Application of DIDSON Imaging Sonar at Qualark Creek on the Fraser River for Enumeration of Adult Pacific Salmon: An Operational Manual

H.J. Enzenhofer, G.M.W. Cronkite, and J.A. Holmes

Fisheries and Oceans Canada
Science Branch, Pacific Region
Cultus Lake Salmon Research Laboratory
4222 Columbia Valley Highway
Cultus Lake, British Columbia
V2R 5B6

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APPLICATION OF DIDSON IMAGING SONAR AT QUALARK CREEK ON THE FRASER RIVER FOR ENUMERATION OF ADULT PACIFIC SALMON: AN OPERATIONAL MANUAL

by

H.J. Enzenhofer [1], G.M.W. Cronkite [2], and J.A. Holmes [2]

[1] Fisheries and Oceans Canada
Science Branch, Pacific Region
Cultus Lake Salmon Research Laboratory
4222 Columbia Valley Highway
Cultus Lake, British Columbia
V2R 5B6

[2] Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9T 6N7

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ABSTRACT

Enzenhofer, H.J., Cronkite, G.M.W., and Holmes, J.A. 2010. Application of DIDSON imaging sonar at Qualark Creek on the Fraser River for enumeration of adult pacific salmon: An operational manual. Can. Tech. Rep. Fish. Aquat. Sci. 2869: iv+ 37 p.

The aim of this manual is to provide a summary for development of a fixed-location acoustic site for estimating fish passage in a river using imaging sonar equipment. This summary includes the procedures specific to the Qualark Creek acoustic site on the Fraser River near Yale, British Columbia, Canada, but many of these procedures can be generalised to any suitable riverine acoustic site. We used the DIDSON imaging acoustic system in 2008 and 2009 at the Qualark Creek site to enumerate migrating salmon. The Qualark site was originally developed using split-beam hydroacoustic technology but much of the infrastructure for the split-beam systems proved useful for imaging sonar as well. Riverine sampling conditions are acoustically challenging, requiring specialised in-river equipment and the proper selection of acoustic sampling techniques. We describe the specialised in-river equipment and modifications to the site to make it favourable for acoustic sampling, together with costs for performing the modifications. Deflection weirs are described that are designed to move fish away from the shore so that they can be reliably counted. Other equipment is described which allows the accurate aiming of the acoustic beam, maintenance of a constant beam configuration during equipment moves, and the performance of beam mapping experiments to verify complete coverage of the area in which the salmon are migrating. We also describe data analysis procedures to review large quantities of imaging acoustic data and develop daily estimates of migrating salmon for in-season fisheries management. Procedures include the daily operation of a drift net test fishery at the site to provide species composition information which is used to apportion the daily acoustic counts to species.

RESUME

Enzenhofer, H.J., Cronkite, G.M.W., and Holmes, J.A. 2010. Application of DIDSON imaging sonar at Qualark Creek on the Fraser River for enumeration of adult pacific salmon: An operational manual. Can. Tech. Rep. Fish. Aquat. Sci. 2869: iv+ 37 p.

Ce manuel est un résumé des procédures de développement d’un site acoustique fixe dans le but d’estimer le passage de poisson dans un cours d’eau à l’aide d’un sonar d’imagerie. Ce résumé inclut les procédures particulières au site acoustique du ruisseau Qualark, tributaire du fleuve Fraser, situé près de Yale, en Colombie-Britannique, mais nombre de ces procédures peuvent être généralisées de sorte à pouvoir être appliquées à tout site acoustique fluvial adéquat. Nous avons utilisé le système DIDSON d’imagerie acoustique en 2008 et 2009 au site du ruisseau Qualark pour énumérer les saumons en migration. Au départ, la technologie hydroacoustique à faisceau partagé a été utilisée pour développer le site Qualark, mais la plus grande partie de l’infrastructure pour les systèmes à faisceau divisé s’est révélée utile aussi pour le sonar d’imagerie. Les conditions d’échantillonnage en milieu fluvial étant exigeantes sur le plan acoustique, il faut disposer d’équipement spécialisé en rivière et bien choisir les techniques d’échantillonnage acoustique. Nous décrivons l’équipement spécialisé mouillé et les modifications apportées au site pour le rendre propice à l’échantillonnage acoustique, y compris les coûts de ces modifications; des déflecteurs conçus pour éloigner les poissons de la rive de sorte à pouvoir être dénombrés avec précision; d’autre équipement qui permet de pointer précisément le faisceau acoustique, de maintenir une configuration constante du faisceau durant les déplacements de l’équipement et de mener des expériences de cartographie par balayage pour vérifier si le secteur de migration des saumons est complètement couvert; et enfin les procédures d’analyse des données pour passer en revue de grandes quantités de données d’imagerie acoustique et faire des estimations quotidiennes du nombre de saumons en migration pour la gestion des pêches du saumon en saison. Les procédures incluent la tenue, au site, d’une pêche expérimentale quotidienne au filet dérivant pour obtenir de l’information sur la composition des prises par espèces; cette information est utilisée pour répartir les dénombrements acoustiques quotidiens selon l’espèce.

1.0 INTRODUCTION

Fixed-location hydroacoustic systems are widely used to monitor migrating fish populations in the riverine environment (Banneheka et al., 1995; Burwen et al., 1995; Xie et al, 1997; Daum and Osborne, 1998; Cronkite et al., 2005). The Qualark Creek facility on the Fraser River was originally developed as a fixed-location hydroacoustic site which utilized digital spit-beam systems from July 1993 to August 1998. We developed the methodology for monitoring the abundance of returning adult anadromous salmonids (*Onchorhynchus spp*.) in the riverine environment and designed, constructed and deployed in-river equipment that would aid the acoustic measurement of these salmon (Enzenhofer and Cronkite, 1998). These techniques and equipment are readily adaptable for implementation in other river systems.

Operation of a hydroacoustic site using split-beam technology requires a high level of acoustic expertise and complex analytical protocols (Xie, 2000; Enzenhofer and Cronkite, 2000). The level of complexity associated with the operation of split-beam systems made the transfer of the technology to operational stock assessment staff difficult and required a greater time commitment for instruction. With the development of the dual-frequency identification sonar (DIDSON; Belcher et al., 2001) we can produce reliable and timely escapement estimates with a simplicity of operation that substantially reduces the training required for new staff unfamiliar with acoustic systems. The fish-count data produced with a DIDSON imaging sonar are as accurate as visual counts of fish migrating through an enumeration fence in a clear water river as long as the system is aimed so that the beams insonify the area through which fish are migrating and there are no blind zones near the surface or bottom (Holmes et al., 2006).

We returned to the Qualark Creek Acoustic Site on the mainstem of the Fraser River during the 2008 and 2009 adult sockeye salmon (*O. nerka*) migration to provide an estimate of the migrating populations. All five Pacific salmon species return to spawn in the Fraser River and pass the Qualark site. Sockeye salmon is the dominant species in even numbered years (e.g., 2008) while in odd numbered years (e.g., 2009), pink salmon (*O. gorbuscha*) are often more abundant than sockeye salmon. The Qualark site is located above most of the major in-river fisheries and below the Fraser Canyon, which is considered the most difficult portion of the river for salmon migration and the likely area in which in-river mortality during migration is highest.

This manual provides an overview of the operating procedures and sampling protocols developed during June – September, 2008 at the Qualark site. We also present minor modifications to the procedures made in 2009 to address lessons learned in 2008, and to estimate the large numbers of migrating pink salmon for the first time using the DIDSON technology. We address all aspects of the site operation from the initial installation of equipment through to the production of the daily estimates of upstream escapement.

This manual describes:

1. Site choice and modifications made to the river banks to automate daily procedures and assist in the acoustic measurement.
2. In-river equipment such as the automated weir and track system, the transducer-weir-bracket and adjustable pole mount for deploying transducers.
3. Establishment of an aim configuration for the DIDSON to detect fish passage around the fish deflection weir while avoiding the requirement for multiple aims. Verification of the ensonified region using lead-filled spheres deployed off the end of the weir.
4. DIDSON software parameters used to collect image files.
5. Software features used to process the data files for both the high frequency (HF) and low frequency (LF) settings.
6. Processing collected data files to produce a fish count by direction of travel, expansion to an hourly net upstream count and final daily estimates apportioned by species.
7. Recount procedure to measure precision among observers and flag anomalous file counts.
8. Implementation of test fishing using a series of drifted gill nets of varying mesh sizes to collect biological data (scales, genetics, length, weight, condition, marks, etc.) from fish in the river, and to collect species composition information which is used allocate the acoustic counts to species.

2.0 BACKGROUND

Historically a mobile, single-beam hydroacoustic enumeration site on the Fraser River near Mission, BC, has provided estimates of gross escapement of migrating sockeye salmon stocks to fisheries managers (Banneheka et al., 1995). Over the years, the Mission estimates plus mortality and harvest combined, have approximated spawning ground estimates within the level of precision achievable by the different enumeration techniques. However, in 1992 the number of fish that returned to spawning grounds was significantly less than expected based on Mission acoustic estimates of gross escapement into the lower Fraser River, leading to an investigation of the discrepancy between the Mission and spawning-ground counts (Larkin and Pearse, 1992). The resulting report recommended that a second hydroacoustic site be established further upstream of Mission, both to corroborate the Mission count and to provide up-to-date estimates of run sizes. This recommendation was acted upon by the Department of Fisheries and Oceans Canada (DFO) in 1993 with the establishment of the Qualark Creek facility. The Qualark site was operated experimentally from 1993-

1998 using digital split-beam acoustic systems with the objective of developing acoustic methods to estimate salmon escapement in rivers. Some of the techniques developed and perfected at Qualark (e.g., side-looking split-beam acoustics using multiple stratified aims to cover the water column) were subsequently transferred to and applied by the Pacific Salmon Commission at the Mission site, which continues to operate. The Qualark site was dismantled after the 1998 migration period and was re-activated in June, 2008 using imaging sonar systems (DIDSON) that had proved useful at other salmon enumeration sites, two examples of which are the Horsefly and Chilko Rivers (e.g., Cronkite et al. 2006; Holmes et al. 2006).

3.0 SITE DESCRIPTION

The Qualark Creek hydroacoustic facility is located on the Fraser River in British Columbia, Canada and is 15 km north of Hope, BC, and 95 km upstream of Mission, BC. The Fraser River is one of the world's largest producers of sockeye salmon (*Oncorhynchus nerka*) (Northcote and Larkin, 1989) and the Qualark site is below many, but not all of the major stock spawning areas (Figure 1).

