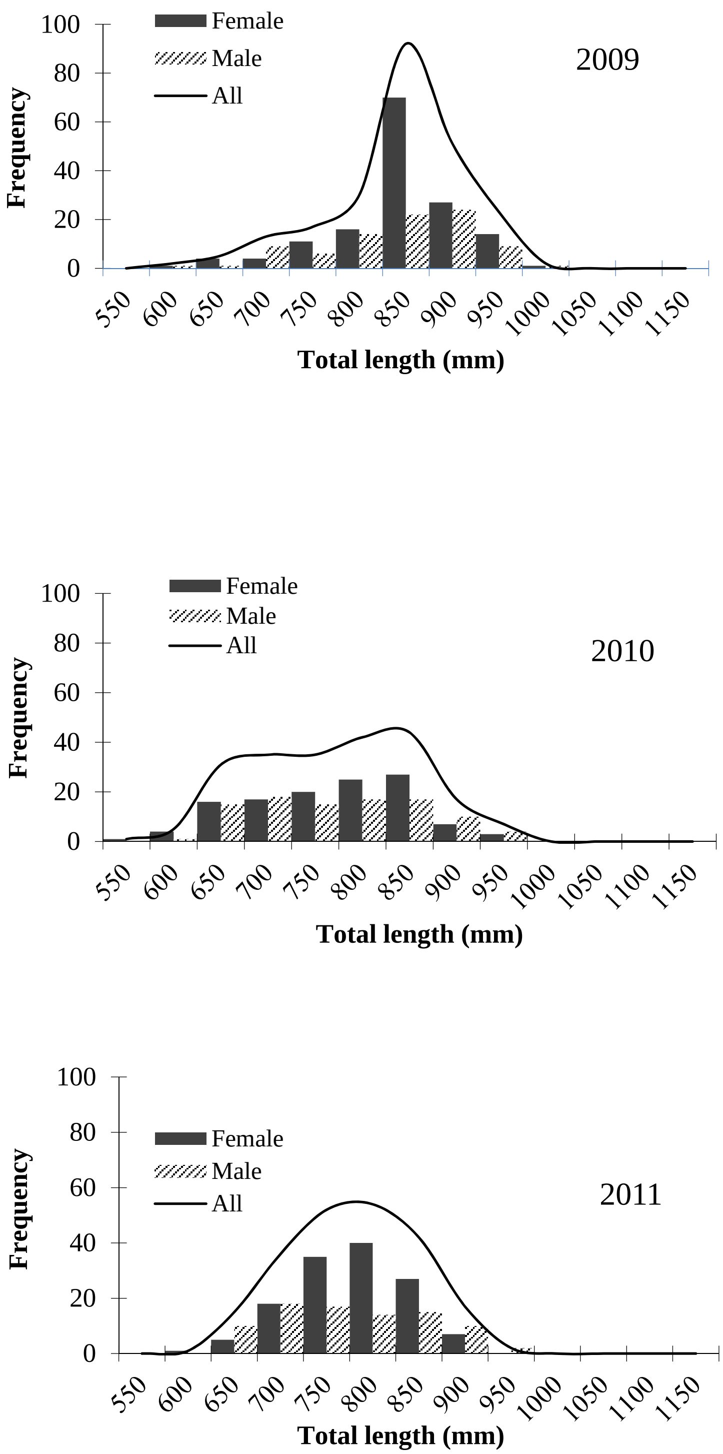
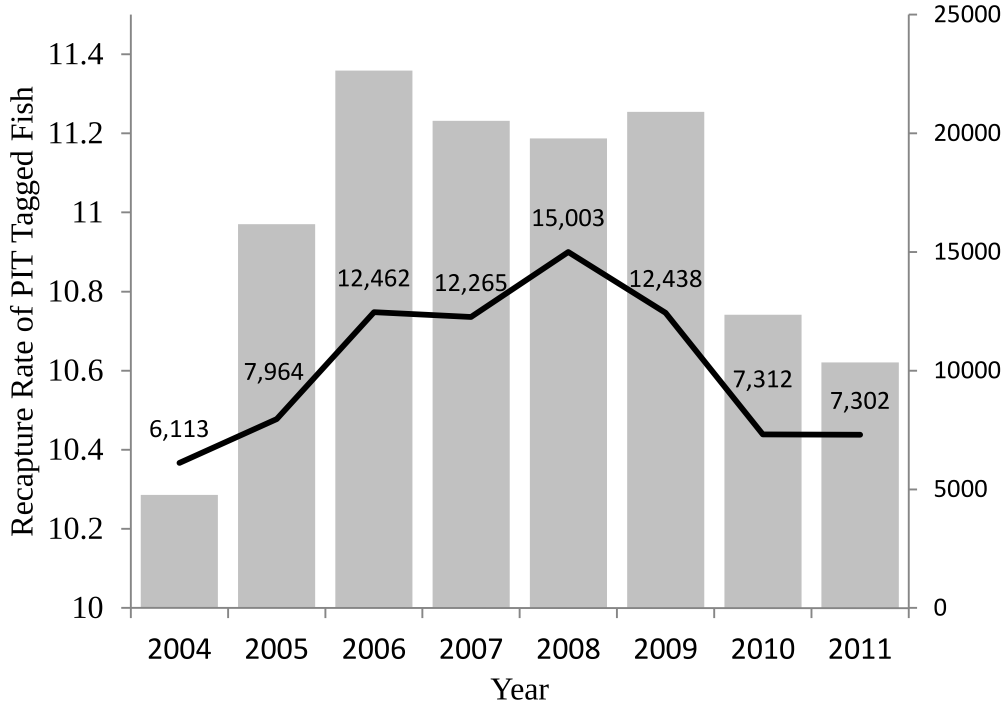


