FINAL REPORT

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MULTI-SPECIES MIGRATION AND IMPROVED ESCAPEMENT ENUMERATION

COWICHAN RIVER DIDSON PROJECT

by

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ABSTRACT

Dual Identification Sonar (DIDSON) has been used in recent years to enumerate adult salmon migrating through freshwater upstream to their spawning grounds. In most projects there is only one species involved, or if there are more than one species present they can be separated easily by diurnal or physical attributes. In this project we attempted to enumerate three species of salmon that have overlapping migration timing in a coastal river using the DIDSON sonar unit.

A DIDSON unit was installed at a location in the lower Cowichan River that was situated below all chinook and most coho and chum salmon spawning areas. The unit was operated from 18-Sep-2006 until 14-Dec-06, with the exception of several short periods. The unit was moved within the site several times as the water level increased.

A seine crew from the Cowichan Hatchery provided species identification through their fishing efforts from broodstock collection and migration assistance, which was necessary due to the low water levels during October. This operation was discontinued in early November when fall storm events resulted in unsafe fishing conditions.

Several issues were considered when separating the target count into species. First, there were numerous small targets recorded on the DIDSON that were not represented in the seining data. These were assumed to be precocious (“jack”) coho and sea-run trout and were not included in the target count when applying the seine results. Second, as the water level increased, the DIDSON was no longer able to monitor the entire width of the river, requiring variation in monitoring techniques and coverage. This resulted in expanding the target counts to account for missed coverage. Third, as the hourly rate of migration increased, we had to discontinue reviewing the entire recording and only review a portion of each hour period. These counts were expanding to the full hour.

Over the sampling period 175,000 fish were estimated to have migrated upstream past the DIDSON unit site. These were divided into adult chinook (1,800 of ± 550), jack chinook (3,400 ± 700, adult coho (10,000 ± 2,400), chum (155,000 ± 5,000), and unassigned (approximately 5,000). The results were compared to standard DFO estimates (1040 adult chinook, 428 jack chinook, 2500 adult coho), which were adjusted from the whole system escapement estimate for broodstock and freshwater fishing removals from downstream of the DIDSON site. There was no standard chum escapement estimate for 2006.

The DIDSON results were significantly higher than the standard estimates. There are several possible contributing factors to this variation including incorrect species separation and incorrect assumptions used for target count expansion for periods when the data was not complete or reviewed.

INTRODUCTION

Background

In the fall of 1988, a study was implemented on Cowichan River chinook with additional information collected from the Squamish and Nanaimo River stocks. These three stocks within the framework of the Pacific Salmon Treaty between Canada and the United States were identified as exploitation and escapement indicators and deemed to represent the status of all lower Georgia Strait chinook stocks. Since then, due to logistical reasons the Squamish River system was dropped as an indicator and in 2002 the Nanaimo River system was dropped as well (Nagtegaal et al., 2004). Chinook assessment activities are ongoing on the Cowichan River.

Chinook escapement is assessed using a fixed point counting fence which is located approximately 8.3 kilometres upstream of the estuary. This location is below all known chinook spawning areas. The fence can be operated at summer low flows but must be removed when flows reach 22 cubic metres per second. This generally coincides with fall storm events and if this occurs earlier than normal then not all chinook spawners will be enumerated. In these situations the population would be estimated using a mark-recapture method.

Estimates for coho and chum cannot be obtained with this fence. Generally, most chum and coho have not entered the system before the fence is removed and must be estimated using difference methods. Coho salmon are estimated by obtaining Area-under-the-curve estimates on selected spawning areas and expanding that data to the whole system. Chum salmon are estimated from one to two aerial surveys. In the last three years these surveys have not been feasible due to very high sediment loads in the river from Stoltz slide upstream of Duncan.

DIDSON systems have been used since the late 1990's on a number of river systems in the Pacific Northwest and have proved to be an effective tool for obtaining escapement counts on river systems that are difficult to assess using any of the more established enumeration techniques such as stream surveys, counting fences and mark recapture.

The application of DIDSON technology provides a possible solution to the on going problem of obtaining reliable escapement estimates for salmon returning to the Cowichan River, especially chum for which no estimate has been possible for several years.

Project Goals

The goal of this project was to obtain an estimate of the number of each species of salmon returning to the Cowichan River system and attempt to identify the species composition of the targets enumerated by the DIDSON. These estimates will be compared to those obtained by more conventional/traditional stock assessment techniques such as the chinook enumeration fence, chum aerial surveys, and coho spawning ground surveys. This will provide an assessment of the feasibility/applicability in using DIDSON technology to obtain escapement estimates of salmon returning to the Cowichan River.

Study Area

The Cowichan River watershed is located on the Southeast coast of Vancouver Island and drains an area totalling 826 km^2 (Figure 1). The Cowichan River system includes Cowichan, Bear, Mesachie, Somenos, and Quamichan lakes. Cowichan Lake (62 km^2), the largest of the five lakes, is situated approximately 50 km west of the Cowichan Bay estuary. Discharge from a flow control dam situated at the outlet of Cowichan Lake ranges from 7 to 326 m^3/s, and averages 44.9 m^3/s (Fielden and Holtby 1987). A total of 26 tributaries drain into the Cowichan River. The largest of these is the Koksilah River, which intersects the mainstem of the Cowichan River approximately 2.5 km upstream of the estuary. The Cowichan River watershed system is a typical Vancouver Island and coastal British Columbia stream in which maximum flows occur during winter months due to heavy rainfall (McDougall 1985).

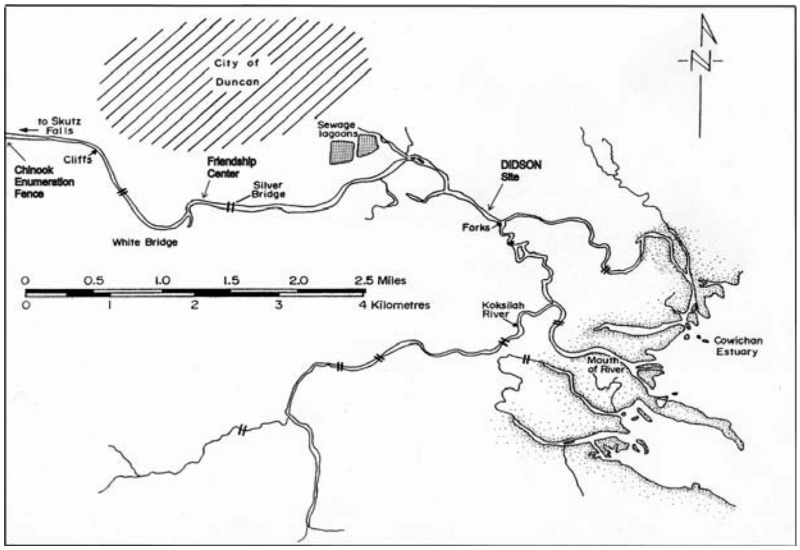

Figure 1. Lower Cowichan River

The Cowichan River supports many salmonid species including chinook (*Oncorhynchus tshawytscha*), coho (*Oncorhynchus kisutch*), chum (*Oncorhynchus keta*), sockeye (*Oncorhynchus nerka*), and pink (*Oncorhynchus gorbuscha*) salmon; as well as cutthroat trout (*Oncorhynchus clarki*), steelhead trout (*Oncorhynchus mykiss*), kokanee salmon (*Oncorhynchus nerka*), and dolly varden char (*Salvelinus malma*). Attempts have been made to introduce several other species including: atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*), and brook trout (*Salvelinus fontinalis*) (Perrin et al. 1988). The salmonids of the Cowichan River support several vital fisheries, which include a First Nations food fishery, tidal sport fishery, and a commercial ocean fishery.

