Workshop on Hydroacoustics for Salmon Management; March 22-23, 2006, Vancouver, B.C.

March 2007

Pacific Salmon Commission Technical Report No. 21

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Workshop Program

WORKSHOP ON HYDROACOUSTICS
FOR SALMON MANAGEMENT
March 22-23 2006

Wednesday March 22, 2006

9:00 am Welcome and Introduction

9:15 am Feasibility of using the Dual-Frequency Identification Sonar (DIDSON) to estimate the abundance of terminal sockeye populations in the Fraser River. Dr. John Holmes

- In 2004, DFO began a program to identify where and how the DIDSON imaging system could be deployed to estimate spawning ground escapement of sockeye salmon. Deployment sites have been identified on several tributary systems in which mark-recapture programs are used for terminal assessment and the accuracy of the data produced by the DIDSON has been calibrated against an enumeration fence. Ongoing research is directed at training operational staff to use this technology and at the development of software designed to assist the counting process and species identification.

9:45 am Use of high-frequency imaging sonar to estimate adult sockeye salmon escapement in the Horsefly River. George Cronkite.

- The 2005 sockeye salmon run in the Horsefly River marked the first operational deployment of the DIDSON imaging system in the Fraser River watershed. Robust data collection and analysis techniques were developed and QA/QC procedures that should become standards for DIDSON deployments were implemented while testing new power supply equipment and a portable weir design. The program was remarkably successful with daily estimates of net upstream migration available within 24 hrs of data collection and a training period of less than a week for staff unfamiliar with hydroacoustic technology. The technology offers potential labour cost advantages when compared to conventional large-scale mark-recapture programs.

10:15 am Coffee Break.

10:30 am Temporal sampling strategy for making terminal area sockeye salmon escapement estimates. Dr. Juha Lilja

Although it is tempting to use the DIDSON technology to conduct a total census of a returning population (record and count every minute of the run), this approach is neither practical in terms of data storage requirements nor an efficient use of staff resources. Subsampling temporally within an hour and estimating the variance associated with the resulting escapement estimates allows us to evaluate the tradeoffs between sampling effort (min/hr) and our confidence in the resulting escapement estimates. This approach assumes that passage rates are not subject to high frequency variation at periodicities under an hour and it assumes that the count data are not biased as a result of undetected fish passing the acoustic site. Here we apply spectral, auto and cross-correlation analyses to assess the temporal patterns in passage rates from the Horsefly River to investigate the effects of different levels of sampling effort on the resulting escapement estimates.

10:50 am Use of hydroacoustic technology to survey juvenile sockeye salmon in lakes in the Fraser River watershed. Jeremy Hume.

- The program is part of ecosystem investigations of sockeye ecology, to determine factors affecting the productive capacity of sockeye rearing lakes. Data are used to determine optimum escapements and for forecasting run sizes to selected major sockeye lakes, including Quesnel and Shuswap lakes.

11:30 am Potential for hydroacoustic technology for the estimation of salmon passage in marine waters. Dr. Svein Vagle.

- Hydroacoustic sampling systems deployed in strategic locations can provide continuous real-time information for managers on the number of adult salmon returning to the Fraser River. Migration routes for returning adult salmon to the Fraser River are limited and cost effective acoustical survey systems could be deployed to form virtual “acoustic fences” at places such as lower Johnstone Strait and in Juan de Fuca to obtain real-time data about fish movements, and migration divergent rates along this approach to the Fraser River.

12:10 pm Lunch

1:15 pm Round Table on information gaps for Fraser River sockeye management.

1. Population assessment including spawner diversity and conservation units (CU’s). Migration information between Mission and the spawning grounds to provide a better understanding of potential enroute loss and to adjust in-season fishery management accordingly. Cost effective alternatives for the estimation of spawner abundance at the system level and at the terminal streams. Assessments in the marine areas and lake systems for the purpose of marine fishery management and the assessment of juveniles in lakes.

2:45 pm Round Table discussion on the possible future developments in hydroacoustic technologies and their potential contribution to our understanding of the abundance and behaviour of fish populations.

2. Hydroacoustic technology has provided a vital contribution in the assessment of fish populations. However there continues to be uncertainty in our understanding of fish migration. Species identification, improved tracking software and quantitative biases remain to be addressed. Are there developments in hydroacoustic technologies on the horizon that will address some of these concerns?

