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Using Hydroacoustic Methods to Enumerate Migrating Salmon in the Copper River, Miles Lake Sonar Project, 2008–2010

by

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

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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

FISHERY DATA SERIES NO. 15-23

USING HYDROACOUSTIC METHODS TO ENUMERATE MIGRATING SALMON IN THE COPPER RIVER, MILES LAKE SONAR PROJECT, 2008–2010

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ABSTRACT

The Miles Lake sonar project is a long-term assessment designed to obtain estimates of adult Pacific salmon *Oncorhynchus* spp. in the Copper River to assist biologists in managing commercial, sport, personal use, and subsistence sockeye salmon *O. nerka* harvests. Traditionally this project used single beam, echo-counting Bendix units to estimate salmon passage. In 2008 the Bendix systems were retired and dual frequency identification sonar (DIDSON) were deployed on both the north and south banks to estimate fish passage.

In 2008, the estimated escapement of 713,544 salmon was 19.5% above the inriver goal but below the 10-year average. Sonar operations began on May 15 on the south bank and May 16 on the north bank. The majority of the salmon (80.2%) were counted along the south bank. In 2009, the estimated escapement of 707,413 salmon was 23.0% above the inriver goal but below the 10-year average. Sonar operations began on May 18 on both banks. The majority of the salmon (83.2%) were counted along the south bank. In 2010, the estimated escapement of 923,732 salmon was 56% above the inriver goal and above the 10-year average. Sonar operations began on May 21 on the south bank and May 20 on the north bank. The majority of the salmon (74.3%) were counted along the south bank.

Key words Pacific salmon, *Oncorhynchus* spp., sockeye salmon *Oncorhynchus nerka*, escapement, sonar, Bendix, dual frequency identification sonar DIDSON, hydroacoustic, Copper River, Miles Lake.

INTRODUCTION

The Miles Lake sonar project is a long-term assessment project designed to provide annual estimates of escapement for sockeye salmon *Oncorhynchus nerka* in the Copper River. Copper River sockeye salmon are harvested in Prince William Sound (PWS) by commercial and subsistence fishermen and inriver by subsistence, sport, and personal use fisheries. Annual escapement estimates from the sonar project are used to set escapement goals and forecast run strength. Daily escapement estimates are used inseason to determine harvest schedules and to ensure escapement goals are met (Lewis et al. 2008).

Copper River sockeye salmon include delta stocks that spawn below the sonar site and are monitored primary by aerial surveys (Botz et al. 2008), upriver stocks that spawn north of the Chugach Mountains, and hatchery salmon propagated in the Gulkana River. Both wild and hatchery sockeye salmon stocks migrate past the sonar site, with the hatchery component representing 17.6% (1997–2006 average) of the upriver stocks (Botz et al. 2008). In 1996, the Alaska Board of Fisheries (BOF) directed the Alaska Department of Fish and Game (ADF&G) to manage the Copper River District commercial salmon fishery to achieve a biological escapement goal (BEG; the escapement that provides the greatest potential for maximum sustained yield) of 300,000 sockeye salmon into the Copper River, with additional fish beyond the goal to allow for subsistence, personal use, and sport fish harvests, and hatchery brood and surplus for the Gulkana Hatchery (Copper River District Salmon Management Plan 5 AAC 24.360). After initiation of the *Sustainable Salmon Fisheries Policy* (5 AAC 39.222), with definitions of sustainable escapement goals (SEG) and biological escapement goals (BEG), ADF&G developed an SEG of 300,000 to 500,000 fish because stock-specific catch information needed to establish a BEG was not available (Bue et al. 2002). An annual inriver goal is established each year that incorporates the SEG, upriver harvest forecasts, and hatchery brood stock.

Monitoring of salmon escapement by sonar in the Copper River began in 1978 using a Bendix[1] counter (Gaudet 1983, 1990) installed on the south bank of the river at the outlet of Miles Lake. The following year, Bendix counters were installed on both banks. Hydroacoustic methods were

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

selected for this project because they could provide daily escapement estimates and be placed reasonably close (generally a 3- to 5-day travel time between the district and sonar site) to the PWS commercial fisheries. Weirs and towers could only operate far upriver in smaller tributaries, and mark–recapture and similar studies could not provide daily estimates of abundance and are expensive to operate. Bendix counters are automated, echo-counting, single-beam sonars designed to count shore-based migrating salmon in rivers. The counters have been used to assess salmon runs in several Alaska rivers including the Kenai, Kasilof, Yentna, Crescent, Nushagak, Sheenjek, and Anvik rivers (Westerman and Willette 2013; Buck 2013; Dunbar 2003; Dunbar and Pfisterer 2004). Currently, these projects have either replaced, or are in the process of replacing, the aging Bendix counters with dual frequency identification sonars (DIDSON). Since 2008, Miles Lake has operated DIDSON on both banks (Appendix A1).

The DIDSON is a multiple beam sonar unit that produces high resolution, video-like images (Belcher et al. 2002; sample fish images at http://www.soundmetrics.com). At close range, DIDSON fish images resemble the actual fish shape. Farther offshore, the images become more blob-like, but are still easily detected because of their upstream movement. Unlike the Bendix counter, the DIDSON's narrow multiple beams and wide view field allow the user to determine the fish's direction of travel and individuals from multiple fish traveling side-by-side or head-to-tail. The DIDSON was first verified for the purpose of counting migrating salmon in 2002 by comparing Bendix and DIDSON counts to visual counts from an observation tower in a clear river (Maxwell and Gove 2004, 2007) and later by comparing DIDSON and weir counts (Holmes et al. 2006). The comparison showed strong levels of agreement between each sonar method and the visual count. The DIDSON's effective range in the turbid Copper River was approximately 17 m (Maxwell and Gove 2004, 2007). The standard range DIDSON (SR DIDSON) evaluated in the comparison study was selected for use on the south bank of the Copper River, where the nearshore current is strong and fish migration is expected to be close to the shoreline. Along the north bank, where the main current flow is farther offshore, an instrument that ensonified a longer range was needed. Sound Metrics Corporation developed a lower frequency, long range DIDSON (LR DIDSON) to fill this need.

Sonar systems are generally not capable of distinguishing one species of salmon from another. The Miles Lake sonar project does not have an on-site apportionment program to separate the sonar counts into species. Most sonar projects in Alaska have on-site programs that use drift gillnetting, beach seining, or fish wheels to apportion the sonar estimates to species (Buck 2013; Pfisterer 2002; Westerman and Willette 2013). These methods were attempted at the Miles Lake site, but few fish were captured (Brady 1986; Morstad et al. 1991). Although the target species of the Miles Lake project is sockeye salmon, other salmon species are present in low numbers. For example, the 10-year average of subsistence and personal use harvests from the Upper Copper River is 93.0% sockeye salmon 5.5% Chinook *O. tshawytscha,* 1.5% coho *O. kisutch*, and negligible pink *O. gorbuscha* and chum *O. keta* salmon (Botz et al. 2010). Sport fishing and aerial survey data also support the assertion that most salmon migrating up the Copper River are sockeye salmon (Botz et al. 2008). The primary apportionment need at the Miles Lake site is between sockeye and Chinook salmon, which overlap in run timing but end prior to any significant coho salmon passage (Botz et al. 2008). This apportionment need is met by subtracting Chinook salmon estimates obtained from upriver mark–recapture studies from the Miles Lake sonar estimates (Evenson and Wuttig 2000; Savereide and Evenson 2002; Savereide 2005; Van den Broek et al. 2008). Prior to 1998, sockeye salmon were apportioned from subsistence and personal use harvest compositions (Botz et al. 2008).

OBJECTIVES

There are 2 primary objectives for the Miles Lake sonar project report:

1. To estimate adult salmon passage rates in the Copper River; and,
2. To analyze river bottom profiles and on-site fish behavior.

METHODS

STUDY AREA

The sonar project is located downriver of the Million Dollar Bridge at the outlet of Miles Lake, Mile 48 of the Copper River Highway (Figures 1 and 2) and is the closest and narrowest single-channel site to the Copper River commercial fishing district located 53 km downriver (Figure 3). The Copper River is approximately 360 m wide at the sonar site, is highly turbid, measuring beyond 1,000 nephelometric turbidity units (Maxwell and Gove 2004), carries a sediment load averaging 69 million tons/year, and has a mean annual discharge of 1,625 m^3/s (Brabets 1997). The site is not tidally influenced, but water level can fluctuate 5 m or more during the summer due to upriver snowmelt, rainfall, and glacial melt (Faulkner and Maxwell 2008; Smith and Lewis 2006). The downriver Childs Glacier occasionally creates wave action and surges in water level, displacing the transducer mounts at the site, and ice calves from the upriver Miles Glacier frequently flow past the site. When heavy ice floes pass nearshore, the sonars are pulled from the water to prevent damage to equipment.

The Million Dollar Bridge underwent repairs from 2003 until the end of June in 2005 to raise a collapsed span on the north bank. A work pad was built in the river around the bridge abutment just upriver of the north bank sonar site. The work pad created a large back eddy extending downriver and significantly changing flow patterns, pushing the current 40 m offshore. There has been no evaluation of the impacts of the work pad on salmon movement and sonar operations.

The ideal river bottom for sonar sampling is linear in the offshore direction with laminar flows and a fine substrate material. Along the south bank of the sonar site, the river bottom is nonlinear with large cobble and boulders. Currently, a concrete pad along the south bank is used for deploying the SR DIDSON. The pad, in use since 2001, is 27.4 m x 5 m with a 13% grade and has an embedded iron rail used to slide the weir along (Smith and Lewis 2006). This pad replaced an older concrete pad located 50 m upriver that was damaged by icebergs. Originally, the Bendix counters were installed with 18.3 m aluminum tubes as substrates (Roberson et al. 1982). Although the aluminum tube provided a smooth, linear surface for the transducer beam, it was difficult to manage in the strong current along the south bank and was replaced after the first field season with the first concrete pad (Roberson et al. 1982). Along the north bank, the offshore slope is more linear and the substrate is made up of sand and small cobble. The natural substrate is used for deployment. In past years, grading has been done during low water conditions in the fall to make the slope more linear. The original aluminum tube substrates were discontinued in 1986 (Morstad et al. 1991).

SONAR OPERATIONS

South Bank Sonar

An SR DIDSON was deployed along the south bank. This DIDSON has 2 frequency options: 1.8 MHz with 96 beams (-0.3°x14°) limited to a 12 m range, and 1.1 MHz with 48 beams (0.4°x14°)

limited to a 4 m range, both with a 29° field of view. The DIDSON transducer was mounted on an H-shaped mount and positioned horizontally for sampling (Figure 4) and vertically for river bottom profiling (Figure 5). An aluminum cylinder protected the DIDSON transducer from ice floes. The DIDSON transducer was tilted with an automated Hydroacoustic Technology, Inc. model 661H rotator with relative feedback and controlled with a laptop computer. Absolute tilt information was obtained from an Applied Geomechanics, Inc. Model 802 attitude sensor aligned with the DIDSON beam and calibrated prior to deployment with a bubble level. Tilt and roll sensor data were displayed with the ZAGI33 program. The cabling from the transducer to the topside box consisted of a 15.2 m (50 ft) cable, a thinnet converter, and an additional 152.4 m (500 ft) cable. The equipment was powered with a 12V system that included solar panels, a generator, batteries, and inverters (Figure 6). The mount was deployed nearshore on the concrete substrate with the sonar beam directed perpendicular to the current flow. The transducer was kept at a relatively constant water depth by moving the mount as water level fluctuated. The nearshore end of the rail in the substrate was considered the zero mark, and numbers painted every 10 ft were used to track the transducer's position along the substrate. To prevent fish from passing undetected between shore and the DIDSON's start range, a weir (metal, chain-linked, A-frame connected to a floating net; Figure 7) was positioned 0.3–0.6 m downriver of the transducer and extended from shore to 1.8–2.4 m beyond the transducer.

DIDSON software[2] was used to collect and process data. The timer data entry function was set to automatically record 10 min/h files at the top of the hour using the following parameters: low frequency, 40 dB receiver gain, 0.82 m start range, 20 m window length (range), the default focal length, and a sampling rate of 8 frames per second (fps), the highest frame rate possible without losing frames. For counting sockeye salmon, sample designs of 10 min/h have been tested and proven satisfactory (Becker 1962; Seibel 1967). Sound speed, calculated from the water temperature (Simmonds and MacLennan 2005), was inputted into the DIDSON initialization file. Image files were processed using the background subtraction feature to remove static background structure, leaving only the objects in motion (Figure 8). Upriver and downriver fish were counted manually from the recorded files using separate tally counters. For an accurate count the frame rate was adjusted depending on fish passage rates: it was set at real time speed (8 fps) or slower at high fish passage (200+ fish/10 min), 2x recorded speed (16 fps) at medium passage (100–200 fish/10 min), and 3x recorded speed (24 fps) at low passage (0–100 fish/10 min). During playback, threshold was set low (2 dB) to avoid reducing fish detection and intensity was 47 dB to brighten fish targets without over-brightening the volume reverberation.

After subtracting the downriver counts, counts from the 10 min files were expanded to produce hourly estimates. If files were unexpectedly shortened, the actual minutes were used in the expansion. Counts were interpolated when 1 hour was missed by averaging the counts from 2 hours before and 2 hours following the missed sample. When 2 hours were missed, 3 hours before and after were averaged; for 3 missed hours, 4 hours before and after were averaged, and so on. The hourly counts were summed to obtain a daily salmon passage estimate. A variance was calculated based on the 10 min sample design using the V5 variance estimator described by Reynolds et al. (2007). Missed data were interpolated prior to calculating the variance. Data were written to external drives and archived on DVDs.

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[2] In 2008, DIDSON software v5.22.06 and in 2010 updated to v5.22.09.

North Bank Sonar

Replacement of the Bendix systems with DIDSONs in 2008 streamlined sonar operations so both banks were working with similar procedures. In 2009, a weir was constructed on the north bank. It was placed 0.5 m downriver of the transducer and extended from shore to 2.0 m beyond the transducer.

A LR DIDSON was deployed along the north bank. The LR DIDSON has low (0.7 MHz) and high (1.2 MHz) frequency options that are range dependent. The low frequency beam widths are 0.8°x14°, the high frequency 0.5°x14°; both have 48 beams spanning a 29° field of view. The LR DIDSON was mounted on an H-frame similar to the one used for the SR DIDSON, and tilted using an Remote Ocean Systems (ROS) rotator with relative feedback. An internal Honeywell sensor within the DIDSON transducer housing provided absolute tilt, roll, and compass feedback.

Data were collected and processed using DIDSON software v5.22.06 (2010–v5.22.09). DIDSON files were sent from the north bank to a computer on the south bank via a wireless connection. The north bank computer saved backup recordings and internal/integrated sensor information as well as controlling the north bank DIDSON transducer alignment. The software was set to automatically record 10 min/h files twice an hour: at the top of the hour and at the quarter hour. The first recorded the nearshore zone (range 1–10 m) with specific parameters: high frequency, 40 dB receiver gain, 0.82± m window start, ≤10 m window length, and a sampling rate of 8 frames per second (fps). The second recorded the offshore zone (range 1,0–50 m) with specific parameters: low frequency, 40 dB receiver gain, ≤10 m window start , ≤40 m window length, and a sampling rate of 5 frames per second (fps). Parameters were adjusted as water level and turbidity changed.

PROFILES AND AIMING

River bottom profiles in the region of the sonar beam were produced using the SR and LR DIDSONs on the south bank and the LR DIDSON on the north bank following methods described by Maxwell and Smith (2007). We obtained profiles perpendicular to the shoreline (or current flow) starting from nearshore and extending to the maximum range of the sonar (Figure 9). The profiles served 2 functions. The primary function was to determine an optimum aim for each transducer that would position the sonar beam along the river bottom across the sampling range. An aiming protocol to accomplish this required exporting information from the DIDSON to plot the river bottom profile, using tilt sensor data to determine the tilt angle of the transducer, measuring the position of the transducer, and then modeling the optimal aim of the transducer in relation to the river bottom (Faulkner and Maxwell 2009). A secondary function for obtaining river bottom profiles was to determine whether the river bottom and river conditions were suitable for sonar. Inaccuracies can occur in the count if the sonar beam cannot be positioned evenly along the river bottom or if the sonar is range limited due to slope changes or high turbidity.

ENVIRONMENTAL DATA

Environmental data were collected daily. Water level (elevation above mean sea level) was measured at 0700 and 1900 hours (2008: 0800 and 2000 hours) each day using a U.S. Geological Survey gauge mounted on the Million Dollar Bridge. Water and air temperatures were measured and the degree of cloud cover estimated.

DATA ANALYSES AND REPORTING

The DIDSON counts were recorded on paper data forms and entered into Microsoft Excel worksheets. The prior day's counts, current day's counts through 0600 hours (0000–0500 hours), and water level were reported daily to fishery managers.

Daily and cumulative salmon passage estimates summed across both banks were plotted in a time series and compared against anticipated and historical estimates. To aid in management of the Copper River sockeye salmon run, anticipated daily and cumulative counts were generated for the duration of the field season and compared daily to the sonar estimates of salmon passage. A forecast of salmon returns each year was applied to the inriver goal and average run-timing curve to generate these anticipated passage estimates (Steve Moffitt, PWS Area Research Biologist, personal communication).

Migrating fish behavior was analyzed by examining bank preferences, hourly passage rate, and upriver and downriver movement. Bank preferences were observed by plotting a time series of daily counts by bank and determining the percentage of total fish monthly passage per bank per month. Data from across the field season were aggregated by hour to examine diurnal patterns. Upriver and downriver fish movements were plotted on a daily time series, and the total and daily percentages of downriver-moving fish were determined. To determine whether water level effects run timing, we ran an ordinary least squares regression between the 2 variables.

QUALITY CONTROL MEASURES

Several quality control measures were in place. Regional sonar staff ensured the field crew was properly trained in DIDSON set up and daily operations as well as in the interpretation of DIDSON images. The crew leader carried out quality control by spot checking counts made by technicians, especially new technicians, and retraining when necessary. In addition, the crew leader or a second technician rechecked the data entry daily.

RESULTS

2008

The 2008 Copper River inriver goal was 615,000–815,000 wild and enhanced salmon. Based on this, the cumulative minimum inriver escapement objective by the end of sonar operation was 601,125 salmon to pass the sonar site. The cumulative estimated escapement of 713,544 salmon exceeded the minimum objective by 19.5% (Table 1). Cumulative estimated escapement was below the anticipated escapement until July 3, and then exceeded the minimum for the remainder of the season (Figure 10). There were 2 daily peaks during the salmon run: 27,566 salmon on June 3 and a larger peak on July 4 of 35,964 (Figure 11). The south bank accounted for 80.2% of the total seasonal escapement and the north bank accounted for 19.8% of the escapement (Figure 12).

The 2008 daily escapement was below the historical average (1978–2007) for the majority of the season. Daily escapements had 2 large and 5 small peaks, each surpassing the historical average (Figure 13). The 2008 cumulative escapement curve was below the recent 10-year (1998–2007) average curve for the entire season (Figure 14).

Water level in 2008 was generally lower than the historical average (1982–2007), with 2 peaks exceeding the historical average on May 30 and June 23 (Figure 15). There was no discernible relationship between salmon passage and water level (Figure 16). Sound speed as determined by water temperature varied over the season from 1,411.8 m sec^{-1} to 1,443.0 m sec^{-1}.