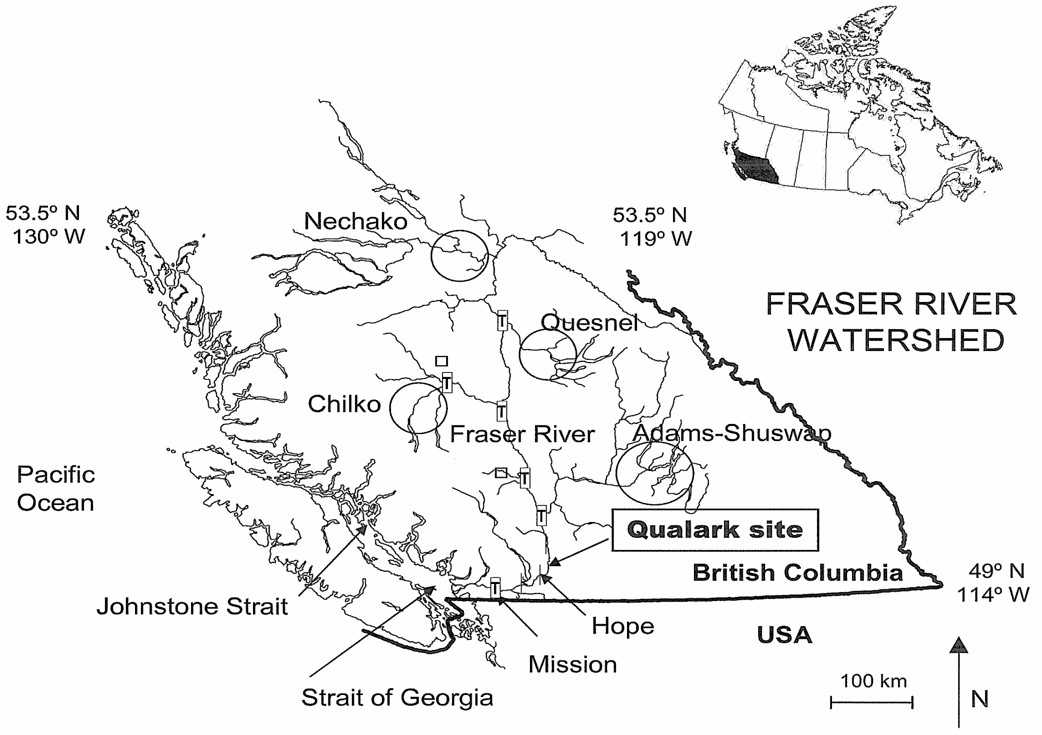


Figure 1: Map showing the Fraser River watershed and location of the Qualark Creek hydroacoustic site near Hope, BC. Some of the major spawning areas are circled.

The Qualark site was originally chosen as an experimental site because it was on a straight stretch of river with laminar flow, water velocity was high, flows were not tidally-influenced, the substrate and bank configurations were planar and free of obstructions (scalloping, benches, large boulders) that might impair fish detection or introduce noise to the acoustic system and there was minimal human activity that would alter fish behaviour (Enzenhofer and Cronkite, 2000). These characteristics ensure that fish actively migrate through this area rather than holding or milling, which is key to the success of a riverine acoustic site. The relatively high water velocities and consistent bank slopes combined with the energy conserving migration schemes of salmon, result in most salmon, including sockeye, migrating through the Qualark site within 15 m of the shore regardless of discharge and water level. Consequently it is not necessary to ensonify the middle of this wide river where the signal to noise ratio is not favourable for the detection of fish.

The Fraser River is 150 m wide at the Qualark site with discharge ranging from 10,000 $m^3 s^{-1}$ during spring freshet to 500 $m^3 s^{-1}$ during the low water period in winter. The river banks have a natural slope of 21° (right-bank) and 20° (left-bank) with the surface layer consisting of 30-50 cm diameter rock with some large boulders (Figure 2) (left-and right-banks are relative to an observer facing downstream). Water velocities at the site range from 1.0 $m s^{-1}$ near shore to 3-4 $m s^{-1}$ in the middle of the river. Flow patterns vary from bank to bank, resulting in scouring of fine materials along the right-bank and the deposition of sand along the left-bank.

The right-bank is accessible by road and heavy equipment was used to refurbish the bank for acoustic work (see below). The left-bank site is approximately 150 m downstream of the right-bank site and is only accessible via boat or railway. Equipment and supplies were moved to the left-bank by boat and the refurbishment of the acoustic ramp and reinstallation of in-river equipment was done manually.

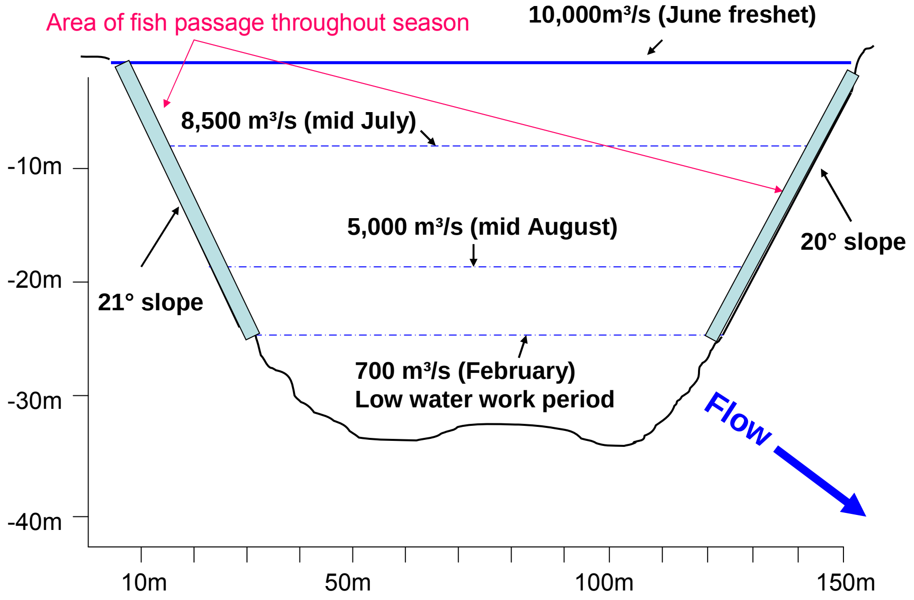


Figure 2. Fraser River cross section at the Qualark Creek site showing average discharge rates throughout the salmon migration period. Note that the vertical and horizontal scales differ. River flow is toward the viewer.

4.0 MODIFICATIONS TO THE RIVER BANKS

Substantial work was required to prepare the banks for the acoustic detection of migrating fish and to automate positioning of acoustic equipment in response to fluctuating water levels. Both banks were modified during the low water period (25 February to 06 March 2008) to create sandbag ramps that conformed to the natural bank slope. On the right-bank the surface layer was removed and replaced with 10 cm crushed rock on top of which partially filled and flattened sandbags were placed to create a ramp 10 m wide and 35 m long, perpendicular to the shoreline (Photo 1). The left-bank required hand levelling of the surface layer and removal of some large rock (30-70 cm diameter) prior to the placement of the sandbag ramp, which was 10 m wide and 30 m long. The sandbag ramps provide a level surface to lay and anchor the tracks for the automated weir (Sec. 5.1) and are less reflective of sound than rock, increasing the signal to noise ratio of fish and improving detection. Ramp lengths on both banks were established to ensure acoustic system operation between high water in spring and low water in the early fall.

Preparation of the acoustic ramp and track system

Photo 1. Right-bank modifications performed at the Qualark Creek hydroacoustic site on the Fraser River. The top left shows the removal of the existing surface layer and the top right shows the addition of the 10 cm crushed rock. The bottom left shows the levelling of the crushed rock and the bottom right shows the installation of the sandbag ramp and track system for the fish deflection weir.

5.0 IN-RIVER ACCESSORY EQUIPMENT

In rivers with moderate to high flow rates, fish migrating upstream tend to be bank and substrate oriented because current velocities are lower in these regions, reducing the energetic cost of migration (Groot and Margolis 1991; Standen et al., 2004). Hydroacoustic systems are generally deployed in a fixed-location with a shore-based transducer aimed perpendicular to the water flow. Fish migrating close to shore must be moved offshore to pass through the beam at a range where the beam width is sufficiently large to ensure a high probability of detection.

Deployment of equipment is difficult in rivers having high current velocities or substantial fluctuations in water levels such as the Qualark site on the Fraser River. To make acoustic measurements at this kind of site requires the use of specialised in-river equipment designed to withstand the force of the current while remaining sufficiently mobile to facilitate repositioning as water levels change (Enzenhofer and Cronkite 1998). This equipment consisted of:

1. A fish deflection weir which moves fish offshore to pass through the acoustic beam where the beam is much larger, and therefore the probability of detection is greater.

2. A transducer-to-weir bracket, which maintains the transducer assembly's geometry relative to the weir, allowing beam configuration to be maintained during equipment moves.

3. An adjustable pole mount for deploying acoustic transducers (Enzenhofer and Cronkite, 2005).

5.1 FISH DEFLECTION WEIR

The fish deflection weir is a free-standing structure supported by a brace system connected to a double track that runs perpendicular to the river flow. The deflection weir moves fish offshore so that they pass through the far field of the acoustic beam, which is located on the upstream side and parallel to the weir (Photo 2).

The weir is 6 m long, trapezoidal in shape to conform to the riverbank, and prevents fish from migrating under or through it. A walkway with handrails runs along the top of the weir to provide access along its length. The walkway also provides a working platform useful for measuring the detection characteristics of the acoustic system. The weir was moved up and down the track with an electric winch mounted on a platform that was attached to the top of the tracks. A complete description and the construction details can be found in Enzenhofer and Olsen (1996).

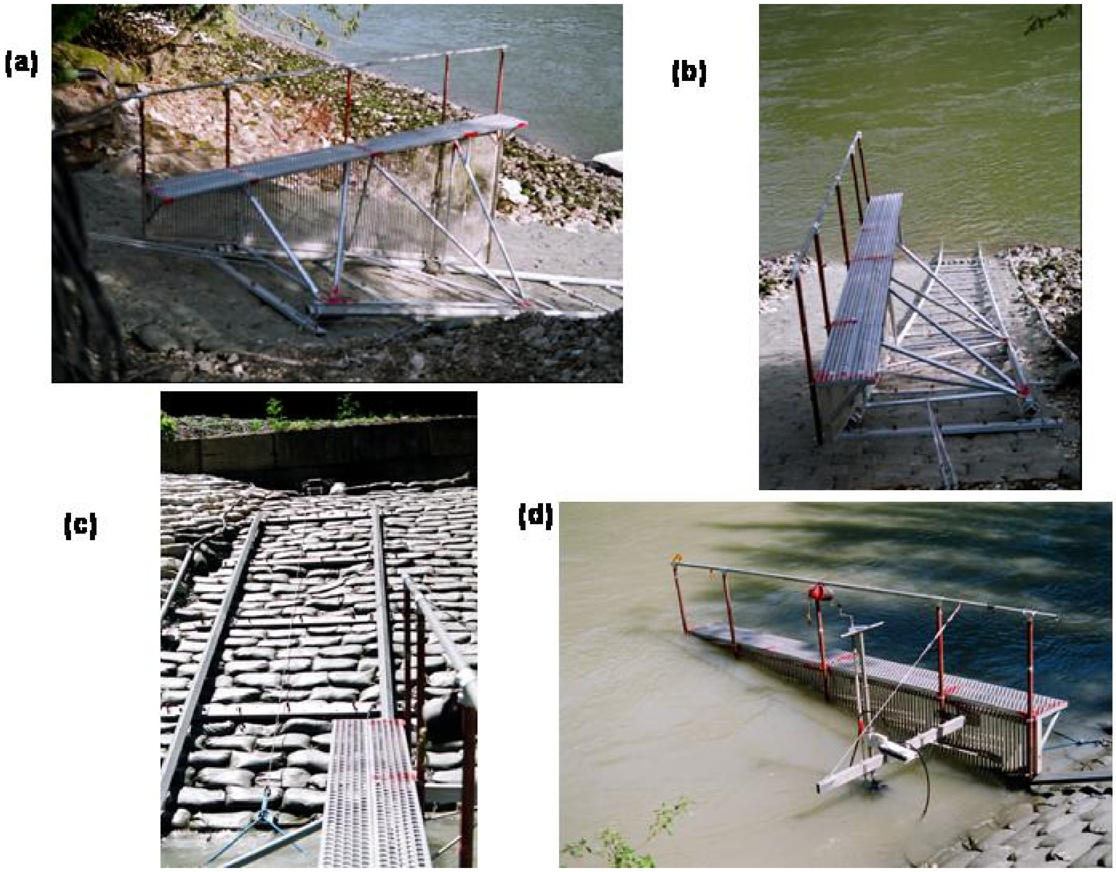


Photo 2. Automated fish deflection weir and track system used at Qualark Creek Hydroacoustic site on the Fraser River. (a) 6 m long trapezoidal shaped weir attached to a track, anchored to the river bottom, (b) 32 m of exposed track with weir and walkway, (c) top portion of the deployed fish deflection weir showing the cable and bridle connected to a winch at the top center of the track, and (d) fish deflection weir with an adjustable pole mount affixed to a transducer-to-weir bracket.

