Upper Fraser Fisheries Conservation Alliance

System-wide DIDSON Estimation of Sockeye Salmon Escapement in the Quesnel River System

Project # 07350-35/FSWP 09 D SIFM 93

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Prepared for:

Fraser Salmon and Watersheds Program

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Upper Fraser Fisheries Conservation Alliance
&
Department of Fisheries and Oceans

Abstract

The Quesnel River is a major producer of sockeye salmon (*Oncorhynchus nerka*) in the Fraser River watershed, particularly on its dominant and sub-dominant cycle years. The Quesnel Lake sockeye population is now classified as the Quesnel Lake sockeye Conservation Unit (CU) via implementation of Canada's Policy for Conservation of Wild Pacific Salmon (DFO, 2005), more commonly called the Wild Salmon Policy (WSP). Under the Pacific Salmon Treaty, the Quesnel River sockeye population is managed as part of the Mid-Summer sockeye aggregate, due to its return migration timing in marine approach areas and the Fraser River.

Successful implementation of the Quesnel River Dual-frequency Identification SONAR (DIDSON) project addresses the need for a total escapement estimate for the Quesnel Lake sockeye CU, and is one of the key Objectives for this project. The DIDSON system is able to produce a video image intuitively similar to an underwater camera, but has the benefit of being able to record fish movement and behaviour in turbid and dark water. The DIDSON system has been successfully deployed in the Fraser River and major tributaries for the purpose of sockeye stock assessment (enumeration) since 2005.

Project Objectives as outlined in the proposal, and used to guide the completion of the project were as follows:

1. DIDSON site selection: Identification and utilization of the best possible DIDSON field site for producing a total Quesnel Lake system sockeye salmon escapement estimate in 2009.
2. Installation and operation of 2 DIDSON systems (one on each river bank, directly opposite) for the entire sockeye salmon migration period, including on-site visual counts.
3. Generation of a total 2009 Quesnel Lake system (Quesnel Lake sockeye Conservation Unit) sockeye salmon escapement estimate, and comparison to the upstream estimates of spawning escapement.
4. Establishment of a capacity-sharing relationship between the UFFCA, NSTC and DFO for providing experience to First Nations fisheries technicians on all aspects of a DIDSON project - from concept to completion phases.

The Quesnel River DIDSON project was located in the Quesnel River watershed in the BC Interior and the upper portion of the Fraser watershed (Fig 1). As a feasibility study, the Quesnel River DIDSON project met all Project Objectives, and was a successful collaborative partnership between the UFFCA, NSTC and DFO from an administrative and operational perspective.

Sockeye salmon migration past the Quesnel River DIDSON project site was observed to have begun on August 8 and continued through September 28. The 2009 Quesnel River DIDSON sockeye salmon escapement estimate into the Quesnel System was 157,541 ± 14,477 (± 9.5%). This result is comparable to DFO's *Near Final Estimate* of sockeye escapement to the Quesnel Lake area of 149,467 (DFO website, 2010).

All project partners indicated the experience resulting from the implementation and completion of this project has provided an excellent foundation from which to base future technical project partnerships.

Due to the non-technical nature of the fourth objective of this project (establishment of a collaborative relationship between Project Partners), the body of the report was formatted as a description of the project, project objectives, background information, and a summary of the methods, results and discussion. The comprehensive technical methods, results and discussion summarized in the body of this report are supported by a stand-alone technical report included as Appendix 1 of this report.

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Introduction

The Quesnel River is a major producer of sockeye salmon (*Oncorhynchus nerka*) in the Fraser River watershed, particularly on its dominant and sub-dominant cycle years. The Quesnel Lake sockeye salmon population is now classified as the Quesnel Lake sockeye Conservation Unit via implementation of Canada's Policy for Conservation of Wild Pacific Salmon (DFO, 2005), more commonly called the Wild Salmon Policy (WSP). Under the Pacific Salmon Treaty, the Quesnel River sockeye population is managed as part of the Mid-Summer sockeye aggregate, due to its return migration timing in marine approach area and the Fraser River.

In the past, the Quesnel River sockeye population has supported First Nations and Commercial fisheries - and more recently Recreational fisheries as well - when return abundance is sufficient. Quesnel River sockeye are subject to intensive pre-season planning, in-season management, and post-season accounting in the form of spawning ground enumeration estimates.

The Quesnel River sockeye population consists of three major spawning area components: the Horsefly River, the Mitchell River and Quesnel Lake "miscellaneous" spawners (Figure 1). In order to estimate the total spawner return to the Quesnel River, it is necessary to account for all the above components. Past enumeration efforts have relied on a combination of low-precision and high-precision estimates of the various major spawning area components to generate the total spawning return estimate. In recent years, funding pressures and overall project costs have reached a point where it has not been possible for DFO to field a complete enumeration program on all three spawning area components on an annual basis. The result of this funding pressure has resulted in both lower accuracy and lower precision in estimation of the total sockeye spawner return to the Quesnel River.

In addition to funding pressures for spawner enumeration, several years of high spawner escapement followed by several years of lower-than-expected sockeye returns to the Quesnel River (including dominant and sub-dominant years) underscore the need for accurate spawner return estimation to this system.

Wild Salmon Policy implementation is a priority focus of the Upper Fraser Fisheries Conservation Alliance (UFFCA) and the First Nations participating in the Alliance. One of the components of implementation of the WSP is the assessment of status of Conservation Units. By definition, Conservation Units (CUs) *are groups of wild salmon sufficiently isolated from other groups that if extirpated are very unlikely to re-colonize naturally within an acceptable time frame* (DFO, 2005). In order to assess the status of a Conservation Unit an overall escapement estimate and assessment of the CU spawner distribution must be completed on an on-going basis.

Successful implementation of the Quesnel River DIDSON project addresses the need for a total escapement estimate for the Quesnel Lake sockeye CU, and is one of the key Objectives for this project.

The utilization of DIDSON technology in salmon stock assessment is a relatively new technology with a reasonably intuitive display and operation which, when correctly deployed, may offer a cost-effective solution for escapement enumeration in specific salmon spawning systems. The DIDSON system is able to produce a video image intuitively similar to an underwater camera, but has the benefit of being able to record fish movement and behaviour in turbid and dark water. The DIDSON system has been successfully deployed in the Fraser River and major tributaries for the purpose of sockeye stock assessment (enumeration) since 2005. The intent of this project was to implement DIDSON technology in the Quesnel River system, a system identified as having the characteristics necessary for a high chance of successful deployment.

Due to the non-technical nature of the fourth objective of this project (establishment of a collaborative relationship between Project Partners), the body of this report was formatted as a description of the project, project objectives, background information, and a summary of the methods, results and discussion. The comprehensive technical methods, results and discussion summarized in the body of this report are supported by a stand-alone technical report included as Appendix 1 of this report.

Description of Project

Project Objectives

Project Objectives as outlined in the proposal and used to guide the completion of the project were as follows.

1. DIDSON site selection: Identification and utilization of the best possible DIDSON field site for producing a total Quesnel Lake system sockeye salmon escapement estimate in 2009.
2. Installation and operation of 2 DIDSON systems (one on each river bank, directly opposite) for the entire sockeye salmon migration period, including on-site visual counts.
3. Generation of a total 2009 Quesnel Lake system (Quesnel Lake sockeye Conservation Unit) sockeye salmon escapement estimate, and comparison to the upstream estimates of spawning escapement.
4. Establishment of a capacity-sharing relationship between the UFFCA, NSTC and DFO for providing experience to First Nations fisheries technicians on all aspects of a DIDSON project - from concept to completion phases.

Project Location

The Quesnel River DIDSON project was located in the Quesnel River watershed in the BC Interior and the upper portion of the Fraser watershed (Fig 1).

The Quesnel River begins at the outlet of Quesnel Lake and terminates at its confluence with the Fraser River in the City of Quesnel. The Quesnel sockeye salmon population migrates up the Quesnel River from the Fraser River to Quesnel Lake, and spawns in three component areas: Horsefly River and tributaries, Mitchell River and tributaries, and Quesnel Lake shoals and various smaller tributaries to the lake (Figs 1 & 2).

Complete sockeye spawner enumeration of the Quesnel Lake CU by DIDSON required a general field site location on the Quesnel River as far upstream as possible but downstream of Quesnel Lake, and in an area that would not disturb or be impeded by Chinook spawners (Figs 1 & 2). As described in methods detailed in Cronkite et al (2005) and Enzenhofer and Cronkite (2000), successful DIDSON sockeye spawner enumeration takes place downstream of spawning areas, and preferably in areas free of milling or downstream movement. The collective Project Partner knowledge of the general spawning behaviour of Quesnel sockeye salmon guided the eventual site selection of this project.

Specific site selection methods and final field site location are detailed in the *Materials & Methods* Section.

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decompressor
are needed to see this picture.

Figure 1. Quesnel River DIDSON site in relation to the major spawning areas of the Quesnel Lake Sockeye Conservation Unit, and the Fraser Watershed (base map from *Holmes et al, 2005).*
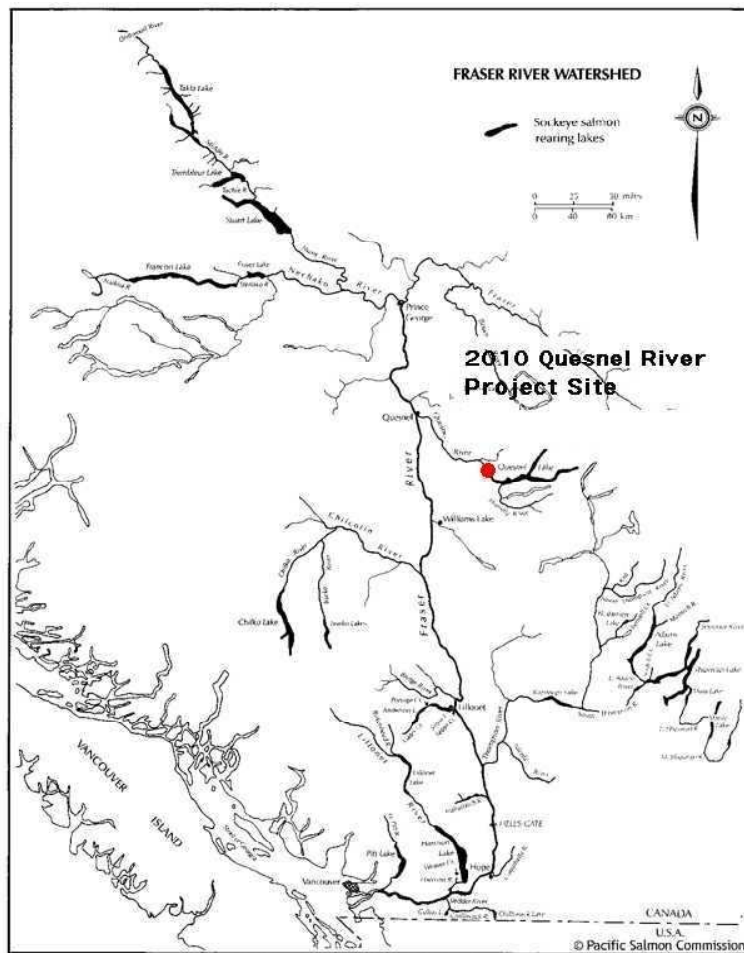
Figure 2. Quesnel DIDSON project in relation to the Fraser River watershed. (Figure from Pacific Salmon Commission website: www.psc.org)

Figure 3. Quesnel River Sockeye spawning area terrain map (Figure from Google Maps)
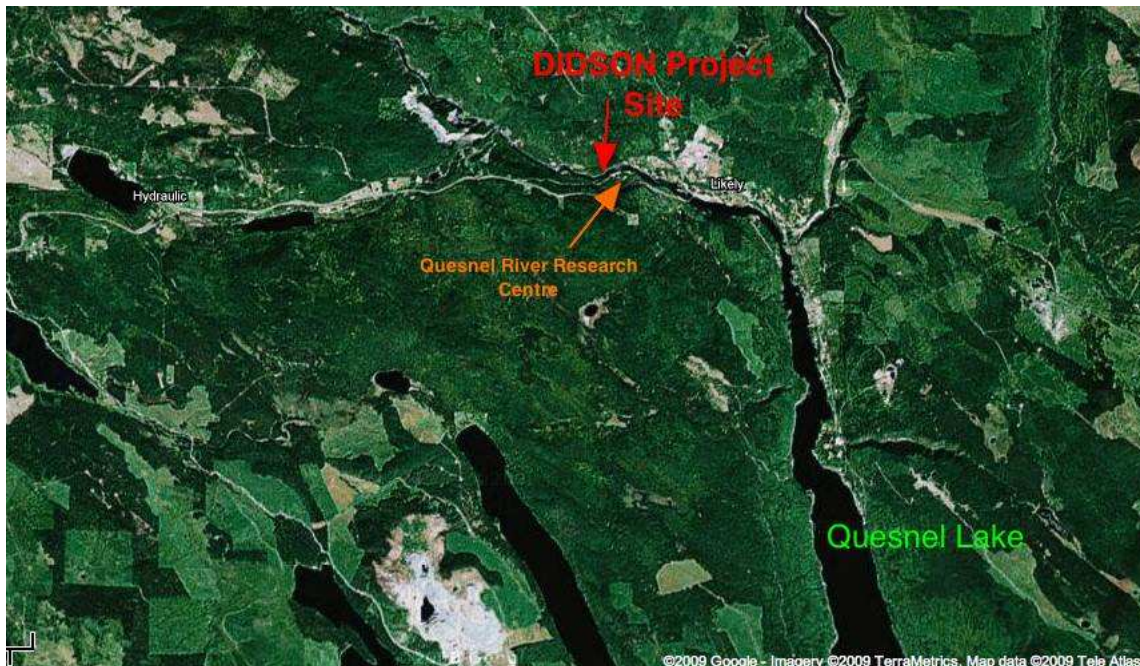
Figure 4. Quesnel River DIDSON site (base figure from Google Earth).

