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Assessment of the Performance of a Flat Panel Resistivity Fish Counter at Peterson Creek, 2007 and 2008

by

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and

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December 2012

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

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

To address the need for a reliable counting method to assess steelhead *Oncorhynchus mykiss* abundance in remote index streams in Southeast Alaska, the Alaska Department of Fish and Game tested a Logie 2100C resistivity fish counter in Peterson Creek to count a small run of spring steelhead in 2007 and 2008. An above-water camera was used during daylight hours to record fish migrating over the white substrate panels to validate the resistivity counts. The video was also used to obtain fish lengths. The resistivity counter classifies signatures as either moving upstream, downstream, or as an event. Video validation revealed highly variable misclassification of fish movement in 2007. During 2007, upstream fish were correctly classified 45.9% of the time, and downstream fish were correctly classified 54.1% of the time. Further, the kelt emigration could not be accurately estimated because only 30% of the upstream fish were accounted for in the downstream count, despite a zero-count snorkel survey at the end of the run. The logarithm of fish length was not correlated with the peak signal size (PSS) of the counter ($r^2 = 0.007$), thus the size of steelhead outside of the video sample could not be estimated. The presumptive problem appeared to be a very low-stream conductivity ($\bar{x}$ = 13.9 µs/cm). A ratio estimator based on the 2007 video validation of number of fish passed to the number of fish detected ($\hat{r} = 2.10$) suggests that less than 50% of the fish passing the counter were detected. An abundance estimate was not generated for steelhead using this ratio because robust estimation of uncertainty was not possible. During the latter half of the 2007 and 2008 field seasons the electrode spacing was reduced in an attempt to amplify the counter signature and improve its function, but this change was not successful. The changes did not improve counter data misclassification so the 2008 data were not analyzed. We do not reccomend a resistivity fish for future use at this site.

Key words: steelhead, resistivity panel, peak signal size, electronic counter, Logie 2100C, Peterson Creek

INTRODUCTION

Panel-type resistivity counters, such as the Logie 2100C[1], have been used successfully to count steelhead *Oncorhynchus mykiss* on the Keogh and Deadman rivers in British Columbia, and more recently on the Harris River on Prince of Wales Island in Southeast Alaska (McCubbing and Ignace 2000; McCubbing et al. 2000; McCubbing 2005). Resistivity counters were thought by the Alaska Department of Fish and Game, Division of Sport Fish (ADF&G DSF) trout research staff to have the potential to be an inexpensive and less intrusive method to census escapement of steelhead in small remote streams throughout Southeast Alaska. Unlike traditional weirs, resistivity counters do not require handling of fish and have minimal potential for restricting or discouraging passage by fish. The counter detects fish passage by measuring a change in the bulk resistance of the water as each fish swims across an array of electrodes that span the stream. Along with recording the time of a signature, the counter can differentiate between upstream and downstream passage, which makes this type of counter particularly attractive for counting iteroparous steelhead. If a stream contains species of fish of markedly different sizes, the counter can also be used to estimate the proportion of each species. However, the counter cannot be used to collect age and sex data.

Bulk resistance is a measure of the ability of the water to resist the flow of electrical current per unit (volume), and is proportional to the resistivity of the water times the volume. Resistivity of water is a function of the solutes dissolved in the water. Distilled water would have a high resistivity as there are very little solutes. Conversely, water conductivity, which is the reciprocal of water resistivity, is a measure of the ability of the water to conduct an electrical current. Therefore, distilled water has low conductivity as there are very little solutes. Solutes, generally ions (salts), come from the underlying geology of streams, and other natural sources such as sea

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

water, run-off, rotting salmon carcasses, or anthropogenic sources such as road run-off, wastewater, or pollution.

Developing a successfully operating resistivity fish counter requires overcoming and managing several logistical challenges and often includes some form of validation such as video (McCubbing and Ignace 2000). In other systems, researchers have needed at least a year to work out site-specific problems associated with newly deployed resistivity counters (D.J.F. McCubbing, Principal Biologist, In Stream Fisheries Research, Inc., Vancouver, personal communication). Problems include: flash flows interfering with counter efficacy due to fluctuating water depth, ice floes, air entrainment, wave action at low water levels, debris accumulation and "partial electrode displacement" (McCubbing and Gray 2004). False counts can also be attributed to beaver, otter, and dog activity (McCubbing and Gray 2004).

OBJECTIVES

The objective of this study was to assess the performance of a flat panel resistivity counter for estimating upstream passage of adult steelhead in Peterson Creek by using video validation. Step one was to install the panels, counter and video equipment to ascertain if the panels would work as described in the literature in a local stream. We expected to refine our methods in future years.

STUDY SITE

Peterson Creek (anadromous stream #111-50-10100), located at mile 25 Glacier Highway on the Juneau road system, contains a small run of steelhead, and serves as an index stream for the ADF&G DSF steelhead snorkel surveys (Harding 2005). Low seasonal flows and good access made Peterson Creek an ideal candidate for testing a resistivity counter for eventual use in remote streams. Peterson Creek is the most important steelhead stream on the Juneau road system (Schwan 1990). From 1989 through 1991 ADF&G DSF operated a weir on the creek to monitor escapement and run timing, and to collect age, sex, and length data on the steelhead immigration. The escapement was 222 in 1989, 179 in 1990, and 215 in 1991 (Harding and Jones 1991).

Peterson Creek drains Peterson Lake and flows for 8 km before it empties into Amalga Harbor from Salt Lake (Figure 1). A barrier falls is located 4 km downstream from the lake, and prevents immigrating steelhead from accessing the upper creek or lake. Steelhead were stocked in the lake several times from 1941 through 1968, and the creek was the source of egg takes for Snettisham Hatchery from 1983 to 1987 (Harding and Jones 1991). The creek was managed from 1961 through 1989 with the belief that stocked rainbow trout rearing in the lake served as a source of recruitment for Peterson Creek steelhead. However, a 1991 mark-recapture study showed that no rainbow trout emigrated that season to contribute to the steelhead production (Harding and Jones 1991). No steelhead have been observed in the winter months, and Peterson Creek steelhead are considered to be ocean-maturing spring-run fish. Resident rainbow trout, cutthroat trout *O. clarkii*, and Dolly Varden *Salvelinus malma* have been documented during snorkel surveys conducted in the creek below the barrier falls where steelhead migrate (Harding 2005).

Three 1.5 m x 3 m resistivity panels were placed across Peterson Creek approximately 10 m downstream of the Glacier Highway bridge at the study site to count steelhead as they migrated upstream from April 19 to June 8, 2007, and from April 7 to June 5, 2008 (Figure 2). We selected a site above saltwater incursion, with moderate flow, and in a reach with a fairly level bottom to accommodate the flat panels. The study site also had stable banks on both sides, and was 10 m wide. Preliminary salinity measurements were 0.000412–0.000448 ppt at 0.2ºC taken on January 5, 2007, on a 5.4 m high tide (i.e., the highest predicted tide in 2007). During 2008, the highest tide was 5.9 m on April 7, 2008, but no change in salinity was detected at the study site. Water is considered to be fresh at salinity levels from 0 to 0.5 ppt, and brackish at levels of salinity from 0.5 to 30 ppt (Venice System 1959). This lower portion of the creek where the panels were placed is classified as a single channel palustrine stream with a moderate-width placid-flow channel (ADF&G 2006). The average gradient on the lower portion of the creek is 0.25% with a 3.0 m incision depth, with an average channel bedwidth of 16.0 m (ADF&G 2006). The dominant substrate is organic with a subdominant sand/silt substrate. The underlying geomorphology is marine greywacke sandstone (Gehrels 2000).

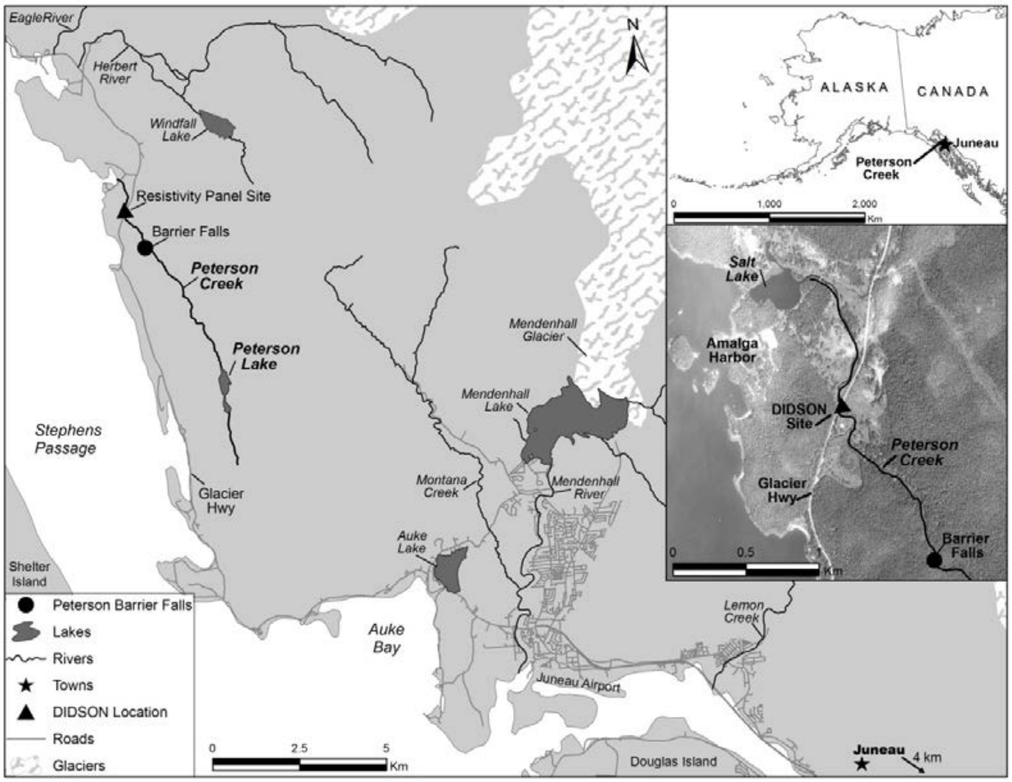


Figure 1.–Location of Peterson Creek resistivity panel study site, mile 25 Glacier Highway, near Juneau, Alaska

METHODS

On April 19, 2007 Don McCubbing, the contractor and owner of the 2100C Logie fish counter (manufactured by Aquantic Ltd.), assisted with the installation of the panels and counter, and trained ADF&G DSF Region I trout research staff to operate the system. This included calibration of the counter with a dummy fish signal, and site-specific peak signal size (PSS) thresholds were determined for Peterson Creek. The threshold at the Peterson Creek study site for both years was set at 10, and the PSS values ranged from 12 to 33. The panels were installed in a small riffle in the middle of the creek with sandbags and bipod weir material extending to both banks to prevent fish passage. The site was monitored daily to ensure that the panels were "fish tight." Snorkel surveys were conducted weekly after May 1 when the panels were fish tight, and before the panels were pulled to assess steelhead presence/absence in the creek.

Figure 2.–Upstream view of a flat panel resistivity counter in Peterson Creek at mile 25 Glacier Highway, Juneau. Fish swim over the panels which contain three electrodes. Fish are less resistive than water, and as a fish passes above the electrodes the change in bulk resistance is detected and recorded by the counter.

We used the identical equipment and configuration that Instream Fisheries used at the Harris River (McCubbing 2005), and followed methods outlined in the Logie 2100C Operating Manual (McCubbing and Gray 2004). The installation consists of resistivity panels, a Logie 2100C counter and overhead camera with a DVR. The resistivity panels consisted of aluminum frames fitted with white high density polyethylene insulating sleeves housing three stainless steel electrodes connected to the electronic counter via a waterproof cable. Initially, the standard 35 cm electrode spacing was used, but reduced it to 20 cm as recommended by our consultant from June 6 to 18, 2007, and during the 2008 field season (Figure 3) due to low measured conductivities. Fish are less resistive than water, and as a fish passes above the electrodes the change in bulk resistance is detected and recorded by the counter. The 24 V DC, 55.2 W Logie 2100C counter recorded the time, direction of travel, and PSS, storing this information on a portable laptop computer. Gain settings ranged between 100 and 400 depending on the water level. Data stored in buffer files were downloaded daily by field staff who visited the site at least one time per day, taken to the Douglas office, and copied onto a network drive. The buffer files contained the date of the download, the counter settings, dummy fish data, and fish records. Graphical records of the PSS (also called traces elsewhere in the literature) were also captured and downloaded, which were used to assess fish behavior and analyze variants of PSS above threshold values determined to be steelhead (Figures 4–6). Files were also stored on external hard drives for back up.

