Feasibility of Deploying a Dual-frequency Identification Sonar (DIDSON) System to Estimate Salmon Spawning Ground Escapement in Major Tributary Systems of the Fraser River, British Columbia

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by

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ABSTRACT

Holmes, J.A., Cronkite, G., and Enzenhofer, H.J. 2005. Feasibility of deploying a dual-frequency identification sonar (DIDSON) system to estimate salmon spawning ground escapement in major tributary systems of the Fraser River, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2592: xii + 51 p.

The dual-frequency identification sonar (DIDSON) system was identified during strategic planning as a new acoustic technology with the potential to deliver a cost-effective means of producing salmon escapement estimates with similar or better levels of precision and accuracy as mark-recapture programs (MRP). The objectives of our 2004 field work were to determine where the DIDSON acoustic imaging system could be used to estimate sockeye salmon (*Oncorhynchus nerka*) and Chinook salmon (*O. tshawytscha*) escapement in the Fraser River watershed and to determine the additional equipment needed (e.g., weirs, mounting system and platform) for effective operation of a DIDSON imaging system. We developed a preliminary list of 22 sites on 10 rivers for investigation through consultation with stock assessment staff in Kamloops and knowledge of the requirements of fisheries managers and general criteria for hydroacoustic sites. Based on a combination of in-stream testing and site visits, we conclude that the DIDSON system could be used effectively to estimate escapement of sockeye salmon in Scotch Creek, Chilko, Horsefly, Mitchell and Seymour Rivers, and probably the Lower Adams River as well. Additional equipment needed to effectively enumerate populations in these systems is minimal but includes a transducer mounting pole and bracket, a modified step-ladder from which the transducer is deployed and that can be used as a viewing platform for species composition estimates, a secure shed for topside equipment (computer and battery bank), solar panels to provide power, and 5-10 m of weir, depending on the site. Although additional work is needed on some systems to choose the most appropriate site for deployment (Mitchell River) or to confirm that fish do not exhibit unusual behaviours (e.g., milling, holding) that would degrade the performance of the DIDSON system (Mitchell River, Scotch Creek, Seymour River), we do not believe that the additional time commitment required to address these issues is large. The Lower Shuswap, Lower Stuart, and Tachie Rivers were not suitable for deployment of the DIDSON system in our judgement. We suspect that acoustic counting of migrating fish in the Lower Stuart River, particularly Chinook salmon, could be accomplished with shore-based side-looking split-beam systems, but at least one season of testing would be required to confirm this hypothesis. Neither the Lower Shuswap nor the Tachie were amenable to acoustic counting because of the high probability of unusual fish behaviour and poor site characteristics, respectively. The list of deployment sites and operational requirements (e.g., accessory equipment and sampling strategy) documented in this report can be cross-referenced to existing management priorities in order to determine deployment opportunities that best exploit the capabilities of the DIDSON technology within existing programs.

RÉSUMÉ

Holmes, J.A., Cronkite, G., and Enzenhofer, H.J. 2005. Feasibility of deploying a dual-frequency identification sonar (DIDSON) system to estimate salmon spawning ground escapement in major tributary systems of the Fraser River, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2592: xii + 51 p.

Le système sonar d'identification double-fréquence (DIDSON) a été cité au cours de la planification stratégique comme étant une nouvelle technologie acoustique qui permettrait d'estimer de façon économique l'effectif des échappés de saumons avec un niveau de précision similaire ou supérieur à celui atteint avec les programmes de marquage et de recapture actuels. Nos travaux sur le terrain en 2004 avaient pour objectif de déterminer si le système d'imagerie acoustique DIDSON pouvait être utilisé pour estimer l'effectif des échappées de saumons rouges (*Oncorhynchus nerka*) et de saumons Quinnat (*O. tshawytscha*) dans le bassin hydrographique du Fraser et pour déterminer quels seraient les équipements supplémentaires à acquérir (p. ex., fascines, systèmes de montage et plates-formes) pour la mise en œuvre de tels systèmes. En collaboration avec le personnel spécialisé dans l'évaluation des stocks à Kamloops, nous avons dressé une liste préliminaire de 22 sites sur les 10 rivières susceptibles d'être étudiées, en tenant compte des besoins des gestionnaires des pêches ainsi que des critères généraux auxquels doivent satisfaire les sites pour les mesures hydroacoustiques. Des tests effectués dans le lit des cours d'eau et plusieurs visites sur les lieux nous ont permis de conclure que le système DIDSON pourrait être utilisé pour estimer efficacement les échappées de saumons rouges dans les rivières Scotch Creek, Chilko, Horsefly, Mitchell et Seymour et probablement aussi dans le cours inférieur de la rivière Adams. L'énumération dans ces cours d'eau ne nécessiterait qu'un minimum d'équipements supplémentaires, en l'occurrence un mât et une patte de fixation pour le transducteur, un escabeau modifié à partir duquel le transducteur sera installé et qui pourra être utilisé comme platte-forme d'observation pour l'estimation de la distribution des espèces, pour la disposition des instruments auxiliaires (ordinateur et jeu de batteries), des panneaux solaires pour l'alimentation électrique et une fascine de 5 à 10 m adaptée au site. Bien que des travaux supplémentaires doivent être effectués pour choisir le meilleur site de déploiement sur certains cours d'eau (rivière Mitchell) ou pour confirmer que les poissons n'ont pas des comportements inhabituels (p. ex., mouvements de va-et-vient généralisés, regroupements statiques) qui risqueraient de dégrader les performances du système DIDSON (rivière Mitchell, rivière Scotch Creek et rivière Seymour), nous ne pensons pas qu'il faudra beaucoup de temps pour résoudre ces questions. Nous ne pensons pas que le système DIDSON soit approprié pour les cours inférieurs de la Shuswap et de la Stuart et pour la Tachie. Nous avons l'impression que dans le cours inférieur de la Stuart, le dénombrement acoustique des poissons migrateurs, en particulier des saumons Quinnat, pourrait être accompli avec des systèmes acoustiques à balayage latéral installés sur les berges. Une saison complète de tests serait néanmoins nécessaire pour confirmer cette hypothèse. Ni le cours inférieur de la Shuswap ni la rivière Tachie ne se prêtent au dénombrement acoustique à cause, respectivement, de la forte probabilité de comportement inhabituel de la part des poissons et des caractéristiques inadéquates du site. La liste des sites de

déploiement et des exigences opérationnelles (équipements auxiliaires et stratégie d'échantillonnage) citée dans le présent rapport peut être rapprochée des priorités actuelles en matière de gestion afin de choisir les possibilités de déploiement qui exploiteront au mieux les capacités du système DIDSON dans le cadre des programmes existants.

1.0 INTRODUCTION

Mark-recapture programs (MRP) are used in the Fraser River to estimate spawning ground escapement of returning sockeye salmon (*Oncorhynchus nerka*) stocks expected to exceed 25,000 fish in preseason forecasts (Woodey 1984; Schubert 1998). The number of sockeye salmon populations on which mark-recapture estimates are conducted has risen over the past decade as a result of stock rebuilding efforts that were initiated in 1987. The success of these stock rebuilding efforts has also increased the pressure on limited assessment resources because mark-recapture programs are often more labour-intensive and costly to operate than other methods of estimating escapement. As a result of these pressures, a strategic planning exercise was initiated in 2003 to better align stock assessment resources and priorities with management needs and to investigate new technologies and best practices in an effort to reduce costs while maintaining assessment coverage. In 2004, the threshold for implementing an MRP was increased to 75,000 returning fish.

The DIDSON (**D**ual-frequency **ID**entification **SON**ar) imaging system (Sound Metrics 2004) was identified through this process as an acoustic technology with the potential to deliver a cost-effective means of producing escapement estimates with similar levels of precision and accuracy as existing techniques and lower operational costs for some field programs in the Fraser River watershed. The DIDSON sonar system was developed for the United States Navy by the Applied Physics Laboratory at the University of Washington as a tool for harbour surveillance and underwater mine detection and has recently been used for fisheries applications in riverine environments (Moursund et al. 2003; Tiffan et al. 2004).

The DIDSON imaging system uses multiple sound beams that are focused by a movable lens to produce near video-quality images of underwater targets, including fish. DFO took delivery of a standard DIDSON acoustic imaging system in July 2004. The standard model has operating frequencies of 1.1 and 1.8 MHz and a field of view that is nominally 29° horizontally and 12° vertically. The low frequency mode uses 48 beams and is able to detect targets up to 40 m from the transducer, although the resolution is not high enough for positive identification, regardless of the range from the transducer. In contrast, the high frequency mode of the standard DIDSON system uses 96 beams to collect information on the size, shape and movement of a target with sufficiently high resolution to permit the identification of different classes of objects (e.g., big fish, small fish, debris) up to 15 m from the transducer. Because the data are collected and displayed as images, interpretation and analysis are much more intuitive than is possible with an echogram displaying data collected with a split-beam sonar system. Consequently, extensive sonar expertise is not required to operate a DIDSON system effectively.

The mainstem of the Fraser River was surveyed in the 1990s as far upstream as the Big Bar ferry crossing, 72 km west of Clinton, B.C., for potential sites to deploy fixed-location split-beam acoustics (Enzenhofer et al. 1998). Knowledge of the hydroacoustic potential in the tributary systems on which mark-recapture programs are conducted for sockeye salmon escapement estimation is lacking at present. Selection of a site for hydroacoustic systems has to meet the needs of both fisheries managers and the acoustic system. Fisheries managers need reliable passage data that represents all of the fish entering a given river and optimum acoustic performance occurs at sites with a single straight channel, planar bottom configuration, gravel-cobble substrate and laminar water flow which promote active fish migration past the acoustic system (Enzenhofer and Cronkite 2000). Sites that are unacceptable for a split-beam system may be suitable for a DIDSON system because its design and operating characteristics are more flexible with respect to physical site characteristics.

We began a DIDSON research program in the summer of 2004, which focused on sockeye salmon (*Oncorhynchus nerka*) and Chinook salmon (*O. tshawytscha*) stock assessment needs. The goals of this program are to:

1. Assess efficacy of the DIDSON technology for making escapement estimates,
2. Provide advice concerning the accuracy and precision of fish count data from a DIDSON system,
3. Develop software tools to automate the process of target identification and counting, and
4. Transfer the DIDSON technology, tools and escapement methodology to user-groups within current sockeye salmon stock assessment field programs in the Fraser River.

The objectives of the present report are to:

1. Catalogue and prioritize potential deployment sites for the DIDSON system in upper Fraser River tributary systems in which mark-recapture programs are currently used (Stuart-Nechako, Quesnel-Horsefly and Chilcotin-Chilko, Adams-Shuswap), and
2. Test the most promising sites to ascertain characteristics and in-river equipment such as weirs that enhance the performance of the DIDSON system.

The promise of the DIDSON system is that it will deliver escapement estimates that are at least as accurate and precise as estimates produced using current techniques but at a lower cost to the salmon assessment program. However, we anticipate that this technology will improve the accuracy and precision of escapement estimates and the scientific defensibility of these estimates compared to existing techniques. The list of deployment sites and operational requirements (e.g., accessory equipment and sampling strategy) documented in this report can be cross-referenced to existing management priorities in order to determine deployment opportunities that best exploit the capabilities of the DIDSON technology within existing programs.

2.0 METHODS

2.1 Site Selection

A preliminary list of rivers on which the DIDSON system could be deployed was developed through consultation with DFO salmon stock assessment staff in Kamloops, based on the requirements of fisheries managers and identification of likely sites for deployment using general criteria for hydroacoustic assessment. Fisheries managers need reliable passage data that represents all of the fish entering a given river and this requirement usually means that an acoustic site is located as close as possible to the mouth of a river system as practical or below all known spawning of sockeye salmon and/or Chinook salmon. General criteria for the selection of a hydroacoustic site include (Enzenhofer and Cronkite 2000):

1. A straight channel with laminar flow. Laminar flow produces less acoustic background noise than turbulent flow, resulting in an increased signal-to-noise ratio and hence, a greater ability to detect fish;
2. Ideally a planar bottom profile, rather than shelved or scalloped. A shelved bank creates riverbed zones that are inaccessible to the acoustic beam;
3. Bottom substrate free of large boulders that can create turbulent flow or mask the passage of a fish;
4. Fish should be actively migrating. Holding or milling fish may be counted several times, leading to overestimates of upstream flux; and
5. Human activity on the river should be minimal because they may alter fish behaviour and affect the flux estimate (estimate of fish passage through the beam per unit time). Such things as propeller wash entrain air bubbles and create background noise.

Access is a particularly important criterion for site selection since many of these systems are remote and travel is difficult. Prioritizing of sites is based on importance of the sockeye run, site characteristics affecting DIDSON performance and access. A site with marginal characteristics for DIDSON performance but good access was chosen for assessment over a site with great characteristics but poor access because DFO has only one system at present.

2.2 Site Surveys

Tributary systems identified in the site selection process are shown in Fig. 1. The reliable detection and enumeration of fish passage in riverine environments with acoustic systems involves the recognition and solving of problems derived from three sources: (1) physical site characteristics, including bottom profile and water flow; (2) operating characteristics of hydroacoustic systems; and (3) fish behaviour and ecology. Sites were assessed to determine the potential for successfully utilizing hydroacoustic technology to estimate fish flux and to determine the need for additional in-river accessory equipment such as fish deflection weirs. We conducted either a wet-testing or dry-testing survey at each site visited.

