

# Hydroacoustics: Rivers

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## Background and Objectives

Hydroacoustic methods are typically used to assess abundance in migrating fish populations when other methods are not feasible (i.e., the river is too wide for weirs or too turbid for observation towers). In many instances, hydroacoustic systems may be preferable to more intrusive devices such as nets or traps. This protocol addresses the use of hydroacoustic systems in rivers from fixed, nearshore positions, although down-looking, mobile methods have also been used to assess migrating fish populations (Xie et al. 2002).

Several types of sonars have been used to assess fish populations in rivers. The simplest was the single-beam sonar. In the early 1960s a single beam, echo counting system—a Bendix counter—was developed to enumerate adult sockeye salmon *Oncorhynchus nerka*. The Bendix counter has been an important tool for in-season management of predominantly sockeye salmon and chum salmon *O. keta* in many commercial fisheries in Alaska (Dunbar 2001, 2003; McKinley 2002; Westerman and Willette 2003; Dunbar and Pfisterer 2004). Dual-beam systems first provided target strength information for individual targets, allowing quantitative estimates of fish abundances using either echo counting or echo integration procedures in the late 1960s and early 1970s (Dragesund and Olsen 1965; Craig and Forbes 1969; Forbes and Nakken 1972). Dual-beam systems have largely been used for lake surveys to assess both adult and juvenile fish (Schael et al. 1995; Vondracek and Degan 1995) but have also been used at fixed, nearshore positions to assess migrating adult salmon in rivers (Gaudet 1990; Enzenhofer et al. 1998; Pfisterer and Maxwell 2000). Later, split-beam systems (see Figure 1) were shown to provide more accurate information on fish position—and thus a more accurate measure of target strength. Split-beam systems are currently used to enumerate migrating adult salmonids in several rivers (Daum and Osborne 1998; Miller and Burwen 2002; Xie et al. 2002). Most split-beam systems are used at sites where fish are relatively spread out and fish passage estimates are relatively low (i.e., less than 2,000 fish/h). Sockeye salmon runs tend to be large and concentrated in time, and split-beam sonars were found to do a poor job of assessing sockeye salmon at passage rates higher than 2,000 fish/h (Biosonics Inc. 1999a, 1999b). Echo-counting, dual-beam, and split-beam sonar methods, along with basic sonar information, are described in Brandt (1996) and MacLennan and Simmonds (1992).

A new sonar—a dual-frequency identification sonar (DIDSON) (see Figure 2)—was recently tested in Alaska and found to work well for enumerating fish at high passage rates (i.e., more than 2,000 fish/h) (Maxwell and Gove 2004). The DIDSON is a high-frequency, multibeam sonar with a unique acoustic lens system designed to focus the beam to create high-resolution images (Belcher et al. 2001, 2002). The evaluation of the DIDSON included comparisons of sockeye salmon counts from the DIDSON, Bendix sonar, and split-beam sonars against visual observations in a clear river; range tests using an artificial target acoustically similar in size to sockeye salmon in a highly turbid river and deployment of the DIDSON on rocky river bottoms and artificial substrates to observe fish behavior at these sites (Maxwell and Gove 2004).

Note: In this protocol, we recommend fixed-location (riverside) DIDSON hydroacoustic equipment, as it has proven to be a significant advance over other fixed-location hydroacoustic equipment used in rivers. Readers planning to utilize mobile (e.g., boat-mounted) hydroacoustic equipment are directed to the Hydroacoustic Protocol for Lakes and Reservoirs (pp. 153–172).

With any sonar type, there are many conditions that need to be met before a sonar system can be used. Practitioners attempting to employ any of the hydroacoustic methods should consider consulting an experienced acoustician to evaluate their particular application. For sonar to be successful in enumerating migrating fish the following conditions need to be met:

- (1) Fish need to be actively migrating. If fish are regularly traveling back and forth across the beam, they will be counted multiple times.
- (2) Fish must be traveling within the detection range of the sonar system, which needs to be tested at each site.
- (3) The river bottom profile must be mostly linear with laminar current flow. With the DIDSON, it is possible to ensonify a region where the slope changes from steeper near shore to a flatter slope offshore. The DIDSON contains a background subtraction algorithm that will subtract out the static background and leave the moving targets visible. If the slope starts out flatter and then grows steeper, the sonar beam may reach the fish but will not be reflected back to the transducer.
- (4) Either the species of interest is the only species present or an alternative technique is used to apportion the sonar numbers to species.

