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Evaluation of Hydroacoustic Site on the Yukon River Near Eagle, Alaska for Monitoring Passage of Salmon across the US/Canada Border, 2004

by

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March 2007

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)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

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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EVALUATION OF HYDROACOUSTIC SITE ON THE YUKON RIVER NEAR EAGLE, ALASKA FOR MONITORING PASSAGE OF SALMON ACROSS THE US/CANADA BORDER, 2004

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ABSTRACT

A 2-week study was undertaken from August 18 to August 30, 2004, to locate an appropriate site to deploy sonar for use in a long-term enumeration study of Chinook *Oncorhynchus tshawytscha* and fall chum salmon *O. keta* on the Yukon River near the Alaska/Canada border. Dual-Frequency Identification Sonar (DIDSON™) and split-beam sonar equipment were tested at Calico Bluff and Six-Mile Bend, both sites within 12 miles of Eagle, Alaska. Bottom profiles were produced for the two potential sites and despite technical malfunctions with the split-beam equipment, which rendered x-y position information unusable, two suitable sonar deployment locations were found. Both split-beam and DIDSON™ systems have their strengths, and by using the DIDSON™ on a relatively steep, short cobble shore (where fish tend to be distributed inshore), and the split-beam on a long, gentle sloping bank, acoustic coverage of the river should be sufficient for fish enumeration. Six-Mile Bend was the most suitable location for a future sonar project because of its linear left-bank, stable cobble substrate, single channel and proximity to the Alaska/Canada Border. Sonar will need to be deployed on the right bank at Six-Mile Bend in future seasons. A long-term enumeration project for Chinook and chum salmon near the border will provide information to help fishery managers meet conservation and management commitments made by the U.S. and Canada under the Yukon River Salmon Agreement.

Key words: Alaska, DIDSON™, Eagle, Hydroacoustics, *Oncorhynchus*, salmon, Chinook, chum, split-beam sonar, Yukon River.

INTRODUCTION

A 2-week study was undertaken from August 18 to August 30, 2004, to locate an appropriate site to deploy sonar for use in a long-term enumeration study of Chinook *Oncorhynchus tshawytscha* and fall chum salmon *O. keta* on the Yukon River near the Alaska/Canada border. Dual-Frequency Identification Sonar (DIDSON™)[1] and split-beam sonar equipment were tested at two sites, one near Calico Bluff and the other at Six-Mile Bend, both within 12 miles of Eagle, Alaska. Bottom profiles were produced for the two potential sites, an estimate of fish passage and the spatial distribution at the sites was obtained, and a side-by-side comparison of the two different sonar units was attempted to examine nearshore detectability of migrating fish.

The Yukon River is the largest river in Alaska, spanning 2,300 miles. It flows northwesterly from its origin in northwestern British Columbia through the Yukon Territory and Central Alaska to its mouth at the Bering Sea. Commercial and subsistence fisheries harvest salmon throughout most of the drainage. These salmon fisheries are critical to the way of life and economy of people in dozens of communities along the river, in many instances providing the largest single source of food or income. Management of the fisheries on this river is complex and difficult because of the number, diversity, and geographic range of fish stocks and user groups. Information upon which to base management decisions come from several sources, each of which has unique strengths and weaknesses. Gillnet test fisheries provide inseason indices of run-strength, but interpretation of these data is confounded by gillnet selectivity. Also, the functional relationship between test-fishery catches and abundance is unknown. Mark–recapture projects provide estimates of total abundance, but the information is typically not timely enough to make day-to-day management decisions. Sonar is used to provide timely estimates of abundance but is limited in its ability to identify fish to the species level.

[1] Product names used in this report are included for scientific completeness, but do not constitute product endorsement by the Alaska Department of Fish and Game.

Alaska is obligated to manage Yukon River salmon stocks according to precautionary, abundance-based harvest-sharing principals set by the Yukon River Salmon Agreement (Yukon River Panel 2004). The goal of bi-national, coordinated management of Chinook and chum salmon stocks is to meet escapement requirements that will ensure sufficient fish availability to provide for subsistence and commercial harvests in both the United States and Canada. A daily estimate of fish crossing the border between Alaska and Canada is crucial to meeting the obligations laid out in the Salmon Agreement. Currently the Canadian Department of Fisheries and Oceans (DFO) provides the only estimate of mainstem salmon passage through the Alaska/Canada border using mark–recapture programs, fish wheel test fisheries, and aerial surveys. Accurate abundance estimates not only help managers adjust harvest inseason, they are also used postseason to determine whether treaty obligations were met.

Because of the highly turbid water and width of the Yukon River, daily passage estimation methodologies such as counting towers, or weirs are not feasible. Split-beam sonar technology has been used successfully by the Alaska Department of Fish and Game (ADF&G) to produce daily inseason estimates of salmon passage in turbid rivers, e.g. the lower Yukon River at Pilot Station (Pfisterer 2002); the Kenai River (Miller and Burwen 2002). DIDSON™ imaging sonar has been used in the Aniak River to give daily passage estimates where bottom profile and river width are appropriate for the wider beam angle and shorter range capabilities of this sonar (McEwen 2005).

In 1992, ADF&G initiated a project near Eagle, Alaska to examine the feasibility of using split-beam sonar to estimate the number of salmon migrating across the US/Canada border (Huttunen and Skvorc 1994; Johnston et al. 1993). This project was the first documented use of split-beam sonar in a riverine environment, and over the 3-year duration of the study a number of problems were identified. Phase corruption was observed and was likely exacerbated by the highly reflective river bottom (Konte et al. 1996). The errors in the phase measurement were believed to have resulted in overly restrictive echo angle thresholds. Echoes from fish that were physically within accepted detection regions were removed from the data files because of errors in angle measurement. These and other equipment issues reflected the early state of development of the new equipment, most of which have since been addressed.

Some recommendations from these border sonar studies were to find a better site with smaller rocks and a smoother bottom profile (Johnston et al. 1993). Too many large rocks or obstructions in the profile, can compromise fish detection by limiting how close to the bottom the hydroacoustic beam can be aimed. Similarly, uneven bottom may have allowed fish to pass undetected by the sonar, and a more linear profile would alleviate this problem and allow detection of fish at longer ranges.

In 2003, ADF&G carried out a study to identify a more suitable location to deploy hydroacoustic equipment to detect salmon passage into Canada, based on the preceding recommendations. A 28-mile section of river from the DFO mark–recapture fish wheel project at White Rock, Canada to 12 miles below Eagle, Alaska was explored (Pfisterer and Huttunen 2004). This area (Figure 1) was investigated because of its proximity to the DFO project, and the US/Canada border. Criteria for suitable sites were: linear bottom profiles on both sides of the river without large obstructions; a single channel; available beach above water level for topside equipment, and sufficient current, i.e., areas without eddies or slack-water where fish milling behavior can occur. A total of 21 river bottom-profiling transects led to narrowing of potential project locations to an area between 6 and 15 miles downriver from the town of Eagle. The 2003 study found that the two most promising sonar deployment locations meeting the above criteria were Calico Bluff, and Shade Creek (Pfisterer and Huttunen 2004). Though sonar was not deployed in 2003, the bottom profiles at the preferred sites indicated that it should be possible to enumerate fish passage with a combination of split-beam on the longer, linear bank, and DIDSON™ equipment on the shorter, steeper bank.

The current study was the next step in locating the optimal site to deploy sonar. Because of the different benefits of these two types of sonar, i.e. the DIDSON™ is useful where profiles are not perfectly linear, and the split-beam is better for longer range, it was decided to use both systems for this site-selection and feasibility study. It was believed that the DIDSON™ could be deployed on the shorter, steeper bank, and that it could also be used to examine the effectiveness of the nearshore counts obtained with the split-beam on the other bank (Pfisterer and Huttunen 2004).

Gaining a better understanding of species composition, behavior and spatial distribution of the fish passing the Eagle sonar project will be important for future operations. Gillnets were used in the early sonar studies to look at species composition but drifting was deemed too difficult because of high water velocities at the sonar site (Johnston et al. 1993). Consequently, set gillnets were deployed downstream of the site with a recommendation to deploy set gillnets upstream of the sonar in the future. A further recommendation was that a wide variety of mesh sizes should be used to obtain a less biased sample of all species present. Based on these recommendations, and the limited scope of the current study, only one method of test fishing was attempted. Drift gillnets of varying mesh sizes were used in the current season to test whether drift gillnetting would be a possible future method for obtaining species composition at the new site. No attempt at species apportionment or species composition was made in the current study, due to the short duration of the project.

We believe, if the site tested further and is suitable, a full-scale sonar enumeration project could provide daily estimates of fish passage, which would complement data collected by DFO and give fishery managers more timely information for making inseason management decisions, thus facilitating fulfillment of commitments made under the Salmon Agreement.

STUDY AREA

The study area was a 9-mile section of the mainstem Yukon River extending 1 mile inside the Yukon-Charley Rivers National Preserve near Calico Bluff to 6 miles below Eagle at Six-Mile Bend.