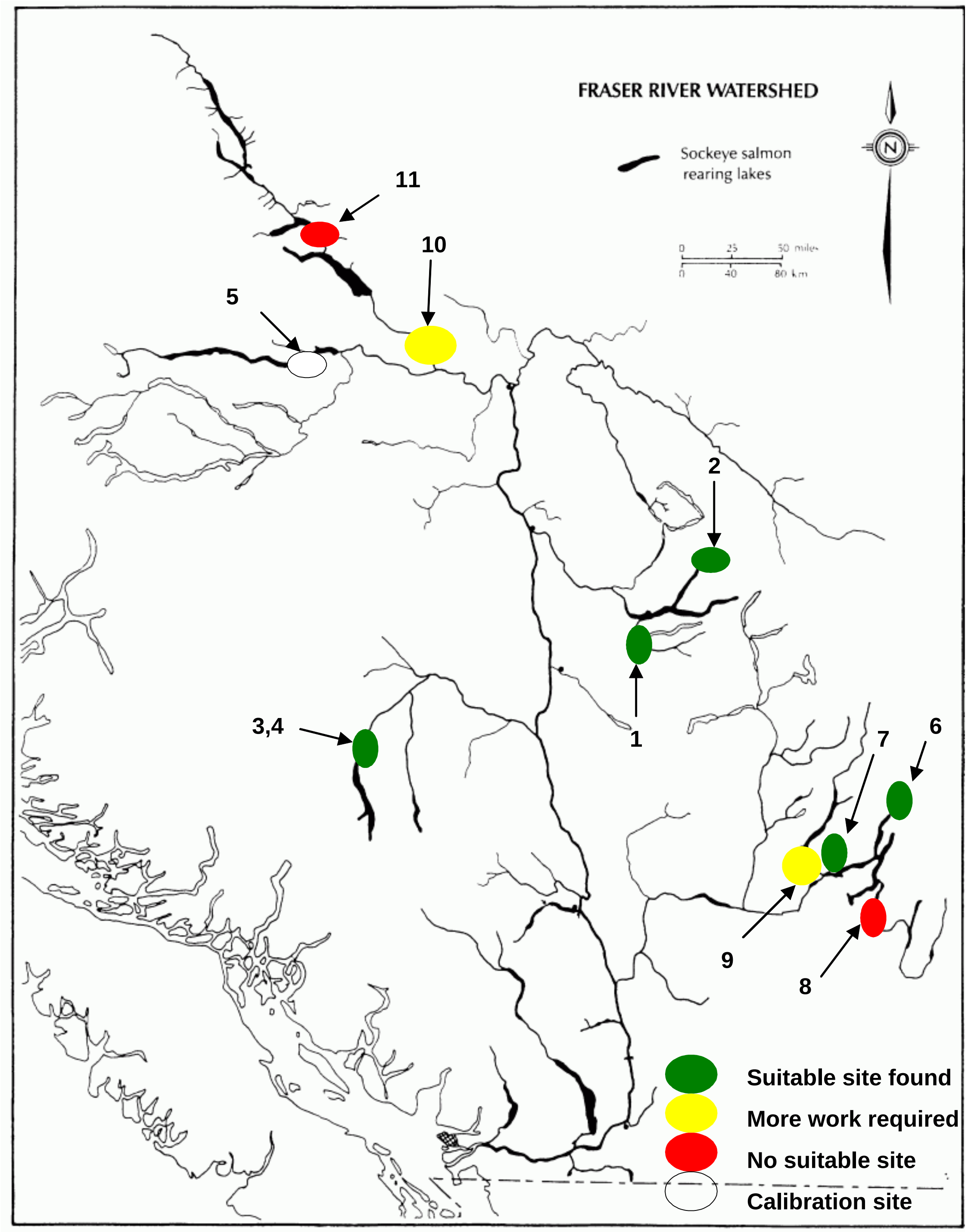

Figure 1. Map of the Fraser River watershed showing tributary systems surveyed for potential DIDSON deployment sites in 2004. Note that the labels on this figure correspond to sub-section numbers in Section 3 of this report. 1 - Horsefly River; 2 - Mitchell River; 3 and 4 - Chilko River; 5 - Stellako River; 6 - Seymour River; 7 – Scotch Creek; 8 – Lower Shuswap River; 9 – Lower Adams River; 10 – Lower Stuart River; 11 – Tachie River.

The DIDSON acoustic system was deployed in the location where it would be used to monitor fish passage during wet-testing surveys and the acoustic system was used to test the beam coverage and to collect data files on migrating fish. Tributary systems in which wet-tested was conducted include:

1. Horsefly River near Mitchell Bay
2. Chilko River at Henry's Bridge and at the confluence with Lingfield Creek
3. Stellako River fish enumeration fence (a joint project of DFO and the Carrier Sekani Tribal Council)

The DIDSON system was not deployed during dry-testing surveys, but the sites visited were assessed for their physical site characteristics and fish behaviour and ecology. Tributary systems that were dry-tested include:

1. Mitchell River (North arm of Quesnel Lake)
2. Seymour River (Shuswap Lake)
3. Scotch Creek (Shuswap Lake)
4. Lower Shuswap River (Shuswap Lake)
5. Lower Adams River (Shuswap Lake)

We catalogued the following information about a site during both dry-test and wet-test surveys.

1. <u>Location:</u> A geographical description of the locality, including latitude, longitude, stream order, river length, site location on the river, and how the site is accessed from the existing road network.
2. <u>Site Description:</u> A description of the physical characteristics of a site including the wetted width (measured with a Bushnell range finder), depth (on the date(s) visited), bottom substrate, estimated water velocity, discharge (from the Water Survey of Canada website), flow pattern (laminar, turbulent, back eddies), and a plot of the cross-section with a description of its shape (wet-tested sites only).
3. <u>DIDSON Evaluation:</u> (wet-tested sites only) During wet-testing, information such as the deployment method and the aiming configuration and settings used to collect acoustic data were recorded. Information on specific acoustic features such as effective beam coverage, maximum range, the DIDSON system location (left or right bank, based on an observer looking downstream with the flow), depth at which the transducer unit was deployed below surface, aim (angle relative to the water surface, usually negative), frequency tested (1.8 MHz or 1.1 MHz), Window Start (start of processing range), Window range window (total range over which data is collected and processed), bottom visible (range on the DIDSON system at which the bottom was first detected), and beam coverage (estimated from cross-section profile) are provided in this section.
4. <u>Fish Behaviour:</u> A list of other Pacific salmon species (*Oncorhynchus* spp.) spawning in a river and resident salmonid (trout, charr) and non-salmonid species that are similar in size and shape to sockeye salmon is provided. This information is based on observations at the site and DFO and provincial records accessed online through the FishWizard website (URL for this site is: http://www.fishwizard.com/index.asp). When other salmon species were observed, we recorded their migratory behaviour with respect to location in the

river cross-section and we assessed the potential for milling/holding behaviour based on current velocity, flow patterns and observed fish behaviour.

5. Deployment Recommendations: Based on the site survey, recommendations for deploying the DIDSON technology are provided including the Site (location in the river), bank(s), number of DIDSON systems required, SONAR settings (processing range, frequency, frame rate), aim (that covers the water column from the surface to the bottom and ensures no blind zones), sampling method (time duration for data collection), potential for visual species composition estimates if necessary, requirements for weirs (length, type and location), power supply recommendations, security, and other considerations pertinent to the site.

2.3 Acoustic data collection

We assessed the efficacy of the standard DIDSON acoustic imaging system for making escapement estimates of sockeye and Chinook salmon. The system is physically small (31.0 cm L x 21.0 cm H x 17.1 cm W) and lightweight (7 kg in air) making it highly portable, and requires 30 W of power to operate. Multiple sound beams are focused by a movable lens to produce near-video-quality images comprised of frames produced by 96 beams in the high frequency mode (1.8 MHz) and 48 beams in the low frequency mode (1.1 MHz). A frame (image) is built in sequence from the echoes received by 4 (low frequency) or 8 (high frequency) sets of 12 beams fired simultaneously (Belcher et al., 2001; Sound Metrics Corporation, 2004). This procedure (or ping cycle) prevents cross-talk among adjacent beams, but it also means that movement of fish before the ping cycle is complete will degrade the image of that fish. The field of view is nominally 29° horizontally and 12° vertically. The system has a dynamic range of 90 dB, was operated at the maximum receiver gain of 40 dB and TVG range compensation was applied to the display data, but not the raw digital data. All digital data were collected and post-processing fish counts were made using Version 4.47 of the DIDSON operating system software (Sound Metrics Corporation, 2004).

We mounted the DIDSON transducer to an adjustable pole mount attached to a modified step-ladder anchored to the riverbed (Enzenhofer and Cronkite 2005). The adjustable pole mounts provides precise manual control of the depth, bearing, roll angle and tilt angle of an attached transducer. The modified ladder had a working platform with an added-on aluminium channel for affixing the adjustable pole mount. Each leg of the ladder had steel pegs driven into the substrate and once secured, visual counts of migrating fish could be made from the working platform.

The acoustic system was housed in a portable Rubbermaid storage shed Model RHP3752 (2.6 m^3) and powered by three 12 V deep cycle batteries and a 700 W (12 V to 120 V) inverter. The battery bank was charged with a combination of two (2) 15 W and one (1) 85 W solar panels (Sharp NE-80EJE) and a 2 kW gasoline generator.

A list of the scientific and common names of all fish mentioned in the text is provided in Appendix I.

3.0 RESULTS

3.1 Horsefly River

Location

Latitude: 52° 27.521' N
Longitude: 121° 24.758' W
Stream Order: 6
River length: 131.09 km
Site: MRP tagging site, about 800 m above river mouth on Quesnel Lake (Fig. 2)
Site access: Private property on the left bank via a driveway off of Mitchell Bay Road, about 5.5 km below a small recreational site with 2-3 camping spots.

Figure 2. View from the left to right bank at the recommended DIDSON site on the Horsefly River on 05 Aug 2004.

Site Description

Wetted width: 25 m at prevailing discharge (Fig. 2), see records below
Depth: 1.14 m max; see discharge records below
Bottom type: Gravel, small cobble (5-10 cm), sand
Water velocity: ~1.25 $m \cdot s^{-1}$ max

Discharge: Environment Canada maintains a real-time flow monitoring station on the mainstem above McKinley Creek (Station 08KH010), with a period of record from 1955 to 2003. Daily flow measurements are not available from July 17 to Sept 10, 2004. Daily discharge ranges from a low of about 5 $m^3{\cdot}s^{-1}$ to a maximum of approximately 90 $m^3{\cdot}s^{-1}$ during the Aug to Oct sockeye salmon migration period in the Horsefly River (Fig. 3). Average daily flows tend to be close to minimum daily flows, which we interpret to mean that the river exhibits flash flooding during storm events, but quickly returns to normal discharge for the period after precipitation stops.

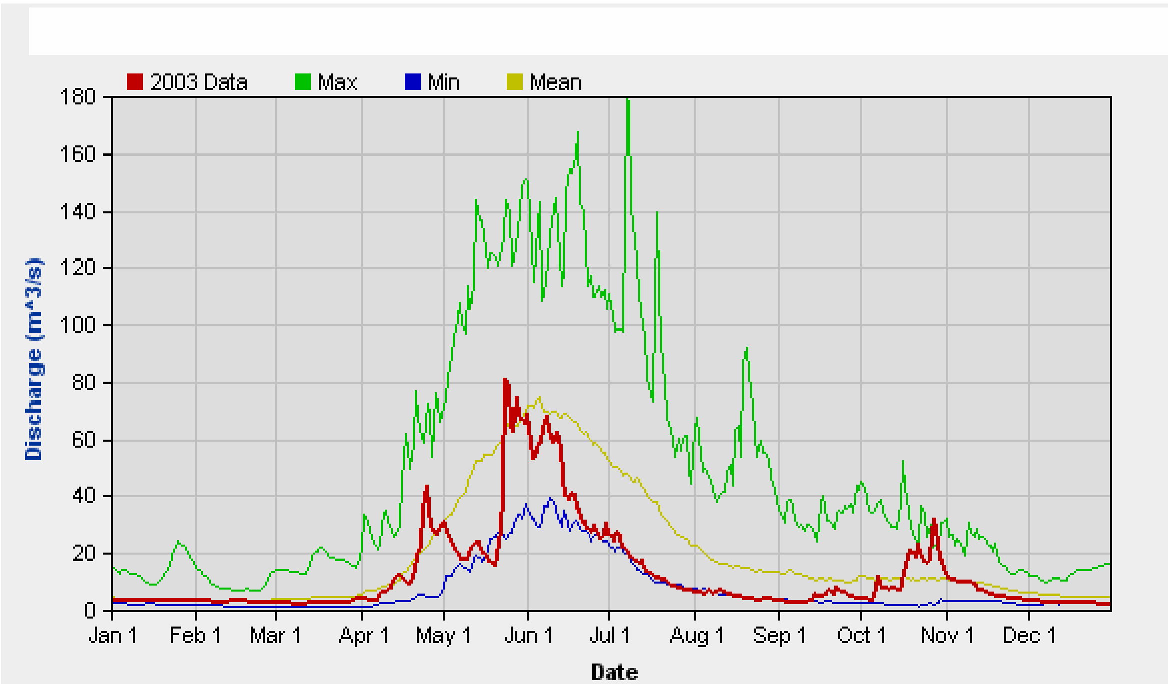

Figure 3. Average daily discharge in the Horsefly River above McKinley Creek between 1955 and 2003. Data retrieved from Water Survey of Canada website accessed 20 Jan 2005.

URL: http:///hydat/H2O/index_e.cfm?cname=WEBfrmMeanReport_e.cfm

Flow pattern: Flow is laminar, little turbulence observed. Majority of water volume is in deep part of the channel, skewed towards the left bank.

Cross-section: Exposed gravel bar on the right bank that would be covered at higher flows and 2 m high eroding sill on left bank. Bottom is planar, no visible scalloping or large boulders that could block the acoustic beams (Fig. 4). Channel is skewed towards the left bank (Fig. 4).

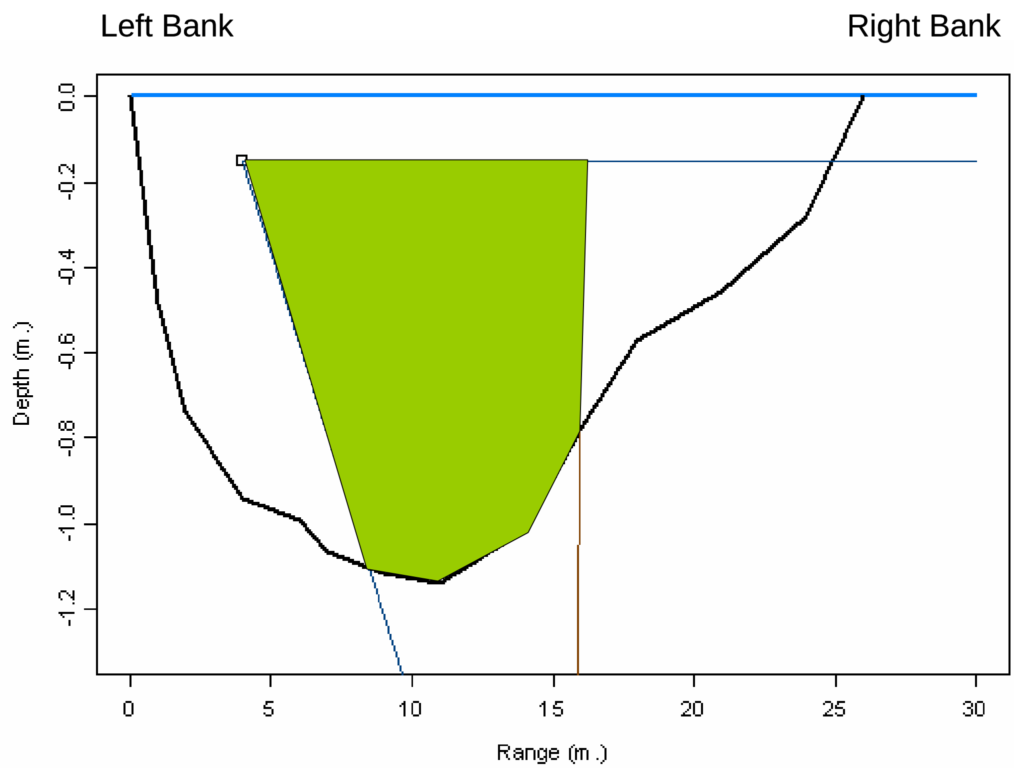

Figure 4. Cross-sectional profile of the Horsefly River showing coverage of the water column by the DIDSON system in high frequency mode, range of 2 to 12 m from the transducer (10 m total) and an aim of - 6° relative to the surface (area in green). Note the difference in vertical and horizontal scales.