Common alternative techniques include drift gill netting (McKinley 2002; Pfisterer 2002) or fish wheels (Westerman and Willette 2003). Although the DIDSON is capable of providing length measurements of fish, because of beam spreading, the subcentimeter accuracy is only possible out to approximately 12 m using the DIDSON's high-frequency mode. To use length measures to determine fish species, the length frequency curves cannot be overlapping. An experiment with broadband acoustics was used successfully to determine sizes of free-swimming rainbow trout *O. mykiss* and Arctic charr *Salvelinus alpinus* (McKeever 1998).



FIGURE 1. — Split-beam system equipment.



FIGURE 2. — A dual-frequency identification sonar (DIDSON) system.

### Rationale

Using hydroacoustic systems to enumerate fish passage is preferable in many instances to more intrusive devices. There is no handling or mortality associated with acoustic sampling. Unlike earlier fixed-location, single- and dual-beam sonar systems (Gaudet 1990; Mesiar et al. 1990), the split-beam technique provides three-dimensional positioning for each returning echo, along with electronic data on the direction of travel and specific location for each passing target (Ehrenberg and Torkelson 1996; Steig and Johnston 1996; Daum and Osborne 1998); however, when mixed species occur at sampling sites, hydroacoustic estimates will need to be apportioned to the array of species using gillnetting, beach seining, fish wheels, or other capture methods. These capture techniques are not used for abundance estimates at these sites because they are confounded by variable water levels and fish densities.

### Objective

Use fixed-station hydroacoustic techniques to enumerate migrating fish in rivers to obtain abundance estimates or indices of abundance.

## Sampling Design

### Site Selection

Sampling sites are selected to optimize data collection and minimize problems with operations of the sonar. The primary criteria for selecting a riverine sonar site include single channel; sand, mud, or small gravel substrate; uniform, nonturbulent flow; linear bottom profile; downriver from known spawning areas; active fish migration past the site (no milling behavior); and upriver from tidal influences (Daum and Osborne 1998). For long-range sampling (i.e., greater than 50 m), the slope needs to be steep enough to fit an acoustic beam from near shore to the maximum range of fish passage.

### Equipment Selection

The DIDSON technology is easy to use and provides higher resolution images compared to other systems. The DIDSON is available in two versions: a standard version with the dual frequencies 1.8 and 1.1 MHz and a long-range version with frequencies of 1.2 and 0.7 MHz. The standard version has a maximum range of 30 m and can be used only in applications where fish migrate within this range. Adult salmon have been detected on the long-range DIDSON out to 50 m. Split-beam sonars are capable of detecting fish at a range beyond 50 m from the transducer and are used to assess fish out to 250 m (Pfisterer 2002). The DIDSON's high frequency beam is divided into 96 0.3°–12° beams with range settings up to 12 m. The 1.1 MHz beam is divided into 48 0.6°–12° beams with range settings up to 40 m. If the DIDSON's multiple beams are positioned horizontally, the field of view is 29° for both versions, and the vertical beam is 12°. Although the large vertical beam may not fit the narrow river, the excess beam can be pushed into the river bottom. Split-beam systems are available in multiple elliptical and circular beam sizes. The river column must be measured to determine the beam that will fit best. Water fluctuations throughout the sampling period also need to be addressed prior to making a beam size selection. Depending on where in the river fish migrate, multiple transducers may be required to adequately ensonify the river profile. For split-beam systems, the beam cannot interact with the river bottom unless the substrate is nonreflective. Split-beam systems are also available in many frequencies. For fish enumerating, traditionally either 420 kHz or 200 kHz (Daum and Osborne 1998; Xie et al. 2002; Pfisterer 2002) have been used for fish assessment. The lower frequencies (200 kHz or lower) will be the most effective at detecting fish at longer ranges (beyond 50 m). Range limitations of sonar systems are dependent both on frequency and power of the unit.

From a statistical perspective, the sampled population is considered “open” and consists of fish passing a site over a fixed time period. Data are usually gathered throughout the entire fish migration to estimate the migrating population. Depending on fish density and human constraints, a daily subsampling schedule may be needed to provide in-season passage numbers in a timely manner. A stratified sample design is often used when each riverbank is sampled separately (Daum and Osborne 1998).