Materials & Methods

Please refer to Appendix 1 for a complete technical description of Materials and Methods employed for the field and analytical components of this project.

Project Planning and Initiation

Although the UFFCA was the lead proponent on this project, one of the overall project objectives was to establish a collaborative and capacity building partnership between the UFFCA, DFO and the Northern Shuswap Tribal Council Fisheries Program. In recognition of this objective, all components of the Quesnel River DIDSON project were completed as a three-way partnership: proposal development, project planning and implementation, reporting of results and sharing of experience and lessons learned.

The continual improvement and successful implementation of DIDSON projects in the Horsefly River (Cronkite et al, 2006) and Chilko River (Stock Assessment

DFO, Kamloops, BC, unpublished data, 2008) resulted in discussions that took place in 2008 between the UFFCA, DFO and NSTC; discussions which explored the possibility of a Quesnel River system-wide sockeye salmon enumeration using DIDSON technology.

In Fall 2008, DFO and the NSTC used the opportunity provided by aerial Quesnel River chinook enumeration to video record the Quesnel River from downstream of the Cariboo River (major tributary to Quesnel River) to Quesnel Lake. This video file, combined with mapping and local knowledge of the Quesnel River provided the initial knowledge base from which to identify several potential field sites for DIDSON deployment subsequent to funding confirmation for this project.

All project partners were involved in project planning and implementation, to the extent possible, once funding for the 2009 project was confirmed (June 2009). The project began with a meeting between the UFFCA, DFO and NSTC in Kamloops to coordinate planning and project implementation. Numerous conference calls and emailing followed the meeting, from which the project completion plan was developed.

Site Selection

Site selection is critical for successful deployment of the DIDSON system, and this component was the first Project Objective.

Several criteria were used to evaluate potential field sites in the Quesnel River prior to final site selection:
- Crew and equipment safety
- Field site logistics

- Suitable hydroacoustic profile – site evaluation followed the general criteria outlined in Enzenhofer and Cronkite (2000) and Holmes et al (2006)
- Suitable sockeye and chinook behaviour at potential sites
- Choosing a location conducive to meeting all of the above criteria while achieving the objective of enumerating the entire sockeye population for the Quesnel Lake sockeye population

The UFFCA Stock Management Biologist and the DFO Project Biologist spent two days in the field (late July and early August 2009) conducting field reconnaissance in order to complete final site selection prior to initiating the field portion of the project. Using the site selection criteria previously detailed, a DIDSON site on River Left (Left Bank) was established approximately 200 metres downstream of the UNBC Quesnel River Research Centre. Landowner access permission was obtained for site establishment on the River Right (Right Bank) side of the river, approximately 5 metres downstream from being directly opposite of the River Left (Left Bank) site (Fig 5).

The logistics of the DIDSON site were exceptional, and better than hoped, due close proximity to the QRRC and the landowner, as well as suitable salmon behaviour and hydroacoustic profile criteria. Crew safety, ease of equipment transfer, dedicated power sources for both DIDSON systems and minimal site preparation all factored into the success of the project.

For complete Methods of site selection please refer to Appendix 1.

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decompressor
are needed to see this picture.

Figure 5. Aerial view of the Quesnel River DIDSON site.

Results

For complete description of the project Results please refer to Appendix 1.

The following is a summary of key results from the project.

Quesnel Lake CU Sockeye Salmon Escapement Estimate

The 2009 Quesnel River DIDSON sockeye salmon escapement estimate into the Quesnel System was 157,541 ± 14,477 (± 9.5%).

Sockeye salmon migration past the Quesnel River DIDSON project site was observed to have begun on August 8 and continued through September 28. The daily escapement plot (Figure 6) reveals a maximum daily net upstream escapement estimate of 8,262 sockeye salmon on August 30, 2009. The halfway point in the 2009 run, when 50% of the total estimate had passed the Quesnel River DIDSON site, occurred on September 1 (Figure 7).
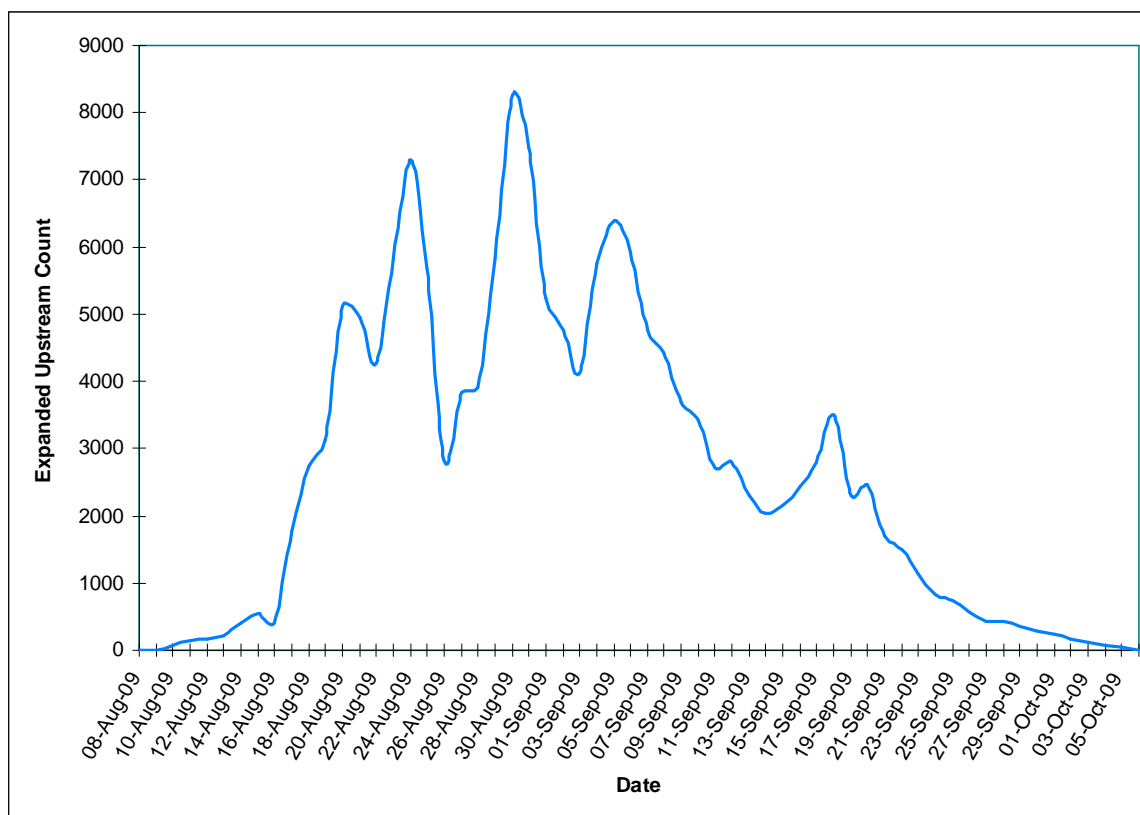
Figure 6. Daily net upstream of sockeye salmon migration past the DIDSON site on the Quesnel River in 2009 (right and left-banks combined).
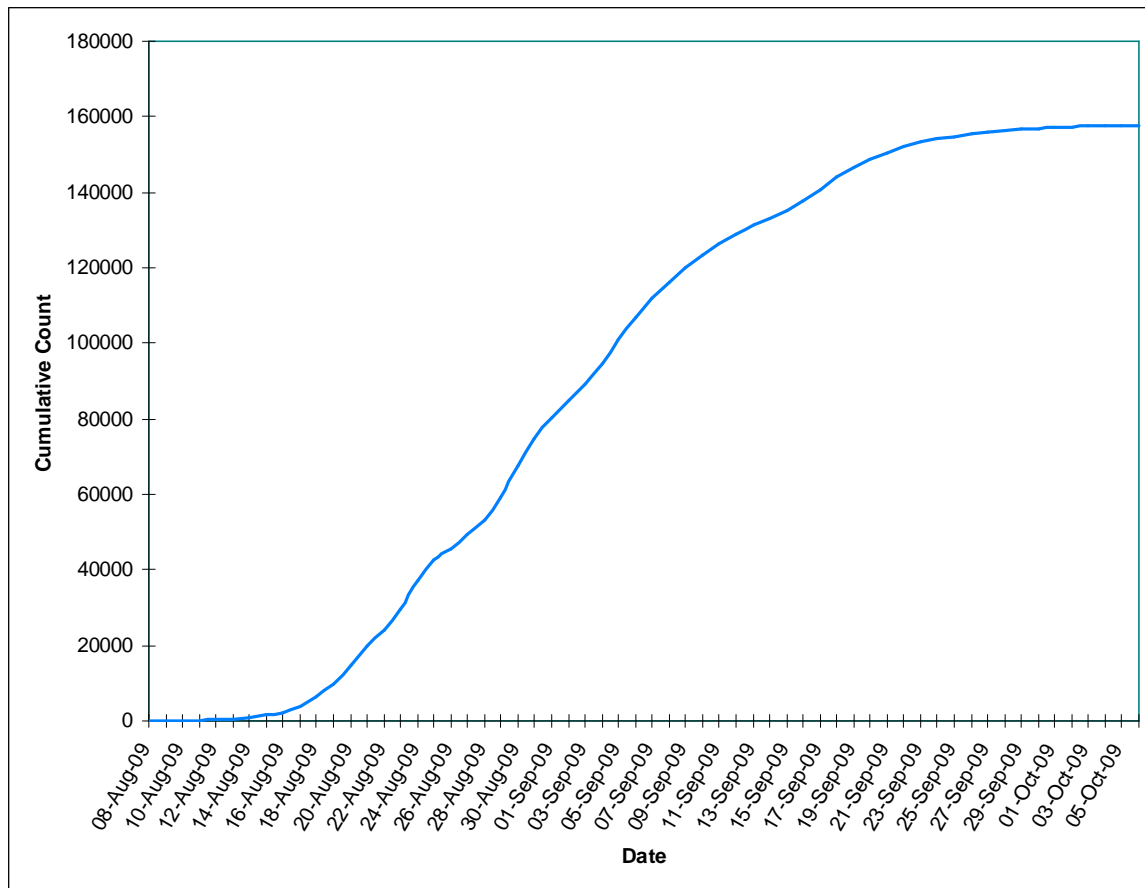
Figure 7. Cumulative daily net upstream of sockeye salmon migration past the DIDSON site on the Quesnel River in 2009 (right and left-banks combined).

A considerable portion of the sockeye migration (59%) occurred during daytime hours (Figure 8), with the majority of sockeye (91%) traveling along the right-bank (Figure 9). The number of downstream migrating salmon was assessed throughout the program and was negligible.