DIDSON Evaluation

Dates: 03-16 August 2004

Testing: Beam coverage surface to bottom, beam width upstream and downstream, maximum range

DIDSON location: Mounted on ladder about 4 m from left bank

Depth: Transducer 20 cm below water surface

Aim: - 6° relative to surface, perpendicular to water flow

Frequency: 1.8 MHz

Window Start: 1.67 m from transducer (5.67 m from left bank)

Range window: 10 m (out to 15.67 m from left bank)

Bottom visible: 2 m from transducer

Beam coverage: 50% of cross-sectional area.

Fish Behaviour

Salmonid Species: Chinook, coho, and sockeye salmon, Dolly Varden, kokanee, rainbow trout and steelhead are reported in the Horsefly River (FishWizard – accessed 06 Dec 2004). Some overlap may occur between chinook, coho and sockeye migration periods. During dominant years > 95% of the fish will be sockeye salmon. During off-years in the sockeye cycle, contribution of other species to total upstream flux may be substantially larger.

Migratory behaviour: Sockeye salmon were not observed during the test period. Stock assessment field staff indicate that sockeye spawn above the potential acoustic site. Chinook were observed actively migrating through this site in the deepest portion of the channel.

Holding/Milling: Not observed in salmon species

Resident Species: Suckers were observed during the day at this site. Typically, 5-6 individuals were observed at one time holding within the ensonified area close to the bottom. At dusk these fish moved out of the ensonified area and returned at dawn the following day. Burbot and northern pikeminnow are also reported in this watershed by FishWizard (accessed 06 Dec 2004).

Deployment Recommendations

Site: Lower end of MRP site

Bank: Left

DIDSON systems: One (1) standard system

SONAR settings: High frequency (1.8 MHz), 10 m range window starting at 1.67 m from transducer, i.e., monitoring area 1.67 to 11.67 m from transducer.

Aim: -8.5° relative to surface and perpendicular to flow

Sampling Method: Record and manually count 10 min out of the hour and expand for unsampled periods.

Visual: Visual confirmation of species composition may be necessary. Ensonified area is visible from ladder mount but polarized glasses needed for proper observation of fish.

Weirs: 6 m weir on the left bank to ensure fish do not move behind the DIDSON and that fish move through area ensonified from surface to bottom of the water column. A weir may be necessary on the right bank across the gravel bar at higher flows.

Power supply, security: Currently no power or telephone lines to site so operations will require solar panels and battery bank plus back-up generator to supply power. Topside equipment can be housed in garden shed to keep it out of the weather. Equipment security is not a major concern since site is not highly visible publicly.

Other: Site is relatively flat and open, few tall trees so solar panels could be deployed effectively for power supply. Because recreational boat traffic (kayak, canoe, rafts) occasionally moves through this site, extensive weirs blocking the channel are not recommended.

3.2 Mitchell River

Location

Latitude: 52° 47.76' N
Longitude: 120° 48.14' W
Stream Order: 6
River length: 31.24 km
Site: Four potential sites were identified between the confluence with Penfold Creek and the MRP tagging site
Site access: All sites are remote and access is via jet boat from the north arm of Quesnel Lake or helicopter (Fig. 5).

Figure 5. Aerial view of a potential DIDSON deployment site in the lower reaches of the Mitchell River below the mark-recapture program tagging site and known spawning locations. Photo taken 11 Aug 2004.

Site Description

Wetted width: 35-40 m
Depth: 1.2 – 1.5 m estimated

Bottom type: Mud, silt
Water velocity: 1.0-2.0 m/s
Discharge: Environment Canada maintained a gauging station at the outlet of Mitchell Lake (Station 08KH014) from Jan 1961 to Dec 1982. Mean daily discharge during this period ranged between 1.18 $m^3 \cdot s^{-1}$ and 63 $m^3 \cdot s^{-1}$, with an average of 12.6 $m^3 \cdot s^{-1}$ (Fig. 6). Maximum discharge occurs in the June to September period, coincident with the migration of sockeye salmon. Flow variations (Fig. 6) related to precipitation in this hydrograph are dampened by the presence of the lake. Further downstream at potential DIDSON sites below Cameron Creek, discharge variations may be more extreme.

Figure 6. Minimum, maximum and average daily discharge in the Mitchell River at the outlet from Mitchell Lake from 1961 to 1982. Data retrieved from Water Survey of Canada website accessed 07 Mar 2005. URL of this page: http:///staflo/index_e.cfm?cname=flow_ daily.cfm

Flow pattern: Laminar, unidirectional, little visible turbulence
Cross-section: Planar, extensive shelving or scalloping not observed.

DIDSON Evaluation

Dates: 11 August 2004
Testing: None, survey of likely sites by helicopter only
Beam coverage: If tested, beam coverage would likely be similar to the coverage achieved in the Horsefly River, i.e., 50% of the cross-sectional area.

Fish Behaviour

Salmonid Species: Chinook, coho and sockeye salmon, kokanee, steelhead, rainbow and bull trout, Dolly Varden are reported in FishWizard (accessed 06 Dec 2004). Escapement data are available for coho and sockeye salmon.
Migratory behaviour: Based on flow patterns and current velocities, we expect that sockeye salmon will actively migrate through all four identified sites. However, fish were not observed during surveys.

Holding/Milling: Unknown, but we believe that holding/milling will not be a problem at any site based on observed flow patterns and current velocities.

Resident Species: Suckers, whitefish, rainbow and bull trout probably resident in this system. Abundance unknown but some individuals may be similar in size to sockeye salmon.

Deployment Recommendations

Site: Four potential sites were identified:

1. 52° 48.585' N, 120° 48.458' W,
2. 52° 47.821' N, 120° 47.870' W,
3. 52° 47.434' N, 120° 48.198' W, and
4. 52° 47.213' N, 120° 48.022 'W (Fig. 5)

Site 1, which is about 1 km downstream of the confluence with Cameron Creek, probably at the MRP tagging site, is not recommended for DIDSON deployment because spawning occurs on gravel in the reach below this site. Sites 2, 3 and 4 are below this gravel but above the Penfold Creek confluence and are recommended for DIDSON deployment in the Mitchell River.

Bank: Deployment 4-5 m from either bank possible, depending on which bank has suitable flat area for topside equipment.

DIDSON systems: One (1) standard DIDSON at any of sites 2, 3 or 4.

SONAR settings: High frequency (1.8 MHz), 10 m range window starting at 1.67 m from transducer, i.e., monitoring area 1.67 to 11.67 m from transducer.

Aim: - 8.5° relative to surface, perpendicular to water flow.

Sampling Method: Record and manually count 10 min out of the hour and expand for unsampled periods.

Visual: Sockeye salmon is the most abundant Pacific salmon species in this system. If this species is numerically dominant throughout the entire 4-yr cycle, then visual estimates of species composition would not be required. If visual estimates are needed, then the ensonified area would be visible from ladder mount using polarized glasses.

Weirs: Approximately 5-10 m of weir off the bank on which the DIDSON is deployed would be required to ensure fish do not pass undetected behind the system or near the bottom prior to bottom detection with the DIDSON system.

Power supply, security: The Mitchell River is remote and access is by jetboat or helicopter only. Solar panels and a battery-bank coupled with backup generator would be necessary for power supply. Topside equipment can be housed in garden shed to keep it out of the weather. Equipment security is not a major concern since site is not highly visible publicly.

Other: Sites 2, 3, and 4 are in flat areas and relatively open with few tall trees to hinder solar panel deployment. However, the open nature of these sites means they will be prone to extreme weather (winds, rains) so shelters for topside equipment and operators should be well-sized and anchored.

3.3 Chilko River (Henry's Bridge Crossing)

Location

Latitude: 51° 42.877' N
Longitude: 124° 06.405' W
Stream Order: 7
River length: 89.02 km
Site: Forest Service road bridge (Henry's Bridge), about12 river km below Chilko Lake outlet (Fig. 7).
Site access: Public access from bridge to either bank, off of Chilko Lake Road near junction with Newton-Redstone River Road (Fig. 7).

Figure 7. DIDSON test site and recommended deployment site on the right bank of the Chilko River at Henry's Bridge, 18 Aug 2004.

Site Description

Wetted width: 37 m
Depth: 1.5-2.0 m maximum estimated depth
Bottom type: Small boulders (20-40cm), cobble, gravel
Water velocity: 2.5-3.0 $m \cdot s^{-1}$ estimated
Discharge: Environment Canada maintains a real-time gauging station (08MA002)

at the outlet of Chilko Lake. Mean daily discharge declines from 120 to 35 $m^3 \cdot s^{-1}$ during the Aug to Nov migration period, with minimum and maximum flows of approximately 20 and 180 $m^3 \cdot s^{-1}$, respectively (Fig. 8). during this period.

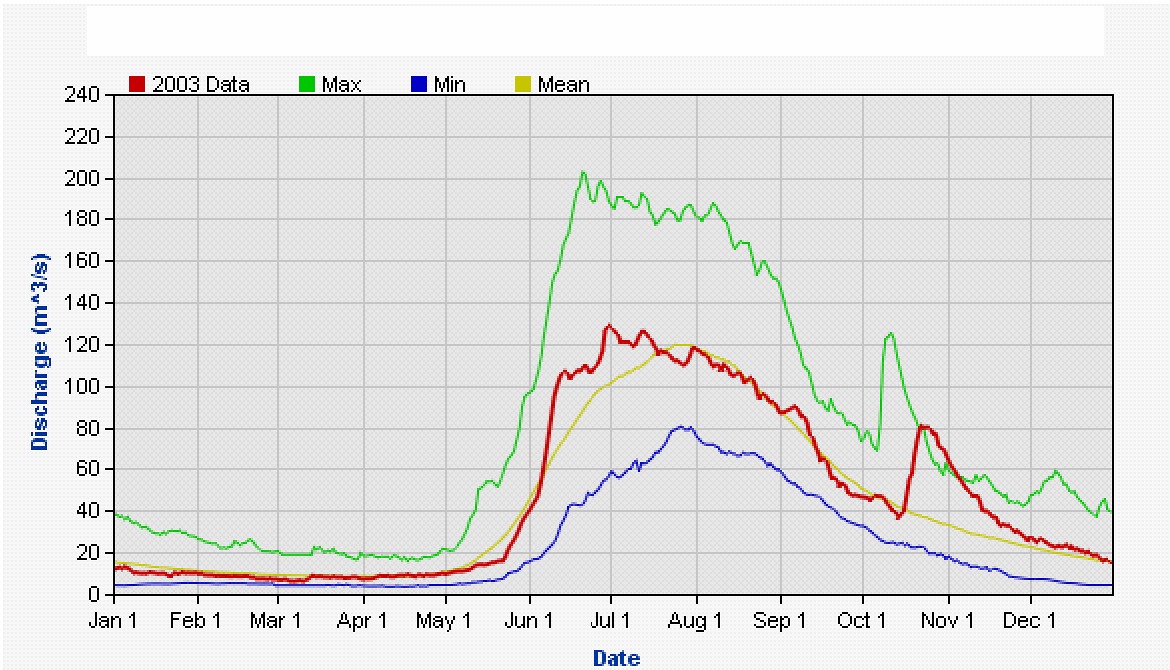

Figure 8. Daily minimum, maximum and mean discharge in the Chilko River at the outlet from Chilko Lake, 1928 - 2001. Data retrieved from Water Survey of Canada website (accessed 20 Jan 2005). URL of this page: http:///hydat/H2O/index_e.cfm?cname=graph.cfm

Flow pattern: Unidirectional but turbulent, especially in middle of river

Cross-section: Short, steep banks with relatively flat bottom (Fig. 9). Flat area about 5 m wide and 30 cm above water level below bridge on right bank. Left bank slopes from top of bridge into river over vertical distance of 7-8 m. Bottom profile not compiled.

DIDSON Evaluation

Dates: 18-20 August 2004

Testing: Beam coverage, maximum range; 30 min timed visual counts of sockeye and chinook salmon within 12 m of right bank for comparison with DIDSON counts

DIDSON location: Right bank, perpendicular to flow; ladder mount was set up on a flat area below the bridge and mounting poles extended below grade to put DIDSON system in the water at the wetted edge of the channel.

Depth: Surface

Aim: -16.5° relative to surface for 20 of 24 timed counts; -8° relative to surface for 4 of 24 timed counts.

Frequency: 1.8 MHz

Window Start: 0.42 m

Range window: 10 m

Bottom visible: About 2.5 m from transducer.
Beam coverage: 6% of cross-sectional area.