### Designs for mobile down-looking equipment

More complex designs are often used in deep rivers where the targets of interest migrate off the bottom. In these cases additional sampling strata are added to account for the additional transducer aims (Xie et al. 2002). Although it is likely moving to a DIDSON-type system, the Pacific Salmon Commission has used a downward-looking single-beam echo sounder (Biosonics Model 105) to estimate the passage of migratory sockeye salmon and pink salmon *O. gorbuscha* in the Fraser River at Mission, British Columbia, since 1977 (Woodey 1987). This program consists of two components: transect and stationary soundings. These two operational modes are designed to provide data on two aspects of migratory salmon abundance: the transecting vessel collects information on fish density across the river; the stationary sounding acquires statistics on migration speed. The data from this program is processed using a duration-in-beam method (Thorne 1988), which leads to daily estimates of salmon movement past the survey site over a 24-h period. The statistical handling of the data has been refined and

improved recently (Banneheka et al. 1995); however, the accuracy of the estimates depends on the validity of a number of assumptions. The following assumptions are the most important:

- (1) All fish swim upstream along trajectories parallel to the riverbanks;
- (2) The majority of the fish are distributed in the midwater portion of the water column with few migrating near the river surface, where they would not be ensonified, or near the river bottom, where target returns would not be discernible from the bottom echo;
- (3) Few fish migrate in the shallow water, where the survey vessel is incapable of sampling;
- (4) Fish swimming speed is negligible relative to the transecting speed of the survey vessel; and
- (5) Fish behavior is not altered by the presence of the survey vessel.

The first four assumptions define fish behavior scenarios that are ideal for a downward-looking acoustic sampling of fish targets; the last is related to a fish–vessel interaction. Violation of these assumptions could result in bias in the daily estimates of abundance, as described in Banneheka et al. (1995); therefore, it is essential that these assumptions be assessed in the river using an independent measuring system (Xie et al. 2002).

### **Sampling Frequency and Replication**

Many salmon species migrations have clumped distributions, which vary with species, site, and density. In these situations, whether using the DIDSON or split-beam sonar, subsampling may be required to assess accuracy and precision in counts due to the high-data loads produced with these methods. A viable option is initially (first year) to conduct random sample 24-h periods throughout the season and then subsample from these 24-h periods to determine the time period required to generate the accuracy and precision stated for the project. Estimates based on 10 min/h samples have proved useful for enumerating sockeye salmon from towers (Seibel 1967). Reynolds et al. (In press) also reference a 10 min/h systematic sampling design for salmon counts. This same subsampling framework could be applied to sonar methods.

## **Field/Office Methods**

### **Setup**

#### **Preseason tasks**

1. Map the river bottom in the selected area. This can be done with downward-looking sonar coupled to a global positioning system (GPS). Or if the river is shallow, directly measure the depth from shore to shore at predetermined intervals (i.e., 1 m or less). A cross-river profile can then be plotted.
2. Determine species mixture at the site. Frequently, a netting program or alternative method is chosen to determine the extent of the migratory corridor and the types of species present. If mixed species are a concern,

an apportionment program also needs to be employed. Current sonar projects use drift gillnetting, beach seining, purse seining, or fish wheels to apportion the sonar estimates to species.

3. Select equipment (see page 146).

### **Events Sequence**

1. Select overall site.
2. Create a bathymetry map of site.
3. Select equipment—type of sonar system, beam size, and so forth.
4. Choose best river-bottom profile.
5. Build mounts for the sonar systems.
6. Deploy and aim equipment.
7. Field calibrate the sonar.
8. Set up an organized structure for collecting and storing data.
9. Begin sampling.
10. Count fish from either the DIDSON images or split-beam echograms.
11. Expand counts for time not sampled.

### **Measurement Details**

In this section, we offer basic measurement details for down-looking hydroacoustic efforts; the remainder of this section will detail the cross-channel aspects of the DIDSON and split-beam equipment.

#### **Down-Looking Equipment**

In the Mekong River (Lao PDR), hydroacoustic data were collected from hired local boats at a cruising speed varying between 3 and 5 knots, using a SIMRAD EY 500 scientific echo sounder (Kolding 2002). The split-beam transducer, model ES70-11, operating at 70 kHz, was mounted on a fixed structure on the fore-port side of the boats at a depth of 0.1–0.3 m below the water surface, and echo recording started 1 m from the transducer (i.e., 1.3 m below the surface).