Average monthly discharge for the Yukon River ranges from 110,500 to 223,600 ft^3/s. Flows are highest in June, with greatest variability in flow occurring in May, after which flow slowly declines and varies only slightly. The estimated annual suspended-sediment load for the Yukon River at Eagle is 33,000,000 tons (Brabets et al. 2000). The Upper Yukon River is turbid and silty in summer and fall as a result of this influx of sediment.

The majority of land in the study area above the ordinary mean high water mark is owned by the Hungwitchin Native Corporation. Permission was granted to operate a 2-week sonar project on Native Corporation land, just inside the Yukon-Charley Rivers Preserve.

OBJECTIVES

The goal for this project is to locate an appropriate site to deploy sonar and determine the equipment needed for use in potential long-term enumeration study of Chinook and fall chum salmon in the Yukon River near the Alaska/Canada border. This will be carried out with the specific objectives below:

1. Obtain more detailed profiles of the preferred sites found in 2003. Ideal location will be determined by meeting some or all of the following criteria: a linear bottom profile with no obstructions, a single channel, sufficient beach above water level for topside sonar equipment, and sufficient current.
2. Deploy both split-beam and DIDSON™ equipment to test whether detection of fish passage at the site is possible, and to determine what type of sonar will be most appropriate for future operations at the site. Considerations for determining this will include:
    a) a beam width that adequately ensonifies the water column based on the depth and slope of the profile, while also maximizing the range ensonified
    b) adequate detection of fish targets over the full range of the beam.
3. In order to fully meet objective 2, deploy the split-beam and DIDSON™ side-by-side to determine whether the near shore counts of the split-beam are compromised due to its narrow beam and reduced ping rate when sampling longer ranges (>100 m).

METHODS

BOTTOM PROFILING AND SONAR DEPLOYMENT SITE SELECTION

Transects were made across the mainstem Yukon River between 6 miles and 15 miles downriver from Eagle to create bottom profiles of the study area. Transects were parallel lines going from bank to bank. A total of 25 transects were made, not including aborted attempts. Areas where topside equipment could not be deployed were not profiled, e.g. bluffs, where rock walls rose out of the water. Two areas were focused on for profiling: The island below Calico Bluff and a 1-mile area from Shade Creek to Six-Mile Bend (Figure 2). Within these two focus areas, transects were completed at roughly 30 to 100-meter intervals. Profiles of the river bottom were collected and saved during transects using a boat mounted Lowrance LCX-15 dual-frequency transducer (down-looking sonar) with a built-in Global Position System (GPS). The GPS was able to obtain a Wide Area Augmentation System (WAAS) signal to enhance the resolution of the position measurements. Typical WAAS correction allows position measurements accurate to within 3 meters 95% of the time. For each transect, an attempt was made to keep ground velocity constant and the path straight, i.e. perpendicular to river flow. Constant velocity was not a requirement though, since the paired depth and positional information allowed for uneven boat velocity.

Bottom profiles were then generated using data files uploaded to a computer and plotted with Microsoft® Excel in the field. Sonar deployment sites were selected using the best bottom profiles generated from the transects. An acceptable profile consisted of: a steady downward sloping gradient without large dips or obstructions that hinder full acoustic beam coverage or detection of targets; a section of river with sufficient current containing no eddies; sufficient beach above water line to house topside sonar equipment.

HYDROACOUSTIC EQUIPMENT

A fixed-location, split-beam, fisheries hydroacoustic system developed by Hydoacoustic Technology, Inc. (HTI) was used to estimate salmon abundance. Fish passage was monitored with a model 241 digital echo sounder which includes time-varied gain and multiple transmit and receive settings (Appendix A1), and a 2° by 10° 200 kHz split-beam transducer. The split-beam system is capable of distinguishing upstream fish from downstream fish and debris, determining fish velocity, and discriminating between random reverberation and fish targets. A laptop computer paired with the sounder provides access to all the Digital Echo Processor (DEP) settings that can be saved for future use. Files are created by the DEP and edited to produce an estimate of fish passage.

The transducer was attached to two HTI model 662H single-axis rotators. Aiming was achieved remotely using a Remote Ocean Systems model PTC-1 pan and tilt rotator control unit that provided horizontal and vertical position readings, accurate to within ± 0.3º. The rotator controller was connected to the rotators with 152.4 m of Belden cable.

The transducer and rotators were mounted on a tripod made of aluminum pipe and deployed 3 to 15 m offshore, based on water depth. The tripod was secured with sandbags and the transducer height was adjusted by sliding the mount up or down along a riser pipe that extended above the water. The transducer was deployed in water ranging from approximately 1.0 m to 1.5 m in depth, and aimed perpendicular to the current along the natural substrate. The transducer was deployed at a location with no eddy or slack water. Water velocity was determined visually by ensuring debris on the surface moved in a linear, downstream fashion, at a pace indicating a strong current.

An artificial acoustic target was used at various distances from the transducer during deployment to verify that the transducer aim was low enough to prevent salmon from passing undetected beneath the acoustic beam, and to test target detection over different ranges. The target, an airtight 250-ml weighted plastic bottle tied with fishing line, was drifted downstream along the river bottom and through the acoustic beams. Several drifts were made with the target in an attempt to pass it through as much of the counting range as possible. Because the target was only used to test the aim and the range of detection, x-y plots of the target strength of the target were not used to test if it was comparable to that of a fish. To calibrate the split-beam system, a 1.5-in. tungsten carbide sphere was held at close range (approximately 2 m outside the nearfield of the transducer) and the target strength obtained was -39 dB. The minimum detection threshold was then set to -40 dB during data collection.

While aiming the split-beam transducer, and viewing the x-y beamplot on the display of the DEP, it became apparent that the upstream half of the acoustic beam was not returning pings consistently because of a malfunction in the digital echo sounder. Although targets were still detected over all ranges, information regarding directionality of the targets was unavailable without all four quadrants of the beam functioning. On the echograms, tracks appeared that had the shape and target strength usually associated with fish, yet the directional color scheme would go from blue to white, but the red end of the spectrum would be absent on many of the tracks. Without complete x-y direction information (blue to red coloration of tracks), which is the most important criteria for the operator to use to determine if a fish is passing upstream, no definitive conclusions about upstream passage can be made. Therefore, fish passage estimated with the split-beam equipment reported here are not assumed to be upstream passage, rather they are the number of fish passing either direction in front of the transducer.

One DIDSON^{TM} long-range unit manufactured by Sound Metrics Corp. was also deployed. This sonar was operated at 0.70 MHz, its low frequency option, using 48 beams for a viewing angle of 29° by 12° (Appendix A2). The maximum window length was set at 40 m. The DIDSON^{TM} was mounted on an aluminum tripod and aimed using an automated rotator similar to the one described above. Operators moved the rotators, while viewing the video image and proper aim was achieved when adequate bottom features appeared over the majority of the ensonified range (0–40 m).

The sampling was controlled by DIDSON^{TM} software loaded on a laptop computer. A 50-m DIDSON^{TM} cable carried power and data between a "breakout box" and the DIDSON^{TM} unit in the water. Ethernet cabling routed data between the breakout box and the laptop. All surface electronics were housed on the beach in a tent. Portable 1,000-watt generators were used to power the equipment.

SONAR DEPLOYMENT AND OPERATION

Having located a suitable site using river transect data, the DIDSON^{TM} unit was deployed August 19 to August 25, on the right bank (facing downstream) less than 1 mile downstream of Calico Bluff. A fish lead was constructed with 2-m metal "T" stakes and a section of small-mesh beach seine. The fish lead was set up approximately 1.5 m downstream shoreward of the right bank DIDSON^{TM} transducer and extended out to 3 m in front of the transducer to provide adequate fish diversion through the beam. A short lead was appropriate for this bank because of the steep drop off (water depth approximately 2.5 m, 2 m from shore) and the short nearfield distance (0.83 m) of the DIDSON^{TM}. The river was ensonified 40 m from the transducer. Fish passage data were collected in 15-minute samples on the right bank 24 hours per day for 6 days. Sonar control parameters included: low frequency mode, 0.83 to 40 m range, and 3 frames/s.

August 20 to August 29, the split-beam sonar was deployed on the left bank at Calico Bluff. A 5-cm by 5-cm by-1.2 m galvanized chain-link fish lead with 2 m metal "T" stakes was set up shoreward 1.5 m downstream of the left bank split-beam transducer to prevent fish passage inshore of the transducer. The fish lead extended 6.8 m in front of the transducer providing adequate fish diversion through the beam. After initial aiming and set-up, the split-beam system collected fish passage data 24 hours per day at this site, and was aimed to ensonify approximately 140 m of the river (total river width at the site was approximately 250 m). Settings for data acquisition included: 3 pings/s ping rate, 0.4 µs transmit pulse width, -40 dB threshold, 2 m to 140 m range, transmit power 14 dB, and -6 dB gain.