North Bank Sonar Operations

In 2008, the north bank DIDSON was deployed on May 16 and operated until August 3. A profile was completed on May 17 with the DIDSON transducer located 188.5 ft south of the sonar shack and a pitch of -8.2°. The top of the lens was 6 inches from the surface of the water in a depth of 23 inches. Tilt varied throughout the season from -2.5° at the start and decreasing to -3.6° on June 17. Tilt was held at -3.6° for the remainder of the season and was only changed twice to -4.6° on June 23 and July 16–20. The bearing remained constant at 157.3° until May 30 when it was changed to 154.0° to place the DIDSON perpendicular to the current. Roll was variable throughout the season and ranged from -2.9° to 2.6°

A total of 414,798 salmon passed the north bank sonar site (Table 1). Peak daily passage of 8,530 salmon occurred on June 2, with smaller peaks occurring on June 11 (3,768 salmon), June 15 (3,198 salmon), and July 3 (4,020 salmon) (Figure 12). The percent of salmon that migrated along the north bank varied each month from 13.2% to 30.7% (Table 1). During each month, salmon passage was generally higher in the afternoon (Figure 17). Salmon moving downriver averaged 4.1% of all fish targets, peaking on June 3 when 300 salmon moved downriver. The percent of downriver fish was highest on July 14 when downriver fish made up 12.2% of the total salmon counted that day (Figure 18).

South Bank Sonar Operations

In 2008, the south bank DIDSON was deployed on May 15 and operated until August 3. A profile was completed on May 15 with the DIDSON transducer located at the end of the substrate and a pitch of 7.4° and roll of -8.6°. The DIDSON transducer was off the concrete substrate where water depth was 27 inches, and the top of the lens was 9.5 inches below the water's surface. The DIDSON transducer was moved to the substrate on May 21 and reached a minimum distance of 30.5 feet on July 16. Pitch varied throughout the season between -6.9° and -8.4°. Roll also varied throughout the season with values between 4.6° and -4.3°.

A total of 571,746 salmon passed the south bank sonar site (Table 1). Peak daily passage of 33,180 salmon occurred on July 4, with smaller peaks occurring on June 3 (20,442 salmon), June 11 (13,788 salmon), and June 27 (10,176 salmon) (Figure 12). The percent of salmon migrating along the south bank varied by month from 69.3% to 86.8% (Table 1). During each month, salmon passage was generally higher in the afternoon (Figure 19). Salmon moving downriver averaged 4.1% of all salmon targets, peaking on July 5 when 1,776 salmon moved downriver. The percent of downriver fish was highest on July 11 when downriver fish made up 10.8% of the total salmon counted that day (Figure 20).

2009

The 2009 Copper River inriver goal was 592,000–792,000 wild and enhanced salmon. Based on this, the cumulative minimum inriver escapement objective was 576,818 salmon past the sonar site. The cumulative escapement of 707,413 salmon exceeded the minimum objective by 23.0% (Table 1). Cumulative escapement was above the anticipated escapement until June 4, fell below the anticipated escapement until June 18, and then exceeded the anticipated escapement for the remainder of the season (Figure 21). There were 3 large daily peaks during the sonar season: 18,813 salmon past on May 25, a smaller peak on June 17 of 16,549 salmon, and a third smaller peak of 14,376 salmon past on July 19 (Figure 22). The south bank accounted for 83.2% of the total seasonal escapement and the north bank accounted for 16.8% of the escapement (Figure 23).

The 2009 daily escapement was generally above the historical average (1978–2008) for the majority of the season except for a 2-week period at the beginning of June. Daily escapements had 3 large and 3 small peaks, each surpassing the historical average (Figure 24). The 2009 cumulative escapement curve exceeded the previous 10-year (1999–2008) average curve until June 6 then fell below the average for the remainder of the season (Figure 25).

The water level in 2009 was higher than the historical average (1982–2008) except for 2 periods June 19 to July 7 and July 24 to July 28 (Figure 26). There was a general decrease in daily salmon passage as river levels increased (Figure 27). Sound speed as determined by water temperature varied over the season from 1,430.6 m sec^{-1} to 1,455.7 m sec^{-1}.

North Bank Sonar Operations

In 2009, the north bank DIDSON was deployed on May 18 and operated until August 3. A profile was completed on May 19 with a tilt of 3.0° and a roll of 2.6°; the bearing was 173°. Tilt was adjusted several times from -2.0° to -8.0° throughout the early portion of the season before stabilizing at -6.0° on June 21; it remained at -6.0° until the end of the season. The bearing remained constant for the season.

A total of 118,322 salmon passed the north bank sonar site (Table 1). Peak daily passage of 5,472 salmon occurred on July 1, with smaller peaks occurring on July 19 (3,930 salmon) and June 2 (3,036 salmon) (Figure 23). The percent of salmon migrating along the north bank varied by month from 10.0% to 25.6% (Table 1). During each month, salmon passage was generally higher in late afternoon and evening (Figure 28). Salmon moving downriver averaged 5.6% of all salmon targets, peaking on May 26 when 480 salmon moved downriver. The percent of downriver fish was highest on May 25 when downriver fish made up 14.3% of the total salmon counted (Figure 29).

South Bank Sonar Operations

In 2009, the SR DIDSON was broken and replaced with another SR DIDSON #243. It was deployed on May 18 and operated until August 3. A profile was completed on May 19 with the DIDSON transducer located at the end of the substrate and a tilt of -7.0°. The tilt was adjusted only once, down to -8.4° on May 24, before returning to -7.0° for the remainder of the season. A total of 589,091 salmon passed the south bank sonar site (Table 1). Peak daily passage of 16,368 salmon occurred on May 25, with smaller peaks occurring on May 29 (15,550 salmon), June 17 (16,045 salmon), and July 19 (10,446 salmon) (Figure 23). The percent of salmon migrating along the south bank varied by month from 74.4% to 90.0% (Table 1). During each month, salmon passage was generally higher in the afternoon (Figure 30). Salmon moving downriver averaged 6.4% of all salmon observed passing the sonar station and peaked on July 18 when 1,500 salmon moved downriver. The percent of downriver fish was highest on August 1 when downriver fish made up 18.9% of the total salmon counted that day (Figure 31).

2010

The 2010 Copper River inriver goal was 667,590–867,592 wild and enhanced salmon. Based on this, the cumulative minimum inriver escapement objective was 592,051 salmon past the sonar site. The cumulative escapement of 923,732 salmon exceeded the minimum objective by 56% (Table 1). Cumulative escapement was below the anticipated escapement until July 4, and then exceeded anticipated escapement for the remainder of the season (Figure 32). There were 2 daily peaks during the sonar season: 26,109 salmon on June 4, and a larger peak on July 9 of 31,188 salmon (Figure 33). The south bank accounted for 74.3% of the total seasonal escapement and the north bank accounted for 25.7% of the escapement (Figure 34).

The 2010 daily escapement was generally above the historical average (1978–2009) for the majority of the season except for a 2-week period from June 9 to June 25. Daily escapement had 2 large peaks surpassing the historical average (Figure 35). The 2010 cumulative escapement curve was generally below the previous 10-year (2000–2009) average until July 9 then exceeded the average curve for the remainder of the season (Figure 36).

Water level in 2010 was higher than the historical average (1982–2009) for the first 3 weeks of the season then fell below the historical average for the remainder of the season (Figure 37). There was a general increase in daily salmon passage as river levels increased (Figure 38). Sound speed as determined by water temperature varied over the season from 1,416 m sec^{-1} to 1,432 m sec^{-1}.

North Bank Sonar Operations

In 2010, the north bank DIDSON was deployed on May 20 and operated until July 31. The tilt angle of the DIDSON was adjusted throughout the season as the DIDSON was moved up the bank with increasing water height. The tilt ranged from -1.5° at the beginning of the season to -5.0° at the highest water level.

A total of 237,776 salmon passed the north bank sonar site (Table 1). Peaks in daily passage occurred on June 6 (8,127 salmon) and July 9 (7,938 salmon) (Figure 34). The percent of salmon migrating along the north bank varied by month from 20.6% to 26.8% (Table 1). Salmon passage in May was generally higher in the afternoon but showed no pattern in June and July (Figure 39). Salmon moving downriver averaged 3.61% of all salmon observed, peaking on July 9 when 594 salmon moved downriver. The percent of downriver fish was highest on July 9 when downriver fish made up 9.8% of the total salmon counted that day (Figure 40).

South Bank Sonar Operations

In 2010 the south bank DIDSON was deployed on May 21 and operated until July 31. Low water prevented sonar deployment on the south bank’s concrete substrate at the start of the field season so it was deployed in the dip immediately offshore. As water levels rose and exposed the concrete substrate, the DIDSON was repositioned near the 95 foot mark on the substrate. An initial off-substrate tilt of -6.0° was established, and adjusted to -8.5° when the DIDSON was moved to the concrete substrate, and finally to -7.0° for the remainder of the season

A total of 685,956 salmon passed the south bank sonar site (Table 1). There were 2 distinct peaks in daily passage, one in the beginning of the season on June 3 of 21,762 salmon, and the other on July 9 with 23,250 salmon (Figure 34). The percent of salmon migrating along the south bank varied each month from 73.2% to 79.4% (Table 1). During each month, salmon passage was generally higher in the late afternoon and early evening (Figure 41). Salmon moving downriver averaged 2.70% of all salmon observed and peaked on June 2 with1,074 salmon. The percent of downriver fish was highest on June 2 when downriver fish made up 5.43% of the total salmon counted that day (Figure 42).

DISCUSSION

Management of commercial salmon fisheries in Copper River District is based primarily on the Miles Lake sonar salmon escapement estimates. Daily and cumulative sonar escapement estimates are compared to anticipated daily and cumulative objectives related to the inriver goal. The commercial fishery is opened as the daily and cumulative sonar estimates are expected to approach or exceed the anticipated estimates. When the first commercial opening happens prior to sonar deployment, early season management is based on actual harvest versus the anticipated harvest related to the preseason forecast and inriver goal. In 2008, the cumulative salmon passage was below anticipated for the first half of the season. The first commercial opening occurred on May 15 for 12 hours. However, openings were not consistent due to low commercial harvest compared to the anticipated levels and the cumulative escapement estimate remaining below the expected cumulative estimate (Bell et al. 2010). Conversely, in 2009, the cumulative estimate of salmon passage by the sonar exceeded the anticipated levels from the beginning of the season so the commercial fishery proceeded with limited restrictions (Botz et al. 2010). Finally, the 2010 season started similar to 2008 with actual cumulative sonar passage below anticipated counts. Additionally, the commercial harvest was below anticipated levels. As a result, commercial fishing began on May 13 but was not opened on a consistent basis due to low escapement numbers (Botz et al. 2012)

Patterns of fish passage are important to site selection and data collection. The majority of the salmon passing the Miles Lake sonar site migrate along the south bank and range distribution indicates that few, if any, fish travel beyond the maximum effective range of the sonar (El Mejjati et al. 2010). Although it is not completely understood why the majority of migrating salmon use the south bank given its higher flow velocities, it is thought that their distribution in the sampling range is intentional. Historically, north bank range data show salmon distribution throughout the sampling range of the sonar, a marked difference from the tight near shore distribution on the south bank. This phenomenon may be attributed to energy expenditure. In high water velocities such as on the south bank, salmon may be found closer to shore attempting to minimize energy expenditure by taking advantage of lower water velocities associated with the shore and bottom (Brett 1995; Webb 1995; Quinn 2005; Hughes 2004; Standen et al. 2004). At the Miles Lake site, the current flow is strong along the south bank, but a back eddy exists along the north bank. The north bank, with a smoother, linear slope, reduced current flow, and main current flow farther offshore, allows the salmon to spread out.

Traditionally, the percentage of total fish passage observed along the north bank is low. This low percentage may be partly due to the effects of the Childs Glacier located downstream along the north bank. The glacier is actively calving, and it extends to the edge of the river. The similarity in north bank fish passage percentages across years also indicates the bridge work conducted in 2003–2005 may not have substantively affected fish passage. The construction work permanently altered the flow patterns along the north bank creating the large, nearshore back eddy. There was concern fish may have moved approximately 40 m offshore to the region where the current flow begins, beyond the sonar’s range. If fish have been pushed farther offshore along this bank, the numbers are so few that the effects are negligible. A more pressing concern for this side of the river is that a weir has never been used to prevent fish from passing inshore of the transducer. It has always been assumed that the slower current along this shore and the shallower bottom keeps fish offshore. Late into the 2009 and all of the 2010 season, a floating weir was installed downriver from the north bank transducer. This may be one cause of the increase in north bank passage in 2010.

Using DIDSON on both banks has streamlined the sonar project. With the exception of the north bank weir, there have been no procedural changes in the project over the last 3 years. There have been some changes to camp and project set up. The Miles Lake field camp was deployed using snowmachines in 2010. Typically, the Miles Lake site is deployed when the Copper River Highway is cleared of snow. In 2010, machinery issues threatened to delay the road opening, so snowmachines were used to tow equipment to the site. Because of its success, we anticipate using snowmachines in subsequent years. Further, this may provide an opportunity to install the DIDSON earlier than previous years. Finally, in fall of 2010, the old camp bunkhouse was removed and replaced with a single story 4-room bunkhouse.

ACKNOWLEDGEMENTS

Thanks go to the Miles Lake sonar crew: Breena Apgar-Kurtz, Shane Shepherd, and Guillermo Gonzales. Additional thanks to ADF&G personnel Susie Maxwell and April Faulkner for guidance on all things DIDSON; Glenn Hollowell and Jeremy Botz for overseeing operations and providing support; Amanda Weise for her help in finalizing the report; and Shannon Royse for publication support.

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TABLES AND FIGURES

Table 1.–North and south bank sonar escapement estimates by month from the Miles Lake sonar site at the Copper River, 1998–2010.

	May				June				July			
Year	North	South	% North	%South	North	South	% North	%South	North	South	% North	%South
1998[a]	ND	ND			9,495	386,319	2.4	97.6	12,636	258,399	4.7	95.3
1999	870	15,791	5.2	94.8	15,494	374,716	4.0	96.0	23,105	389,923	5.6	94.4
2000	14,137	29,326	32.5	67.5	27,303	285,101	8.7	91.3	11,892	213,214	5.3	94.7
2001	36,208	167,774	17.8	82.2	16,856	321,235	5.0	95.0	41,186	236,327	14.8	85.2
2002	2,602	51,027	4.9	95.1	17,519	305,983	5.4	94.6	27,169	415,590	6.1	93.9
2003	12,692	99,319	11.3	88.7	25,776	349,375	6.9	93.1	29,744	183,637	13.9	86.1
2004	8,688	180,067	4.6	95.4	10,768	320,346	3.3	96.7	2,068	147,577	1.4	98.6
2005	24,920	176,793	12.4	87.6	62,290	362,407	14.7	85.3	44,984	183,730	19.7	80.3
2006	17,932	104,708	14.6	85.4	64,704	462,174	12.3	87.7	48,322	261,866	15.6	84.4
2007	6,039	110,832	5.2	94.8	48,504	415,344	10.5	89.5	50,056	261,330	16.1	83.9
2008	29,282	66,124	30.7	69.3	73,306	248,156	22.8	77.2	39,210	257,466	13.2	86.8
2009	23,131	144,294	13.8	86.2	27,598	248,299	10.0	90.0	67,593	196,498	25.6	74.4
2010	19,524	75,209	20.6	79.4	100,392	274,501	26.8	73.2	117,860	336,246	26.0	74.0
Average	13,788	103,960	14.5	85.5	29,871	358,300	10.2	89.8	29,116	255,159	12.9	87.1

[a] North bank was not deployed until June 5.

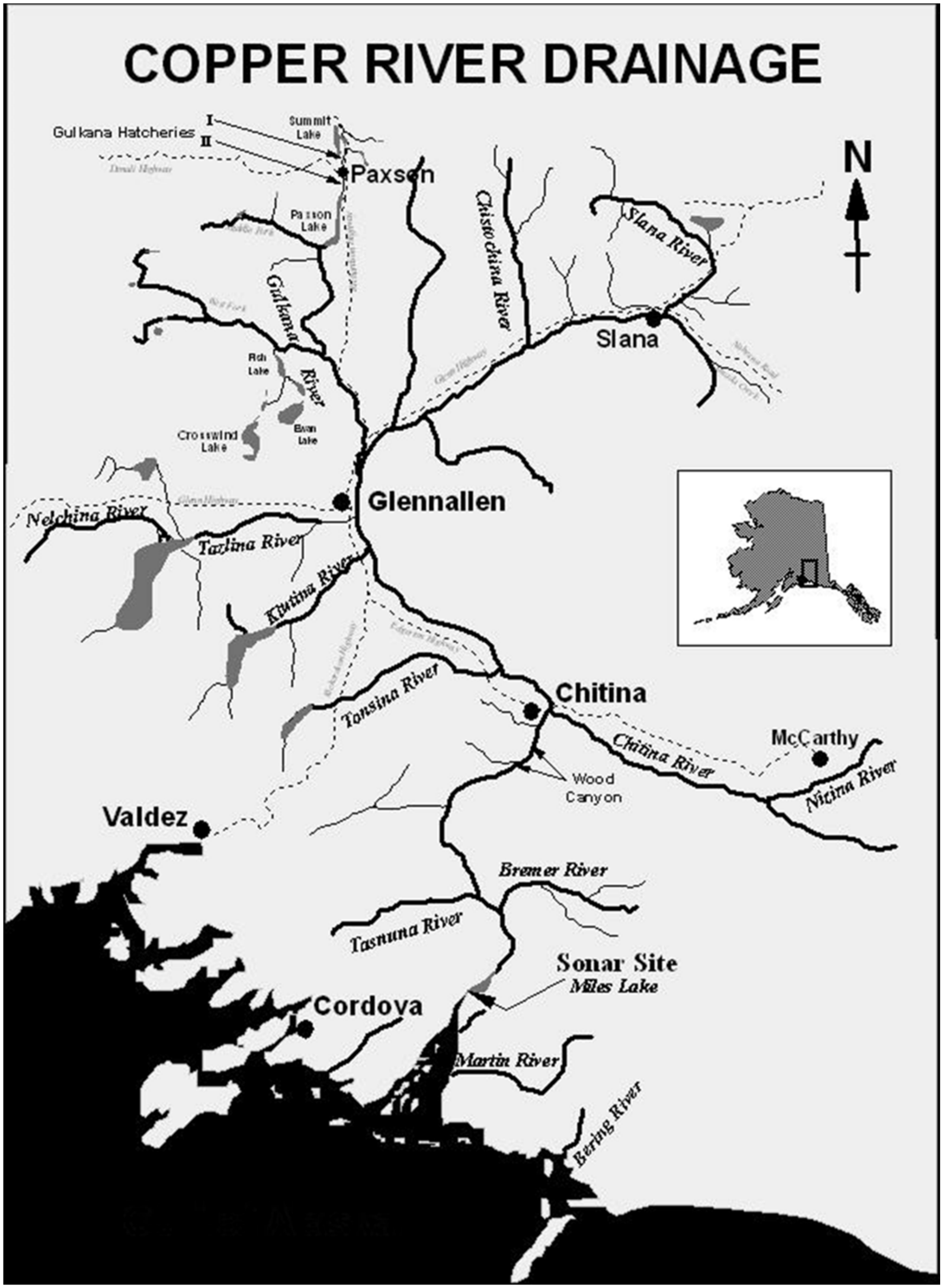


Figure 1.–Copper River drainage showing the Miles Lake sonar site.