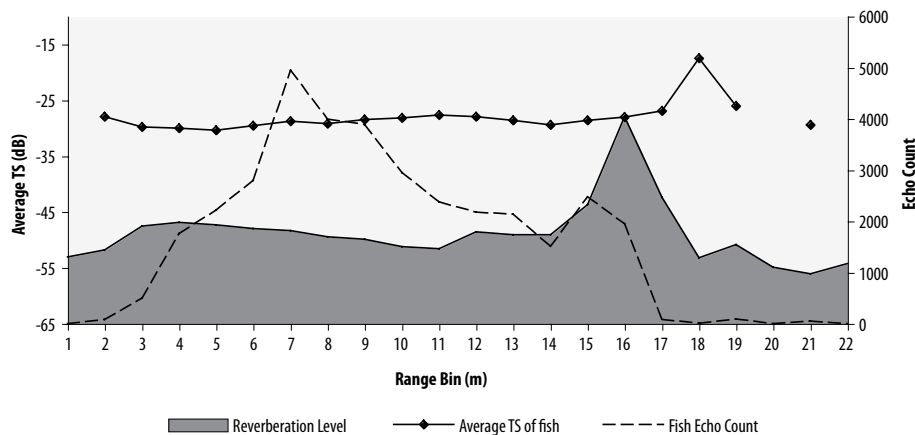
In the Fraser River (British Columbia, Canada), the electronic components of the hydroacoustic system operated by Xie et al. (1997) and Xie et al. (2002) were set up inside a cabin of a boat that was tied to a log-boom piling. Acoustic transducers were mounted on a tripod deployed on the river bottom and linked to the echosounder via underwater cables. The transducer's aiming was controlled manually through a rotator controller and monitored with the underwater positioning sensor. They used the following hardware: Hydroacoustic Technology, Inc. (HTI; Seattle, Washington) Model 240 split-beam digital echo sounder; two acoustic transducers; HTI Model 340 split-beam digital echo processor; ASL 10-kHz Sounder Digitizer; HTI Model 660 remote rotator controller; PT 25 Dual Axis rotator; underwater positioning sensor and tripod; and a Communication Systems International Model GBX-8A differential GPS receiver.

#### **DIDSON and split-beam systems**

Methods to enumerate migrating fish are described below for both DIDSON and split-beam systems. In addition to collecting the passage estimates, several

environmental measures should be collected at the acoustic site. These measures include

1. daily water level—measured from a permanent marker so inter-year data can be compared,
2. daily turbidity (i.e., if turbidity affects signal propagation),
3. daily water temperature—input into sonar software to calculate range, and
4. reverberation level—set sonar to lowest possible threshold and record signal when no fish are present. This represents the background reverberation (see Figure 3).



**FIGURE 3.**— Sample plot illustrating background reverberation levels (filled area) with the average target strength of fish plotted within 1 m range bins (solid line). The dashed line shows the number of echoes used to determine target strength at each range. The background reverberation level was collected with split-beam sonar at very low threshold levels (-150 decibels). The peak at 16 m is a combination of volume reverberation and reverberation from the river bottom.

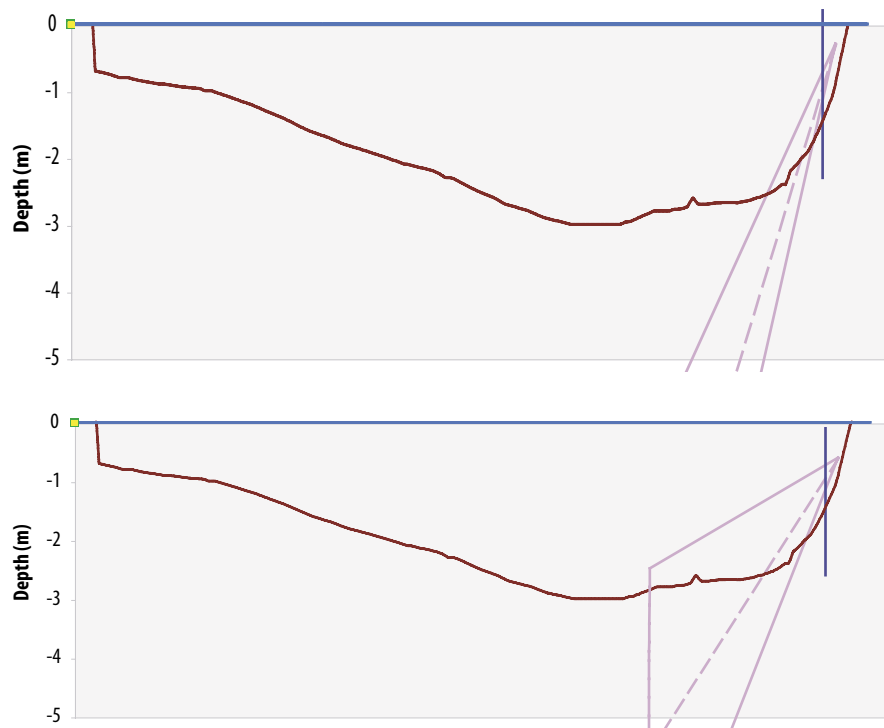
## DIDSON

Methods described below on how to use the DIDSON to enumerate migrating adult salmon are drawn predominately from Maxwell and Gove (2004).

