Evaluation of the BlueView ProViewer 900 Imaging Sonar as a Tool for Counting Adult Sockeye Salmon in the Adams River, British Columbia

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2008

Canadian Technical Report of Fisheries and Aquatic Sciences 2798

Fisheries and Oceans Canada
Pêches et Océans Canada

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Canadian Technical Report of Fisheries and Aquatic Sciences

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Canadian Technical Report of
Fisheries and Aquatic Sciences 2798

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EVALUATION OF THE BLUEVIEW PROVIEWER 900 IMAGING SONAR AS A TOOL FOR COUNTING ADULT SOCKEYE SALMON IN THE ADAMS RIVER, BRITISH COLUMBIA

By

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Cat. No. Fs97-6/2798E ISSN 0706-6457

Correct citation for this publication:

Cronkite, G.M.W., Enzenhofer, H.J., and Holmes, J.A. 2008. Evaluation of the BlueView ProViewer 900 Imaging Sonar as a tool for counting adult sockeye salmon in the Adams River, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2798: iv + 21 p.

ABSTRACT

Cronkite, G.M.W., Enzenhofer, H.J., and Holmes, J.A. 2008. Evaluation of the BlueView ProViewer 900 Imaging Sonar as a tool for counting adult sockeye salmon in the Adams River, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2798: iv + 21 p.

We evaluated the BlueView ProViewer 900 imaging acoustic system as a tool for counting migrating adult sockeye salmon (*Oncorhynchus nerka*) in clear-water riverine spawning environments in British Columbia, Canada. Hourly fish passage rates during our testing on the Adams River did not exceed approximately 252 fish/hour because spawning returns were much lower than the predicted returns available when we chose this stock for our testing. We applied standard techniques to perform tests on the accuracy and precision of the resulting ProViewer counts compared with concurrent visual counts. The results showed that the salmon count data produced using the Blueview ProViewer 900 were systematically biased relative to visual counts, except if we assumed that all the variability in these data was associated with the visual counts. Variability between observers counting the net upstream passage from the ProViewer data files was high at 25.7%, and with repeated independent counts of the ProViewer files expecting to achieve the same count 80.7% of the time. These results were believed to be due to the level of image resolution and idiosyncrasies of the ProViewer software. Improvements to the software could increase the usefulness of the ProViewer for counting migrating salmon in rivers.

RÉSUMÉ

Cronkite, G.M.W., Enzenhofer, H.J., and Holmes, J.A. 2008. Evaluation of the BlueView ProViewer 900 Imaging Sonar as a tool for counting adult sockeye salmon in the Adams River, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2798: iv + 21 p.

Nous avons évalué le système d’imagerie acoustique ProViewer 900 de BlueView en tant qu’outil de dénombrement des saumons rouges (*Oncorhynchus nerka*) adultes en migration dans des frayères des cours d’eau limpides de la Colombie-Britannique, au Canada. Les taux de passage des poissons lors de nos essais dans la rivière Adams n’ont en moyenne pas dépassé 252 poissons/heure, car la remonte des saumons était beaucoup moins importante que nous ne l’avions prévu au moment où nous avions choisi ce stock pour notre étude. Nous avons utilisé des méthodes normales pour mener des essais sur l’exactitude et la précision des dénombrements obtenus au moyen du système ProViewer en les comparant à des dénombrements visuels effectués simultanément. Les résultats ont démontré que les données sur le dénombrement des saumons obtenues au moyen du système ProViewer 900 de BlueView étaient systématiquement biaisées par rapport aux dénombrements visuels, sauf si nous présumions que cette variabilité était liée aux dénombrements visuels. La variabilité entre les dénombrements obtenus par les observateurs du passage en amont et les données recueillies par le système ProViewer atteignait 25,7 %. Après plusieurs comptages individuels des fichiers du ProViewer, nous avons évalué à 80,7 % les probabilités d’arriver aux mêmes résultats. Les résultats sont attribuables à la résolution de l’image et aux idiosyncrasies du logiciel ProViewer. Des améliorations apportées au logiciel pourraient accroître l’utilité du système ProViewer pour le dénombrement des saumons en migration dans les cours d’eau.

1.0 INTRODUCTION

Single-beam or split-beam hydroacoustic systems are often used to monitor migrating fish populations because these technologies are non-invasive, cost effective, and they can be deployed on a continuous 24-hour basis (Banneheka et al., 1995; Daum and Osborne, 1998; Xie, 2000; Chen et al., 2004; Cronkite et al., 2005). However, riverine hydroacoustics is confounded by difficulties detecting fish signals near the surface or bottom, detecting fish near the transducer, and detecting multiple fish in the beam simultaneously (Mulligan, 2000) and as a result data processing requires a high level of acoustic expertise and complex analytical protocols (Enzenhofer and Cronkite, 2000; Holmes et al., 2006). The latest development in acoustic technology is the imaging sonar system such as the dual-frequency identification sonar (DIDSON; Belcher et al., 2001). These systems are a viable alternative to the single- or split-beam technology in riverine applications because they produce video-like images, do not require extensive training to operate effectively, and are not always adversely affected by the presence of surface or bottom signals. The simplicity of operation and the adaptability of these systems to a wide range of sites means that training periods for personnel are short, and reliable and timely escapement data required by fishery managers for in-season management can be obtained for a larger number of stocks than is possible with conventional sonar technology (Cronkite et al., 2006).

Previous studies using the DIDSON imaging system focused on the use of this technology for stock assessment as an alternative to the mark-recapture programmes used to enumerate escapement of migrating Pacific salmon (*Oncorhynchus spp.*) (Cronkite et al., 2006; Holmes et al., 2006; Lilja et al., 2008). In the present study we evaluate the performance of the BlueView Technologies, ProViewer (900 kHz P900-20) miniature multi-beam imaging sonar as a tool for salmon escapement estimation. Although the ProViewer has lower image resolution than a standard DIDSON system, the unit price of this technology is about a third of the cost of the DIDSON technology. Thus, if the benefit-cost ratio is favourable, then implementation of this technology within existing salmon stock assessment programs could be more widespread than the DIDSON technology. Our study was conducted from October 2-6, 2007, on sockeye salmon (*Oncorhynchus nerka*) returning to Adams River in the Shuswap Lake system. The Adams River exhibits a fluctuation in abundance on a 4-yr cycle and was chosen for testing because 2007 was the sub-dominant year and pre-season forecasts projected total escapement of 1 million fish. Overall the study had the following objectives:

1. Record imaging acoustic system data of fish passage through a delineated sample area;
2. Perform a real-time visual count of fish passage over the delineated sample area during the recording of each acoustic file;
3. Examine the acoustic data for bias relative to visual counts and assess counting precision;
4. Describe and evaluate the technical characteristics of the imaging acoustic system that affect its use as a fish passage monitoring tool;
5. Evaluate the utility of the acoustic system for estimating fish escapement;

6. Provide recommendations concerning the viability of the BlueView ProViewer P900-20 as a tool for implementation in stock assessment programs to estimate Pacific salmon escapement.