After monitoring right bank passage at Calico Bluff, the DIDSON^{TM} was moved to left bank and deployed next to the split-beam transducer for side-by-side data comparison. The purpose of this comparison was to examine whether the slower ping rate used for long range detection of fish with the split-beam sonar caused a lowered detection probability nearshore. From August 25 to August 28, the two sonar devices collected data 24 hours per day on the same bank and their counts were compared.

On August 28, the split-beam sonar system was removed from the Calico Bluff site and moved to left bank on Six-Mile Bend, approximately 6 miles downriver from Eagle near Shade Creek. After initial aiming, the transducer ensonified 129 m of the river at this new site and data were collected a total of 24 hours until the evening of August 29 when the transducer was removed for the end of the project. The DIDSON^{TM} unit was not tested at the Six-Mile Bend site.

SONAR DATA PROCESSING

Split-beam data were collected by the DEP in text files, in 60-minute samples each hour of the day, and saved to an external hard drive for postseason tracking and editing. To facilitate tracking, echoes from stationary objects were removed using a custom bottom removal program created in *Java* programming language (Dunbar and Pfisterer 2004). Echoes from stationary objects were removed before tracking by dividing data into range bins (0.2 m), calculating the moving average (averaging window of 1,000 echoes) of the voltage in each range bin, and then removing the echo if the voltage was within 1.7 standard deviations of the mean and at least 100 echoes were within that range bin. In order to reduce the chance of excluding echoes from non-stationary objects (such as fish), echoes were not removed if the missed echoes relative to observed echoes was greater than 80% for the 1,000 echoes in the moving average. The percentage of missed relative to observed echoes was calculated by summing differences between observed ping numbers minus one and then dividing by the total number of echoes in the range bin.

After processing the split-beam data with the bottom removal program described above, the operator selected groups of echoes considered to be fish. Targets were identified and selected as fish using the following criteria: length of time in the beam, target strength, and shape of trace. These selected fish were then tracked and counted using *Polaris*, an echogram editor developed by Mr. Peter Withler through a cooperative agreement with the DFO, ADF&G, and HTI. Tracked files were saved and used to produce passage estimates, range distributions, and a fish-by-fish comparison to DIDSON™ fish tracks.

DIDSON™ data were collected and files stored to the computer for postseason tracking. The echograms created by the DIDSON™ software were used to count fish. Fish were tracked and counted by locating a target on an echogram and selecting it with the computer's mouse. Only upstream targets were tracked and counted after verification with the video. Each file was tracked and saved.

The counts from each split-beam and DIDSON™ sample were entered into a Microsoft® *Excel* spreadsheet where counts were expanded for periods of missing data. When a portion of an hour was missing, the hourly passage was estimated by dividing the count by the fraction of the hour sampled. In instances where total hours were missed, the daily passage was estimated by dividing the total daily count by the fraction of the day sampled.

Split-beam files were 1 hour long, and DIDSON™ files were 15 minutes long, so for the side-by-side comparison, files were compared by hour and start time. These comparable files resulted in 49 side-by-side 'samples' i.e., a 'sample' consisted of the counts from one complete 60-minute split-beam file and the sum of the counts for four complete 15-minute DIDSON™ files. For instance, if a 60-minute split-beam file started at 1202 hours, the counts from the 15-minute DIDSON™ files starting at 1200, 1215, 1230, and 1245 hours would be summed and that summed count would be compared to the split-beam count for the same time period. The split-beam files often had a lag in start time, e.g. 1202 hours instead of 1200 hours start time. To account for this disparity between split-beam and DIDSON™ file lengths, each split-beam file was extrapolated to account for missed minutes of the full hour as explained above, but only files missing less than 5 minutes of data were used for the comparison.

To determine whether the narrow beam and relatively slow ping rate compromised the split-beam counts, we regressed the split-beam counts against DIDSON™ counts to see if the slope (forced through zero) was close to one.

Initial comparison of the split-beam and DIDSON™ counts revealed differences which prompted us to ascertain the cause. Time and distance from the transducer for each target were used to locate, verify and compare tracks on DIDSON™ video images, which led to the following processing procedure adjustments:

1. Downstream fish apparent on the DIDSON™ files were matched to the corresponding split-beam tracks by time and range. The downstream tracks were then removed from the total split-beam count. This was done to correct for the lack of x-y positional information due to the malfunctioning split-beam sounder.
2. Split-beam targets which were previously counted as fish, which appeared to result from strong bottom return when verified on the DIDSON™ video image, were removed from the total split-beam count. This would not have been a problem if the split-beam had functioned correctly.
3. Split-beam targets from 0 m to 40 m determined to be fish when found on the DIDSON™ file, were tracked if they appeared to have a strong return but too few echoes. These tracks were added to the total split-beam count.
4. In the case of targets that were tracked on split-beam files but not found on the DIDSON™ echograms, we re-examined the video and if a fish was found, it was added to the total DIDSON™ count.

The numbers of occurrence of each case were noted so that we could try to determine the largest sources of error. The count procedure adjustments made above were only applied to the compared samples, they were not applied to all files over the course of the study, i.e., passage estimates were created using original processing procedures.

Fish range distributions were created postseason by exporting the text file containing the range distribution (z positional) data associated with all fish tracks and plotting them in R, a statistical program (R Development Core Team 2004). Histograms were made of the fish range distributions and were used to investigate the spatial behavior of fish passing the sonar site.

TEST FISHING

Exploratory test fishing was undertaken at the Calico Bluff site to assess the feasibility of drift gillnetting in the general area of the study site, and through the section of river ensonified. The amount of test-fishing performed was limited by the rental boat and outboard motor (a deep-hulled, military issue 20 ft skiff powered by a 35 hp outboard tiller motor) which was not the ideal equipment for drift gillnetting with large nets. Three 50 fathom by 5 fathom nets (150 ft long by 30 ft deep) of three different mesh sizes (2.75 in, 5.25 in, 8.5 in) were deployed, each net drifted once per bank for a total of 6 drifts. For each drift the soak time was 10 to15 minutes, and the net passed through the river roughly 150 m upstream and 150 m past the transducers downstream. An effort was made to keep the net perpendicular to river flow, and to ensure that the lead lines were touching bottom. Minimal debris load for the river at this location and absence of underwater snags ensured ease of drifting. Drift gillnetting was not undertaken at Six-Mile Bend because of limited time and equipment.

RESULTS

BOTTOM PROFILES AND SITE ATTRIBUTES

River bottom profiles created in the study area provided information indicating two suitable sonar deployment sites. The first site was on the upstream end of an island near Calico Bluff (N 64°93.065' W 141°17.04') approximately 12 miles downriver from Eagle in the Yukon-Charley Rivers National Preserve, and the second site was Six-Mile Bend (N 64°87.79' W 141°07.96'), 6 miles downriver from Eagle (Figure 2). Figure 8 shows bottom profiles (cross-sectional views) of the Yukon River at Calico Bluff and Six-Mile Bend sonar sites. The left bank substrate at Calico Bluff was silt, and had a gentle, linear slope extending 225 m. The right bank at Calico Bluff was also linear but steeper, consisting of cobble and extending approximately 50 m to the thalweg. The left bank sonar site at Calico Bluff was located on an island with a dry slough running behind it. The right bank site at Calico Bluff was located directly across the river from the left bank site. Both banks at Calico Bluff had sufficient beach above water level to house topside equipment. The left bank bottom profile at Six-Mile Bend was approximately linear, extending 190 m to the thalweg. The right bank profile was less linear, but shorter and steeper, extending 87 m to the thalweg. The substrate at Six-Mile Bend was large cobble to small boulder on the right bank, and cobble and silt on the left bank. The Six-Mile Bend site consisted of a single channel and had sufficient beach above water level to house topside equipment.

FISH PASSAGE

The fish passage estimates for both sites, by bank and sonar type, from August 19 to August 29 are listed in Table 1. The maximum daily rate of fish passage observed during the study was 1,168 fish/day on August 27 on the left bank at Calico Bluff, and the minimum was 25 fish/day on August 19 on the right bank of Calico Bluff (Table 1).

SPLIT-BEAM AND DIDSON™ SIDE-BY-SIDE COMPARISON

Initial comparison suggested problems with our methodology, after adjusting methodology, the data were plotted. Figure 3 shows the hourly split-beam and DIDSON™ fish counts by sample. Figure 4 shows the regression of split-beam vs. DIDSON™. The slope of the regression (1.0290), forced through 0, was nearly indistinguishable from one ($R^2 = 0.8564$, $p < 0.001$).

FISH RANGE DISTRIBUTION

Fish were detected close to shore at all sites. On the right bank of Calico Bluff, 90% of the fish were detected within 14 m of the transducer and 95% were within 16 m (Figure 5). On the left bank of Calico bluff, 90% of the fish were detected within 37 m and 95% of the fish within 40 m (Figure 6). At the Six-Mile Bend location on the left bank, 90% of the fish were detected within 41 m of the transducer and 95% within 51 m (Figure 7).

TEST FISHING

Out of 6 drifts, one female chum salmon was captured near the right bank of the Calico Bluff site using the 5.75 in mesh gillnet on August 28.