5.2 TRANSDUCER-TO-WEIR BRACKET

The transducer-to-weir bracket is an aluminium bracket mounted to the upstream side and shore end of the fish deflection weir (Figure 3, Photo 2d). This bracket maintains the acoustic beam configuration between the river and the fish deflection weir whenever equipment moves are made. The main horizontal component of the bracket is 5.1 cm x 10.2 cm x 2.12 m long and has a bolting plate and two struts on the weir end for bolting to the weir's vertical pipes. A 6 mm diameter galvanized aircraft cable is connected to the outer end of the bracket and provides adjustable support through a turnbuckle installed on the weir handrail.

The adjustable pole mount is installed on the transducer-to-weir bracket by attaching the slide and receiver bracket portion of the pole mount (Figure 4).

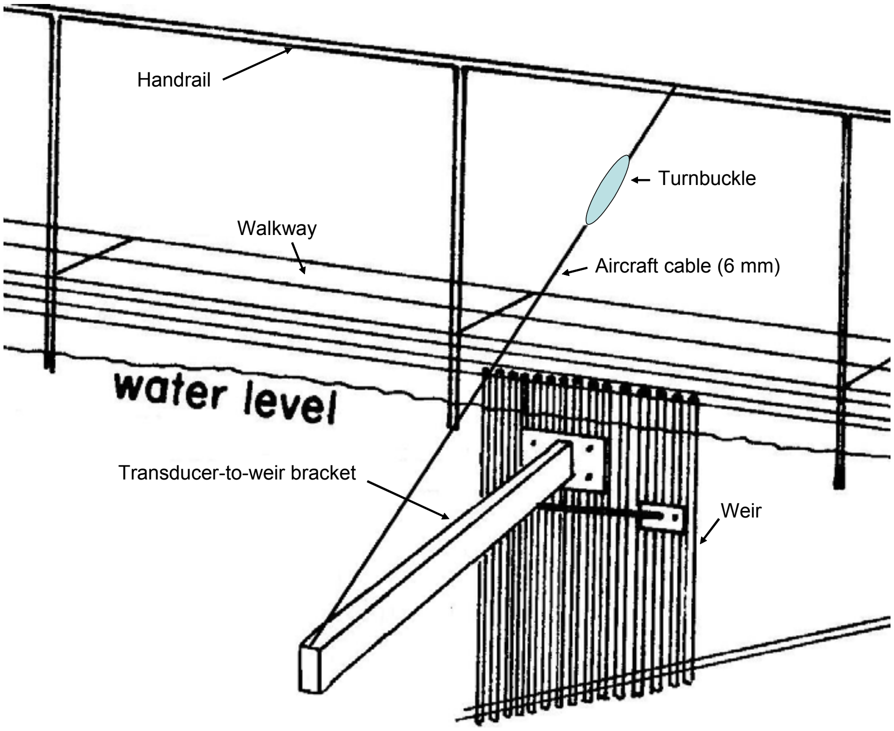


Figure 3. Three-dimensional view of the transducer-to-weir bracket mounted to the shore end of a fish deflection weir which has walkway access along its length. The galvanized aircraft cable gives guy line support by tightening the turnbuckle.

5.3 ADJUSTABLE POLE MOUNT

The adjustable pole mount (see Enzenhofer and Cronkite 2005 for construction details) provides precise manual control of the depth, bearing, roll angle and tilt angle of an attached transducer (Figure 4). A pole mount stabilizer between the pole mount and the transducer-to-weir bracket prevents movement of the DIDSON sonar head in fast current, which could result in blurred images (Photo 3).

The DIDSON can be bolted directly to the transducer mount plate or to a 90° hinged bracket added to the transducer mount plate if adjustment of the roll angle is desired. Once the DIDSON is secured, the depth, bearing, tilt angle, and roll angle can be adjusted and measured as follows:

1. Depth adjustment is made by loosening the locking sleeve for pole depth adjustment, setting the pole mount to a desired depth and re-tightening the sleeve (Figure 4).

2. Bearing (upstream/downstream) is made by releasing the wing nut that holds the pole mount stabilizer to the pole mount (Photo 3) and turning the pole mount using the handle bars at the top.
3. Tilt angle (surface/substrate angle) is adjusted by turning the tilt adjustment crank. The tilt angle can be measured directly with a carpenter’s protractor placed on the transducer mount plate. The mount plate can be levelled to 0° with a protractor (i.e., parallel with the water surface), and 5° increments (represented by the 10 mm spaced marks) can be read directly with the stainless steel pointer.
4. Roll angle can be adjusted up to 90° rotation by mounting the DIDSON to the 90° hinged bracket, loosening the wing nut of the pivot arm and reading the roll angle directly with a carpenter’s protractor. The pivot arm can also be marked with angles from 0° to 90° and roll angles measured directly from the graduated pivot arm assuming the mount is levelled at the start.

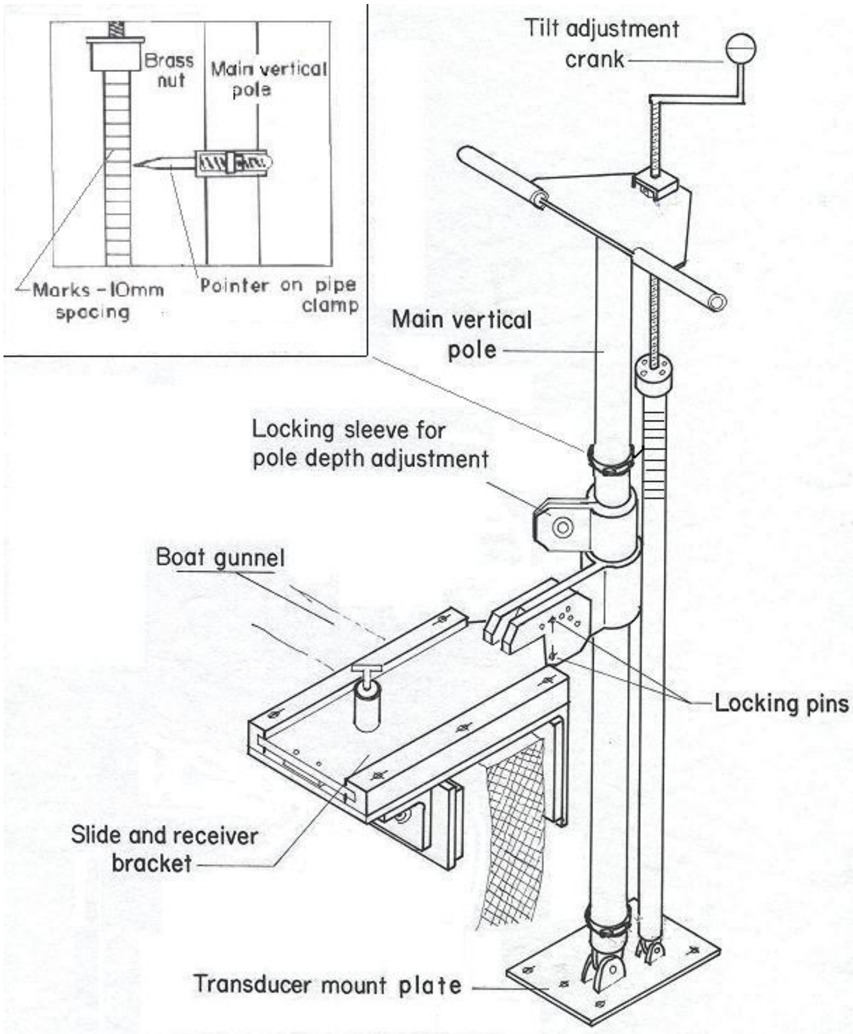


Figure 4. Three-dimensional view of the adjustable pole mount attached to a boat. The slide and receiver bracket can be mounted to any solid attachment

structure. The enlarged diagram shows the stainless steel pointer mounted to the main vertical pole and is used to measure the change in tilt angle of the transducer mount plate by rotating the tilt adjustment crank.

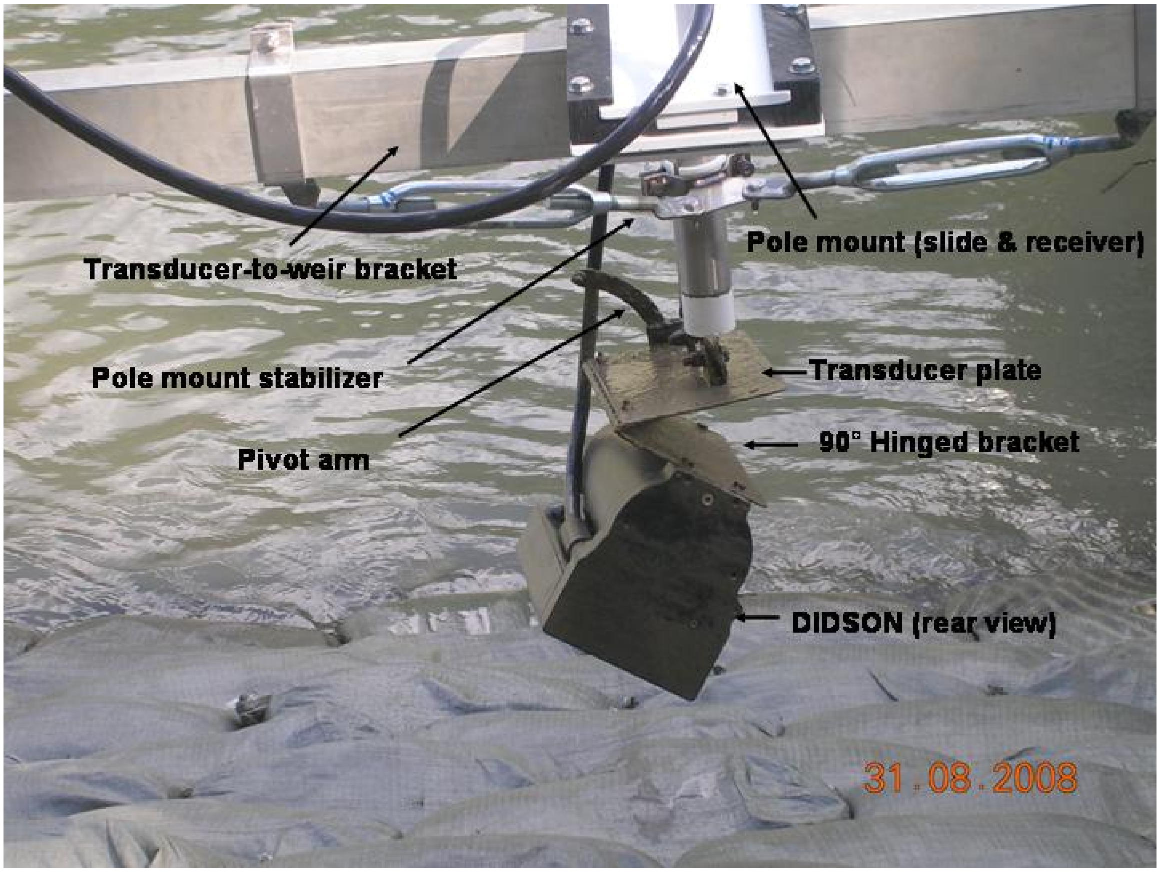


Photo 3. Rear view of the DIDSON sonar system mounted to an adjustable pole mount affixed to a transducer-to-weir bracket on the right-bank (water flow is left to right). The pole mount stabilizer secures the pole mount to the transducer-to-weir bracket and prevents motion of the sonar head caused by current flow. The DIDSON unit has been mounted to a hinged bracket that allows tilt adjustment from 0° to -90° relative to the water surface.