2.0 SITE DESCRIPTION

The Adams River is a major sockeye salmon producing tributary of the Fraser River watershed entering the northwest portion of Shuswap Lake (Figure 1). The total length of the river is 131 km and includes the upper Adams River, Adams Lake and the lower Adams River (Holmes et al., 2005). The lower Adams River, bordered by the Roderick Haig-Brown Provincial Park, is 12 km long from the outlet of Adams Lake to its entrance into Shuswap Lake.

Our study site was on the lower Adams River approximately 300 m upstream from its mouth on Shuswap Lake. This site was chosen because it met the acoustic site criteria outlined in Enzenhofer and Cronkite (2000) which include a straight stretch of river with laminar flow and a planar bottom free of obstructions that might impair fish detection or introduce noise to the acoustic system. Also, the site was located below the majority of spawning habitat in the Adams River system and so would provide sufficient returning adult salmon to meet the objectives of our study. However, fish spawn in the immediate area and exhibit milling behaviour, which would normally preclude the use of this site for hydroacoustic estimation of total escapement. Since our objective was to compare a visual count to an acoustic count over a delineated sample area to asses the performance of an acoustic system rather than estimating total run size, we did not attempt to find another site.

The Adams River had a wetted width of 34 m and was gradually sloped from the right-bank to a maximum depth of 2 m near the left-bank (left- and right-banks are identified when facing downstream) at our acoustic site (Figure 2 and Photo 1). Water velocity was estimated at 1.5 $m \cdot s^{-1}$ with bottom type consisting of sand and gravel-cobble (5-10 cm diameter). Fish passage mainly occurred beyond 10 m from the right-bank and extended across the river to within several metres of the left-bank shore. Fish migrating more than 20 m from the right-bank were not included in our visual or acoustic counts because they were outside the delineated sample area (see Section 3.1 for a description of this sampling area). We did not require a deflection weir to move fish offshore of the transducer, as fish migration occurred in the far field of the ProViewer system, where the acoustic beam is fully formed.

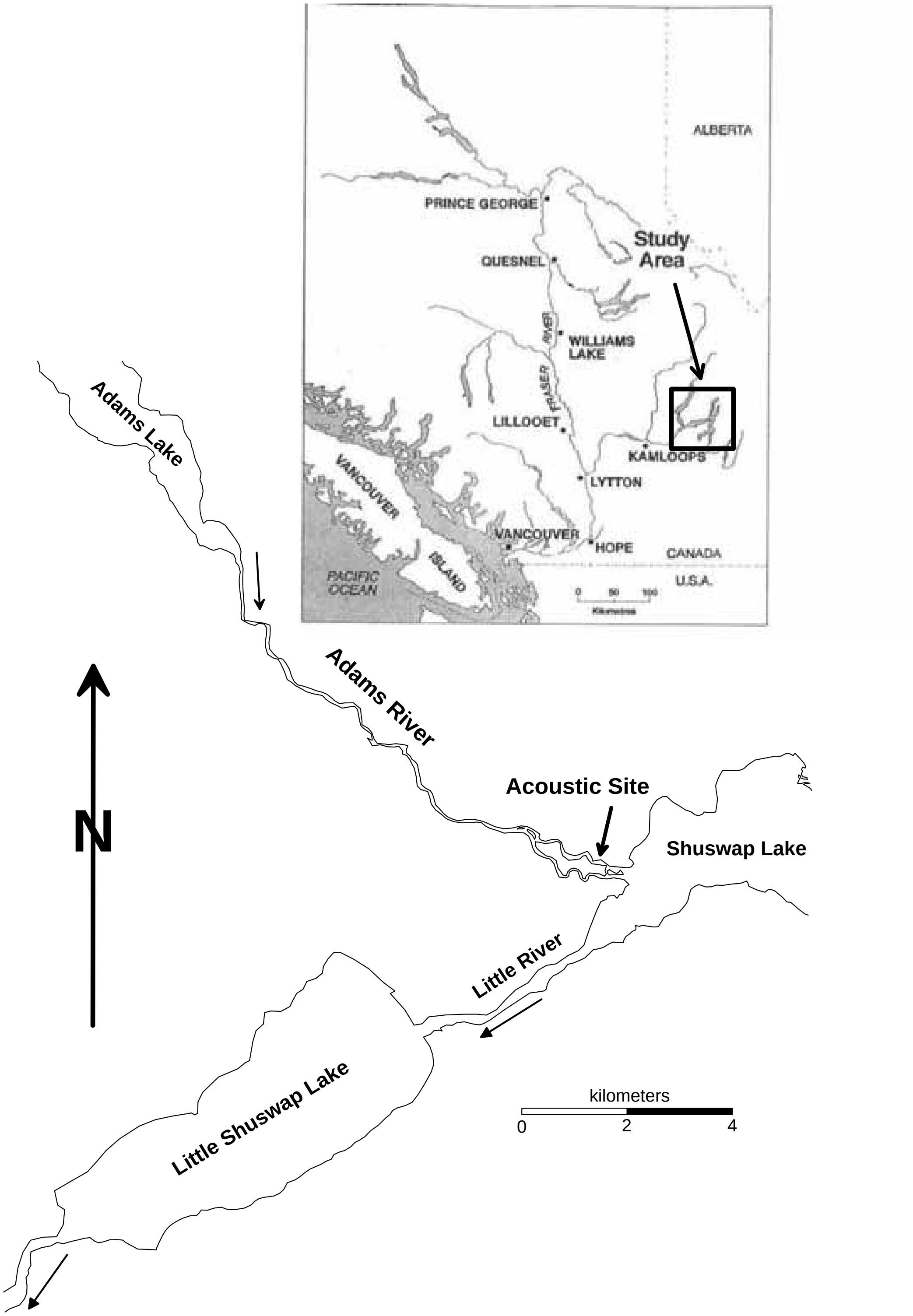

Figure 1. The study area showing the acoustic site on the Adams River and it's location relative to the Fraser River watershed in British Columbia.