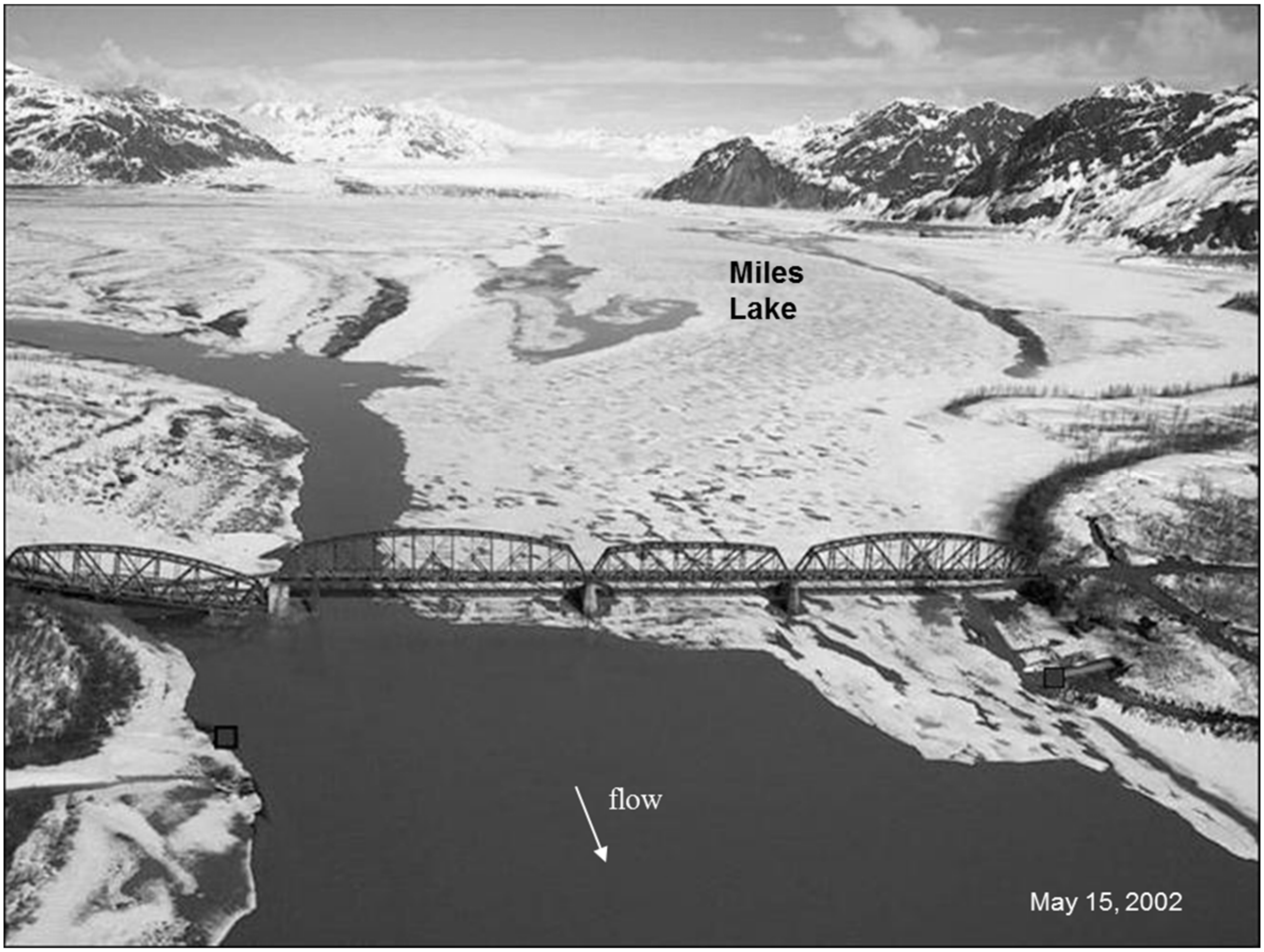


Figure 2.–The Copper River at mile 48 of the Copper River Highway showing the Million Dollar Bridge.

Note: The north and south bank deployment sites are indicated by the shaded markers, and the concrete substrate visible on the south bank.

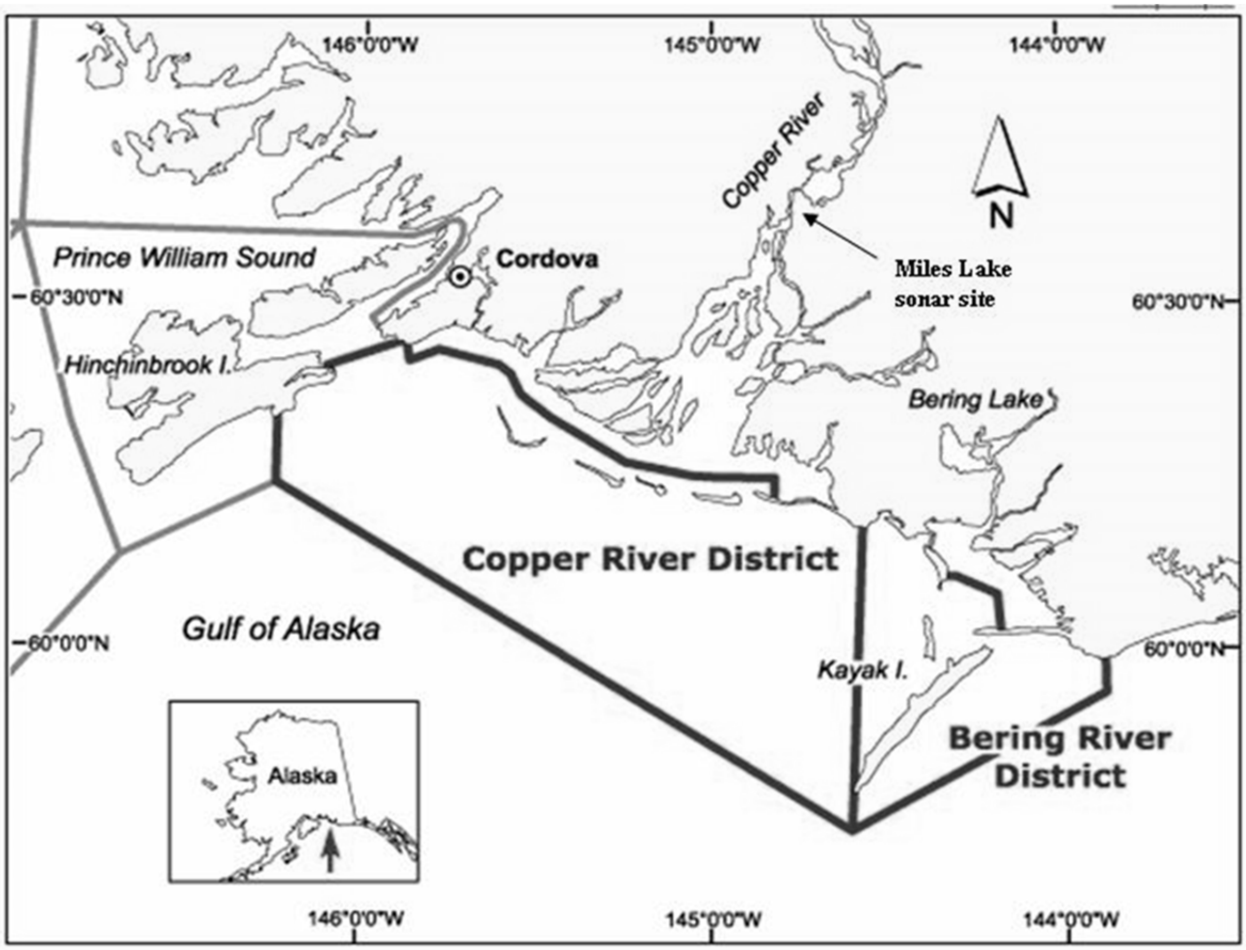


Figure 3.–The location of the Miles Lake sonar site 53 km upriver of the Copper River District commercial salmon fishery.

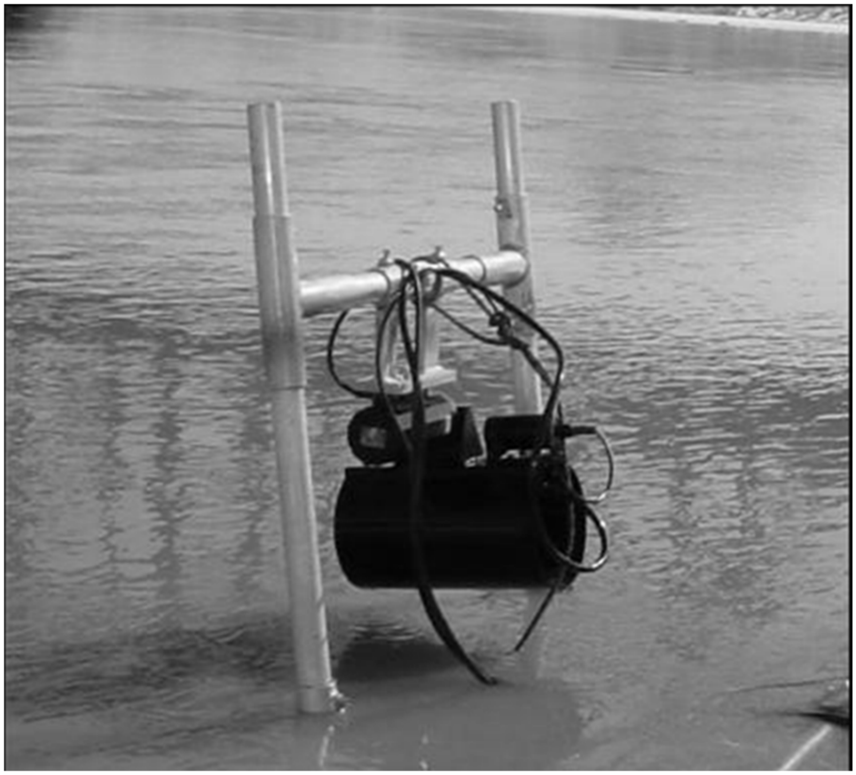


Figure 4.–A DIDSON positioned horizontally for estimating salmon passage, encased in an aluminum cylinder, attached to a single-axis, automated rotator mounted to an aluminum H-mount, with an attached tilt and roll sensor along the Copper River's south bank, Miles Lake sonar.

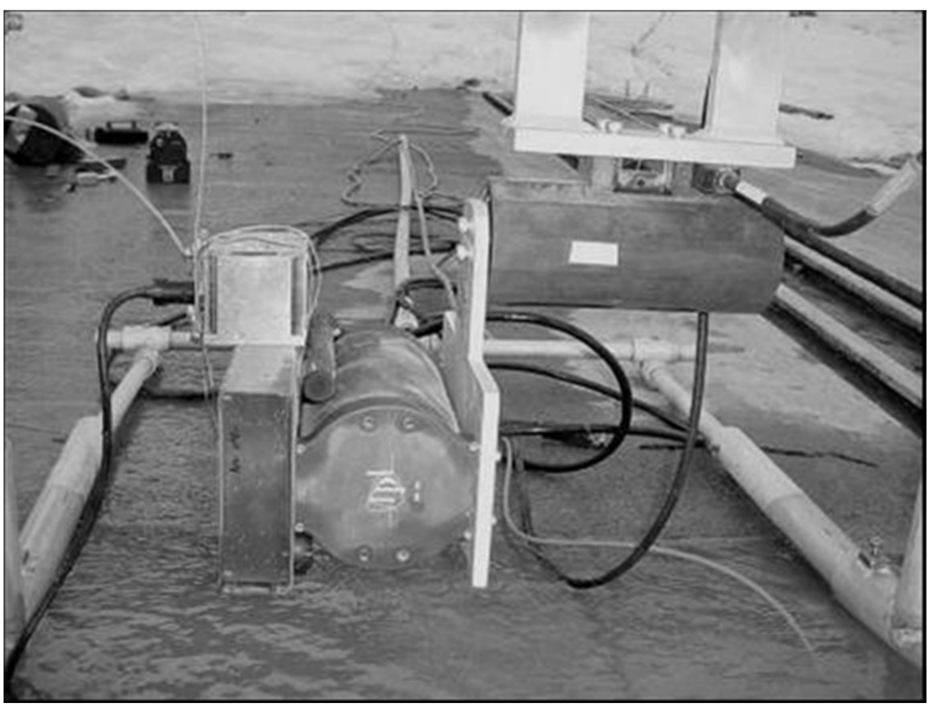


Figure 5.–A DIDSON mounted vertically to record river bottom profiles along the Copper River, Miles Lake sonar.

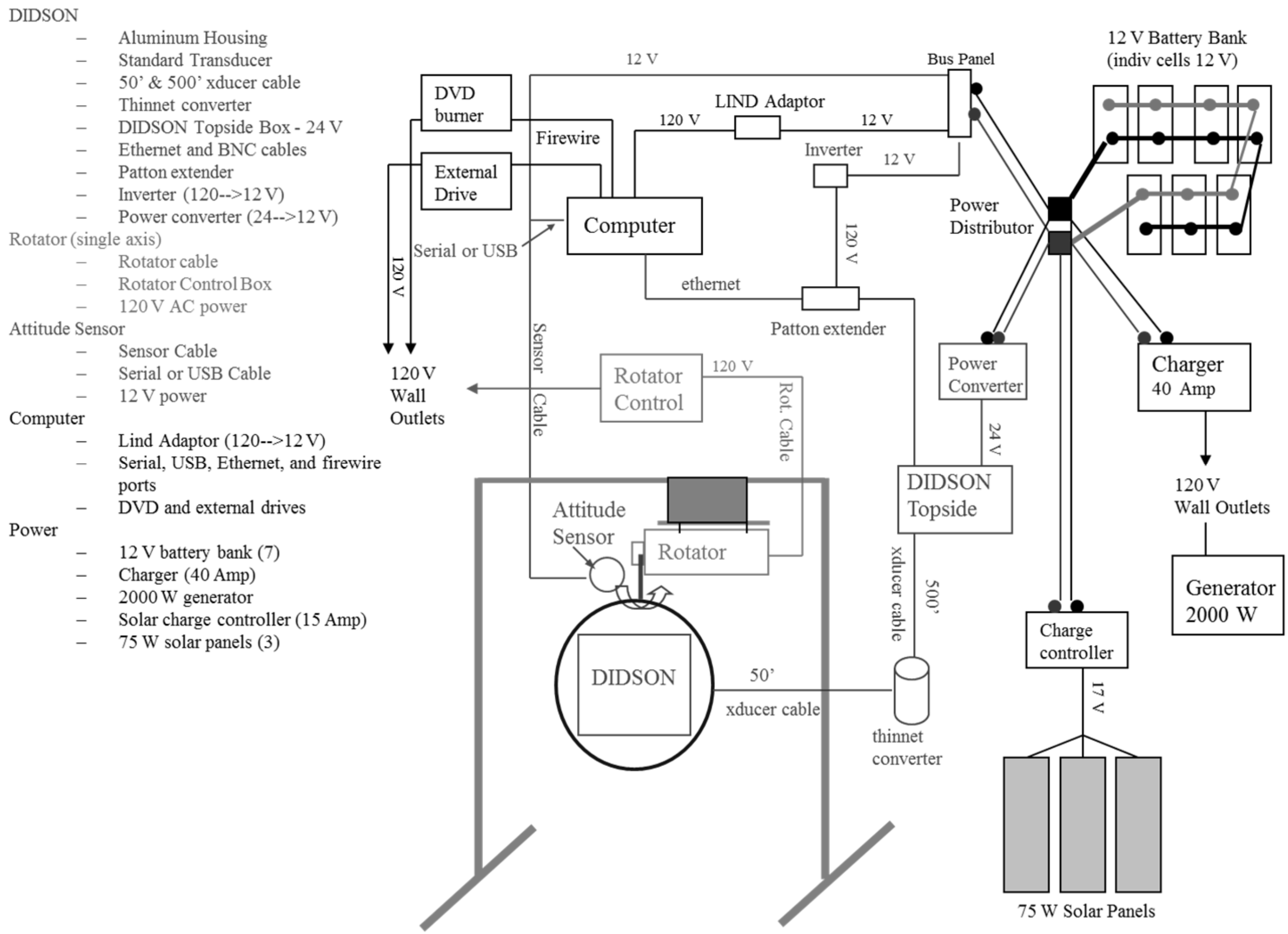


Figure 6.–Diagram of the DIDSON setup along the south bank, Miles Lake sonar project.

Figure 7.–The south bank weir on the downriver side of the DIDSON at the Copper River, Miles Lake sonar.

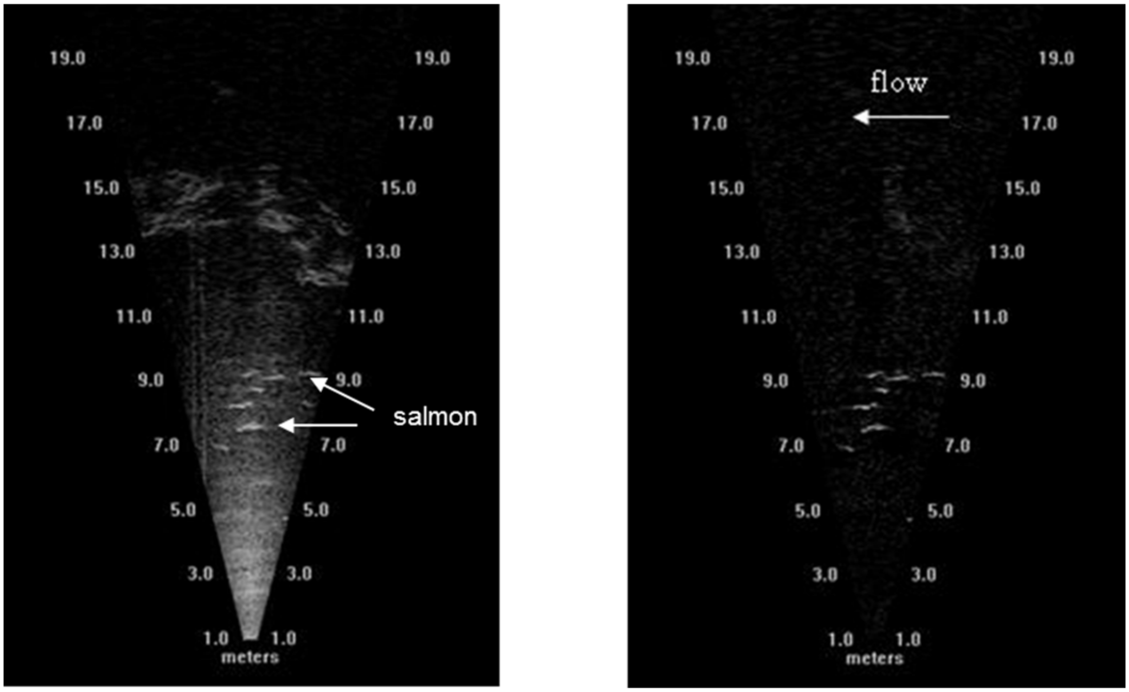
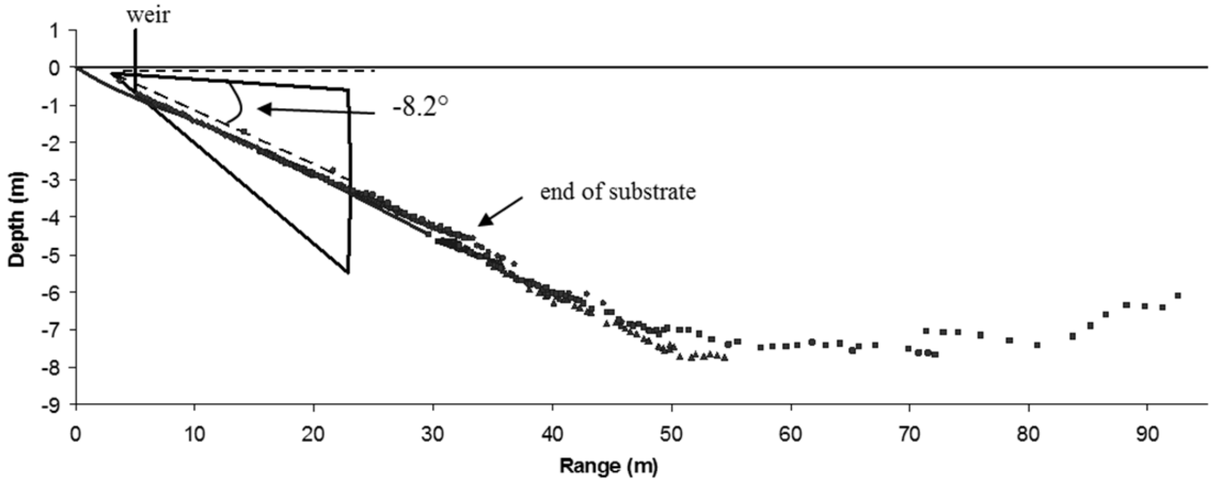


Figure 8.–A raw DIDSON image of migrating salmon (left) and the same image processed using the DIDSON's background subtraction algorithm (right), Copper River south bank, Miles Lake sonar, June 8, 2005.