METHODS

Equipment

The sonar unit used in this study is a dual-frequency identification sonar (DIDSON) model Unibody Standard with 1.1 and 1.8 MHz operating frequency settings, manufactured by Sound Metrics Corporation (2810 Hudson St., Chesapeake, VA). This technology was originally developed for the US Navy by the Applied Physics Laboratory at the University of Washington.

The DIDSON uses multiple beams of sound scanning across the river to form a near video quality real time image of all underwater features (Cronkite et al. 2005). The standard model used in this project can be set to high frequency (1.8 MHz) or low frequency (1.1MHz) and has a field of view 29^o wide and 12^o in height. The high frequency mode uses 96 separate sonar beams with an adjustable horizontal "window" length of 10m. It can image targets out to 15 m if the window is set to start at 5 m from the transducer. In this mode the resolution ranges from 3 mm close to the transducer up to 30 mm at the maximum range of 15 m. This is sufficient resolution to easily differentiate targets such as small fish and moving debris within the field of view. The low frequency mode use only 48 beams but has a greater horizontal window length of 20m and a maximum range of 40m. However, the lower resolution of this setting reduces the accuracy of target identification and smaller fish can be lost in the background noise.

The image built from the sonar returns can be displayed at frame rates ranging from 1 to 12 per second and shows a top down view of the segment of river covered by the field of view. Fish moving through this area can be counted in real time, and the data files can be saved electronically so they can be reviewed at a later time. The image forming capabilities are generally not affected to any extent by varying sediment loads or turbulence in the water column although at the low frequency setting a reduction in target definition can be noted at extreme range.

The DIDSON was controlled with a Toshiba Satellite 1900 laptop computer. It was connected to the sonar unit via a 60m waterproof cable that provided a network link and power to the sonar unit. The operating software used to control the sonar, display real time images, record and playback the data is provided with the DIDSON by Sound Metrics Corporation. The sonar could generate up to 19 GB of data a day, depending on settings such as frame rate, range etc. This data was continually recorded to an external 250 GB hard drive connected via USB 2.0 to the laptop. Three separate hard drives were used so that data could be periodically transferred to longer term storage at the Nanaimo DFO office. A second laptop at the sonar site was used by site personnel to review data from these external drives. The use of a second computer was necessary as recorded data could not be reviewed with the primary laptop while it was controlling the DIDSON.

Power for the system was supplied by two deep cycle S-460 6 volt batteries (Surrette Battery Company, Springhill, Nova Scotia) connected in series to a Cotek 600 watt inverter. The batteries were charged using a Xantrex TrueCharge 40amp charger and a 1500 watt Honda generator. The generator only needed to be run twice a day for approximately 4 hours at a time to maintain adequate charge in the batteries.

A 2 m by 2 m plastic garden shed (Royal Yard Mate) mounted on a flat bed trailer was used as a field office for the duration of the project. This was used to house the computers and power supply system and to provide shelter for the personnel who were required to be on site at all times for system monitoring and security.

Figure 2. DIDSON ladder mount

The DIDSON was mounted on a pole attached to a modified aluminium step-ladder (Enzenhofer and Cronkite, 2005). The ladder was placed in the river at a depth of about 0.5 m approximately 6 m from the waters edge. It was anchored in place with six stainless steel pins hammered into the substrate and clamped to the ladder (Figure 2). This left a gap of approximately 12 m to the far bank that could be adequately covered by the sonar beam. There was sufficient height and angle adjustment in the attachment mechanism to compensate for moderate daily fluctuations in water level.

A diversion fence was constructed on the downstream side of the unit to direct salmon into the field of view (Figure 3). The fence was built with four sections constructed with 2 by 4 frames 2 m long by 1 m high. The frames were braced on the corners with plywood gussets and covered with plastic Vexar fencing (2 cm mesh). The fence sections were anchored to the river substrate with re-bar pins and wood back braces.

Figure 3. DIDSON ladder and diversion weir

The advantage of using this design of fence and DIDSON mount was the flexibility it allowed for rapidly repositioning the sonar in the event of rising water levels or if the chosen site proved to be inadequate for some unforeseen reason. As part of the objectives for this project was to test the suitability of this technology and the potential of the sites chosen for a longer term enumeration program it was important to use a temporary instillation that could be easily relocated if necessary.

Site Selection

Successful deployment of a DIDSON requires a site with specific characteristics related to the inherent limitations of sonar use in a riverine environment and the behaviour of migrating fish. These characteristics have been outlined in Enzenhofer and Cronkite (2000), and ideally should include:

- Single channel so that fish are not able to by-pass the DIDSON;
- Adequate flow to discourage milling or holding behaviour of the salmon within the ensonified area;
- Planar bottom configuration. Complex bottom morphology such as shelves, hollows, gravel bars etc. will create shadowed areas in which fish would be masked;
- Substrate free of obstructions such as logs and boulders behind which salmon would be hidden;
- Fish actively migrating through the site;
- Downstream of known spawning areas to obtain as complete as possible escapement estimate;

- Minimal human activity as this can affect fish behaviour;
- Good access to site for set-up and maintaining DIDSON equipment.

Several sites were considered for deployment of the DIDSON (Figure 1). In the original proposal the Pumphouse site was suggested so the sonar could be run in conjunction with the chinook enumeration fence. This would have provided species composition information at least for the period covered by the fence operation. Although this site is downstream of known chinook and most coho spawning areas, it is above the majority of the chum spawning in most years.

Three other locations were considered. First was the Cowichan Tribes Friendship Centre in the City of Duncan approximately 5.5 km upstream. Although the site characteristics fitted with most of the requirements listed above, it was still upstream of the majority of the chum spawning and even at low water was over 30 m wide. This would result in incomplete sonar coverage or the installation of a more substantial diversion fence and the increased problems of maintenance during higher water flow. The next site under consideration was immediately above a fork in the main channel approximately 2.0 km upstream from the estuary. Although below most of the chum spawning areas this site is primarily a large back-eddy and even at summer river flows was, at 3 m, a little too deep. The likelihood of fish milling in the ensonified area was also considered to be potential problem. The site eventually chosen for the DIDSON is 300 m upstream of the forks. It was considered to have the best potential with an ideal bottom profile, good vehicle access and still downstream of the majority of the chum spawning habitat. At summer low flows the wetted area was only 18 m wide and approximately 1.0 m deep in the thalweg. This location consisted primarily of a wide gradually slopping gravel bar and it would therefore be relatively simple to reposition the DIDSON assembly as water levels increased through the sampling period. Appendix 1 is a comparison of the site characteristics.

Data collection

The objective was to record sonar data 24 hours a day, seven days a week, excluding downtime from the occasional technical issues and flooding situations. This was considered to be the best course of action as run timing and diurnal fluctuations in migration for the three species of salmon was not fully known at the beginning of the project. The DIDSON operating system was set to record data in 15 minute files making it easier to manage the 19 GB of data generated each day. The files are automatically named with the date, time and type (low or high frequency) of data they contain. File size was dependent on the frequency setting and the number of frames per second (fps) being used. All of the Cowichan data was recorded at 5 fps as this gave the

Figure 4. DIDSON redeployment - 150 m^3/s flow

best compromise of sufficient detail for any faster moving fish, especially in the close range narrow part of the sonar beam but limited the individual file sizes to manageable 240 MB.