An above-water 12 V DC, 1.8 W Micro Video™ Products black and white video camera was also installed at this site to validate the counts of steelhead on the resistivity counter during daylight hours. The camera had an 80 degree field of view, and was placed above the panels on a pole looking down and adjusted to cover the entire length and width of the panels. The white panels increased the visibility of fish as they migrated upstream. As the power supply was limited, we did not wish to film at night with lights. The daylight validation was assumed to allow for night time validation of the counter as well, as we assumed that steelhead signatures during the evening were similar to those during the day, albeit the frequency could vary. All fish crossing the panels were to be counted, and those traveling during light hours were verified via video. The video was downloaded continuously onto a Capture™ DVD recorder with a closed

Electrode spacing

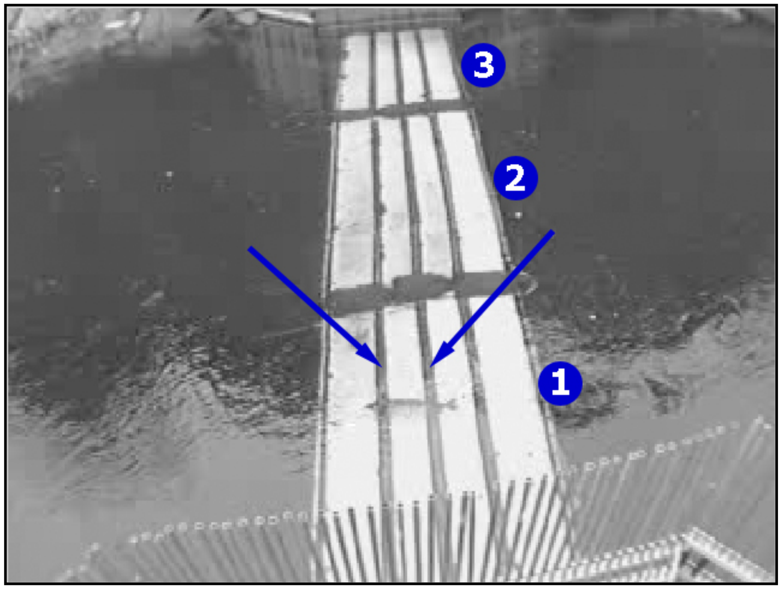
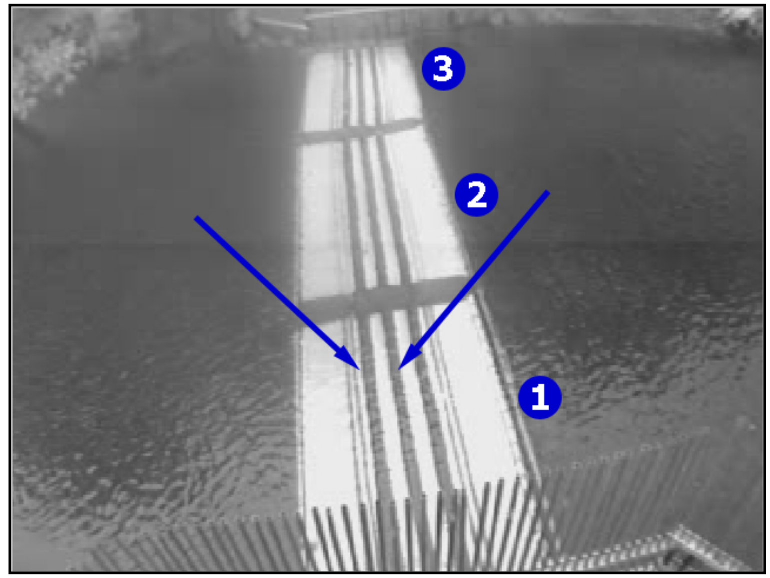
4/23/2007– 6/7/2007	6/8/2007–6/18/2007 and 4/8/2008–6/6/2008
	
35-cm electrode spacing	20 cm electrode spacing

Figure 3.–Electrode spacing on resistivity panels in Peterson Creek at mile 25 Glacier Highway, Juneau from April 23, 2007, through June 7, 2007, a standard 35 cm electrode spacing was used. From June 8, 2007, to June 18, 2007, and during the 2008 field season (4/8/2008–6/6/2008), a reduced electrode spacing of 20 cm was used in an attempt to amplify the PSS. The panels correspond to the electrical channels on the Logie 2100C counter, and were numbered from the north side of the creek (where the camera was located) across the creek as panel (channel) 1, panel (channel) 2 and panel (channel) 3. In the photos flow moves from left to right (the fish in the 35 cm electrode photo is moving upstream).

circuit television monitor. During 2007 a 110 V AC, 230 W Model CPT-SDR410 Capture™ DVD recorder was used, and during 2008 a 12 V DC, 81.6 W Model CPT-MDR400 DVD recorder[2] with hot-swappable drives was used. Data files were downloaded onto a 110 V AC, 230 W Toshiba Tecra 8000. During 2007, power for both systems was provided by a Global Thermoelectric 5120 thermoelectric generator with a 452 amp battery bank. During 2008, power was provided by an EFOY 1600 methanol fuel cell, which powered a 900 amp battery bank. All equipment was housed in a locked aluminum waterproof truck box contained within a locked chain link dog kennel camouflaged with tarps to hide it from sight and protect the equipment from vandals, bears, and weather.

Approximate salinity was measured daily to the nearest 0.5 microSiemens/cm (μS/cm) and specific conductivity (EC) to the nearest μS/cm with a YSI Model 30 SCT conductivity meter. Daily measurements of stream temperature to the nearest 0.5ºC were also recorded. Water flow to the nearest L/s, and depth to the nearest cm were monitored and recorded with an Odyssey™ electronic stream gauge monitored by the United States Forest Service Forestry Sciences Laboratory staff. Water turbidity was measured and recorded daily with an Oakton T-100 Waterproof Turbidity meter, and water color was monitored in 2008 with a LaMotte TC-3000e Waterproof Turbidity meter. During 2008, the pH was measured with a Hannah pHEP5-N pH pen. Precipitation was measured daily with a rain gauge, and recorded along with the weather conditions. The area was scrutinized for signs of beavers, otters and dogs, and their presence/absence was recorded. As the study site was on the Juneau road system, signage was posted describing the project and asking people not to disturb the area.

Buffer files were downloaded from the laptop daily. Each fish record contained the time of fish passage, water conductivity, panel of fish passage, direction of travel (upstream versus downstream) and PSS in a tabular format (Figure 7).

DATA ANALYSIS

How the Counter Works

The data stream for the resistivity panels begins as a fish moves across and perpendicular to the three electrodes on the panel (which extend across all three panels in parallel) (Figure 3). Fish are less resistive than water, resulting in the change in bulk resistance, which is detected and analyzed by the counter using an internal algorithm. If the signature (also called trace) fits a fish pattern, the signature is recorded as a fish by the counter. Fish moving upstream are recorded as a U (Figure 4), fish moving downstream are recorded as a D (Figure 5), and changes that do not fit the fish signature pattern are recorded as an E, or event (Figure 6). The Logie 2100C puts out two kinds of data files. The counter downloads raw count data in a buffer file that lists the date, time, classification of the signature (U, D, or E), panel number, and the PSS (Figure 7). The PSS is the maximum change in bulk resistance, and is proportional to the size of the fish. The counter also outputs graphics files that display the signature or trace from which the "event" was derived. These files graphically show the PSS. This allows the operator to: 1) check the PSS against the raw data file and video footage for concurrence; and 2) use the PSS with the video footage to estimate lengths of the fish. All paired streams of video and counter data collected were screened for concurrence.

[2] This and subsequent product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

Signature Recognition and Analysis

Concurrent video and raw counter data were scrutinized visually, and all obvious spurious signatures made by debris, wave action, or ghosting (shadow of one signature on another panel) were removed from the raw counter data set.

Any signatures recorded with a signature amplitude slightly below the threshold value for fish were viewed, validated with the associated video footage, and changed as needed in the data set postseason. Total counter efficiency was calculated per the Logie 2100C resistivity counter manual (McCubbing and Gray 2004):

$$Ce = Tv/Tc \times 100 \tag{1}$$

where:

Tv = the total count of fish from the video, and

Tc = the total fish counted on the counter.

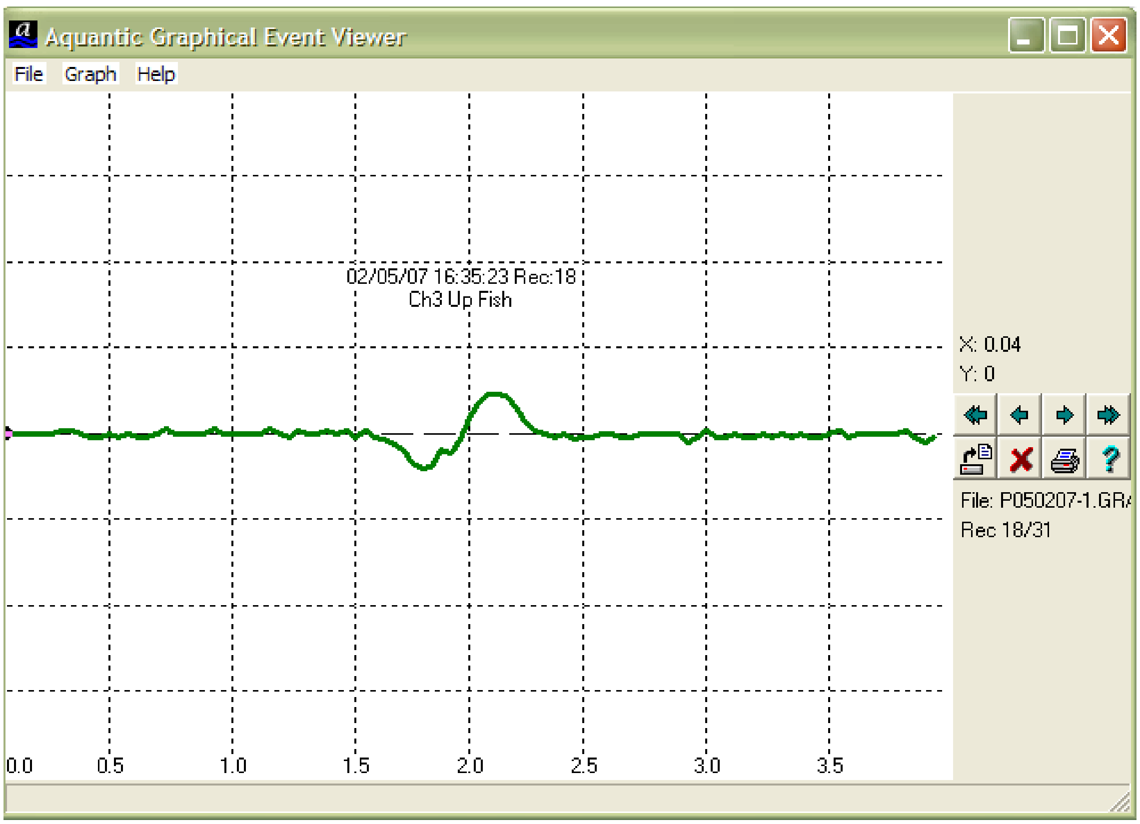


Figure 4.–Example of a typical signature of an upstream fish as viewed in the Aquantic Graphical Event viewer at Peterson Creek, mile 25 Glacier Highway Juneau. The direction of travel of the fish is indicated by the signature (trace): the crest of the resulting sinusoidal curve indicates the side from which the fish crosses the panel. Fish moving upstream cross the downstream side of the panel first, therefore the crest is on the right side of the signature and the trough is on the left side. The PSS is the maximum amplitude of the signature from minimum sinus to maximum sinus, and is generally positively correlated to the size of the fish. This fish moved upstream over panel (channel) 3 on May 2, 2007, at 1635.