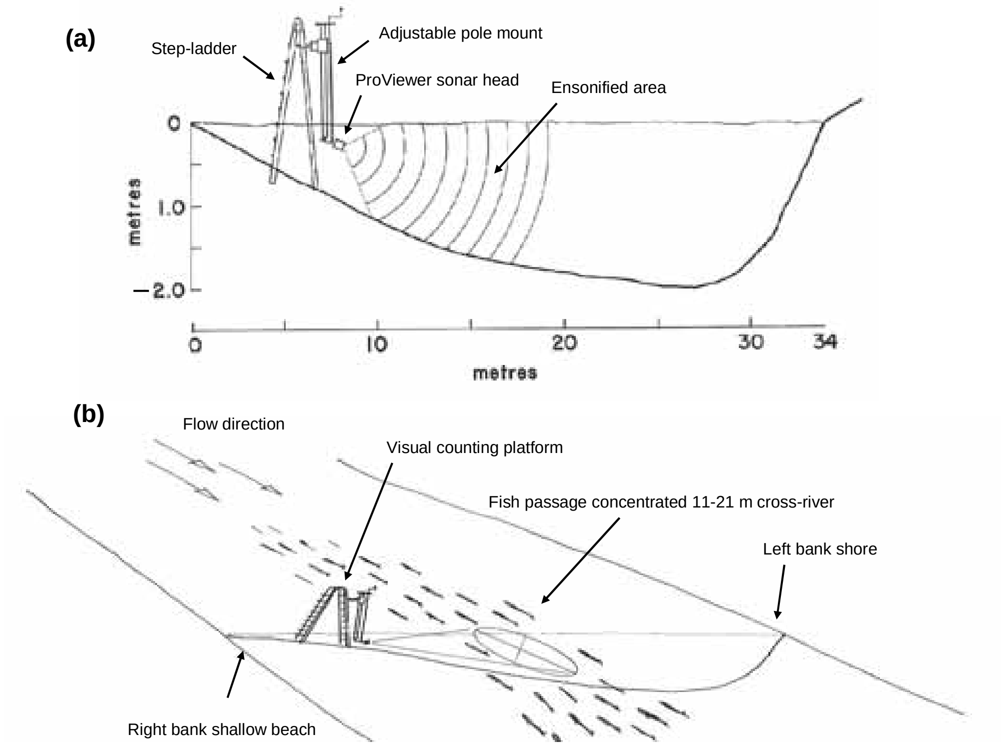

Figure 2. River cross-section and bottom profile (a), and the straight stretch of river with migrating fish passage used for comparison of simultaneous visual and acoustic system counting (b) on the Adams River in 2007. Note that the vertical and horizontal scales differ.

Photo 1. View of the ProViewer hydroacoustic site on the Adams River. The in stream step-ladder, with the adjustable pole mount and attached sonar head, was also used as a tower for visual counting. The boat anchored to the shoreline housed the operating computer and junction box with cable attached to the sonar head. Photo taken by Ted Sweeten on October 4, 2007.

3.0 MATERIAL AND METHODS

3.1 ACOUSTIC DATA COLLECTION

The ProViewer high definition imaging sonar system is produced by BlueView Technologies, Inc. (© 2003-2006 BlueView Technologies, Inc.). We used the high frequency 900 kHz system (Model P900E-20) with factory specifications listed as follows:

Max Range	54.9 m
Update Rate	Up to 10 Hz
Swath Width (total width of detection)	45°
Beam Width (size of individual beams)	1° x 20°
Number of Beams	256
Range Resolution	2.54 cm
Beam Spacing	0.18°
Depth Rating	304.8 m
Weight in air	1.86 kg
Weight in fresh water	0.45 kg
Dimensions (Max)	19.8 cm x 10.2 cm
Operating frequency	900 kHz
Communications	Ethernet, 10base-T or 100base-T
Power	12-48 volts @ 10 watts (15 m cable)

The ProViewer is a high-definition imaging sonar that utilises many small acoustic beams to produce images in a movie-like format (BlueView Technologies, 2007). The maximum attainable range with the 900 kHz ProViewer system is 55 m. BlueView Technologies also manufactures a 450 kHz system for long range detection, but we used the higher frequency system in our testing as fish passage occurred within 10 m of the sonar head and therefore required the shorter near-field (range from the transducer in which the sound beam is not fully formed) of the higher frequency system. Additionally, the higher frequency system provided higher resolution images of the fish.

All data were collected using the ProViewer Software (BlueView Technologies, 2007) and were stored in a proprietary file format. Overall the operation of the acoustic system is straightforward for users familiar with Windows-based software and features basic controls through a drop down menu toolbar (see Sec. 3.2)

We operated the system using a range window length of 7 m (3 m to 10 m from the transducer). Threshold and intensity settings were adjusted automatically by the system “to produce optimum images in most situations”, according to the factory manual. Data collection frame rate appeared to be controlled by the screen resolution setting used on the laptop computer and window size of the operating program making the frame rate difficult to determine. With these settings, approximately 3.7 MB/min were recorded. The ProViewer system starts recording when the toolbar record button is selected, and stops with a second selection of the record button. The user is prompted to save the file with a default file naming structure using date and time (***yyyy_mm_dd_hh_mm_ss)*** with a ***.son*** extension. There are no options for automated control of sampling times such as repeated sub-sampling within the hour. The user must initiate and terminate the sample files, and if the system is left to run for long periods, then one large file is created which can then be broken into smaller files with supplied post-processing software. Collected data files were backed up to an external 300 GB hard drive.

The ProViewer system was deployed on an adjustable pole mount attached to a modified step-ladder anchored to the riverbed (Enzenhofer and Cronkite 2005) approximately 8 m from the right-bank shoreline (Figure 2). The adjustable pole mount provides precise manual control of the depth, bearing, roll angle and tilt angle of an attached transducer. A stabilising bracket between the pole mount and the ladder prevented movement of the transducer in the current, which could result in blurred images. The system was positioned so that the sonar head was 10-12 cm below the water surface and the transducer was aimed at -9° relative to the water surface and perpendicular to the shoreline and water flow. Using this aim, the ProViewer beams ensonified the entire water column. The upstream/downstream boundaries of detection were physically confirmed by observing the limits at which a person standing in the river could be observed with the ProViewer system. These boundaries were then marked with rocks wrapped in florescent orange surveyors tape and placed on the substrate. The 10m range was visually identified by a naturally occurring submerged log that lay perpendicular to the acoustic beam.

Topside equipment including the operating computer and the ProViewer junction box were housed in an aluminium tool chest set on the rear deck of our transportation boat (Photo 1). The boat was required to provide a dry platform due to the short length of the sonar-to-surface cable, which connects the sonar head to the ProViewer junction box, provided with our test system (longer cables are available). All electronic components and the acoustic system were powered by a portable 2 kW generator (Honda EU-2000).