DISCUSSION

Both Calico Bluff and Six-Mile Bend sites had suitable bottom profiles, and sufficient current for initial sonar deployment. Based on the criterion of ideal profile alone, the Calico Bluff Site was the preferred initial deployment site, and the majority of the project's focus was on this site. Despite being a good sonar location in the current season, the Calico Bluff site has a slough running behind the island which could present two possible problems. First, in years of high water levels, fish could be diverted behind the island, thus missed by the sonar. Second, the best location for deployment on left bank at Calico Bluff will be submerged during high water and could render the site unusable during a large portion of the Chinook salmon run, when water levels are historically highest. It was decided inseason that the single channel should have more priority among criteria for a suitable sonar site. For these reasons, the Six-Mile Bend site was tested after completing the side-by-side data collection at Calico Bluff. Split-beam sonar was only deployed on the left bank at Six-Mile Bend. Future operations will need to include more profiling of the right bank at Six-Mile Bend to determine the precise deployment site that will be used for that bank because the profile directly across from the left bank sonar site at Six-Mile Bend (Figure 8) was not the ideal linear profile observed at right bank Calico Bluff. The substrate and general shape of the bottom profile of right bank at Six-Mile Bend were very similar to the right bank at Calico Bluff, therefore we are confident that a suitable site for DIDSON™ deployment can be found at Six-Mile Bend. The substrate and beach of Six-Mile Bend is rocky, and therefore we believe bottom profiles will be more stable over time and beach erosion should be less of a problem than the silty substrate of the Calico Bluff site.

Personal communication with local residents operating fish wheels upriver of the sonar sites suggest that salmon catches were very small in the first week of the study, and that chum salmon catches increased approximately the same time as did the sonar counts during the second week of the study. These communications indicate that the Chinook salmon run was almost completely over and the fall chum salmon run was beginning to arrive in the Upper Yukon during the second week of the study. Because of the timing of the project (between the Chinook and fall chum salmon runs) the fish passage estimates reported here are not indicative of the strength of salmon runs for this season and are only an approximation of fish passage at the study area over the period of operation. Precise fish enumeration was not the objective of the current season, and therefore these estimates are not intended for management purposes. No attempt at species apportionment was made in the current season, so fish counted are not assumed to be salmon and may include non-salmon species such as whitefish (*Coregonus* sp) or suckers (*Catostomus* sp).

When the original side-by-side counts of split-beam and DIDSON™ samples did not correlate, the operators went through files fish-by-fish to investigate possible causes of the disparity between the counts. It was determined that the main sources of error that caused the counts to differ was the malfunctioning split-beam echosounder. The fact that directionality information of each target was not consistently available to the operator caused the following problems:

1. Some downstream targets were included in the original split-beam counts. Normally, when x-y positional data are available, direction of travel is often the first criteria used by the operator to determine an upstream passing object from a downstream object. (It is assumed that upstream passing tracks with appropriate target strength and track shape are fish, since debris cannot move upstream in areas of strong current.) Overall, downstream targets increased the split-beam counts by 15%.

2. A particularly strong signal return from a bottom feature would occasionally appear on the split-beam echogram resembling a fish target. Normally these intermittent traces can be discerned from fish targets by direction of travel when all four quadrants of the beam are functioning, i.e. a strong bottom feature may appear somewhat fish-shaped, but will not have directionality coloration showing downstream to upstream movement. This increased the split-beam counts by 16%.
3. The slower pulse return (ping) rate of the split-beam needed to ensonify the longer range resulted in very short traces at close ranges on the echogram that the operator might not have tracked. When fish that had been counted on the DIDSON™ were looked for on the split-beam, often they were found, but with the pings not being returned consistently on the split beam system, the tracks had too few pings and thus had not been tracked. This problem decreased the split-beam counts by 18%. One method of addressing this source of error will be to break the range into two range strata, each sampled 30 minutes of every hour. This will allow increased ping rates in the nearshore and slower ping rates in the offshore.

Two problems that were not caused by the malfunctioning split-beam contributed to the differing counts of the compared samples from the side-by-side study. These were examined more thoroughly and appropriate changes to processing procedures are discussed:

1. The split-beam ensonified a much greater range of the river (140 m) than the DIDSON™ (40 m), so fish could be counted by the split-beam that could not be detected with the DIDSON™. Due to nearshore distribution of fish, this only increased the split-beam counts by 7%. If a side-by-side comparison is to be attempted more thoroughly in future, the processing of the split-beam files will have to include a step for minimizing the display of the echogram, so that only the range ensonified by the DIDSON™, e.g. 0-40 m, is counted on the split-beam echogram (even though data will be collected over a much longer range).
2. Targets often appeared faintly on the DIDSON™ echogram and some went undetected (by the operator) because of the frame rate used for data collection (3 frames per second) may have been too slow for the fish swimming velocity. This happened most often near the outer extent of the DIDSON™ range, where the resolution was not as clear. Though this was encountered in 24% of the samples, it only caused a 4% decrease in the DIDSON™ counts. Changing to a faster frame rate; increasing the number of center beams averaged over, (i.e. from 3 to 5); and adjusting the image contrast, are all things the operator can do to improve the resolution and visibility of fish targets on the DIDSON™ echograms. These kinds of changes will be incorporated into future processing procedures. If further side-by-side comparison of split-beam and DIDSON™ is done in the future, the effective maximum range of the DIDSON™ will need to be reduced by about 1 m, because in the last meter of the viewing window the resolution is poorest and fish traces might be very hard to discern, even from the video image.

Because the malfunctioning echosounder caused processing problems which accounted for nearly 50% of the split-beam's counting bias, a properly working split-beam system should alleviate these problems. The two problems associated with the DIDSON™ system can be resolved with minor data collection and processing procedural changes. Though this season's comparison of the two systems was not a true blind test, the suggested processing methods changes can be incorporated, and a blind test of the two system's counts can be attempted in future. A recommendation to improve methodology for ease of sample comparison, is to use the same file lengths and viewing window lengths for both DIDSON™ and split-beam systems.

The nearshore distribution of fish observed on right bank this year at Calico Bluff, indicates that fish in the area are passing relatively close to shore on that side of the river, which is what we would expect, based on right bank's steep profile, fast current, and relatively short distance to the thalweg. We expect the fish behavior on the right bank at Six-Mile Bend to be similar because it has similar physical attributes. Based on the steep, short profile of right bank at Six-Mile bend, we believe the DIDSON™ will be the most appropriate sonar for that side of the river, because of its wide beam angle. However, the DIDSON™ will need to be deployed at Six-Mile Bend, in the next study and data should be collected for a full season to determine whether the maximum range of the DIDSON™ will be sufficient for salmon enumeration on that bank.

The 129 m detection range achieved with the split-beam at the Six-Mile Bend site covered almost 70% of the 190 m long left bank. And fish range distributions indicate that nearly all of the fish passed within the ensonified range, therefore, we suggest continuing to use a split-beam system on that bank. We believe the river coverage achieved this year, approximately 170 m, will be sufficient to monitor salmon passage, since the range distributions for both left and right banks indicate that the majority of fish were detected within 40 m of shore. However, this study did not address the question of whether there are significant numbers of salmon migrating in the unensonified portion of the river, so these distributions will need to be verified and tested further in future operations, and potential methods of investigating the unensonified portion of the river will need to be explored. One method to investigate is mounting a DIDSON™ to an anchored boat to look for fish near the thalweg.

Species composition of fish passing the site was not investigated in the current study. The drift gillnetting done in this study did, however, indicate that it will be a feasible method of test-fishing for the section of river in the study site. Though few drifts were attempted, it was clear that the current was not so strong at the study site as to rule out the method, as had been indicated at the former site nearer Eagle (Johnston et al. 1993). We determined that it was possible to drift nets based on the following criteria: there were no apparent snags in the area of Calico Bluff; the lead line reached the bottom; the debris load in the river was minimal and thus not a hindrance to effective drifting. The catch was very low, which was expected, because the study took place between salmon runs. Though drifting did not take place at Six-Mile Bend, the river attributes, i.e. current, debris load, depth of the profiles, at that site are similar to that of Calico Bluff, so it is assumed that drifting will be possible there. The rocky substrate may provide unforeseen effects, so future operations will need to incorporate a more extensive test fishing program at Six-Mile Bend, which includes drifting nearshore and offshore, over different time periods. Other methods of test fishing, e.g., set gillnets and fish wheels, to ascertain species composition of fish passing the sonar site should also be explored more thoroughly.

CONCLUSIONS

Results of this study indicate that sonar will be useful for counting fish at Six-Mile Bend. We gained insight into data collection and processing procedures that will improve accuracy of counts. Having located a suitable site to deploy split-beam sonar at Six-Mile Bend, we suggest initiating a full scale sonar enumeration project at that location in 2005 during the Chinook and/or chum salmon runs. The specific location to deploy DIDSON™ on the right bank of

Six-Mile Bend will need to be determined at the start of the 2005 season. Once the exact deployment site is found, using the DIDSON™ on the right bank, and a functioning split-beam system on the left bank should provide adequate river coverage to estimate salmon passage. A full season of daily enumeration data is needed to fully test the equipment, and examine spatial patterns of migrating fish and species composition at the site during the period of enumeration. A side-by-side comparison of the split-beam and DIDSON™ counts should be undertaken next season, to see if the nearshore counts of a fully-functioning split-beam system are compromised when ensonifying long ranges.