Unusually extreme flood conditions were experienced from the beginning of November onwards resulting in the DIDSON first being shut down and removed from the river for five days then re-deployed on the river bank on 9th November (Figure 4). Water flows did not drop below 100cms (normal winter flood levels) for the remainder of the project resulting in a bank to bank wetted width of over 45 m (Figure 5). As this distance is too

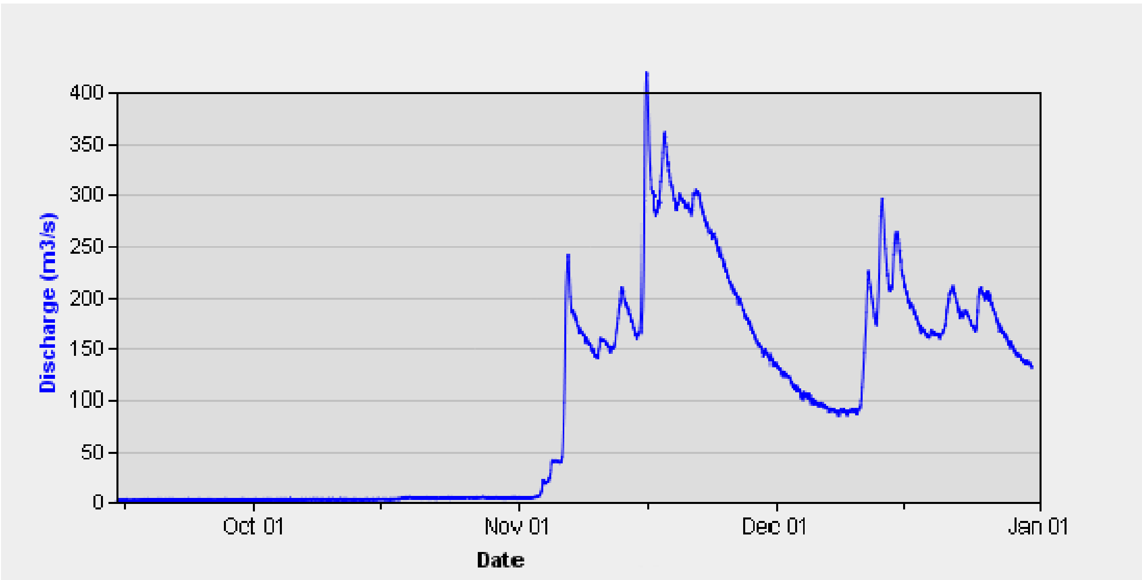

Figure 5. Cowichan Water Flow

large to be fully covered by the DIDSON, a variety of different settings were tried. Initially low frequency mode was used with a field of view from 1.7 m out to 21 m, providing coverage of about 40% of the river. On 12th November range switching was initiated with the first 15 minutes of each hour using the initial 20 m field of view, then for the next 15 minutes the DIDSON switched to a view starting at 18 m and going out to 38 m. This cycle was repeated giving two 15 minute files with short range data and two with longer range data for every hour. This provided a “theoretical” coverage of approximately 75% of the flooded river width.

Data review over the following 12 days revealed that the vast majority of targets were moving upstream within 10 m of the bank and that due to the drop in resolution when using low frequency a more realistic maximum range for target identification was only about 30 m. It was therefore decided to switch back to high frequency with a range of 1.7 m to 11. 7 m for the first 15 minutes then low frequency covering 11 m to 31 m for the second 15 minute period. These setting provided the best combination of high resolution close to the bank where the majority of the fish activity occurred but with adequate coverage of over half of the river to monitor for any future changes in fish migration behaviour. Table 1 summarizes the settings used over the season.

Target enumeration
Recorded data was reviewed five days a week by field staff using the second laptop computer. In the early days 24 hours of recorded data took approximately 5 hours to review. As expected more time was required to review data as increasing numbers of salmon moved into the river and from late October onwards only the first 30 minutes of every hour were counted. Target counts were recorded on data sheets and later entered into a spreadsheet for further analysis and compilation.

Generally, when the data files were being reviewed the information was played back at 15 to 40 fps, or four to eight times faster than the recorded speed. This rate was slowed down at times when target activity was high, primarily during the peak of the chum migration. During these periods there were 20 to 30 spawning chum holding within the field of view with newly arriving fish migrating upstream through them. During exceptionally busy periods the low frequency data files were reviewed twice, using the zoom function to display only half of the 20 m window length at a time.

Target Count Expansions
At the start of the project all of the recorded data was reviewed to better understand any diurnal fluctuations in numbers of migrating salmon. As the numbers of migrating salmon increased the target review procedure was changed to reviewing only the first thirty minutes of each hour. The resulting data were expanded to provide full hour estimates. Previous work by Cronkite et al. 2006, indicated that reviewing 10 minutes and 20 minutes per hour were ± 10% and 5% respectively from a full hour count.

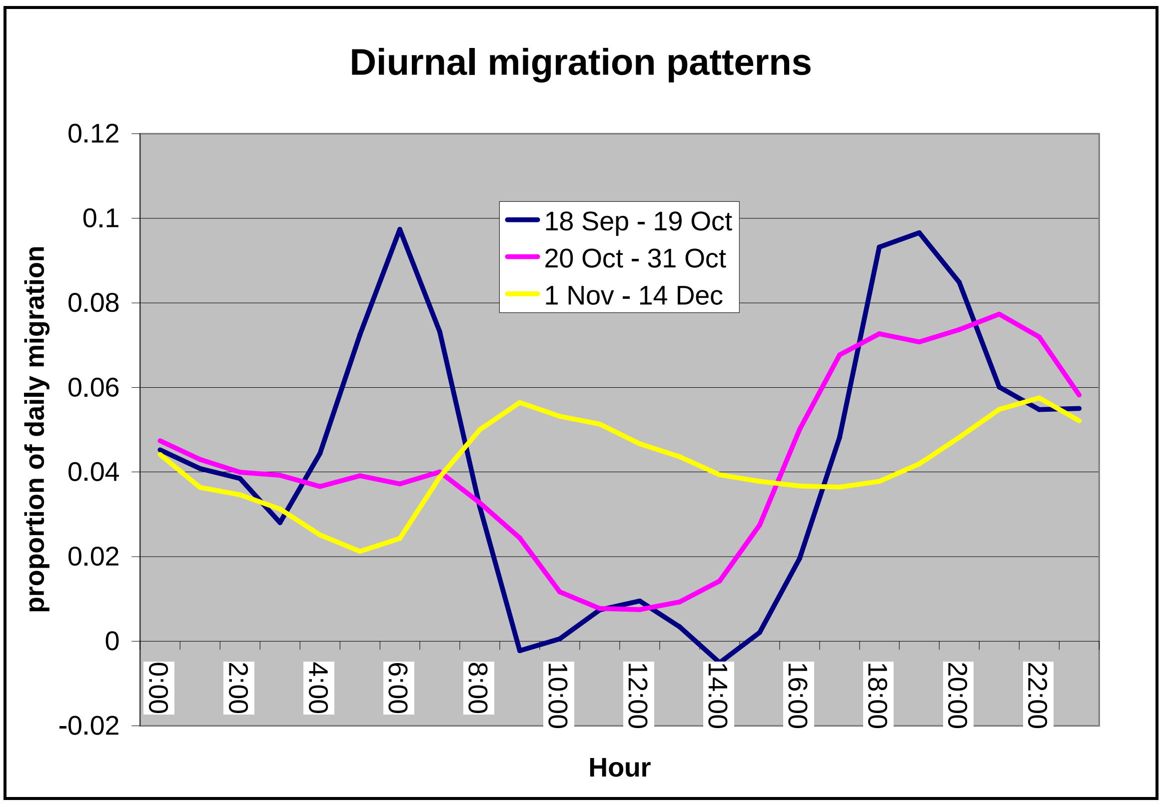

Figure 6. Diurnal migration pattern

Some days do not have target counts for every hour due to time constraints for data reviewing and periods when the DIDSON was shut down. In this situation the available hourly counts were expanded to provide an estimate for the full 24 hour period. These expansions were adjusted for diurnal variation in the number of fish moving past the DIDSON. As this pattern of variation changed over the course of the project three different models were used for the expansions. These covered the periods; 18th September to 19th October, 20th to 31st October and 1st November to 14th December (Figure 6). Eight to ten representative days with complete counts were used from each of these three periods to derive an average hourly proportion of targets moving through the site. Any extrapolated hourly counts were then weighted according to the average proportion of daily targets for that time of day. This expansion for the missing data more accurately reflects the typical migration patterns observed over the periods in question.