Figure 6.–Histograms of total length (mm) for steelhead kelts on the Situk River 2009–2011.

(a)



(b)

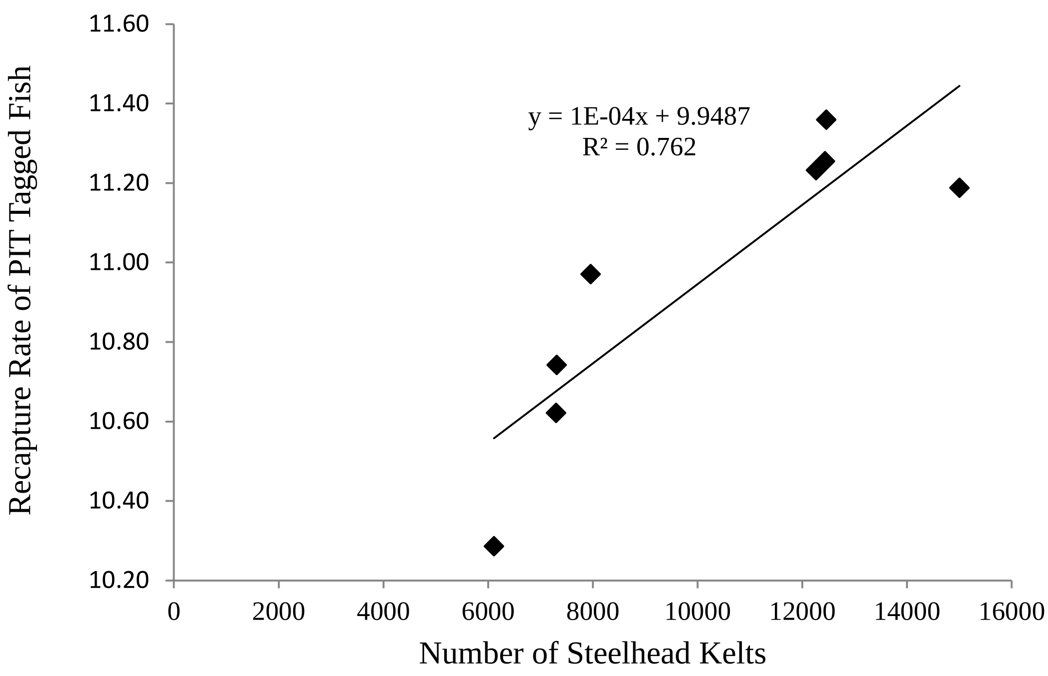
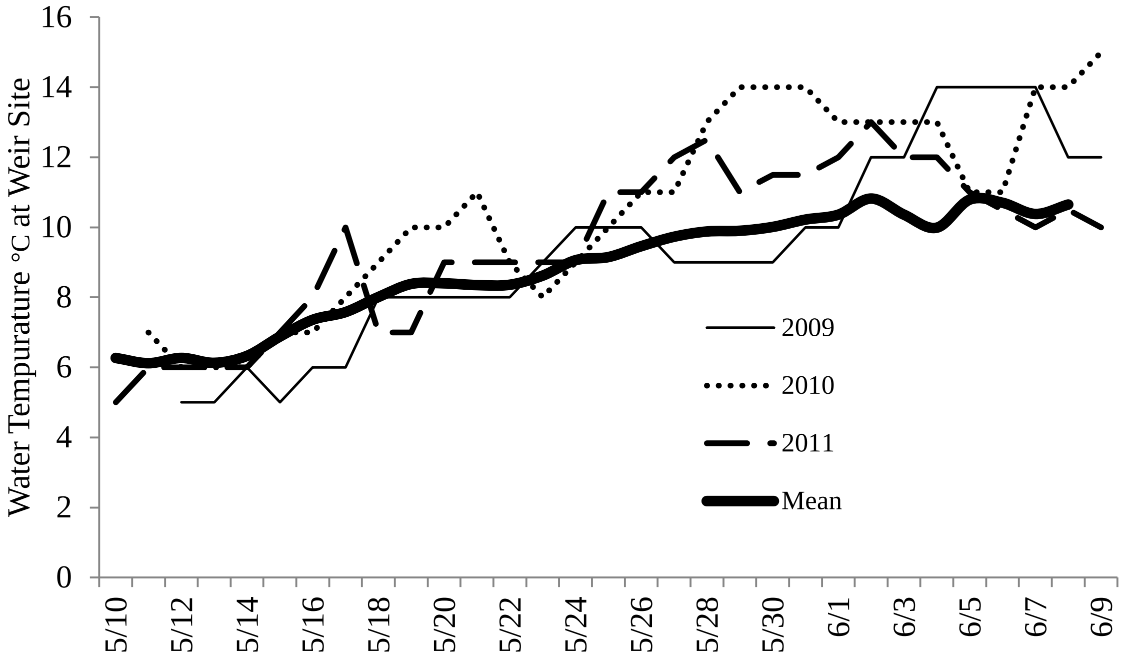