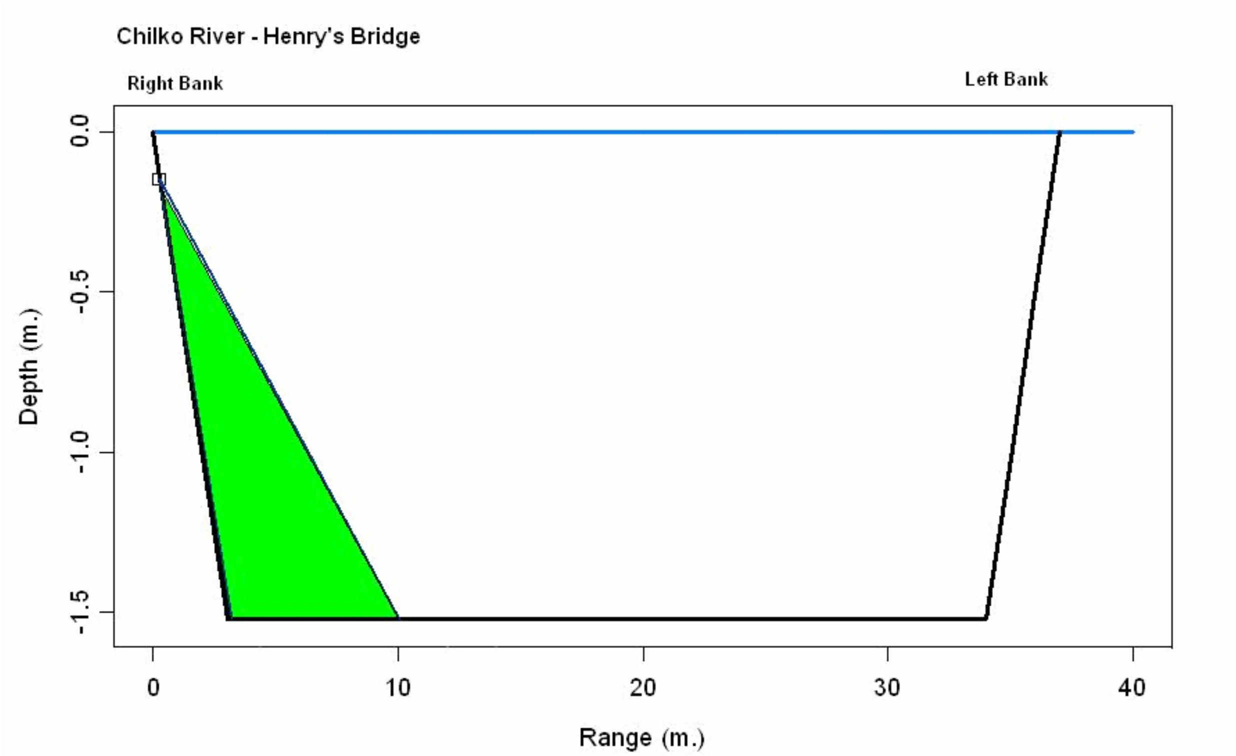

Figure 9. Estimated cross-section profile of the Chilko River at Henry's Bridge, showing DIDSON beam coverage during testing (green area) on the right bank with the high frequency mode, a range of 2-2-12 m from the transducer, and an aim of -16.5° relative to the surface.

Fish Behaviour

Salmonid Species: Chinook, coho and sockeye salmon, bull trout, rainbow trout, Dolly Varden and steelhead are recorded in the Chilko watershed. Chinook and sockeye salmon and probably rainbow trout were observed and recorded at Henry's Bridge.

Migratory behaviour: Sockeye salmon are shore-oriented and swim close to the bottom within 5 m of both banks at this site. Chinook salmon also move through this site, but these fish are further offshore and in higher current velocities than sockeye salmon. At greater range from the transducer, the majority of actively migrating fish are chinook salmon and less commonly, sockeye salmon.

Holding/Milling: The majority of chinook salmon at this site were holding near the bottom in strong current in centre of the cross-section.

Resident Species: Rainbow trout, bull trout and Dolly Varden are smaller in size than sockeye salmon or chinook salmon migrating through this site. Because of the high current velocities at this site, these trout species tend to take up position near the bottom and remain on station rather than moving extensively from bank to bank.

Deployment Recommendations

Site: Recommended site for system enumeration of sockeye salmon escapement in the Chilko River. Upstream side of Henry's Bridge (see Fig. 7).

Bank: Left and right banks

DIDSON systems: Two (2) standard DIDSON systems operating independently on each bank. Each system can be deployed as close to the wetted edge of each bank as possible.

SONAR settings: 1.8 MHz frequency, 10 m range window starting at 0.42 m from transducer

Aim: -16.5° relative to surface. This aim was designed to look down the bank slope to the bottom and out from the bank 6-7 m, minimizing blind areas along the slope and the bottom. Fish near the surface would not be detected with this aim, but such behaviour would be unusual at this site, given the current velocities at the time of our field work.

Sampling Methods: 10-15 min hourly samples, 24 hr per day for entire migration period. Manually counting from screen with expansion for time not sampled. Based on analysis of the files collected over two nights, fish movement past Henry`s Bridge slows but does not stop between sunset (≈21:00) and sunrise (≈06:00). Nighttime movements consist of individual fish rather than groups as observed during the day. The majority of these fish are moving within 5 m of the transducer and are probably sockeye salmon if daylight observations are representative of nighttime conditions.

Visual: Overlap with chinook salmon means that visual confirmation of species composition required. This can be accomplished from the bridge overlooking the site.

Weirs: None required. Sockeye salmon actively migrate through site within 5 m of either the left or right bank.

Power supply, security: Remote site, no power or phone lines within 40 km consequently solar panels and battery bank coupled with back-up generator needed for each DIDSON system deployed. Highly visible and public site requires secure area and 24 hr watch for equipment deployed in the water and topside equipment.

Other: Popular fishing area with dipnets and rods just below Henry's Bridge; when fishing activity is intense, active migration stops or shifts to other bank. Fish may form dense schools which could temporarily impede ability to count successfully. Fishing activity at this site probably also affects existing bridge counts system so procedures already in place to account for the resulting changes in migration behaviour could be adapted to DIDSON sampling scheme.

Chilko River is popular river for rafting expeditions. Effects of rafts on actively migrating sockeye salmon at this site are not known at present.

Comparison of visual and DIDSON counts compiled during test period will be reported separately in Holmes et al. (2005).

3.4 Chilko River (Lingfield Creek)

Location

Latitude: 51° 46.747' N
Longitude: 124° 06.346' W
Stream Order: 7
River length: 89.02 km
Site: MRP tagging site about 100 m above confluence with Lingfield Creek, 8 river km below Chilko Lake (Fig. 10).
Site access: Private driveway across Lingfield Creek Ranch, about 2 km to an abandon crossing over Lingfield Creek and 100 m walk to cabins on left bank of Chilko River.

Figure 10. DIDSON test site on the left bank of the Chilko River (looking downstream) above the confluence with Lingfield Creek. Photo taken 21 Aug 2004. Red arrow marks downstream location or right bank at top of riffle below Lingfield Creek mouth where migrating salmon were observed.

Site Description

Wetted width: 59 m
Depth: 3.1 m maximum
Bottom type: Sand, gravel, cobble (5-15 cm diameter)
Water velocity: 1.0-1.5 $m \cdot s^{-1}$ estimated
Discharge: A real-time monitoring station (08MA002) is maintained by Environment

Canada at the outlet of Chilko Lake. Mean daily discharge declines from 120 to 35 $m^3 \cdot s^{-1}$ during the Aug to Nov migration period, with minimum and maximum flows of approximately 20 and 180 $m^3 \cdot s^{-1}$, respectively (Fig. 8). during this period.

Flow pattern: Majority of water volume moves through a deep trench in the middle of this site. Flow is unidirectional, with little turbulence.

Cross-section: Relatively flat and shallow shelves extend approximately 14 m off the left bank and 10 m off the right bank to a deep trench down the middle of the site (Fig. 11).

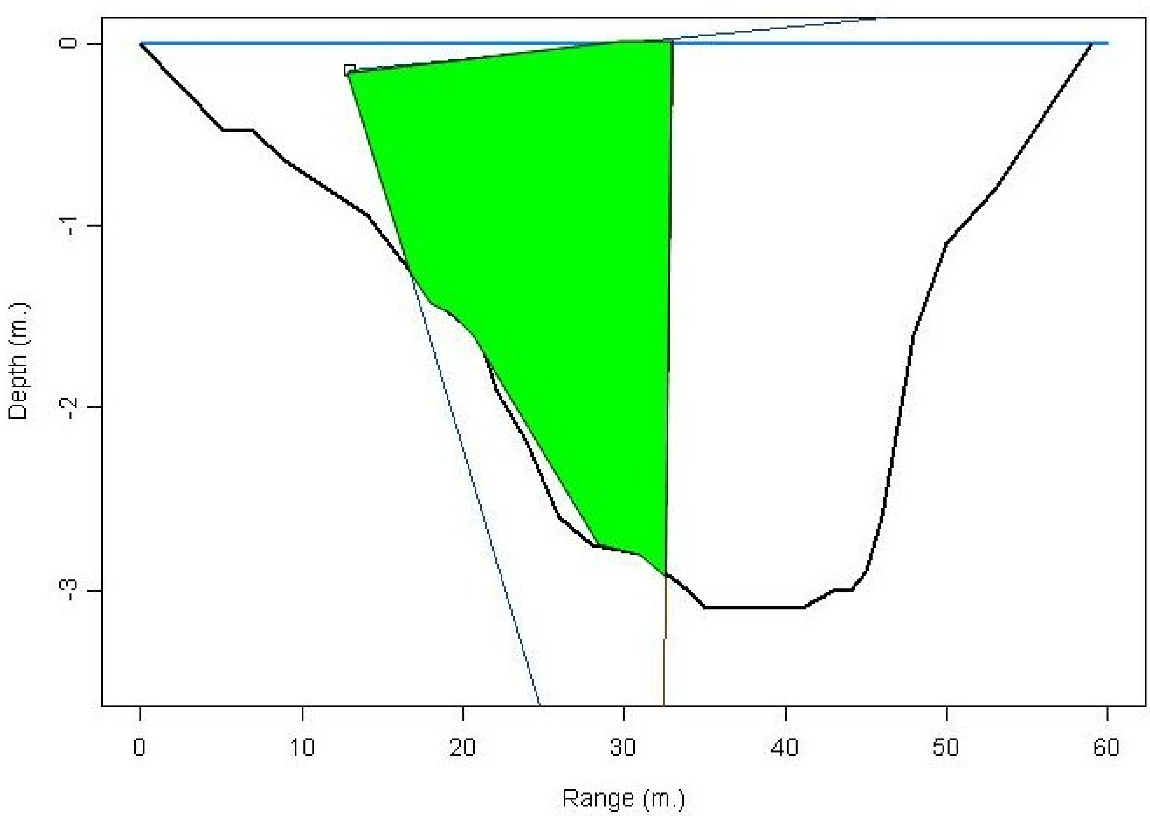

Figure 11. Cross-section profile of the Chilko River at the Lingfield Creek test site showing the area ensonified (in green) during low frequency mode and range set to for 2 to 22 m (20 m total) from the transducer. The transducer is positioned 12 m off the left bank, looking towards the right bank.

DIDSON Evaluation

Dates: 21-28 Aug 2004

Testing: Beam coverage, maximum range, beam width. Note: this was the only location in which the 150 m cable was deployed, necessitating a change in the Ethernet protocol used for data transfer to the topside computer

DIDSON location: 12 m off the left bank, perpendicular to flow; spent one day 5 m off the right bank.

Depth: About 10 cm below the surface

Aim: -8° relative to surface on left and right banks.
Frequency: Low frequency (1.1 MHz)
Window Start: 1.49 m from transducer
Range window: 20 m
Bottom visible: 3 m from transducer
Beam coverage: 23% of site cross-section

Fish Behaviour

Salmonid Species: Chinook, coho and sockeye salmon, bull trout, rainbow trout, Dolly Varden and steelhead are recorded in Chilko River watershed. Chinook, and sockeye salmon, rainbow and bull trout and Dolly Varden were captured by the tagging program at the Lingfield site.

Migratory behaviour: Active chinook or sockeye salmon migration was not observed at this site from either bank despite continuous sampling over an 8-day period. During a brief test of a site on the right bank in a fastwater area about 100 m below the MRP (red arrow in Fig. 10), we counted 140 sockeye salmon moving upstream within 5 m of the bank in a 1-hr period.

Holding/Milling: Chinook salmon hold in the trench down the middle of this site, which begins about 10 m from the transducer and extends out beyond 42 m from the left bank. These fish slowly move up- and downstream, but rarely leave the acoustic beam. Numbers are sufficiently high that we were not able to detect any active migration past this site. This holding behaviour is observed both day and night and similarly, detection of active migration was not possible at night.

Sockeye salmon may hold in this location as well, however, we were not able to determine species composition of holding fish because the low frequency resolution is not sufficient for identification.

Resident Species: Mountain whitefish and suckers as well as Dolly Varden, bull trout and rainbow trout. Abundance of these species was minimal compared with Chinook salmon during the test period so these species would not be a significant challenge for identification or counting purposes.

Deployment Recommendations

Site: Not recommended as a site for sockeye salmon escapement estimation. High abundance of Chinook salmon (and presumably sockeye salmon) holding at this location because the river is wide and current velocities are relatively low. This holding behaviour severely hampers our ability to detect migrating fish, either visually or with the DIDSON system. Although this detection problem may change at higher sockeye salmon passage rates than we observed in 2004, a DIDSON system at this site would be required to use the low frequency, low resolution mode to enumerate fish because they could be almost anywhere in the water column.

The lower right bank site (red arrow in Fig. 10) at which migrating sockeye salmon were observed and recorded may be suitable as an enumeration site. However, this site is at the bottom of a high unstable bank, so access is by boat only and would be dangerous at night because of the high current velocities. A working platform would have to be anchored into the bank for our equipment and shed. We did not investigate the left bank at this location.

Bank: A total system count at this site would require a DIDSON system on both banks.

DIDSON systems: Two (2) standard DIDSON systems operating independently on each bank.

SONAR settings: 1.1 MHz (low frequency); 20 m range window starting 1.5 m from transducer.

Aim: -8.5° relative to the surface and perpendicular to flow from both banks.

Sampling Methods: 10-15 min hourly samples, 24 hr per day for entire migration period. Manually counting from screen with expansion for time not sampled and adjustment for double counting in overlapping area ensonified from both banks. Knowledge of diurnal migration patterns at this site, if any, is lacking.

Visual: Some method of estimating species composition would be required. Visual estimates from the ladder mounts would probably be useful for 10 m range only; fish are found at much greater ranges but currently we have no method of determining species composition at these longer ranges.

Weirs: Extensive weirs blocking the flat shelves along both banks (at least 12 m on the left bank and 10 m on the right bank) would be required to prevent fish from moving behind the sonar systems.

Power supply, security: Remote site, no power or phone lines within 40 km. Therefore, solar panels, battery-banks and back-up generators required for each DIDSON system. Both banks are forested so there are no obvious locations for solar panel deployment. Equipment security is not as high a priority as at Henry's Bridge, because public exposure to this site, which is on private property, is minimal.