### *Deployment and Aiming*

For the DIDSON, an attitude sensor that provides absolute pitch angle should be attached to the DIDSON transducer prior to deployment. The attitude sensor should be aligned with the transducer and leveling the transducer onshore prior to deployment using a bubble level. Any change from level can be used to adjust the pitch data obtained from the sensor. The height of the transducer should be determined by plotting the beam on a plot of the river-bottom profile and surface and determining the best height and pitch that will reduce shadowing effects and cover the needed range requirements (see Figure 4). Maxwell and Gove (2004) mounted the lower edge of the transducer 36 cm from the river bottom and pitched  $-8.0^\circ$  from level, matching the pitch of the bottom slope. This position facilitated coverage of the area directly in front of the DIDSON transducer and reduced shadowing from fish traveling close to the transducer. The DIDSON beam can be pushed into the river bottom if necessary, but the beam should not interact with the river's surface. The bottom subtraction algorithm built into the software works well to remove static bottom reflections from the image.

A weir (e.g., 5 × 10 cm mesh) is erected just downstream of the site to prevent fish from swimming behind and in the nearfield of the transducer. The weir should extend a minimum of 1 m beyond the face of the transducer and ideally be placed at a slight upriver angle to direct fish offshore more gradually. With the weir angled, fish are less likely to make a sharp turn around the weir in an attempt to return nearshore. Fish moving upstream and close to the shore would encounter the weir, be forced to move offshore, and then pass through the sonar beam. For best detection, passing fish should be perpendicular to the beam when ensonified.



**FIGURE 4.** — Two extreme riverside transducer aims illustrate how to reduce shadowing effects (top) and increase range (bottom). The optimal beam geometry will be between these two positions.

#### *Settings*

The only settings on the DIDSON that affect data collection are the start range, end range, frame rate, and frequency. The frequency is automatically set based on the range settings but can be overridden as long as the ping requirements are still met. Using the minimum range setting to meet the sampling needs will result in the choice of frequency. The 1.8 MHz ranges out to 12 m, the 1.0 MHz ranges to approximately 40 m, and the 0.7 MHz ranges to approximately 90 m (with fish perpendicular to the beam). Higher frequencies (dependent on range) and higher frame rates (dependent on range and computer RAM and speed) will produce higher resolution images. Settings controllable on playback that do not affect data collection can be adjusted to maximize fish detection. Primary settings include threshold, intensity, and background subtraction.

#### *Data Collection and Processing*

Once the transducer is adequately aimed and settings are chosen, the current DIDSON software allows for subsampling. Subsampling can be set up for any



portion of each hour. Sound Metrics (DIDSON Vendor) has added the option of subsampling hours or minutes within the day. (It has also created added the option of including an attitude sensor to the DIDSON, which can be retrofitted to an existing unit.) The sizes of DIDSON files depend on the frequency. The middle frequency produces files approximately 26 megabytes/min, with the higher frequency being twice that and the lower frequency roughly half that. These files can be saved directly to external drives to avoid one data transfer step.

Once saved, the files can be replayed using the same DIDSON data acquisition software. Technicians manually count upstream traveling fish on one hand using a counter and downstream fish on the other. Files can be sped up or slowed depending on passage rates. Cross-river range distributions can be obtained by mouse clicking on fish (with the fish count function checked) as the fish cross the image. The clicked positions are saved to a file that includes the fish number, time, range, length, and thickness of the image (length and thickness are only produced if the software is able to recognize the fish image). To date, the automated fish counter included in the DIDSON software package is not effective, largely because of shadowing effects. Work is in progress to solve the auto-tracking issues. Counts of fish images can be input onto a Microsoft Excel worksheet.

### **Split-beam**

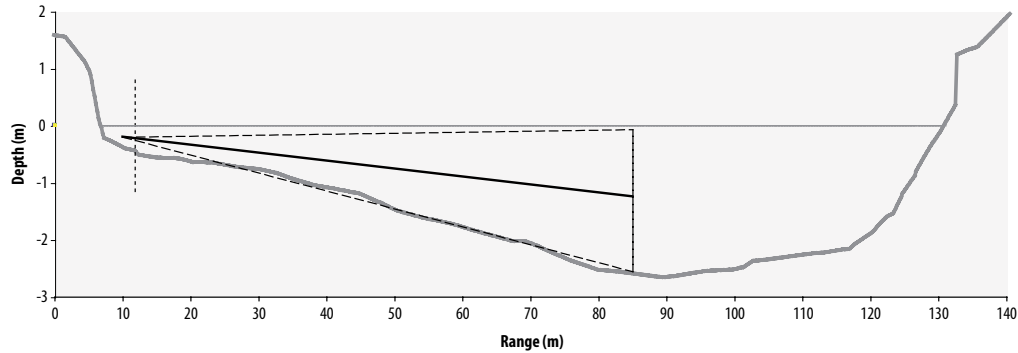
Recommended split-beam methods for enumerating migrating salmon are drawn from Daum and Osborne (1998) and Xie et al. (2002).