3.2 PROVIEWER FISH COUNTING

All ProViewer files were counted manually using a hand held counter (tally whacker) and the numbers of upstream and downstream fish were recorded on a spreadsheet. Acoustic data files were 15 minutes in duration with several being up to 18 minutes in duration and coincided with the visual counting time. Operation of the ProViewer imaging sonar is described in the ProViewer software handbook (BlueView Technologies, 2007) and has a screen display window shown in Figure 3. We used the following features of this software package during our study:

- Toolbar: Contains the drop down menus which allow the user to connect to a sonar head or open a file for playback. To record live sonar data the toolbar menu item ***Record sonar image data*** icon is clicked once to start a record session and a second time to end a record session. Users are then prompted for a location to save the file. The screen display can be changed to various pre-loaded user-specified colour schemes, including bone, hot, green, cool and jet, based on lighting conditions experienced at the time of viewing. The display menu has an auto intensity function that will select default image intensity to produce an optimum image. If the auto intensity feature is disabled, then manual threshold and intensity controls appear in the toolbar. Changing the threshold controls the amount of background signal displayed in the image whereas the intensity controls the brightness of the image.

- Range Controls: Allows the user to use range sliders to select start and end ranges for data collection and processing. A target can be isolated within a desired range bin by using both controls, allowing the target to be viewed as a larger image.
- Playback Controls: Appear at the bottom of the window when a recorded file is loaded and includes the following icons:
    1. **Pause**: pause playback at the current ping;
    2. **Play**: resume playback;
    3. **Fast-Forward**: controls the playback speed up to 64X. We found this feature to be similar to the record data frame rate in that screen resolution and window size affect the frame rate achieved;
    4. **Previous Ping**: allows user to go back one ping;
    5. **Playback time slider**: shows the current location inside the file and allows the user to select a new location within the file; and
    6. **Next Ping**: allows user to advance to the next ping.

- Cursor location readout: Displays the cursor location in range and degrees off axis relative to the screen display.

Recorded acoustic files were replayed and counted at a user preference frame rate which generally was 16X on the Fast-Forward control. The files were processed once for the upstream count and then replayed a second time for the downstream count (Table 1). We used the same criteria for the upstream or downstream tally as the criteria used for the visual count (see Section 3.3).

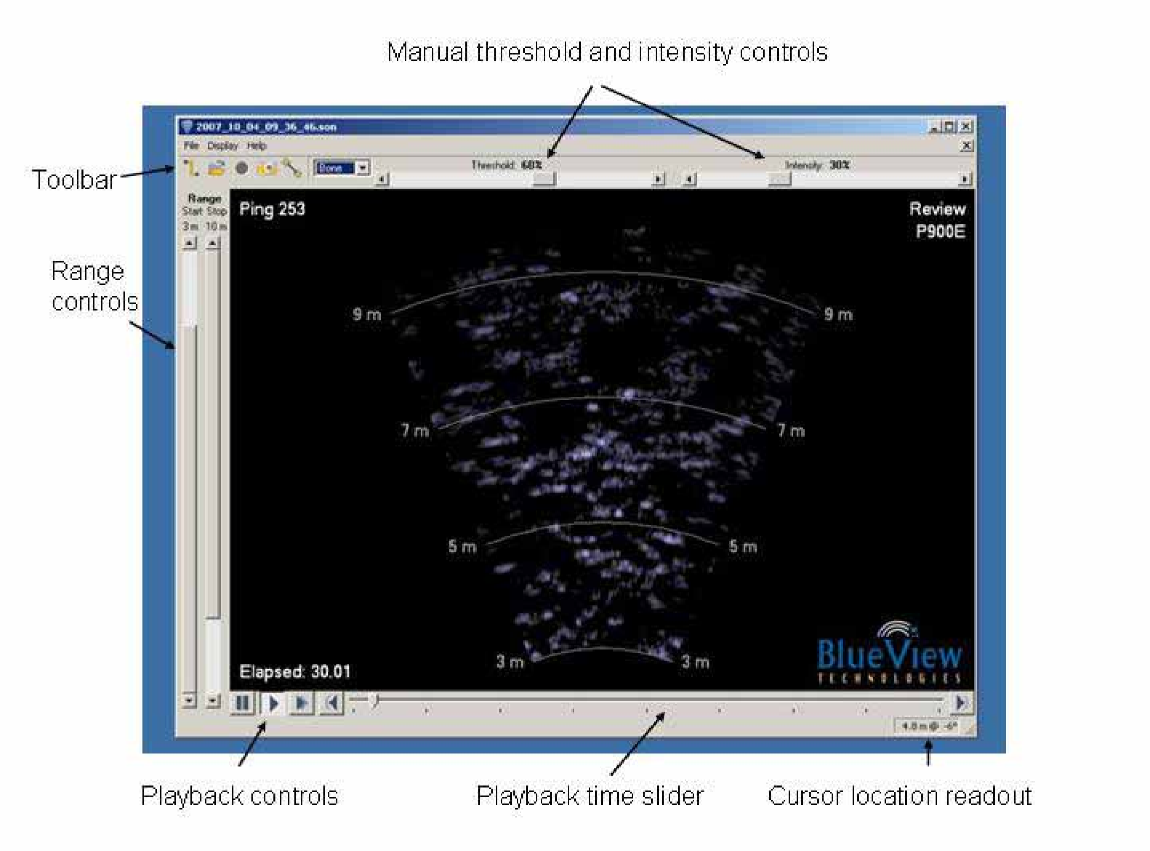

Figure 3. ProViewer window showing a collected file in playback mode used for manual counting of the upstream and downstream fish. The image shows the cobble substrate at the acoustic site.

3.3 VISUAL COUNTS

We collected visual counts and recorded simultaneous ProViewer acoustic files of fish passage during daylight hours from October 2 to October 6, 2007. All visual counts were made by an observer wearing Polaroid sunglasses standing on top of a modified step-ladder. The adjustable pole mount and sonar head were also attached to the same step-ladder (Enzenhofer and Cronkite 2005). Visual data collection was synchronised with the ProViewer data collection by verbal command to the visual observer at the start and the end of an acoustic file. Acoustic files were saved with date and time stamps for post-processing in playback mode to produce counts. The visual counter recorded the passage of upstream and downstream fish migrating within the delineated sample area, which coincided with the area ensonified by the acoustic system. The following criteria were used for a fish to be counted:

- Any fish present in the delineated area at the onset of a data set must pass the upstream boundary within the 10 m range to be included in the count;
- Fish passage included in the downstream count must pass both the upper and lower boundaries of the horizontal beam width and be within the 10 m range boundary;

- Any fish passage closer than the 3 m range boundary was not included in either the upstream or downstream counts;
- Fish entering the beam during a data set were included in the upstream count only if they crossed the downstream and upstream boundaries within the range window. This was done in order to exclude fish that entered the ensonified region from beyond 10 m range.