6.0 POWER SUPPLY SYSTEM

Since the left-bank (boat access side) lacked line power, we used a power supply system (Power-Pac) designed for remote sites to run the equipment (Enzenhofer et al. 2007) rather than the diesel generator that was used from 1993 to 1998. This power supply system (Figure 5) was successfully tested at other sites (e.g., Cronkite et al. 2006). Electricity is generated and stored in the battery bank as 12 VDC and is converted to 120 VAC to power equipment by an inverter. The system is designed so that individual components such as wind turbine, water generator or solar panels (or any combination) can be used to keep the battery bank continuously charged or the Power-Pac can be operated on batteries alone using a stand-by generator and 40 Amp charger to recharge the battery bank periodically. Individual power source components can be added at any time through pre-wired cable connection points as the Power-Pac has the charge controllers and electrical components required for their operation. By switching to this alternate power source, we eliminated the impact of continuous noise and the high cost of providing fuel to a generator and reduced our equipment maintenance requirements.

The DIDSON system and operating computer had a continuous draw of 7 Amps and our Power-Pac had a battery bank storage capacity of 840 Amps (20 Amp hour rate) at 12 VDC. We found that the 4 solar panels (combined 20 Amp maximum output) could supply the power demands of the DIDSON system as well as maintain the charge of battery bank for most of the study period. Top-up charges were needed occasionally due to periods of prolonged heavy cloud cover. The water generator was deployed from the end of the left-bank weir but the current flow was too slow to produce significant power at this site. The charge status of the battery bank, the power demand and input from the power sources was readily observed on the battery monitor readout in the control panel container (see Enzenhofer et al. 2007 for details).

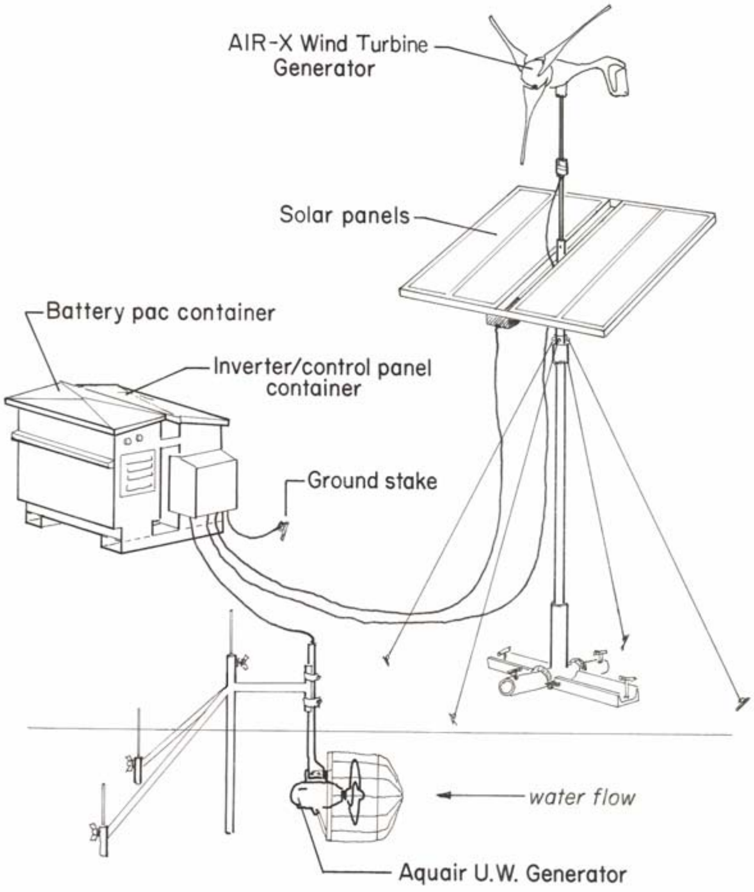


Figure 5. Three-dimensional view of the power supply system for a remote site utilizing wind, solar and water energy to charge a battery bank for power storage (taken from Enzenhofer et al. 2007).

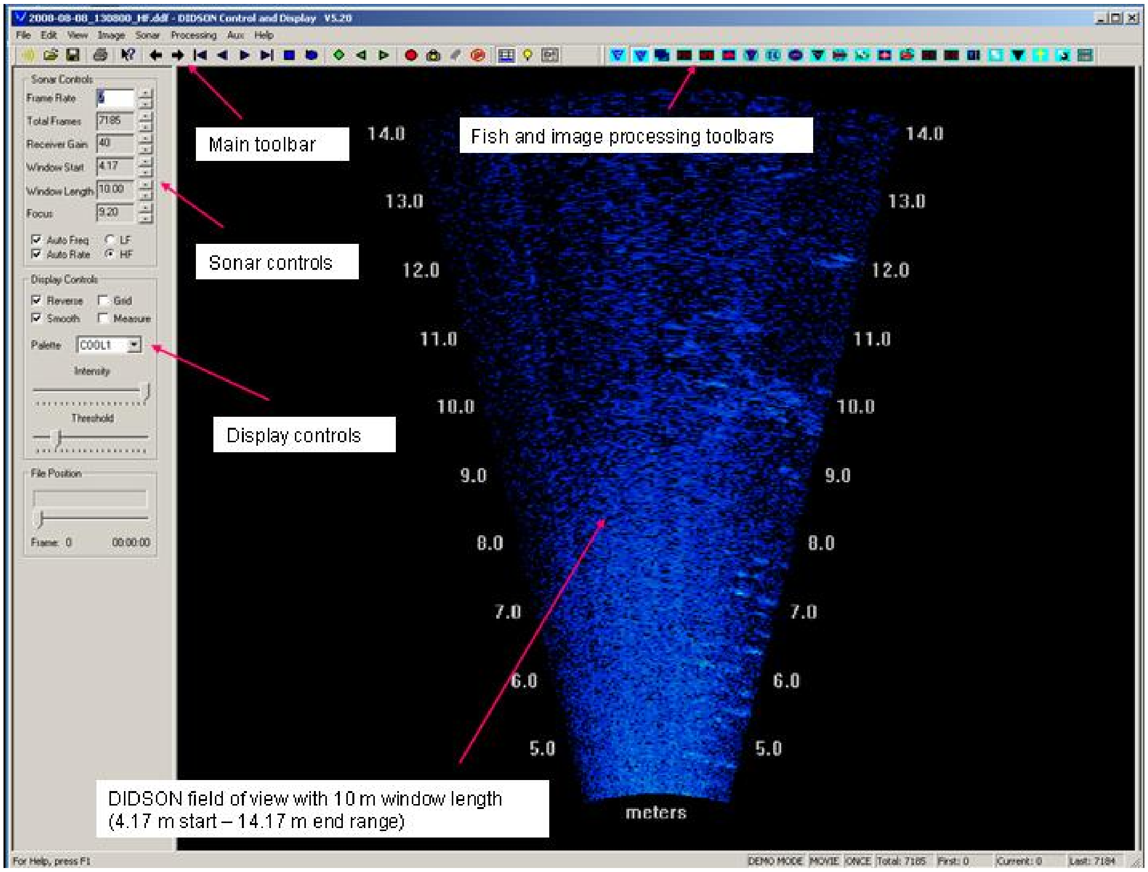
7.0 ACOUSTIC SYSTEM

We used standard DIDSON acoustic imaging systems on both banks. These systems have high frequency (1.8 MHz) and low frequency modes (1.1 MHz) and their output consists of images created by multiple sound beams focused through a moveable lens giving a field of view that is 14° vertical and 29° horizontal (Belcher et al. 2001, Sound Metrics 2007).

The high frequency mode uses 96 beams, each of which is 0.3° wide, and produces images comprised of frames. A frame (image) is constructed in sequence of 8 sets of 12 beams fired consecutively to prevent cross-talk between adjacent beams. The maximum attainable range with the high frequency setting is 15 m, using a window length of 10 m and a start range of 5 m. Frame rate (the number of frames recorded per second) varies inversely with range, but is typically between 5-10 frames sec^{-1}) in high frequency mode.

Images at the low frequency setting are comprised of frames produced from 48 beams, each of which is 0.6° wide, and are constructed from 4 sets of 12 beams fired consecutively. The maximum attainable range window is 40 m and this window can be started as far as 26 m from the transducer for a maximum range of 66 m. However, at these extreme ranges the fish images will be small and very faint in intensity, making interpretation of the images very difficult.

The DIDSON system is operated through a software package provided by the manufacturer, Sound Metrics Corporation and is described in operation Manual Version V5.15 (Sound Metrics, 2007). Once the acoustic system is set up, a data collection and record session can be initiated through a drop down menu toolbar (Figure 6).


2008-08-08_130800_HF.ddf - DIDSON Control and Display V5.20

Sonar Controls
Frame Rate: 5
Total Frames: 7185
Receiver Gain: 40
Window Start: 4.17
Window Length: 10.00
Focus: 9.20
☑ Auto Freq ○ LF
☑ Auto Rate ● HF

Display Controls
☑ Reverse ☐ Grid
☑ Smooth ☐ Measure
Palette: COOL1

File Position
Frame: 0 00:00:00

For Help, press F1
DEMO MODE | MOVIE | ONCE | Total: 7185 | First: 0 | Current: 0 | Last: 7184

Figure 6. DIDSON operating window showing the high frequency mode using a window length of 10 m (4.17 m to 14.17 m from the transducer). This configuration was used at the Qualark Creek site on the Fraser River with the

DIDSON at a roll angle of 30° (see Sec. 8.0) and the image shows the sandbag ramp on the right side of the view window.

We used the following features of the DIDSON software to process collected data files:

- Playback frame rate: Acoustic data files could be played back at an increased or decreased frame rate from that used to collect the data. Choice of frame rate was dependent on the fish passage rate and the ability of the observer to accurately count the salmon.
- Zoom: This feature allows the expansion of a selected range window over the entire DIDSON screen. For example, one playback with a range bin of 4.17 m to 9.17 m and then a second playback from 9.17 m to 14.17 m could be used to cover the entire range from 4.17 m to 14.17 m. The zoom feature could also be used to highlight a single image and expand it over the screen when measuring tools are used.
- Background subtraction: This feature removes the static portion of the acoustic image, showing only objects that move such as fish. This was established as the mandatory setting for manually counting salmon.
- Correct for transmission loss: Corrects the displayed image for acoustic transmission loss with range, making fish images from longer ranges appear the same as those at closer ranges.
- Echogram: Allows the user to display a recorded data file similar to a chart recorder to display averaged beams in the center of the sonar image over time. This feature was effective when few fish were present in a file and the echogram could be scrolled through to an event, the event marked and then played back as a DIDSON image for identification.
- Measure: Allows the user to measure the width, height and range in meters of a selected image.
- Mark fish: Enables manual counting of fish in playback files and allows the user to draw a zoom box around an image, mark its range, measure the length and automatically enter the data to a fish count file.