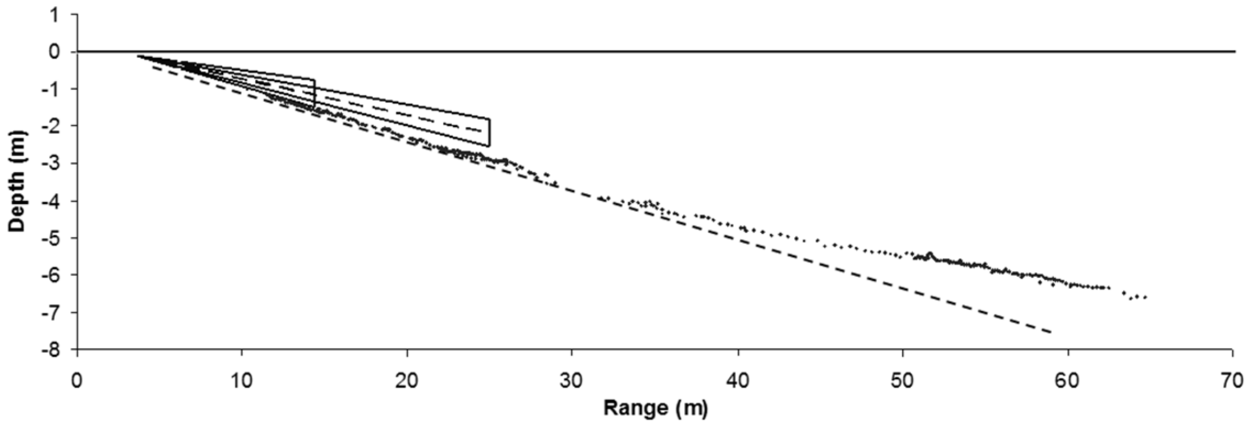


Figure 9.–River bottom profiles of the Copper River south bank concrete pad and beyond (top) and the north bank site (bottom), Miles Lake sonar site.

Note: Profiles were created with the DIDSON at multiple positions merged based on each transducer position measured from a fixed point along the shore.

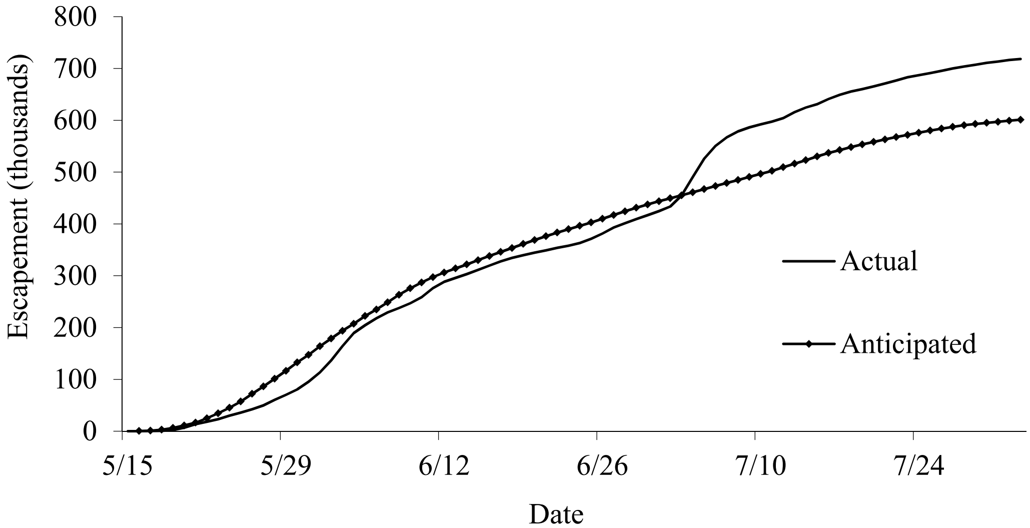


Figure 10.–Cumulative actual and anticipated salmon escapement estimates for the Miles Lake sonar project, 2008.

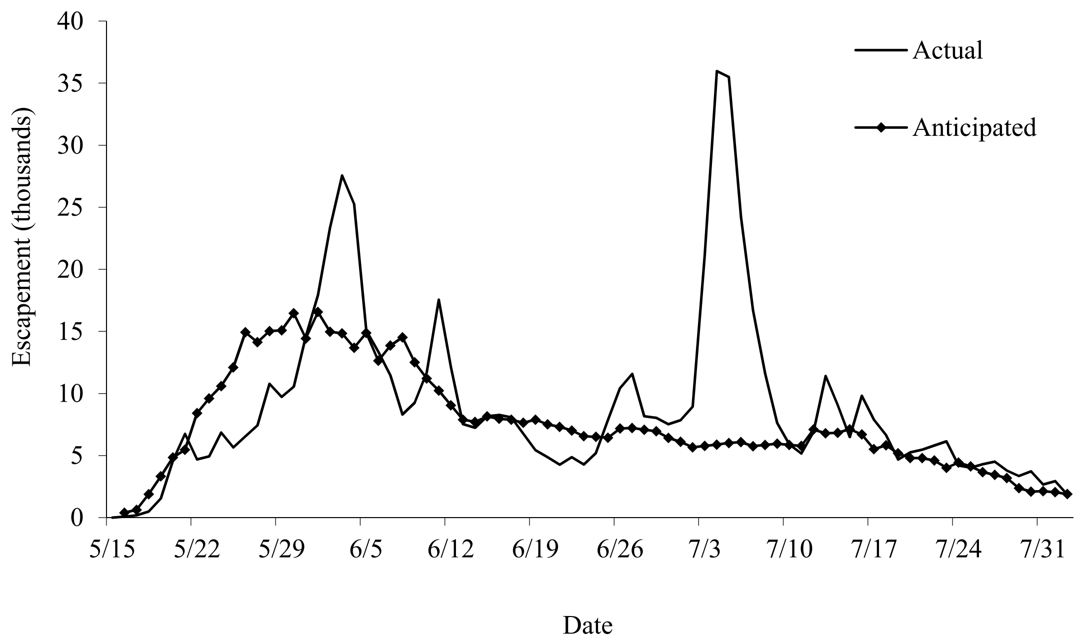


Figure 11.–Daily actual and anticipated salmon escapement estimates for the Miles Lake sonar project, 2008.

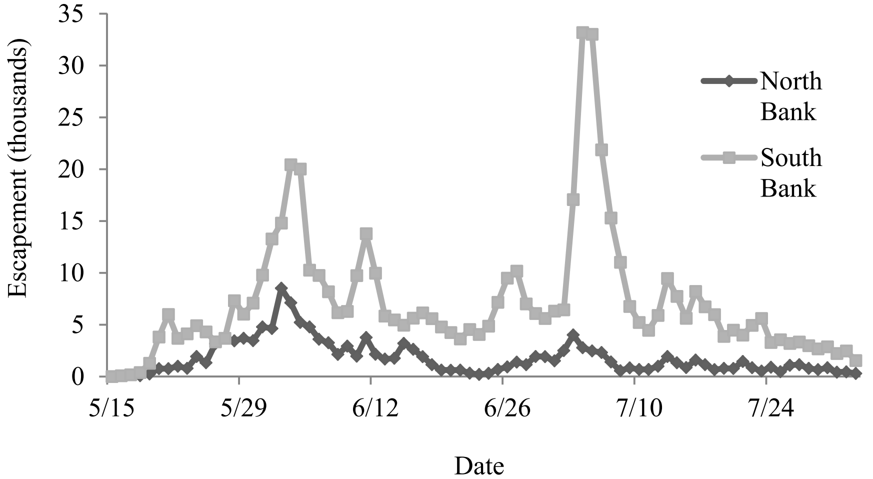


Figure 12.–Daily salmon escapement estimates by bank, Miles Lake sonar project, 2008.

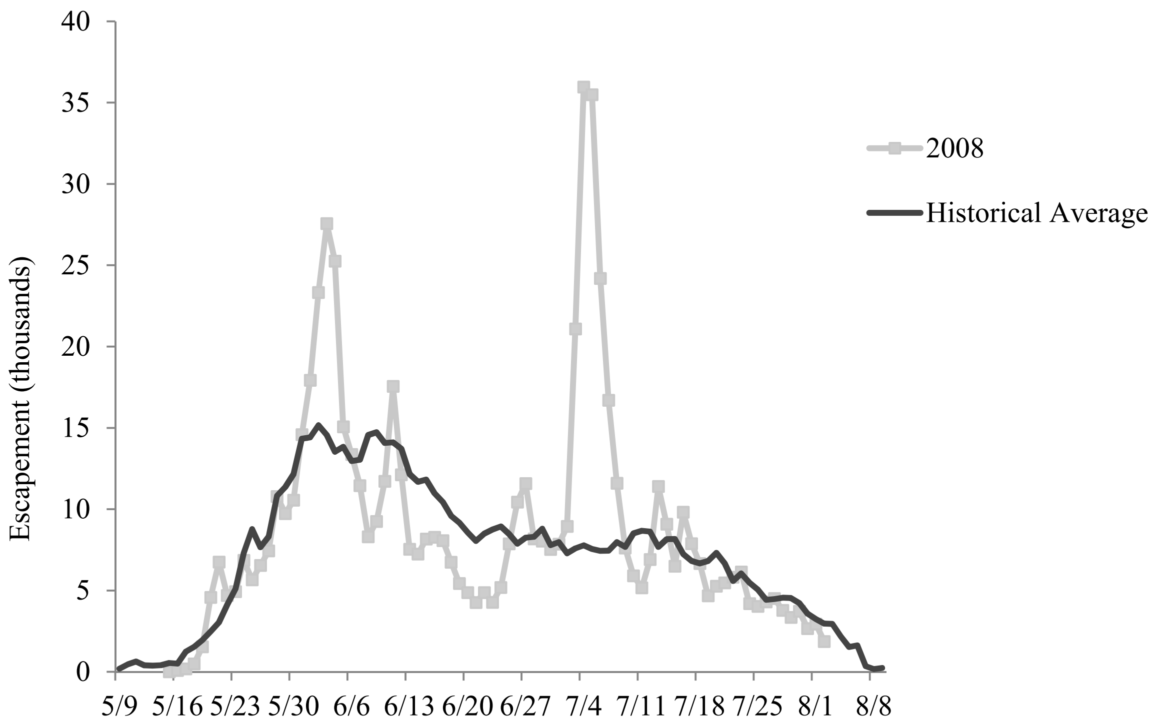


Figure 13.–Daily 2008 salmon escapement estimates compared to the historical average (1978–2007) for the Miles Lake sonar project.

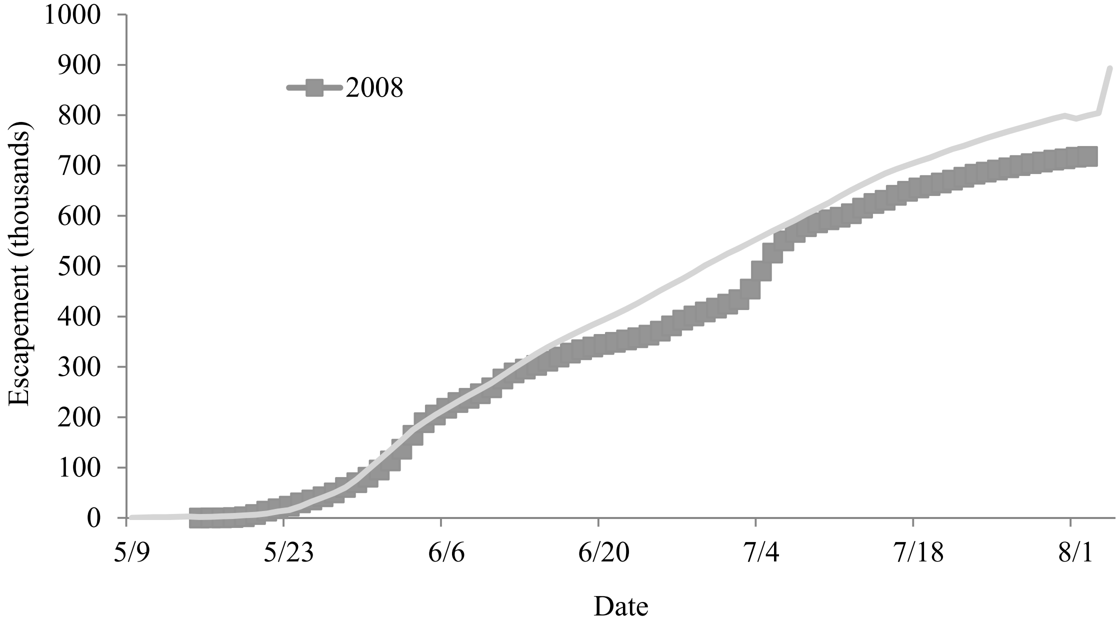


Figure 14.–Cumulative 2008 salmon escapement estimate compared to the historical average (1998–2007) for the Miles Lake sonar project.

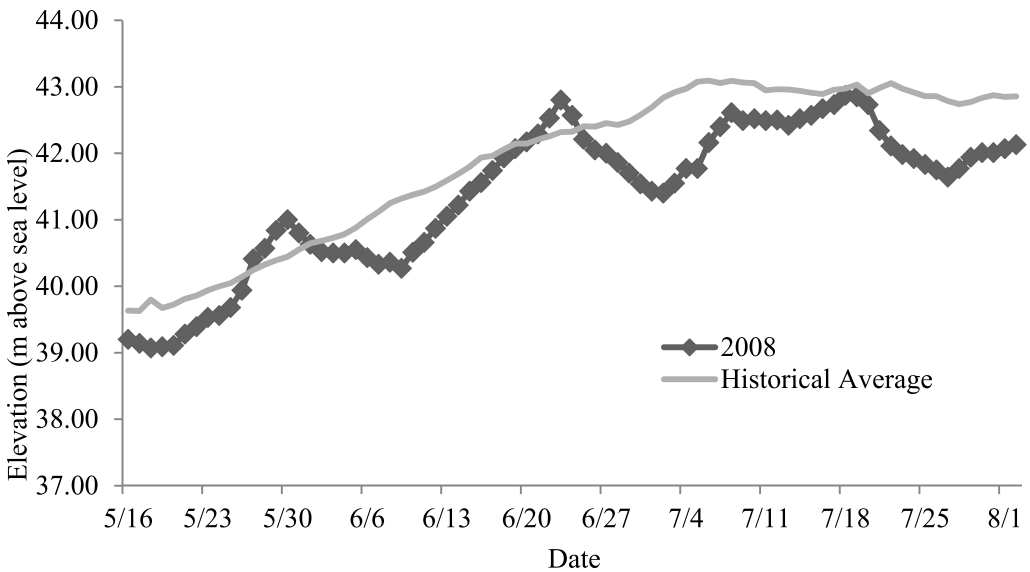


Figure 15.–Water level (elevation above sea level) for 2008 compared to the historical average (1982–2007) for the Miles Lake sonar project.

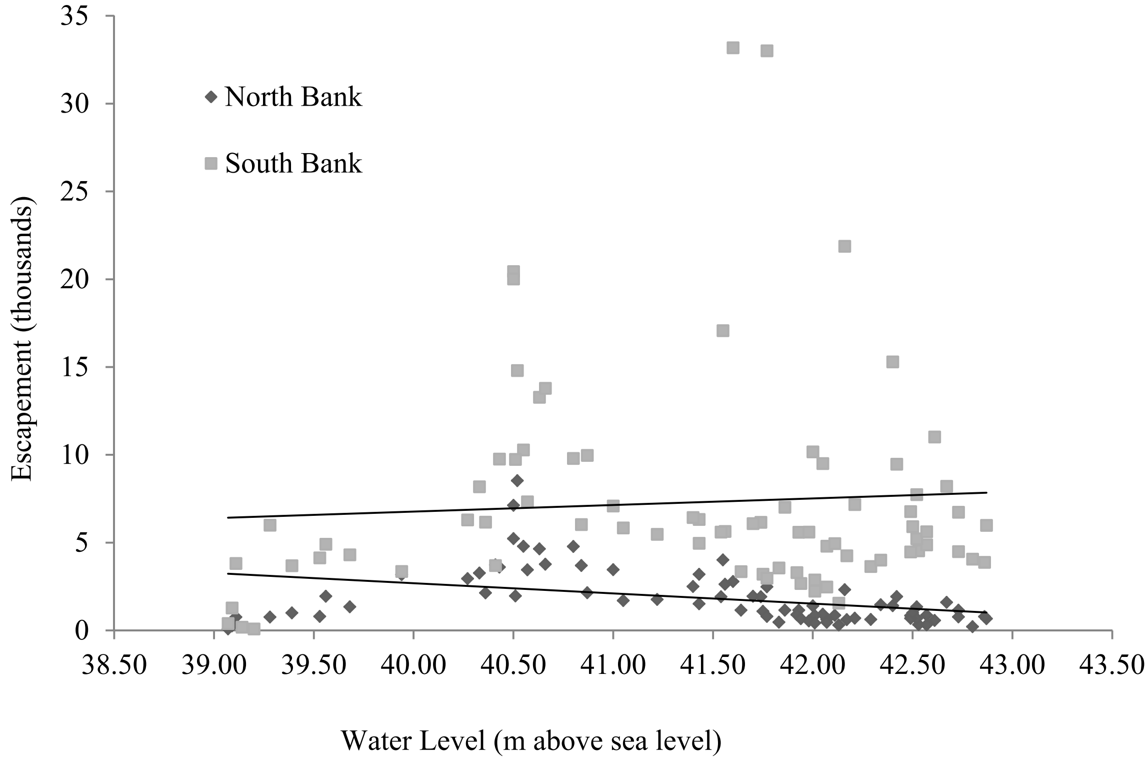


Figure 16.–Water level versus fish passage by bank for the Miles Lake sonar project, 2008.