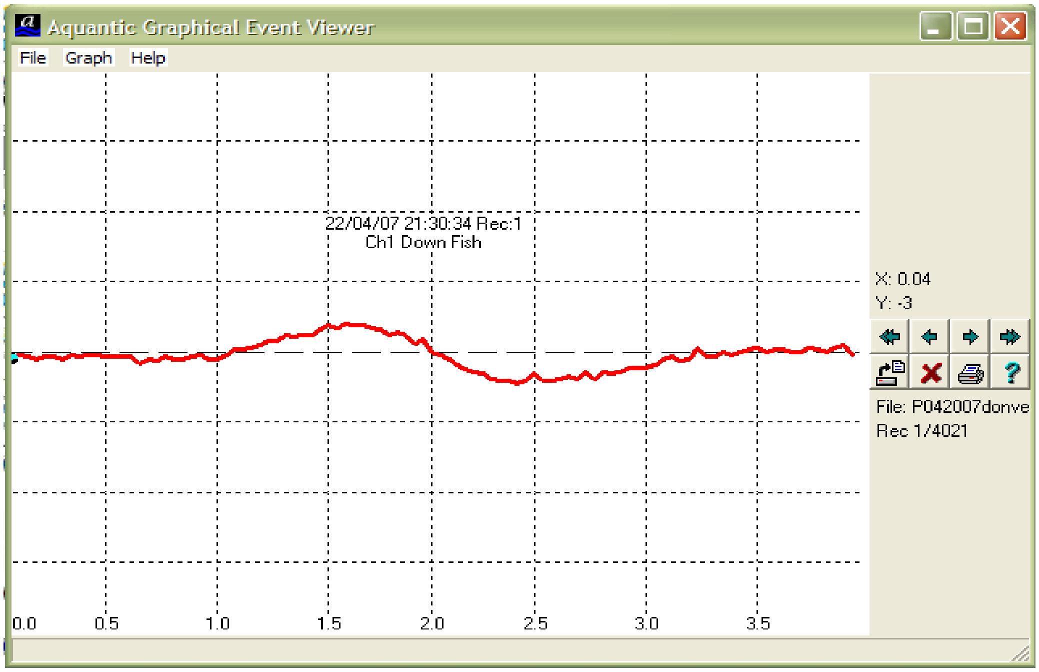


Figure 5.–Example of a typical signature of a downstream fish as viewed in the Aquantic Graphical Event viewer at Peterson Creek, mile 25 Glacier Highway, Juneau. The direction of travel of the fish is indicated by the signature (trace): the crest of the resulting sinusoidal curve indicates the side from which the fish crosses the panel. Fish moving downstream cross the upstream side of the panel first, therefore the crest is on the left side of the signature, and the trough is on the right side. The PSS is the maximum amplitude of the signature, and is generally positively correlated to the size of the fish. This fish moved downstream over panel (channel) 1 on April 22, 2007, at 2130.

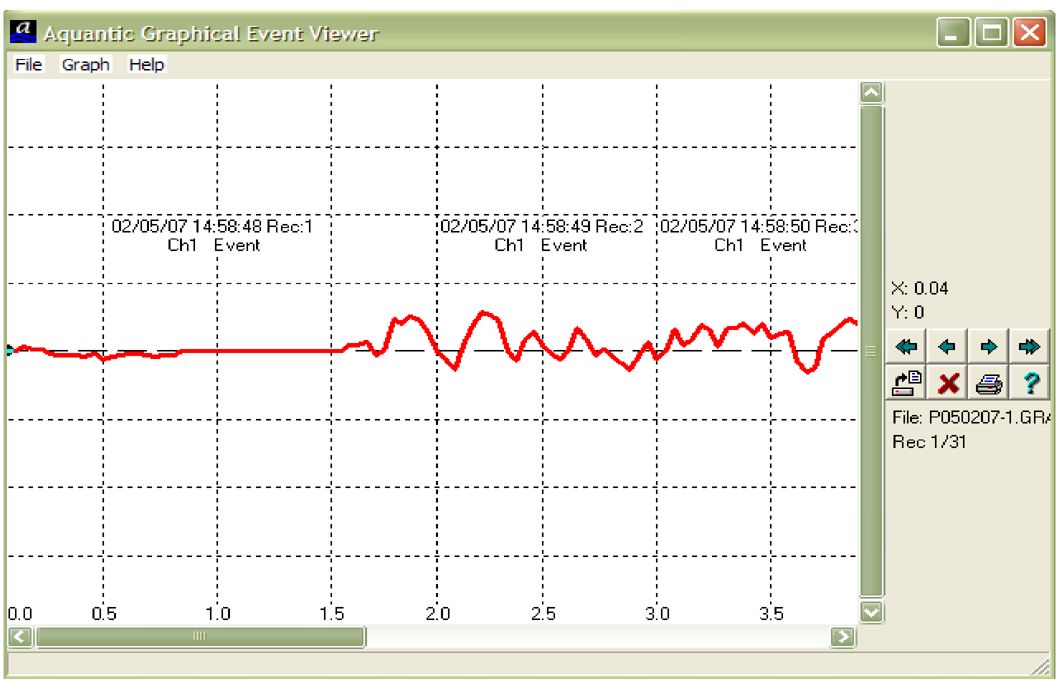
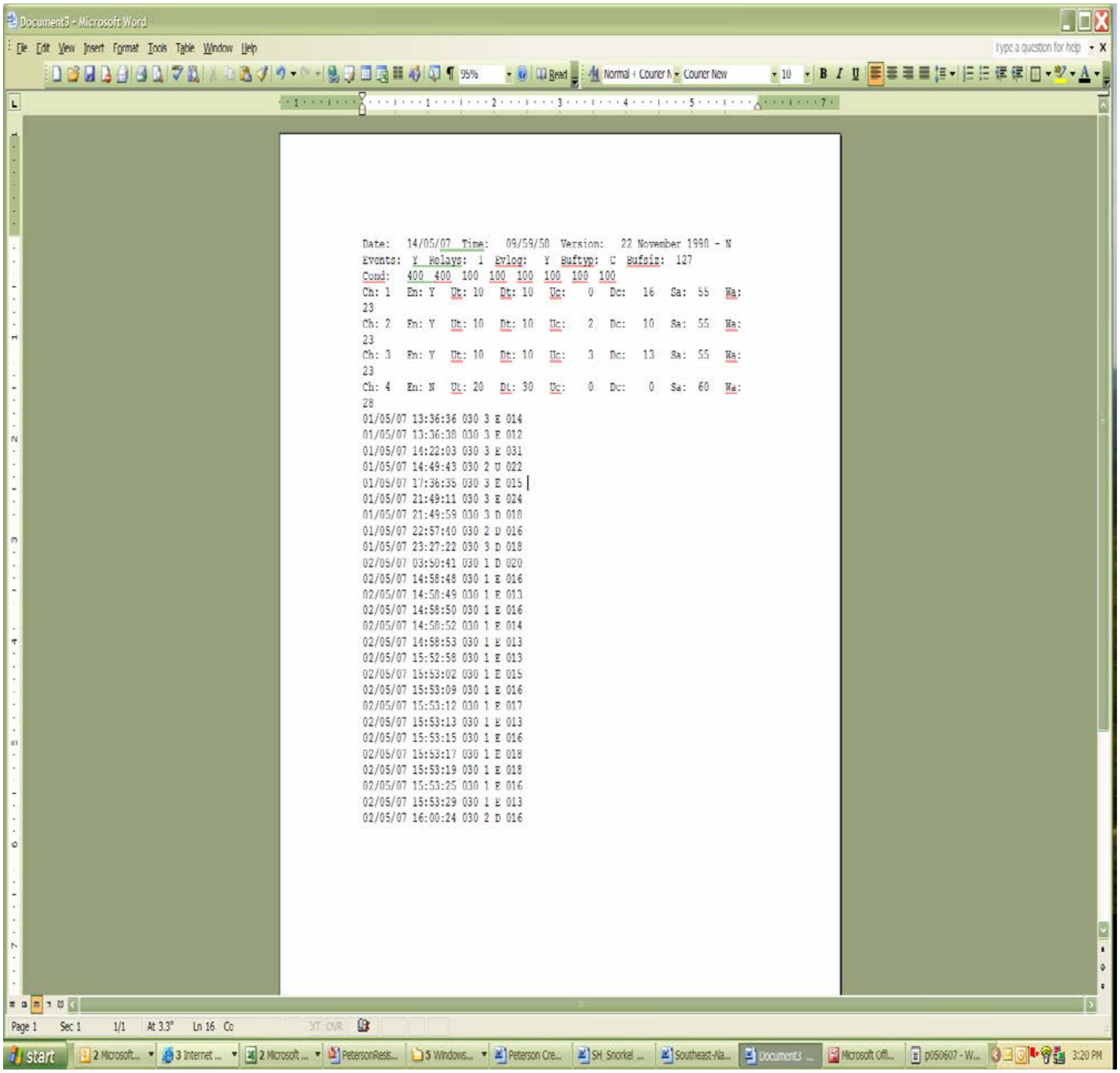


Figure 6.–Typical "events" as viewed in the Aquantic Graphical Signal Event view at Peterson Creek, mile 25 Glacier Highway, Juneau. This represents a disturbance to the resistivity of the water over the resistivity panels.



```
Date:   14/05/07  Time:   09/59/58  Version:   22 November 1998 - N
Events:  Y  Relays:  1  Evlog:   Y  Buftyp:  C  Bufsiz:  127
Cond:   400  400  100  100  100  100  100  100
Ch: 1   En: Y   Ut: 10   Dt: 10   Uc:    0   Dc:   16   Sa:  55   Wa:
23
Ch: 2   En: Y   Ut: 10   Dt: 10   Uc:    2   Dc:   10   Sa:  55   Wa:
23
Ch: 3   En: Y   Ut: 10   Dt: 10   Uc:    3   Dc:   13   Sa:  55   Wa:
23
Ch: 4   En: N   Ut: 20   Dt: 30   Uc:    0   Dc:    0   Sa:  60   Wa:
28
01/05/07 13:36:36 030 3 E 014
01/05/07 13:36:38 030 3 E 012
01/05/07 14:22:03 030 3 E 031
01/05/07 14:49:43 030 2 U 022
01/05/07 17:36:35 030 3 E 015
01/05/07 21:49:11 030 3 E 024
01/05/07 21:49:59 030 3 D 018
01/05/07 22:57:40 030 2 D 016
01/05/07 23:27:22 030 3 D 018
02/05/07 03:50:41 030 1 D 020
02/05/07 14:58:48 030 1 E 016
02/05/07 14:58:49 030 1 E 013
02/05/07 14:58:50 030 1 E 016
02/05/07 14:58:52 030 1 E 014
02/05/07 14:58:53 030 1 E 013
02/05/07 15:52:58 030 1 E 013
02/05/07 15:53:02 030 1 E 015
02/05/07 15:53:09 030 1 E 016
02/05/07 15:53:12 030 1 E 017
02/05/07 15:53:13 030 1 E 013
02/05/07 15:53:15 030 1 E 016
02/05/07 15:53:17 030 1 E 018
02/05/07 15:53:19 030 1 E 018
02/05/07 15:53:25 030 1 E 016
02/05/07 15:53:29 030 1 E 013
02/05/07 16:00:24 030 2 D 016
```

Figure 7.–Download of a typical buffer file from the Logie 2100C resistivity counter in Peterson Creek at mile 25 Glacier Highway, Juneau. The buffer files contained the date of the download, the counter settings, dummy fish data, and fish records. Each fish record contained the time of fish passage, water conductivity (not connected), panel of fish passage, direction of travel (upstream vs. downstream) and the PSS in a tabular format.

Errors were coded (Table 1), summarized and calculated as percentage of total error per the Logie 2100C resistivity counter manual (McCubbing and Gray 2004). From these errors the percent correct was calculated as:

$$\%c = n_c/n_t \times 100 \qquad (2)$$

where:

n_c = number of correctly classified signatures, and

n_t = total number of counting signatures.