4:30 pm **Wrap-up of first day and general discussion.**

5:00 pm **Reception and Social**

Thursday March 23, 2006

8:30 am **Research and application of Hydroacoustics for the estimation of the daily passage and abundance of Fraser River salmon at Mission, B.C. Dr. Yunbo Xie**

3. Operated by the PSC, this program is one of the cornerstones of the management of Fraser River sockeye and has been in operation since 1977. The program and its technology have been rigorously scrutinized during a series of reviews over the past 14 years. Research has been directed at evaluating the assumptions in the methodology and the variability of the behaviour of migrating sockeye at the site. Most recently the program has adopted split-beam technology for the estimation of salmon flux. Dual-Frequency Identification Sonar has been used to verify estimates of salmon flux and to examine fish behaviour in the Fraser River.

9:30 am **Success in estimating the daily passage of sockeye in the mainstem of the Fraser River is site-dependent: characterizing the ideal site. Hermann Enzenhofer**

4. From 1994 to 1998, research was conducted on the passage of sockeye salmon in the mainstem of the Fraser River near Qualark Creek. Although the river is wide, because of the high water velocities the majority of sockeye salmon move upstream within 10 m of either bank and there is very little milling or holding behaviour. These and other lessons learned about the impact of site characteristics and fish behaviour on our ability to detect and count upstream moving salmon reliably with hydracoustic systems have been applied to the DIDSON program.

10:15 am Coffee Break.

10:30 pm **Assessment of the application of Dual-Frequency Identification Sonar (DIDSON) in the Fraser River at Boston Bar. Andrew Gray**

5. Studies were carried out using Dual-Frequency Identification Sonar (DIDSON) at an upstream site in the Fraser River near Boston Bar. This technology was found to be applicable for the riverine conditions in that area.

11:00 am **Feasibility of a hydroacoustic counting system for sockeye salmon in the Upper Fraser River. Dr. David Levy**

6. The Lheidli T'enneh Treaty requires in-season salmon stock assessment information for the management of fisheries. A feasibility study was undertaken in 2004 using a side-looking fixed aspect system at a location near Woodpecker.

The location was conducive for quantitative fish assessment and test fisheries provided biological samples for stock identification using DNA methods. Future work is planned to obtain absolute population estimates in near-real time, with a view towards applying the approach throughout the Middle and Upper Fraser watersheds.

11:45 Lunch

12:45 pm Discussion on the need to develop programs to obtain estimates of sockeye abundance at sites upstream on the mainstem of the Fraser River.

7. Studies have shown that programs can be developed to obtain estimates of sockeye abundance at sites upstream on the mainstem of the Fraser River. This information could provide a better understanding of potential enroute loss and an opportunity to adjust in-season fishery management accordingly.

- Treaties with First Nations require in-season salmon stock assessment information to trigger or curtail fisheries. In addition, Under the Pacific Salmon Treaty, there is an obligation on the part of Canada to continue the programs at a level of accuracy attained by the IPSFC. Can hydroacoustics programs be directed to provide information to address the requirements for these Treaties.

2:30 pm Workshop Conclusions

- Can the participants rank the information gaps in Fraser River sockeye management and stock assessment, and what contributions can hydroacoustics programs make towards closing some of these gaps?

3:15 pm Workshop adjourned.

WELCOME AND INTRODUCTION

Jim Cave welcomed participants. He noted the Southern Boundary Restoration & Enhancement Fund Committee of the Pacific Salmon Commission requested that a group be formed to develop a Stock Assessment Framework for Fraser River sockeye in 2006. Initiated by the Department of Fisheries and Oceans, Canada, (DFO) the purpose of the Stock Assessment Framework is to conduct an inventory of stock assessment activities, identify knowledge gaps, opportunities for efficiencies, and priorities for the provision of science-based advice on conservation risk and resource management objectives. The Framework is based on four types of survey activities, namely in-season escapement estimation, stock-identification, catch estimation and spawning-ground enumeration. Each of the four activities will be evaluated within the context of a system-wide approach to stock assessment. A series of workshops will be held to solicit and increase inputs from the broader stock assessment community as required. This is the first in the series of workshops. In addition, The Fraser River Panel wishes to ensure the hydroacoustics program at Mission meets the challenging fishery management objectives and that the best available science is used. The proceedings of this workshop would be recorded and shared with relevant PSC panels and committees.