Other: Chilko River is popular river for rafting expeditions. Weirs extending out from both banks would restrict navigation on this portion of the river. Furthermore, when rafts pass through this site we observed (and recorded) a strong avoidance response by fish holding in the deep trench.

This was the only site at which the 150 m cable was tested and we had difficulty on several occasions re-establishing contact with the sonar when the system was shutdown by a low power supply.

There is no vehicle access to this site. Heavy equipment such as cables and weir components would have to be brought downriver by boat from the DFO camp at Chilko Lake.

3.5 Stellako River

Location

Latitude: 54° 02.72' N
Longitude: 124° 55.562' W
Stream Order: 6
River length: 13.5 km
Site: Fish fence, about 250 m upstream of pool near upstream side of fish fence (Fig. 12).
Site access: Private road across Stellako First Nation land to right bank; footpath about 200 m upstream to fish fence.

Figure 12. DIDSON equipment configuration used for count comparisons at the Stellako River Fish Enumeration Fence, 01 Sept 2004. The DIDSON equipment is about 5 m off of the right bank. Gate through which fish pass during counting is behind counting shed.

Site Description

Wetted width: 33 m
Depth: 0.99 m: depths measured within 1 m of upstream side of fish fence, which creates small head due to restriction of flow between spindles in weir panels
Bottom type: Sand, small gravel

Water velocity: 1.0 $m \cdot s^{-1}$ estimated

Discharge: Discharge records date to Jan 1929 and since 1950 a recording staff gauge has been maintained by Environment Canada (Station 08JB002). Peak discharge occurs in the May-June period and declines through the sockeye salmon migration period (Jul-Oct). Mean daily discharge during the migration declines from 42.2 $m^3 \cdot s^{-1}$ in July to 10.8 $m^3 \cdot s^{-1}$ through Oct (Fig. 13).

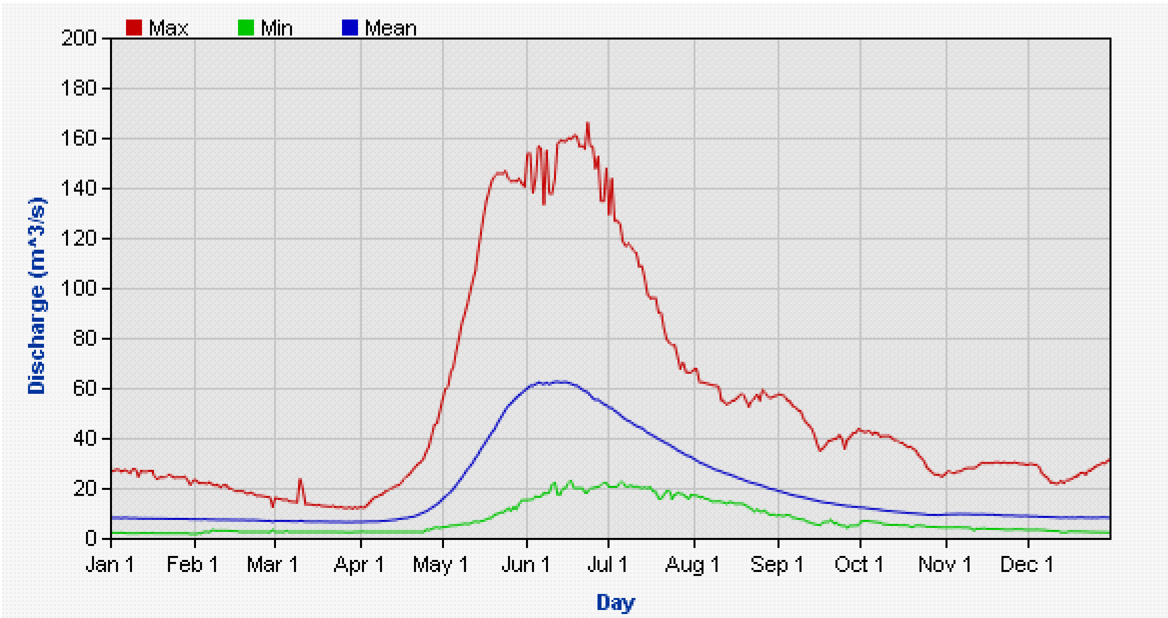

Figure 13. Minimum, maximum, and mean daily discharge in the Stellako River at Glenannan, Jan 1929 to Dec 2003. Data retrieved from Water Survey of Canada website (accessed 08 Mar 2005). URL of this page: http:///staflo/index_e.cfm?cname=flow_daily.cfm

Flow pattern: Laminar, unidirectional, no turbulence observed.

Cross-section: Bank slopes are planar and cross-sectional profile is bowl-shaped.

DIDSON Evaluation

Dates: 1-10 September 2004

Testing: None. Site used to calibrate DIDSON counts against known standard, i.e., counts of fish through the fish fence (see Holmes et al. 2005).

DIDSON location: 11 m off right bank, 1.25 m upstream of fence and 3.5 m from gate through which fish pass.

Depth: Transducer 10 cm below surface

Aim: -8° relative to surface and perpendicular to flow (parallel to fence). Aim designed to ensure no blind zones through which fish can move undetected between surface and bottom or either side of fence gate. Fence gate on right edge of view at 3.5 m range.

Frequency: 1.8 MHz (high frequency)

Window Start: 1.67 m from transducer

Range window: 5.0 m (maximum range 6.67 m from transducer)

Bottom visible: 2.0 m from transducer.

Beam coverage: Not estimated.

Fish Behaviour

Salmonid Species: Chinook and sockeye salmon, rainbow trout, Dolly Varden, kokanee

Migratory behaviour: Majority of sockeye salmon move through gate and upstream. A few individuals hold momentarily and then proceed upstream and some individuals exhibit high speed milling behaviour for several minutes before disappearing upstream. The highest passage rates through the gate occurred between 2100 and 2400, with much lower but steady rates of passage between 0000 and 0700. During the day, very few sockeye moved upstream through the fence.

Holding/Milling: Several sockeye salmon exhibited holding/milling behaviour for limited periods of time. Resident mountain whitefish and rainbow trout were holding and milling continuously during the 10 day calibration period.

Resident Species: Large numbers of mountain whitefish and rainbow trout hold over the sandbags protecting the upstream side of the fence apron. Numbers are much higher during the night when substantial milling activity is also observed. The magnitude of these activities, especially at night, was sufficient to impede our ability to count salmon moving through the fence gate on several occasions.   Burbot and northern pikeminnow are other large species present in watershed (FishWizard – accessed 18 Jan 2005).

Deployment Recommendations

Site: No deployment recommendations. Fence site visited for calibration purposes only. Not contemplated as a site where the DIDSON could (or would) be deployed operationally.

Results: A total of 90 counting events were recorded during the 10-day calibration period. Fence counts ranging from 1 to 932 sockeye salmon per event. A counting event occurred when the fence gate was open and ranged from about 15 to 60 min in duration. Fence and DIDSON count data were analyzed for accuracy and precision (among DIDSON counters) and these results are reported separately in Holmes et al. (2005).

3.6 Seymour River

Location

Latitude: 51° 15.735' N
Longitude: 118° 54.039' W
Stream Order: 5
River length: 70.71 km
Site: 1 km above the mouth at the end of a light plane airstrip (Fig. 14).
Site access: To left bank via airstrip in Silver Beach Provincial Park. Direct vehicle access to the bank, which is about 2.5 m high.

Figure 14. Potential DIDSON deployment site near the mouth of the Seymour River. Photo taken 22 Sept 2004 from the left bank at the end of an airstrip in Silver Beach Provincial Park.

Site Description

Wetted width: 25 m
Depth: 2 m estimated, near left bank
Bottom type: Sand, gravel, cobble up to 12 cm in diameter.
Water velocity: 1.5 $m \cdot s^{-1}$ estimated
Discharge: A real-time monitoring station (08GA077) is maintained by Environment

Canada on Seymour River below Orchid Creek. The period of record is only 10 years, so the hydrograph exhibits high-frequency variability (Fig. 15). Minimum and maximum daily discharges during the sockeye salmon migration period are < 1 and about 45 $m^3 \cdot s^{-1}$ respectively.

Flow pattern: Flow is laminar and unidirectional, with most of the flow near the left bank because site is below a slight curve to the right.

Cross-section: Bottom slope is planar and shallow off the right bank. Short and steep off the left bank. Cross-sectional profile measurements were not compiled.

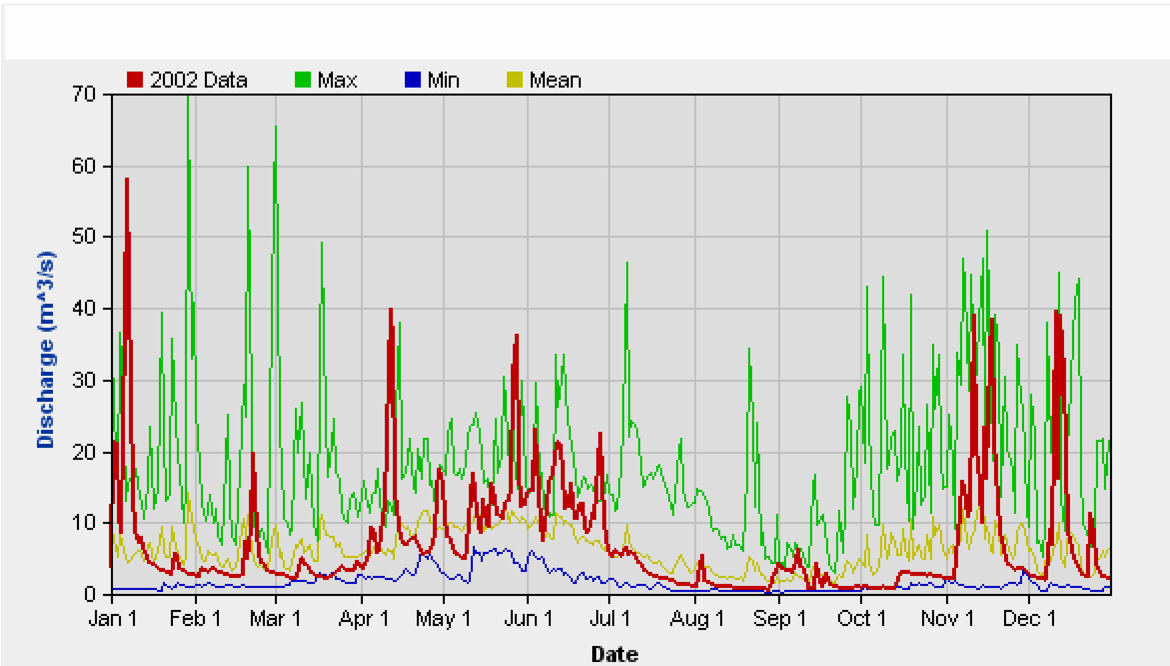

Figure 15. Average daily minimum, maximum, and mean discharges in Seymour River between 1992 and 2001. Data retrieved online from Water Survey of Canada website (accessed 20 Jan 2005). URL of this page: http:///hydat/H2O/index_e.cfm?cname=graph.cfm

DIDSON Evaluation

Dates: 22 September 2004

Testing: None. Visual survey of potential sites only.

Fish Behaviour

Salmonid Species: Chinook salmon, coho salmon, kokanee, rainbow trout, sockeye salmon (FishWizard – accessed 18 Jan 2005).

Migratory behaviour: Based on the width, estimated current velocity and flow pattern, we believe that sockeye salmon will actively migrate through this site. Several sockeye salmon were observed in mid-channel actively migrating upstream (1 downstream) during the site visit, however, confirmation of active migration requires in-river testing.

Holding/Milling: Unknown at present. Requires in-river testing to confirm or refute.

Resident Species: Resident species such as largescale suckers, mountain whitefish and trout may hold or mill over near the right bank where current velocities are low. However, a small weir on this bank should force sockeye salmon into high current areas ensonified by the DIDSON system. Burbot also present in system (FishWizard – accessed 18 Jan 2005).

Deployment Recommendations

Site: Recommended site is beside an airstrip site about 1 km above the mouth in Silver Beach Provincial Park (Fig. 14). Other sites examined but rejected for DIDSON deployment include Celista Road bridge crossing, (largely white water, with large rock outcrops), the Flying Dutchman's curve (above spawning habitat), and the mouth (slough-like and access is via a walking trail about 1 km long).

Bank: Left

DIDSON systems: One (1) standard system

SONAR settings: 1.8 MHz (high frequency),

Aim: Between -6 and -9° relative to surface. Final angle to be determined during onsite testing

Sampling Methods: 10-15 min hourly samples, 24 hr per day for entire migration period. Manually counting from screen with expansion for time not sampled. Knowledge of diurnal migration patterns at this site, if any, is lacking.

Visual: Visual confirmation of species composition may be necessary. Ensonified area is visible from ladder mount but polarized glasses needed for proper observation of fish.

Weirs: A small weir extending about 5-10 m from the right bank would be needed to ensure that sockeye salmon pass through the acoustic field fish and to move fish into an area of the beam (beginning 2 m from the transducer) where coverage is from the surface to the bottom, i.e., there are no blind zones.

Power supply, security: Currently, no power or telephone lines nearby. Therefore solar panels and battery bank plus backup generator required to run site. Shed to house topside equipment and 24 hr watch would likely be required because this site next to an airstrip and visible publicly.

Other: An MRP is conducted in the Seymour system. Enumeration costs are high two out of every four years.

Site is relatively flat and open, few tall trees so solar panels could be deployed effectively for power supply.

Our recommendation assumes no unusual fish behaviour (holding, milling, extreme densities) occurs during the migration period.

3.7 Scotch Creek

Location

Latitude: 50° 55.2468' N
Longitude: 119° 28.7696' W
Stream Order: 5
River length: 56.54 km
Site: 1 km above mouth, right bank (Fig. 16).
Site access: Direct vehicle access as site is beside Squilax-Anglemont Rd.

Figure 16. Potential DIDSON deployment site near the mouth of Scotch Creek. Photo taken from the right bank, 22 Sept 2004.

Site Description

Wetted width: 20 m
Depth: 1.0-1.5 m estimated at current discharge
Bottom type: Sand, gravel
Water velocity: 1.5-2.0 $m \cdot s^{-1}$ estimated
Discharge: Not measured while onsite. Three years of discharge data recorded between Jan 1915 and Dec 1948 are available for a station (08LE030) near

Sorrento (Fig. 17). These data are incomplete, but show that peak discharge occurs in late May and June. Average discharge during the sockeye salmon migration period declines from 14.0 $m^3 \cdot s^{-1}$ in July to 3.07 $m^3 \cdot s^{-1}$ by Sept (Fig. 17).