8.0 AIMING CONFIGURATION

Accurate estimation of fish escapement requires careful aiming of the DIDSON system to ensure that all fish passing the site are detected. The transducer of a DIDSON system consists of a horizontal array of single beam elements that cannot measure target angle in the beam (Belcher et al., 2001), which means that the position of fish in the ensonified volume can be resolved by differences in their horizontal (upstream-downstream) and range dimensions (x- and z-dimensions in Cartesian coordinates) but not their vertical (surface-substrate, or y) dimension. Aiming the DIDSON must meet two criteria: (1) the entire water column from surface to substrate must be ensonified with one aim because multiple stratified aims will have unknown vertical overlap, resulting in double-sampling of fish in areas of overlap, and (2) the direction of fish travel through the beams must be estimable (Holmes et al. 2006).

The majority of fish passage at the Qualark Creek site occurs within 15 m of shore due to the high current velocity but fish may be anywhere in the water column between the surface and substrate. The water depth at the end of the fully deployed 6 m long weir was 2.6 m with the existing bank slopes (21° right-bank and 20° left-bank) (Photo 2d, Figure 7). We placed the DIDSON 1.4 m from the shoreline on the upstream side of the weir and aimed the beam parallel to the weir and along the river substrate. The area ensonified at the end of the weir (4.5 m range from the DIDSON) was 1.2 m vertical x 2.6 m horizontal (based on DIDSON nominal field of view 14° vertical and 29° horizontal). This aiming configuration would be ideal if the DIDSON beam at this range was sufficient to cover the water column from surface to substrate. However, as shown in figure 7(b), a large area above the beam is not ensonified and could result in fish moving upstream past the site undetected. As an alternative, we adjusted the horizontal roll angle of the DIDSON to -90°, which places the horizontal axis of the beam in a vertical position and covers the water column from bottom to surface (Figure 7c). In this configuration, fish vertical position and range from the transducer can be determined, but the direction of travel cannot be determined with certainty.

After experimenting with several different roll angles, we adopted a roll angle of -30° because it satisfied the aiming criteria: a -30° angle was sufficient to ensonify the water column from the substrate to 20 cm below the surface (Figure 7d), it provided direction of travel information, and it ensured detection of all fish within the water column (Figure 8). The -30° roll angle also provides some vertical position information for migrating fish. For example, fish which first appear in the middle of the DIDSON display were probably higher in the water column than those fish observed to be disappearing in the middle of the DIDSON display when the beam is tilted downwards to the right, and the fish are migrating from right to left.

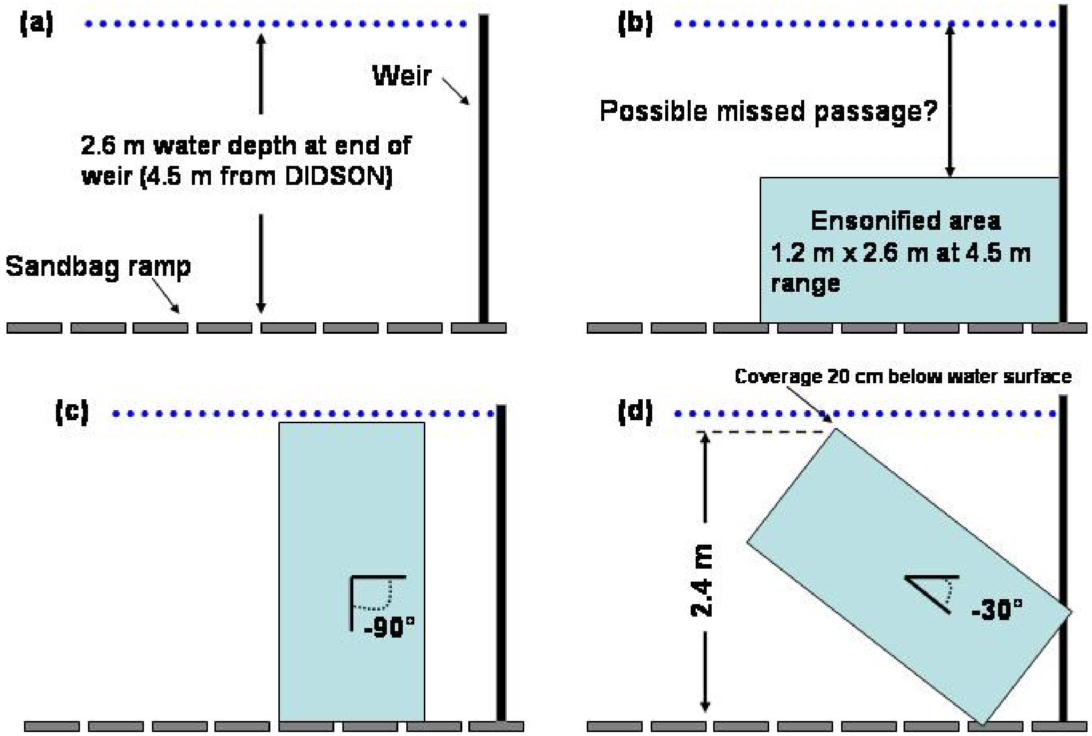


Figure 7. Area ensonified using a standard DIDSON in a fixed-location aimed perpendicular to the shoreline at the Qualark Creek site on the Fraser River. (a) Water depth at the end of the 6 m long fish deflection weir, (b) Ensonified area by a standard DIDSON at 4.5 m range to the weir end, (c) Ensonified area covered with the DIDSON roll angle rotated 90°, and (d) Ensonified area with the roll angle at -30°.

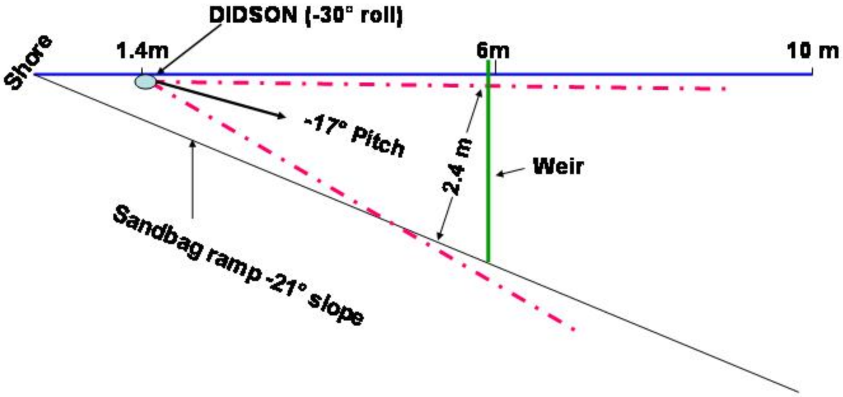


Figure 8. Side view of the DIDSON ensonified region used at Qualark Creek with the sonar head aimed perpendicular to the current flow with a -17° pitch (tilt angle) and a -30° roll angle relative to the surface. The solid green line represents the end of the fish deflection weir and the dotted red lines represent the vertical beam coverage of the water column.

8.1 Verifying beam coverage

Manual verification of the beam coverage throughout the water column is an important quality assurance procedure of the aiming protocol described by Holmes et al. (2006). These measurements should be made whenever practical to confirm that the beam covers the entire water column and that there are no acoustic blind zones through which fish could move past the acoustic system undetected. Measurements of beam coverage in-situ at Qualark were made using a 2 kg lead sphere suspended from a line and pole off the end of the 6 m long fish deflection weir walkway. The DIDSON was mounted 1.4 m from the shore and the range was 4.5 m to the end of the weir where the target was deployed. We used 2-way radios between the DIDSON operator and the person deploying the target to verify target detection and record depths and distances.

9.0 SAMPLING STRATEGY

The majority of migrating fish were expected to pass through the Qualark site near the shore along both banks given the water velocities, the swimming preferences of salmon and from previous experience at this site. In the absence of human intervention, these fish would be travelling too close to the banks for acoustic measurement. We used the fish deflection weir to move fish offshore so that they were between 4 m and 14 m from the DIDSON (approximately 5 to 15 m from shore). Fish at this range were at the ideal range for enumeration with the DIDSON since it could be operated in high frequency mode, which provides the best image resolution for counting. However, we also periodically sampled ranges out to 40 m with the low frequency mode to check for passage beyond the range of the high frequency (maximum range is 15 m for high frequency) to ensure that the fish were not migrating at longer ranges.

The value of the long range low-frequency mode sampling became apparent during First Nations fishery openings using set gillnets. A small proportion of fish were consistently observed moving upstream beyond the range of the high frequency mode (Figure 9) during fishery openings, but this behaviour did not persist outside of the fishing periods. Similar behaviour was previously observed at the Qualark site using split-beam acoustic systems during 1993 - 1998 when fish migration was observed to shift offshore during the opening of the fishery and then shift inshore once the nets were removed (Macdonald et al., 2000).

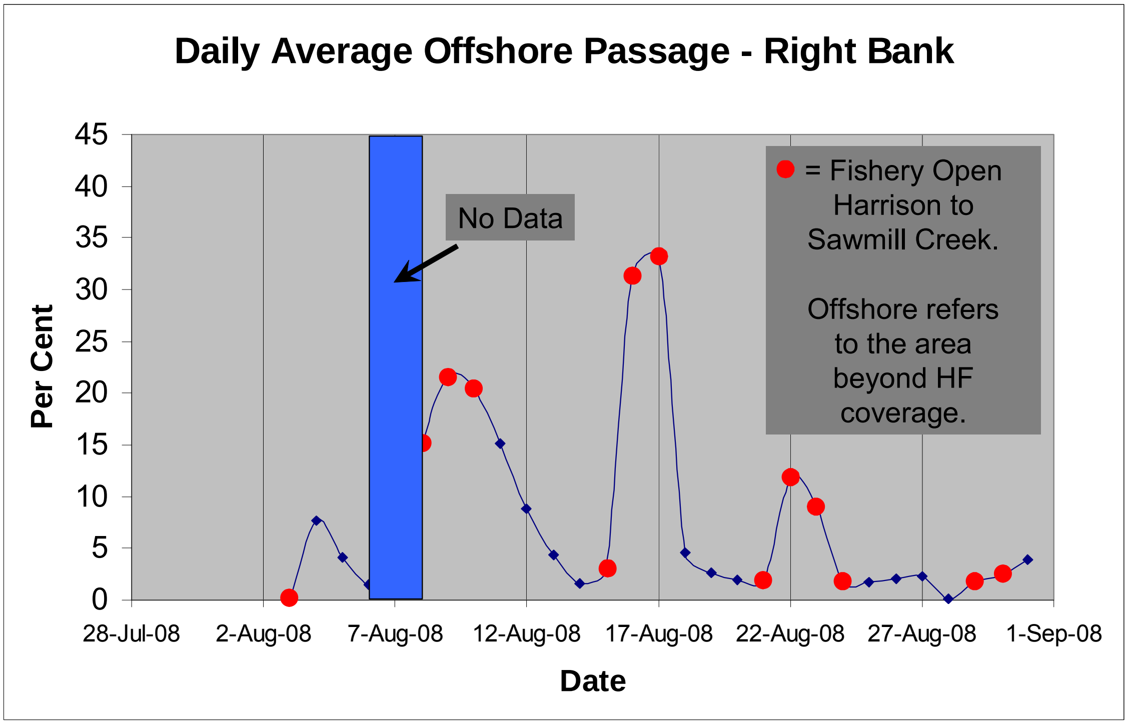


Figure 9. Percentage of the daily passage observed at the Qualark Creek site that migrated beyond the high frequency range of the DIDSON (i.e., offshore passage) during First Nations set gillnet harvesting periods in 2008. Counts were derived using the low frequency setting at a range from 14.17 m to 24.17 m. The

red dots represent fishery openings on the Fraser River from the Harrison River confluence to Sawmill Creek near Spuzzum, BC. The period from August 6 to August 8 is annotated as No Data because exploratory long range DIDSON files were not collected for this time period.