Figure 8. Total hourly sockeye migration past the DIDSON site on the Quesnel River in 2009.
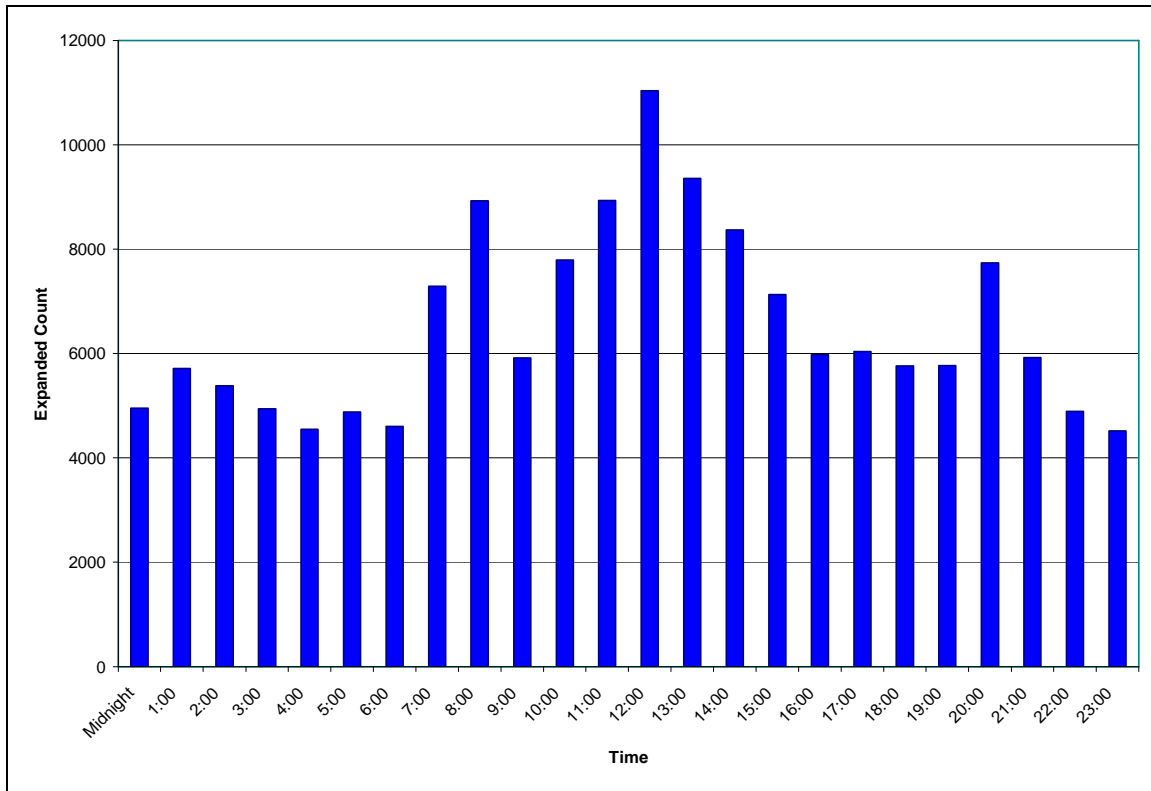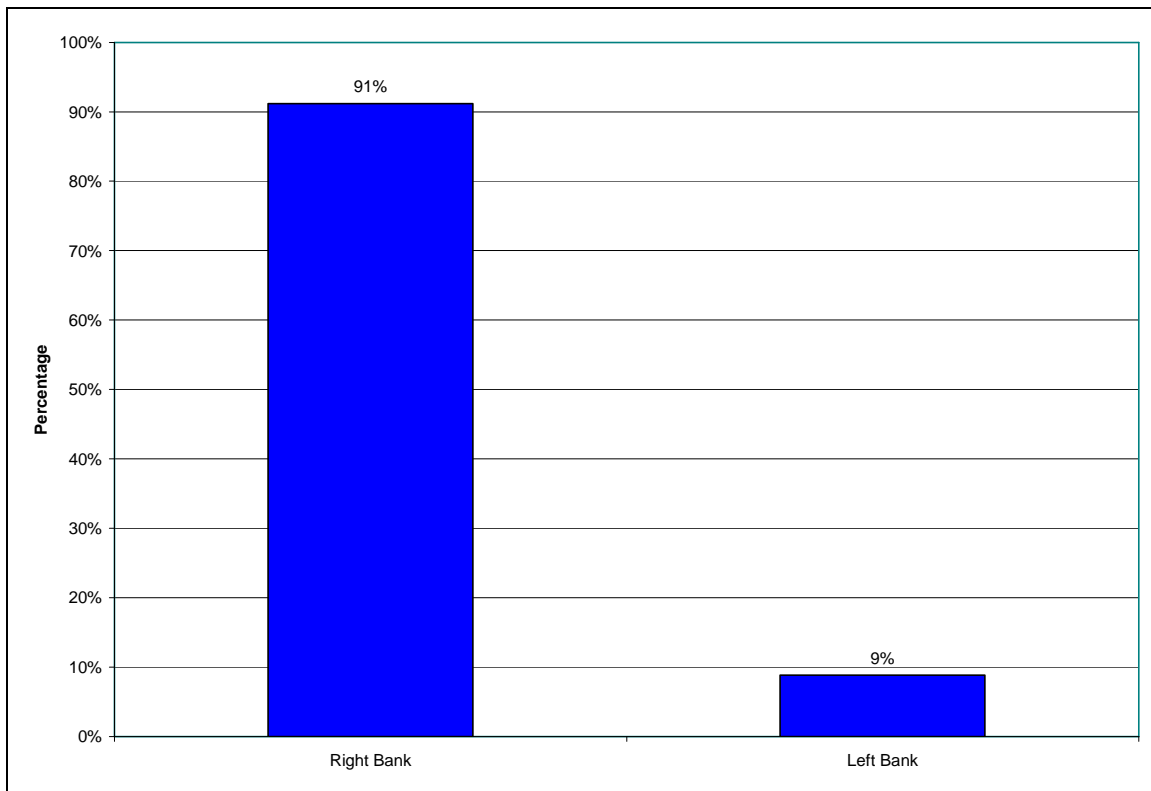
Figure 9. Total migration of sockeye counted past the right and left-bank DIDSON units on the Quesnel River in 2009.

Discussion and Recommendations

As a feasibility study, the Quesnel River DIDSON project met all Project Objectives, and was a successful collaborative partnership between the UFFCA, NSTC and DFO from an administrative and operational perspective.

Objective 1: DIDSON site selection: Identification and utilization of the best possible DIDSON field site for producing a total Quesnel Lake system sockeye salmon escapement estimate in 2009.

In general the DIDSON site chosen for the project was excellent according to the criteria outlined previously.   Decreasing river water volume throughout the season proved to be challenging on both sides of the river, but not insurmountable. Evaluation and feedback by the project field crew and project partners near the end of the field portion of the project identified the recommendation to move the River Right (right bank) DIDSON site downstream approximately 10 – 15 metres for future projects.

As the river dropped to lower volumes in 2009, the hydroacoustic profile of the river approximately 10 metres downstream of the original right bank site appeared to be superior to the site used in 2009. Should project funding become available for 2010, the right bank site will be located at this downstream site.

The overall width of the Quesnel River (55 metres wetted width) at the project site did not permit full ensonification of the entire river by the two DIDSON systems. However, the hydrology of the river (high velocity mid-channel flows) forced sockeye migration to near-shore migration and orientation in a similar manner observed in the Chilko River DIDSON program. Periodic verification by increasing the operational DIDSON ensonification window from 10 metres to 20

metres with the right bank DIDSON confirmed near shore migration patterns. Therefore this site is considered viable for the methods employed in this project.

Objective 2:   Installation and Operation of two DIDSON systems on opposite river banks for the duration of sockeye salmon migration.

The project met this Objective.

A long-range DIDSON unit was installed on the Left bank, with an operational window of 20 metres. A second short-range DIDSON was installed and operated on the Right bank, with an operational window of 10 metres. Periodic checks using a 20 metre window to confirm near-shore migration were conducted with the Right bank DIDSON. Visual observation platforms were constructed with partial weirs on both banks in order to verify DIDSON counts with visual observation.

Both DIDSON systems – including observation decks and partial weirs - were installed to allow DIDSON mobility into the channel as water volumes dropped through the migration period.

The DIDSON systems were operational from August 8th through to September 28th. Although a relatively low number of sockeye were still migrating past the site in the final few days of the field project, the number had decreased to the point that continuing the field project was determined to be unnecessary (Figure 6).

Objective 3: Generation of a total 2009 Quesnel Lake system (Quesnel Lake sockeye Conservation Unit) sockeye salmon escapement estimate, and comparison to the upstream estimates of spawning escapement.

The project met this Objective, but not with the original intent of comparison to upstream estimates.

The 2009 Quesnel River DIDSON sockeye salmon escapement estimate into the Quesnel System (Quesnel Lake and tributaries) was 157,541 ± 14,477 (± 9.5%). This result is comparable to DFO's *Near Final Estimate* of sockeye escapement to the Quesnel Lake area of 149,467 (DFO, 2010).

However, the project was originally conceived and implemented as a full estimation of sockeye salmon escapement to the Quesnel Lake system, based on a final comparison of the Quesnel River DIDSON estimate to the sum of high accuracy and precision estimates in two of the three spawning components in the Quesnel Lake area – the Horsefly and Mitchell Rivers – and a low precision estimate of the Quesnel Lake spawner component. High precision estimates are not possible for the Quesnel Lake shoal spawning and small tributaries.

Although a high precision estimate was completed by DFO in the Mitchell River in 2009, it was a first-time DIDSON estimate of that system, and unverified by a mark and recapture comparison. The Horsefly River mark and recapture project was cancelled in the summer of 2009 due to the much lower than expected return of Horsefly sockeye, and DFO completed a low precision visual estimate of the river escapement instead. Therefore a comparison of the Quesnel River DIDSON project to a combination of two high precision component estimates (in the Horsefly and Mitchell Rivers) and the low precision estimate of the Quesnel Lake shoal spawning and small tributaries component was not possible for this project.

For these reasons the Project Partners agreed the Quesnel River DIDSON project would be considered a feasibility study rather than a full escapement estimate of the Quesnel Lake sockeye CU.

It is recommended that a future Quesnel River DIDSON project be compared to the sum of high precision estimates in the Mitchell and Horsefly Rivers, as well as a low precision visual estimate of the Quesnel Lake component in order to better verify the DIDSON results.

Objective 4: Establishment of a capacity-sharing relationship between the UFFCA, NSTC and DFO for providing experience for First Nations fisheries technicians on all aspects of a DIDSON project - from concept to completion phases.

The Project met this Objective.

The Upper Fraser Fisheries Conservation Alliance was the lead proponent, primary administrator and project manager for this project. The project was managed in a way designed to meet Objective 4 from proposal development through to the project completion phase.

All project partners were involved in development of the administrative tools necessary to meet funding criteria and complete the project on-budget. Operational planning was conducted via teleconferences, email and face-to-face meetings prior to project implementation.

Field operations – site installation, operation and de-mobilization - were completed by the combined efforts of the UFFCA, NSTC and DFO. The primary field crew consisted of a DFO Project Supervisor and two NSTC Fisheries Technicians. UFFCA, NSTC and DFO senior personnel provided additional biological and project management field support throughout the project.

The NSTC Fisheries Technicians were trained in all aspects of DIDSON operations, and worked with the DFO Project Supervisor on all tasks related to visual count verification, DIDSON file analysis, site and equipment maintenance and field safety procedures.

The UFFCA Project Manager/Stock Management Biologist coordinated weekly de-briefing sessions with the NSTC Fisheries Resource Manager and the DFO Project Biologist to keep the lines of communication open between project partners and redress any issues arising throughout the project. The UFFCA Project Manager and DFO Project Supervisor communicated with regular telephone updates (on average every two days) throughout the project.

The UFFCA Project Manager arranged a field site visit and tour with FSWP representatives and the UFFCA Chair/Facilitator approximately half way through the field portion of the project. The UFFCA extended an open invitation to Upper Fraser First Nations Fisheries Representatives for a field site visit during the project.

DFO provided a one-day information/discussion session (in early February 2010) for the UFFCA and NSTC in order to walk the Project Partners through the analytical process and results of the project.

As part of the overall communication and information sharing process, the UFFCA Project Manager developed and delivered a technical Quesnel DIDSON project presentation for the Fraser River Aboriginal Fisheries Secretariat (FRAFS) Fraser Watershed Joint Technical Forum and the UFFCA in early March 2010 (Appendix 2). First Nations Fisheries Representatives and DFO personnel from many parts of the Fraser Watershed participate in these meetings.

The UFFCA Project Manager/Stock Management Biologist and the DFO Project Biologist were lead authors of this report, while the NSTC Fisheries Resource Manager provided a final review.

All project partners indicated the experience resulting from the implementation and completion of this project has provided an excellent foundation from which to base future technical project partnerships.

Acknowledgments

This project was made possible with funding from the Fraser Salmon and Watersheds Program and in-kind contributions from the Northern Shuswap Tribal Council Fisheries Program, Department of Fisheries and Oceans and the Upper Fraser Fisheries Conservation Alliance.

We are grateful to Richard Holmes and staff at the Quesnel River Research Centre for support for this project in terms of site access, a dedicated power source for equipment, and accommodations for the field crew. Thanks go to Pat Baron for site access, power use and general interest in our project.

Finally, this project would not have been successful without the combined efforts and willingness of the NSTC, DFO, FSWP and UFFCA to take the idea of collaborative management and put it into practice.