1. Integrating DIDSON in Fraser River stock assessment

John Holmes

Fisheries and Oceans Canada's (DFO) Riverine Acoustics Group develops, evaluates and transfers new technology for stock assessment. The group provides ongoing technical support in the use of technology to DFO's Stock Assessment Division and collaborates with the PSC on technical issues at the Mission facility. Holmes' presentation gave an overview of DIDSON technology, an evaluation of sites in the Fraser River watershed, data quality, and experience with the DIDSON system in terminal areas.

Why use acoustic technology in terminal areas? Cost-effective solutions are needed because resources have not kept pace with the growing number of stocks assessed using mark-recapture techniques and rising costs of mark-recapture programs.

DIDSON uses high frequency sound to produce video images of objects. Developed by the U.S. Navy, it has long-range and standard versions. The latter has maximum working ranges of 40 m for low frequency (1.1 MHz) and 15 m for high frequency (1.8 MHz). The beam is usually oriented at a slight grazing angle to provide shape information about a target, but the point of view of the resulting image appears to be from directly above and looking straight down. One of the limitations of transducer design is that when the high-resolution composite beam is oriented perpendicular to the migration direction, the elevation of fish in the water column is not known such that two fish at the same range, but different elevations in the same beams cannot be distinguished. This situation will be transitory for tracking the fish since two fish are not likely to be perfectly aligned in this manner for more than 1 or 2 frames as they move across the DIDSON field of view (29° horizontally). However, the system can only provide 2-dimensional information on spatial distributions of imaged fish. During set-up, the aim must be carefully checked to eliminate any blind zones near the surface or bottom. The DIDSON system comes with software tools that can measure and record the length of objects.

Holmes' group has evaluated and rated several potential sites for using this technology in the upper and lower Fraser. Site selection is key to success. Ideal conditions include a single channel, laminar flow, planar bottom configuration, fish actively migrating through the site with no milling or holding behaviour, a location below known spawning areas and a site that is easily accessible from nearby roads. Appropriate sites fall under two main categories: wide, high velocity sites (e.g., mainstem Fraser at Qualark Creek, Chilko, Adams) and narrower, lower velocity sites at which fish passage can be constricted by weirs (e.g., Horsefly, Mitchell, Seymour).

The group also looked at accuracy and precision (among individuals counting files) of data. DIDSON counts of up to 932 fish/hour were calibrated against concurrent visual counts at the Stellako fish fence and it was concluded that DIDSON was as accurate as the visual count as long as the beam was insonifying the area through which fish are swimming, i.e., no surface or bottom blind zones. Automated counting remains a challenge—current image analysis software cannot yet replicate human capabilities at rates of more than about 1,200 fish/hour. However, manual counting from the image files worked well at all observed passage rates (up to 7,300 fish/hour).

Current DIDSON technology can provide 24-hour monitoring of spawning escapement, can monitor escapement in tributaries not amenable to other sonar technology, can estimate net hourly upstream passage at rates up to at least 7,300 fish/hour, can derive run-timing curves for spawning areas and can measure and record the lengths of passing fish. The standard version DIDSON cannot detect fish beyond ranges of 15 m (high frequency) or 40 m (low frequency). The DIDSON system cannot collect biological information other than length or detect external tags on fish nor can it automatically count fish or reliably identify different salmon species in a mixed group, although software that may address the latter two issues is currently being developed.

The group's ongoing DIDSON work includes further experiments to improve its understanding of the physics of the DIDSON system, deriving practical sampling strategies, benefit-cost comparisons of DIDSON and mark-recapture escapement estimates, continuing development of external image analysis and tracking software for use on DIDSON files, finding new locations and uses for the DIDSON system and providing ongoing technical support to DFO's Stock Assessment Division.

Holmes concluded that DIDSON is versatile and easy to use, with appropriate training. It offers a practical alternative to mark-recapture and can provide more timely escapement data to managers.

Discussion

- In comparing data quality of visual/DIDSON counts, why was there lower precision at lower abundance? Holmes explained that any errors at lower passage rates had higher leverage on precision estimates, e.g. an error of one or two fish in a file with a total of 5 fish yields a higher percent error than an error of one or two fish in a file with a 100 fish.
- How soon will automated counting be possible? Holmes said it's not even clear yet that it can be done.
- What precision was found at the Horsefly count? Holmes said he didn't have the exact figure but it was similar to the precision of high count events on the Stellako River, i.e., about 5 %.
- Is shadowing a concern? Yes, Holmes replied. This is why we are interested in higher density passage events, especially if fish stay exactly parallel all the way across the beam. This challenge also complicates image analysis.