The goal of our sampling strategy at Qualark was to provide accurate and precise estimates of fish passage in a cost-effective manner. Although every minute of every hour of every day during which fish are migrating can be recorded and counted, this approach is not cost-effective in terms of the resources allocated to data processing given the minimal gains in the precision of daily estimates achievable (Lilja et al., 2008) and the increases in electronic data storage requirements. Temporal sub-sampling is an effective way of handling continuous 24 hr data collection as shown on the Horsefly River in 2005 (Cronkite et al., 2006). Lilja et al. (2008) demonstrated that systematic hourly sampling ranging from a minimum of 10 minutes to a maximum of 20 minutes per hour produced upstream migration data that are representative of the entire hour with a precision of ± 10 to ± 5% of the estimate, respectively. At times of extremely high migration, as was experienced during the 2009 pink salmon season, we limited the counting to the first 10 minutes of each file if the file contained more than 1500 fish in the first 10 minutes of a 20 minute file. The uncounted proportions of these files could be re-visited at a later time if an increase in precision was desired. However, we note that these files were recorded during periods of heavy pink salmon passage in 2009 (more than 95% of fish were pink salmon) so the need for increased precision should be carefully weighed against the cost of achieving that precision.

10.0 DATA COLLECTION

We used the standard DIDSON acoustic imaging system in high frequency mode (1.8 MHz) for data collection from June 25 to August 31, 2008. We operated the DIDSON using a 10 m window length (4.17 m to 14.17 m), a frame rate of 6 frames per second and a maximum receiver gain of 40 dB. With these settings, approximately 17.5 megabytes per minute (MB/min) were recorded, resulting in data files of 350 MB for the 20 minute time period we collected each hour. The DIDSON was programmed to create new files (time and date stamped) on a random start within each hour up to August 9.

We also collected files with the DIDSON in low frequency mode (1.1 MHz) in 2008 using a 20 m window length (4.17 m to 24.17 m), a frame rate of 4 frames per second and a maximum receiver gain of 40 dB. With these settings, approximately 8.5 MB/min were recorded, resulting in data files of 170 MB for 20 minutes of recording. The low frequency mode files were collected on a periodic basis (during First Nations fishery openings) from June 25 to August 9 and then on a continuous basis after August 9 (see Figure 9), and were in addition to the 20 minutes collected in high frequency mode. When more than one file is recorded within an hour, the DIDSON must be programmed to systematically collect files with user specified start and stop times.

In 2009 we used a data collection protocol that included a 20 minute high-frequency file with a range window from 4.17 m to 9.17 m, followed by a 20 minute low-frequency file with a range window from 9.17 m to 19.17 m on both banks. Data volumes from this scheme were similar to those mentioned for 2008. In addition, a 5 minute file was collected every hour covering a range window from 19.17 m to 29.17 m off the left bank to test for presence/absence of migrating salmon in the far offshore areas. Review of these longer range files demonstrated virtually no passage of salmon beyond the 19.17 m range from the DIDSON. Fish detected at the longer ranges appeared to be either indigenous species such as sturgeon or moribund/dead salmon floating downstream.

11.0 DATA PROCESSING

All DIDSON data files were counted manually using a hand held counter (tally whackers) and the numbers of upstream and downstream fish were recorded on a spreadsheet. The spreadsheet was used to calculate the net upstream count and expand these counts for the portions of the hour not sampled. The average count was used in the spreadsheet to calculate the hourly net upstream passage when randomly selected files were counted more than once by different observers. The majority of the manual counts were from the high frequency files, displaying the entire range strata and with user selected playback rates.

The hourly count data obtained with the DIDSON system were used in a simple model (Xie et al. 2002) to estimate the net upstream flux (fish per unit time) of salmon passing through the acoustic site. This model is:

$$N = U - D \qquad (1)$$

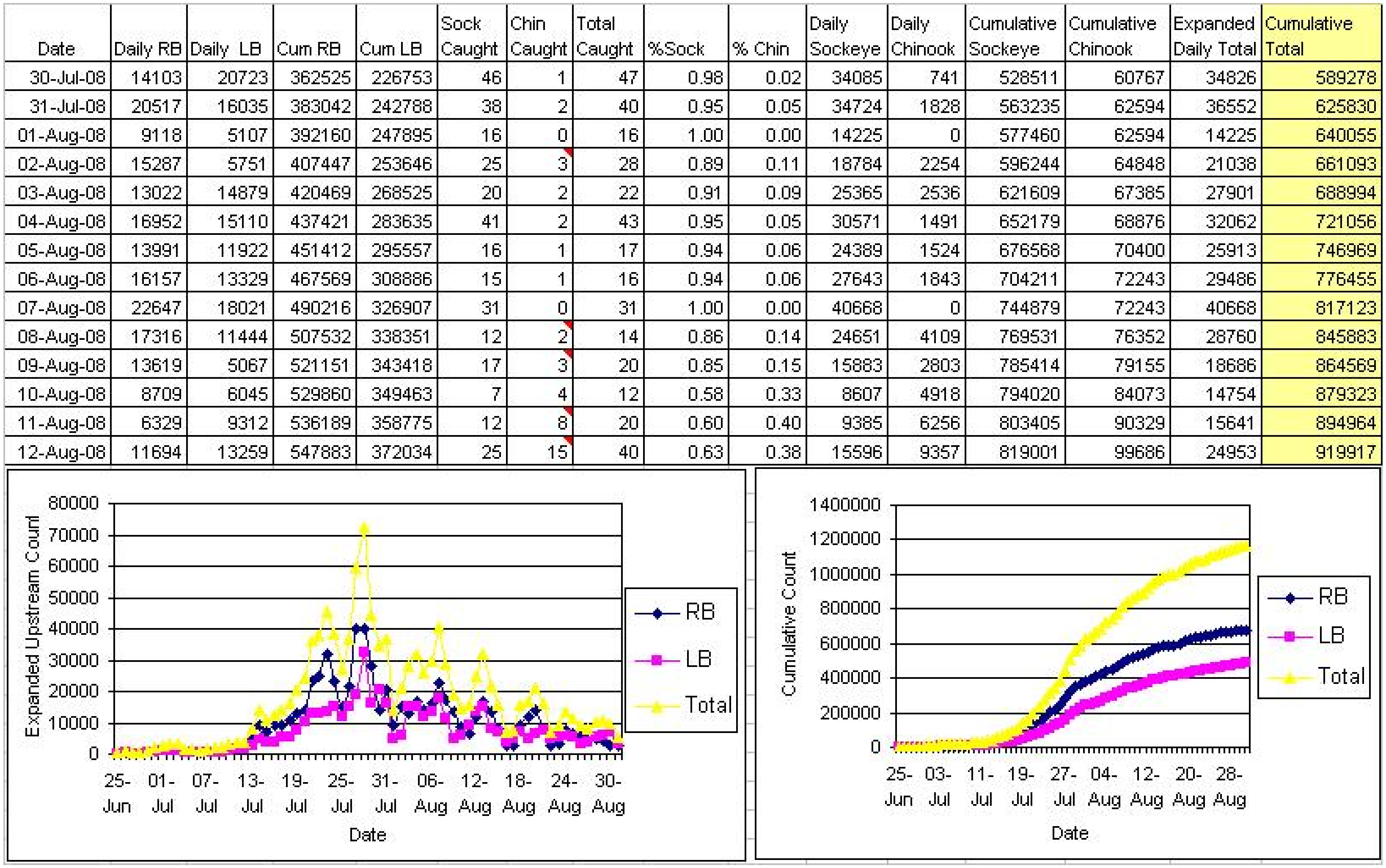
where N is the net upstream flux, U is the upstream actively migrating fish and D is the downstream actively migrating fish. For resident species not engaged in migration, the model assumes that there is an equal probability of upstream or downstream movement past the site, and therefore U = D. The flux model also accounts for milling fish, provided these fish eventually move upstream through the acoustic beam. Milling was not an issue at the Qualark site as salmon were actively migrating upstream but we did observe large milling sturgeon and small resident species that were excluded from the count as they were easily identifiable in the DIDSON images as non-salmon.

After experimentation with different aiming schemes in 2008 (see Section 10.0), we arrived at an effective scheme that covered the area of salmon migration at the Qualark site. This involved a high-frequency aim covering 4.17 m to 9.17 m and a low-frequency aim covering 9.17 m to 19.17 m. This scheme was used to sample both banks of the river. All fish were counted in the close-range data files but any fish observed in the long-range data files that crossed into the close-range at some point, were not counted as they would have been accounted for in the short-range data. This avoided potential positive bias from double sampling the same range stratum.

Production of the daily flux estimate is illustrated in Table 1 showing the manual count data for July 30 right-bank, expanded to an hourly net upstream estimate and a total daily upstream estimate of 14,103 fish. The daily net upstream estimate for both river banks is apportioned to species based on the daily test fishing catch. The spreadsheet was designed to plot daily cumulative run-timing curves along with per cent downstream moving fish, to allow the assessment of run strength, timing and migration behaviour (Figure 10). Changes in migration behaviour such as milling or increased downstream migration can indicate a stress reaction by salmon, or it can indicate the approach of the end of a particular run. For example, an increase in downstream movement in October was a precursor to the end of the sockeye salmon migration on the Horsefly River in 2005 (Cronkite et al. 2006). In 2009 an increase in downstream migration at Qualark was noted near the end of the Early Stuart migration, and was especially prominent near the end of the pink salmon migration in late September.

Table 1: Example of manual fish count data from hourly files collected at the Qualark Creek DIDSON site expanded to a daily net upstream passage.

Qualark Creek DIDSON Count Expansion Sheet, 2008 Right-Bank						
		DIDSON				
Date	Count Hour	Time Counted (min.)	Fish Count UP	Fish Count DN	Fish Count Net UP	Expanded Count (fish/hour)
30-Jul-08	00:00 to 24:00					
	0	20	116	1	115	344
	1	20	110	4	106	318
	2	20	150	0	150	450
	3	20	124	2	122	366
	4	20	488	4	484	1 452
	5	20	513	3	510	1 530
	6	20	382	1	381	1 143
	7	20	39	3	36	108
	8	20	298	0	298	894
	9	20	346	1	345	1 035
	10	20	312	0	312	936
	11	20	578	2	576	1 728
	12	20	211	2	209	627
	13	20	123	0	123	368
	14	20	64	0	64	192
	15	20	93	0	93	279
	16	20	61	1	60	180
	17	20	63	0	63	189
	18	20	78	0	78	234
	19	20	1	0	1	3
	20	20	52	0	52	156
	21	20	44	1	43	129
	22	20	246	38	208	624
	23	20	313	40	273	819
Daily Totals		480	4 804	103	4 701	14 103



Date	Daily RB	Daily LB	Cum RB	Cum LB	Sock Caught	Chin Caught	Total Caught	%Sock	% Chin	Daily Sockeye	Daily Chinook	Cumulative Sockeye	Cumulative Chinook	Expanded Daily Total	Cumulative Total
30-Jul-08	14103	20723	362525	226753	46	1	47	0.98	0.02	34085	741	528511	60767	34826	589278
31-Jul-08	20517	16035	383042	242788	38	2	40	0.95	0.05	34724	1828	563235	62594	36552	625830
01-Aug-08	9118	5107	392160	247895	16	0	16	1.00	0.00	14225	0	577460	62594	14225	640055
02-Aug-08	15287	5751	407447	253646	25	3	28	0.89	0.11	18784	2254	596244	64848	21038	661093
03-Aug-08	13022	14879	420469	268525	20	2	22	0.91	0.09	25365	2536	621609	67385	27901	688994
04-Aug-08	16952	15110	437421	283635	41	2	43	0.95	0.05	30571	1491	652179	68876	32062	721056
05-Aug-08	13991	11922	451412	295557	16	1	17	0.94	0.06	24389	1524	676568	70400	25913	746969
06-Aug-08	16157	13329	467569	308886	15	1	16	0.94	0.06	27643	1843	704211	72243	29486	776455
07-Aug-08	22647	18021	490216	326907	31	0	31	1.00	0.00	40668	0	744879	72243	40668	817123
08-Aug-08	17316	11444	507532	338351	12	2	14	0.86	0.14	24651	4109	769531	76352	28760	845883
09-Aug-08	13619	5067	521151	343418	17	3	20	0.85	0.15	15883	2803	785414	79155	18686	864569
10-Aug-08	8709	6045	529860	349463	7	4	12	0.58	0.33	8607	4918	794020	84073	14754	879323
11-Aug-08	6329	9312	536189	358775	12	8	20	0.60	0.40	9385	6256	803405	90329	15641	894964
12-Aug-08	11694	13259	547883	372034	25	15	40	0.63	0.38	15596	9357	819001	99686	24953	919917

Figure 10. Example of a summary sheet from the Qualark Creek DIDSON site showing two weeks of daily counts apportioned by species from the daily test fishing program. The bottom plots show the daily passage and accumulated fish estimates by river bank and river total.