Fish Length Verification and Steelhead Identification

Fish lengths were collected on all fish passing over the panels from the video images. We expected to have a bimodal split of length frequencies of trout (rainbow trout, cutthroat trout, and Dolly Varden) versus steelhead; steelhead were considered to be those trout migrating upstream that were larger than 22 in (56 cm) TL per the ADF&G DSF regulatory definition of a steelhead trout (5 AAC 75.220 (A) (B)). Of 17,912 steelhead lengths collected from various streams in Southeast Alaska from 1989 to 2006, 24 fish were less than 22 in (0.13%) (Harding et al. 2009). During the 1989–1991 weir operations at Peterson Creek, none of the steelhead measured were less than 25 in (64 cm) (Harding and Jones 1990–1992). We had no data on trout length in Peterson Creek, but the maximum length of rainbow trout measured in Sitkoh Creek from 2004 to 2006 was 18.8 in (48 cm, n = 82), indicating that little overlap between the length frequency modes of trout and steelhead should exist (D. Love, fisheries biologist, ADF&G, unpublished data located at S:\Trout\SITKOH\Sitkoh_08\05to06 FDS Report Files\FINAL files for 0506FDS, accessed 2011). Therefore, fish estimated to be <50 cm from video images were considered to be trout, and fish estimated to be ≥50 cm from video images were classified as steelhead (this number includes a 10% rounding error).

Table 1.–Codes used to cross check resistivity files with video footage. Only those codes in bold are correctly classified. The other codes are mistakes that the resistivity counter made when the counts were compared to the video footage.

Code	Identification
UU	**Upstream fish recorded as an upstream fish**
UE	Upstream fish recorded as an event (missed upstream fish)
U2U	2 upstream fish recorded as 1 upstream fish
U4U	4 upstream fish recorded as 1 upstream fish
U7U	7 upstream fish recorded as 1 upstream fish
EE	**Event recorded as an event**
EU	Event recorded as an upstream fish (false upstream count)
ED	Event recorded as a downstream fish (false downstream count)
DD	**Downstream fish recorded as a downstream fish**
DE	Downstream fish recorded as an event (missed downstream count)
OU	Otter counted as an upstream fish

To determine the fish species and size, signatures from the counter during daylight hours with video validation were examined (Figure 8). By measuring the relative size of fish on the video screen in proportion to the width of the panel on the screen, and knowing the actual size of the width of the panel, the fish length could be estimated as a relative proportion of the known panel width:

$$\hat{F} = (f)(P)/p \qquad (3)$$

where:

$\hat{F}$ = estimated length of the fish,

f = fish length on the video screen,

P = known width of the actual panel (fixed, actual width = 1.524 m), and

p = width of the panel on the video screen (changes with position on panel, day, frame, etc).

PSS is proportional to the water that a fish displaces and therefore proportional to the size of the fish crossing the counter. PSS is based on fish mass, and the relationship between fish mass and fish length is known to be logarithmic. Video validation yielded daytime fish lengths. Therefore log-linear regression was used to estimate the length frequency of steelhead in the system during dark hours based on their PSS. McCubbing (Principal Biologist, In Stream Fisheries Research, Inc., Vancouver, personal communication) has used triangulation of fish with underwater videos, but finds this overhead video method useful to separate steelhead from rainbow trout. Steelhead and rainbow trout from Deadman Creek, British Columbia were separated by PSS over a four-year study despite a variety of environmental conditions (McCubbing and Ignace 2000).

Detection of Steelhead

Spawning escapement would be estimated as the sum of daily estimates:

$$\hat{E} = c \times \hat{r} \tag{4}$$

with variance estimated:

$$\hat{\mathrm{var}}(\hat{E}) = \sum_{i=1}^{n} \hat{\mathrm{var}}(\hat{E}_i) = \sum_{i=1}^{n} c_i^2 \, \hat{\mathrm{var}}_{pred}(\hat{r}) \tag{5}$$

where:

$\hat{E}_i$ = estimated escapement of steelhead on day i (i = 1 to n),

n = number of days of resistivity counter counts over the spawning season,

c_i = total counter estimate of fish over 50 cm on day i, and

$\hat{r}$ = estimated ratio of steelhead passage to resistivity counter counts from video validation.

The ratio was estimated (Cochran 1977) using the following equations:

$$\hat{r} = \frac{\sum_{d=1}^{D_v} c_{(v)d}}{\sum_{d=1}^{D_v} c_{(w)d}} \tag{6}$$

and

$$\hat{\mathrm{var}}(\hat{r}) = \frac{D_v}{\left(\sum_{d=1}^{D_v} c_{(w)d}\right)^2} \frac{\sum_{d=1}^{D_v} c_{(v)d}^2 - 2\hat{r}\sum_{d=1}^{D_v} c_{(v)d}c_{(w)d} + \hat{r}^2 \sum_{d=1}^{D_v} c_{(w)d}^2}{D_v - 1} \tag{7}$$

where:

D_v = the total number of days video validation was conducted,

$c_{(v)d}$ = the daily $(d\,; d = 1$ to $D_v)$ upstream video count of steelhead during daylight hours, and

$c_{(w)d}$ = the daily resistivity count during the hours corresponding to $c_{(v)d}$.

An approximation of the variance of daily observed values of r was calculated:

$$\hat{\text{var}}_{pred}(\hat{r}) = (1 + D_v)\,\hat{\text{var}}(\hat{r}) \tag{8}$$

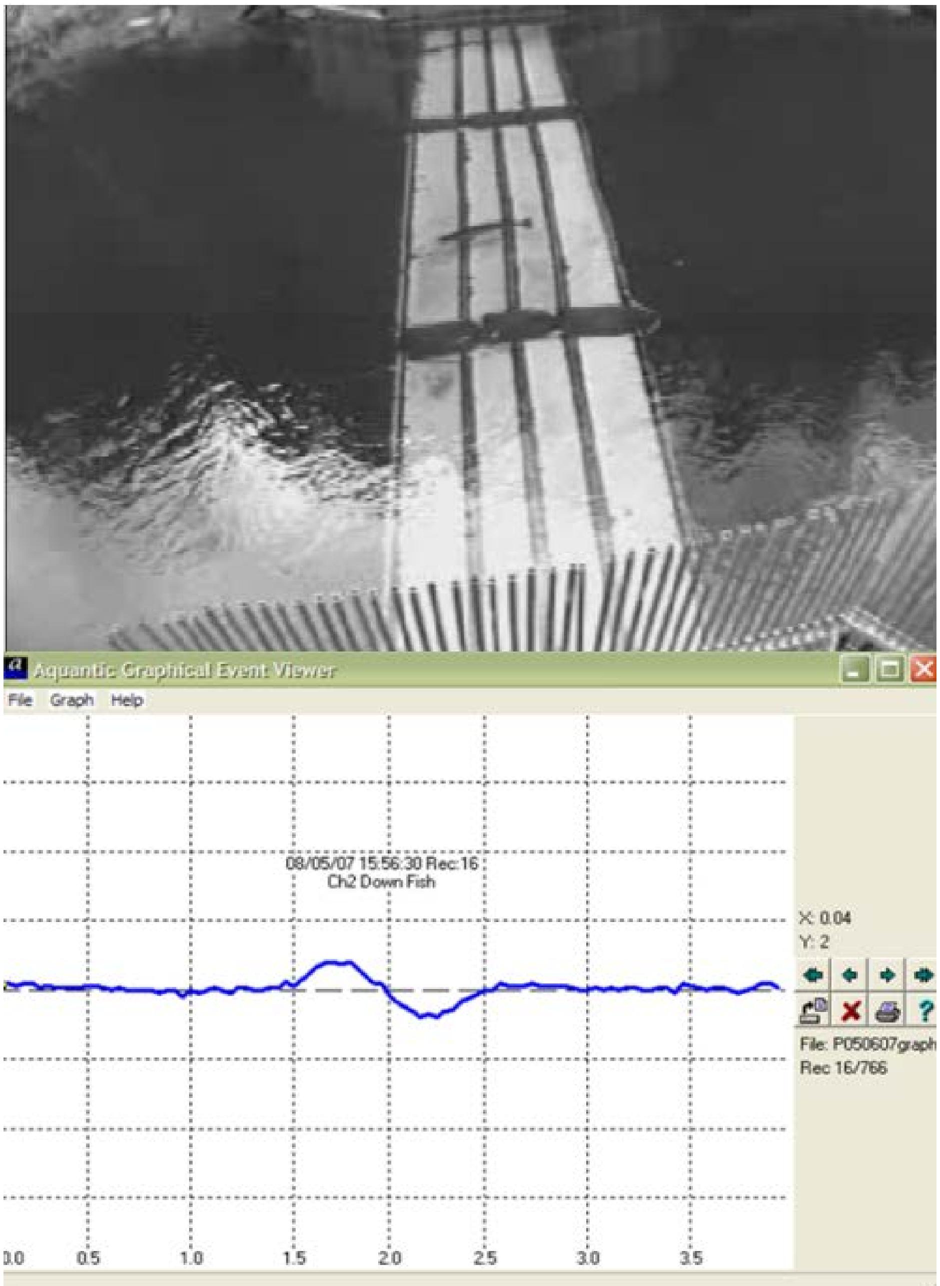


Figure 8.–Video image of a fish backing downstream (top photo) with its corresponding signature displayed below. Video image and graphics record from May 8, 2007 at 1556.

RESULTS

Count and PSS files created by the resistivity fish counter were continuously collected from April 21 to June 7. There were multiple equipment failures related to the power system. The panels were also video recorded with an overhead camera from May 1 to June 7 to validate the resistivity count. The first fish recorded migrating over the panels was an upstream fish at 2117 hours on April 21. A snorkel survey was conducted from just below the barrier falls to the resistivity panels on April 25 and zero adult steelhead were observed. DSF area management staff conducted additional snorkel surveys from May 1 to May 24 (Table 2). DSF research staff conducted a final snorkel survey on June 22 before removing the resistivity panels, and counted zero steelhead above the panel site. We were therefore confident the panels were in for the entire adult steelhead migration.

Table 2.–Snorkel survey counts at Peterson Creek, mile 25 Glacier Highway, Juneau, Alaska, 2007 and 2008.

2007		2008	
Date	Number of steelhead counted	Date	Number of steelhead counted
4/25	0	4/11	0
5/1	5	5/2	1
5/7	2	5/9	6
5/11	7	5/14	13
5/14	16	5/23	26
5/15	24	5/30	17
5/18	26	6/5	2
5/24	17		
6/22	0		

From April 21 to June 6, 28 days of video were collected and from June 8 through 17, and additional 7 days of video were collected for approximately 11 hours per day (Table 3). The two different periods represent the different electrode spacings (35 cm and 20 cm, respectively). For both the 35 cm and 20 cm electrode spacing the counter efficiency using equation 2 was 140.0%, indicating that the counter undercounted fish crossing the panels by 60.0%.

Video validation revealed highly variable misclassification of fish moving both upstream and downstream (Table 3). The three code classifications for correct count comparisons were: EE, UU and DD (Tables 1 and 3). The first initial of the code represents the video classification, and the second initial of the code represents the resistivity counter classification. EE is an event validated by video as an event, and also recorded by the resistivity counter as an event. UU and DD were similarly categorized as upstream or downstream steelhead validated by video, and also counted by the counter as single upstream/downstream moving steelhead. Other codes were delineated to the other misclassifications in a similar fashion as seen in Table 1. The rank of most common misclassifications is as follows: UE = 14, EU=6, DE = 4, U2E = 2, U2U = 4, U4U= 1, U7U = 1, ED = 1, and OU = 1. Please note that EU and UE are two different types of misclassification. For example UE is a missed upstream fish, whereas EU is a false upstream count (Table 1).

Using the errors coded per Table 3, the percent of correct classifications was 47.9% for the video validation from April 21 to June 6, and 35.4% from June 7 to 17. Note that the percent correct does not include the EE, as we were interested in the how well the counter classified fish.

The ratio estimator calculated from 18 of the non-zero observations between April 21 and June 6 was $\hat{r}$ = 2.10, with an approximate prediction variance of 3.69. A true binomial process with similar sample sizes and similar probability of detection would yield a prediction variance of approximately 2.60, indicating that the process of failing to detect steelhead with the resistivity counter displayed variation in excess of a binomial process.