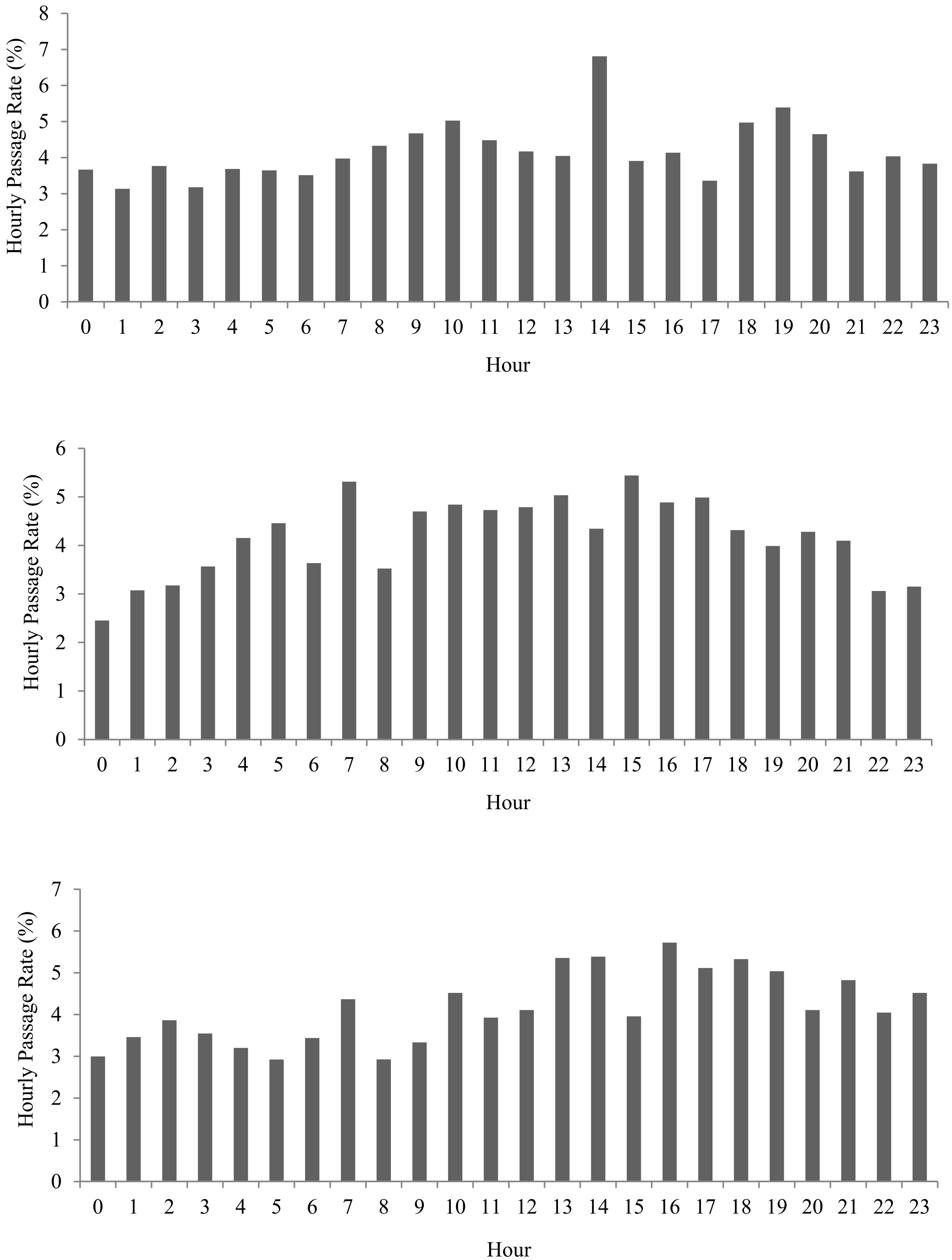


Figure 17.–North bank hourly salmon passage rates by month, Miles Lake sonar project, 2008.

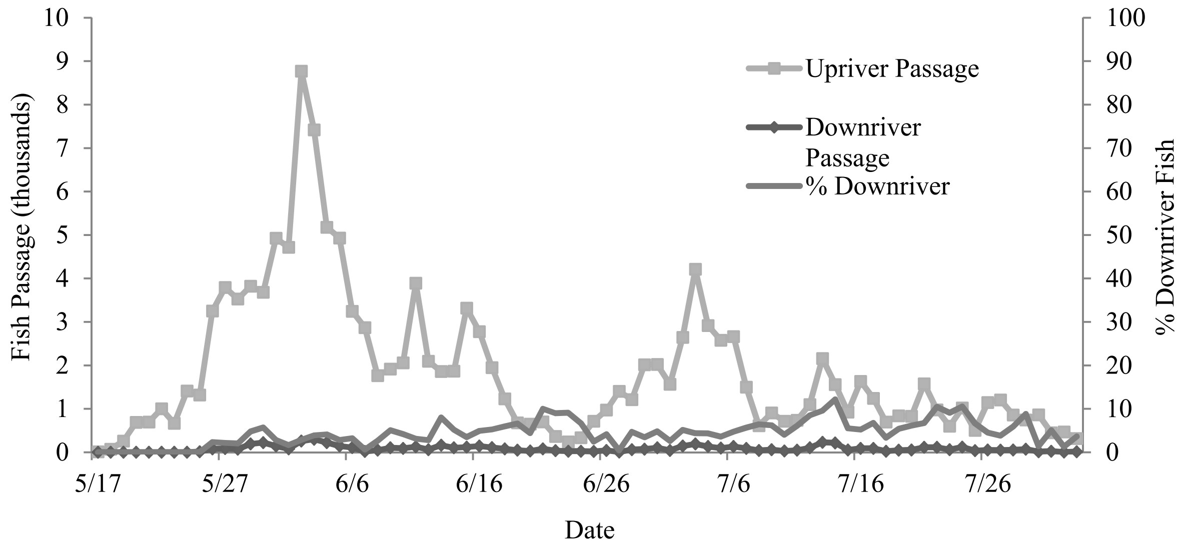


Figure 18.–North bank daily salmon escapement estimates and percentage of downriver fish, Miles Lake sonar project, 2008.

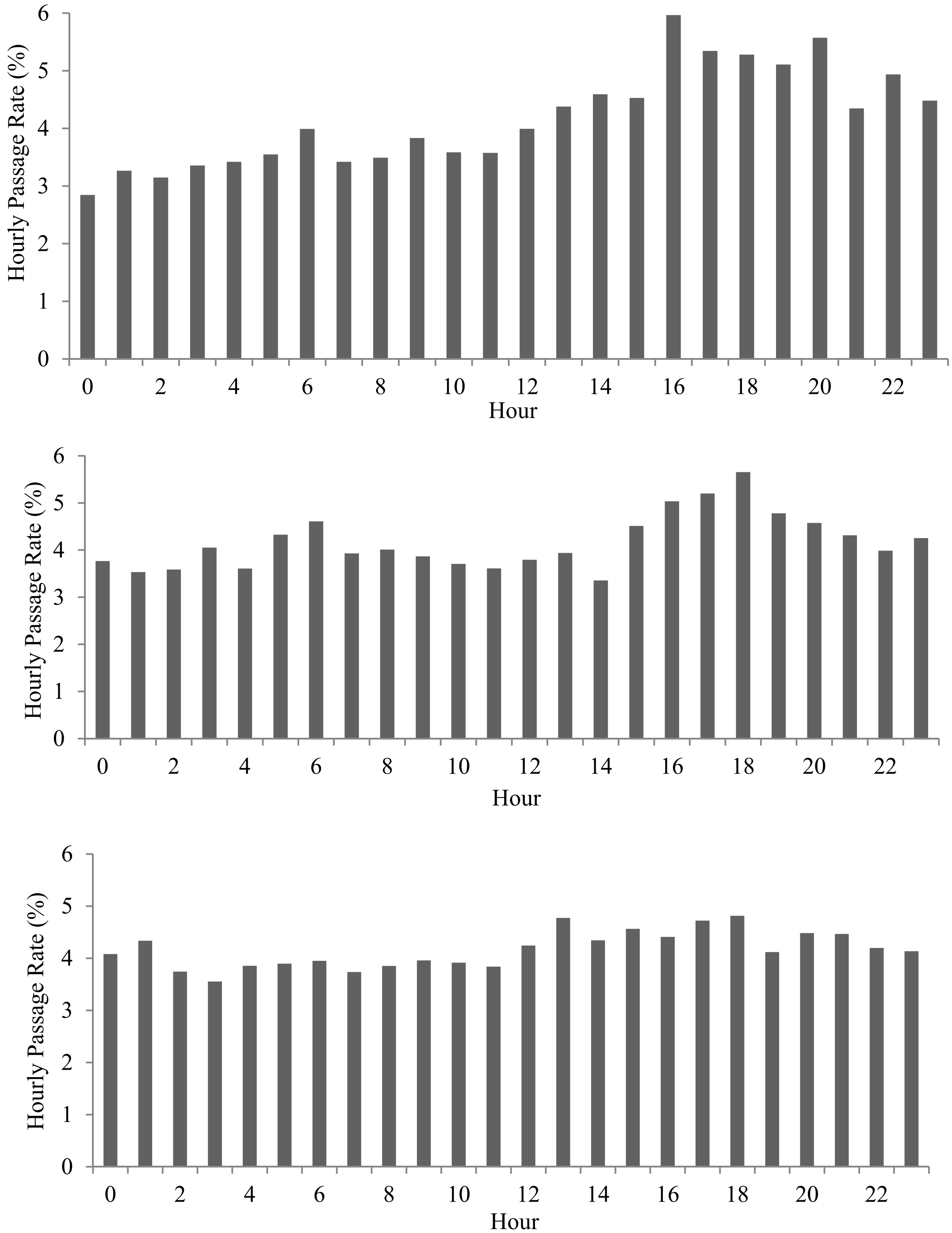


Figure 19.–South bank hourly salmon passage rates by month, Miles Lake sonar project, 2008.

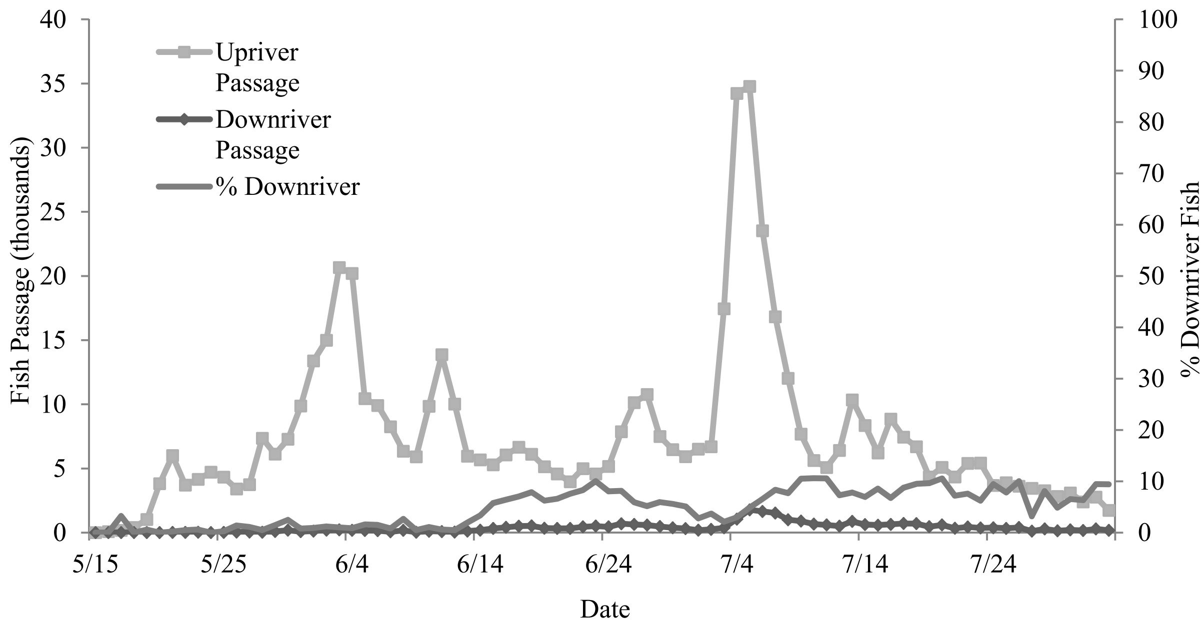


Figure 20.–South bank daily salmon escapement estimates and percentage of downriver fish, Miles Lake sonar project, 2008.

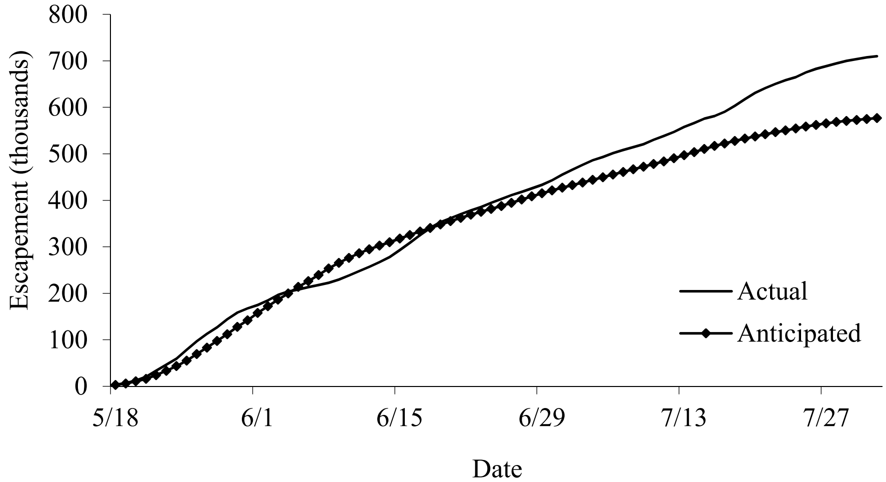


Figure 21.–Cumulative actual and anticipated salmon escapement estimates for the Miles Lake sonar project, 2009.

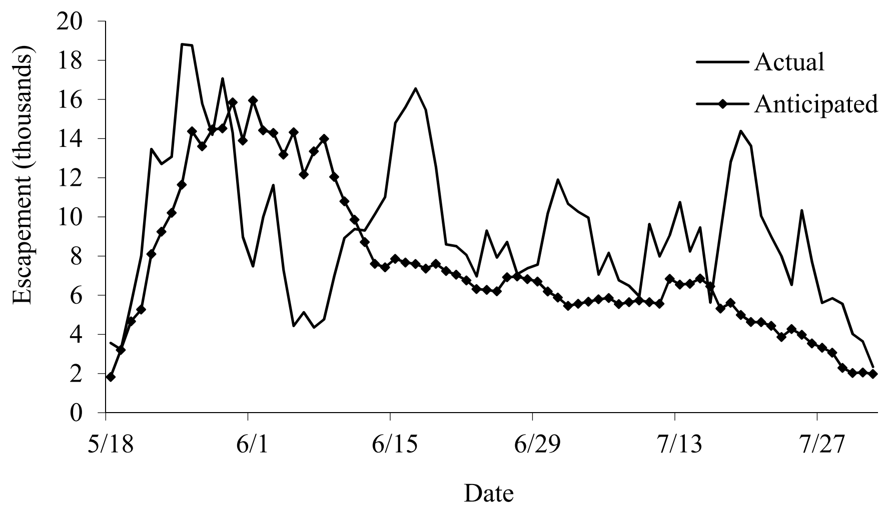


Figure 22.–Daily actual and anticipated salmon escapement estimates for the Miles Lake sonar project, 2009.

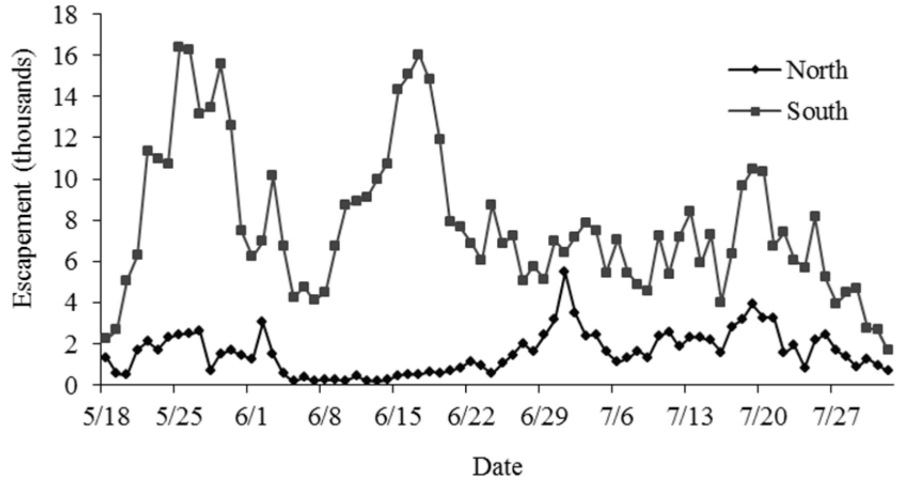


Figure 23.–Daily salmon escapement estimates by bank, Miles Lake sonar project, 2009.

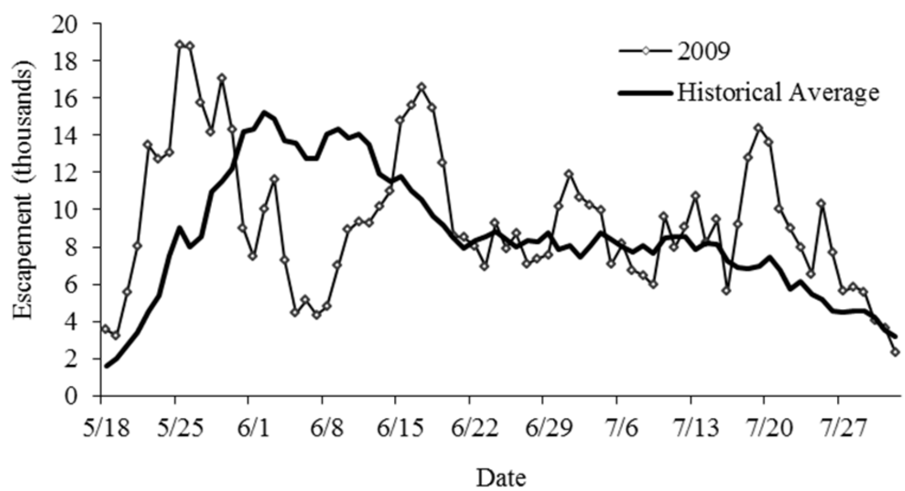


Figure 24.–Daily 2009 salmon escapement estimates compared to the historical average (1978–2008) for the Miles Lake sonar project.