12.0 DATA STORAGE

In 2008, raw data was saved to external hard drives of 500 gigabytes in size. Six hard drives were used to create two redundant copies of the data from each bank. Each DIDSON system collected 12.5 gigabytes of data over a 24 hr period based on a 20 minute high frequency, and a 20 minute low frequency file per hour. In 2009 we switched to a 4 drive, Drobo® backup system which held 4 TB of data including an automatic backup copy in the event of drive failure.

13.0 PRECISION

Precision refers to the repeatability of a count between different individuals for the same data file. We assessed the precision of the DIDSON counts among individuals using the coefficient of variation (CV) and average percent error (APE) (Chilton and Beamish, 1982) as was done by Holmes et al. (2006). APE is an index of the repeatability of counts across the entire dataset, whereas CV is a measure of the variability in counts of a particular file among observers and is a useful daily statistic for flagging files that are difficult to count or individual counters that are having difficulties. CV and APE are calculated as follows:

$$CV = \sqrt{\frac{\sum_{i=1}^{R}(X_{ij} - \overline{X}_j)^2}{\overline{X}_j^{\,2}}} \text{ x } 100 \tag{2}$$

$$APE = \frac{1}{N}\sum_{j=1}^{N}\left[\frac{1}{R}\sum_{i=1}^{R}\frac{\left|X_{ij} - \overline{X}_j\right|}{\overline{X}_j}\right]\times 100 \tag{3}$$

where N is the number of events counted by R observers, Xij is the i^{th} count of the j^{th} event and Xj is the average count of the j^{th} event.

During the initial training phase for technicians, all files were counted by each technician. This was done until all technicians were comfortable with the software and the production of the manual count (generally a one week training period). The project manager and senior research technician would perform periodic spot checks to flag outliers. After the training period we adopted a random recount process where 17% (e.g. 8 out of 48 daily files) of all DIDSON files were re-counted by senior staff on a daily basis. This process reliably identified staff that needed additional training attention or unusual data files that required further scrutiny or alternate methodologies. One example of a training issue flagged by this testing is the counting of small fish targets by some observers and not by others. To resolve the problem and ensure consistent counting among staff, a minimum image size was established for acceptance of counts. The DIDSON software measure tool was used to provide an onscreen display of minimum acceptance size for fish targets, allowing observers to determine fish size and consequently their inclusion in, or exclusion from, the manual count.

The APE of the Qualark counts was in the order of 4 to 5% overall for hourly counts ranging from approximately 50 fish/hr to over 35,000 fish/hr experienced in 2009. The CV of files with very low counts could at times be quite high but this was also seen by Holmes et al. (2006), who attributed this phenomenon to the high leverage that small numerical differences in low counts have on the calculation of CV. For example, counts of 1 fish and 2 fish will have a CV in the order of 50%. The important point is that error of this magnitude when file counts are low has very little impact on the overall estimate of escapement. However, errors of this magnitude when counts are much higher (e.g., > 50 fish/hr) are a more serious matter and if detected, then the cause should be determined and resolved as soon as is practical.

14.0 TEST FISHING

We implemented a test fishing program at the Qualark Creek site to determine salmon species composition for acoustic counts, to collect biological data for stock identification and to test for presence/absence of fish passage. The test fishing was performed by members of the Yale First Nation under a Scientific Permit through DFO. The test fishery consisted of a drift sequence in the morning (07:00-08:00) and another drift sequence in the evening (about one hour before dusk). A drift sequence was composed of three consecutive drifts of approximately 4 minutes duration, beginning 150 m upstream of the acoustic system and moving approximately 700 m downstream through the Qualark site along the right-bank (Photo 4). In 2008, from the onset of migration to 01 August mesh sizes of 5⅛, 6 and 8 inches (stretched mesh, 70 mesh hang, and 30 m length) were used, with the 8 inch mesh replaced by a 4 inch mesh after 01 August. The 8 inch mesh is used to sample adult Chinook salmon (*O. tshawytscha*) during the early portion of the migration period and the smaller 4 inch mesh was used in the later half to ensure that sockeye salmon jacks, Chinook salmon jacks and pink salmon (*O. gorbuscha*) were adequately sampled.

The river cross section was divided into near- (0-25 m from shoreline) and far-range (beyond 25 m from the shoreline to the middle of the river) areas for test fishing. Drift sequences described above were performed in the near-range. Far-range drifts using 5¼ inch mesh were performed periodically to test for the presence of salmon. The date, time, drift number, drift duration, mesh size, number and species of fish caught were recorded. All fish were counted and sex, length and weight were recorded for retained fish. In addition, scale samples and DNA samples (adipose fin punch) were taken from up to 50 fish per day and stored for further analysis.

In 2009 the test fishery mesh sizes and methodology were modified based on advice from the Pacific Salmon Commission to ensure that the sample was representative of the salmon passing the Qualark site at the time of sampling. The drift sequence consisted of 6 drifts per day, seven days per week, one 3-drift set in the morning and one 3-drift set in the evening. Each set of 3 drifts was made close to shore and directed at capturing salmon. Two additional drifts per week, spaced out over the week, were made beyond 25 m using the 5¼ inch mesh net to test for presence/absence of migrating salmon in the offshore regions. The mesh sizes used for the drifts included 4, 4 ¾, 5 ¼, 5 ¾, 6 ¾ and 8 inch (stretched mesh, 70 mesh hang, and 30 m length). The morning drifts began on the first day using the 4, 5 ¼, and 6 ¾ inch meshes in sequence, and the evening drifts began using the 4 ¾, 5 ¾ and 8 inch meshes in sequence. On the second day the morning and evening sequences were reversed. On the third day the pattern was returned to that of the first day. This alternation of mesh sizes continued on a daily basis to allow some randomisation of the sampling but still allow for operational realities.

The objective of the test fishing was to determine species composition of the migrating salmon. As a result, a broad range of mesh sizes were used. The main advantage of the test fishery is that it was conducted in the vicinity of the acoustic systems, avoiding the uncertainty introduced when an acoustic site and a test fishery are separated, and catch results may not be representative of the species composition at the acoustic site due to differences in fish behaviour. We believe that a drift net test fishery is the only viable method to obtain representative species composition information at the Qualark site.

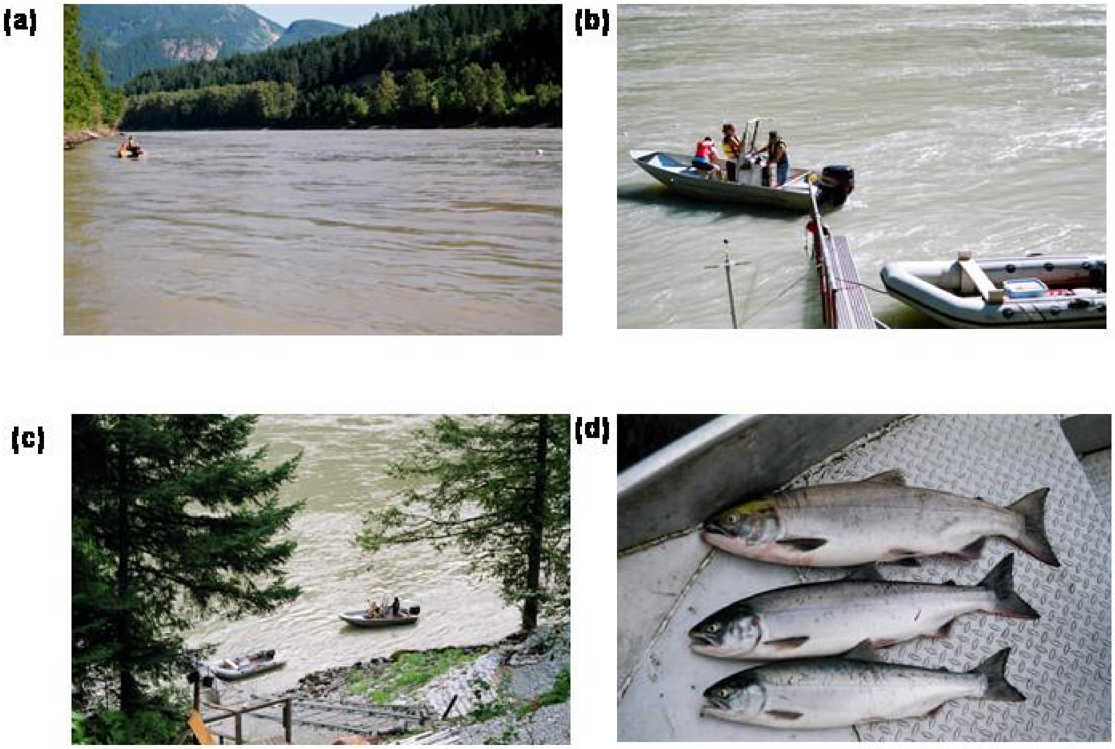


Photo 4. Test fishing program using a drifted gillnet at the Qualark Creek hydroacoustic site on the Fraser River. (a) 30 m gillnet deployed by the fishing boat immediately upstream of the right-bank acoustic site, (b) gillnet drifts past the fish deflection weir, (c) boat and gillnet moves towards shore once past the weir, and (d) sample results of a drift sequence showing size differences in sockeye salmon.

15.0 FUTURE CONSIDERATIONS

The objectives for the Qualark site for 2008 and 2009 were to develop the methodology for producing daily estimates of fish passage using DIDSON imaging sonar systems. The estimates of migrating fish were apportioned to species using the catch information from the test fishing program. As with any ongoing program, improvements can be implemented as the need arises or when there are advancements in technology or software. Future considerations include:

- Improved internet access for the site: Site operation would benefit from high speed internet access either through the local cable network or local phone company (if available).
- Automated counting: Producing software generated counts is not an easy task as the verification of the produced counts is not always achievable.

Automated counting and tools to aid in manual counting are both works in progress and remain difficult because we are attempting to program a computer to track and interpolate moving objects in a manner similar to the human eye and brain. At present we do not use any form of automated counting software as quite often the fine tuning of parameters required by a particular software program is time consuming and the results may be inconsistent among data sets.