When the DIDSON was re-located to the river bank on 9th November it was switched to low frequency giving the sonar a window length of 20 m with a field of view out to 22 m. This placed the far side of the river out of range of the DIDSON. We assumed that similar numbers of salmon would be migrating upstream along the far bank therefore target counts were doubled to provide a full river estimate.

On 12th November when range switching on the DIDSON was initiated the first two 15 minute files being reviewed now covered different sections of the river channel. Therefore each of the 15 minute target counts was expanded by four times to provide full hour estimates of fish passage in the half of the river channel being observed with the sonar. This hourly estimate was then doubled to provide a total estimate of targets for the full river width. This pattern of recording and data analysis was maintained for remainder of the project. On 24th November we started using the high frequency setting on the near range recording.

Target Size

The need to differentiate targets in to small and large was only necessary in September through to mid October when groups of fish approximately 30 cm or smaller were observed migrating upstream around dawn and dusk. These schools of fish may have been migrating sea-run cutthroat trout or possible early returns of coho jacks. These fish were not caught in the beach seines therefore it is not possible to determine their species.

Only targets that were 39 cm or larger were used in the DIDSON escapement estimates. Targets less than 39 cm in length were considered to be species other than chinook adults, chinook jacks, coho adults and chum. This lower limit was derived from aged chinook jack broodstock sampled at Cowichan Hatchery.

Species composition

Species composition was estimated from beach seining above and below the DIDSON site during September and October. This work was done by the broodstock collection crew from the Cowichan River hatchery. Just prior to the first flood event target numbers started to increase considerably with the onset of the chum return. No further beach seining was possible with the high water levels that persisted through to the end of the project and we were unable to use this means to determine species composition. Attempts were made using other methods to determine species composition during the flood period but these were unsuccessful.

The species composition was summarized by stat week, except for week 10-4 and 11-1. During these two weeks the species composition was rapidly changing as the number of chum salmon increased. This period was divided into four sub-weeks, each consisting of similar numbers of targets moving per day.

Escapement estimates
The escapement estimate from the DIDSON data was estimated by taking the target count by stat week, deducting the number of small targets, and applying the species composition to that number. The results were summed over the entire season to provide an estimate. The 95% confidence interval for each stat week estimate was calculated using the formula (from Fowler et al.1999):

$$1.96 * \sqrt{\frac{p(1-p)}{(n-1)}} \text{, where}$$

p is the proportion of each species and *n* is the number of individuals used in the calculation. The confidence interval for the total is the summation of the stat week intervals.

The DIDSON estimates will be compared to the escapement estimates that are derived using standard DFO escapement models and formulae. The chinook escapement is estimated using the counting. Broodstock collection and First Nations catch are added to this total to estimate the freshwater escapement. In addition, a swim count was conducted between the fence and the DIDSON site on 26th October when the fence was removed and this count was included as well. Coho are estimated using Area-Under-the-Curve (AUC) estimates from standard reaches in the watershed, then expanding those counts using a distributional model. Chum are estimated using periodic aerial surveys, but this method has not been available for the last three years due to the turbid conditions of the river.

RESULTS

Weather and water levels
Water level in the Cowichan River is normally maintained at 7 m^3/s. In 2006 a large scale restoration project was carried out in the Stoltz slide area. One result from this project was a purposeful decrease of the water flow to 4.5 m^3/s. The expectation was that late summer and early fall rain events would allow the water system to discharge a normal 7 m^3/s. Unfortunately this did not occur. The low water levels continued until the first fall storm event on 3rd November. A series of storm events followed and flow rates continued to climb peaking at close to 250cms on 6th November (Figure 5). Water flow peaked at 420 m^3/s on 15th November.

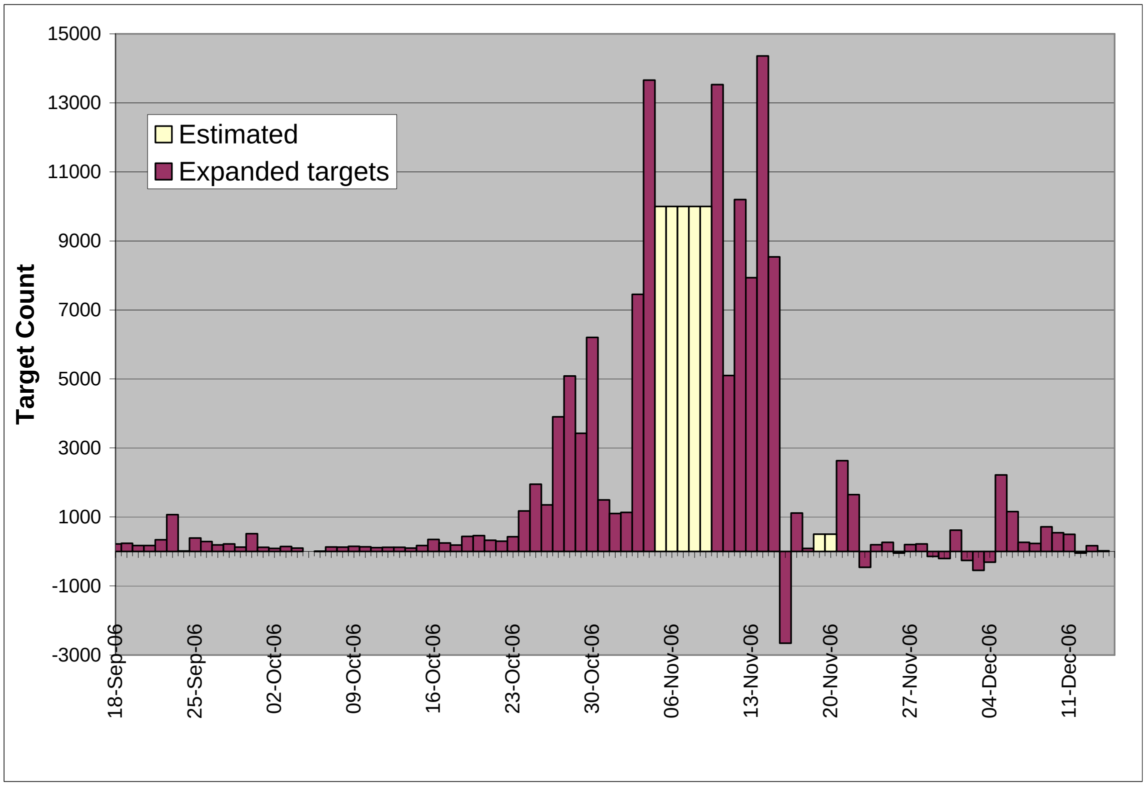

Figure 7. Daily net count of targets

Target Counts

The final estimate for expanded net upstream targets from the DIDSON data is 175,000 (Figure 7, Table 2). The majority (70%) of these targets moved through the study site between the 3rd and 15th November during the peak of the chum migration. This also coincided with the first of the fall storms and therefore includes the five days during which the sonar was removed from the river. An estimate of 10,000 upstream targets was used for each of these five days when the system was shut down. This estimate was derived from the average of the eight daily counts that were available for this 13 day period between 3rd and 15th November.