Figure 7.–(a) Comparison of recapture rate of PIT tagged steelhead kelts, lagged two years (represented as bars), and steelhead kelt abundance (line); and (b) association of recapture rate and kelt abundance as evaluated through linear regression.

(a)



(b)

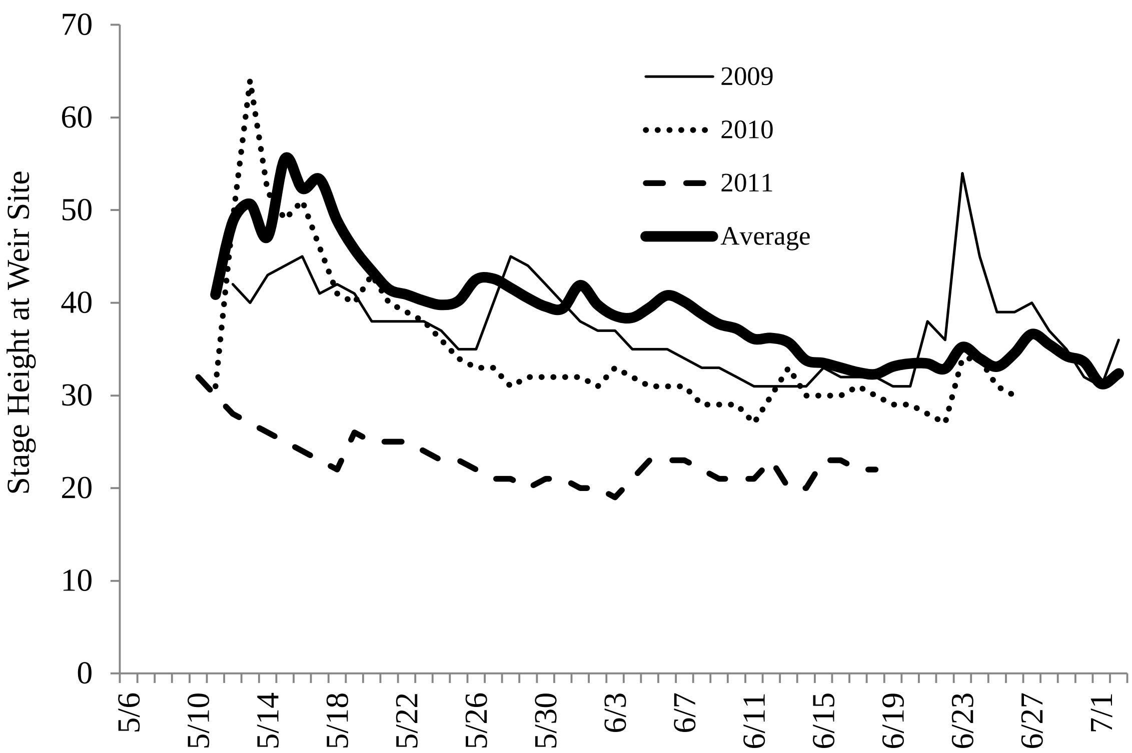


Figure 8.–River temperature (a) and river stage height (b) observed during steelhead kelt emigration at the Situk River steelhead weir, 2009–2011.