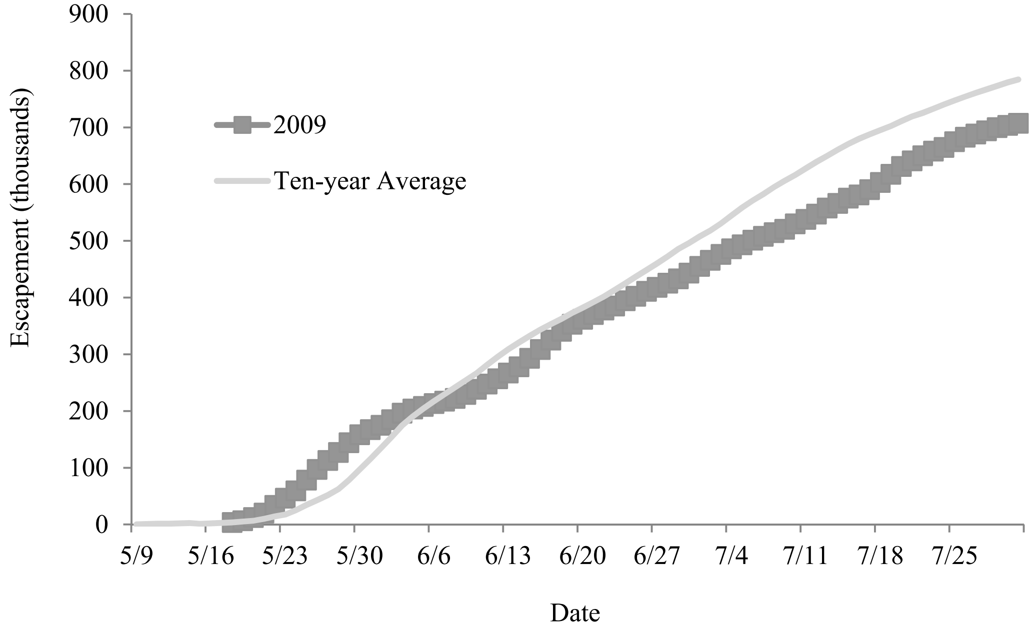


Figure 25.–Cumulative 2009 salmon escapement estimate compared to the average of the previous 10 years (1998–2008) for the Miles Lake sonar project.

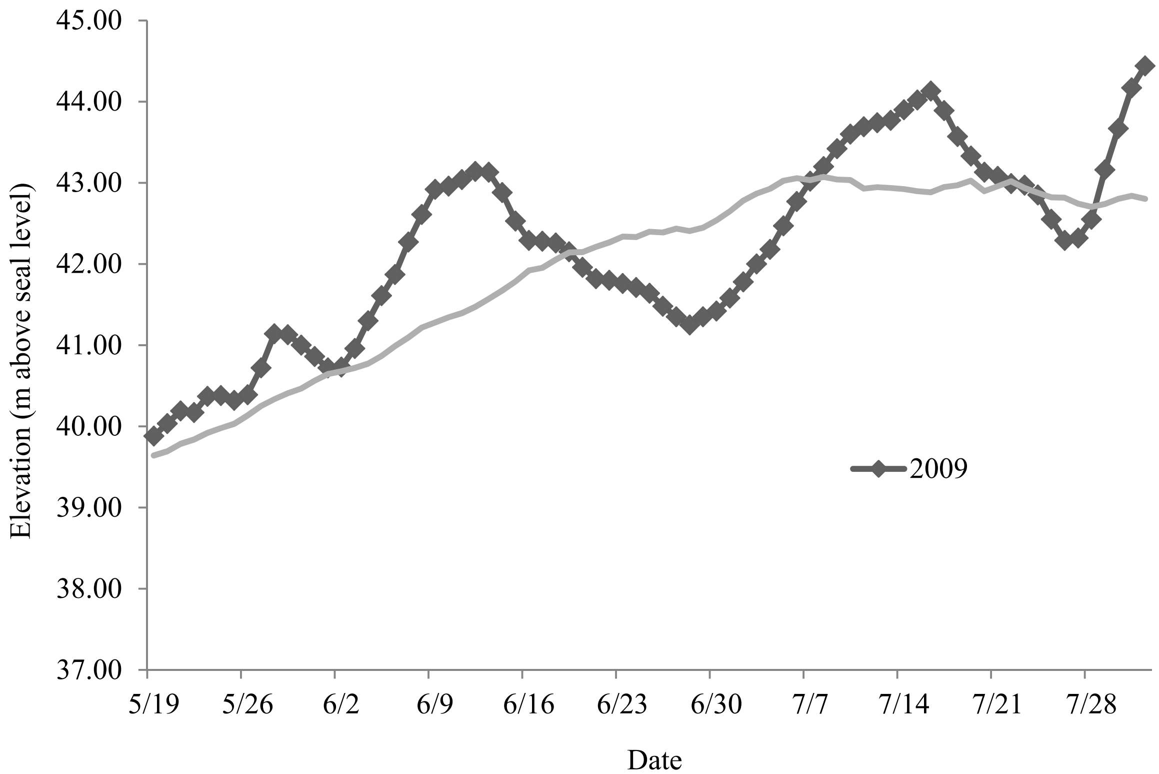


Figure 26.–Water level (elevation above sea level) for 2009 compared to the historical average (1982–2008) for the Miles Lake sonar project.

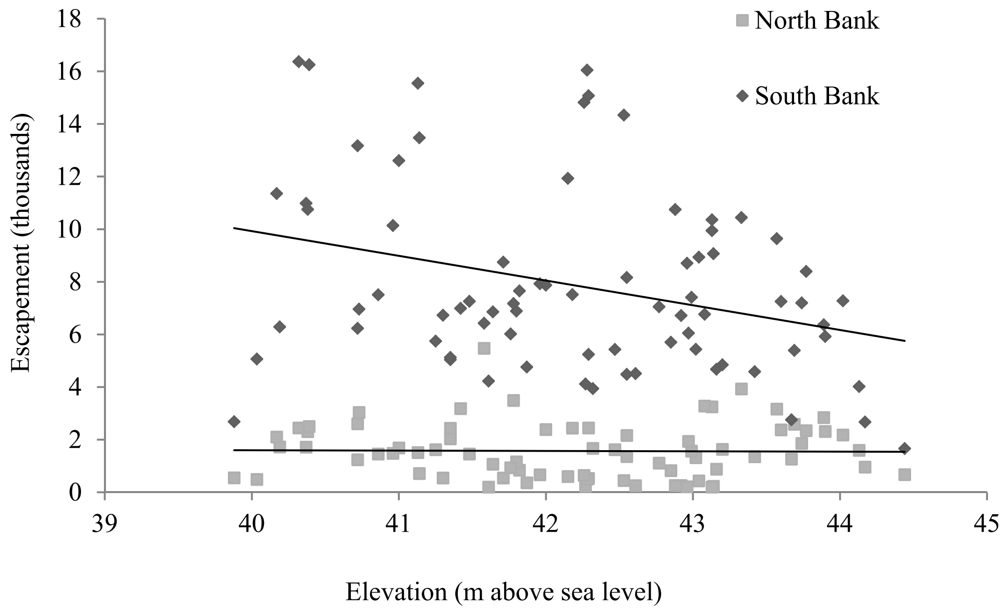
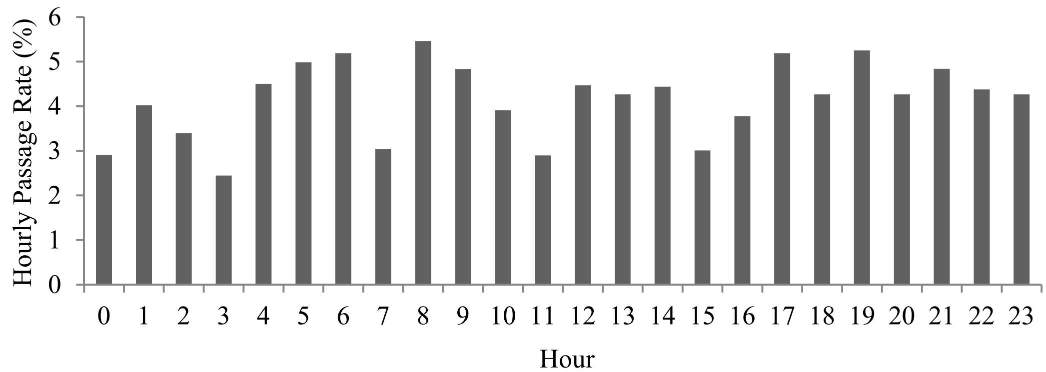
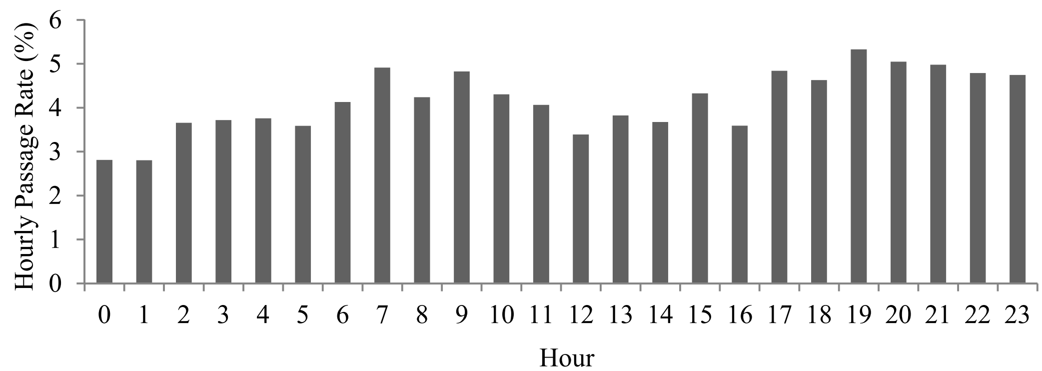


Figure 27.–Water level versus fish passage by bank for the Miles Lake sonar project, 2009.





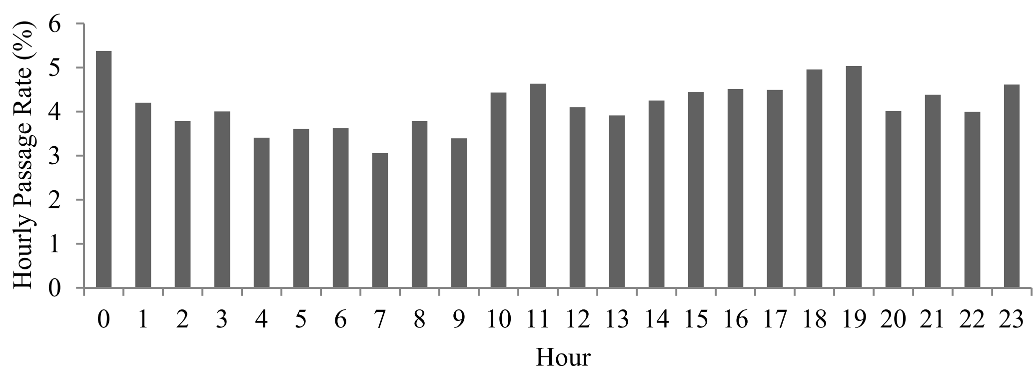


Figure 28.–North bank hourly salmon passage rates by month, Miles Lake sonar project, 2009.

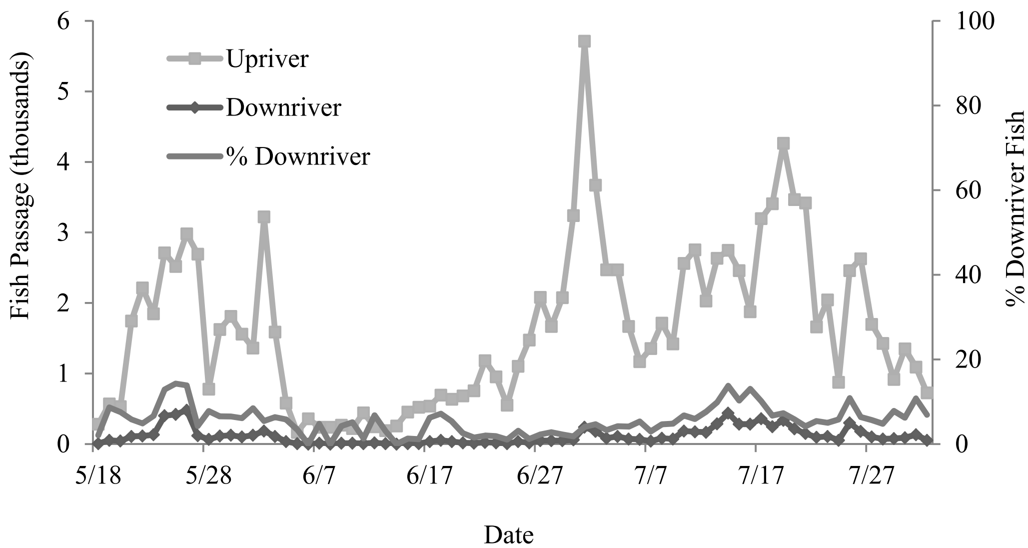


Figure 29.–North bank daily salmon escapement estimates and percentage of downriver fish, Miles Lake sonar project, 2009.

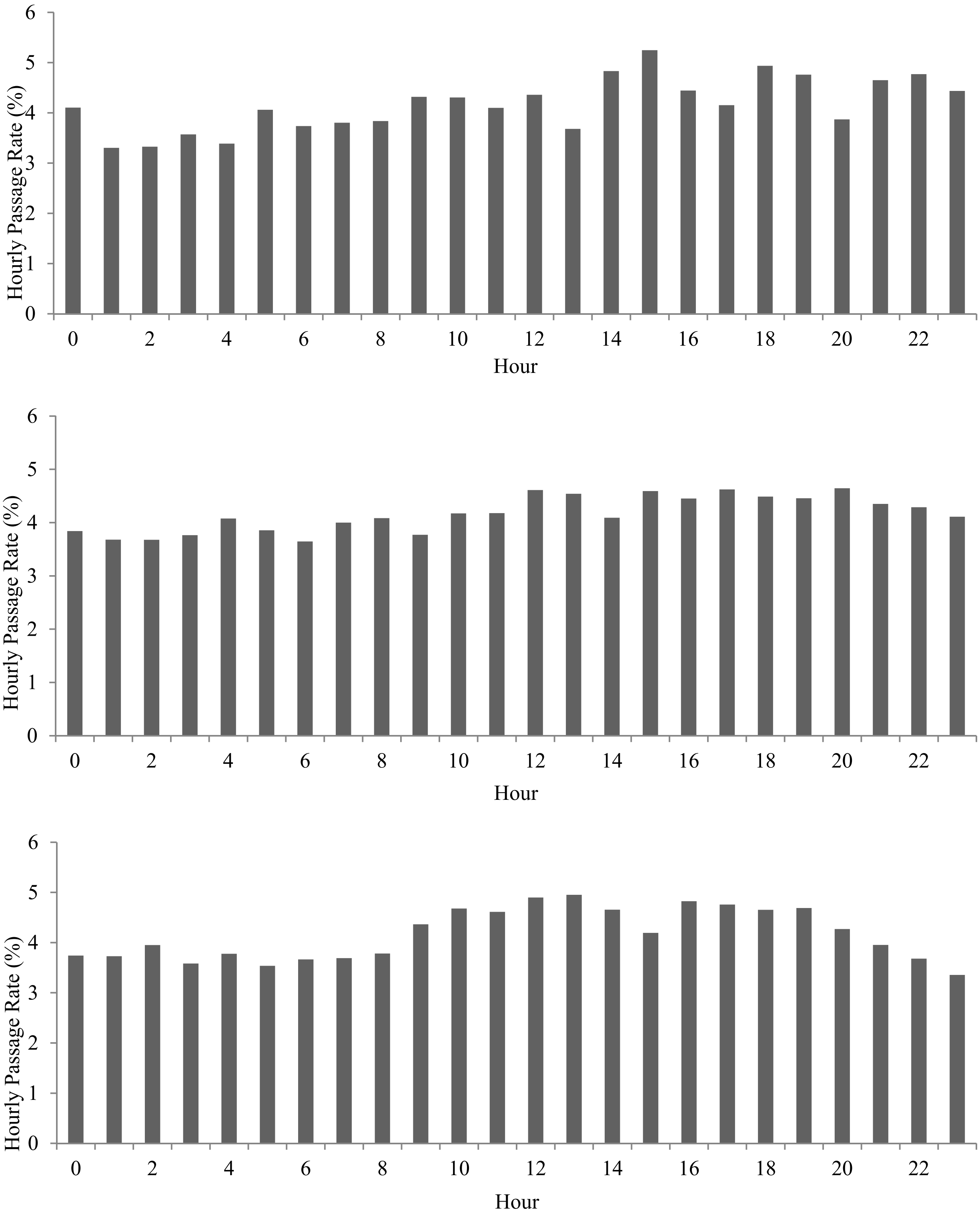


Figure 30.–South bank hourly salmon passage rates by month, Miles Lake sonar project, 2009.

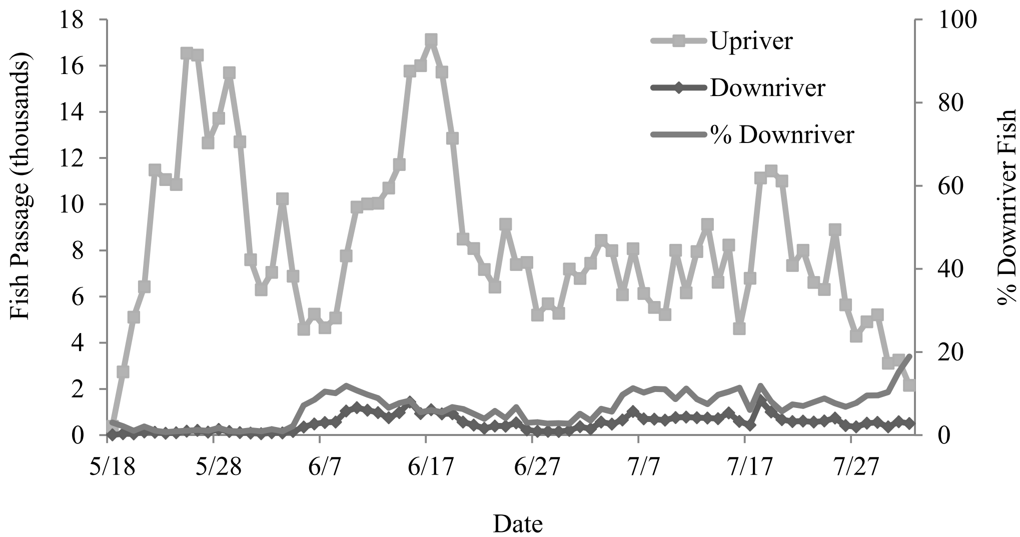


Figure 31.–South bank daily salmon escapement estimates and percentage of downriver fish, Miles Lake sonar project, 2009.