Flow pattern: Laminar, unidirectional downstream. Some surface turbulence due to debris pile. Majority of water volume flows along right bank,

Cross-section: Planar bottom. Right bank is more steeply sloped and channel is deeper than left bank.

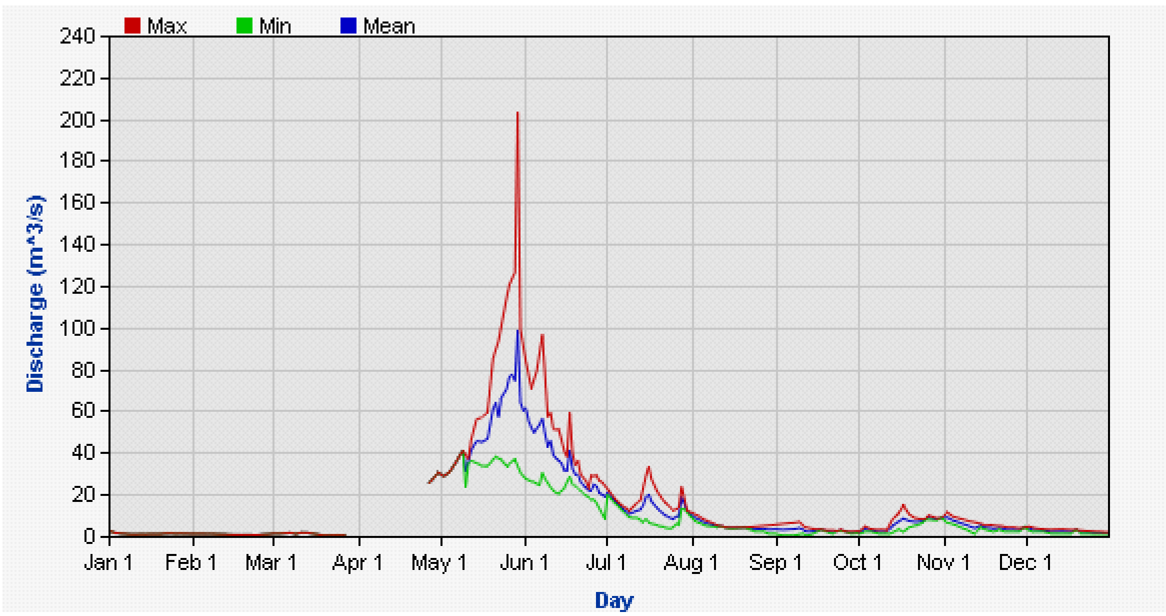

Figure 17. Average daily minimum, maximum, and mean discharges in Scotch Creek based on 3 years of data collected between 1915 and 1948. Data retrieved online from Water Survey of Canada website (accessed 09 Mar 2005). URL of this page: http:///staflo/index_e.cfm?cname=flow_daily.cfm

DIDSON Evaluation

Dates: 22 September 2004

Testing: None. Visual survey to identify potential sites only.

Fish Behaviour

Salmonid Species: bull trout, Chinook salmon, coho salmon, Dolly Varden, kokanee, rainbow trout, sockeye salmon (FishWizard – accessed 18 Jan 2005)

Migratory behaviour: Based on estimated current velocity and observed bottom profile, we believe sockeye salmon will actively migrate through this site. Instream confirmation is required.

Holding/Milling: Unknown at present. Requires in-river testing to confirm or refute.

Resident Species: burbot, mountain whitefish, northern pikeminnow, suckers (FishWizard – accessed 18 Jan 2005).

Deployment Recommendations

Site: I km above mouth (Fig. 16).

Bank: Right or left bank

DIDSON systems: One (1) standard system

SONAR settings: 1.8 MHz (high frequency); 10 m range window starting 1.5 m from transducer.

Aim: -8.5° relative to surface and perpendicular to flow

Sampling Methods: Temporal sampling, 10 $min \cdot hr^{-1}$. Depth stratification unnecessary since one aim will cover water column from bottom to surface

Visual: Visual confirmation of species composition may be necessary as mixed species migrations possible. Ensonified area is visible from ladder mount but polarized glasses needed for proper observation of fish.

Weirs: A small weir extending about 5 m from the bank off of which the DIDSON is deployed would be needed to ensure that sockeye salmon pass through the acoustic field and to move fish into an area of the beam (beginning 2 m from the transducer) where coverage is from the surface to the bottom, i.e., there are no blind zones.

Power supply, security: Currently, no power or telephone lines nearby. Therefore solar panels and battery bank plus backup generator required to run site. Shed to house topside equipment and 24 hr watch would likely be required because this site is near a provincial park and visible publicly.

Other: Topographic maps show two main channels near the mouth. Extensive reconnaisance failed to find a second channel with water flow. Our recommendation assumes that there is only one active channel near the mouth of the Scotch Creek and it also assumes that fish move straight through the site.

An MRP is conducted in Scotch Creek, resulting in high enumeration costs one in every four years.

3.8 Lower Shuswap River

Location

Latitude: 50° 49.548' N
Longitude: 118° 55.754' W
Stream Order: 6
River length: 195.55 km – mouth to headwaters, includes Lower portion of river.
Site: Four sites between Mara Lake and Enderby, two sites between Enderby and Mabel Lake.
Site access: Site 1: picnic site near mouth off of Hwy 97A
Site 2: Bridge crossing from Riverside Dr to Mara (Fig. 18).
Site 3: Grindrod Bridge Crossing of Hwy 97A
Site 4: Boat launch on left bank in Enderby
Site 5: Junction of Watershed and Mabel Lake Roads
Site 6: Ashton Creek – Trinity Valley Road bridge crossing

Figure 18. Bridge crossing from Riverside Drive (right bank) over the lower Shuswap River to Mara (left bank). The second of four potential DIDSON sites between Mara Lake and Enderby. Photo taken from right bank on 23 Sept 2004.

Site Description

Wetted width: Site 1 – 100 m; Site 2 – 130 m; Site 3 - 145 m; Site 4 – 100 m; Site 5 – 83 m; Site 6 – 65 m

Depth: Site 1 – 1 m; Site 2 - 2-3 m; Site 3 – 1.5 m; Site 4 – 2-3 m; Site 5 – 1 m; Site 6 – 3-5 m

Bottom type: Site 1 – mud and silt with substantial milfoil growth; Site 2 – mud and silt; Site 3 – fine gravel and sand; Site 4 - gravel and cobble up to 10 cm in diameter; Site 5 - gravel and cobble up to 12 cm in size; Site 6 – sand, gravel and cobble.

Water velocity: Site 1 - little appreciable current velocity; Site 2 – low, < 0.5 $m \cdot s^{-1}$; Site 3 - < 1.0 $m \cdot s^{-1}$; Site 4 - < 1.0 $m \cdot s^{-1}$; Site 5 - >1.0 $m \cdot s^{-1}$; Site 6 - < 1.0 $m \cdot s^{-1}$

Discharge: Real-time monitoring station at Enderby (08LC002) maintained by Environment Canada. Discharge varied from 67.5 m3/s (01 Sep) to 78 $m^3 \cdot s^{-1}$ on Sep 25, 26 (Fig. 19). Discharge on 23 September was about 77 m3/s. Water level changed from 1.95 to 2.42 m during this period and on Sept 23 was 2.40 m (Fig. 19). Average minimum and maximum discharge between 01 Aug and 01 Nov are 25 and 275 $m^3 \cdot s^{-1}$, respectively (Fig. 20).

Flow pattern: Flow patterns at all sites are generally laminar in nature, but slow and sluggish.

Cross-section: Cross-sectional profiles were not compiled at any of the sites investigated.

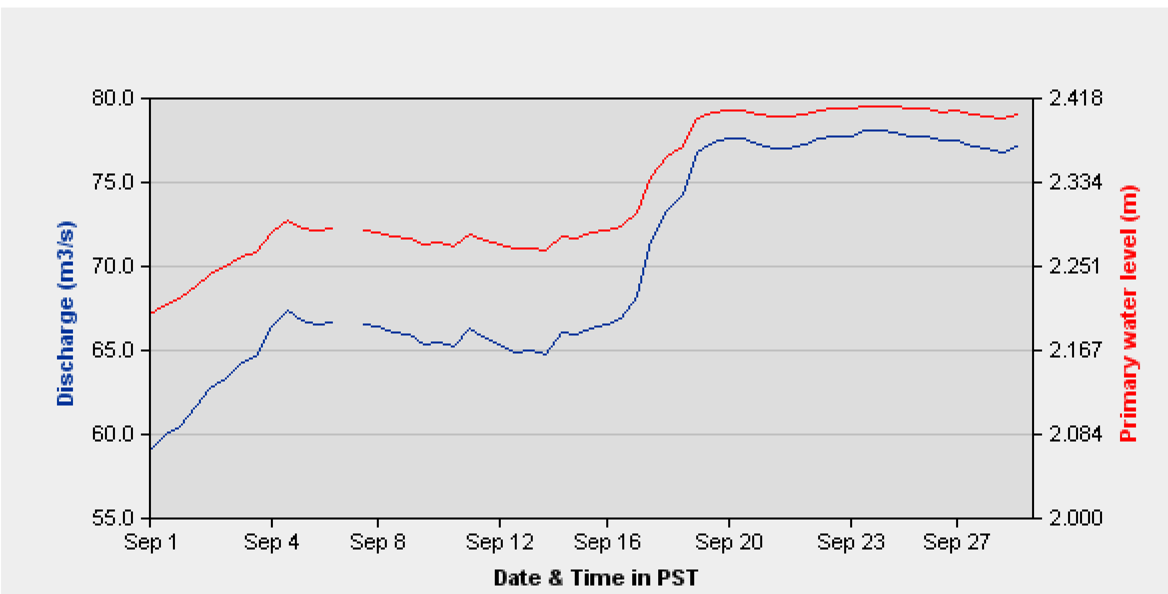

Figure 19. Daily discharge in the Lower Shuswap River at Enderby between 01 and 30 Sept 2004. Data Retrieved from Water Survey of Canada website (accessed 20 Jan 2005). URL of this page:http://scitech.pyr.ec.gc.ca/waterweb/fullgraph.asp

DIDSON Evaluation

Dates: 23 September 2004

Testing: None. Visual survey to identify potential sites only.

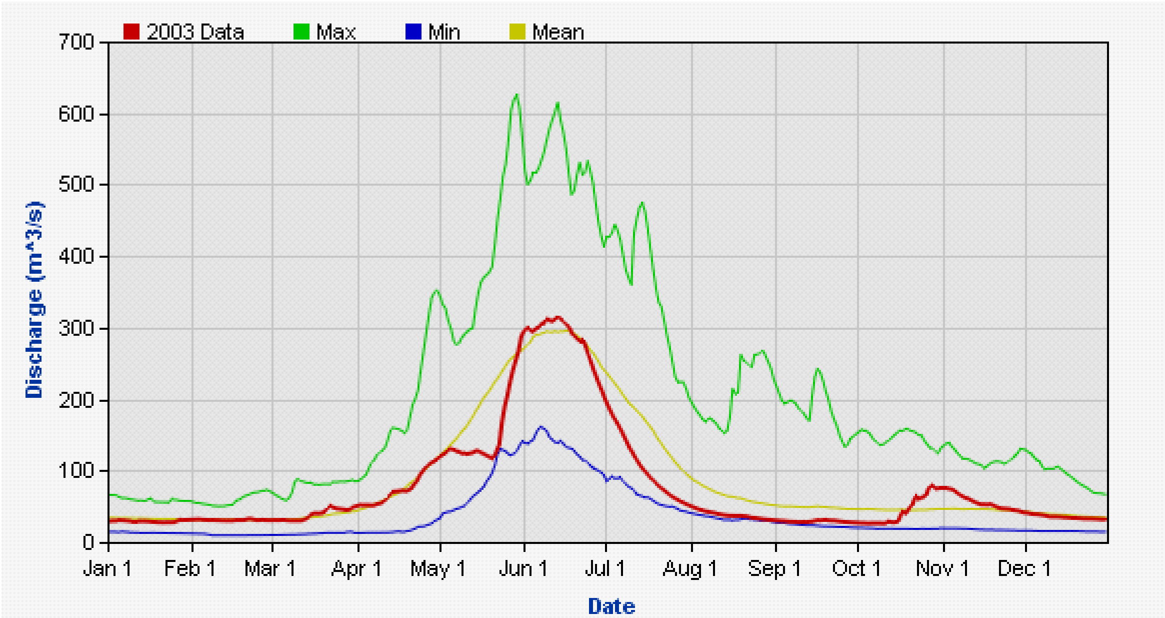

Figure 20. Historic minimum, maximum and mean daily discharge in the Lower Shuswap River at Enderby. Data retrieved from Water Survey of Canada website (accessed 20 Jan 2005). URL of this page: http:///hydat/H2O/index_e.cfm?cname=graph.cfm

Fish Behaviour

Salmonid Species: bull trout, Chinook salmon, coho salmon, cutthroat Trout, Dolly Varden, kokanee, lake trout, pink salmon, rainbow trout, sockeye salmon FishWizard - accessed 18 Jan 2005).

Migratory behaviour: Given the low current velocity and sluggish nature of the Lower Shuswap, there is no strong stimulus for swimming. Thus, there is a high probability that milling would occur. Furthermore, because current velocity is low, sockeye salmon may not exhibit shore-orientation during their migration.

Holding/Milling: High probability of holding/milling occurring among migrating sockeye salmon, regardless of site chosen.

Resident Species: bridgelip sucker, largescale sucker, longnose sucker, mountain whitefish, northern pikeminnow (FishWizard - accessed 18 Jan 2005).

Deployment Recommendations

Site: We do not recommend deploying the DIDSON system in the Lower Shuswap River. Sites 5 and 6 are not suitable because they are both above Enderby, which is the lower limit of sockeye salmon spawning in the river. Sites 1-4, between Enderby and Mara Lake, are not suitable because there is a high probability that fish will mill at these sites and because there is a high probability that fish are not shore-oriented, which would result in fish migrating through areas in the center of the river that are beyond the detection range of a DIDSON system in either high frequency or low frequency modes. We cannot easily compensate for these behaviours in migrating fish with current equipment and techniques, except to change sites.

3.9 Lower Adams River

Location

Latitude: 50° 54.110' N
Longitude: 119° 35.691' W
Stream Order: 5
River length: 130.99 km (lower and upper combined)
Site: Downstream side and below single lane bridge over the Lower Adams River (Fig. 21).
Site access: Public access off the Squilax-Anglemont road

Figure 21. Lower Adams River at the Squilax-Anglemont Road Crossing. Photo taken from the left bank on 22 Sept 2004.