Table 3.–Results of video validation of resistivity counts. Peterson Creek, mile 25 Glacier Highway, Juneau, 2007. Only days when video was running approximately 11 hours are included. All counts reported here were in concurrence with fish signatures from the signature files (traces). The ratio estimator $\hat{r}$ = 2.10, with a prediction variance of 3.69. The percent of the counts that were correctly counted by the counter was 47.88% for the video validation from April 21,2007–June 6, 2007 and 35.42% for the video validation from June 7, 2007–June 17, 2007. The first period represents the 35 cm electrode spacing, and the second period represents the 20 cm electrode spacing. From April 21 2007–June 6, 2007, only steelhead are reported, and from June 7, 2007–June 17, 2007, only smaller trout (likely rainbow trout) are reported as no steelhead were left in the creek. Column headings (codes) are defined in Table 1.

Date	UU	UE	U2U	U4U	U7U	EE	EU	U2E	D2E	ED	DD	DE	OU	Total	w/o EE	UU+ DD	% Correct
4/21	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	100.00
5/1	3	0	0	0	0	2	1	1	0	1	0	0	0	8	6	3	50.00
5/2	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	100.00
5/4	1	0	0	0	0	9	1	0	0	0	0	0	0	11	11	1	50.00
5/6	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0.00
5/7	0	0	0	0	0	7	2	0	0	0	0	0	0	9	9	0	0.00
5/8	3	0	1	0	0	8	0	0	0	0	1	0	0	13	13	4	80.00
5/9	3	0	1	0	0	0	0	0	0	0	0	0	0	4	4	3	75.00
5/10	0	0	0	0	0	42	0	0	0	0	0	0	0	42	42	0	
5/12	1	0	0	0	0	2	0	0	0	0	0	0	0	3	3	1	100.00
5/13	0	0	0	0	0	6	0	0	0	0	0	0	0	6	6	0	
5/15	0	0	0	0	0	14	0	0	1	0	0	0	0	15	15	0	0.00
5/17	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0.00
5/18	0	0	0	0	0	38	0	0	0	0	0	0	0	38	38	0	
5/19	4	1	0	0	0	31	0	0	0	0	1	0	0	37	6	5	83.33
5/20	0	3	0	0	0	18	0	0	0	0	0	1	0	22	4	0	0.00
5/21	0	0	0	0	0	37	0	0	0	0	0	0	1	38	1	0	0.00
5/22	0	1	0	0	0	43	0	0	0	0	0	0	0	44	1	0	0.00
5/23	1	1	0	0	0	60	0	0	0	0	1	0	0	63	3	2	66.67
5/24	0	1	0	0	0	7	0	0	0	0	0	0	0	8	1	0	0.00
5/25	0	3	0	0	0	22	0	0	0	0	0	0	0	25	3	0	0.00
5/26	0	0	0	0	0	196	0	0	0	0	0	0	0	196	0	0	
5/27	0	0	0	0	0	18	0	0	0	0	0	0	0	18	0	0	
5/28	0	0	0	0	0	19	0	0	0	0	0	0	0	19	0	0	
5/31	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	
6/4	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	100.00
6/5	1	0	0	0	0	0	0	0	0	0	0	2	0	3	3	3	100.00
6/6	1	0	0	0	0	1	0	0	0	0	0	0	0	2	1	1	100.00
6/8	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0.00
6/9	0	0	0	0	0	17	0	0	0	0	0	1	0	18	1	0	0.00
6/13	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	
6/14	5	2	0	0	0	3	1	1	0	0	0	1	0	13	10	5	50.00
6/15	3	1	0	0	0	17	0	0	0	0	0	0	0	21	4	3	75.00
6/16	7	0	0	0	0	20	1	0	0	0	0	0	0	28	8	7	87.50
6/17	0	1	0	0	0	69	0	0	0	0	0	0	0	70	1	0	0.00

Although the ratio formula used to calculate $\hat{r}$ provided a reasonably unbiased method of estimating r, there was not a robust method for estimating the sampling variance of an estimate of escapement using $\hat{r}$, as described in the Methods. Seven of the 18 paired observations used to calculate $\hat{r}$ had denominator values of 0, suggesting the sampling distribution for predicted values of r was heavily skewed to the right. Using bootstrapping techniques on the observed data was precluded by the expected occurrence of periodic infinite values calculated from bootstrap samples.

As we cannot provide an unbiased measure of variance for an escapement estimate that is clearly characterized by a high degree of uncertainty based on the data, we decided that a point estimate without the appropriate statistical qualifications would be of little utility.

Further, the estimate of r using video data collected during daylight hours is potentially biased, both in terms of central tendency and measures of uncertainty when the majority of steelhead passage occurred during non-daylight hours. The data suggest that accurate interpretation of groups (more than one) of passing steelhead was poor. If a higher proportion of groups passed the resistivity counter during non-daylight hours than was observed during daylight hours, there is a significant potential for bias by using the estimate of r based on daylight observations to infer detection rates for fish passing during non-daylight hours. If the probability of detecting a passing steelhead were a true binomial process, the potential for bias would be minimal. However, that is not the case with the data.

Application of equation (5) suggests that a point estimate for steelhead escapement will be on the order of magnitude of 200–300 fish. This size of escapement is plausible given the escapements from 1989 through 1991 that ranged from 179 to 215 steelhead (Harding and Jones 1991). However, further speculation about the escapement is not justified by the data.

The relative size of 36 steelhead on the video screen was measured in proportion to the width of the panel on the video screen. These steelhead were both upstream and downstream moving fish that were videotaped from April 21 through June 6 while using the 32 cm electrode spacing. Fish size was not correlated with the PSS using a log transformed linear regression ($r^2 = 0.007$), thus we were unable to estimate the size of steelhead outside of the video sample (Figure 9). The average size of the steelhead measured in the video sample was 72.2 cm (28.4 in), and ranged from 60.5 cm (23.8 in) to 91.8 cm (36.2 in). Only 1 fish in the video sample was estimated to be above the 36 in minimum retention size. From April 21 to June 6, all fish in the video sample were steelhead. The last steelhead emigrated on June 5. The PSS for the steelhead crossing the counter ranged from 12–33, with a mean value of 17.0 (SE = 0.86).

From June 7 until June 18 the electrode spacing was reduced to 20 cm. The counter began counting smaller fish, albeit the PSS remained about the same at an average of 16.7 (13–25), SE = 0.59. Because the counter was now counting smaller fish with similar-sized PSS, this indicated that the signature had been amplified. This resulted in plans to test the reduced electrode spacing on steelhead in 2008. After June 8 the steelhead run was over, and these fish were likely rainbow and cutthroat trout (A. Crupi, fisheries biologist, ADF&G, unpublished data located at Y:\DJ_ReportingPlanning\Technical_Reporting\Peterson_Sashin_PhaseI_II\Final_ARCHIVE_ DATA_folder, accessed 2010).Stream depth above the panels was measured on panel 1 on the shallow side (Figure 3). There was a 20 cm depth difference between panel 1 and panel 3 (i.e., when panel 1 was 15 cm, panel 3 was 35 cm). The following water depth measurements are adjusted for panel 3. Adjusted water depths ranged from 22 to 86 cm, with a mean of 53 cm (SD = 36 cm) during the period April 23 to June 18 (Appendix A1). Discharge ranged from 19.7 to

4,402.3 L/s, with a mean of 1,848.9 L/s (SD = 1,170.7 L/s) (Figure 10, Appendix A3). The specific water conductivity (EC) ranged from 10.1 to 24.4 µS/cm, with a mean of 13.9 µS/cm (SD = 3.2 µS/cm) (Appendix A1).

The ambient conductivity ranged from 6.4 to 18.2 µS/cm, with a mean of 8.9µS/cm (SD = 2.7 µS/cm) (Appendix A1). Salinity was 0 at the resistivity panels. Water temperature ranged from 1.7°C to 13.5°C with a mean of 5.5 °C (SD = 3.7 °C) (Appendix A1). Water turbidity ranged from 0.5 to 2.9 NTU with a mean of 1.4 NTU (SD = 0.72 NTU) (Appendix A1). Measurements for water color, pH and rain quantity were not collected.

2008

In 2008 the compressed (20 cm) electrode spacing was used, and we attempted to collect count and signature files created by the resistivity fish counter continuously from April 8 until June 6. The field crew visited the site daily during 2008, and downloaded both counter data and video data. This data collection was fraught with technical difficulties with the DC DVR and the counter. The system had been upgraded to a DC DVR with hotswappable drives to facilitate inseason viewing, but the DVR could not be programmed into pre-event recording mode due to a problem with the DVR's capacitors. On May 1, two adult steelhead were observed swimming over the panels at 1400 hours. The counter data was downloaded and reviewed, and it was discovered that the steelhead had not been detected (or even classified as a signature event). In spite of repeated attempts to resolve all of the problems with both the counter and the DVR throughout the field season, there was so little useable data that analyses were not performed. We did collect 563 hours of real time video footage of the panels, which was 68 % viewed during 2008, 2009 and 2010 (Appendix A5). During daylight hours from April 9 to May 24, 79 steelhead were filmed moving upstream, and 97 steelhead were filmed moving downstream (Appendix A5).

A foot survey was conducted from just below the barrier falls to the resistivity panels on April 11 and 0 adult steelhead were observed. DSF area management staff performed snorkel surveys from May 2 to 30 (Table 1). DSF research staff snorkeled again on June 5 before removing the resistivity panels, and two steelhead were counted above the panel site.

Stream depth above the panels was measured on panel 1, the shallow side (see Figure 3). There was a 20 cm depth difference between panel 1 and panel 3 (i.e., when panel 1 was 15 cm, panel 3 was 35 cm). The following water depth measurements are adjusted for panel 3. Adjusted water depth ranged from 23.8 to 94.5 cm, with a mean of 41.5 cm (SD = 14.8 cm) during the period April 7 to June 5 (Appendix A2). Discharge ranged from 537.6 to 6,354.5 L/s, with a mean of 2,202.7 L/s (SD = 1,102.4 L/s) (Figure 11, Appendix A3). The specific water conductivity ranged from 10.7 to 15.1 µS/cm with a mean of 12.1 µS/cm (SD = 1.3 µS/cm) (Appendix A2). The ambient conductivity was a little bit lower as it is not referenced to 25°C, and ranged from 6.6 to 8.8 µS/cm, with a mean of 7.4 µS/cm (SD =0.54 µS/cm), (Appendix A2). Salinity was 0 at the resistivity panels from. Water temperature ranged from 1°C to 9.2°C, with a mean of 4.3°C (SD = 2.5°C) (Appendix A2). Water turbidity ranged from 0.6 to 2.8 NTU with a mean of 1.2 NTU (SD = 0.5 NTU) (Appendix A2). Water color ranged from 27.7 to 145.0 CU, with a mean of 48.5 CU (SD = 23.2 CU) (Appendix A2). Rainfall ranged from 0.00 to 1.20 in, with a mean of 0.16 in (SD = 0.27)(Appendix A2).

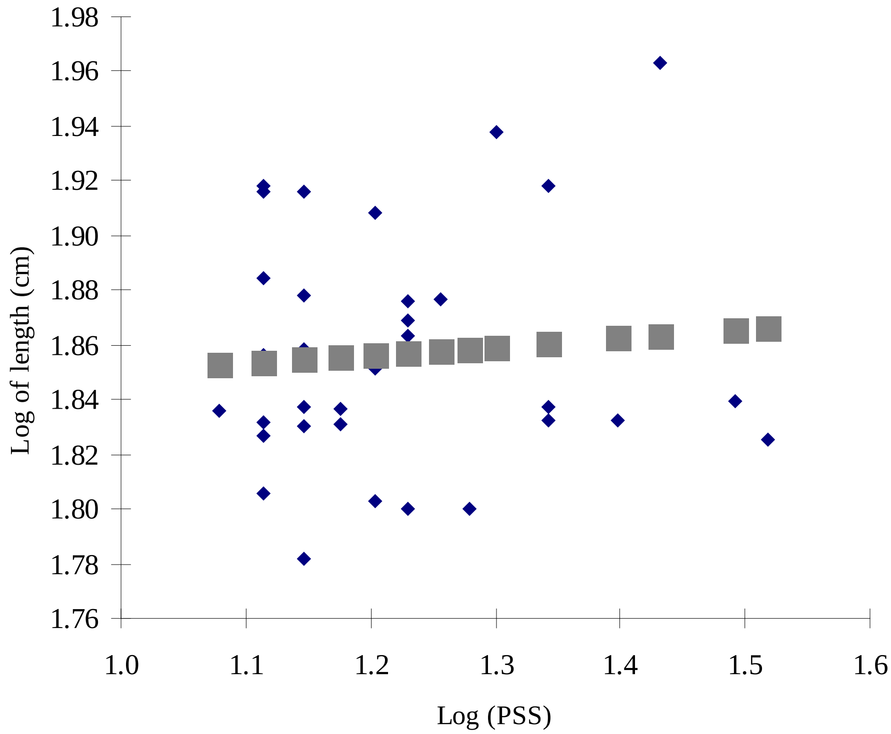


Figure 9.–Log transformed total lengths (cm) versus log of PSS from the resistivity counter and the predicted log of total length (cm) for fish passing over the counter for adult steelhead at Peterson Creek, mile 25 Glacier Highway, Juneau, 2007. Estimated fish size (from video sample) was not correlated with the PSS of the counter using a log transformed linear regression ($r^2 = 0.007$, $n = 36$). Diamonds represent the relative lengths of the fish measured in relation to the panels on the video. Squares represent the predicted regression curve using formula $\log_{10}(L) = 0.031 \log_{10}(PSS) + 1.819$.