We believe that, once established, a long-term sonar project near the border could provide U.S. fishery managers with useful information for managing the Chinook and chum salmon fisheries to better meet commitments made by the U.S. under the Yukon River Salmon Agreement.

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TABLES AND FIGURES

Table 1.–Fish passage data estimated at Calico Bluff and Six-Mile Bend sonar sites on the Yukon River, near Eagle, Alaska, August 19 to August 29, 2004.

Date	Location	Bank	Sonar Type	Count	Number of Minutes Sampled	Fraction of Day Sampled	Expanded Daily Rate (fish/day)
8/19/2004	Calico Bluff	Right Bank	DIDSON	9	525	0.365	25
8/20/2004	Calico Bluff	Right Bank	DIDSON	39	1434	0.996	39
8/20/2004	Calico Bluff	Left Bank	split-beam	83	298	0.207	401
8/21/2004	Calico Bluff	Right Bank	DIDSON	34	1263	0.877	39
8/21/2004	Calico Bluff	Left Bank	split-beam	196	776	0.539	364
8/22/2004	Calico Bluff	Right Bank	DIDSON	63	1401	0.973	65
8/22/2004	Calico Bluff	Left Bank	split-beam	603	1433	0.995	606
8/23/2004	Calico Bluff	Right Bank	DIDSON	128	1410	0.979	131
8/23/2004	Calico Bluff	Left Bank	split-beam	711	1010	0.701	1014
8/24/2004	Calico Bluff	Right Bank	DIDSON	102	1440	1.000	102
8/24/2004	Calico Bluff	Left Bank	split-beam	724	1005	0.698	1037
8/25/2004	Calico Bluff	Right Bank	DIDSON	40	630	0.438	91
8/25/2004	Calico Bluff	Left Bank	DIDSON	169	735	0.510	331
8/25/2004	Calico Bluff	Left Bank	split-beam	976	1307	0.908	1075
8/26/2004	Calico Bluff	Left Bank	DIDSON	174	750	0.521	334
8/26/2004	Calico Bluff	Left Bank	split-beam	648	799	0.555	1168
8/27/2004	Calico Bluff	Left Bank	DIDSON	202	895	0.622	325
8/27/2004	Calico Bluff	Left Bank	split-beam	315	944	0.656	481
8/28/2004	Calico Bluff	Left Bank	DIDSON	393	1440	1.000	393
8/28/2004	Calico Bluff	Left Bank	split-beam	339	837	0.581	583
8/28/2004	Six-Mile Bend	Left Bank	split-beam	148	360	0.250	592
8/29/2004	Six-Mile Bend	Left Bank	split-beam	232	713	0.495	469
8/29/2004	Calico Bluff	Left Bank	DIDSON	340	1218	0.846	402

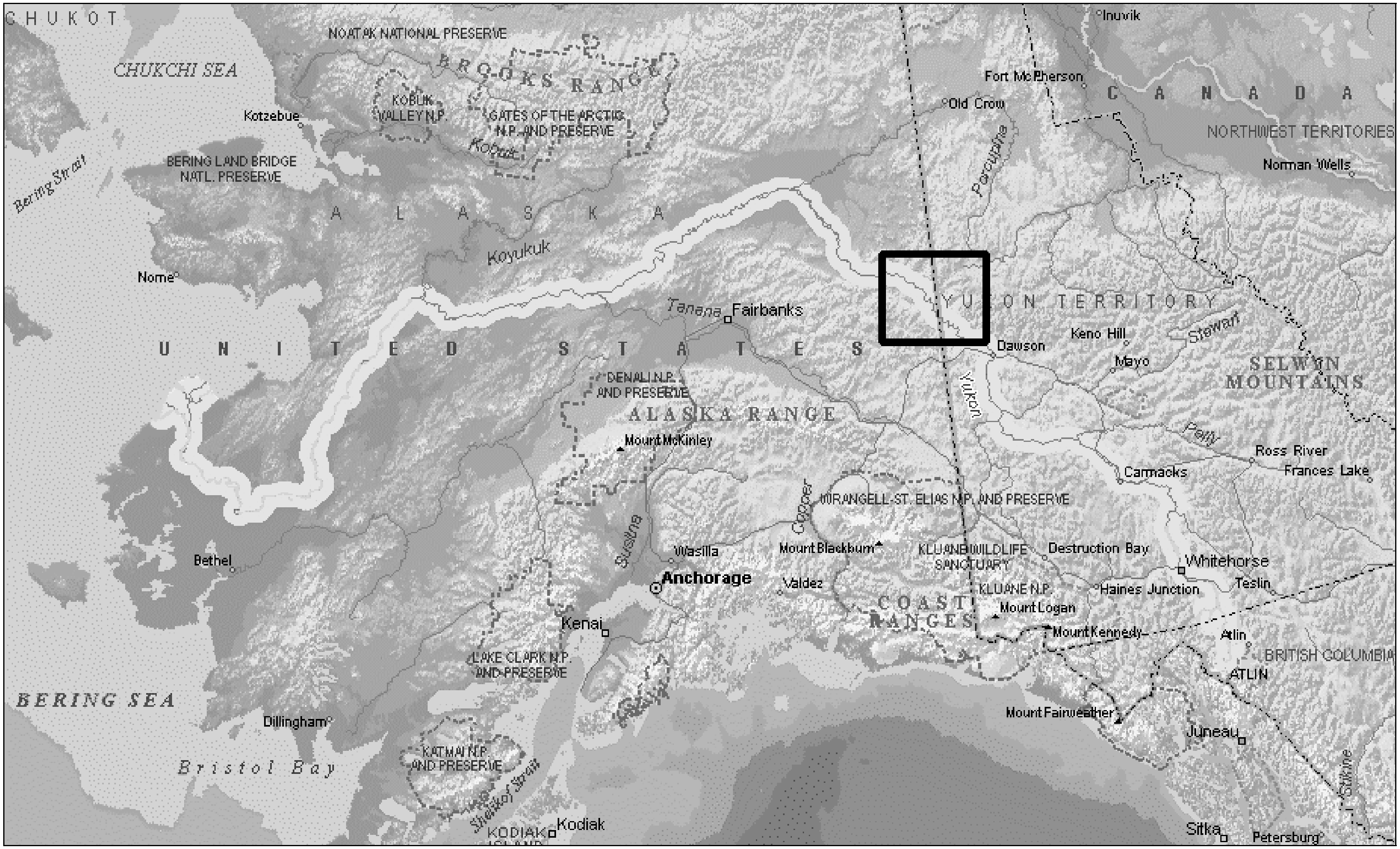


Figure 1.–Section of the Yukon River near the US/ Canada border where potential location for hydroacoustic sites were explored, August 18 to August 30, 2004.