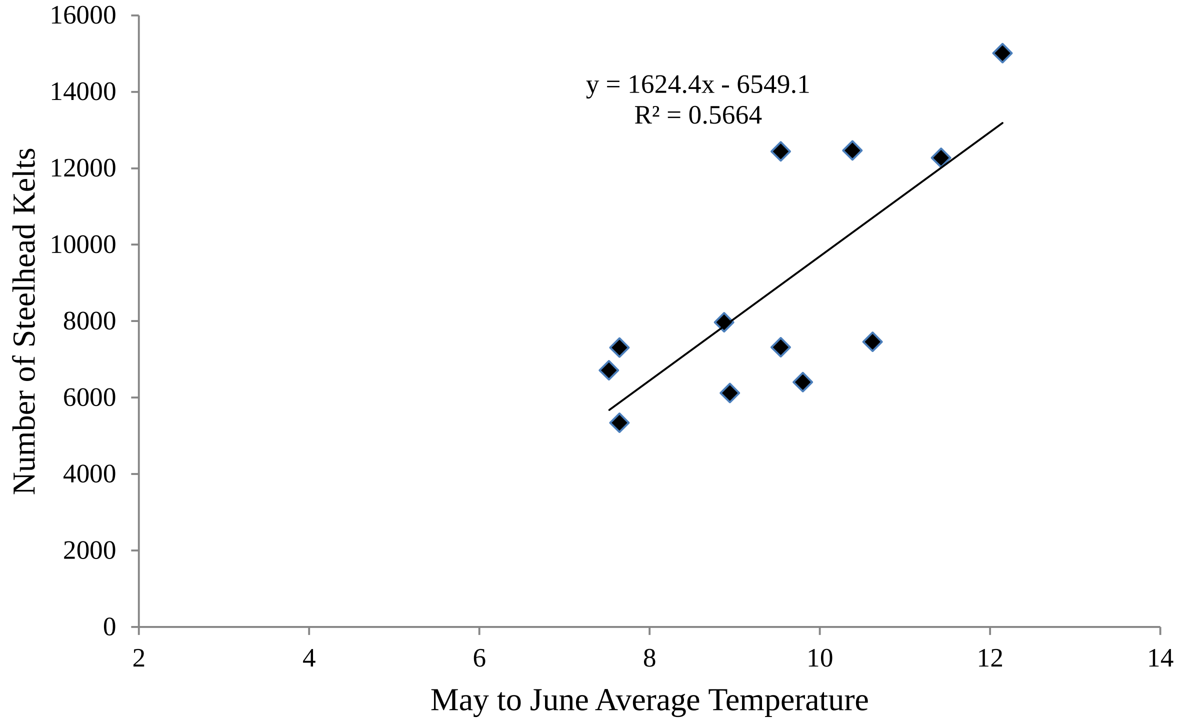


Figure 9.–Association of river temperature in spring (May–June) and steelhead kelt counts the following year 1999–2011 as evaluated through linear regression.