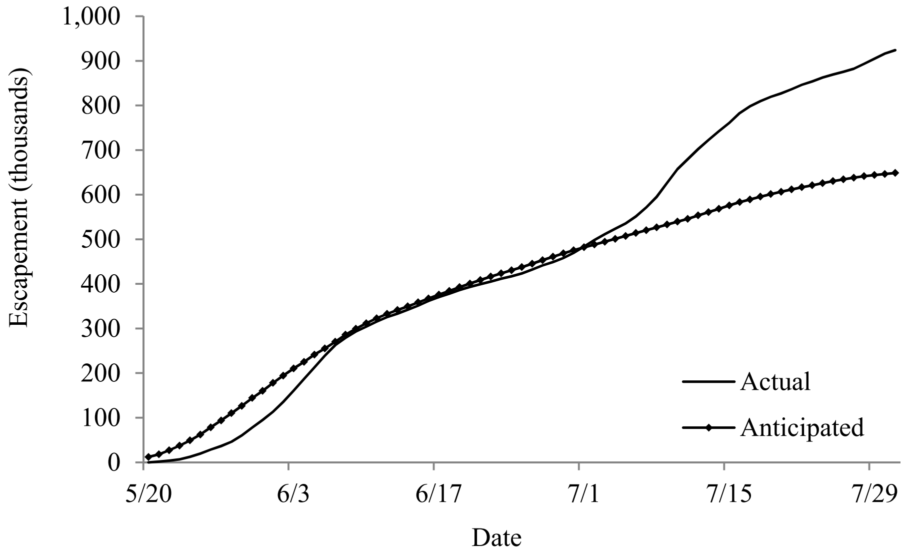


Figure 32.–Cumulative actual and anticipated salmon escapement estimates for the Miles Lake sonar project, 2010.

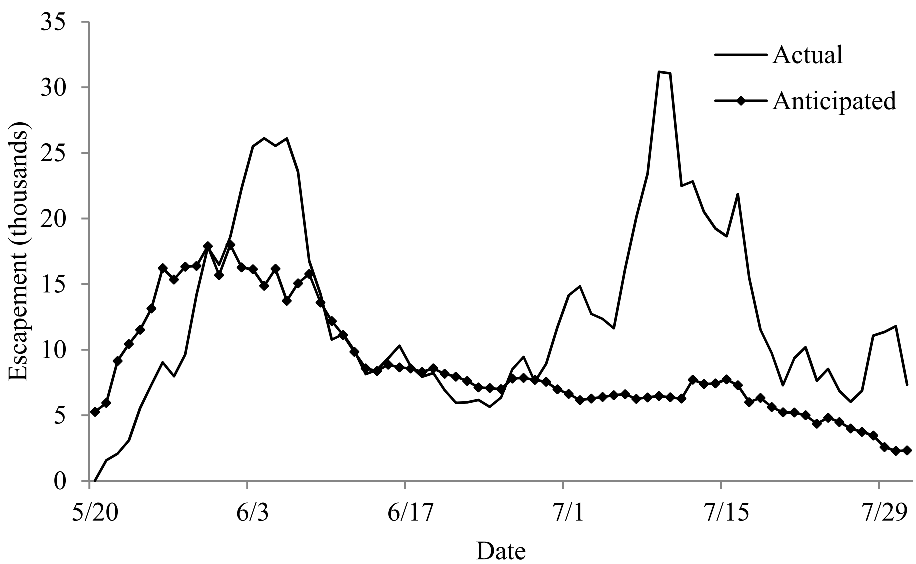


Figure 33.–Daily actual and anticipated salmon escapement estimates for the Miles Lake sonar project, 2010.

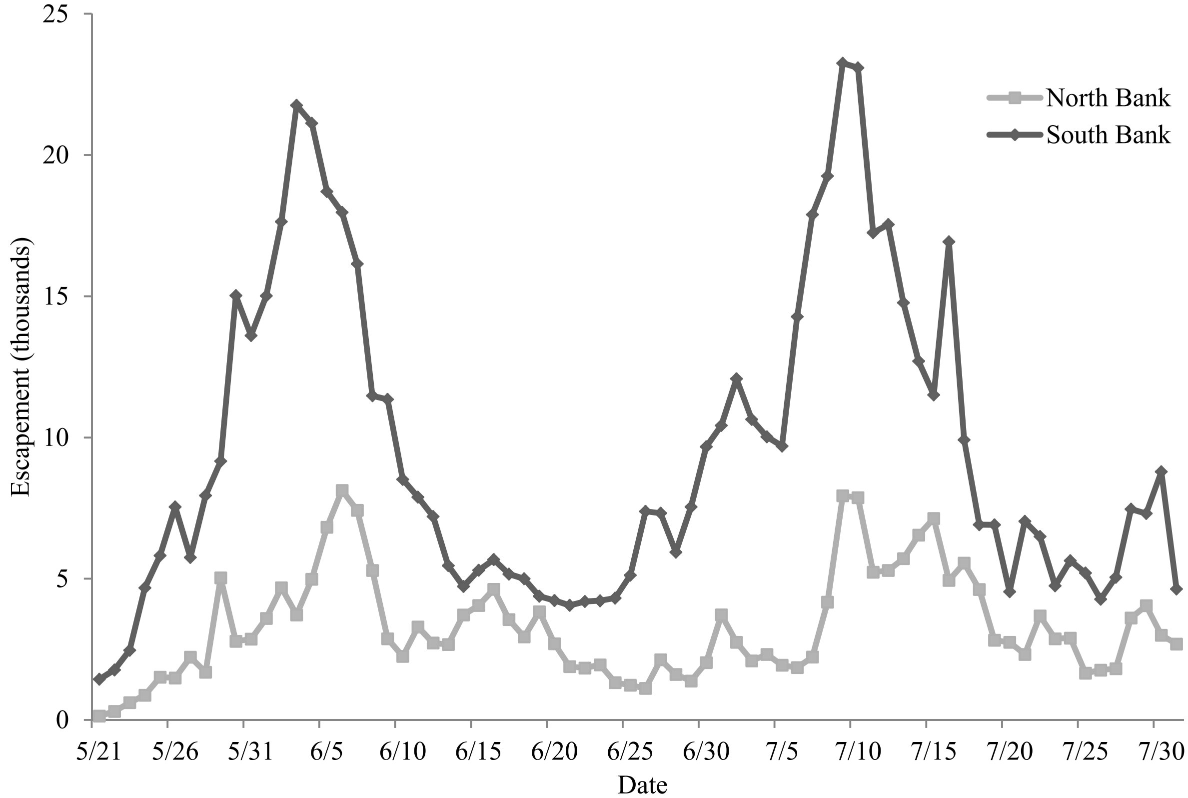


Figure 34.–Daily salmon escapement estimates by bank, Miles Lake sonar project, 2010.

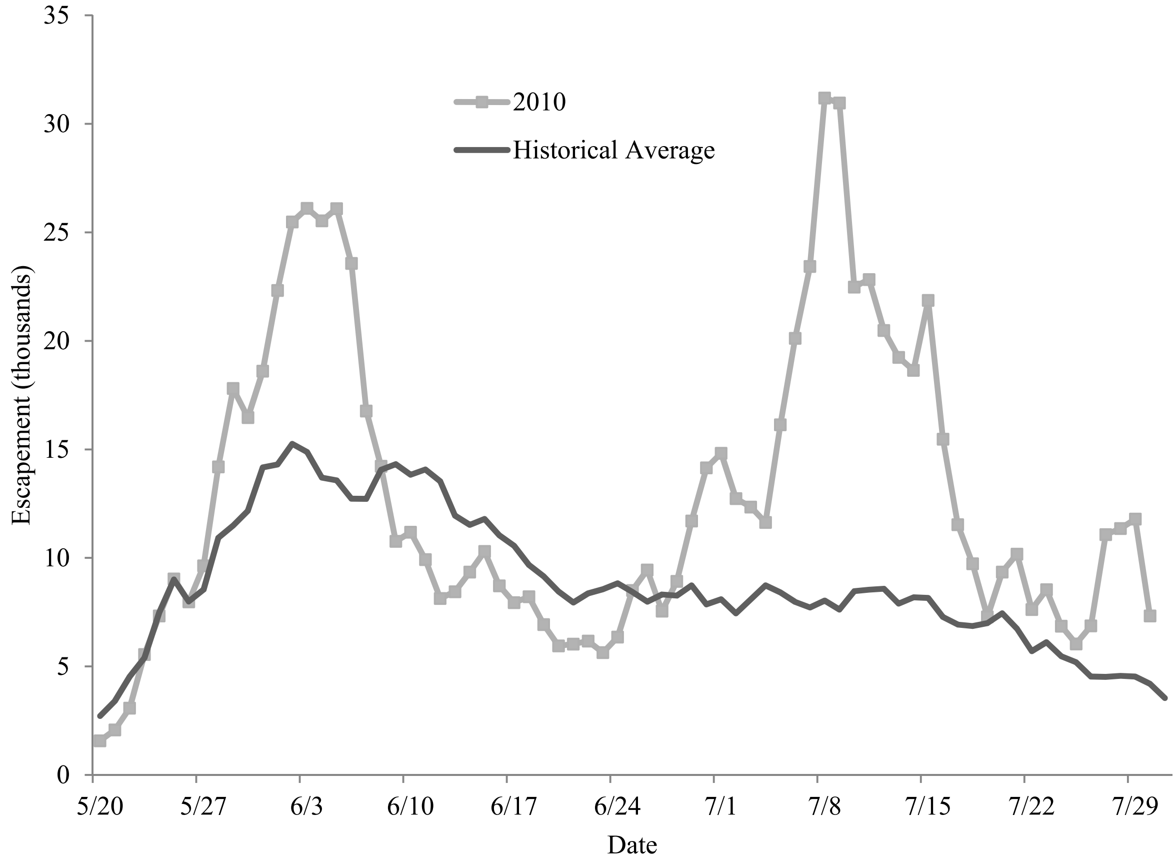


Figure 35.–Daily 2010 salmon escapement estimates compared to the historical average (1978–2009) for the Miles Lake sonar project.

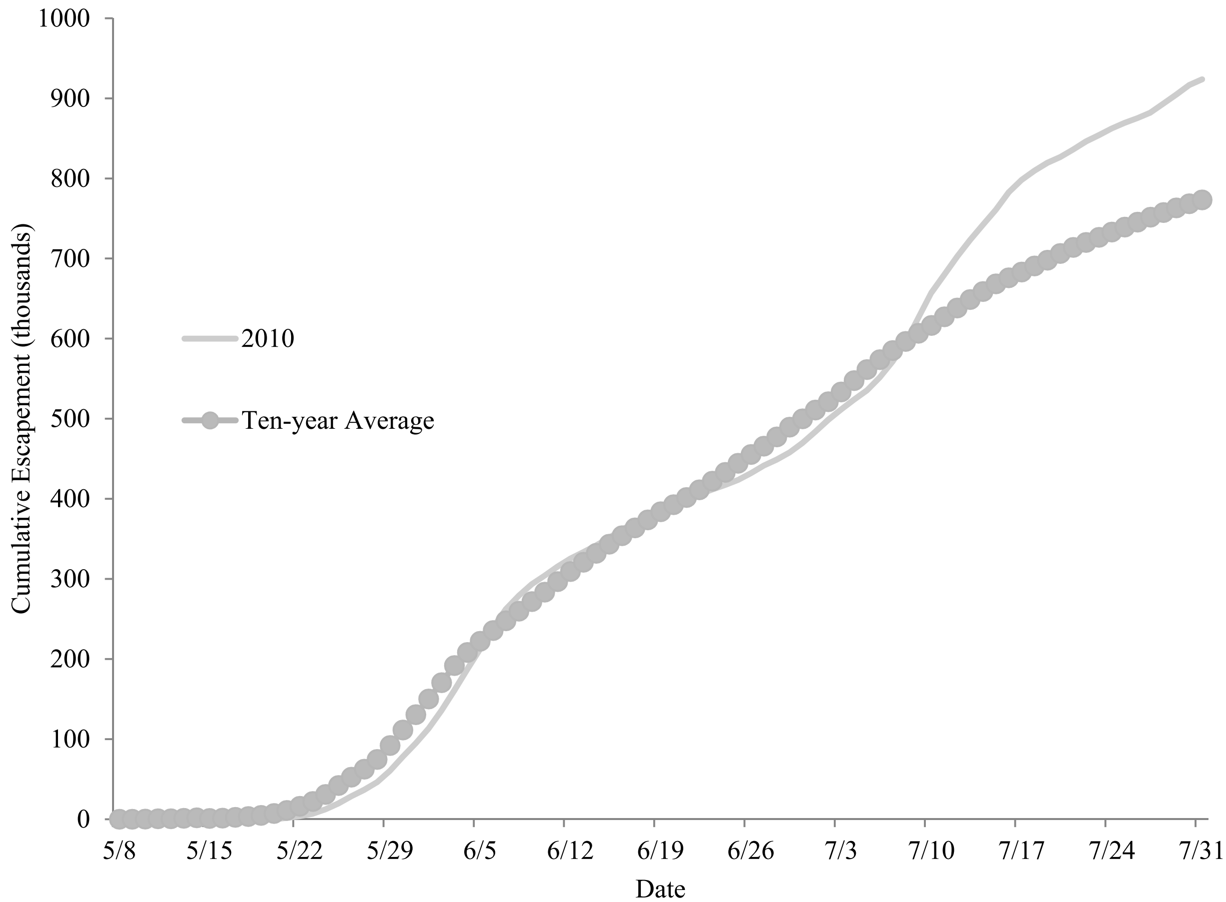


Figure 36.–Cumulative 2010 salmon escapement estimate compared to the average of the previous 10 years (1998–2009) for the Miles Lake sonar project.

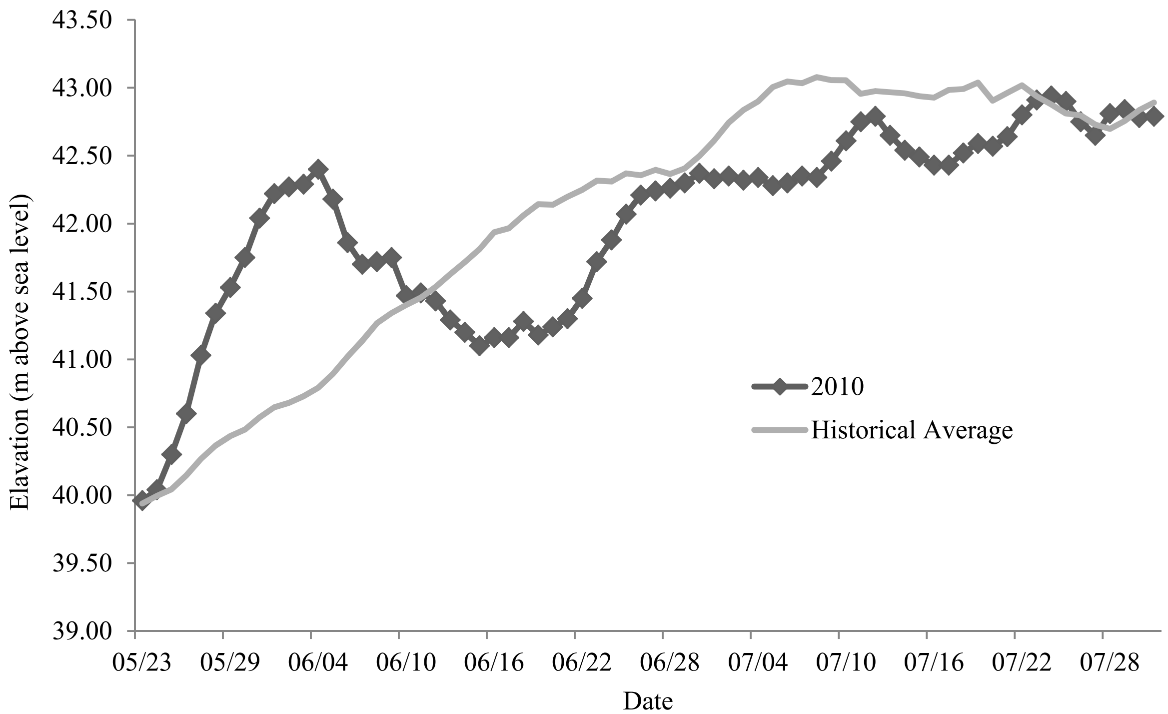


Figure 37.–Water level (elevation above sea level) for 2010 compared to the historical average (1982–2010) for the Miles Lake sonar project.

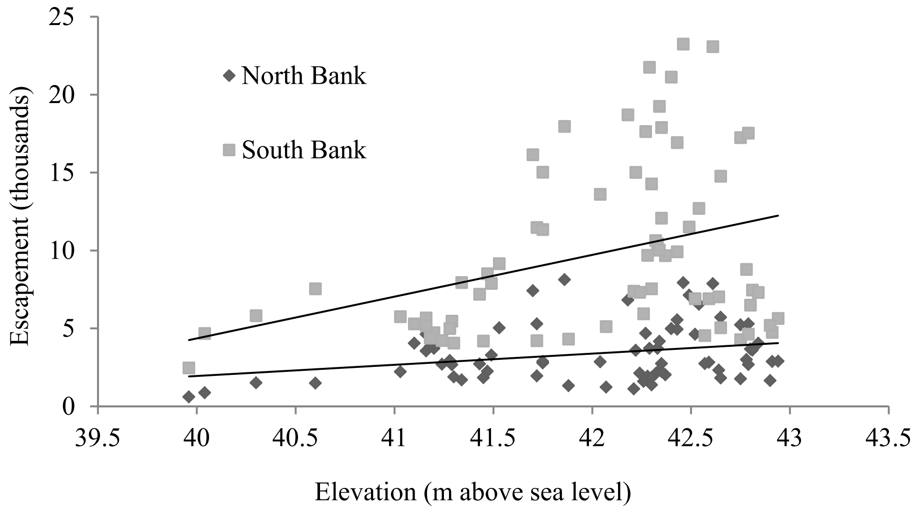


Figure 38.–Water level versus fish passage by bank for the Miles Lake sonar project, 2010.