Site Description

Wetted width: 75 m
Depth: 2.0-3.0 m (left bank), 0.5-1.5m (right bank) at current discharge
Bottom type: Sand, gravel and large boulder
Water velocity: 1.5-2.5 $m \cdot s^{-1}$ estimated
Discharge: Not measured during visit. Water level data at the outlet of Adams Lake

(Station 08LD003) into the Lower Adams River are available for a 55 year period of record from Jan 1949 to Dec 2003 (Fig. 22). Water levels exhibit a strong season cycle that peaks in June and declines through the sockeye salmon migration period (July to Oct). There is little short-term variability in average water levels in Adams Lake, as expected. Presumably, discharge in the Lower Adams Rivers probably shows similar stability during the salmon migration period.

Flow pattern: Laminar flow (left bank for 10 m), surface turbulence and white-water mid-channel

Cross-section: Planar bottom on right bank and more steeply sloped and deeper on the left bank

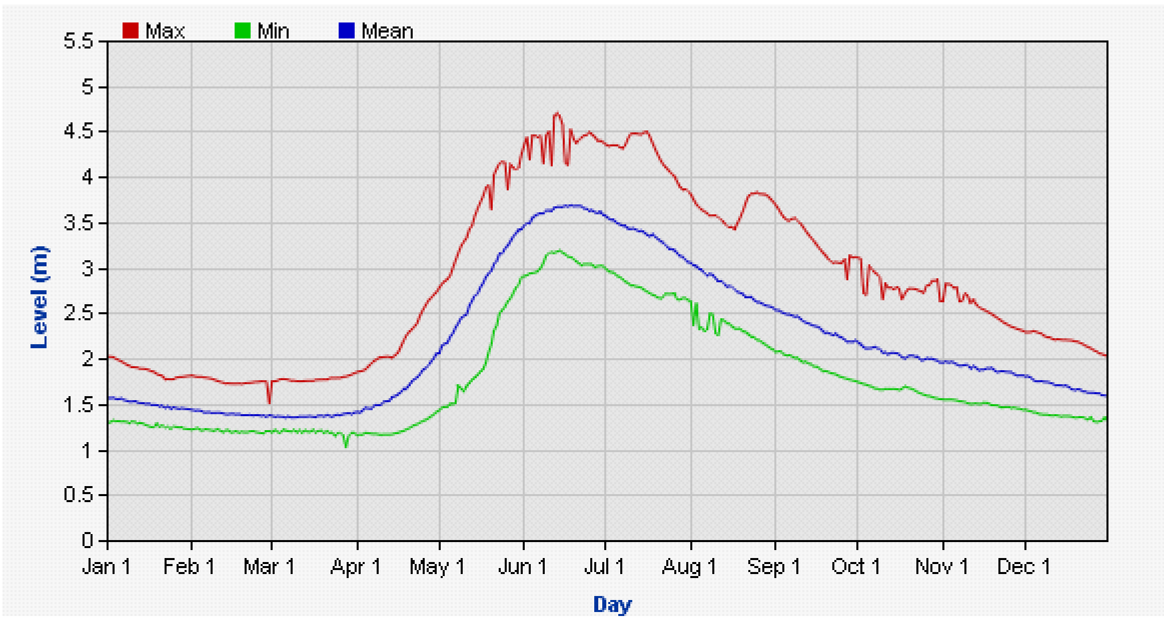

Figure 22. Mean, minimum, and maximum water levels at the outlet of Adams Lake into the Lower Adams River for the Jan 1949 to Dec 2003 period. Data retrieved from the Water Survey of Canada website (accessed 09 Mar 2005). URL of this page: http:///staflo/index _e.cfm?cname=level_daily.cfm

DIDSON Evaluation

Dates: 24 September 2004

Testing: None. Visual survey to identify potential sites only.

Fish Behaviour

Salmonid Species: Chinook salmon, coho salmon, Dolly Varden, kokanee, pink salmon, rainbow trout, sockeye salmon, trout fry <70mm in length (FishWizard – accessed 18 Jan 2005)

Migratory behaviour: Based on the estimated water velocity we believe sockeye salmon would actively migrate through this portion of the river.

Holding/Milling: Holding fish may become prevalent especially on the left bank as fish are spawning directly below and upstream of this area.

Resident Species: longnose dace, mountain whitefish, northern pikeminnow, redside shiner (FishWizard – accessed 18 Jan 2005).

Deployment Recommendations

Site: Directly below the downstream side of the highway bridge over the Lower Adams River (Fig. 21).

Bank: Left and Right bank

DIDSON Systems: Two (2) standard systems required.

Sonar settings: 1.8 MHz (high frequency): 10 m range window starting 1.5 m from transducer (left bank) and 1.8 MHz, 10 m range window starting 3m from transducer (right bank).

Aim: -8.5° relative to the water surface and perpendicular to the flow.

Sampling Methods: Temporal sampling, 10 $min \cdot hr^{-1}$ on both banks. Depth stratification would not be required for the right bank as one aim would cover the water column. The left bank although deeper should require only one aim as well.

Visual: Visual confirmation of species composition may be necessary as mixed species migration occurs through the area to the upper Adams. Visual confirmation can be done for both banks from walkway on the highway bridge.

Weirs: 8 m weir required on the right bank and 4 m long weir on left bank

Power supply: security: Site is near hydro power and may be available through BC Hydro for an installation fee. Otherwise solar panels and 12 V battery supply would be required. Site is highly visible to the public and would require 24 hour supervision.

Other: Large numbers of sockeye salmon spawn below this site in dominant cycle years. Consequently, escapement estimates produced at this site represent only that portion of the total escapement into the Adams River that moves through Adams Lake into the Upper Adams River.

3.10 Lower Stuart River

Location

Latitude: 54° 1.142' N
Longitude: 123° 33.738' W
Stream Order: 7
River length: 109.28 km (includes Stuart Lake)
Site: 20 m upstream at end of Sturgeon Point Rd (Fig. 23).
Site access: Public access to the right bank off Sturgeon Point Rd near the Stuart River Bison Game Farm.

Figure 23. Lower Stuart River at the end of Sturgeon Point Road. Picture taken from the right bank on 21 July 2004.

Site Description

Wetted width: 120 m
Depth: Not measured because it would require a boat and nearest launching ramps are in Fort St. James at the outlet from Stuart Lake or Finmar on the Nechako River.

Bottom type: Near shore area with grass, soft sand, silt, small gravel.
Water velocity: 0.5-1.0 m·s^{-1} estimated.
Discharge: Environment Canada maintains a recording staff gauge located near Fort St. James (Station 08JE001) with a period of record extending from Jan 1929 to Dec 2003. Discharge in the lower Stuart River peaks in July and declines from an average of 293 m3s-1 in July to 83.9 m3s-1 by Nov (Fig. 24). The hydrograph for the lower Stuart River exhibits little short-term variability, likely due to the dampening effect of the lake. Discharge measurements further downstream near Sturgeon Point Road or the confluence with the Nechako River may exhibit a greater range of variability because of flow from unregulated tributaries.
Flow pattern: Laminar flow mid-channel.

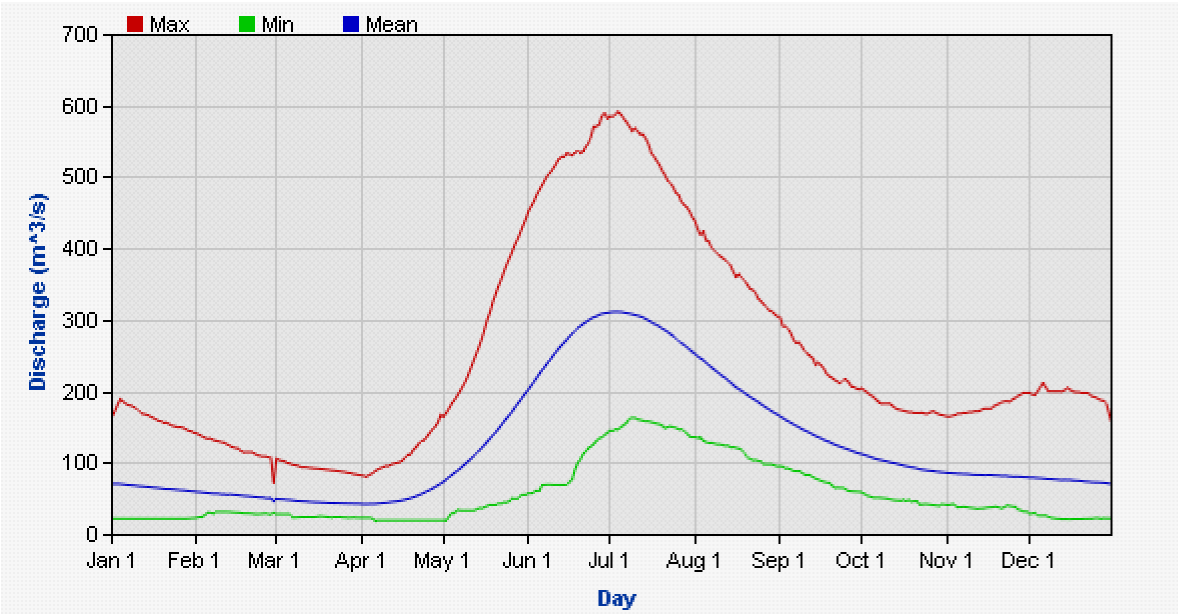

Figure 24. Historic minimum, maximum and average discharge in the Lower Stuart River near the outlet from Stuart Lake at Fort St. James for the Jan 1929 to Dec 2003 period. Data retrieved from the Water Survey of Canada website (accessed 09 Mar 2005).
URL: http:///staflo/index_e.cfm?cname=flow_daily.cfm

DIDSON Evaluation

Dates: 21 July 2004
Testing: None. Visual survey of potential sites only.

Fish Behaviour

Salmonid Species: Chinook salmon, Dolly Varden, kokanee, Rainbow trout, sockeye salmon (FishWizard – accessed 18 Jan 2005)
Migratory behaviour: Not observed, but given the relatively wide profile and low estimated water velocity at this site, there is a low probability that salmon will exhibit shore-oriented behaviour, i.e., migrating salmon could be anywhere in the river cross-section at this site.

Holding/Milling: Unknown. Requires on-site testing to confirm or refute.
Resident Species: bridgelip sucker, burbot, largescale sucker, longnose dace, longnose sucker, northern pikeminnow, peamouth chub, prickly sculpin, redside shiner, whitefish (FishWizard – accessed 18 Jan 2005)

Deployment Recommendations

Site: Not recommended as a DIDSON deployment site. Site may be better suited for operation with 200 kHz split-beam systems
Bank: One split-beam system on each bank; two (2) in total.
DIDSON Systems: Not recommended for DIDSON deployment. We believe that two (2) 200 kHz split-beam systems with 2° x 10° elliptical transducers may be effective for enumeration purposes at this site.
Sonar settings: Requires on-site experimentation with split-beam systems to determine appropriate ping rate, receiver gains and ranges.
Aim: Unknown. Requires on-site testing to determine appropriate aims and ensonification ranges.
Sampling Methods: Continuous sampling on both banks for the migration period.
Visual: Species identification would require some method of test fishing to apportion the acoustic estimate either with set nets or drift net.
Weirs: 20 m long weirs required for both banks to eliminate upstream migration in the shallow weeded shore areas and to ensure that fish passage occurs where detection has been optimized.
Power supply, security: Left bank would require a combination of solar panels and 12 V battery supply. Hydro power is possible for the right bank as power lines exist on Sturgeon Point Rd.
Other: At least one field season of on-site testing with the split-beam systems is needed to determine if the upstream flux of migrating fish can be effectively estimated at this site. A second site at Chandalar (about 5 km above the confluence with the Nechako River) has been suggested (R. Elson, DFO, Prince George, pers. comm.) but we were not able to assess this site as it is remote access by jetboat from Finmar on the Nechako River. The Sturgeon Point Road and Chandalar sites are believed to be below all known sockeye salmon and Chinook salmon spawning locations in the Stuart system (B. Nutton, DFO, Prince George, pers. comm.), but confirmation of this point is lacking at present.
The Lower Stuart River is a high priority for Chinook salmon stock assessment. Chinook salmon typically migrate further offshore in faster water velocities than sockeye salmon and they exhibit a protracted spawning migration in the Lower Stuart, starting as early as May-June and finishing in Nov. On-site testing is required to assess the migratory behaviour of Chinook salmon and determine how effectively and efficiently this species can be enumerated with split-beam systems.

3.11 Tachie River

Location

Latitude: 54° 54.26' N
Longitude: 124° 47.56' W
Stream Order: 7
River length: 25.9 km (including Trembleur Lake)
Site: Immediately upstream of a steel logging bridge over the Tachie River (Fig. 25).
Site access: Public access approximately 9 km along Tanzuil Road from the junction of Tanzuil Road and the Tachie Village Road.

Figure 25. Tachie River on the upstream side of the Tanzuil Road bridge. Picture taken near the left bank on 21 July 2004.

Site Description

Wetted width: 90 m
Depth: Multi channel to 2 m depth
Bottom type: Gravel, cobble, small boulder (<50 cm) and large boulder (>50 cm)
Water velocity: Estimated 1.0-2.0 $m \cdot s^{-1}$
Discharge:

Flow pattern: Some laminar flow along the right bank and in the centre, but large parts of the cross-section exhibit turbulent white-water in shallow areas (Fig. 25).

Cross-section: Multiple channels with shallow areas.

DIDSON Evaluation

Dates: 21 July 2004

Testing: Wet-testing not conducted. Visual survey of potential sites only.

Fish Behaviour

Salmonid Species: Chinook salmon, Dolly Varden, kokanee, rainbow trout, sockeye salmon (FishWizard – accessed 18 Jan 2005).

Migratory behaviour: Unknown. Not observed during visit.

Holding/Milling: Unknown.

Resident Species: mountain whitefish (FishWizard – accessed 18 Jan 2005).

Deployment Recommendations

Site: Not recommended as a site for DIDSON or split-beam acoustic deployment. The existence of the multiple channels, white-water sections and shallows make this area acoustically unfriendly as a result of high background noise levels in the water. Several DIDSON systems would be required to cover the possible areas of fish passage.