The diurnal variations observed in the hourly counts displayed a distinct bimodal pattern during the 18th September to 19th October period of the project (Figure 6). These peaks accounted for approximately 50% of the total daily count and occurred around 06:00 and 18:00. There was also very little net upstream movement of fish during daylight hours. For the middle period up to 31st October the early morning peak disappeared and daily counts were dominated by a single broader peak around 19:00 hours when approximately 36% of the daily count moved upstream. Day time movement during this period remained minimal. For the last period to 14th December hourly net upstream counts become somewhat bimodal again although less distinct than the pattern noted in the early part of the project. There was no obvious reduction in the net upstream movement during the day noted in the first two periods. The peaks had also shifted to 09:00 and 22:00 and now only accounted for approximately 32% of the daily count.

Target Size

Target size composition was examined for the stat weeks 9-4 and 10-1 and results from subsequent data are pending. The proportion of the targets that were greater than 39 cm was 44% and 39%, respectively for these two weeks. The proportion of large targets for the rest of the data were assumed to be 55%, 70%, and 85% for Stat weeks 10-2, 10-3 and 10-4A, then 100% for the remainder of the study period.

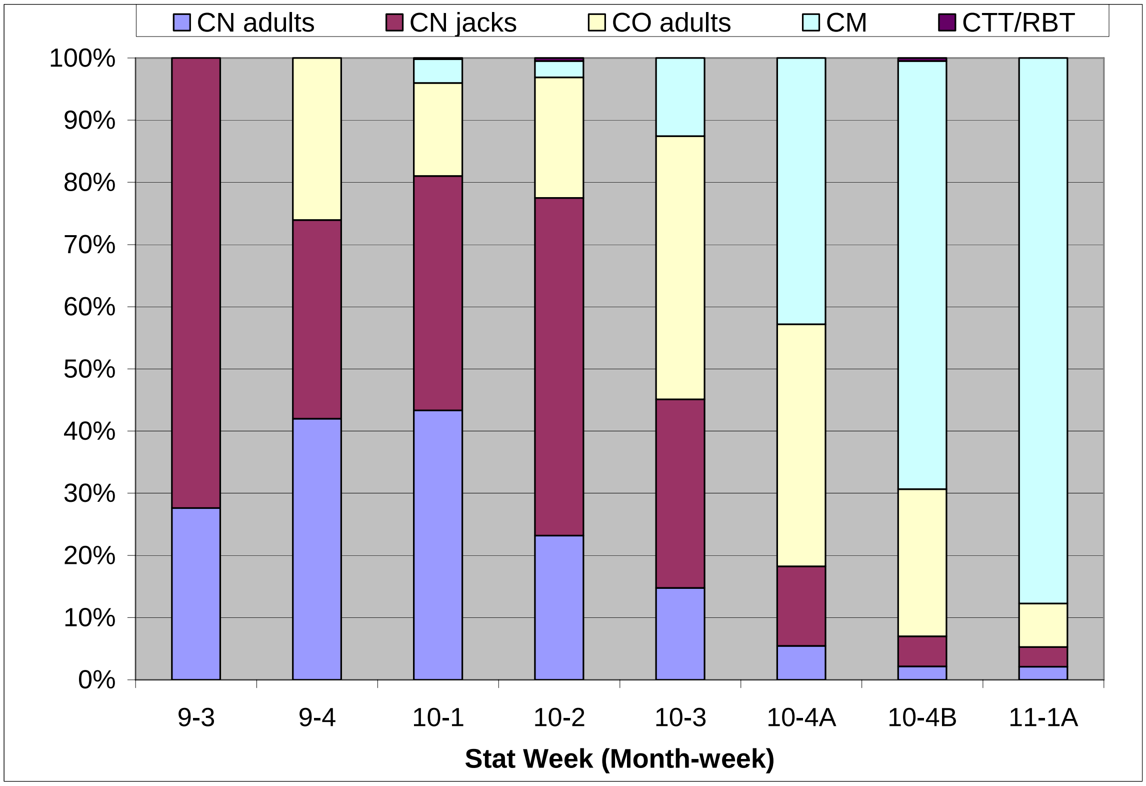

Figure 8. Species Composition by Stat Week

Species Composition

Species composition estimates are presented by stat week in Table 3 and Figure 8. Chinook jacks and adults comprised 100% of the fish caught in the first week of beach seining. Coho started to show up by the late September, comprising 26% of the catch in stat week 9-4. This composition of chinook and coho continued through September and October although with a steady decline in the percentage of chinook throughout the later month. Chum were first caught in stat week 10-1, however they remained a small percentage of the total until the last week in October when numbers began to rapidly increase. By the beginning of stat week 11-1 when the last beach seine sets were made, chum comprised 88% of the fish being caught.

The increased water level in early November when beach seining could not be safely attempted coincided with the increase in chum migration to levels that were substantially higher than the coho and chinook levels. Consequently we were unable to examine the species composition from this point until the end of the migration season therefore we made the following assumptions:

Chinook: migration had ended during Stat week 11-1A (2% adult CN and 3 % jack CN) and the species composition was 0% thereafter.

Coho: migration continued until the end of the sample period with a increase in number during the initial flood events. 5% was assumed for Stat week 11-1B and 1% thereafter.

Chum: migration continued until the end of the sample period and comprised the remnant of the species composition. 95% was assumed for Stat week 11-1B and 99% thereafter.

DIDSON Escapement Estimates

Table 3 also shows the escapement estimate and the process from target count through species composition and the final estimates, rounded to two significant digits.

The adult chinook escapement estimate produced by the DIDSON is 1,800 with a 95% confidence interval of $\pm$ 550. The chinook jack estimate is 3,400 with a 95% confidence interval of $\pm$ 700.

The coho escapement estimate produced by the DIDSON is 10,000 with a 95% confidence interval of $\pm$ 2,400.

The chum escapement estimate produced by the DIDSON is 155,000 with a 95% confidence interval of $\pm$ 5,000. `

Comparison to Standard DFO Estimates

The chinook freshwater escapement estimate for the Cowichan using standard DFO stock assessment techniques is 2,165 adults and 885 jacks. These numbers are derived from the enumeration fence counts, broodstock collection, trap and truck program and First Nations in-river fishery. 791 adult and 441 jack chinook were removed by the Hatchery crew and an estimated 334 adult and 16 jack chinook were caught by fishers from below the DIDSON site and therefore have to be subtracted from the standard estimate before it can be compared to the DIDSON data. This makes the comparable standard estimate 1040 adults and 428 jacks.

The conventional estimate for coho escapement is 2500 adults. In 2006 we were unable to use the upper Cowichan River mainstem reach as part of the estimate due to the high water. This estimate is based on results from 14.9% of the spawning population. Freshwater removals from the river have taken place prior to the enumeration so they do not have to be factored in.

There is no standard estimate to compare the DIDSON chum result to as aerial surveys have not been possible for the last four years due to the turbid water conditions. The chinook enumeration fence cannot provide any kind of estimate as it is generally removed before the majority of the chum have entered the system and it is upstream of the primary spawning areas. No comparison with escapement estimates from conventional DFO stock assessment methods is possible. Conversely the application of the DIDSON technology has provided an estimate that would normally not have been possible to obtain.

DISCUSSION

Results Comparison

There is significant discrepancy between the DIDSON escapement estimate of chinook adults and jacks and coho adults from those derived from standard estimate methods. This discrepancy could be attributed to a number of different factors causing error in the standard methods, the DIDSON estimate or both.

Possible errors with traditional enumeration

Incomplete fence count: It is possible that the enumeration fence count is low due to chinook bypassing the structure. Although there were some minor issues with the fence panels in the first week or so of operation this is unlikely to be a significant source of error as the fence is manned 24 hours a day and water conditions were low and clear for the full period of operation. Any significant by-pass of the fence trap box would have been noticed by the crew.