#### *Deployment and aiming*

To enumerate migrating fish at a riverine site, a transducer is placed on either bank of the river and positioned near the shore. A weir is erected downstream of the site to prevent fish from swimming behind and in the nearfield of the transducer. Ideally, the weir should extend beyond the range of the transducers nearfield (dependent on both frequency and beam size). The transducer should be deployed as low to the river bottom as possible (a boot width from the bottom to the lower edge of the transducer). The beam is then aimed along the river bottom matching the slope. Prior to aiming, a profile should be created or extracted from bathymetry data. The river bottom profile and surface should be plotted and sample beams drawn to determine the optimal aim and beam size. Once this has been completed, the aim is fine-tuned using the techniques on page 146. If the bottom substrate is fairly reflective, the beam will need to be raised until minimal or no bottom reflections are received at the sampling threshold level (see Figure 5). If the bottom is absorptive, as is common, the beam is aimed into the river bottom, positioning the axis of the beam just above bottom. According to Daum and Osborne (1998), on the Chandalar River, where the dominant species is chum salmon, precise aiming is critical because most of the fish travel close to the bottom. Once an aim has been selected, real-time electronic echograms can be monitored to ensure that the aim remains constant. Any changes in the nonfish reverberation or vertical position of passing fish should alert the operator to a change in the aim. The transducer should be reaimed if this occurs. Also, monitoring the real-time target strength of passing fish can detect a change in aim (i.e., the same size fish become acoustically smaller due to orientation changes in the beam).

To aim the split-beam transducer

1. Measure
  - a. Distance from the river bottom to the bottom of the transducer.
  - b. Distance from river bottom to water's surface at the transducer.
  - c. Distance from transducer to shore.
  - d. Distance from transducer to the end of the weir.
2. Start aiming process with this aim obtained from the beam profile plots.
3. Wrap a salmon-size target (10-cm-diameter sphere partially filled with copper BBs) in a mesh bag using a 23 kg or heavier monofilament line. Tie a loop on the end of the line, far enough up so that the knot will be above water level when the target is near the river bottom. (Note: this target has been shown to be the approximate acoustic size of a sockeye or chum salmon. If other species are being assessed, find a new acoustic target that returns an echo that is similar in strength to the fish.)
4. Attach the salmon-size target to an extension pole and extend it in front of the transducer beyond the nearfield (1 m for a  $6^\circ \times 10^\circ$  201 kHz split-beam sonar). (Note: a loop can be tied on the end of the line to the extension pole; then, the target's loop can be drawn through the pole's loop, making it easier to remove and add targets.)
5. Position the target so that a line drawn from the transducer mount to the target would perpendicularly bisect a line parallel to the river's current; then lower the target to approximately 10 cm off the river bottom.
6. Adjust the aim of the split-beam transducer until the target appears in the center of the beam horizontally and in the central portion of the lower half of the vertical beam. If the river bottom consists of a hard substrate, the transducer beam may have to be raised so that the target rests closer to the lower edge of the beam. If the river bottom is soft, the transducer may be lowered slightly, moving the target closer to the central axis of the beam. Use the Alt + Print Screen command to copy a picture showing the position of the target in the two-dimensional graphs of HTI's Department of Environmental Protection program, and then paste it either to a drawing program or PowerPoint presentation to document the aim. (Note: if fish targets are present, it may be necessary to raise and lower the target until the operator is assured that the echoes are coming from the target.)
7. Use the target to check the aim of the beam at several ranges. If the target is not visible at multiple ranges, it may be necessary to use a multiple transducer system.



**FIGURE 5.**— Transducer beam plot showing the relationship of the beam to the river bottom and surface. In this situation, the beam is lightly touching the river bottom.

If the current is strong, migrating fish will most likely be found near the river bottom. There are situations in which fish rise up off the bottom and pass over the beam. In these cases, a more complex sampling structure is needed. This can be achieved by either creating multiple aims or adding additional transducers to ensoundify more of the water column. Xie et al. (2002) used multiple aims to adequately ensoundify the regions of the water column utilized by migrating fish.

#### *Settings*

In Daum and Osborne (1998), the HTI split-beam sonar settings used for sampling chum salmon passage were pulse width 0.10–0.38 ms; on-axis threshold –40 decibels (dB) (10 dB lower than the predicted target strength estimate [Love 1977] for the smallest chum salmon in the Chandalar River); horizontal off-axis criteria set to the half-power beam width; and vertical off-axis criteria increased beyond the half-power beam width so that echoes from fish traveling close to bottom would be accepted; maximum range was 11–16 m on one bank and 65–78 m on the opposite bank.