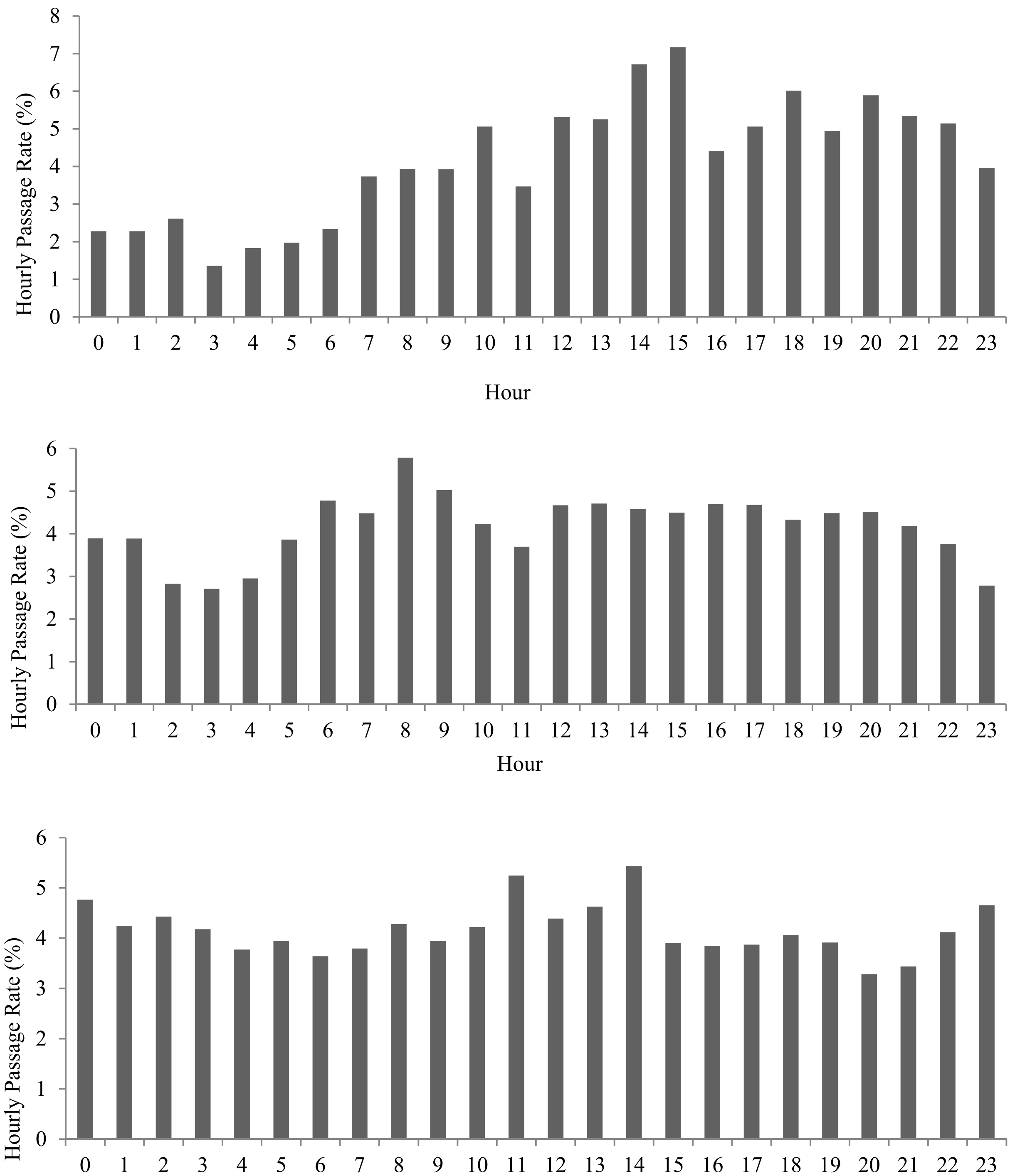


Figure 39.–North bank hourly salmon passage rates by month, Miles Lake sonar project, 2010.

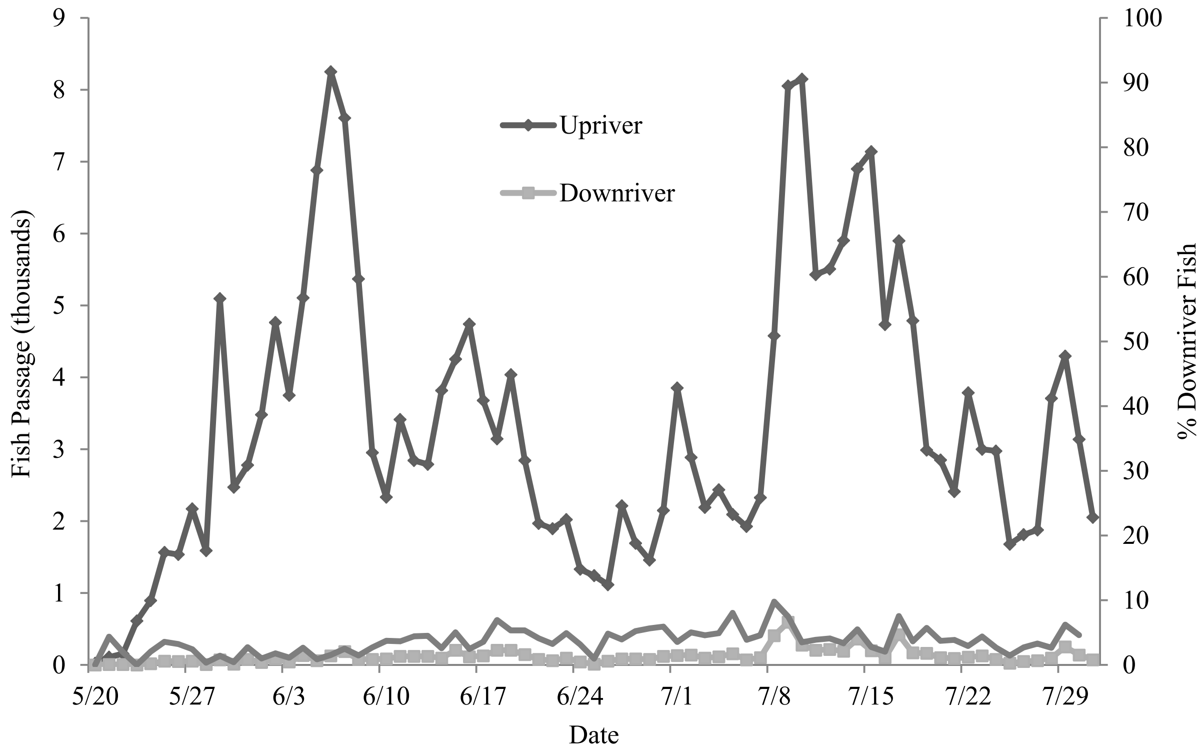


Figure 40.–North bank daily salmon escapement estimates and percentage of downriver fish, Miles Lake sonar project, 2010.

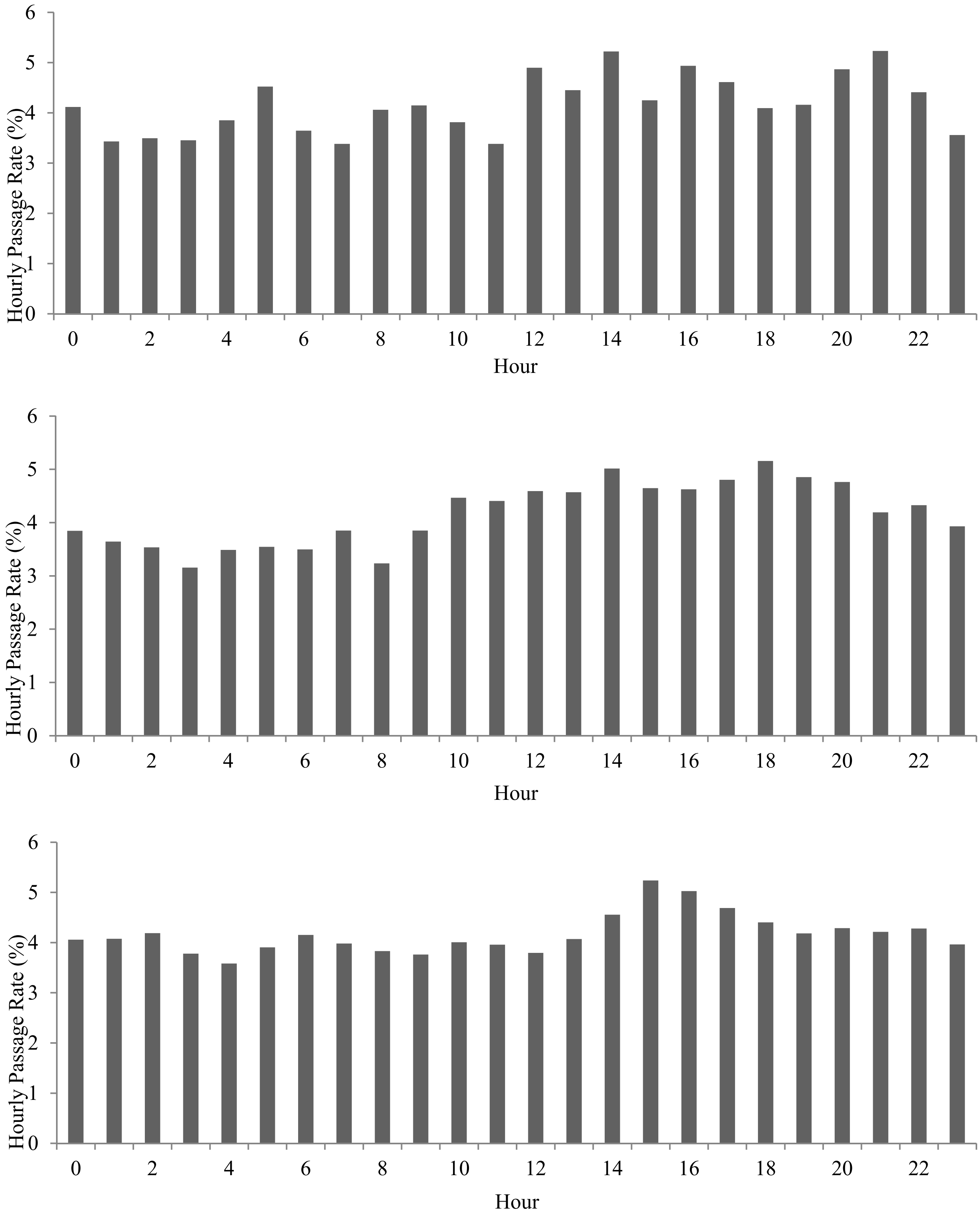


Figure 41.–South bank hourly salmon passage rates by month, Miles Lake sonar project, 2010.

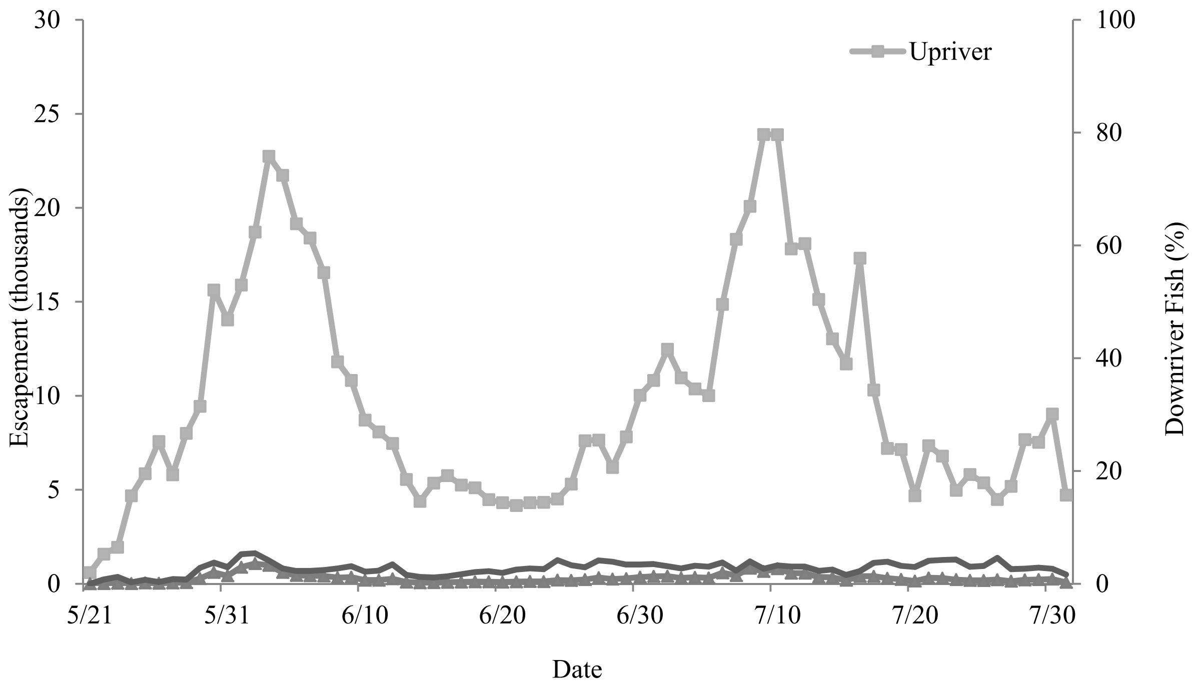


Figure 42.–South bank daily salmon escapement estimates and percentage of downriver fish, Miles Lake sonar project, 2010.

APPENDIX A

Appendix A.–Timetable of operation and major changes of the Miles Lake sonar project, 1978–2010

Year	Event

1978

- Sonar project conducted by the Alaska Department of Fish and Game (ADF&G) (Roberson 1978) with federal funding (1978–1981) from the National Marine Fisheries Service under the Anadromous Fish Conservation Act to estimate adult salmon *Oncorhynchus* spp. escapement.
    - Deployed a 1978 model Bendix sonar counter along the south bank (SB).
    - Directed the Bendix transducer beam along an 18.3 m long x 20.3 cm wide aluminum tube substrate positioned perpendicular to current flow.
    - Counter calibrated every 6 h for a total of 4 h/day.
    - Recorded raw amplified echoes received by the transducer on audio cassette tape for 3.75 min/h (1978-1983).
- Operated 2 fish wheels to assess species composition, provide index of fish passage, and obtain age and length sampling (Roberson 1978).
- Conducted a tagging study using gillnets in the commercial fishery; note: no tagged fish recovered at the Miles Lake site, 89% recovered in the commercial fishery zone (Roberson 1978).
- October Constructed a permanent 26.5 m long, 14% grade, concrete substrate with embedded railroad on the SB. The transducer mount was fit to the rail and moved up and down depending on water level.

1979

- Deployed a 1978 model Bendix counter along both south and north banks (NB) (Roberson et al. 1982)
    - Aluminum tube substrates used along both banks during low water; moved SB transducer to concrete substrate as water level reached high enough for deployment.
    - Calibrated both counters every 6 h for a total of 4 h/day.

1980

- No significant changes from previous year (Roberson et al. 1982).

1981

- Graded the NB substrate prior to the '81 season (Roberson et al. 1982).

1982

- Sonar project supported solely by ADF&G.
- Recorded river level relative to the SB permanent substrate offshore end twice a day.
- Measured water velocity along the length of the SB permanent substrate with a Gurley current flow meter (Merritt and Roberson 1983).

1983

- Grading on NB prior to and after the season during low water levels. A 2° slope with a steep drop-off offshore was changed to a consistent 6° slope (Merritt and Roberson 1984).

1984

- Test fishing program at the sonar site with set and drift gillnets from 1984–1987 (Brady 1986; Morstad et al. 1991). Few fish were captured and the program was discontinued.
- In the fall, the NB site was graded with a D-8 Caterpillar tractor. The natural substrate was built up 3 ft nearshore and graded down 3 ft offshore, generating a uniform slope of ~7% extending ~235 ft in front of the shed (Brady 1986). Done to provide an improved surface for substrateless deployments.

-continued-

1985

- 1978 model Bendix counters used, a modified 1981 model with long range capability deployed for a portion of the season.
- Sonar deployment over natural river bottom first tried on NB.

1986

- Sonar project (Morstad et al. 1991).
    - A modified 1981 and a new 1985 model Bendix counter used on the SB (each used for half of the season). New 1984 and 1985 model Bendix counters were used on the NB (each used for half of the season).
    - Water level now measured at a U.S. Geological Survey gauge mounted on the Million Dollar Bridge, Copper River height relative to elevation above sea level.
    - NB transducer deployed on natural substrate. Aluminum tubes no longer used.
    - Automated rotator tested on NB.
- Test fishing program – beach seining first tried, but few fish were captured (Morstad et al. 1991).
- On the NB, 2 transducers were compared for 3 days at separate sites using new Bendix 1984 model counter. Data was recorded alternatively for each transducer in 30-min time periods (Morstad et al. 1991).
- Efforts made to map the river bottom at the sonar and test fishing sites using a portable echosounder (Morstad et al. 1991).

1987

- A 1985 model Bendix counter was used on both banks until July 27 when the NB unit was moved to the SB to replace a malfunctioned counter and a 1978 model was used on the NB; NB automated rotator malfunctioned mid-season, so transducer was manually adjusted (Morstad et al. 1991).
- Examined the river bottom around the steel piling adjacent to the partially collapsed bridge span on NB with a portable echosounder.

1988

- 1985 model Bendix counters used on the SB and NB with two 1981 counters available as spares (Morstad 1992).
- Calibrated counters every 2 h (SB) and every 4 h (NB) for 20 min or until 100 fish were counted.

1989-1991

- No significant changes from the previous year (Morstad 1992).

1992

- Calibrated counters every 3 h (SB) and every 4 h (NB) for 30 min or until 100 fish were counted (Morstad 1993).

1993

- No significant changes from previous year (Morstad 1994)

1994

- SB aluminum tube no longer used during low water (Morstad 1994). Deployed transducer on a tripod and manually counted fish for 30 min every hour expanding to an hourly count until the transducer was mounted on the rail of the concrete substrate.

1995

- Lower portion of the SB permanent substrate damaged by an iceberg requiring a higher water level before transferring transducer from tripod to concrete substrate (Morstad 1997).

-continued-

1996-2000

- No significant changes from previous year (Morstad 1997, 1999; Dunbar 1999, 2001).

2001

- Last day of counting set for July 31 (2001-2006) (Dunbar 2001); the end date has varied from July 25 to August 9 since 1978.
- In October, a 26.5 x 5 m concrete substrate was constructed on SB, 30 m downriver from old substrate.

2002

- A 1978 model Bendix counter was used on the NB (Smith and Lewis 2006).
- Preliminary testing of DIDSON sonar on the new SB concrete substrate (Maxwell and Gove 2004).
- A new SB sonar shack constructed.

2003

- A 1985 model Bendix counter was used on the NB (Smith and Lewis 2006).
    - Visual oscilloscope only counts conducted on the NB fro 30 min, 6 times daily; no sector (range) data available.
- SB – Year 1 of 2-year comparison study between standard-range (SR) DIDSON and Bendix (Maxwell et al. 2011).

2004

- SB – Year 2 of 2-year SR DIDSON vs. Bendix comparison study (Maxwell et al. 2011).
- Construction crews raised the collapsed span of the Million Dollar Bridge (upriver of the NB site) during the field season. A construction pad around the NB bridge abutment and a temporary bridge leading to it was installed, altering the NB flow pattern (Smith and Lewis 2006).

2005

- SB – SR DIDSON first used for management purposes, installed on the new concrete pad (Faulkner and Maxwell 2008).
- NS – Year 1 of 3-year long range (LR) DIDSON vs. Bendix comparison study.
- Cross-river tests conducted with a mobile DIDSON
- Million Dollar Bridge construction pad (upriver of NB site) no longer visible on surface and temporary bridge removed before season; construction ended in June.

2006

- NB – Year 2of 3-year LR DIDSON vs. Bendix comparison study.
- Cross-river tests conducted with a mobile DIDSON
- Phone and internet connection established at the sonar site.

2007

- NB – Year 3 or 3-year LR DIDSON vs. Bendix comparison study (Maxwell et al. 2011).
- Deployed SB DIDSON 395 m downriver of the concrete substrate from May 20–26 because of shore ice.
- Last day of counting extended to August 4 because of higher fish passage during this time period.

2008

- NB – Bendix permanently replaced with LR DIDSON.

2009

- NB – floating weir installed.

2010

- Snow machines used to haul gear to camp site
- Sonar operations ended on July 31.