Hatchery crew data inconsistencies: There were some errors in the chinook broodstock collection data when beach seining took place, but again it is extremely unlikely that it could contribute to any significant underestimate of numbers of fish handled. Broodstock numbers are definitive by the end of gamete collection when all salmon are noted.

Freshwater fishery estimate: Chinook and coho creel survey data is collected by the First Nations Fisheries Guardians who also perform regular patrols for regulation enforcement. These personnel do an excellent job with good coverage of the lower river and although the final estimates of First Nation catch could have some error it is not likely to be significant. It is unlikely that any significant levels of poaching occurred in 2006 as reports of individuals caught fishing during closures from both the Cowichan Tribes Fisheries Guardians and DFO C&P staff was lower than in previous years.

Coho Escapement model: We were unable to obtain an estimate of the coho spawners in the upper Cowichan mainstem reach, which represents 45% of the escapement. The reaches that were used represent 14.9% of the escapement. There are a number of assumptions in the spawner distributional model that is used to expand the reach estimates that could affect the true number of coho spawners. There has been no evidence, however, that major shifts to the spawning ground preferences that would significantly alter the model.

Pre-spawn mortality: Finally, no significant occurrences of pre-spawn mortality in river sections below the enumeration fence were observed by the beach seine crews, Fisheries Guardians or DIDSON personnel.

Possible errors with the DIDSON estimates

Time and budget constraints limited the amount of verification that was done with the reviewed files, but those that were repeated did not have any significant inaccuracies.

Data Expansion: Several types of expansion were applied to the raw counts. First, expansions to full hour estimates based on 15 and 30 minute reviews. Second, when the DIDSON unit was moved to the bank of the river, only half of the area was in view, resulting in a doubling of the counts. Third, there was expansion for any hours with no counts. These expansions took into account the diurnal variation observed during similar migration periods. The final expansion covered whole days when no data was available.

For these periods the daily target count was interpolated from data from prior to and after the missing time.

Target size: The total target count contains a group of fish that was not represented in the species composition data and the unknown small length group has to be separated from the large length group. This separation is not complete and represents a source of error in the magnitude of the target count. There may be errors with the measuring technique that would bias the length frequency distribution of the targets.

We have assumed that the targets that are larger than 39 cm are comprised of the species represented in the beach seine catches, but have not included coho jacks. Very few were caught in the beach seining, but some of these larger targets would have been coho jacks.

Species Composition: Another source of error is with the species composition ratios derived from the beach seining. Although this method of determining chinook and coho composition was reasonable for September and most of October, the chance of error would have increased with the arrival of large numbers of chum at the end of October. The chinook estimate for the period of 27th to 30th October (stat week 10-4A in Figure 8.) accounts for 402 (23%) and 897 (27%) of the total DIDSON adult and jack escapement, respectively. The chinook ratio of targets is based on only tow beach seine sets, one each on 27th and 29th October. This was during a period when the numbers and ratios of salmon species entering the river were rapidly changing with the onset of the chum migration. A total of 413 salmon were caught in these three sets but only 9 were adult chinook and 20 jacks. It is possible these jacks and adults were just the remnant of the chinook migration holding in this pool rather than a representative proportion of the newly arriving salmon. If this were the case then using these chinook as representative of the species ratio in the rapidly increasing numbers of targets moving upstream past the DIDSON would be misleading, resulting in an inflated chinook estimate.

Errors in the species composition assumptions after Stat week 11-1B would have a relatively minor effect on the chum estimate but as we assumed the coho and chinook comprised very small components of the number of targets, any errors would have large relative changes to the estimated escapements.

No comparison for chum was possible as there is no standard estimate available because aerial surveys have not been possible for the last four years. However, this project has demonstrated that the DIDSON is capable of provided an estimate under extreme flood conditions and that in a more typical year with consistent temporal coverage accuracy and precision of the final chum estimate could be increased.

Possible Solutions

The main problem encountered during this project is the determination of species composition for target counts during high water. This will likely not affect the chum estimate as they comprised the vast majority of targets, or the chinook migration which occurred during the early period when reasonable beach seining data was collected. However, lack of species composition data does impact the coho estimate for which a small adjustments in the percentage will result in a large changes to the final estimate. It is not certain if the DIDSON technology will be able to provide a reasonable coho escapement estimate in the Cowichan River except for some years when the river remains low enough to continue beach seining operations through November.

The second problem with the DIDSON escapement estimates concerns the last third of the run when an increasing proportion of the downstream targets are spawned-out fish that have already been counted. This downstream movement will to a certain extent mask the declining numbers of fish still migrating upstream. Visual observation of fish moving downstream should be used to determine the proportion of moribund post-spawners to pre-spawn fish (Ref. Cronkite et al. 2006), however, zero visibility in the river from November onwards prevented this. Consequently, target counts for late November and into December provide a conservative escapement estimate as it is comprised of upstream minus downstream target counts.

Time constraints were encountered with regard to data review resulting in some periods for which data was collected but has not yet been reviewed. To a large extent this was a result of initially attempting to review complete hours rather than expand sub-samples of the sonar data. We now have a better idea of migration patterns and behaviour and can therefore make better use of the field personnel's time by adopting the sub-sampling protocols suggested by Cronkite et al 2006.

The biggest gap in the data set is during the five days when the first storm event occurred and the DIDSON was removed from the river. In retrospect we could have almost immediately installed the DIDSON on the river bank therefore obtaining half-river counts during much of the critical period when chum and coho migration was peaking. This type of data loss could therefore be avoided in the future.

The First Nation in-river chinook fishery taking place throughout the lower river did not prove to be an issue with regard to keeping track of discrete upstream and downstream target movement. Although there were periods during the fishery openings when human activity resulted in fish moving repeatedly up and down through the ensonified area it was not a problem keeping track of this movement. Similarly it was thought that any fish holding or milling within the field of view might create difficulties with maintaining accurate net upstream target counts (George Cronkite pers com.). Although there were 20 to 30 chum holding and spawning within the field of view for much of early November, it was still possible to track and count the individuals moving up or downstream. This increased target activity did slow down the review process as files had to be replayed at a slower 10 to 15 fps.

Recommended Improvements

The site selected for the 2006 project worked well in fulfilling the primary requirement for deployment of a DIDSON as listed in the methods section above. River conditions experienced during flood situations were underestimated for this site and it is recommended that a small bulkhead be constructed on the bank ten meters upstream of the location used in 2006. This would provide a more secure foundation on which to mount the DIDSON during high water events giving greater protection from damage by debris carried in the water and blocking the movement of any fish behind the transducer.

Providing BC Hydro power supply to the site is highly recommended. This would deliver an increased level of reliability to the operation of the DIDSON as the majority of the technical issues causing data loss were due to temporary power failures in the battery based power system used in 2006. Safety and security of the site and night-watch personnel would also be improved as better lighting could be installed as well as a phone line. The latter could also be used for remote monitoring of the DIDSON operation enabling issues such as system freezes and transducer aiming problems to be detected more timely. High speed data transfer to and from the site may also be an option which would improve management of the huge amount of data generated by the DIDSON.

There were some problems with timely review of data especially in the first half of the project. This can mostly be alleviated by reviewing only 30 minutes of every hour, or possibly less when levels of target activity increase during the chum migration peak. This would then provide a more consistent set of data reducing the amount of extrapolation required for missing hourly counts.

Target species separation for all sizes was a major focus of this project and is still an issue. We believe that the beach seining was sufficient to determine species composition of the larger salmon groups, and will continue to review the recorded information to resolve the deficiencies with the small and medium targets and the species composition in the elevated water level period.