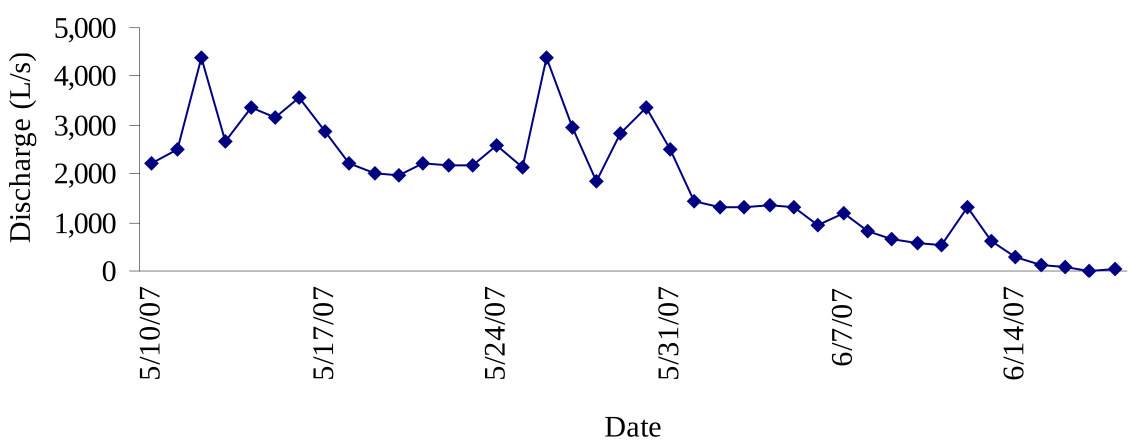


Figure 10.–Daily discharge in Peterson Creek, mile 25 Glacier Highway, Juneau, 2007.

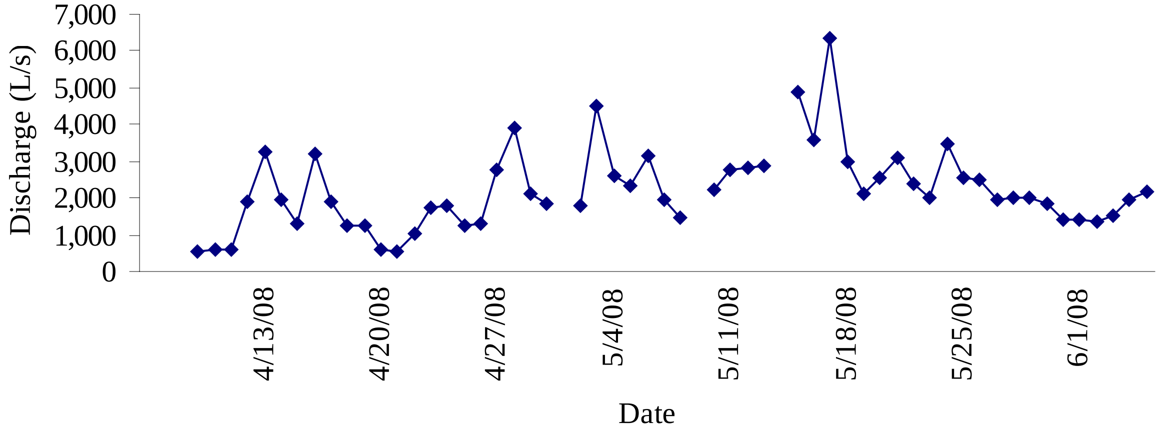


Figure 11.–Daily discharge in Peterson Creek, mile 25 Glacier Highway, Juneau, 2008.

DISCUSSION

Only a portion (Table 3) of the data could be analyzed due to recurrent power problems. The 452 amp battery bank and thermoelectric generator put out marginal power for our needs. When the voltage neared 12 volts, the graphics files would be lost. The system was supplemented with a gas generator as needed to collect data. The inability to download both the graphics and video data during the field season was problematic as well. A USB drive was installed on the laptop during the field season, but the video drive was not hotswappable therefore the video analysis was done postseason. The resistivity counter software was cumbersome to use as it was based on Windows 98. The electrode spacing on the panels was changed in hope of amplifying the signatures at the suggestion of the manufacturer and our consultant.

The portion of video validation data that could be analyzed (Table 3) showed highly variable misclassification of fish moving both upstream and downstream regardless of the electrode spacing. The combined data indicates that most of the errors were upstream fish that were missed by the counter (UE) (43.7%), involved multiple fish crossing the counter simultaneously (21.8%), or events misclassified as upstream fish (EU = false upstream counts) (18.8%). For the 32 cm spacing the errors are broken down into 45.5% missed upstream fish (UE), 18.2 % false upstream counts (EU), and 22.7 % multiple fish counted as single fish. For the 20 cm spacing the errors were slightly less as 44.4% of the error in upstream counts were missed fish (UE), 11.1% were false upstream counts (EU), and 22.2% were multiple fish counted as single fish both upstream and downstream (Table 3).

Resistivity fish counter misclassifications have been documented by different studies using various counters, albeit not as frequently as we experienced (Simpson 1978; Dunkley and Shearer 1982; Smith et al. 1996; Aprahamian et al. 1996; Forbes et al. 1999; McCubbing and Ignace 2000; McCubbing et al. 2000; and McCubbing 2005). The Logie 2100 type series counter (Logie 2100A) using flat panels has been used with fairly good success for counting salmonids on the River Lune in the United Kingdom (Aprahamian et al. 1996), the Deadman River, British Columbia using a Logie 2100C (McCubbing and Ignace 2000), and on the Keogh River, British Columbia again using a Logie 2100C (McCubbing et al. 2000). The counter efficiencies for these studies were: 86.9% for upstream counts of Atlantic salmon and brown trout on the River Lune (Aprahamian et al. 1996), 94.0% for pink salmon on the Keogh River (McCubbing et al. 2000), 88% for coho salmon on the Keogh River (McCubbing et al. 2000), and 95.9% (excluding beavers) for upstream moving steelhead on the Deadman River (McCubbing and Ignace 2000). McCubbing (2005) also used the same Logie 2100C, panels, and DVR at the Harris River prior to their use at Peterson Creek, where the counter efficiency was approximately 85%. The counter efficiency at Peterson Creek in 2007 was 140.0% overall in comparison. One problem with the efficiency calculation (equation 1) occurs when the counter misses all the fish during an entire day and a zero is left in the denominator. Three days of undercounts were therefore left out when calculating the counter efficiency for the season (Table 4). Equation (2) was used for calculating counter efficiency to be consistent with other recent studies and for comparative purposes. Counter efficiencies have been reported as species dependent (McCubbing et al. 2000), size dependent (Aprahamian et al. 1996), and also dependent on the number of fish passed per hour (McCubbing et al. 2000). McCubbing (Principal Biologist, In Stream Fisheries Research, Inc., Vancouver, personal communication) cautions that the counter must be calibrated to the conditions at each site, and that could take up to several field seasons.

Missed counts have been attributed to fish not being counted that had PSS values just under the threshold size (Aprahamian 1996; McCubbing et al. 2000; McCubbing and Ignace 2000; and McCubbing 2005). The threshold at the Peterson Creek study site in 2007 was set at 10, and the PSS values ranged from 12 to 33. Threshold values (for signature/trace) can be set from 1 to 127, but McCubbing et al. (2000) state that lower thresholds are more prone to noise and should be avoided. Manual gain settings were also used between 100 and 400 depending on the water level; the lower gain was set for lower water and was increased with increased water depth and discharge. The Logie 2100C counter did not have a conductivity card/probe, but the conductivity was measured manually each day. However, the counter did not compensate automatically for changes in conductivity, but did compensate for changes in bulk resistance.

Water conductivity levels only varied 14.3 µS/cm (Appendix A1). Aquantic (manufacturer of the Logie fish counters) recommends the use of this accessory for streams with water conductivities below 300 µS/cm. However, the Logie 2100C has been used to count fish without the conductivity probe in streams with water conductivity levels well below this with success (D.J.F. McCubbing, Principal Biologist, In Stream Fisheries Research, Inc., Vancouver, personal communication), and found that the variation in the water conductivity was more critical to counter function than the water conductivity (McCubbing and Ignace 2000). Future use of resistivity counters in water conductivities as low as those at Peterson Creek should try to use the conductivity card/probe with the Logie 2100C counter.

Other resistivity counter studies in the literature report confusing conductivity information or no conductivity information at all. The SI units have changed over the years, and it should be noted that 1 µmho/cm = 1µS/cm. Also water conductivity is often reported just as that, whereas this parameter should be either measured and/or reported as water conductivity or as specific water conductivity (EC), the ambient water conductivity corrected for 25°C. Using specific conductivity (EC) allows for comparison of conductivity measurements. These values can vary because ambient water conductivity varies with water temperature by an estimated 2% per °C in fresh water (Barron and Ashton 2005). Water conductivity, reported as ambient conductivity, on the River Lune is reported to have ranged from 60–230 µs/cm (Aprahamian et al. 1996). Authors

Table 4.–Percent efficiency calculated using methods of McCubbing and Gray (2004) for the resistivity counter in Peterson Creek , mile 25 Glacier Highway, Juneau, 2007, where Tv = the daily total of fish counted by video, and Tc = the daily total of fish counted by the Logie 2100 C fish counter. Percent efficiency (Ce) = Tv/Tc. The percent efficiency (Ce) for the entire season is the ΣTv/ΣTc, and was equal to 140.0%, which is an undercount of fish.

Date	Tv	Tc	Ce	Error +/-
4/21	1	1	100.0	
5/1	4	6	66.7	counter overcounted
5/2	1	1	100.0	
5/4	1	2	50.0	counter overcounted
5/6	1	0	undefined	
5/7	0	2	0.0	counter overcounted
5/8	6	5	120.0	counter undercounted
5/9	5	4	125.0	counter undercounted
5/10	0	0	0	
5/12	1	1	100.0	
5/13	0	0	0	
5/15	2	0	undefined	counter undercounted
5/17	4	1	400.0	counter undercounted
5/18	0	0	0	
5/19	6	5	120.0	counter undercounted
5/20	4	0	undefined	counter undercounted
5/21	0	0	0	
5/22	1	0	undefined	counter undercounted
5/23	3	2	150.0	counter undercounted
5/24	1	0	undefined	counter undercounted
5/25	3	0	undefined	
5/26	0	0	0	
5/27	0	0	0	
5/28	0	0	0	
5/31	0	0	0	
6/4	1	1	100.0	
6/5	3	3	100.0	
6/6	1	1	100.0	
6/8	7	1	700.0	counter undercounted
6/9	1	0	undefined	
6/13	0	0	0	
6/14	8	8	100.0	
6/15	4	3	133.3	counter undercounted
6/16	7	8	87.5	counter overcounted
6/17	1	0	undefined	

did not report water conductivity measurements for the Keogh, Deadman, and Harris rivers during any of the years a resistivity counter was operated. McCubbing relays that EC on the Keogh River ranges from 20 µS/cm to 45 µS/cm, and ranges 80 µS/cm to 250 µS/cm on the Deadman River (where the conductivity card is required for sizing due to the large range in EC). A measurement taken on the Harris River during a steelhead snorkel count on May 8, 2008, was 37.3 µS/cm EC (Table 5). McCubbing (2005) attributes low water conductivity to the failure to accurately size fish on the Harris River during that study. At Peterson Creek, even lower water conductivity interferes with accurate counting, in addition to preventing accurate fish sizing.