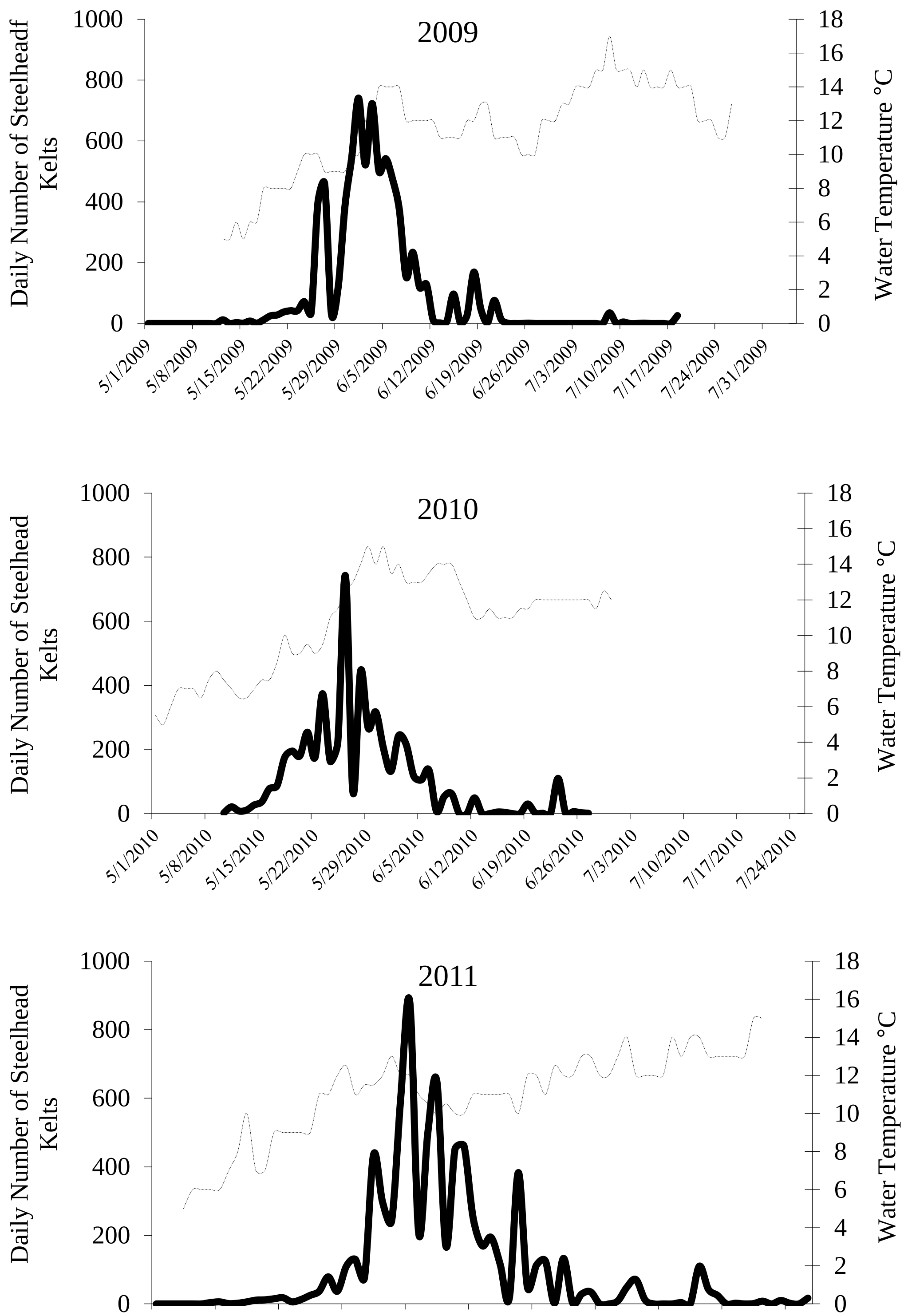


Figure 10.–Daily kelt abundance (bold line) per year (2009–2011) on the Situk River and the daily water temperature °C (stippled line).

DISCUSSION

The abundance of steelhead kelts recorded on the Situk River has varied by almost 66% since 2006 and has historically (since 1988) cycled between periods experiencing very low to very high abundance, most recently reverting back to low abundance. Kelt abundance for the most recent study years (2009–2011) remained low on the Situk River, although 2011 was a slight improvement over the low count of 2010. The year 2010 count was one of the lowest recorded abundances since 1995. Historical estimates of steelhead abundance have been considerably lower than the 2010 kelt count, but assessment method and sites were not consistent prior to 1995. The current low kelt counts do not appear to suggest a conservation concern for the Situk River steelhead as long as future counts continue to cycle upwards above the current levels and do not decrease to approach historically low assessments. Sport fishery use of the Situk River was consistently high since the mid-1990s. Management measures enacted in 1995 that preceded the increases to historically high counts in the mid-2000s appear to be sufficient to maintain the steelhead population as well as the current level of sport fishery use. Regional trends in steelhead abundance appear to be similar to kelt abundance trends on the Situk River (Coyle 2012). The Situk steelhead fishery remains the largest fishery for this species in Alaska. Continued monitoring of Situk River steelhead abundance will help ensure the continuation of this prized steelhead fishery and will continue to help the overall regional understanding of the status of steelhead in the Southeast Alaska region.