Project Team

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Appendices

1. Technical Report: *System-wide DIDSON Estimation of Sockeye Salmon Escapement in the Quesnel River System (DFO, 2010)*
2. Project Presentation to the Fraser Watershed Joint Technical Forum (Kamloops, March 2, 2010) and UFFCA General Meeting (Prince George, March 12th, 2010)

Appendix 1

Technical Report: *System-wide DIDSON Estimation of Sockeye Salmon Escapement in the Quesnel River System (DFO, 2010)*

Use of High Frequency Imaging SONAR to Estimate Adult Sockeye Salmon Escapement in Quesnel River, BC: A Feasibility Study

Prepared for:

Fraser Salmon and Watersheds Program

&

Upper Fraser Fisheries Conservation Alliance

Prepared by:

Department of Fisheries and Oceans

March 2010

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1.0 INTRODUCTION

The Quesnel River System is a major sockeye salmon (*Oncorhynchus nerka*) producing river in the Fraser River watershed. The system supports over 80 sockeye salmon populations that spawn in the Horsefly and Mitchell river systems and several smaller tributaries and shore spawning areas of Quesnel Lake. Like other major sockeye populations within the Fraser watershed, those within the Quesnel Lake Conservation Unit (CU) exhibit a well developed quadrennial escapement cycle. Since 1941, escapements to this system increased consistently on all cycle-years, with dramatic increases occurring through the 1990's. Abundance to the system peaked in 2001, with one of the largest spawning escapement estimates in recorded history at approximately 3,500,000 adult sockeye. However, since 2004 annual declines to the system relative to the brood year have raised concerns with respect to juvenile rearing capacity limitations in Quesnel Lake as a result of the large annual escapements from 1993-2003.

Despite the recent declines, the Quesnel Lake CU remains a significant component of the total annual Fraser sockeye return and a major contributor to annual harvests of Fraser sockeye. These populations are part of the Summer Run complex which co-migrates with several other bilateral commercial, aboriginal and recreationally targeted stocks. Through the Pacific Salmon Treaty, Canada has international obligations to deliver high precision spawning escapement estimates which are crucial to all aspects of Fraser sockeye salmon management including annual stock reconstruction, production forecasting, and the evaluation of management decisions and catch sharing. High precision escapement estimates also assist to reduce uncertainty in the process of determining the biological status, vulnerability and benchmarks for the sockeye CU's, all which are critical requirements under the Wild Salmon Policy (WSP). To meet these obligations, current assessment activities in the Quesnel system require expensive mark-recapture programs on the Horsefly and Mitchell River populations coupled with low precision visual estimates of the remaining tributary and lakeshore spawning populations. Due to funding limitations, these projects have been cancelled in recent years resulting in the loss of valuable escapement information.

Recent studies conducted by Fisheries and Oceans Canada comparing DIDSON to mark-recapture estimates at the Horsefly and Chilko Rivers (2005-2008) indicate that Dual-frequency IDentification SONar (DIDSON) acoustic imaging technology provides a cost-effective and precise alternative for enumerating large sockeye salmon spawning escapements. The Quesnel system is of particular interest for the application of this technology, not only to address the high annual cost of sockeye salmon enumeration in this system but also because of the potential to improve the accuracy of the total spawning escapement estimates to this system due to difficulties assessing the lake shore spawning component of the system.

In 2009, a study was implemented to determine the feasibility of using DIDSON in the Quesnel River to estimate the sockeye salmon escapement to the entire Quesnel system (i.e. Horsefly and Mitchell Rivers and Quesnel Lake). The overall objectives of the study were:

1. To identify potential sites where DIDSON may be deployed to accurately enumerate sockeye salmon in the Quesnel River.
2. To assess the ability of DIDSON technology to produce a total escapement estimate of migrating adult sockeye salmon returning to the Quesnel River System, and ultimately
3. To improve population abundance estimation of the Quesnel River System, while developing cost benefit comparisons for transition to system wide DIDSON enumeration in the Quesnel system.

2.0 SITE DESCRIPTION

2.1 Study Area

The Quesnel River is a large tributary of the Fraser River located on the western edge of the Cariboo Mountain Range in Central British Columbia. The river drains Quesnel Lake and flows northwest for approximately 95 km, before entering the Fraser River near the city of Quesnel (Figure 1).
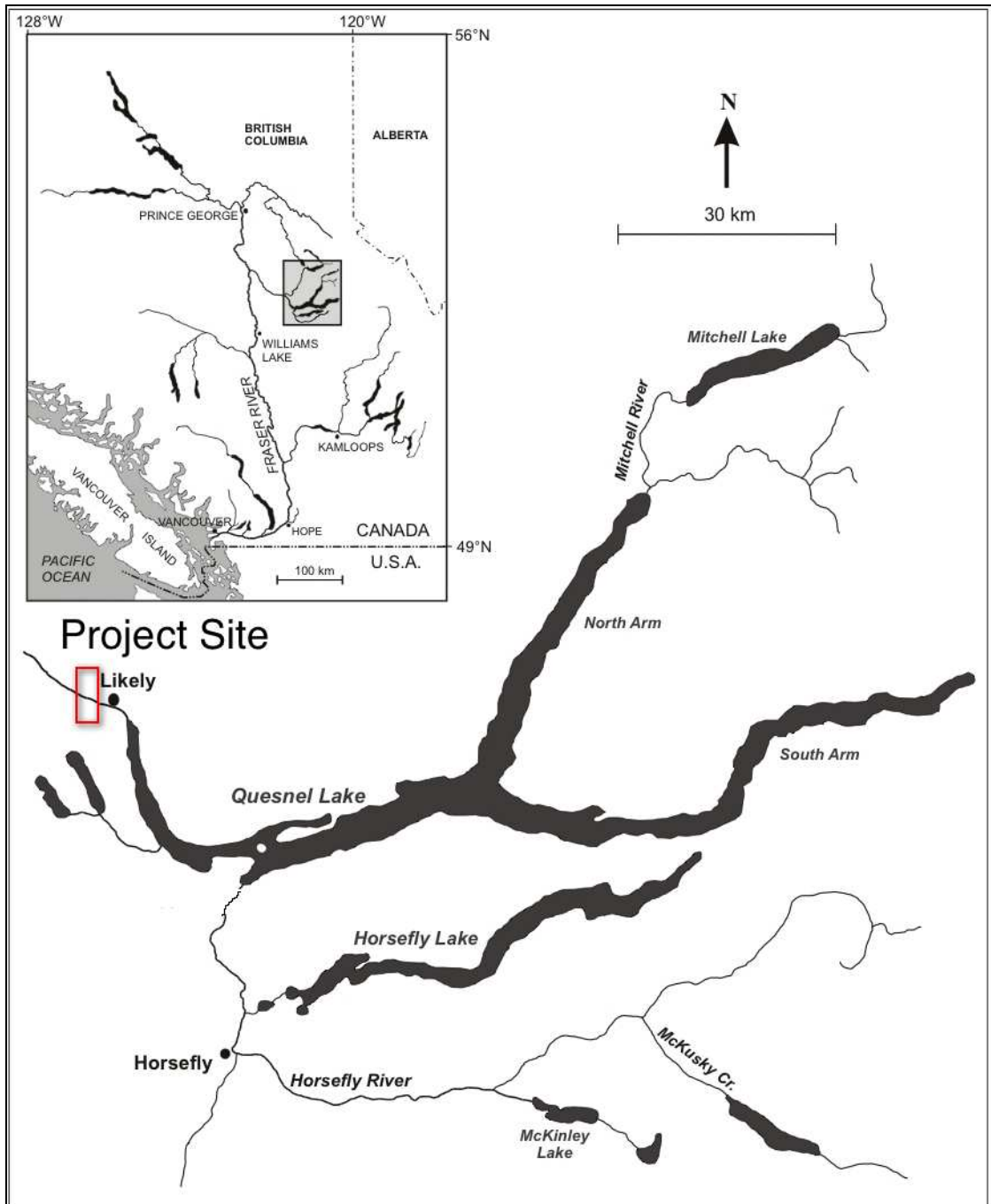
Figure 1. The study area showing the DIDSON site on the Quesnel River.

The DIDSON site is located approximately 1.5 km downstream from the outlet of Quesnel Lake and is well below all traditional sockeye salmon spawning locations (Figure 1). The Quesnel River is approximately 55m in wetted width at the acoustic site with mean monthly discharges ranging from $184m^3s^{-1}$ to $96.5m^3s^{-1}$ during the August to October migration period (Water Survey of Canada website accessed Dec 16, 2009). Water clarity at the site can be characterized as clear with a flow regime that is primarily unidirectional and turbulent, especially in the

middle of the river. Less turbulent water with reduced velocity exists along each bank. The right-bank substrate is composed of large gravel, cobble and boulders over a low gradient (<5%) planar bottom descending to an approximate depth of 2m to 3m towards the centre of the channel.   The left-bank substrate is composed of cobble and boulders and is relatively shallow and flat, but descends gradually (<5% gradient) immediately beyond the weir.   Mid-channel is composed predominately of boulders.

Site selection was based on criteria outlined in Enzenhofer and Cronkite (2000). When using DIDSON to enumerate sockeye these criteria include:

1. A straight, confined channel with a high water velocity in the middle that promotes sockeye travel along the banks. When using only one DIDSON unit to observe the entire river, laminar flows are preferred since they produce less acoustic background noise than turbulent flow.
2. A planar bottom, rather than shelved or scalloped. A shelved bank creates riverbed zones that are inaccessible to the acoustic beam.
3. A bottom substrate free of large boulders. Boulders can interfere with the path of the acoustic beam or create turbulent flow.
4. Human activity on the river should be minimal because this may alter fish behaviour and affect the flux estimate (estimate of fish passage through the beam per unit time).
5. Fish should be actively migrating and not holding or milling. Fish that tend to remain in the sampling area may be counted several times, which would lead to overestimates of flux. However, with the DIDSON imaging sonar system these holding fish can generally be identified and separated from the upstream flux.

3.0 MATERIALS AND METHODS

3.1 Power Supply Equipment and Weir Material

Laptop computers controlling the acoustic systems were housed in 2 small, portable counting sheds located on the top of each bank (3.5m x 3.5m and 2m x 2m). Left-bank electronic and acoustic equipment was operated by power from the University of Northern British Columbia (UNBC) Quesnel River Research Facility; whereas, the right-bank electronic and acoustic equipment was operated by power from a private residence located approximately 200m from the DIDSON site.

Approximately 6m of sectional fish deflection weir was installed on both the left-bank and right-bank. The DIDSON units were installed on the upstream side of each weir and were placed approximately 2m back from the end of the weir to ensure optimal hydro acoustic coverage and counting conditions (Figure 2).

Figure 2. Downstream view of the Quesnel River DIDSON site in 2009 (photo taken from right-bank).

3.2 Acoustic Data Collection

Two (2) DIDSON acoustic imaging systems were used for data collection; each operating independently on opposite banks. A standard DIDSON (DIDSON-S) unit was utilized on the right-bank, operating at a 10m window length , a window start length between 0.83m and 2.08m, and a frame rate of 10 frames per second in high frequency mode (1.8 MHz). With these settings, approximately 20.2 megabytes per minute were recorded, resulting in data files of 404 megabytes per 20 minute time period. The right-bank DIDSON unit periodically operated at a 20m window length to confirm that sockeye migration was occurring within 10m from the shoreline. A long range unit (DIDSON-LR) was utilized on the left-bank, operating at a 20m window length, a window start length between 1.67m and 4.17m and a frame rate of 10 frames per second in high frequency mode, but at a lower frequency (1.2 MHz) than the DIDSON-S. With these settings, approximately 10.2 megabytes per minute were recorded, resulting in data files of 203 megabytes per 20 minute period. The field of view for both units was 14° vertical and 29° horizontal.

The DIDSON-S system was programmed to create new files (time and date stamped) beginning at the top of the hour while the DIDSON-LR was

programmed to create new files (time and date stamped) 15 minutes after the top of the hour. The staggering of recording times enabled crew members the flexibility to perform other tasks outside of the programmed recording times as well as providing an easy way of identifying the right-bank files from the left-bank files.

All digital data recording and post-processing of fish counts were conducted using Version 5.22.04 of the DIDSON operating system software (Sound Metrics Corporation 2009). Due to the large size of the files, data had to be downloaded daily onto external hard drives and then transferred and stored permanently onto a designated 1 Terabyte office external hard drive. Once the data was successfully transferred onto the office external hard drive, it was deleted from the operational computer the following day. Data was not deleted from the travelling external drive until the files had been analyzed and the results recorded. This ensured there were always two copies of files before analysis and at least one copy following analysis, which appeared to be sufficient for archiving and storage purposes.