3.4 DATA ANALYSIS

Fish count data were analysed on a data file basis where a data file was approximately 15 minutes in length. Three individuals counted the data files and the mean count was used to compare with the visual count. For each file (N = 47), we compiled paired visual and ProViewer fish counts. Since both the visual and acoustic counts are subject to error from biological and measurement variability, we used an errors-in-variables approach (Schnute et al., 1990) to analyse these data. Standard linear regressions, representing two extreme assumptions concerning variability in the counts, were fitted to the ProViewer counts vs. visual counts and visual counts vs. ProViewer counts, with the true relationship between these extremes. Three possible outcomes for describing the true relationship between the visual and ProViewer count data are possible. First, both counting methods agree, which means that the true relationship is coincident with a line with slope of 1.0 passing through the origin, i.e. the y = x line (accuracy, defined here as not statistically different from visual counts). Second, one counting method exhibits a constant bias (offset) relative to the other method, which would occur if the true relationship is parallel to but not coincident with the y = x line, i.e. the intercepts differ significantly from 0. Third, the counting methods exhibit a systematic bias as the counts increase, which means that the true relationship is not parallel to the y = x line. The ideal result is a finding that both counting methods agree, i.e., the true relationship is y = x. A finding of constant bias can be corrected during post-processing, but a finding of systematic bias in these data is the worst possible outcome. We bootstrapped with replacement, 1000 replicates and plotted the distributions of possible slopes and Y-intercepts with their 95% confidence intervals. We then determined from these distributions if the 95% confidence intervals of slopes and intercepts included 1 and 0 respectively.

Precision refers to the repeatability of a count between different individuals for the same data file. We assessed the precision of the ProViewer counts among individuals using the coefficient of variation (CV) and average percent error (APE) as was done by Holmes et al., (2006) and is widely used to report the precision of the fish ageing process. APE is an index of the repeatability of counts across the entire dataset, whereas CV is a measure of the variability in counts of a particular file among observers. A total of 47 files were counted by two observers, and 20 were additionally counted by a third observer.

We define image resolution as the qualitative trait of how clearly identifiable the acoustic image is based on shape, detail and movement, and also the persistence of the image as it passes across the acoustic beam. We wanted to make the distinction from the acoustic definition of spatial resolution, which is dependant on wavelength, and dictates the fundamental limit for discriminating between targets. The smaller the wavelength or the higher the frequency, the easier it is to discriminate targets that are close together (Simmonds and MacLennan, 2005).

4.0 RESULTS

4.1 PROVIEWER COUNTS COMPARED TO VISUAL COUNTS

Net upstream passage rates estimated from the visual count data ranged from approximately 0 to 252 fish/hr while net passage rates estimated from concurrent ProViewer counts ranged from approximately 0 to 200 fish/hr (Figure 4). The regressions defining the lower and upper bounds fitted to the count data, which are two measures of the same phenomenon are:

LB: Ln ProViewer = -0.1237 + 1.0226 x Ln Visual, R^2 = 0.77, N = 47, P = 0
UB: Ln ProViewer = 0.7708 + 0.7535 x Ln Visual, R^2 = 0.77, N = 47, P = 0

The solid lines in Figure 4 represent the regressions assuming that all of the error is in the ProViewer counts (red) and assuming that all of the error is in the visual counts (blue). The true relationship lies somewhere between these two lines and in this case displays a systematic bias relative to the one-to-one or y = x line (dashed line). The bootstrapped 95% confidence intervals around the slopes of these lines (Figure 5) and the intercepts (Figure 6) include values of 1.0 and 0 respectively for the blue line, but do not include values of 1.0 and 0 respectively for the red line.

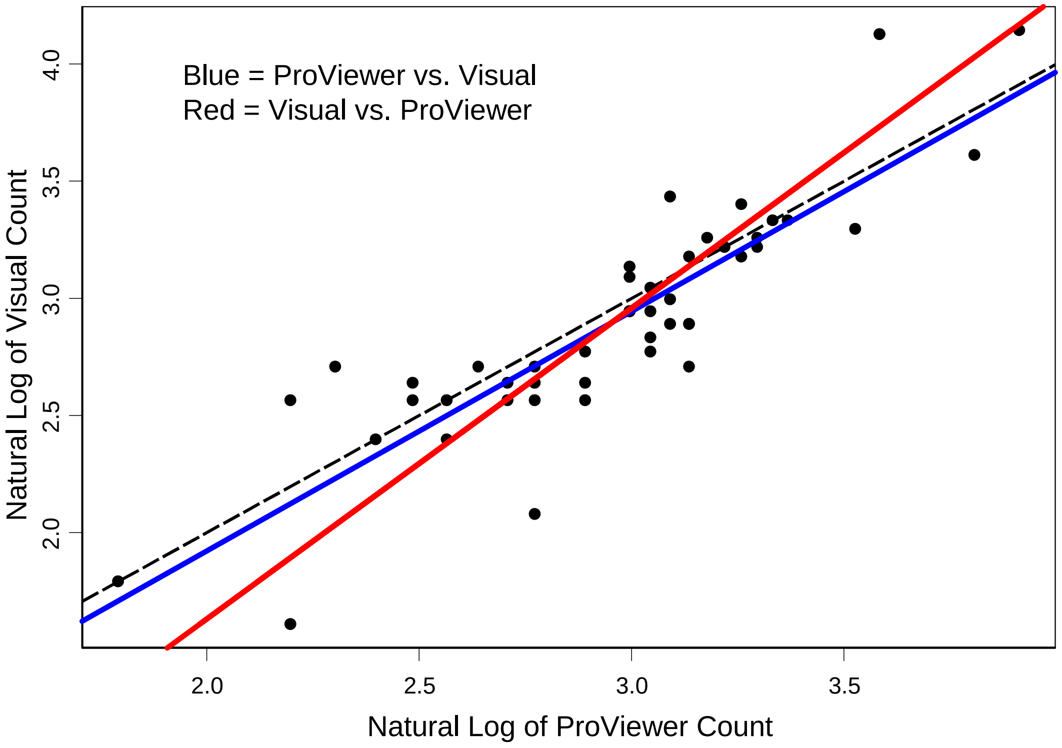

Figure 4. The natural log relationship between the visual and ProViewer counts (counts for 15 minute files) for net upstream migrating sockeye salmon. The dashed line is the one-to-one line and the red line represents the regression line assuming that all of the error is in the ProViewer count and the blue line represents the regression line assuming all of the error is in the visual count.