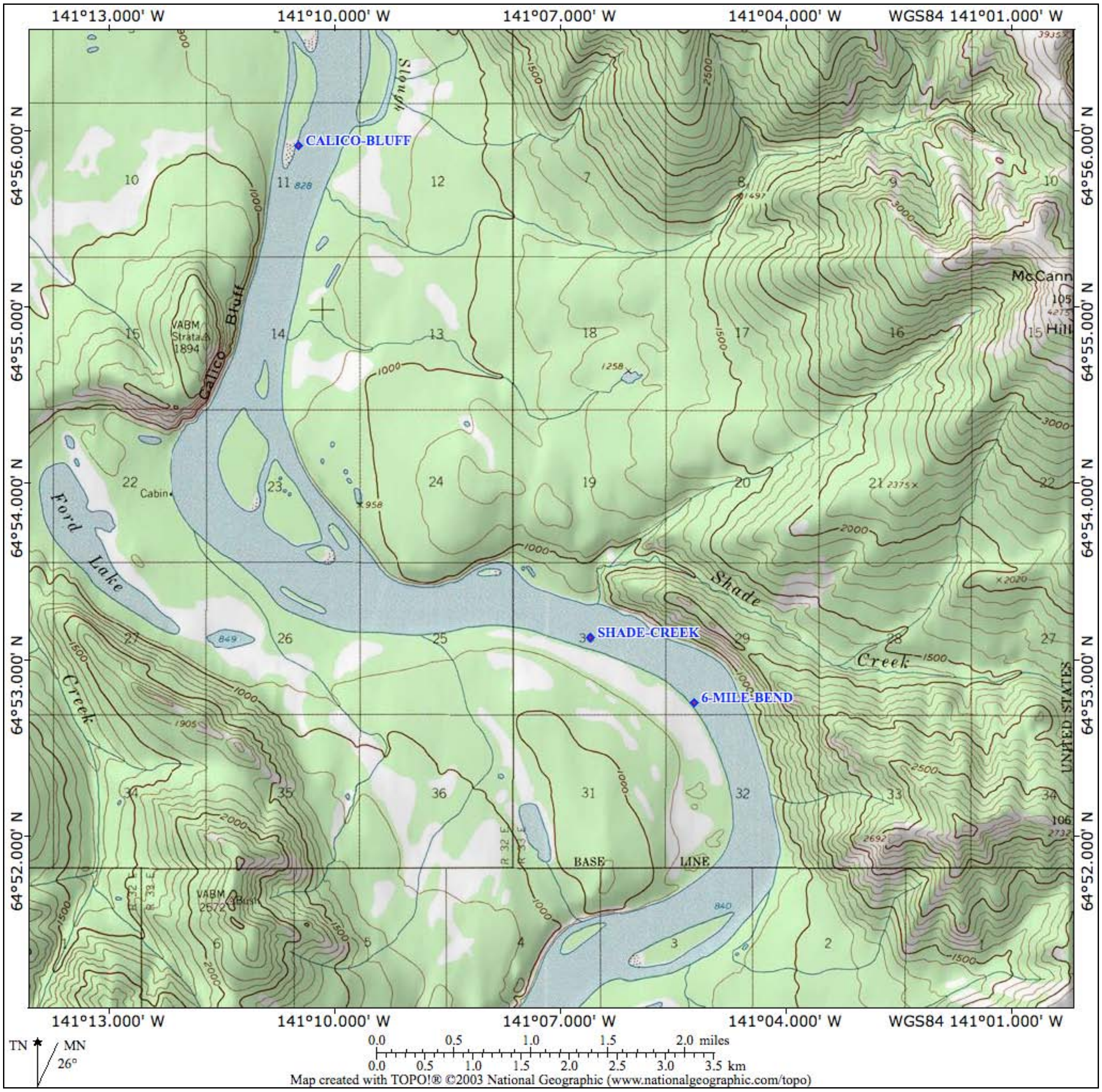


Figure 2.–Specific locations explored for deployment of hydroacoustic equipment, August 18 to August 30, 2004

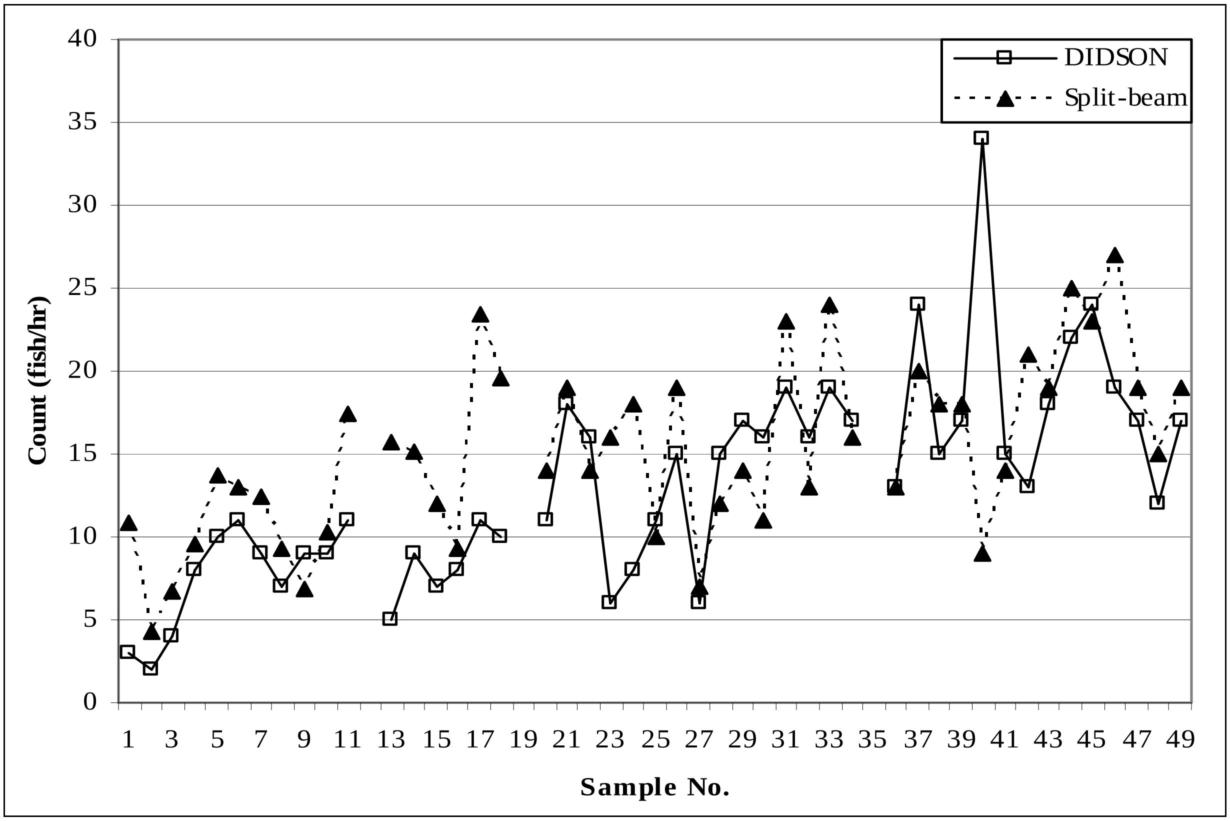


Figure 3.–Split-beam and DIDSON™ counts estimated with improved processing procedures, compared by sample, from a side-by-side data collection, August 25 to August 28, 2004 at Calico Bluff, near Eagle, Alaska.

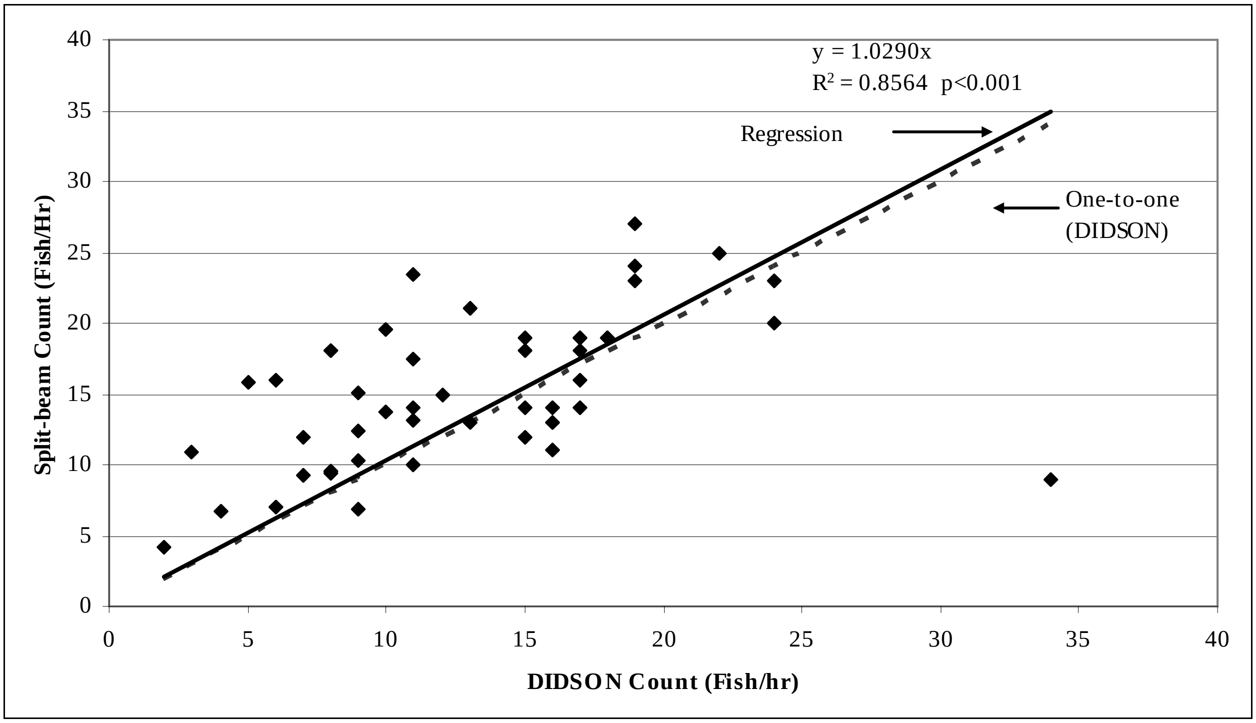


Figure 4.–Split-beam vs. DIDSON™ counts estimated with improved processing procedures, from a side-by-side data collection, August 25 to August 28, 2004 at Calico Bluff, near Eagle, Alaska.