Each DIDSON unit was deployed on an adjustable mounting apparatus anchored to the riverbed (Enzenhofer and Cronkite 2005) approximately 1m from the edge of each shore. Both DIDSON units were installed following the aiming procedures and protocols as described in Holmes *et al.* 2006. As water levels dropped, the DIDSON units were gradually moved further out from the banks. The system was positioned so that the lens was 10cm to15cm below the water surface and the transducer was aimed at -8° to -12° angle relative to the water surface and perpendicular to the shoreline and water flow. Using this aim, the DIDSON beams ensonified the entire area within the 10m or 20m window length. The upstream/downstream boundaries of detection could not be physically confirmed safely beyond the weir due to the swift current. Instead, the upstream/downstream boundaries of detection were confirmed by having a crew member observe fish migration from on top of the weir and communicating the location of migrating fish to the crew member observing the DIDSON monitor at the same time. The vertical boundaries were also confirmed similarly.

3.3 DIDSON Fish Counting

All DIDSON data files (1 file per hour; 24 files per day) were counted manually using a hand held counter (tally whacker) and the numbers of upstream and downstream fish were recorded on a spreadsheet. A minimum of 10 files per day (5 on the right-bank and 5 on the left-bank) that were chosen randomly were counted twice. The spreadsheet was designed to calculate the net upstream count and the expansions for the un-sampled portions of the hour. Most data files were 20 minutes in length; however, some files were less than 20 minutes or completely missed due to power failures or DIDSON adjustments. If files were counted more than once by different observers, then the average count was used in the spreadsheet to calculate the hourly net upstream passage. The

spreadsheet was designed to plot daily cumulative run-timing curves to allow the assessment of run strength and timing. The visual count data were also recorded in the spreadsheet for later analyses. Notes were kept of unusual events or items that needed later attention, such as fish behaviour, other fish species and DIDSON adjustments (i.e. aiming, mount / weir repositioning, etc.).

The display images used for upstream and downstream counts were analyzed using background subtraction. This subtraction removed the static portion of the acoustic image, showing only objects in motion. Removing the background allowed for easier fish detection. This processing function is advantageous for the Quesnel River due to the turbulent conditions of the river. All data files were processed using the tools and software package and described in the DIDSON operation Manual (Version 5.22) (Soundmetrics 2009).

Sockeye salmon migration behaviour at the DIDSON site was extremely shore orientated, which resulted in sockeye traveling in tight, single-file bands primarily within the first 7m range from the transducer. As a result, the DIDSON files were relatively simple to count manually.

3.4 Downstream moving fish and the flux model

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

$$N = U - D \tag{1}$$

where N = the net upstream flux, U = the upstream actively migrating fish and D = the downstream actively migrating fish. Milling fish can be accounted for in this model, provided these fish eventually move upstream through the acoustic beam. Spawned-out moribund fish have to be removed from the downstream estimate since the model relates only to actively migrating fish, and moribund fish would have been included in the spawning population as upstream fish. Summed over 24 hours, this model produces daily escapement estimates that are compiled to estimate the total spawning population entering a river. Overall, because the DIDSON site is located a considerable distance below all Quesnel system spawning populations, downstream movement of sockeye is almost zero.

3.5 Visual Counts

Visual counts were collected simultaneously with real-time DIDSON counts during daylight hours throughout the study period. A total of four (4) visual counts/day were conducted (2 counts on the right-bank and 2 counts on the left-bank). Right-bank counts were primarily performed between 900hrs and 1100hrs while left-bank counts were predominately conducted between 1200hrs and

1500hrs. These times corresponded to the best lighting conditions for visual counts. Any deviations from these scheduled times were due to power failures or acoustic equipment adjustments. All visual counts were made by an observer standing at the end of the left and right-bank weirs (Figure 2) wearing polarized sunglasses to reduce glare at the water surface.

Visual data collection was synchronised with the DIDSON data collection by radio notification to the visual counter of the start and end of the concurrent DIDSON file. Both the visual counter and the DIDSON counter recorded the number of fish moving upstream and downstream during the counting event, including the upstream and downstream movements of other species, such as chinook salmon (*Oncorhynchus tshawytscha*); however, only the DIDSON files that were post-processed in playback mode were used to compare to visual count results. In addition, file time, file length (minutes), visibility conditions, and any comments for the visual counts (categorized as poor, fair, good or excellent) were recorded on the Visual Counts Reference Form (Appendix 1).

The collection of simultaneous visual and DIDSON count data is important as it represents the data quality assurance and quality control procedures for DIDSON enumeration sites as described by Holmes *et al.* 2006. Ideally, in clear and shallow rivers suitable for conducting live counts, the accuracy of count data from a DIDSON system can be determined (Holmes *et al.* 2006). In such a system, visual and DIDSON count data are plotted and a regression line fitted to determine potential bias in the counts. Deviations detected in count data would indicate potential bias in the counts associated with fish migrating through acoustic blind zones undetected by the DIDSON system. At the 2009 Quesnel DIDSON site, only the visual counts on the right bank were used since they were able to coincide with the 10m DIDSON acoustic beam window length. Due to water depth, high water velocity and the 20m operating window length on the left bank, the visual and DIDSON count data could not be appropriately compared to determine accuracy, as it was only possible to effectively visually enumerate fish within the first 7-8m.

3.6 Species Identification

The most common resident species inhabiting the upper Quesnel River include rainbow trout (*Oncorhynchus mykiss*) and Rocky Mountain whitefish (*Prosopium williamsoni*). It is uncommon for individuals from these species in the Quesnel River to grow as large as sockeye salmon, and thus, can be easily distinguished from sockeye salmon (R. Dolighan, Biologist, MOE, Williams Lake, BC, pers. comm.). In addition, resident species often display a greater tendency to mill within the ensonified area; whereas, sockeye typically display directed upstream migration. These characteristics assisted crew members in excluding resident species from the DIDSON counts.

Non-resident species such as co-migrating chinook, coho *(Oncorhynchus*

kisutch) and pink *(Oncorhynchus gorbuscha)* salmon are also present in the Quesnel River during the sockeye salmon migration period. Co-migrating chinook salmon impose the greatest influence potentially affecting the accuracy of sockeye counts past the DIDSON unit due to their considerably higher abundance and similar migration timing to sockeye, compared to coho or pink salmon. It was determined by visual counts that chinook and sockeye salmon could be appropriately separated in the DIDSON files due to their size, spatial and behavioural differences.

3.7 Sub-Sampling Analysis

The estimate of total passage was based on sampling a total of 20 minutes out of every hour. Procedures outlined in Holmes *et al.* 2005, were followed in order to estimate variance caused by the temporal expansion from 20 minute counts into hourly estimates. The method of successive difference was used to estimate a variance caused by temporal expansion from 20 minute counts into hourly estimates (Wolter 1985; Eggers *et al.* 1995, Lijha *et al.* 2007). In this method, the variance can be estimated strictly from adjoining pairs of counts using the systematic sample-variance estimator (Holmes *et al.* 2005).

Power failures occurred on occasion that resulted in consecutive data file loss within the data set. These data gaps were interpolated using data averaged from the previous and subsequent day's migration. Data was extrapolated using a linear function after the DIDSON unit was removed on September 28th to represent the tail end of the run.

3.8 Data Analysis

Precision estimates were generated by assessing and combining the error associated with temporal sub-sampling (20min / 1hr) and the error associated with the variability in counts between individuals for the same data files. The error between individuals was stratified by passage rates to provide more accurate representation. We followed the analytical procedures outlined in Holmes *et al.* 2005 to assess the precision of the DIDSON counts among individuals using the coefficient of variation (CV) and average percent error (APE). The estimate of total variance for the upstream escapement estimate is the sum of the sub-sampling variance and the variance between individuals and expressed as the standard deviation for the total count ($SD_{TotalCount}$). The 95% confidence interval is calculated by multiplying the standard deviation by ± 1.96 for normally distributed data (Pagano 1981).

4.0 RESULTS

4.1 Estimate of Sockeye Salmon Population

The 2009 sockeye salmon escapement estimate into the Quesnel System was 157,541 ± 14,477 (± 9.5%). Sockeye salmon migration into the Quesnel River was observed to have begun on August 8 and continued through September 28. The daily escapement plot reveals a maximum daily net upstream escapement estimate of 8,262 sockeye salmon on August 30, 2009. The halfway point in the 2009 run, when 50% of the total estimate had passed the DIDSON site, occurred on September 1. Figures 3 and 4 display the daily and cumulative sockeye salmon escapement for the Quesnel River in 2009.
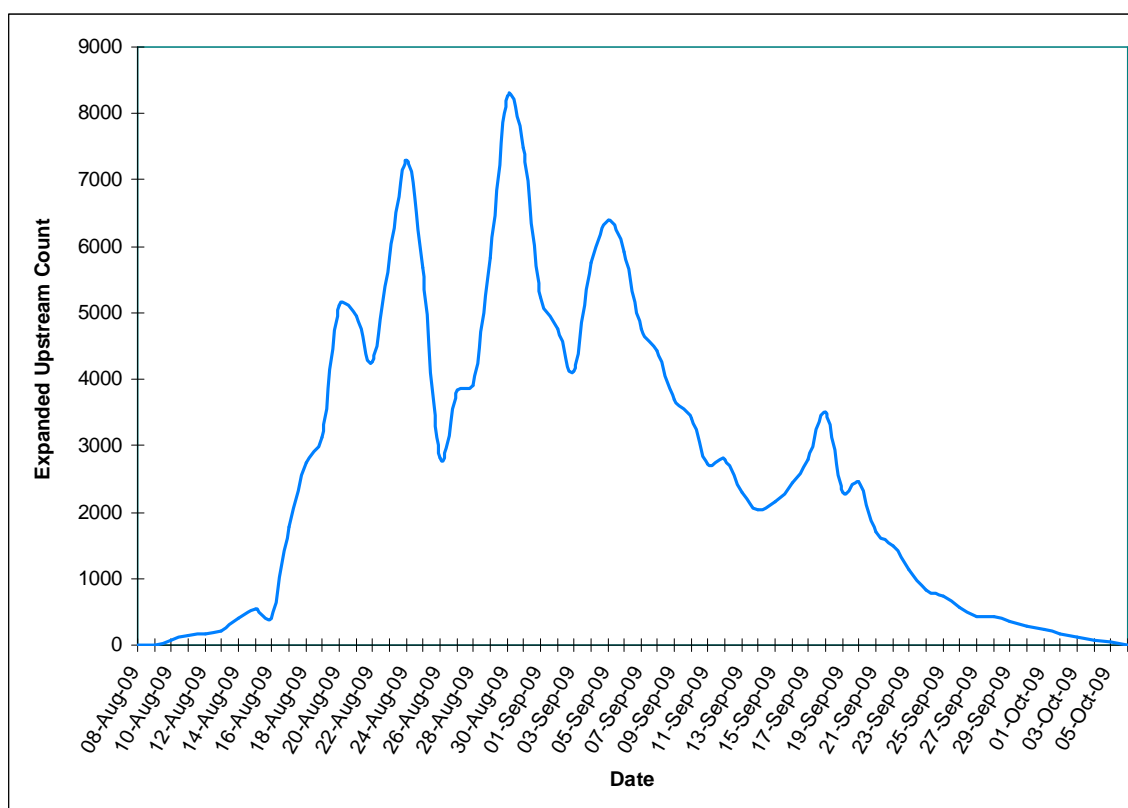