Table 5.–Conductivity readings taken by ADF&G Division of Sport Fish area managers in steelhead snorkel index streams throughout Southeast Alaska, 2008. Measurements were taken with a YSI Model 30 conductivity meter. All systems were spot checked except Peterson Creek, wherein the average for 2008 is reported.

Date	System	Ambient conductivity (µS/cm)	Specific conductivity (EC) (µS/cm)	Salinity (ppt)	Temperature (°C)
4/22	White River	14.2	31.3	0	3.4
5/1	McDonald River	ND[a]	5.9	0	1.2
5/8	Harris River	24.6	37.3	0	7.1
5/9	Eagle	25.5	40.7	0	6.5
5/12	Pleasant Bay Creek	33.8	59.6	0	2.4
3/28	Sitkoh Creek	ND[a]	19.6	0	0.9
5/20	Petersburg Creek	13.7	20.8	0	7.5
5/19	Slippery Creek	8.3	12.8	0	6.5
6/9	Ford Arm	18.9	29.8	0	5.9
Average	Peterson Creek	8.8	28.6	0	4.0

[a] Too cold to estimate.

Specific water conductivity (EC) at Peterson Creek from April 23 to June 18 ranged from 10.1 to 24.4 µS/cm, with a mean of 13.9 µS/cm (SD = 3.2 µS/cm) (Appendix A1). The mean specific water conductivity is even lower as 11 days of readings were not included because the YSI Model 30 conductivity probe would not calculate specific conductivity (EC) at temperatures less than 2°C. Thus, specific conductivity (EC) was lower than other studies reported (or were inferred from) with a flat panel resistivity counter. Spot checks outside this study indicated that water conductivity outside of the study period did increase over the summer to a high of 84.3 µS/cm (Appendix A4).

False counts on upstream migrants have been attributed to wind generated wave action, fish at the edge of the video field and not noticed by viewer, fish lingering on panels, and debris. One otter was misclassified as an upstream steelhead in this study. Like McCubbing and Ignace (2000), the signature has an extra sinus (Figure 12). However, similar to all signatures in the low conductivity waters of Peterson Creek, the amplitude was very small.

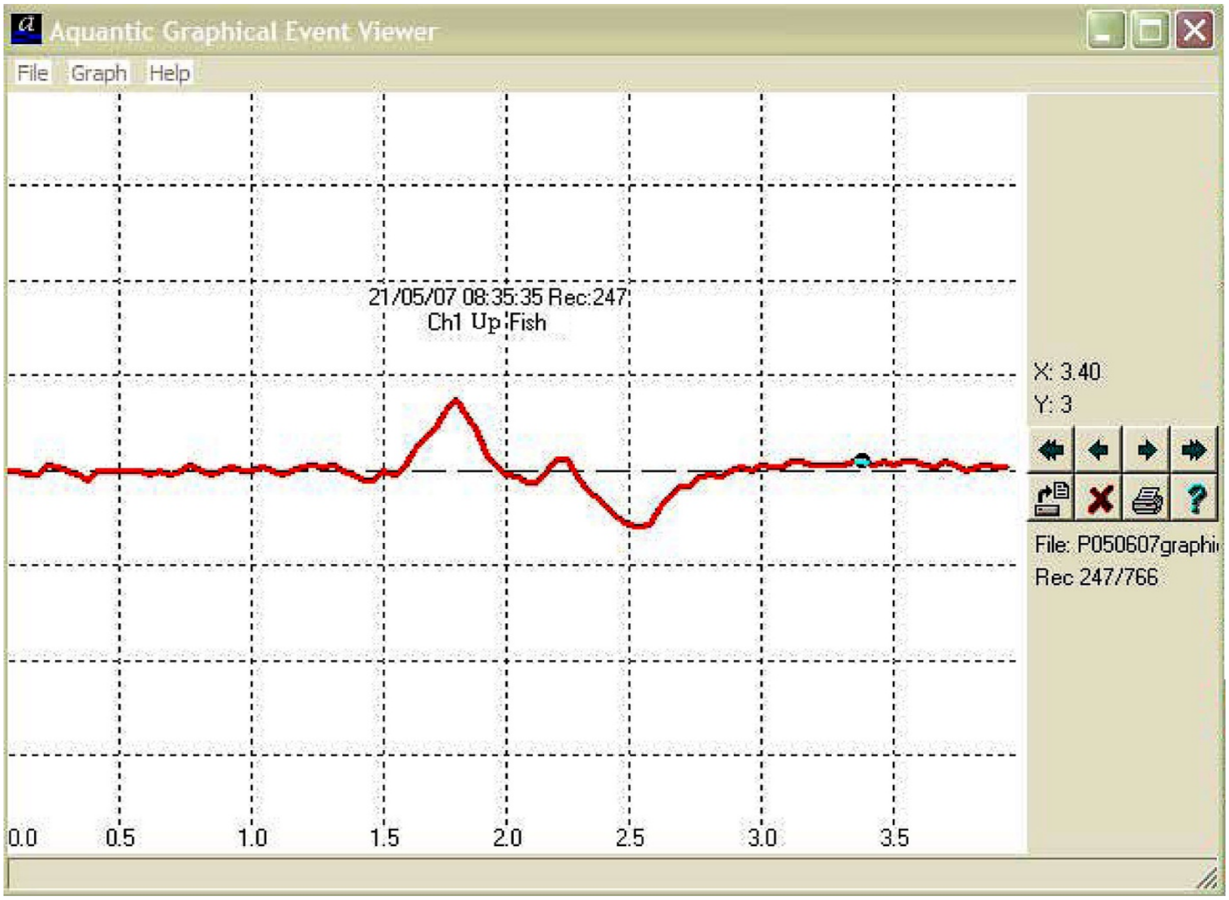


Figure 12.–Example of a signature that was an otter misclassified as an upstream fish at Peterson Creek, mile 25 Glacier Highway, Juneau. Similar to McCubbing and Ignace (2000), the signature has an extra sinus. However, similar to all the Peterson Creek signatures (signatures), the amplitude is very small. This record is from May 21, 2007, at 0835.

Two or more fish that simultaneously crossed the electrodes and were counted as a single fish have been reported by authors cited using various resistivity counters. Multiple fish counts seemed to be less of a problem as the proportion of that particular misclassification remained small. In our video validation, multiple fish accounted for 21% of the misclassifications for both electrode spacings, and included two fish crossing the counter simultaneously (n = 2), four fish crossing the counter simultaneously (n = 1), and seven fish crossing the counter simultaneously (n = 1). Not only is this percentage high relative to the other miscounts, but a miscount of this nature could represent a variable amount of fish, thus further confusing the total count obtained.

As for errors in the classification of downstream migrating fish, Dunkley and Shearer (1982), Smith et al. (1996), Forbes et al. 1999, McCubbing and Ignace (2000), McCubbing (2005) all agree that various resistivity counters do a much better job of counting fish that are moving upstream than downstream. Lower counter efficiencies of downstream moving fish have been attributed to fish behavior. Descending fish are thought to move higher in the water column, thus the signal is weaker compared to upstream fish, which have been observed to move along the bottom close to the panels, thus creating a stronger signal. Descending Atlantic salmon observed crossing the electrodes at angles other than perpendicular were also missed in downstream counts. Fish were observed moving both near the bottom as well as higher in the water column in the few underwater video observations collected during 2008. Dissimilar upstream versus downstream counts can be problematic if net counts are being used, as the undercounting of downstream counts would cause an overestimate of upstream net movement.

PSS is also used to estimate the length of fish passing the panels. At Peterson Creek this was not possible due to the poor fit of the log transformed regression to the data for the steelhead moving over the panels with electrode spacing of 35 cm from April 21 to June 6 (Figure 9). Log transformed regressions with just the upstream data provided results that were also too poor for predicting length ($r^2 = 0.32$, $n = 9$). Fish moving across the panels between June 8 and June 17 were smaller fish (mean = 24.07 cm). Aprahamian et al. (1996) found that log fish length accounted for roughly 70% of upstream signatures and 58% of downstream signatures, and water level, water temperature, and conductivity accounted for the remainder of the variability in PSS. McCubbing (2005) states that low correlation between fish size and PSS could be due to the low water conductivity and varied swim height of the steelhead crossing the counter. At Peterson Creek, the PSS values are even lower, and other parameters such as water conductivity and water level appear to account for the variability in PSS.

During the 1989–1991 steelhead weir operations at Peterson Creek, no adult salmon were counted through the weir from April 22 to June 9, therefore it is unlikely that salmon were the source of miscounts during this period in 2007 and 2008 (Harding and Jones 1991).

2008

During 2008, in response to the very poor performance of the resistivity panels, a variety of underwater video cameras, infrared lights with an overhead video camera, and a mini-DVR (Van Alen 2008) were evaluated for future electronic counting options. Most underwater cameras used for fish counting use a motion-detect feature, which limits the range of detection of the camera. These are usually used in conjunction with some kind of trap, which requires that a barrier be in place in order to use underwater cameras as an accurate counting method. The overhead camera worked well using the white resistivity panels as defacto counting/flash panels. However, both underwater and overhead cameras only worked during daylight hours. For both underwater and overhead applications, infrared lights had a lighted range too small to be useful. Only the closest of the three panels could be seen with the overhead infrared light, and with the underwater infrared camera, visibility was further restricted.

The quality of video from the mini-DVR was impressive, but use of the associated net weir to divert steelhead into a camera trap in a minimally-staffed project was dismissed as too risky. Gates and Palmer (2006a, 2006b) counted steelhead using a trap, with a motion-detect video camera and resistance board weir. Building a resistance board weir was also costly, running around $10,000–$30,000 (Ken Gates, fisheries biologist, USFWS, Soldotna, personal communication). Pipal et al. (2007) used a dual-frequency identification sonar (DIDSON) to count steelhead in small streams in California. These options will be considered for future use at Peterson Creek.

Relative to other studies, our specific water conductivity (EC) was the lowest by far at an average 13.9 μS/cm for 2007 and 12.1 μS/cm in 2008. Conductivity in Peterson Creek is suspected to be below the point at which the Logie 2100C works accurately. Missed fish, false counts and multiple fish counted as single fish have been documented before with other studies, but seemed to be exacerbated at Peterson Creek. Researchers should take this into account when considering a resistivity fish for future use at this site.

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APPENDIX A

Appendix A1.–Physical data recorded at Peterson Creek, mile 25 Glacier Highway, Juneau, 2007.

Date	Stream depth above panels (cm)	Staff gauge (m)	Conductivity (µS) Specific (EC)	Conductivity (µS) Ambient[a]	Temperature (ºC)	Turbidity (NTU) Oakton	Color	Rain (cm)
4/23	54.0	ND	ND	8.7	ND	ND	ND	ND
4/24	52.0	ND	ND	8.5	1.8	ND	ND	ND
4/25	46.0	ND	ND	8.4	1.7	ND	ND	ND
4/26	48.5	ND	ND	8.7	1.7	ND	ND	ND
4/27	39.0	ND	ND	8.5	1.9	ND	ND	ND
4/28	29.0	ND	ND	8.9	1.7	ND	ND	ND
4/29	29.0	ND	ND	9.1	2.0	ND	ND	ND
4/20	45.0	ND	ND	8.3	2.1	ND	ND	ND
5/1	37.0	ND	ND	8.7	2.7	ND	ND	ND
5/2	34.5	ND	16.0	8.3	2.0	ND	ND	ND
5/3	33.0	ND	ND	7.9	1.7	ND	ND	ND
5/4	38.5	ND	14.3	8.6	3.0	ND	ND	ND
5/5	42.5	ND	13.1	7.4	1.9	ND	ND	ND
5/6	45.0	ND	ND	7.6	1.9	ND	ND	ND
5/7	66.0	ND	13.2	7.5	2.2	ND	ND	ND
5/8	38.0	ND	13.3	7.6	3.0	ND	ND	ND
5/9	32.0	ND	15.0	8.5	2.7	ND	ND	ND
5/10	36.0	0.7	13.2	7.8	3.1	1.1	ND	ND
5/11	39.0	0.8	14.1	8.1	2.7	0.9	ND	ND
5/12	64.0	1.0	ND	6.4	1.8	ND	ND	ND
5/13	42.0	0.8	11.9	6.8	2.7	ND	ND	ND
5/14	51.0	0.9	11.9	6.7	2.2	2.90	ND	ND
5/15	49.0	0.9	11.9	6.9	2.8	2.24	ND	ND
5/16	36.0	0.8	11.6	6.7	2.5	1.67	ND	ND
5/17	44.5	0.8	11.4	6.6	2.8	1.02	ND	ND
5/23	35.0	0.7	12.0	7.1	4.6	1.20	ND	ND
5/24	39.0	0.8	11.6	6.8	3.8	1.04	ND	ND
5/25	48.5	0.7	11.8	6.9	4.6	0.61	ND	ND
5/26	49.0	1.0	10.1	6.5	5.6	1.55	ND	ND
5/27	50.0	0.8	10.3	6.6	4.8	2.31	ND	ND
5/28	29.0	0.7	12.7	7.9	4.9	1.63	ND	ND
5/29	41.0	0.8	11.0	6.9	5.3	2.62	ND	ND
5/30	57.5	0.9	11.0	6.9	5.3	2.40	ND	ND
5/31	38.0	0.7	10.4	7.1	6.4	1.07	ND	ND

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Appendix A1.–Page 2 of 2.