In Maxwell and Gove (2004), a Biosonics' 201 kHz, 6.4o circular, split-beam transducer and attitude sensor were deployed in water 36 cm deep and 12 cm above the river bottom (to the lower edge of the transducer), and pitched –4.4° from level to sample sockeye salmon. Other settings included 17.2 pings/s; 0.2 mS transmit pulse width; –50 dB data collection and editing threshold; 1.0–8.5 m range; and single target criteria, including a –50 dB target threshold, 0.02–0.6 pulse width acceptance measured 6 dB below the pulse peak, 10 dB maximum beam compensation, and 3 dB maximum standard deviation of the alongship and athwartship angles. A sound speed of 1,443 m/s (Del Grosso and Mader 1972) and absorption coefficient of 0.013068 dB/m (Francois and Garrison 1982) were calculated using a measured water temperature of 9°C.

#### *Field Calibration*

Daum and Osborne (1998) had the sonar system calibrated in a laboratory based on the comparison method (Urick 1983). Field calibrations were performed three times during the season with a calibration sphere (38.1 mm tungsten carbide sphere) to ensure that the systems' electronics were functioning properly. Other good calibration techniques are found in Robinson and Hood (1983), Foote (1990), and Simmonds (1990).

To field-calibrate the split-beam transducer

1. Mount the transducer so it is no more than 8–10 cm off the ground (you should be barely able to stick the toe of your boot under it).
2. Wrap the carbide sphere in a mesh bag using 10–12 kg monofilament line (monofilament line reflects very little signal). Tie a loop on the end of the line, far enough up so the knot will be above water level when the target is near the river bottom.
3. Attach the target to an extension pole and extend in front of the transducer just beyond the nearfield (1 m for a  $6 \times 10^\circ$  201 kHz split-beam sonar), lowering it to approximately midway between the river's surface and bottom to avoid reverberation interference from either surface. (Note: a loop can be tied on the end of the line to the extension pole, and then the target's loop can be drawn through the pole's loop, making it easier to remove and add targets.)
4. Position the transducer beam so the target is centered both vertically and horizontally.
5. Set the sonar parameters as you would for sampling, except the threshold should be set as low as possible. Collect 1,000 pings or more from the target. (Note: if fish targets are present, it may be necessary to raise and lower the target until the operator is assured that the echoes are coming from the target.)
6. Determine the average target strength of the target and compare to the laboratory calibration. Adjust the calibration parameters if necessary by changing the system gain. Document the target file name, the sonar parameters, and the average target strength in a logbook.

### **Sampling Processing/Data Analysis**

Split-beam sonar data was displayed, auto-tracked, edited, and exported using SonarData's Echoview software with the integrated Blackman auto-tracking algorithm (Maxwell and Gove 2004). The split-beam sonar counts were obtained by visually counting the echogram traces (by manual count) and by auto-tracking using the Blackman algorithm. Other researchers use the HTI Trackman to mark and store tracked fish data from electronically produced echograms.

A second method of obtaining counts is to print charts (Pfisterer 2002) and mark and count individual fish traces. The counts can then be transferred to spreadsheets or a database.

There should be enough personnel to produce daily counts during the field season. Following the field season, the postprocessing responsibilities include assessing ancillary data such as cross-river distributions, fish swimming speed, and examinations of overall aspects of fish movements.

## **Personnel Requirements and Training**

### **Responsibilities**

**Project leaders will be responsible for**

1. purchasing and assembling needed sonar equipment.

2. deploying and aiming the sonar.
3. verifying the aim periodically through the season (split-beam) and conducting real-time monitoring of fish to detect changes in the vertical distribution of fish or the abrupt change in target strength of passing fish when species composition has not changed.
4. calculating thresholds (split-beam).
5. selecting optimal sampling configurations for the specific riverine environment (split-beam).
6. setting up the configuration files (split-beam).
7. developing a series of diagnostic tests to ensure that the sonar is functioning correctly (split-beam).
  - a. performing threshold tests,
  - b. monitoring signal from each channel separately, and
  - c. testing the gain.
8. training technicians.
9. redeploying and reaiming if environment conditions require it (split-beam).

Technicians will be responsible for

1. camp logistics (if remote site),
2. setting up basic equipment,
3. hauling supplies to sampling site,
4. learning to aim, set up, and deploy the DIDSON,
5. redeploying and aiming if necessary (DIDSON only),
6. doing manual fish counts from either DIDSON images or split-beam echograms, and
7. recording counts on spreadsheets.