Emigration timing for steelhead kelts on the Situk River has varied considerably across the historical records for the drainage, as well as in the most recent study years (Marston et al. 2012). Historically, the mid-point emigration date has ranged from 18 May to 16 June (median date 31 May) (Bain et al. 2003). In general, the 2009–2011 emigrations started late but tended to end at more normal dates (Figure 4). The 2009 run also peaked late, although 2010 peaked early and 2011 peaked at about normal timing. The end dates of 2009 and 2010 were about normal ending around mid-June, but the 2011 emigration timing was extended out into July with two late daily counts of 100 or more fish. Unlike 2009 and 2010, deep and persistent snow conditions in spring 2011 were such that temperatures and river flows were low early in the season and the emigration was delayed. Temperature has been shown to affect run timing in past years (Marston et al. 2012). Flow conditions were particularly low in 2011 and no spring pulse of flow occurred (Figure 8), which may have passively slowed some downstream movement of kelts during that year. Emigration timing that is significantly delayed so that a large portion of the kelts are still passing after late June can result in more fish encountering commercial salmon fishing nets. The commercial fisheries in Situk Inlet open the 3rd Sunday in June each year. Consistently late outmigrations could lead to increased incidental interceptions of steelhead in the commercial fishery and depress kelt survival, lowering the overall population of steelhead in the Situk River.

Size attributes of kelts on the Situk River have varied across time, but some of the largest yet recorded have been observed in recent years. The large sizes for both female and male fish in 2009 preceded a very low abundance count in 2010. The length composition (Figure 6) observed in 2009 was extremely skewed in favor of larger sizes, with most fish in the frequency bins greater than 850 mm. The 2010 year showed a quasi-bimodal length frequency that included significant numbers of very small fish (especially females), suggesting recruitment was occurring with smaller and presumably younger fish entering the spawning population for the first time. It also appears the larger fish may not have survived in great number past 2009, because the populations observed in 2010 and 2011 contained relatively few fish over 850 mm. In 2009, 8% of the sampled fish were at or above the trophy size class of 36 inches, which was more than twice the proportions found in subsequent years of 2010 and 2011. Only steelhead >36 inches are subject to legal harvest on the Situk River. The effect of harvest on Situk River steelhead abundance is probably not driving overall abundance, because recorded harvest averaged 21 fish for the decade including these study years. However, the 2009 harvest was slightly above average at 25 fish, whereas 2010 and 2011 were recorded as zero harvest. Additionally, the longer historic data set of lengths that dates back to 1999 showed that abundance and length may have been linked. Years when average total lengths were some of the smallest (2006 and 2007) coincided with high abundance, whereas years with larger fish (2001 and 2009) coincided with years of low abundance counts (Figures 3 and 5; Appendix A1). This relationship could arise after favorable ocean conditions produce high numbers of first-time spawning fish. High numbers of these presumably smaller fish would drive the overall average length of all spawners down, but overall abundance would be high. Conversely, when ocean conditions are less favorable to young fish recruitment, the following conditions are apparent: only larger fish survive and spawn, overall abundance is low, and the average length of spawners is high.

Overall PIT tag return rate remained constant over time on the Situk River. Utilizing these tagged fish, a scale archive has been created, so that scale aging techniques can be verified with known age increment scales from individual fish that have had multiple scales taken across years. This archive is currently under analysis. The total recapture sample increased by 12 to total 77, in the recent study years of 2009 to 2011, while the yearly rate of recapture has remained constant at approximately 11% for the total tags at liberty (Figure 11). This recapture rate has remained constant in spite of the fact that the tag insertion rate (tags inserted per year) has fluctuated greatly. Tags were inserted in fish that were unwounded and of small size because these fish are typically vigorous and can be handled easily. We did not attempt to tag a set percentage, a large proportion of kelts, or a randomized sample. As such the fish available and the number selected for tagging has changed. Our tag return rate is not indicative of the iteroparity rate of the entire population of steelhead in the Situk River, although it is similar to observations in other rivers (Love and Harding 2009). In our study, fine scale changes in the yearly return rate were positively related to the overall abundance of kelts with a 2-year lag (Figure 7). This indicates that changes in abundance are at least partially influenced by the rate of return of the size group of kelts—small size (and without wounds) that we tagged the previous years. Additionally, the association linked to a 2-year lag suggests that successful iteroparous steelhead may skip years between spawning attempts.