CONCLUSION

The purpose of this project was to examine whether a DIDSON unit could be used to obtain escapement estimates for multiple salmon species. The approach we took was to compare the results obtained from this project to the results from standard estimates techniques. For chinook adults and jacks, and coho adults the DIDSON estimates were not consistent with the standard estimates. For chum salmon there was no standard estimate to compare with.

In the discussion we have identified a number of areas and assumptions that have contributed to the results. We feel that the following is a list of the important issues that will need to be addressed in future work

- Species composition of large fish became impossible with flood conditions making any kind of estimate of composition an educated guess.
- A method of examining species composition of medium sized fish will need to be developed.

On the positive side, the system continued to work under extreme conditions and we were able to maintain a target count at times when traditional fixed point enumeration is impossible. We were able to provide daily in-season estimates of run strength and timing which can be very useful for managing any local/associated fisheries.

The chosen site worked well for the DIDSON with good profile, continued access through flood conditions and no major issues with maintaining counts of fish.

Next Steps

If the recommended changes and improvements are undertaken then escapement estimates using the DIDSON technology can be improved and at the very least should provide reasonable estimates for chinook and chum. It may continue to be a problem obtaining reliable coho estimates due to the time of year and the likelihood of flood water conditions hampering beach seining for species composition. The relatively small numbers of coho will always be overwhelmed by higher numbers of chum migrating at the same time.

Further analysis of the data set could be undertaken by refining the target measurements and making adjustments to the daily net target count to remove post-spawn chum from the totals, however this would require additional time resources that are not available. Any changes to the video review would precipitate weeks of effort due to the volume of data that was collected through the fall sampling period.

Instead, we have decided to treat the project results from this first year of operation as a basis for developing the in-season approach for the second year.

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This project could not have been conducted without the cooperation of Cowichan Tribes. We would like to thank them for allowing the project to be conducted on their territory.

We would like to thank the field crew, especially Bill Rice. Bill was the lead crew member who reviewed the majority of the in-season data and provided constant updates in response to a seemingly endless supply of requests from us.

Finally, we would like to express our gratitude to Don Elliott, Manager of the Cowichan Hatchery, and his staff. In addition to managing of the DIDSON field crew, Mr. Elliott provided the services of his broodstock collection crew to conduct the beach seining activities, without which we would not have been able to complete this project. It was the knowledge, experience and energy of this crew that gave us the opportunity to answer the questions posed by this project. Huy ch q'u

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TABLES

Date	DIDSON setting	Cross-section coverage	Review	Comment
18-Sep-06	High frequency	Full	24/7, some partial days, some 30 mins/hour	Start of data collection
24-Oct-06	High frequency	Full	30 mins/hour, some partial days	Targets too numerous to count all
4-Nov-06				Removed unit from river because of rising water level
9-Nov-06	Both frequencies used at times. Different distance settings tried.	Half	30 mins/hour, some partial days	Reinstalled on bank
12-Nov-06	Low frequency, alternating Near (2.5-22.5m) and Far (18-38m) every 15 mins.	Half	15 min Near setting and 15 min Far setting per hour, some partial days	Far setting (18-38m) shows very few targets. Almost all are moving closer to unit.
18-Nov-06				No data. Unit was hit by floating debris and was not aimed in correct direction
21-Nov-06	Low frequency, alternating Near (2.5-22.5m) and Far (18-38m) every 15 mins.	Half	15 min Near setting and 15 min Far setting per hour, some partial days	Unit readjusted back to normal
24-Nov-06	Alternating High frequency, 1.7-11.7m and Low Frequency 11.7-31.7m	Half	15 min High and Near setting and 15 min Low and Far setting per hour, some partial days	
14-Dec-06				End of data collection

Table 1. DIDSON settings used over the field season.

Stat Week	Date	Target count/estimate	Comments
9-3	18-Sep-06	221	DIDSON installed
	19-Sep-06	238	
	20-Sep-06	173	
	21-Sep-06	173	
	22-Sep-06	336	Many small targets in first 6 weeks
	23-Sep-06	1068	
	24-Sep-06	16	
9-4	25-Sep-06	392	
	26-Sep-06	287	
	27-Sep-06	188	
	28-Sep-06	217	
	29-Sep-06	127	
	30-Sep-06	513	
	1-Oct-06	119	
10-1	2-Oct-06	89	
	3-Oct-06	139	
	4-Oct-06	98	
	5-Oct-06	1	
	6-Oct-06	6	
	7-Oct-06	128	
	8-Oct-06	125	
10-2	9-Oct-06	151	
	10-Oct-06	135	
	11-Oct-06	114	
	12-Oct-06	116	
	13-Oct-06	116	
	14-Oct-06	96	
	15-Oct-06	169	
10-3	16-Oct-06	348	
	17-Oct-06	249	
	18-Oct-06	183	
	19-Oct-06	435	
	20-Oct-06	461	
	21-Oct-06	327	
	22-Oct-06	296	
10-4A	23-Oct-06	424	
	24-Oct-06	1172	
	25-Oct-06	1950	
	26-Oct-06	1348	
10-4B	27-Oct-06	3903	
	28-Oct-06	5085	
	29-Oct-06	3426	
	30-Oct-06	6204	
11-1A	31-Oct-06	1494	
	1-Nov-06	1099	
	2-Nov-06	1130	

11-1B	3-Nov-06	7452	
	4-Nov-06	13658	Flood - unit removed
	5-Nov-06	10000	Interpolated from the average of observations from 3rd November to 15th November
11-2	6-Nov-06	10000	
	7-Nov-06	10000	
	8-Nov-06	10000	
	9-Nov-06	10000	
	10-Nov-06	13529	Unit installed on bank
	11-Nov-06	5099	chum spawning in view
	12-Nov-06	10199	
11-3	13-Nov-06	7935	
	14-Nov-06	14357	
	15-Nov-06	8539	
	16-Nov-06	-2656	Water flow peaked at 420 m3/s
	17-Nov-06	1110	
	18-Nov-06	88	
	19-Nov-06	500	Assumed data
11-4	20-Nov-06	500	
	21-Nov-06	2630	chum no longer spawning in view
	22-Nov-06	1650	
	23-Nov-06	-456	
	24-Nov-06	195	
	25-Nov-06	264	
	26-Nov-06	-48	
11-5	27-Nov-06	203	
	28-Nov-06	216	
	29-Nov-06	-146	
	30-Nov-06	-202	
	1-Dec-06	616	
	2-Dec-06	-260	
	3-Dec-06	-544	
12-1	4-Dec-06	-312	
	5-Dec-06	2217	
	6-Dec-06	1154	
	7-Dec-06	264	
	8-Dec-06	232	
	9-Dec-06	712	
	10-Dec-06	544	
12-2	11-Dec-06	496	
	12-Dec-06	-43	
	13-Dec-06	165	
	14-Dec-06	19	DIDSON removed
	Total targets	174,958	