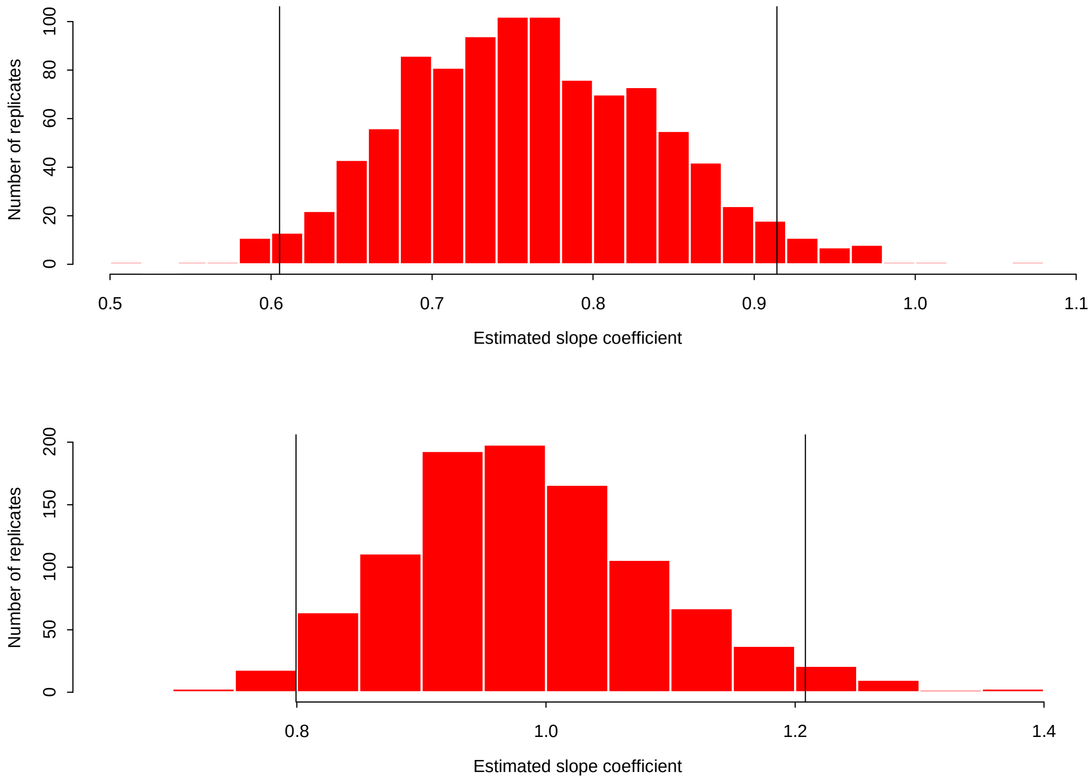

Figure 5. Distribution of boot-strapped estimates of slope coefficients for ProViewer vs. visual and visual vs. ProViewer regressions in Figure 4, based on 1000 replicates. The top histogram assumes that all of the error is in the ProViewer counts and the bottom histogram assumes that all the error is in the visual counts. The vertical lines represent the 95% confidence intervals.

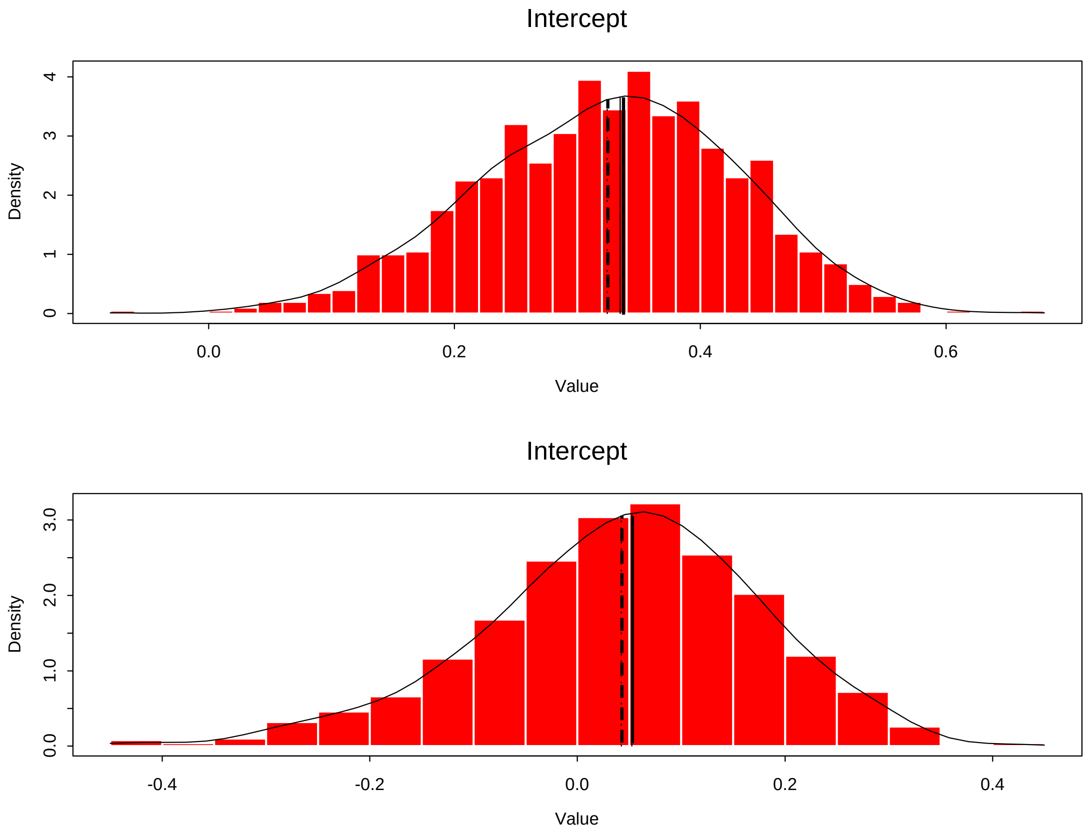

Figure 6. Distribution of boot-strapped estimates of Y-intercept values for ProViewer vs. visual and visual vs. ProViewer regressions in Figure 4, based on 1000 replicates. The top histogram assumes that all of the error is in the ProViewer counts and the bottom histogram assumes that all the error is in the visual counts. The solid vertical lines indicate the observed intercept values for the original data, and the dotted vertical lines indicate the means of the replicates. The difference between these two lines is the estimated bias.

4.2 COMPARISON OF PROVIEWER COUNTS BETWEEN OBSERVERS

The data sets that were counted by multiple observers contained net upstream passage rates ranging from 0 to approximately 252 fish/hour. Based on the average percent error (APE), repeated independent counts of the ProViewer data sets would be expected to produce the same count 80.7% of the time (19.3% APE) for the net upstream travelling fish. The average error between observers (CV) was 25.7%. For the upstream travelling fish the CV was 11.9% and the APE was 22.6%. For the downstream travelling fish the CV was 23.2% and the APE was 27.1%.