Counts of emigrants considered in light of environmental observations during these study years showed that Situk River steelhead were sensitive to water temperature specifics, and temperature may play a role in limiting abundance by increasing kelt survival to the following year. We observed changes across years of both flow and temperature on the Situk River both in the recent study years (2009–2011) and across the historical dataset (1995–2011) (Figure 8). The river condition that steelhead encountered during spawning season, inclusive of run timing, was a dynamic combination of flow (discharge and velocity) and temperature. The steelhead spawning season on the Situk River crosses from fall (immigration of river maturing fish) to spring the following year (immigration of ocean-maturing fish, spawning, and emigration of all fish), and as such, weather variations of 3 seasons across years can influence yearly spawning conditions. The iteroparous aspect of steelhead life history can also further complicate matters with across-year interactions of fish abundance and river conditions. Utilizing temperature records from the USGS recording station at midriver, we have observed that kelt abundance was positively associated with warmer river temperatures during 2009–2011, as seen in other years (Marston et al. 2012). Cold spring river conditions were typically followed by lower kelt counts the following year. Additionally, as with past years (Marston et al. 2012), we have observed that the onset of kelt emigration is linked to temperatures that exceed 6°C. Daily kelt passage tended to be low until the river temperatures surpassed 6°C (Figure 10). These observations suggest that in the Situk River, temperatures may have triggered movements and/or limited abundance of fish in some circumstances. These realities may be why, even though resident forms of *O. mykiss* exist well north of Southeast Alaska, anadromous steelhead populations north of Southeast Alaska are rare. Water temperatures in rivers much farther north, beyond the climates of the Southeast Alaska panhandle, may be too cold, unable to consistently support the anadromous life history triggers or physical requirements of steelhead. *O. mykiss* populations at the southern end of its range in California could be limited by a similar mechanism, although in that geography warm temperatures or high altitudes may be the limiting factor(s).

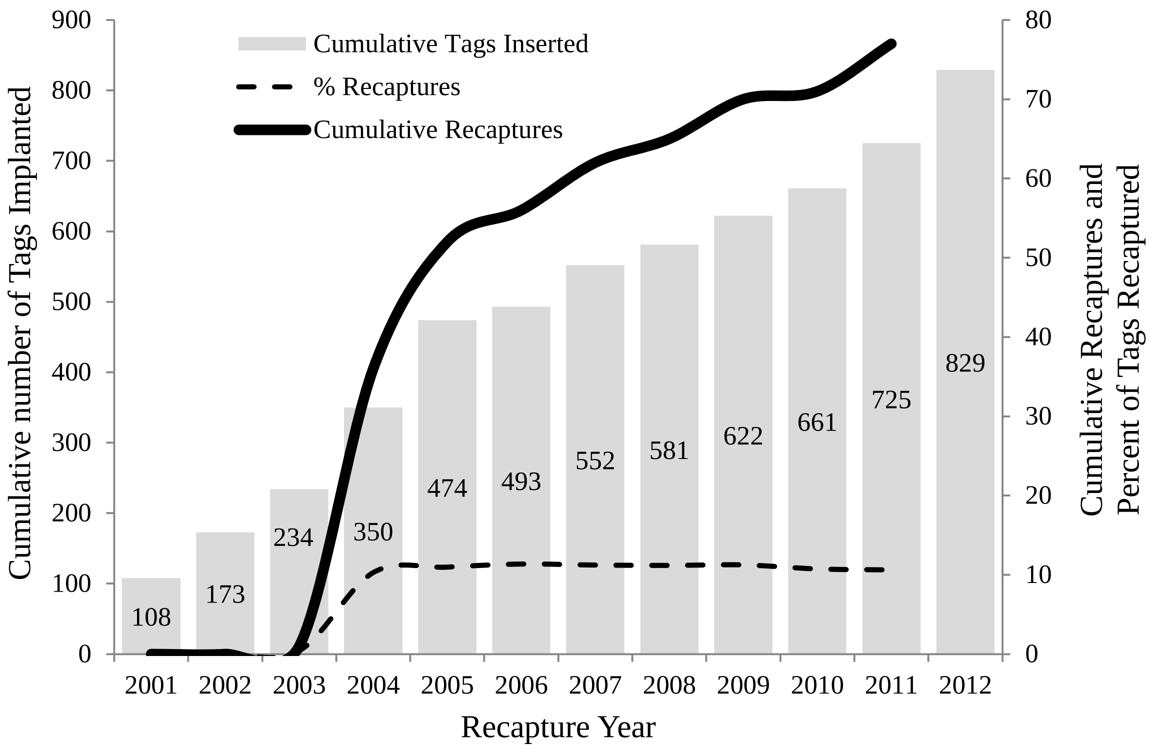


Figure 11.–Number of PIT tags inserted into steelhead kelts and numbers recaptured in the Situk River 2001–2011.