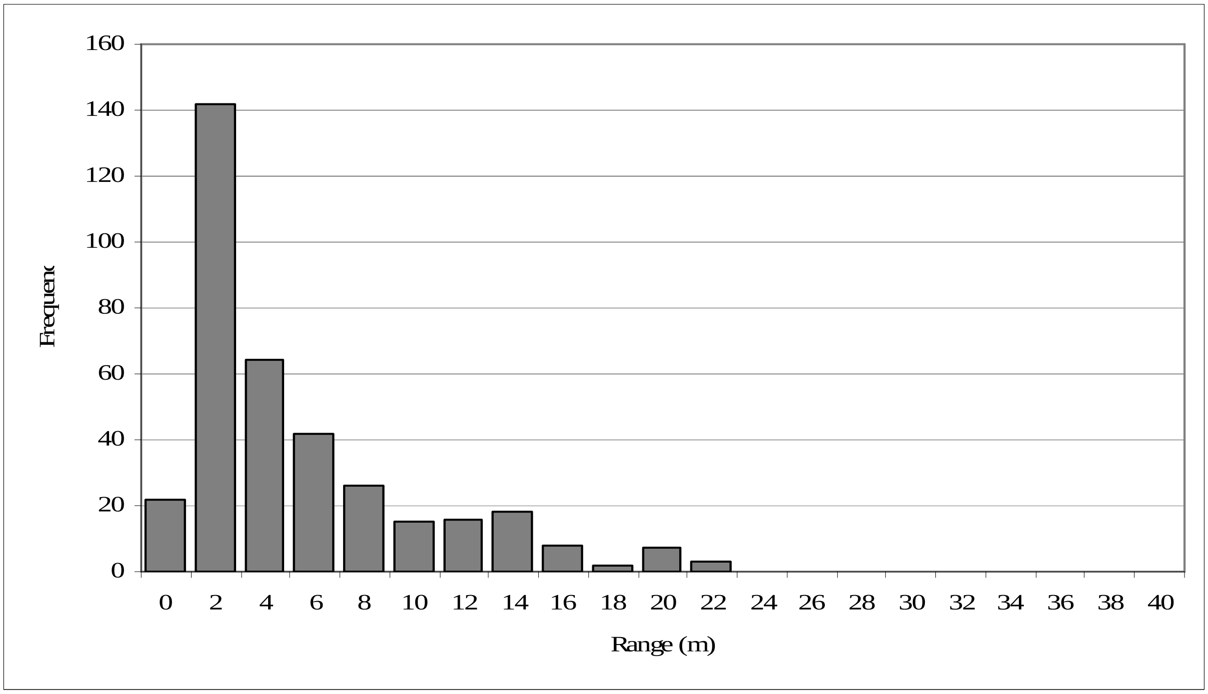


Figure 5.–Range distribution of upstream fish detected by the DIDSON™ on the right bank of Calico Bluff, near Eagle, Alaska, August 19 to August 25, 2004.

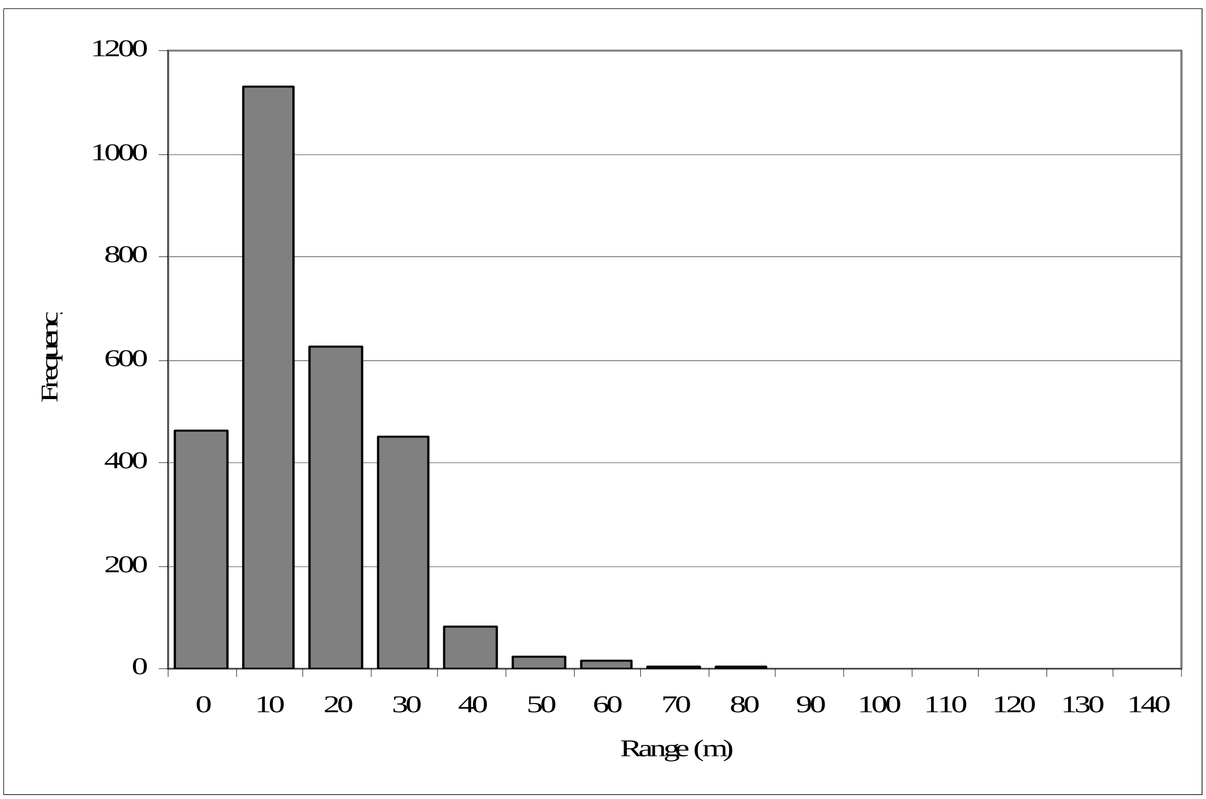


Figure 6.–Range distribution of fish detected by split-beam on the left bank of Calico Bluff, near Eagle, Alaska, August 20 to August 28, 2004.

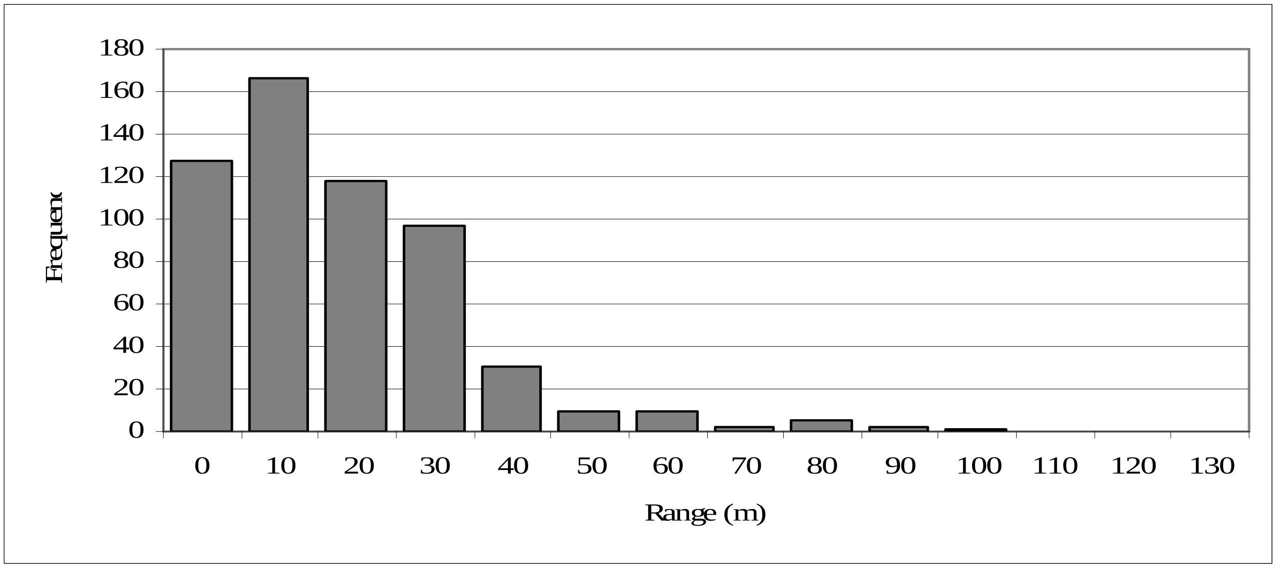
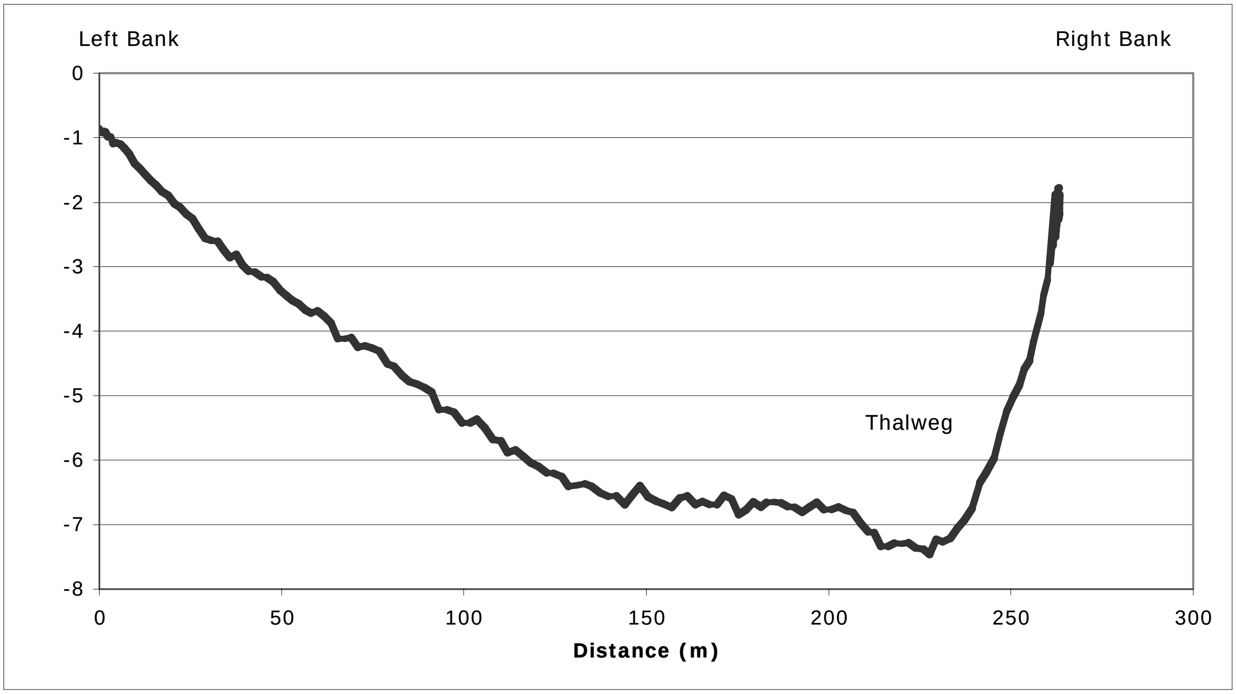