5.0 DISCUSSION

5.1 PROVIEWER COUNTS COMPARED TO VISUAL COUNTS

Accuracy and precision are the most important scientific criteria used to judge the suitability of a hydroacoustic system for a particular application. Ideally, the true relationship between the ProViewer counts and visual counts would coincide with the 1:1 line, meaning the ProViewer counts were accurate, and exhibit high precision (APE ≥ 95%). However, we found that the salmon count data produced by the Blueview ProViewer 900 were systematically biased relative to visual counts (Fig. 4), except when we assume that all of the variability in these data is associated with the visual counts (blue line in Fig. 4) and that the precision of these data was not high (average APE of 80.7%). The finding that the ProViewer count data are systematically biased was unexpected since we used the same deployment and aiming protocol as Holmes et al., (2006), who concluded that data collected with this protocol will be as accurate as counts of fish through an enumeration fence, which is the most accurate method of estimating escapement in clear-water rivers in B.C. (Cousens et al., 1982). Count data with a systematic bias were also reported by Holmes et al., (2006) for a 2004 comparison of DIDSON and visual counts of sockeye salmon (*O. nerka*) on the Chilko River. These authors attributed this bias to difficulties visually detecting migrating salmon in a relatively deep turbulent environment and the variable effects of glare on the surface. In contrast, the site on the Adams River used to test the ProViewer system was ideal for visual counting with shallow, non-turbulent waters, minimal surface glare due to equipment configuration, and a visually delineated sampling area for observers. Furthermore, based on our findings of systematic bias and low precision, we conclude that the ProViewer 900 system does not meet the accuracy or precision standards needed for implementation in existing salmon stock assessment programs.

Given the protocol used during aiming and deployment of the ProViewer system and test site characteristics on the Adams River, we are confident that the systematic bias in our data (Fig. 4) is related to the non-detection of fish passing through the ProViewer beams by observers conducting the screen counts rather than our visual counts. Based on our test experience, we identified five hardware and software characteristics of the ProViewer system that likely contributed to this bias.

First, to count migrating salmon, data must be collected and played back at a high frame rate, especially when milling fish are present in the beam. Speeding up the playback improves the ability of the user to visually track migrating fish as they pass through an area with near stationary fish. The frame rate used by the ProViewer during both data collection and playback is tied into the computer screen resolution and the size of the active window. To maximize the data collection rate, screen resolution must be set to minimum and the size of the active ProViewer window must be reduced to approximately 5cm by 5cm (collection) or 10 x 10 cm (play back). These settings create a small viewing window during data collection and playback. The playback software has playback speed options (2x, 4x, 8x, 16x, 32x, 64x of collection rate), but the maximum playback speed attainable when using a 10 x 10 cm window is approximately 8x with higher settings seeming to have no effect. The hardware/software limitations behind these restrictions on performance are not known to us, but the system would be much more useful for counting migrating fish if the frame rate was not tied into screen resolution and window size.

Second, we believe that poor visual resolution of the images also biased the count data. All three observers commented on the difficulties they experienced in counting these files. The downstream fish were more problematic to count than upstream, as indicated by the high variability between counters for the downstream counts (APE 27.1%; CV=23.2%). Acoustic image resolution is a trade-off with range requirements, as higher frequencies yield shorter effective ranges. Useful software tools can be applied to the data to help in resolving the fish images. A Time Varied Gain (TVG) adjusts image intensity so that it does not decrease with range, i.e., it makes fish at longer ranges appear as bright as fish at shorter ranges. However, the ProViewer system does not have TVG so we often lost sight of fish migrating at longer ranges, leading to under counting. This study was undertaken with a relatively short data collection range and the problem of low signal targets (targets appearing dimmer) would become even more problematic for targets at longer ranges.

Third, in the relatively shallow waters of salmon spawning rivers, a high intensity signal is often reflected back from the substrate resulting in a bright bottom image that sometimes masks fish images when using acoustic imaging systems. A useful tool for this situation is background subtraction or its equivalent, which removes signals from stationary targets (e.g., substrate), leaving only images of the moving targets. The application of this type of algorithm would likely improve fish target recognition when viewing the ProViewer data.

Fourth, based on our experience with other acoustic software, the ProViewer requires software development to improve the counting of migrating salmon and to make manual counting satisfactory to observers. Increased resolution is not likely to be possible with the 900 kHz frequency used by the system, but software development such as implementation of a TVG and background subtraction could compensate partly for frequency limitations.

Fifth, the ProViewer system has a relatively large near-field of approximately 3.0 m. Although some large targets can be detected within < 1 m of the instrument, they appear broken up when closer than 3.0 m in range. These broken images make accurate counting difficult, as the observer is not able to determine how many fish are passing through the beam. This problem was not evident during our study on the Adams River, as all of the fish passage was beyond the 3.0 m range. However, there are operational applications of this technology (e.g., the Horsefly River, see Cronkite et al., 2006) where this near-field limitation would be a serious impediment to successful estimation of salmon escapement.

5.2 COMPARISON OF PROVIEWER COUNTS BETWEEN OBSERVERS

The test that we performed with the ProViewer system on the Adams River was an example of a simple deployment situation due to the low passage rates experienced and the short processing range needed at our test site. Nevertheless, all three observers experienced difficulty in counting the migrating salmon recorded in the

ProViewer images. In general the fish were detectable within the ranges we used, but the fish images were frequently hard to interpret because they seemed to disappear as they neared the edge of the beam or appeared very faint and difficult to follow by eye. These problems were demonstrated in the results of the comparison of counts between observers with the variation between observers (CV) being 26%, meaning that two observers counting the same file would be as much as 26% different in their estimate of net upstream counts. For the downstream travelling fish the APE reached 27.1%, meaning that repeated independent counts would be expected to produce the same count 72.9% of the time. Observers noted that they had a particularly difficult time counting the downstream images as demonstrated by the CVs between observers, which were 11.9% for upstream targets and 23.2% for downstream targets. These precision levels are much lower than were obtained for comparable tests with the DIDSON imaging sonar system by Holmes et al., (2006), who reported a CV of 1.7% and APE of 1.2% for counts greater than 50 net upstream migrating fish per data file. We would prefer to obtain a CV of less than 10% if possible, as this is only one bias that can affect the accuracy of the overall count. Lilja et al., (2008) discussed the various errors that include: 1) counting the data sets (accuracy); 2) the repeatability of counts between different individuals for the same data sets (precision); and 3) temporal sub-sampling (representativeness of the sampling). Precision of count data from imaging sonars is related to image resolution, since higher resolution means clearer and more detailed images that are less subject to interpretation. Using the DIDSON system on the Horsefly River, we calculated a 95% C.I. of ± 14% for a total population of approximately 645,000 sockeye (Cronkite et al., 2006) which accounted for these three main sources of error. The Horsefly River C.I. is less than this study’s APE (net upstream) of 19.3% variability alone.