16.0 DISCUSSION

Assessment of fish flux is dependent on a combination of factors that if not addressed will bias escapement estimates. First, the selection of an appropriate site is the single most important factor that will contribute to the success of the operation. Choosing a site where fish actively migrate is critical. In the case of Qualark, fish migration occurs near shore, which enabled us to view their passage with a single aim of the DIDSON system. In addition, the test fishing used to apportion the acoustic estimate by species, benefits from the near-shore migration as this limited area can be sampled effectively with gill nets.

Second, infrastructure development, modification of the river banks, and the use of in-river accessory equipment all help to optimise the collection of acoustic data. Sandbag ramps provide visual cues that assist the detection of fish near the substrate. The fish deflection weir and track system eases equipment moves in response to fluctuating river levels. Walkway access to the end of the deflection weir allows verification of acoustic detection throughout the water column where fish migration occurs.

Third, the sampling and data collection protocols are designed to ensure accuracy and precision in the estimates, as these are important scientific criteria. Previous findings on the Horsefly River (Cronkite et al., 2006), and the Chilko and Stellako Rivers (Holmes et al., 2006) demonstrated that DIDSON counts were as accurate as counts through an enumeration fence and as accurate as visual counts in clear water. The precision of the manual counts from the DIDSON system among different observers, as measured by the CV and APE is also high, typically less than 7% and 5% respectively, after 1-2 weeks of training.

Fourth, the methodology using the DIDSON acoustic system is more easily transferable to staff with limited acoustic experience. The DIDSON system has simplicity of operation that was not evident in previous hydroacoustic systems. We found that simple manual counting of collected files was effective and manageable even at very high migration rates.

17.0 MAINTENANCE

A regular maintenance schedule at the Qualark site includes:

- Care of the DIDSON sonar systems
- Power supply system for the boat access site
- In-river equipment
- Sandbag ramps

The DIDSON systems at the Qualark site require weekly removal of accumulated silt from the lens compartment since the lower Fraser River is turbid. Accumulation of silt in the lens compartment causes a gradual dimming of images and reduced detection range. Cleaning is accomplished by shutting down the DIDSON system, removing the lens tray (four Philips screws) and using a soft paint brush while flushing the compartment with river water. This procedure will ensure operation of the focus shaft and maintain image quality and can be completed in approximately 10-15 minutes. Additionally, the front lens can form a bubble due to a slow influx of air which can be removed with the lens maintenance kit supplied by Sound Metrics Corporation and outlined in the operation manual. The DIDSON should not be operated out of the water for any length of time as this may eventually cause damage.

Maintenance of the remote power supply system is minimal. Users should check for deterioration or damage at the beginning of the field season and all electrical connections and cables should be checked. Proper battery care should be followed during use and storage. Batteries should never be stored in an uncharged state in sub-zero weather and battery fluid levels should be checked and maintained using distilled water. Periodically the batteries' state of charge should be equalized (e.g., monthly or every 10 discharges) by using the equalize function on the solar charge controller (Blue Sky Energy 2004) during periods of direct sunlight. During extended periods of cloud cover, the battery charge will need to be maintained with a generator and charger.

In-river equipment requires minimal maintenance during the operating period. The weirs should be kept clear of debris and any accumulation can be cleared by winching the weir out of the water. The vertical pipes on the weir should be checked periodically for breaks, which could create holes through which fish may move past the site undetected behind the DIDSON system. Broken pipes can also dislodge and jam the weir track mechanism. The electric winch battery (12 VDC) should have its charge maintained through periodic charge with battery charger and generator. The pole mount and transducer-to-weir bracket require little maintenance other than keeping them clean and free of debris. At the season's end, the transducer-to-weir brackets and the pole mounts should be removed and the fish deflection weirs winched to the top of the tracks. The winches are then removed and the weirs are chained in place throughout the winter and the spring freshet. Worn or torn bags on the sandbag ramps should replaced with new ones as the water level drops through the migration period. A final visit during the low water period (winter) should be made to replace torn bags in preparation for the next season.

18.0 SITE OPERATIONS AND COSTS

An acoustic site has operational requirements which can be broken down to two general types: 1) one-time only costs that include infrastructure development, bank modifications, equipment purchases (Table 2), and 2) on-going seasonal costs that include staffing, the test fishing program, utility charges, rental agreements and routine maintenance (Table 3).

Much of the infrastructure developed at the Qualark site on the right-bank (road access side) during the 1993-1998 period remained viable and was reused in 2008 and 2009, including the equipment cabin ($8000 original cost) and line power supplied by the power utility company ($7000 original cost). In-river accessory equipment was removed at the end of 1998 and stored at the Cultus Lake Laboratory. This equipment was refurbished and reinstalled in Feb-Mar 2008 during the low flow period on the mainstem Fraser River. Infrastructure such as stairs, cabins and site access were completed prior to the spring freshet (early June 2008). Total one-time-only costs to refurbish equipment and re-establish the Qualark site in 2008 were $80,000 CAD, excluding the purchase of two standard DIDSON units which were approximately $77,000 USD each.

The on-going seasonal costs relate to personnel requirements, utility charges, rental agreements and regular maintenance items which are dependent on the operation period in a given season (Table 3). The site is operated on a 24 hour basis, which requires continuous staffing to process data files for production of the daily estimates and to ensure proper function of the site. Staffing of this project consisted of a project manager, who is responsible for the overall operation of the site, and a senior technician with acoustics experience, who could assume the responsibilities of the project manager, and oversee the other technicians doing the daily counts and maintenance. Costs outlined in Table 3 include these two positions but only for the period of site operation. DFO health and safety regulations require that the site be staffed with at least two people at any point in time for safety reasons. The greatest continuity is achieved when experienced personnel return each season. Monthly operating costs, excluding test fishery and Project Manager costs, were $52,000 CAD in 2009.

The test fishing program was performed through contract with the Yale First Nation. The contractor provided the labour and all equipment required to perform the test fishing program other than the drift gillnets which were provided by DFO. Funding was acquired through the Larocque test fishery programme agreement. The future of the Larocque program funding is uncertain at present.

Table 2: Cost in Canadian dollars for infrastructure, bank modifications and equipment purchases considered as one-time purchase for the Qualark Creek DIDSON site on the Fraser River, British Columbia, Canada.

Item	Description	Cost
Modification to the left-bank (LB) with boat access	-remove surface layer and level bank grade -install sandbag ramp (10 m x 35 m) -includes all labour and materials	$22,000
Fish deflection weir (LB)	6 m trapezoidal weir with: -handrails, walkway, bracing and track carriages -includes assembly and installation	$12,000
Weir track system (LB)	Double track (1 section = 3.7 m length) -(7) sections required -includes winch, winch mount platform, 12VDC battery, track pegs and installation	$15,000
Power supply (LB) with boat access	Complete system utilizing solar panels, water generator and wind turbine to charge a battery bank	$20,000
Equipment cabin on wood deck (LB)	-2.5 m x 3 m equipment shed -4 m x 4 m wood deck with railing -Aluminium stairway	$ 7,100
Modification to the right-bank (RB) with road access	-level bank grade -import 200 m³ (10 cm crush rock) -install sandbag ramp (10 m x 40 m) -includes all labour and materials	$18,500
Equipment cabin upgrade and stairway construction (RB)	-new roof, paint interior, office furniture and phones - stairs and landings to access RB sandbag ramp -includes all labour and materials	$12,500
Fish deflection weir (RB)	6 m trapezoidal weir with: -handrails, walkway, bracing and track carriages -includes assembly and installation	$12,000
Weir track system (RB)	Double track (1 section = 3.7 m length) -(8.5) sections required -includes winch, winch mount platform, 12VDC battery, track pegs and installation	$16,000
Transducer-to-weir bracket (RB and LB)	-Aluminium bracket bolted to weir and provides an attachment base for an adjustable pole mount -(2) units required at cost of $1000 each	$ 2,000
Adjustable Pole Mount (RB and LB)	-stainless steel and powder coated aluminium mount provides control of depth, bearing, tilt and roll angles of an attached transducer -(2) units required	$ 5,800
Computers (RB and LB)	-(2) units for data collection (LB & RB) -(2) units for data processing -(4) units total required at cost of $1500 each	$ 6,000
DIDSON acoustic systems (RB and LB)	Standard version (1.1 MHz and 1.8 MHz) -includes 50 ft cable, topside box, lens kit, software -additional (2) 200 ft cables required -(2) units required at $77,000 each (US funds)	(approx.) $200,000

Table 3: On-going seasonal cost in Canadian dollars for the operation of the Qualark Creek DIDSON site on the Fraser River. Cost is based on a 4 month period of operation and includes the Project Manager.

Item	Description	Cost	Monthly
Project manager	-overall site responsibility -posses strong quantitative analytical skills -knowledge of the theory and operation of acoustic systems -$35 rate per hour	$ 24,000	$ 6,000
Senior technician	-experience in testing and developing hydroacoustic technology -posses quantitative analytical skills -able to assume overall site responsibility -$30 rate per hour	$ 20,500	$ 5,125
Research technicians (8) required	-perform day to day project requirements -basic computer skills (Windows, Word, Excel) -provide site maintenance and security -participate in hydroacoustic experimentation -$20 rate per hour	$105,000	$26,250
Meals, room, travel	-accommodation and board for project manager (on call when not at site) -accommodation and board for senior technician as required -miscellaneous program travel	$ 27,000	$ 6,750
Test fishing program	-under direction of the project manager provide daily drift sequences (AM & PM) -collect biological samples of processed fish -includes boat, materials and labour -$800 rate per day	120 days $ 96,000	$24,000
Vehicle rental	-1 vehicle for project manager (on call when not at site) -1 vehicle for site operation	$ 10,400	$ 2,600
Power utility	-provides line power to the right-bank site	$ 1,200	$ 100
Phone service	-provides phone service to the right-bank site -2 lines provided	$ 1,800	$ 150
Sanitation facility	-portable unit with hand wash station -serviced weekly by local company	$ 600	$ 150
Land lease	-yearly lease paid to the land owner -includes rental of the right-bank cabin	$ 6,000	$ 1,500
Drift gillnets	-30 m drift gill net (70 mesh hang) -individual nets @ 4, 4 ¾, 5 ¼, 5 ¾, 6 ¾ and 8 inch mesh	$ 4,800	$ 1,200
Materials and supplies	-acoustic and office supplies -software and computer upgrades -equipment development and repairs -fuel for trucks, boats, generator -crew and safety supplies -low water river bank site maintenance -miscellaneous expenses	$ 32,000	$ 8,000
External hard drives (RB and LB)	500 GB -(6) units required at $150 each	$ 900	$ 225

19.0 SYNOPSIS

We include the following section as a quick reference guide for the seasonal start up of an acoustic site such as Qualark Creek. The initial site modifications and installation of the fish deflection weir are assumed to have been completed and the DIDSON system has been mounted and aimed as described in Sections 5.2 and 5.3 and beam coverage has been verified (Section 8.1). To produce a 24 hour passage apportioned by species from manually counted hourly DIDSON files the following steps referenced by section number should be followed:

1. Start the DIDSON program using the high frequency mode, 10 m window length and start range of 4.17m to verify the DIDSON system is functioning and images are being viewed (see DIDSON operation manual V5.15).
2. Set up the operating system of the DIDSON sonar for data collection of hourly files with the desired duration, frequency mode and range strata (see Sec. 9.0 and 10.0).
3. Process collected DIDSON data files to produce manual counts of fish passage (see Sec. 7.0 and 11.0).
4. Enter the daily flux estimate of passage for each river bank into the summary spreadsheet for reporting daily and cumulative results (see Sec. 11.0).
5. Apportion the acoustic estimate of fish passage by the results of the daily test fishing program to yield daily and cumulative run size by species (see Sec. 14.0).
6. Measure precision through random recount of processed daily files (see Sec. 13.0).

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