Figure 3. Daily net upstream of sockeye salmon migration past the DIDSON site on the Quesnel River in 2009 (right and left-banks combined).
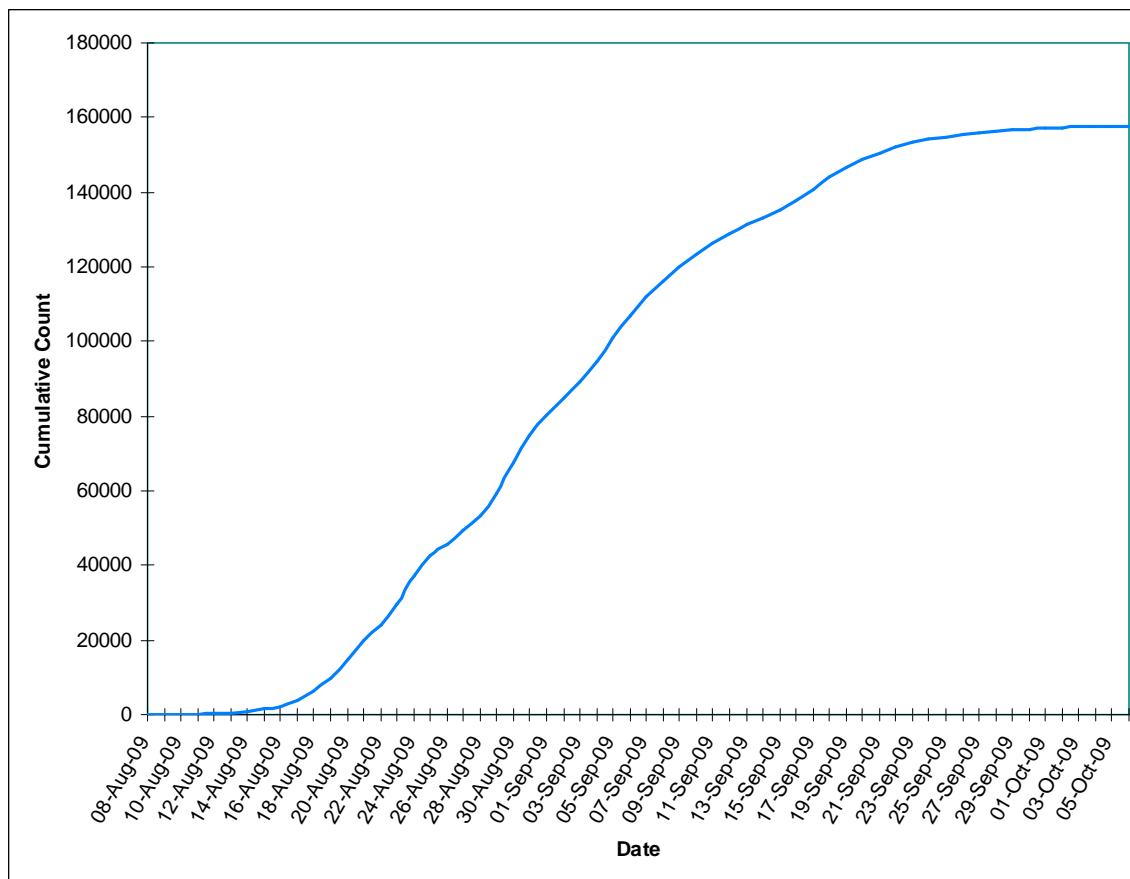
Figure 4. Cumulative daily net upstream of sockeye salmon migration past the DIDSON site on the Quesnel River in 2009 (right and left-banks combined).

As mentioned earlier, the 95% confidence interval width of ± 9.5% reflects precision errors associated with the variability in counts between individuals for the same data files and temporal sub-sampling. The repeatability of counts using the APE is discussed in section 4.3 and contributed an overall error of ±4.2% and the temporal sub-sampling of 20 minutes out of every hour contributed an overall error of ±5.0% (Holmes *et al.* 2006).

A considerable portion of the migration (59%) occurred during daytime hours (Figure 5), with the majority of sockeye (91%) traveling along the right-bank (Figure 6). The number of downstream migrating salmon was assessed throughout the program and was negligible.
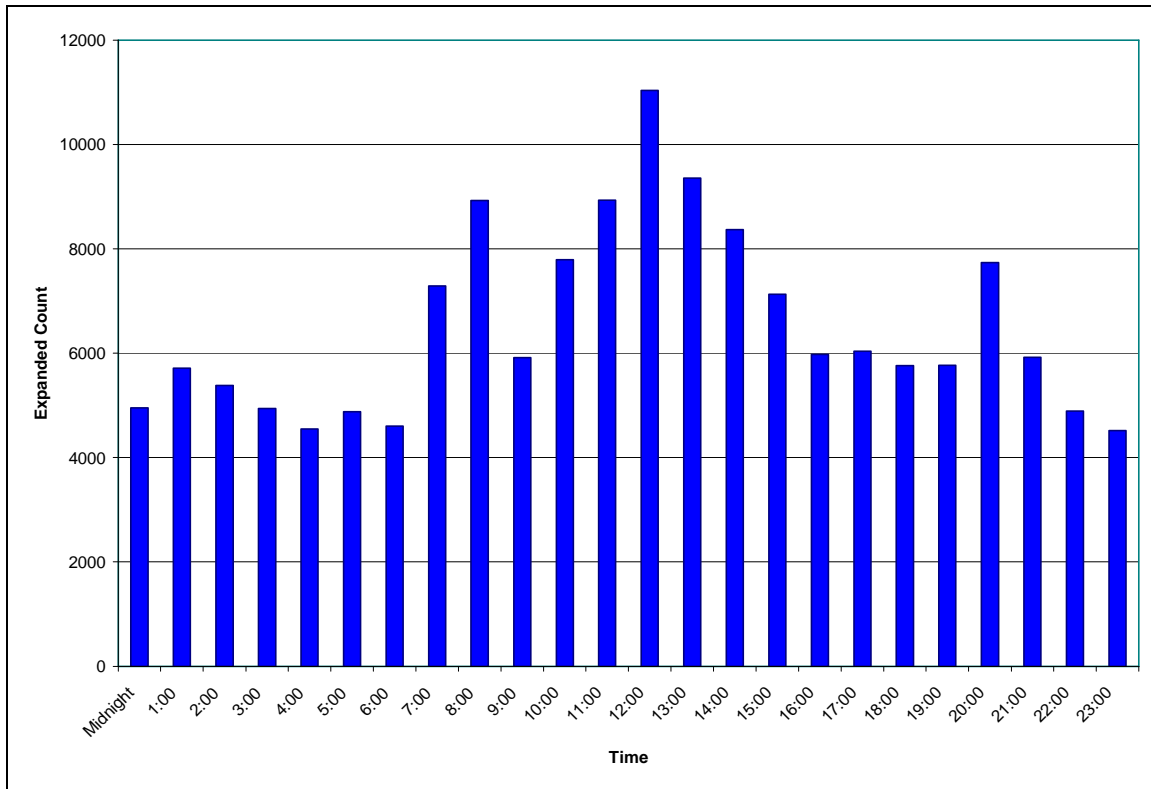
Figure 5. Total hourly sockeye migration past the DIDSON site on the Quesnel River in 2009.
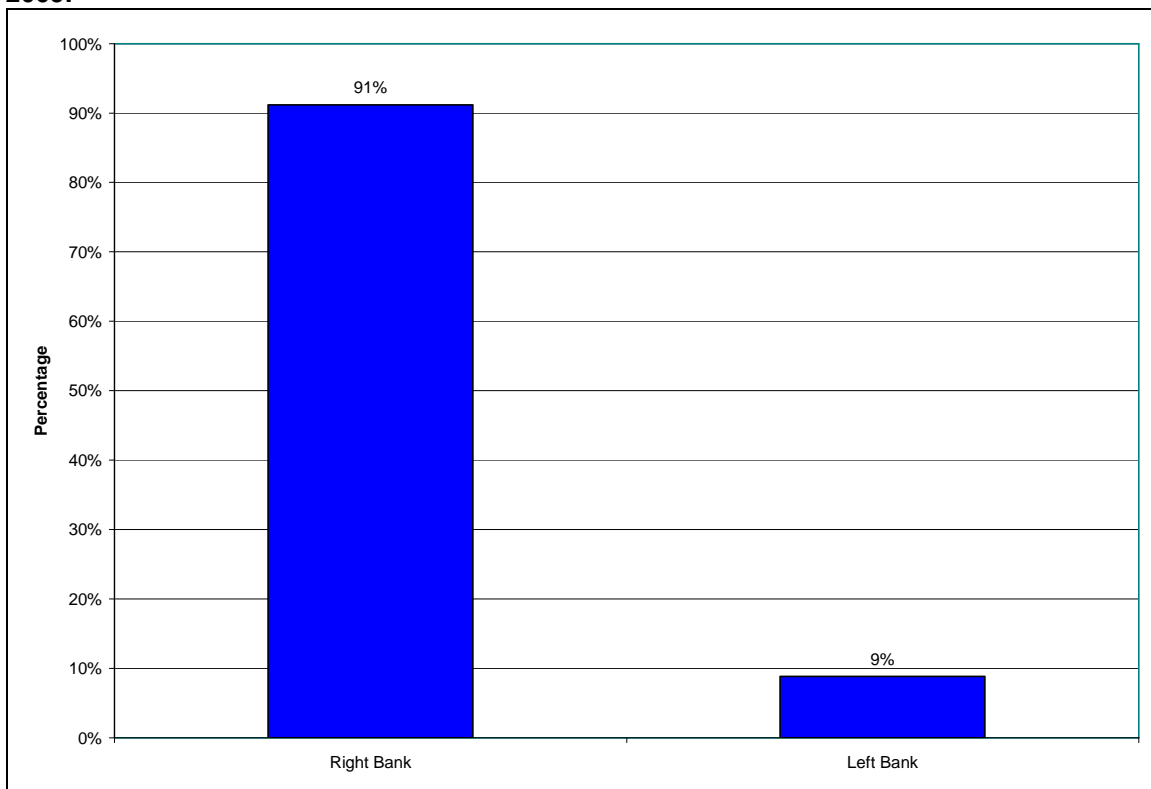
Figure 6. Total migration of sockeye counted past the right and left-bank DIDSON units on the Quesnel River in 2009.

4.2 DIDSON Counts Compared to Visual Counts

Net upstream passage rates on the right-bank that were estimated from the visual count data ranged from 0 to 690 fish/hr while net passage rates estimated from simultaneous DIDSON counts ranged from 0 to 662 fish/hr (Figure 7). The regressions defining the lower and upper bounds fitted to the count data, which are two measures of the same phenomenon are:

RB: Ln VISUAL = -0.5087 + 1.1151 x Ln DIDSON, R^2 = 0.9731, N = 73
RB: Ln DIDSON = 0.3953 + 0.9103 x Ln VISUAL, R^2 = 0.9634, N = 73

Figure 7a. The natural log relationship between the visual (y-axis) and DIDSON (x-axis) counts for net upstream migrating sockeye salmon along the right-bank.

The chart shows:
Y-axis: LN DIDSON COUNT (0 to 6)
X-axis: LN VISUAL COUNT (0 to 6)