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APPENDIX A

Appendix A1.–Historic data for length samples from the Situk River steelhead weir, 1999-2011.

	Preceding decade years										Current study years			2009–2011	1999–2008	All years
Sex	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	average	average	mean
								Count (*n*)								
F	443	462	390	413	489	520	337	648	238	117	148	120	133	134	406	343
M	254	195	242	232	267	237	137	413	85	47	87	97	86	90	211	183
All	697	657	632	645	756	757	474	1061	323	164	235	217	219	224	617	526
								Average of Total Length								
F	792	773	811	807	767	780	697	745	745	777	825	749	760	778	769	771
M	798	749	826	774	722	774	667	760	762	761	821	754	755	776	759	763
All	794	766	817	795	751	778	688	751	751	772	823	751	758	778	766	769
								Standard error								
F	2.6	3.1	3.1	3.4	3.2	3.0	2.2	2.7	4.3	5.6	5.4	8.0	5.4	6.2	3.3	4.0
M	4.5	6.4	5.6	5.7	5.5	5.6	4.3	4.4	10.5	12.3	8.5	8.8	8.9	8.7	6.5	7.0
All	2.3	2.9	2.9	3.1	2.9	2.7	2.1	2.4	4.2	5.4	4.6	5.9	4.8	5.1	3.1	3.6
								Standard deviation								
F	55.8	66.6	61.0	69.5	69.9	67.8	41.3	69.8	65.8	61.1	65.2	87.1	62.0	71.4	62.9	64.8
M	71.2	89.2	87.2	87.5	90.5	86.8	50.4	90.4	97.2	84.2	79.1	87.3	82.5	83.0	83.5	83.4
All	61.9	74.8	72.4	78.0	80.6	74.3	46.1	78.9	75.4	68.7	70.5	87.1	70.6	76.1	71.1	72.3

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Sex	Preceding decade years										Current study years			2009–2011 average	1999–2008 average	All years mean
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011			
								Maximum								
F	965	935	995	1020	950	945	945	925	990	885	960	920	900	926.7	955.5	948.8
M	945	950	1060	1010	1100	1020	770	945	1090	925	960	920	940	940.0	981.5	971.9
All	965	950	1060	1020	1100	1020	945	945	1090	925	960	920	940	940.0	1002.0	987.7
								Minimum								
F	640	520	615	610	550	570	520	510	550	600	600	450	600	550.0	568.5	564.2
M	575	380	420	575	400	470	420	530	520	585	600	590	610	600.0	487.5	513.5
All	575	380	420	575	400	470	420	510	520	585	600	450	600	550.0	485.5	500.4

APPENDIX B

Appendix B1.–PIT tag data from the Situk steelhead weir 2001–2011.

Year	Tags implanted	Cumulative tags at liberty	Recaptured tags	Cumulative Recaptures	Recapture Rate (%)	Kelt Abundance
2001	108	108	0	0	Na	6,400
2002	65	173	0	0	0.00	6,113
2003	61	234	1	1	0.43	7,964
2004	116	350	35	36	10.29	12,462
2005	124	474	16	52	10.97	12,265
2006	19	493	4	56	11.36	15,003
2007	59	552	6	62	11.23	12,438
2008	29	581	3	65	11.19	7,312
2009	41	622	5	70	11.25	7,302
2010	39	661	1	71	10.74	5,335
2011	64	725	6	77	10.62	7,458
Average	66	—	—	—	10.96 [a]	—

[a] Average recapture rate was calculated from 2004 to 2011 due to changes of recapture techniques prior to that date.

APPENDIX C

Appendix C1.–Data files for steelhead sampling at the Situk River weir, 2009–2011.

Data file[a]	Description
A Paper figs FDS 09-11 Situk Steelhead.xlsx	Compilation of figures in Excel
A situk 9 mile temp 99-11 kelt abundance test.xlsx	Temperature and kelt abundance tests
A Situk steelhead data 2002-2008 length data.xls	Steelhead length data 2002–2008
A Steelhead ASL historic 99-2011.xlsx	Steelhead length data archive
A Steelhead SexLength COMP 2009-2011.xlsx	2009–2011 steelhead length analysis
A Steelhead SRWeir2009-2011 and history.xlsx	Steelhead kelt abundance archive
A Steelhead SRWeir2009-2011-analysis.xlsx	Steelhead abundance analysis
A weirtemps - 88 - 2011.xlsx	Temperature archive for Situk river

[a] Data files were archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, 1 Fish and Game Plaza, Yakutat, AK 99689.