Table 2. Daily net target count

Stat Week	Net Target count	% larges	est. # of large targets	CTT/RBT		CN adults		CN jacks		CO adults		CM	
				%	Count	%	Count	%	Count	%	Count	%	Count
9-3	2224	44%	979	0.00%	0	27.63%	270	72.37%	708	0.00%	0	0.00%	0
9-4	1842	44%	810	0.00%	0	42.00%	340	31.95%	259	26.05%	211	0.00%	0
10-1	586	39%	229	0.17%	0	43.35%	99	37.68%	86	14.94%	34	3.86%	9
10-2	897	55%	494	0.49%	0	23.19%	114	54.31%	268	19.39%	96	2.63%	13
10-3	2299	70%	1609	0.00%	0	14.77%	238	30.34%	488	42.33%	681	12.56%	202
10-4A	4894	85%	4160	0.00%	0	5.47%	227	12.80%	533	38.90%	1618	42.83%	1782
10-4B	18618	100%	18618	0.48%	90	2.16%	402	4.82%	897	23.70%	4413	68.84%	12817
11-1A	3723	100%	3723	0.00%	0	2.11%	78	3.16%	118	7.02%	261	87.72%	3266
11-1B	31111	100%	31111	0.00%	85	0.00%	0	0.00%	0	5.00%	1556	95.00%	29555
11-2	68827	100%	68827	0.00%	0	0.00%	0	0.00%	0	1.00%	688	99.00%	68139
11-3	29873	100%	29873	0.00%	0	0.00%	0	0.00%	0	1.00%	299	99.00%	29574
11-4	4734	100%	4734	0.00%	0	0.00%	0	0.00%	0	1.00%	47	99.00%	4687
11-5	-118	100%	-118	0.00%	0	0.00%	0	0.00%	0	1.00%	-1	99.00%	-116
12-1	4811	100%	4811	0.00%	24	0.00%	0	0.00%	0	1.00%	48	99.00%	4763
12-2	636	100%	636	0.00%	0	0.00%	0	0.00%	0	1.00%	6	99.00%	630
				Sum	199		1770		3356		9957		155319
				Estimate	200		1800		3400		10000		155000

Table 3. Estimate of salmon escapement

APPENDICES

	Fish activity					physical attributes									
Attribute	**Chum spawning**	**Coho spawning**	**Chinook spawning**	**Estimated proportion of spawning below site**	**schooling behaviour**	**slope of substrate**	**narrow channel**	**sonic shadows**	**Power to site**	**vehicle access to machine**	**nearby seining site**	**human activity**	**operate under winter storms**	**other considerations**	**other comments**
Ideal →	**below spawning activity**					**even**	**Yes**	**no**	**yes**	**yes**	**yes**	**none**	**yes**		
Pumphouse site	above most of spawning area	below most spawning area	below spawning area	100% CN, 95% CO, 20% CM	some	rough	Yes	maybe	yes	no	yes	little	yes	all CN fishing activity is below. All CO fishing activity is above	near existing fence for comparison. Original proposed location. Phone available, may be too deep and slow, but depends on site selection
Friendship site	middle of spawning area	below most spawning area	below spawning area	100% CN, 95% CO, 50% CM	some	even	No	some, but can be avoided	yes	yes	yes	yes, below fishing area, public activity	no	most CN fishing activity is below. All CO fishing activity is above	high profile for community, partial security if unmanned. Need wide deflection weirs which won't hold up in winter storms, requires Nav Waters permit
Hatchery site	below most spawning area	below spawning area	below spawning area	100% CN, 100% CO, 98% CM	none	even	Yes	no	no, will need to run line from Hatchery	yes	yes	yes, above fishing area	yes	middle of CN fishing activity. All CO fishing activity is above	near hatchery, requires Nav Waters permit
Forks site	Below most spawning area	below spawning area	below spawning area	100% CN, 100% CO, 98% CM	some	even	No	no	no, will need to run line from Hatchery	no	yes	yes, middle of fishing area	no	middle of CN fishing activity. All CO fishing activity is above	near hatchery, requires Nav Waters permit

Appendix 1. Site Selection information
Matrix of selected sites and associated attributes. The 'ideal' attribute is noted in the second row and the lower four rows are the attribute notes for each site.

Appendix 2. Financial Statement

The original Proposal for this project was submitted by Dick Nagtegaal in Fall 2004 and was scheduled to start in April 2005 with field work completed by Winter 2005 and a final report finished by Summer 2006. Subsequently Mr. Nagtegaal was unable to lead this project and it was assigned to Steve Baillie. Mr. Baillie was not able to maintain the original time line so the Collaborative Agreement was amended twice, with changes to the contribution dates and the project timeline. There were no changes to the total amount of the contribution from the PSC.

In addition, there were changes made to the field operation of the project. The site of the DIDSON installation was moved to the lower river which allowed greater coverage of chum salmon. This also meant that the counting fence would not be used for species identification and another method was employed. These changes were made for the following reasons:

- The fence can only be operated until the first fall storm events, and must be removed at that time, or by the end of October. Because of this limitation the entire population of coho cannot be counted at the fence site.
- The fence is located upstream of the major chum spawning areas, except in years of high escapement. Very few chum salmon are enumerated before the fence is removed.

The main objects of this project is to evaluate the effectiveness of the DIDSON technology in enumerating the chinook, coho and chum escapement to the Cowichan River and the accuracy of species identification. We approached this task by using the project to estimate the escapement of the three species of salmon independent on traditional methods. Those estimates were compared to the standard escapement estimates.

The result of these changes is that the original proposed budget was not adhered to. The major changes were a field crew that staffed the site continuously for security reasons as well as data review, and additional site supplies and materials required to run the remote field office. These items and the purchase of the DIDSON unit were funded by the Collaborative Agreement funds. In addition, there were direct and indirect costs to DFO for staff to provide support for the project, as well as purchasing supplies and equipment not covered by the Agreement. We have also included in-kind contributions by Cowichan Tribes to this project.

The decision to move the field site from the fence area to the lower river was correct. When the fence was removed from the river, a total of 179 adult and 126 jack chinook, 18 adult and 4 jack coho, and 6 chum had been enumerated. In contrast, approximately 14,000 targets had been recorded by the DIDSON by that time. The fence is not designed to enumerate the smaller species of salmon, and would not have been able to operated after the end of October and provide a species composition.

Direct Costs

Original Budget		Expenditures	
Technical support staff	$ 14,080.00	Technical support staff	$ -
field technicians	$ 6,528.00	field technicians	$ 24,056.00
Facility modifications	$ 1,760.00	Facility modifications	$ -
electrical	$ 560.00	electrical	$ -
site supplies and materials	$ 500.00	site supplies and materials	$ 10,672.89
work and safety gear	$ 350.00	work and safety gear	$ -
safety training and supplies	$ 100.00	safety training and supplies	$ -
technical monitoring	$ 250.00	technical monitoring	$ -
Swiftwater training	$ 2,800.00	Swiftwater training	$ -
report documentation	$ 5,400.00	report documentation	$ -
DIDSON sonar purchase	$100,000.00	DIDSON sonar purchase	$ 96,197.93
		Travel	$ 1,389.33
		Interest	$ 11.85
l	$132,328.00		$132,328.00

DFO - in kind

Project management	$ 47,000.00	Project management	$ 55,690.00
facility modifications	$ 5,000.00	facility modifications	$ -
travel	$ 15,000.00	travel	$ 5,000.00
tools and equipment	$ 5,000.00	tools and equipment	$ 25,500.00
site supplies and materials	$ 3,500.00	site supplies and materials	$ 2,000.00
work and safety gear	$ 4,000.00	work and safety gear	$ 200.00
safety training and supplies	$ 1,500.00	safety training and supplies	$ -
alarm monitoring	$ 1,000.00	alarm monitoring	$ -
swiftwater training	$ 1,200.00	swiftwater training	$ -
office space	$ 1,500.00	office space	$ 500.00
telephone	$ 500.00	telephone	$ 200.00
underwater camera	$ 2,600.00	underwater camera	$ -
TV	$ 200.00	TV	$ -
Digimux recording unit	$ 3,500.00	Digimux recording unit	$ -
		field technicians	$ 27,600.00
l	$ 91,500.00		$116,690.00

Cowichan Tribes - in kind

		Hatchery staff	$ 12,000.00
		Swiftwater Rescue	$ 2,000.00
		field equipment	$ 4,000.00
			$ 18,000.00