5.3 CONSIDERATIONS

The ProViewer system proved to be compact, light weight and easy to deploy and operate in the riverine environment. The hardware operation was dependable during this study and the images generally identifiable for search and retrieve type scenarios, especially when viewing larger stationary objects. In addition the system is relatively low in cost when compared with some of its competitors. We were generally impressed with the manufacturing quality of the unit and its ease of operation and it is certainly an interesting development in the field of imaging sonar.

One of the problems with the ProViewer system was that the software has not been developed for fisheries related operations and the company has indicated that they are not in the business of software development. The ProViewer software is currently not programmable by the user, which means recording must be manually activated and deactivated. The absence of programming capabilities is a major disadvantage as the kinds of fisheries projects in which the BlueView Technology would be used involve operating the system to sample at a site for a fraction of an hour, 24 hrs/day, over several weeks. At times we randomise the sampling effort within the hour to avoid temporal biases. Typically, acoustic sites are staffed during the day, but the systems are left to record files periodically overnight for counting by site personnel the following day. The ProViewer cannot record hourly files if left overnight, but instead will create one large data file which if corrupted, would cause the loss of an unacceptable quantity of data. Large data files also add numerous complications to the process of determining the daily counts of migrating fish.

Other issues have been discussed earlier and include the lack of TVG and the lack of background subtraction. Furthermore, the frame rate being tied to the size of the open viewing window results in a trade-off between the image collection rate and the size of the viewing window, which is unacceptable for fisheries applications. Higher frame rates are necessary to allow accurate counting especially in situations where milling fish are present in the field of view. The human eye requires increased visual input in the form of higher frame rates to allow the eye to track the path of the migrating fish, and ignore the near stationary images of the milling fish.

We have found that fish counting in the riverine environment poses unique challenges that require some unique solutions. Our past experiences show that as passage rates increase it becomes increasingly difficult for an observer to count fish in the acoustic images, and that the highest degree of visual resolution possible is desirable. The lower the visual resolution then the harder it is for the observer to obtain adequate visual cues to determine the behaviour of a particular fish as it swam through the beam. The pragmatic interpretation of this would be the ‘quality’ of the images, not a feature that is easily measured or defined, but intuitively obvious to the observer. The quality of the images of the salmon targets is limited by the physical nature of the instruments utilised, but can be enhanced by software routines to aid in counting. Development of the mentioned software tools may improve the utility of the ProViewer system for counting salmon in the riverine environment. Development of functional software usually takes a great deal of time and requires that factors such as data file structure be non-proprietary.

6.0 ACKNOWLEDGEMENTS

Financial support for this project was provided by the Southern Boundary Restoration and Enhancement Fund of the Pacific Salmon Commission. We thank Keri Benner, Paul Welch and Tony Rathbone for their expert assistance and support throughout the experiment. We thank Ted Sweeten for his help and photographs, Itsuo Yesaki for his professional drawings of our site and structures and Steve MacLellan for his critical review of this technical report.

Table 1. Visual counts and ProViewer counts by multiple observers of sockeye salmon migrating up the Adams River.

Date	File	Visual Up	Visual Down	Obs. 1 Up	Obs. 2 Up	Obs. 3 Up	Obs. 1 Down	Obs. 2 Down	Obs. 3 Down
02-Oct	12-08-25	70	8	41	41		7	3	
02-Oct	13-08-06	17	12	20	17		10	9	
02-Oct	14-14-37	37	13	29	36		11	9	
03-Oct	09-35-27	32	8	22	41		7	5	
03-Oct	09-51-14	37	7	30	34		5	7	
03-Oct	10-07-21	35	8	40	39		7	5	
03-Oct	10-44-23	23	8	21	23		8	9	
03-Oct	11-01-10	23	5	27	28		5	4	
03-Oct	11-18-07	21	7	20	25		6	3	
03-Oct	11-33-48	11	3	20	21		7	2	
03-Oct	12-41-15	18	5	17	20		6	7	
03-Oct	12-56-59	23	2	21	32		5	6	
03-Oct	13-16-02	27	4	24	31		7	9	
03-Oct	13-31-55	25	6	27	31		9	10	
03-Oct	13-47-20	20	6	20	22		10	8	
03-Oct	14-20-00	16	5	18	21		5	8	
03-Oct	14-36-46	30	5	32	40		9	10	
03-Oct	15-09-36	24	13	18	24		12	9	
03-Oct	15-27-14	27	7	30	33		9	10	
03-Oct	15-43-16	21	4	29	22	29	4	6	
04-Oct	09-14-03	76	13	50	69		11	9	
04-Oct	09-36-46	39	13	36	35		9	9	
04-Oct	09-53-23	37	6	27	33	22	6	5	6
04-Oct	10-21-34	27	8	22	30	27	7	4	6
04-Oct	10-39-16	27	9	27	32	30	9	6	8
04-Oct	11-50-10	35	9	32	36	33	9	9	10
04-Oct	12-40-45	27	5	26	30	23	8	4	7
04-Oct	12-57-19	25	7	32	24	33	10	5	5
04-Oct	13-48-07	27	13	27	27	25	11	12	7
04-Oct	14-09-26	25	6	28	30	32	10	9	11
04-Oct	14-25-41	42	14	35	41	45	13	14	10
05-Oct	09-13-14	46	9	50	54	48	6	7	5
05-Oct	09-29-15	34	6	37	36	39	9	8	7
05-Oct	09-45-23	24	8	26	27	34	9	8	6
05-Oct	10-28-54	20	7	24	26	20	9	9	7
05-Oct	11-15-51	26	10	32	26	25	9	8	11
05-Oct	13-42-46	18	5	27	20	20	6	5	3
05-Oct	14-08-25	23	8	33	27		9	6	
05-Oct	14-58-16	22	9	23	25		14	8	
06-Oct	09-12-21	34	9	31	34	26	7	8	
06-Oct	09-28-30	30	11	26	35		14	7	
06-Oct	09-44-44	20	5	19	18		9	8	
06-Oct	10-27-57	13	7	15	17		13	8	
06-Oct	10-46-13	18	4	22	22	23	5	10	
06-Oct	11-04-00	23	10	22	23	23	5	8	
06-Oct	12-29-02	17	4	13	13	16	4	4	
06-Oct	13-42-44	20	5	23	20		7	5	

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