Date	Stream depth above panels (cm)	Staff gauge (m)	Conductivity (µS) Specific (EC)	Ambient[a]	Temperature (ºC)	Turbidity (NTU) Oakton	Color (CU)	Rain (cm)
6/1	24.5	0.6	12.7	8.5	7.9	0.72	ND	ND
6/2	25.0	0.6	12.7	8.5	7.3	0.89	ND	ND
6/3	21.0	0.6	12.7	8.5	7.6	0.71	ND	ND
6/4	22.0	0.6	12.7	8.7	8.3	1.28	ND	ND
6/5	25.0	0.6	13.3	8.7	8.5	0.84	ND	ND
6/6	17.0	0.5	13.7	9.9	9.1	1.05	ND	ND
6/7	18.5	0.5	13.3	9.2	8.7	1.73	ND	ND
6/8	15.0	0.5	14.2	10.1	9.1	2.00	ND	ND
6/9	13.0	0.5	15.3	10.7	8.8	2.65	ND	ND
6/10	14.0	0.5	15.6	12.0	11.3	2.67	ND	ND
6/11	12.0	0.5	16.3	11.8	10.9	1.59	ND	ND
6/12	21.0	0.6	12.6	9.1	10.6	2.09	ND	ND
6/13	12.0	0.5	13.2	10.0	11.7	1.32	ND	ND
6/14	7.0	0.4	18.1	13.7	12.3	0.69	ND	ND
6/15	6.5	0.4	19.6	15.2	13.5	0.63	ND	ND
6/16	4.0	0.4	20.6	15.7	12.8	0.62	ND	ND
6/17	2.0	0.4	22.6	16.9	11.7	0.80	ND	ND
6/18	7.0	0.4	24.4	18.2	10.7	0.52	ND	ND

[a] The number in the left sub-column is the specific conductivity (EC) or temperature compensated conductivity, which is the conductivity reading as it would be at 25ºC. The conductivity value on the right is the ambient conductivity at the temperature of the water. At very cold temperatures (less than approximately 2ºC), the YSI model 30 SCT meter reports the specific conductivity (EC) value as an error.

Appendix A2.–Physical Data recorded at Peterson Creek, mile 25 Glacier Highway, Juneau, 2008.

Date	Stream depth above panels (cm)	Staff gauge (m)	Conductivity (µS/cm) Specific (EC)	Conductivity (µS/cm) Ambient[a]	Temperature (ºC)	Turbidity (NTU) Oakton	Color (CU)	Rain (cm)
5/3	68.5	1.1	ND	7.6	1.0	1.35	49.8	0.9
5/4	44.0	0.8	ND	7.9	1.6	1.24	67.5	0.5
5/5	40.0	0.7	14.2	8.0	2.2	1.00	70.0	0.4
5/6	51.0	0.8	13.4	7.6	2.3	1.24	43.9	0.6
5/7	34.4	0.7	14.2	8.1	2.5	0.66	37.2	0.0
5/8	27.0	0.6	15.1	8.7	2.7	1.09	39.0	0.0
5/9	29.5	ND	14.8	8.8	3.8	0.66	45.8	0.0
5/10	38.0	0.7	13.7	7.9	2.7	0.90	40.7	ND
5/11	44.5	0.8	12.9	7.4	2.3	0.62	39.5	ND
5/12	45.7	0.8	12.4	7.0	2.2	0.94	60.4	0.3
5/13	44.4	0.8	12.6	7.2	2.2	1.16	61.3	0.5
5/14	38.8	ND	13.2	7.5	2.1	0.85	59.3	1.1
5/15	74.4	1.1	ND	ND	2.5	2.68	53.9	1.9
5/16	57.0	0.9	12.2	6.9	2.2	1.91	44.3	1.3
5/17	94.5	1.3	ND	7.0	1.8	2.85	51.3	3.2
5/18	50.0	0.8	11.6	6.6	2.5	1.36	37.9	0.3
5/19	36.0	0.7	12.0	7.0	3.3	1.36	145.0	0.0
5/20	40.5	0.8	11.7	6.7	3.0	0.99	49.4	0.0
5/21	48.2	0.8	11.3	6.6	3.5	1.00	33.5	0.4
5/22	36.6	0.7	11.6	6.9	3.8	0.82	37.6	0.0
5/23	32.5	0.7	11.9	7.1	4.1	1.39	39.4	0.0
5/24	37.3	0.9	11.2	7.1	5.4	0.99	60.2	0.0
5/25	42.0	0.8	10.9	6.8	4.9	1.61	34.5	0.0
5/26	39.2	0.7	11.5	7.3	5.5	0.71	49.7	0.0
5/27	32.0	0.7	10.7	7.2	7.6	0.99	102.0	0.0
5/28	34.0	0.7	10.9	7.1	7.0	1.44	28.0	0.0
5/29	34.5	0.7	10.8	7.0	6.4	1.28	32.0	0.0
5/30	30.5	0.7	10.9	7.3	7.4	0.95	29.7	0.0
5/31	24.2	0.6	11.9	6.9	7.1	0.96	28.7	0.0
6/1	23.8	0.6	11.1	7.8	8.4	1.08	37.3	0.0
6/2	ND	0.6	ND	ND	9.2	ND	ND	0.0
6/3	26.2	0.6	11.5	7.8	8.5	0.75	27.7	0.3
6/4	32.0	0.7	10.7	7.3	8.2	1.70	31.9	0.9
6/5	37.0	0.7	10.9	7.3	7.6	1.29	33.4	0.5

[a] The number in the left sub-column is the specific conductivity (EC) or temperature compensated conductivity, which is the conductivity reading as it would be at 25ºC. The conductivity value on the right is the ambient conductivity at the temperature of the water. At very cold temperatures (less than approximately 2ºC), the YSI model 30 SCT meter reports the specific conductivity (EC) value as an error.

Appendix A3.–Discharge at Peterson Creek, mile 25 Glacier Highway, Juneau, 2007 and 2008.

Date	2007 discharge (L/s)	2008 discharge (L/s)
	ND	ND
4/8	ND	ND
4/9	ND	557.5
4/10	ND	577.5
4/11	ND	577.5
4/12	ND	1,892.2
4/13	ND	3,246.9
4/14	ND	1,971.9
4/15	ND	1,294.6
4/16	ND	3,207.0
4/17	ND	1,892.2
4/18	ND	1,274.7
4/19	ND	1,274.7
4/20	ND	577.5
4/21	ND	537.6
4/22	ND	1,015.7
4/23	ND	1,732.9
4/24	ND	1,812.6
4/25	ND	1,254.8
4/26	ND	1,294.6
4/27	ND	2,768.8
4/28	ND	3,884.3
4/29	ND	2,131.3
4/30	ND	1,852.4
5/1	ND	ND
5/2	ND	1,812.6
5/3	ND	4,482.0
5/4	ND	2,609.4
5/5	ND	2,330.5
5/6	ND	3,127.3
5/7	ND	1,932.1
5/8	ND	1,454.0
5/9	ND	ND
5/10	2,211.0	2,211.0
5/11	2,489.9	2,768.8
5/12	4,402.3	2,808.6
5/13	2,669.2	2,888.3
5/14	3,366.4	ND

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Appendix A3.–Page 2 of 2.

Date	2007 discharge (L/s)	2008 discharge (L/s)
5/15	3,167.2	4,880.4
5/16	3,565.6	3,565.6
5/17	2,848.4	6,354.5
5/18	2,211.0	2,968.0
5/19	2,011.8	2,131.3
5/20	1,971.9	2,569.6
5/21	2,211.0	3,087.5
5/22	2,171.1	2,370.3
5/23	2,171.1	2,011.8
5/24	2,569.6	3,446.1
5/25	2,131.3	2,569.6
5/26	4,402.3	2,489.9
5/27	2,968.0	1,932.1
5/28	1,852.4	2,011.8
5/29	2,808.6	2,011.8
5/30	3,366.4	1,852.4
5/31	2,489.9	1,414.1
6/1	1,454.0	1,414.1
6/2	1,294.6	1,334.4
6/3	1,294.6	1,533.7
6/4	1,334.4	1,971.9
6/5	1,294.6	2,171.1
6/6	936.0	ND
6/7	1,175.1	ND
6/8	816.5	ND
6/9	657.1	ND
6/10	577.5	ND
6/11	537.6	ND
6/12	1,294.6	ND
6/13	617.3	ND
6/14	298.6	ND
6/15	139.2	ND
6/16	99.3	ND
6/17	19.7	ND
6/18	59.5	ND
Average	1,848.9	2,202.7

Appendix A4.–Conductivity measurements taken at Peterson Creek, mile 25 Glacier Highway, Juneau outside of the study period in 2007 (April 23, 2007–June 18, 2007).

Date	Specific conductivity (EC) (µS/cm)	Ambient conductivity (µS/cm)	Temperature (ºC)	Staff gauge (m)
7/13	16.7	12.8	11.8	ND
7/20	23.9	18.4	13.0	ND
8/17	84.3	66.7	13.9	ND
8/24	55.1	41.9	12.5	0.4
9/7	20.9	15.6	11.5	0.5
10/16	19.3	12.2	5.7	0.6

Appendix A5.–Results of daylight video counts from Peterson Creek at mile 25 Glacier Highway, Juneau, 2008.

Date	Upstream steelhead	Downstream steelhead
4/9	0	0
4/10	0	0
4/11	0	2
4/12	0	0
4/13	0	0
4/14	0	0
4/15	0	0
4/16	0	0
4/17	0	0
4/18	0	0
4/19	0	0
4/20	0	0
4/21	0	0
4/22	0	2
4/23	0	1
4/24	0	1
4/25	0	1
4/26	0	1
4/27	0	0
4/28	0	1
4/29	4	1
4/30	0	1
5/1	2	1
5/2	2	4
5/3	0	1
5/4	0	1
5/5	1	4
5/6	1	2
5/7	4	2
5/8	2	1
5/9	2	3
5/10	6	4
5/11	5	6
5/12	0	0
5/13	2	3
5/14	0	7
5/15	1	5
5/16	3	2
5/17	4	2
5/18	2	0
5/19	9	10
5/20	17	13
5/21	10	11
5/22	0	2
5/23	2	1
5/24	0	1
Total	79	97

APPENDIX B

Appendix B1.–Computer data files used to prepare and generate estimates for "Assessment of the performance of a flat panel resistivity fish counter at Peterson Creek, 2007 and 2008". All files are organized on the Region 1- Douglas Sport Fish Server under S:\Trout\PETERSON\Peterson_2007\FDS Report Archive.

Data file	Description
2007ResistivityData Spreadsheet.xls	All graphs and spreadsheets for 2007
2007PetersonEfficiency.xls	Counter efficiency spreadsheet
Peterson Stage Curve.xls	Stage curve for calculating discharge