$$y = 0.9103x + 0.3953$$
$$R^2 = 0.981$$

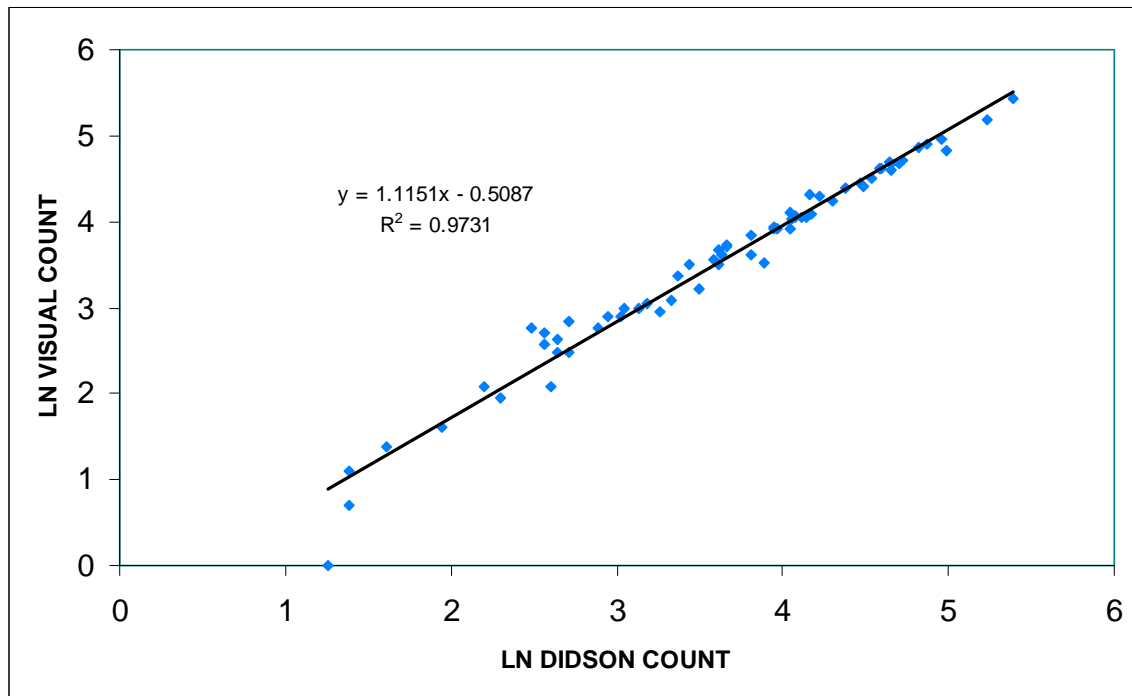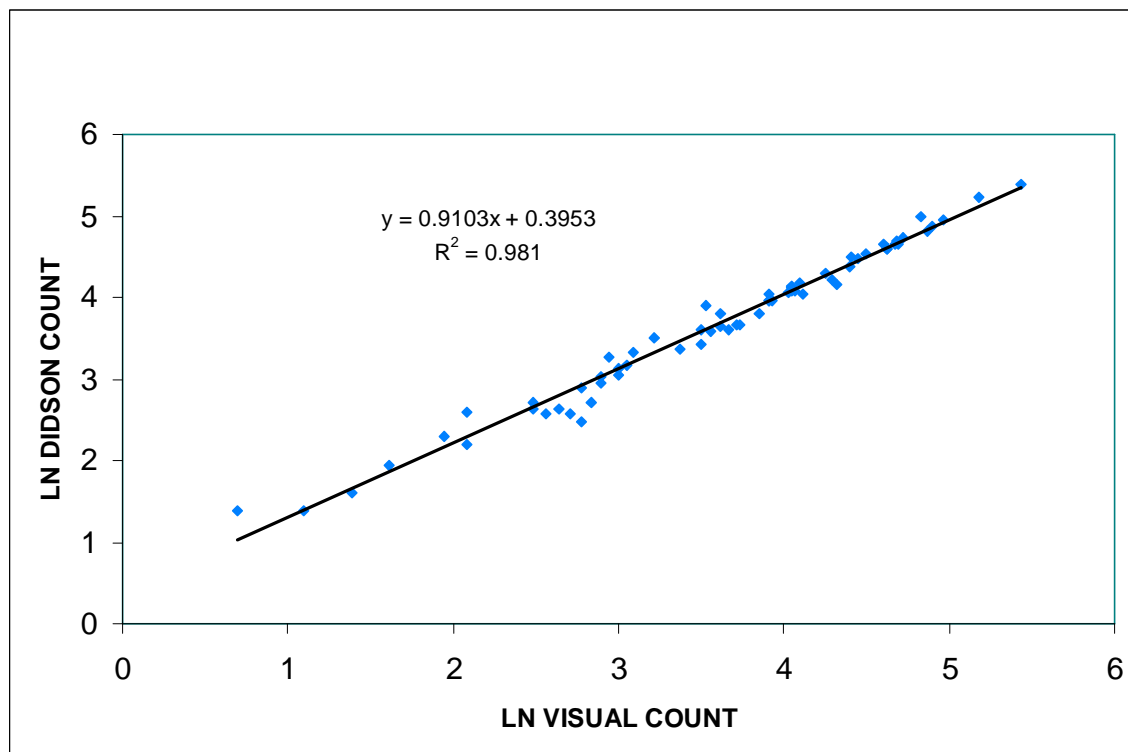**Figure 7b. The natural log relationship between the visual (x-axis) and DIDSON (y-axis) counts for net upstream migrating sockeye salmon along the right-bank.**

Figure 7a represents the regression assuming that all of the error is in the visual counts, while Figure 7b represents the regression assuming that all of the error is in the DIDSON counts. In both cases, the simultaneous visual and DIDSON counts are statistically indistinguishable from the 1 to 1 line.

4.3 Comparison of DIDSON counts between observers

A total of 430 data sets that were distributed over the entire migration period were counted by multiple observers. Expanded upstream passage rates from these files ranged from 0 to approximately 843 fish per hour. Based on the average percent error (APE) from these data, repeated independent counts of the DIDSON data sets would be expected to produce the same count 95.8% of the time (4.2% APE) for the net upstream travelling fish. At no time during the file counting was precision jeopardized and accuracy reduced due to high passage rates (saturation).

4.4 Sub-sampling analysis

The sub-sampling analysis directly followed the procedures outlined in Holmes *et al.* 2006. The report outlines that approximately 5% sampling error would be incurred if sampling effort was increased to 20 minutes per hour. The data used for the temporal expansion analysis included 775 sampled hours (20 minute sub-samples) collected between August 8 and September 28, 2009.

5.0 DISCUSSION

5.1 DIDSON Counts Compared to Visual Counts

The ability to compare DIDSON count data to visual count data represents an important component of the DIDSON protocols and procedures developed by Holmes *et al.* in 2005. Deviations between the visual and DIDSON count data could infer that there may be issues with either the sonar aiming procedures resulting in potential blind zones or limitations with visual observations. Figure 7 reveals little deviation between the count data by displaying a strong one-to-one relationship (R-value), indicating that both the visual and DIDSON count data are not biased. Some minor differences were observed between the data sets; however, it is difficult to assess and confirm the direction and magnitude of the bias. In 2006 at Stellako River, Holmes *et al* 2005 demonstrated that a properly aimed DIDSON can achieve counts as accurate as those obtained from a weir on a clear water river system; thus, it is assumed that fish were not passing thru the ensonified area undetected. At the Quesnel River site, it appears that variations with viewing conditions may be responsible for any differences observed between count data. In 2006 at Chilko River, Holmes *et al* showed evidence of systematic bias in the visual count data when viewing conditions were sub-optimal. Fewer fish were counted visually than were counted with the DIDSON at low passage rates as a result of turbulence and glare; whereas, more fish were counted visually than the DIDSON at higher passage rates. Consequently, any bias observed from analysing the visual and DIDSON count data, albeit extremely small, is more likely associated with error in the visual counts.

The river width at the DIDSON site was 55m, resulting in approximately 20m of river not being assessed (ensonified). To address this issue, a site was chosen that was very similar to the DIDSON site at Chilko River, where a straight, confined channel with a high water velocity in the centre of the river naturally pushes sockeye to migrate along the banks. Upon satisfying this critical site criterion, we feel confident that sockeye did not utilize the centre of the river for migration and pass the DIDSON site undetected; however, there was not a complete high precision terminal area escapement estimate to compare results to and substantiate this view.

5.2 Comparison of DIDSON Counts between Observers

It is necessary to continually compare DIDSON counts between observers (precision) to not only ensure quality control for obtaining DIDSON generated population estimates, but also to identify error associated with differences between observer counts. A disagreement between observers of more than 20 to 30% should be used as a benchmark to determine why a large error occurred (Holmes *et al.* 2006). Large differences between observer counts with the Quesnel files were minimal. Any disparity that did occur between observer

counts could be attributed to fatigue, interruptions during the counting process, mechanical malfunction of the hand operated counter (i.e. tally wacker) or failure to reset the hand operated counter.

Most error that was incurred during the double counting process was associated in files with low passage rates. During extremely low passage rates there is a higher likelihood that a fish may be missed or misinterpreted as another species by the observer over a 20 minute period compared to those at high passage rates. For example, if a mistake occurs when passage rates are less than 10, as compared to 100, the relative error will be exaggerated. Because of this, the mean passage rates were stratified to accurately reflect the overall error associated with differences between observer counts.

5.3 Sub-Sampling Analysis

The temporal sub-sampling of 20 minutes out of every hour was developed and recommended in Holmes *et al.* 2006. It has been demonstrated that uncertainty in the point estimates can be reduced to approximately 5% if sampling effort was set at 20 minutes per hour. Sampling and counting 20 minute files versus 10 minute files were conducted in an attempt to minimize error, while maximizing efficiency. Sub-sampling more than 20 minutes does not appear to be practical when comparing the benefits (i.e. narrower confidence interval around the point estimate) to the increased cost and effort for greater accuracy (Holmes *et al.* 2006). In addition, the extremely large data volume that is characteristic of the DIDSON data sets would become much more difficult to manage.

5.4 Correction for Species Composition

The ability to differentiate between co-migrating species can potentially pose significant bias regarding the accuracy with DIDSON enumeration programs. At Quesnel River, the major species of concern is chinook salmon. Live counts conducted throughout the program were able to accurately identify species composition and were used for validation purposes with the DIDSON counts. Post-season analysis of visual and DIDSON count data over the past few years at Chilko River has revealed that it is easier to distinguish chinook from sockeye when counting DIDSON files than previously thought (P. Welch, Stock Assessment Biologist, DFO, Kamloops, BC, unpublished data).

A number of unique characteristics make it possible to differentiate between sockeye and chinook salmon when viewing the DIDSON files. First, the overall size (length and thickness) differs considerably between the two species. Second, the tail beat frequency of chinook differs greatly in that they appear to move their caudal fins with greater amplitude than sockeye. Third, migration behaviour differs between the two species in that chinook do not appear to engage in schooling behaviour during migration, which is in direct contrast with sockeye. Chinook were often viewed migrating upstream individually or on rarer

occasions in small groups of 2 or 3 fish. Many chinook would tend to hold in deeper water before moving through the ensonified area; whereas, sockeye migrated through the ensonified area quickly without holding. Last, there is noticeable spatial separation between the two species as they co-migrate. Chinook primarily migrate within the centre portions of the river, utilizing the deeper and faster flowing parts of the river. Wave drag (i.e. resistance generated by surface waves near the air/water interface) may explain why large fish such as chinook choose to migrate further from the bank as opposed to sockeye. It is thought that chinook swim in deeper, faster water as opposed to swimming in shallower, slower water with increased wave drag.   Chinook may also be exploiting small vortices created by increased streambed roughness towards the centre of the river which could reduce drag and make it easier for upstream migration (Hughes 2004).   Conversely, sockeye were primarily observed as being bank orientated in most portions of the upper Quesnel River. Compared to chinook, sockeye are considerably smaller in length and rounder in width producing a "torpedo" shape which appears to enhance water flow over their bodies; thus, decreasing drag and increasing stride length (Hinch and Rand 2000).   Due to the small size of sockeye as compared to chinook, it appears advantageous to travel closer to the banks where water flow velocities are lower.

Small precocious chinook salmon, referred to as jacks, could potentially create difficulties in differentiating between chinook and sockeye salmon; however, in most years, jacks are not believed to be very common to the Quesnel River. The 2009 preliminary estimate of chinook salmon in the Quesnel River is estimated at 1,944 individuals making the number of co-migrating chinook salmon relative to sockeye salmon fairly insignificant (R. Bailey, DFO, Kamloops, BC, pers. comm.). Similarly, the number of coho and pink salmon migrating through the upper Quesnel River is also relatively insignificant compared to sockeye salmon. Coho and pink salmon migrate through the Quesnel River much later than sockeye salmon, resulting in only the possibility of minimal overlap in migration. If co-migration does occur it can be difficult, if not impossible, to acoustically distinguish sockeye salmon from coho or pink salmon. Consequently, a small bias in a positive direction may exist through the misidentification of species, but the magnitude cannot be quantified and should be considered negligible.

5.5 Strengths of the Quesnel River DIDSON System for Escapement Estimation

Successful enumeration of migrating fish using DIDSON technology depends on a variety of critical elements relating to river morphology, acoustic transmission and the behaviour of migrating fish. Project logistics relating to site access, power availability, safety and site security also represent important elements required for the successful implementation of DIDSON sonar. These elements may vary greatly between systems; however, for the most part, they are all interconnected and need to be taken into account when assessing the unique

characteristics of a particular system that is being enumerated. The Quesnel DIDSON site appeared to be very suitable since it adequately met all of the DIDSON criteria outlined in section 2.1.

The acoustic performance at any DIDSON site likely represents the most important element required to effectively enumerate or observe any animal as they travel by the site. The bottom profiles on both sides at the Quesnel site were relatively straight and descended evenly throughout the ensonified area. For the most part, both sides were free of large boulders or shelves, which allowed for sufficient acoustic transmission without any considerable blind zones.

The behaviour of sockeye and other co-migrating species at the DIDSON site was optimal for effective operation of DIDSON sonar. Downstream movement of live (moribund and non-moribund) sockeye was negligible and milling fish were not observed in the vicinity of the DIDSON site. Observed downstream movement was usually moribund chinook. This was determined visually from weir observations and DIDSON file analysis. The lack of milling fish can be attributed to the location of the DIDSON site which was situated a considerable distance downstream from all major spawning areas. In addition, as mentioned previously, flow velocities within this portion of the Quesnel River are characterized as high, resulting in sockeye to travel in relatively consistent, unidirectional, tight bands along the shorelines.

The Quesnel DIDSON site was secure and manageable from an operational perspective. The site is located approximately 1.5 km from the Likely Hwy and can only be accessed through the UNBC Quesnel River Research Facility. Because the site was highly secure, the crew was able to leave the acoustic equipment operating un-supervised, 24 hours/day with little concern of vandalism or interference from the public. Additionally, the DIDSON units were able to utilize AC power from the UNBC facility and a private residence on the right bank, which resulted in dependable and consistent data recording as opposed to potentially more frequent power failures associated with gasoline generators.

Another positive aspect of the Quesnel site was that due to the shore oriented migratory behaviour of the sockeye, only 2 panels of the portable weir was required on each bank. The installation of small weirs required less time and effort and the impact on the natural movement of migrating and resident fish was most likely minimized.