Figure 7.–Range distribution of fish detected by split-beam on the left bank of Six-Mile Bend, near Eagle, Alaska, August 28 to August 29, 2004.



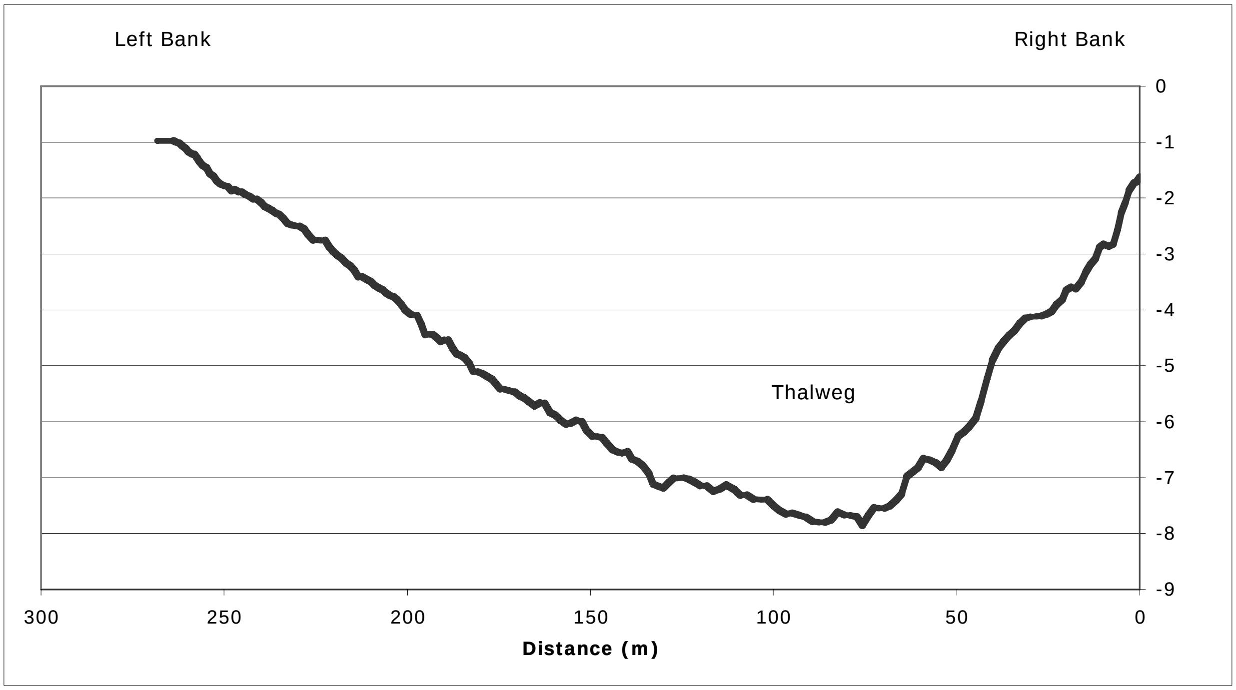


Figure 8.–Depth profiles made August 21, 2004 at Calico Bluff sonar site (top), and August 24, 2004 at Six-Mile Bend sonar site (bottom), near Eagle, Alaska**.**

APPENDIX A

Appendix A1.–Technical specifications for the Model 241 Portable Split-Beam Digital Echo Sounder.

Size:	10 inches wide x 4.3 high x 17 long, without PC or transducer (254 mm wide x 109 high x 432 long).
Weight:	20 lb. (9 kg) without PC or transducer.
Power Supply:	Nominal 12 VDC standard (120 VAC and 240 VAC optional).
Operating Temperature:	5-50°C (41-122°F).
Power Consumption:	30 watts (120 - 200 kHz), without laptop PC.
Frequency:	200 kHz standard (120 kHz and 420 kHz optional).
Transmit Power:	100 watts standard for 120-200 kHz. 50 watts standard for 420 kHz.
Dynamic Range:	140 dB
Transmitter:	Output power is adjustable in four steps over a 20 dBw range (+2, +8, +14, and 20 dBw).
Pulse Length:	Selectable from 0.1 msec to 1.0 msec in 0.1 msec steps.
Bandwidth:	Receiver bandwidth is automatically adjusted to optimize performance for the selected pulse length.
Receiver Gain:	Overall receiver gain is adjustable in five steps over a 40 dB range (-16, -8, 0, +8, +16 dB).
TVG Functions:	Simultaneous 20 and 40 log(R)+2αr TVG. Spreading loss and alpha are programmable to nearest 0.1 dB. Total TVG range is 80 dB. TVG start is selectable in 1m increments. The minimum TVG start is 1.0 m to maximum of 200 m.
Receiver Blanking:	Start and stop range blanking is selectable in 1m steps.
Undetected Output:	12 kHz, for each formed beam
Detected Output:	10 volts peak
System Synchronization:	Internal or external trigger
Ping Rate:	0.5-40.0 pings/sec
Phase Calculation:	Quadrature demodulation
Angular Resolution:	+/- <0.1° (6° beam width, 200 kHz)
Tape recording:	With Split-Beam Data Tape Interface and optional Digital Audio Tape (DAT) recorder, directly records the digitized split-beam data, permitting complete reconstruction of the raw data output.
Calibrator:	Local receiver calibration check using internal calibration source. Pulse and CW calibration functions provided in step settings.
Positioning:	GPS positioning information (NMEA 0183 format) via serial port of computer

Source: HTI 2000.

Appendix A2.–Technical specifications for the Dual-Frequency Identification Sonar**.**

Detection Mode	
Operating Frequency	0.700 MHz
Beamwidth (two-way)	0.8° H by 12° V
Number of beams	48
Range settings	
window start	0.75 m to 23.25 m in 0.75-m intervals
window length	9 m, 18 m, 36 m, 72 m
Range bin size relative to window length:	17 mm, 35 mm, 70 mm, 140 mm
Pulse Length relative to window length:	23μs, 46μs, 92μs, 184 μs
Identification Mode	
Operating Frequency	1.2 MHz
Beamwidth (two-way)	0.5° H by 12 ° V
Number of beams	48
Range settings	
start range	0.38 m to 11.63 m in 0.38-m steps
window length	2.25 m, 4.5 m, 9 m, 18 m
Range bin size relative to window length:	4.4 mm, 9 mm, 18 mm, 36 mm
Pulse Length relative to window length:	7μs, 13μs, 27μs, 54 μs
Both Modes	
Max frame rate (window length dependent)	2-10 frames/s
Field-of-view	29°
Remote Focus	1 m to max range
Power Consumption	30 Watts typical
Weight in Air (DC option)	7.0 kg (15.4 lb.)
Weight in Water (DC option)	0.61 kg neg. (1.33 lb.)
Dimensions	30.7 cm by 20.6 cm by 17.1 cm
Depth rating	152 m (500 feet)
Control	Ethernet

Source: Sound Metrics Corporation 2006.