The only other possible site was 400 m upstream on the left bank where a narrow channel (20 m width) with high current velocities and high discharge is found. This site would only be suitable if the majority of migrating fish moved upstream through this chute. The need for extensive weirs to cover the shallow areas makes this an extremely challenging site for acoustic enumeration of migrating salmon. We do not recommend this site for acoustic deployment in the Tachie River.

4.0 DISCUSSION

The reliable detection and enumeration of salmon escapement hydroacoustically involves the recognition and solving of problems derived from three sources: (1) physical site characteristics, including bottom profile and water flow; (2) operating characteristics of the hydroacoustic system; and (3) fish behaviour and ecology. An important objective of our fieldwork during the 2004 sockeye salmon migration was to determine where the DIDSON acoustic imaging system could be used to estimate escapement in the Fraser River watershed. We investigated 22 sites on 10 tributary systems in which spawning escapement is estimated using MRPs and based on site criteria established for riverine applications of side-looking split-beam acoustic systems (Enzenhofer and Cronkite 2000) and we conclude that the DIDSON system could be used effectively to estimate escapement in six of these systems (Table 1; Fig. 1). Although additional work is needed on some systems to choose the most appropriate site for deployment (Mitchell River) or to confirm that fish do not exhibit unusual behaviours (e.g., milling, holding) that would degrade the performance of the DIDSON system (Mitchell River, Scotch Creek, Seymour River), in our judgement the additional time commitment for this work is low and would not materially delay the initial production of escapement estimates on these systems. Three of the 10 river systems examined (Lower Shuswap, Lower Stuart, Tachie – Table 1; Fig. 1) were not suitable for deployment of the DIDSON system. We suspect that acoustic counting of migrating fish in the Lower Stuart River could be accomplished with shore-based side-looking split-beam systems, but at least one season of testing would be required to confirm this hypothesis. Neither the Lower Shuswap nor the Tachie were amenable to acoustic counting because of the high probability of unusual fish behaviour and poor site characteristics, respectively.

A second important objective of our 2004 fieldwork was to determine the additional equipment needed (e.g., weirs, mounting system and platform) for effective operation of a DIDSON imaging system. In order to wet-test the DIDSON system, we designed and fabricated an adjustable pole mount and attachment bracket system that is both adaptable and effective (Enzenhofer and Cronkite 2005). The attachment bracket is adaptable to different deployment options including in the water, from a river bank or lake shore, and attached to the gunwale of a boat and the pole mount allows the user to add a second transducer, rotate a transducer 90 degrees, or to extend the pole mount an additional 1 m. Using a modified step-ladder as a stationary platform for the mount (Enzenhofer and Cronkite 2005), we found that this system is effective in that it provides a steady platform with precise pan-and-tilt capabilities for aiming the DIDSON system and the ladder can be used as a visual counting tower. At most sites except Henry`s Bridge on the Chilko River, small lengths (5-10 m) of weir are needed on the bank from which the DIDSON system is deployed to move migrating fish off the bank and through the ensonified area and to prevent fish from moving undetected behind the transducer. The majority of sites investigated for DIDSON deployment are remote from power lines so we also assessed the feasibility of using solar panels coupled to a battery bank as a primary power source, with a 2 kW gasoline generator as an alternate power supply. At most sites, the vegetation is sufficiently open to permit

Table 1. Summary of recommendations concerning the deployment of the DIDSON acoustic imaging system for sockeye salmon escapement estimation in the Fraser River watershed.

River	DIDSON Deployment	Site	Number of systems	Bank	Additional equipment
Chilko	Yes	Henry's Bridge	2	Left and right	• Secure shed for topside equipment • Solar panels and battery bank for only power option. • Modified step-ladder for transducer deployment
Chilko	No	Lingfield Creek			
Horsefly	Yes	MRP tagging site near mouth off Mitchell Bay Road	1	Left	• Secure shed for topside equipment • Modified step-ladder for deployment and visual species composition • 6 m of weir off left bank • Solar panels and battery bank for power; Power line nearby so connection possible if site used permanently.
Mitchell	Yes	4 potential sites below MRP tag site	1	Left or Right[A]	• Bear-proof and wind-proof shed • Modified step-ladder for deployment and visual species composition • 5-10 m of weir depending on site • Remote site, solar panels and battery bank for power only option
Stellako[B]					
Seymour	Yes	Top end of airstrip	1	Left	• Secure shed for topside equipment • Modified step-ladder for deployment and visual species composition • Solar panels and battery bank for power; Power line in provincial park surrounding

River	DIDSON Deployment	Site	Number of systems	Bank	Additional equipment
					site may be available for connection if site use is frequent • 5 m of weir on left bank
Scotch	Yes	Near mouth on Shuswap Lake	1	Right or left	• Secure shed for topside equipment • Modified step-ladder for deployment and visual species composition • Solar panels and battery bank for power • 5 m of weir of deployment bank
Lower Shuswap	No	Six potential sites off of Hwy 97A			
Lower Adams	Yes[C]	Squilax-Anglemont road bridge over Adams River	2	Left and right	• Secure shed for topside equipment • 8 m weir on right and 4 m weir on left • Power lines crossing river at the bridge • Modified step-ladder for deployment
Stuart	Yes[D]	End of Sturgeon Point road Chandalar?	2	Left and right	• Not clear; additional investigation necessary to determine requirements for split-beam operation
Tachie	No				

A – Bank of deployment depends on site chosen.
B – Stellako River site was investigated for calibration purposes only (see Holmes et al. 2005 for details).
C – Deployment is dependent on impact of spawning fish in adjacent areas and the rationale for deploying.
D - Site is not suitable for a DIDSON system but may be a suitable for a split-beam system. Further work at this site and Chandalar, near the confluence with the Nechako River, is needed to make a determination..

adequate access for solar panels and we found that three solar panels producing 115 W of power connected to three 12-V deep cycle batteries were adequate for our purposes, although this combination left little reserve power for overcast days. Therefore, we recommend the use of four (4) 85 W solar panels coupled to a bank of four (4) 6-V deep cycle batteries serially connected to produce 12-V to meet the power requirements of the DIDSON system (30 W) and the topside computer (90-110 W).

Conventional side-looking split-beam acoustic systems are unable to reliably detect fish in the near-field region of the beam or fish close to boundaries created by the surface or bottom. The near-field detection problem occurs because the transducer electronics do not have sufficient time to switch from sending a pulse to listening for echoes when a fish target is very close to the transducer (MacLennan and Simmonds 1992). Echoes reflecting from the bottom or surface back to the transducer are typically much stronger than echoes from fish near these boundaries. In contrast, the DIDSON system is not hindered by these detection problems. The near-field of the system is 0.42 m and bottom features do not obscure migrating fish. Furthermore, the system software has a background subtraction tool that allows the user to remove static portions of the acoustic image, leaving only moving targets (Sound Metrics 2004). Based on these operating characteristics, we conclude that the DIDSON system is more adaptable and amenable to a variety of site types for deployment for salmon escapement estimation.

The DIDSON technology has two limitations which are important to the process of estimating salmon escapement. First, the vertical position of a fish in the ensonified area with respect to the water surface or distance from the bottom cannot be determine. This constraint stems from the transducer design, which consists of a horizontal array of single-beam elements that cannot measure target angle in the beam (Belcher et al. 2001). The position of a target in the ensonified volume at a given time is known only with respect to horizontal (upstream-downstream) location due to the parallel horizontal arrangement of beam elements and range from the transducer. Recognizing the potential for blind zones through which fish could swim past the system undetected, our aiming protocol emphasized an approach that compares the capability of the DIDSON system to our objective of detecting all fish in a specified volume of water through manual on-site validation of the ensonified volume with a salmon-sized target. This protocol required that we deliberately aim the DIDSON system at an oblique angle into the bottom to maximize near-bottom detection of fish and minimize blind zones. Conventional split-beam systems use a similar approach but are aimed parallel to the bottom in riverine applications because these systems are less tolerant of interference or distortion of the fish signal by the bottom boundary (Mulligan, 2000). We were able to aim this way because the DIDSON system does not require phase measurements, which are sensitive to noise and boundary effects, to determine target position in the beam, in contrast to a split-beam system. Future deployment of the DIDSON system for salmon escapement estimation in the Fraser River will require that field crews carefully set the aim and manually check beam coverage with suitable targets to ensure that the system ensonifies from the water column from bottom to the surface so that there are no blind zones through which fish could swim by the acoustic site undetected. When this protocol is followed during the deployment and aiming of the DIDSON system, the resulting data will be both correct and accurate (see Holmes et al. 2005).

The second limitation of the DIDSON technology is the fact that the maximum range of detection is 15 m in high frequency mode and 40 m in low frequency mode (Belcher et al. 2001; Sound Metrics Corporation 2004). We expect that the majority of DIDSON applications in the Fraser River watershed will attempt to use the high frequency mode, but even the low frequency mode will provide better acoustic target recognition and resolution than a split-beam system operating at the same site. Successful enumeration of migrating fish with a DIDSON system depends on the migrating fish exhibiting shore-oriented behaviour, i.e., within 15-40 m of either bank, or the installation of structures such as weirs in the river to constrict the migration range of fish to the ensonified water volume. Shore-oriented migratory behaviour is typically observed in sockeye salmon migrating through high velocity environments (Woodey 1984) such as Henry's Bridge on the Chilko River or the mainstem of the Fraser River at Qualark (Enzenhofer and Cronkite 2000). Based on our results, we conclude that when migrating fish are shore-oriented or the migration range is restricted by weirs and fish can be ensonified by a DIDSON acoustic imaging system using the high frequency mode, the resulting count data are accurate and exhibit very high precision among different observers doing the manual counting (Holmes et al. 2005).

Other factors such as background noise, boundary conditions, aeration, water temperature and turbidity also affect the fish detection ability of sonar systems (MacLennan and Simmonds, 1992), including the DIDSON. The effect of water temperature and turbidity on signal attenuation and scattering, respectively, are negligible at the ranges covered by the DIDSON system compared to the effect of TVG on the signal and the uncertainty concerning the TVG function that should be applied to an imaging system (20 log R, 40 log R or some other function). However, of more importance for sonar estimates of salmon escapement is the effect of turbulence and air entrainment since high velocity, turbulent environments tend to elicit the shore-oriented migratory behaviour in salmon required for successful enumeration. The Henry's Bridge site on the Chilko River is turbulent, but we were able to use the DIDSON system successfully because sockeye salmon migrate through less turbulent areas along the banks. Although the DIDSON system is able to produce images of adult fish in highly turbulent environments(J. Holmes, pers. obs., near a fishwheel at Siska on the mainstem Fraser, July 2004), turbulence and air entrainment adversely affect the range over which detection occurs and the probability of detecting smaller fish, particularly salmon smolts or other small-bodied species.

Although we tested the DIDSON system at a variety of sites in different systems, we did not observe high densities of migrating fish in 2004. When the density of fish in the ensonified volume exceeds some threshold, saturation of the beams will occur because fish in the same beam elements at different elevations cannot be distinguished as separate targets. The onset of saturation from high fish density would likely be observable in the display data as overlapping and crossing of fish paths. The density threshold at which this bias begins to occur is not easily defined for the DIDSON system because saturation depends on several factors including the range and volume over which the density persists. Our DIDSON counts approached 1000 fish event-1 and are probably well below the limit at which saturation begins to bias the count data.

Saturation of a split-beam system occurs when multiple targets are in the pulse volume that is defined by the pulse length and the effective beam cross section at a given range. Enzenhofer et al. (1998) found that their acoustic counts of migrating salmon were negatively biased when fish density (measured as the number of fish per linear m of flashboard per counting interval) in the ensonified volume was > 408 fish·m^{-1}·hr^{-1} (corresponding to passage rates > 2000 fish·hr^{-1}). The onset of saturation was characterized by an inability to track individual fish through the acoustic beam correctly when echo density within the beam was sufficiently high, as would be the case when multiple fish passed through the beam at the same range at once. We expect that the performance of the DIDSON system with manual counting will equal or exceed that of the split-beam system tested by Enzenhofer et al. (1998), but we cannot ascertain the upper threshold at which the bias due to the inability to distinguish targets at different elevations in the same beams will become apparent. Even with this limitation, estimates of fish movement (vector direction and velocity) and net upstream flux (upstream – downstream fish) should still be possible with the DIDSON system when fish densities exceed those that we observed on the Stellako River. The DIDSON transducer can be rotated 90° (see Enzenhofer and Cronkite, 2005) during deployment (aligning the transducer vertically rather than horizontally), allowing the user to validate the position of fish in the water column, i.e., elevation, while keeping range data in common during both horizontal and vertical alignments.

The DIDSON acoustic imaging system has a software package that controls the collection and playback of files, including tools designed to automate the counting fish targets in real-time or during post-processing. Based on our fieldwork in 2004 and earlier collaboration with staff from the Alaska Department of Fish and Game, we found that these tools are adequate for automated counting only in very simple situations where the density of fish targets is low and all fish are actively migrating in one direction. At present, manual counting and estimation of the upstream flux of migrating salmon is a the most viable procedure with the DIDSON system when sockeye salmon in a mixed-species assemblage must be differentiated from other salmon species, when resident non-migratory species or milling fish are present, or debris or other unwanted targets are observed. However, the process is tedious and may be prone to considerable counting error, especially when fish densities are very high. Thus, an important goal of the DIDSON research program is the development of software for automated data collection and counting of fish targets to produce daily net upstream escapement estimates. Ultimately, this software will mimic the integration of the human eye and brain in detecting, tracking and counting fish moving upstream.

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APPENDIX 1

Common Name	Scientific Name
sockeye salmon	*Oncorhynchus nerka*
kokanee	*Oncorhynchus nerka*
Chinook salmon	*Oncorhynchus tshawytscha*
coho salmon	*Oncorhynchus kisutch*
pink salmon	*Oncorhynchus gorbuscha*
rainbow trout	*Oncorhynchus mykiss*
steelhead	*Oncorhynchus mykiss*
cutthroat trout	*Oncorhynchus clarki*
bull trout	*Salvelinus confluentus*
Dolly Varden	*Salvelinus malma*
lake trout	*Salvelinus namaycush*
mountain whitefish	*Prosopium williamsoni*
burbot	*Lota lota*
northern pikeminnow	*Ptycheilus oregonensis*
longnose dace	*Rhinichthys cataractae*
redside shiner	*Richardsonius balteatus*
peamouth chub	*Mylocheilus caurinus*
prickly sculpin	*Cottus asper*
suckers	*Catostomus sp.*
largescale sucker	*Catostomus macrocheilus*
bridgelip sucker	*Catostomus columbianus*
longnose sucker	*Catostomus catostomus*