### **Qualifications**

For DIDSON projects, project leaders should have a basic understanding of sonar principles. They can work with the vendor to obtain needed training to operate the DIDSON. Technicians should have experience in operating computers in a Windows environment and saving and transferring files.

For split-beam sonar projects, the project leader needs a more extensive background in sonar principles and a basic understanding in how the sampling parameters affect the data being collected. Technicians should have computer experience and some knowledge of sonar principles and the ability to quickly learn new software programs.

Use of both technologies requires a project leader with experience in budgeting, purchasing, project planning, data analysis, and report writing.

## **Training**

### **Project leaders**

We recommend classes or reading on basic sonar principles, training at multiple sites to understand how the sonar parameters affect the data collection, and extensive training on transducer aiming for split-beam operations. Several vendors have classes on sonar principles. Some classes may also be available through local colleges or universities.

### **Technicians**

We recommend training, which is traditionally done on site. A few hours of training are usually necessary to become familiar with DIDSON operations. Once technicians are familiar with the setup, they may be allowed to move and redeploy and reaim if necessary. If they are to set up a split-beam site, extensive training is required. It is not recommended that they move or redeploy the sonar without oversight by trained personnel. Aiming is critical and if off, the estimates will become completely invalid. Training on how to select fish from nonfish items also needs to be covered. If printed charts are used, trained personnel should check their progress until they feel comfortable that the technician is able to distinguish fish from nonfish.

## **Operational Requirements**

### **Workload and Field Schedule**

Three to four technicians and one project leader are needed to operate a two-bank sonar operation for either system. The project leader will either need to be on-site or quickly available for split-beam operations. In addition, the site should be checked periodically to ensure that the system is operating correctly.

### **Equipment Needs**

1. Sonar unit (either DIDSON or split-beam sonar)
2. Automated rotators if needed (automated tilt is very useful)
3. Attitude sensor (this is a must; without it aiming requires much more guesswork)
4. Controller computer for primary operations
5. Data processing computer (may be controller computer if budgets are tight but a backup is essential)
6. External drives or other means to store data
7. Permanent data storage devices (DVD writers plus disks)
8. Power; if site is remote, generator, solar panels, water turbines, etc., may be utilized singly or in conjunction with one another
9. Calibration equipment (tungsten carbide spheres)

### **Budget Considerations**

A sample budget using 2003 costs in U.S. dollars is included below for the DIDSON system. The split-beam system would be the same with the exception of the

unit cost. Today a split-beam costs approximately \$40,000. The costs listed are approximations and will change over time. The DIDSON, although more costly for the equipment, will be cheaper to operate as more experienced staff are only needed for the initial deployment.

### Estimated costs of DIDSON and accessory equipment

Item	Estimated cost per unit
Sonar equipment	
DIDSON sonar w/cables	\$80,000
Rotator and control	\$15,000
Attitude sensor	\$4,000
Transducer mount	\$500
Laptop computer	\$3,000
Misc. cables, USB, ethernet, etc.	\$200
Electronic storage devices	\$1,000
Power needs/per river bank	
Combination of small Honda generator, solar panels, batteries, and chargers	\$5,000
Total	\$108,700

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**Appendix A: Hydroacoustics: Rivers Data Sheet - Sonar Field Calibration**

Project \_\_\_\_\_ Date \_\_\_\_\_  
Location \_\_\_\_\_ Depth \_\_\_\_\_

Sphere \_\_\_\_\_ TS -39.5dB

Temperature \_\_\_\_\_ alpha \_\_\_\_\_

Salinity \_\_\_\_\_ Sound Velocity \_\_\_\_\_

**15 Degree Circular Transducer**

Calibration File: \_\_\_\_\_ G<sub>1</sub>40 \_\_\_\_\_ G<sub>1</sub>2

Acquisition File: \_\_\_\_\_

Observed TS: \_\_\_\_\_ Adjust Gains: Y / N G<sub>1</sub>40 \_\_\_\_\_ G<sub>1</sub>2

Acquisition File: \_\_\_\_\_

Notes: \_\_\_\_\_

**4x10 Elliptical Transducer**

Calibration File: \_\_\_\_\_ G<sub>1</sub>40 \_\_\_\_\_ G<sub>1</sub>2

Acquisition File: \_\_\_\_\_

Observed TS: \_\_\_\_\_ Adjust Gains Y / N G<sub>1</sub>40 \_\_\_\_\_ G<sub>1</sub>2

Acquisition File: \_\_\_\_\_

Notes: \_\_\_\_\_