An important advantage of using the DIDSON system to enumerate migrating salmon is that daily estimates of upstream migration can be provided in a timely fashion - usually the following day. The data also provides the ability to examine the migration patterns and temporal distribution of sockeye and chinook salmon throughout the duration of the program. Hourly and diurnal variation in passage rates can be observed and the cumulative escapement of a species to a river system can be recorded and reported immediately. Such information can be

useful to resource managers regarding potential adjustments to in-season fisheries in order to achieve specific escapement goals.

The DIDSON system does not provide biological information such as sex, state of maturity, age and spawning success. Such critical information must be gathered from the spawning grounds in the terminal areas.

Overall, it appears that the Quesnel River DIDSON site has the potential of providing a precise, accurate and cost effective method of obtaining escapement estimates for the entire Quesnel System for future management purposes.

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Appendix 2

Quesnel River DIDSON Project Presentation to the Fraser Watershed Joint Technical Forum (Kamloops, March 2, 2010) and UFFCA General Meeting (Prince George, March 12th, 2010)

Upper Fraser Fisheries Conservation Alliance

Quesnel River DIDSON System-
wide Sockeye Enumeration
Feasibility Study
March 2, 2010
Pete Nicklin

Introduction

- Project Partners
- DIDSON background
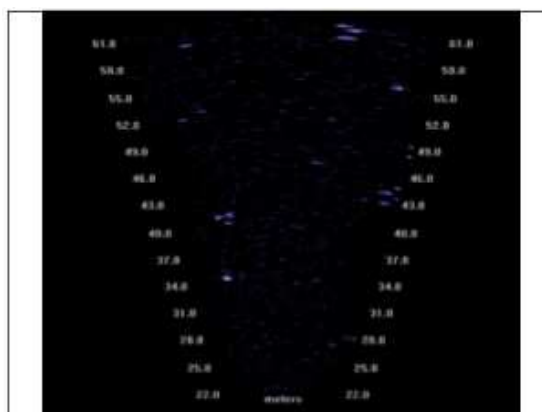- Project Objectives
- Project Results

Project Partners

- Collaborative Project between:
  - UFFCA
  - Northern Shuswap Tribal Council
  - DFO
- Funded by Fraser Salmon & Watersheds Program (FSWP)
- In-Kind contributions

Background: What is DIDSON?

- DIDSON = Dual-frequency Identification SONAR
- Using hydroacoustics as fish counter (following image from Soundmetrics website)

DIDSON Backstory

- 2004 - DIDSON Feasibility Study (Holmes, Cronkite, Enzenhofer).

  - to determine where DIDSON technology could be used to estimate sockeye salmon (*Onchorhynchus nerka*) escapement on the Fraser Watershed.

Sox Enumeration History in Fraser

- DIDSON was conducted simultaneously with M/R programs for the purpose of estimating sockeye salmon escapement during the first four years:
  - 2005 – Horsefly (SB Funded)
  - 2006 – Horsefly & Chilko
  - 2007 – Horsefly (SB Funded)
  - 2008 – Chilko
  - 2009 - Chilko (stand alone method)
  - 2009 - Mitchell (stand alone method)
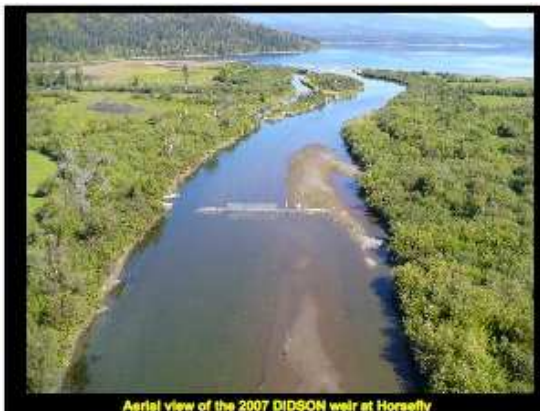 - 2009 - Qualark (stand alone method)
  - 2009 - Quesnel

Lingfield DIDSON site - power cable spanning the Chilko River
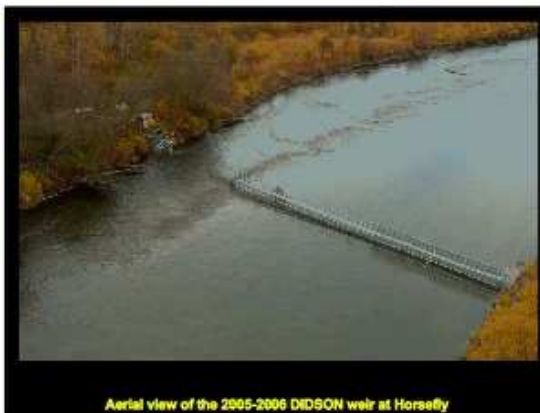
Aerial view of the 2005-2006 DIDSON weir at Horsefly

Aerial view of the 2007 DIDSON weir at Horsefly

Aerial view of the 2007 DIDSON weir at Horsefly

Quesnel DIDSON Project Objectives

- DIDSON Site Selection on Quesnel River
- Installation and operation of 2 DIDSONS
- Generation of total Quesnel Lake sox estimate
- Establish capacity-sharing/collaborative relationship between UFFCA/NSTC/DFO

Project Objectives

- How did we do?
- From feasibility standpoint: success
- Con: unable to compare results with high-precision estimates upstream (no Horsefly M/R)

Objective 1: DIDSON Site Selection Criteria

- A planar bottom, rather than shelved or scalloped that is free of large boulders.

- Minimal human activity - may alter fish behaviour and affect the flux estimate (estimate of fish passage through the beam per unit time).

- Fish should be actively migrating and not holding or milling / spawning.

DIDSON Site Criteria

- *Large (Swift) Rivers*: Operating 2 DIDSONs - A straight, confined channel with a high water velocity in the middle that promotes sockeye to travel along the banks.
  - Small weirs on each bank

- *Medium sized (Slow moving) Rivers*: Operating 1 DIDSON – When observing the entire river, laminar flows through a U-shaped trough are preferred.
  - Large weir required to funnel migrating sockeye

DIDSON Site Criteria

- Crew and equipment safety
- Site logistics

Site Selection: Project Location

- Enumerate Quesnel Lake CU
- Downstream of spawning areas
- Upstream of Cariboo River

Project Results: Methods & Materials

- 2 DIDSON units
  - 1 Standard unit (96 beams) used on the right bank.
  - 1 Long range unit (48 beams) used on the left bank.
  - Standard unit operated with a window length of 10 metres while the long range unit operated with a window length of 20 metres.
  - Total ensonified area was 30 meters. 20 meters of river not ensonified
- Right and left bank weirs were constructed.
  - Both weirs extended approximately 6 metres from each bank
  - Constant power from landowner and QRRC

Potential Sources of DIDSON Error

1. Variability between counters
   - The repeatability of counts between different individuals for the same data sets
2. Temporal sub-sampling
   - Sub-sampled 20 minutes out of every hour.
3. Non-Detection of fish
   - We followed DIDSON protocols
     - Consistent setup and aiming procedures, testing for blind zones, etc
   - Comparison of DIDSON counts to Visual counts
     - Regression lines - strong relationships
4. Species Composition
5. Downstream Counts (pre-spawn, post-spawn or milling/spawning?)

Variability between Counters

- 430 data files were counted by multiple observers
- Data files were 0 to 830 fish per hour
- Repeated independent counts would produce the same result 96% of the time
- At no time was saturation a problem

Sub-sampling Analysis and Expansion

- 20 minute sub-samples (counts) from each hour are generated
- August 8th to September 28th
- 5% sampling error
  - Trade off for large data files, time for counting

Visual compared to DIDSON

- Visual Counts are compared to DIDSON counts
  - "Make sure the DIDSON is seeing what we think it is seeing"

$y = 0.9103x + 0.3953$
$R^2 = 0.981$

(LN DIDSON COUNT vs LN VISUAL COUNT)
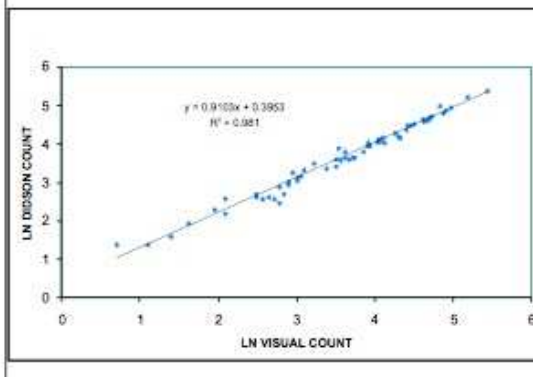
Species Composition

- Chinook were distinguishable from sockeye visually and by DIDSON
- Approximately 2000 chinook in Quesnel River in 2009 (small number compared to sockeye)
- Pinks and coho are also in relatively small number
  - pinks were identified by behaviour on DIDSON

Downstream Counts

- Negligible
- No milling fish near site
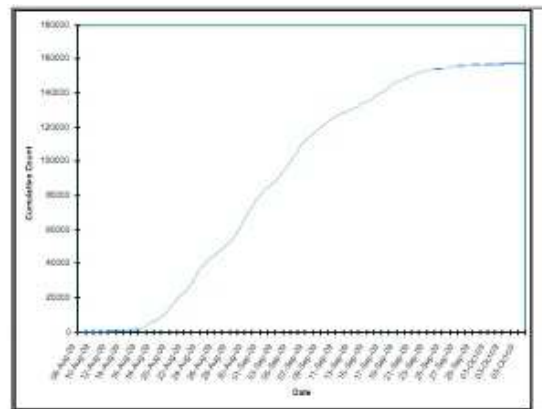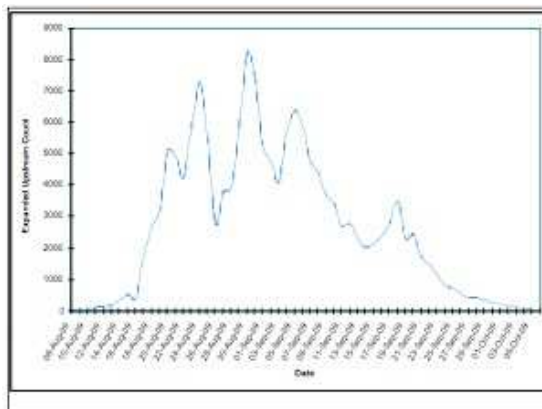- Any downstream fish were moribund chinook

Results: How Many Sox?
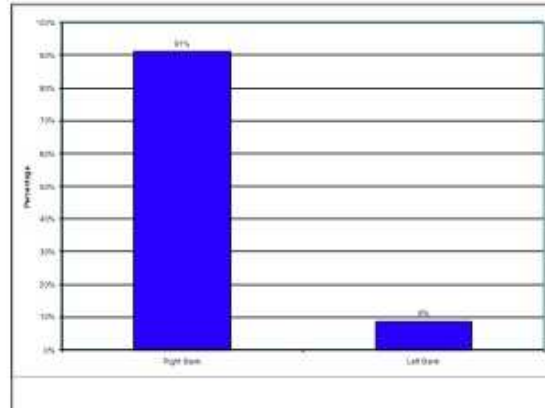
- 157,541 ± 14,447 (± 9.5%)
- 95% CI
- Compare to Preliminary Estimate of
  - Area total: 149,467
  - Horsefly: 82,383 (55%)
  - Mitchell: 46,065 (31%)
  - Quesnel Lake: 21,019 (14%)

Migration Period

- August 8 to September 28
- Daily peak of 8,262 on August 30th
- 50% date of September 1st
- 91% sockeye passage on right bank
- 59% of sockeye during daylight hours

Collaboration

- UFFCA: Project Management, Administration, Technical
- NSTC: Technicians/Logistics
- DFO: Science Lead - Project Supervision/Analysis
- FSWP: Funding and "make it work attitude"

Summary

- Overall the feasibility study was successful
  - Site selection: generally happy - needs a bit of tweaking
  - Sockeye migration is shore oriented
  - Milling and/or downstream movement of sockeye is almost nonexistent
  - Species comp doesn't seem to be an issue
  - Installation of small weirs require little effort and the impact on migrating and resident fish is minimal
  - On budget!
  - Great Team to work with
  - Need a high precision comparison.....2010?

Shout-Outs!

- UFFCA: Brian Toth, Marcel Shepert, Me
- NSTC: Gord Sterritt, Charlotte Morrow, Cheryl Meshue
- DFO: Paul Welch, Tanya Vivian, Keri Benner, Timber Whitehouse, Brian Leaf
- FSWP: Deana Machin, Saul Milne
- QRRC: Rick Holmes and staff
- Landowner: Pat Baron

Finally...

- The End