2. 2005 DIDSON Enumeration of Horsefly sockeye

George Cronkite

The presentation gave an overview of the enumeration site on the Horsefly River and the set-up of the DIDSON counter there. The team did visual counts for comparison. Test files were 10 – 60 minutes long and some were repeat-counted to check observer precision. A comparison of DIDSON counts to visual upstream counts showed a very close agreement.

The data showed changing patterns of fish behaviour over the study period. For example, most fish passed at night or at sunset during the early portion of the run (Aug), but during the latter part of the run, passage occurred throughout the day, , and most fish passed mid-river during certain periods. A comparison of fish length measured with the DIDSON to fish length measured at the tagging site showed an over-estimation bias of approximately 1.6 cm by the DIDSON, for fish migrating at the ranges examined. Other researchers have noted larger biases in length measurements for fish migrating farther from the transducer.

The data provided daily run timing, cumulative run timing and mapped upstream and downstream movement over the study period.

This project also established confidence limits on the DIDSON population estimates. Fish detection errors were zero. Average percent error between observers was ± 6% and temporal error due to sub-sampling in time ranged from ± 0% to ± 10% (for 60 minutes to 10 minutes). Overall error was ± 14% for 2005. This could be reduced to ± 10% if all the 20 minute files were fully counted, but this would not change the point estimate. The result was an escapement estimate with 95% confidence of 645,310 sockeye ± 90,599.

Discussion

- What transmission-loss compensation factor was used for image analysis? Cronkite said it was 30 Log R, but this was somewhat subjective, based on viewer preference.
- Asked about the zero error rate for detection, Cronkite said this was based on the beam covering the entire passage area which was tested in the field (comparison of visual and DIDSON counts), and that fish were not "stacking vertically, nor did the fish reach high enough densities to cause shadowing."
- Were observer comparisons done at the same settings? "Pretty much," Cronkite replied. If significant disagreement was found, this was a good flag of problems.
- How did this result compare to the traditional mark recapture count? Keri Benner reported that the mark-recapture method estimated just over 800,000 for the Horsefly. Cronkite replied that we did not make these comparisons. We have presented our estimates along with our measures of accuracy and precision. We believe our estimates are defensible and have realistic confidence limits.
- What about fence integrity? Cronkite said there was one high-water incident, but it was insignificant due to low passage rates at the time (late season) and also the break in the fence was on the side of the river where fish did not prefer to migrate. The site was fully manned and the fence inspected daily.
- What about the durability of this equipment? Cronkite said it has been very reliable. It was run 24 hours a day with no problems, and has been moved around a lot for several years now.
- Given the 20% difference from mark recapture estimates, is there confidence that this technology can replace existing programs? Cronkite said he would like to test the system at higher passage rates, but believes that this could serve as the sole estimation tool for the Horsefly next year. Keri Benner added that conditions at Horsefly were ideal this year and suggested first testing the system in fluctuating water conditions. Cronkite replied that the DIDSON beam is large enough vertically to cover much deeper water than was experienced at Horsefly.

- Were the 20-minute blocks of time randomly chosen for counting? No, Cronkite replied, but there was no reason to think fish are tied to hourly behaviour.

Participants further discussed the discrepancy between the mark-recapture and DIDSON estimates, noting the following:

- The literature suggests mark-recapture methods over-estimate.
- No mark-recapture/DIDSON comparisons have been done elsewhere, but Cronkite was confident in the DIDSON results.
- What are the confidence limits in mark-recapture?
- There could be a consistent bias for visual and DIDSON counts.
- You would expect divergence at higher passage rates
- At higher densities, there might be fish detection errors due to acoustic shadowing.

3. Temporal sampling strategy: terminal escapement

Juha Lilja, DFO

This study involved counting terminal sockeye salmon escapement over a 2-week period (September 15 – 25). The number of fish passing was counted in the first 10 minutes of every hour (x1, x2…), and then again in the second 10 minutes (y1, y2…). Three time series were constructed to compare the two samples, plus the combined samples for each hour and this showed good correlation. Correlation analysis showed that changes in upstream migration in the first-differenced series between hours are negatively correlated whereas significant correlations were not observed within hours. Thus, measurements of escapement estimated from first and second 10-min samples were similar and variation between them was random suggesting that the choice of 10-min sample period within the hour made no difference in the overall result. A day/night analysis found significant peaks just before sunset and at night.

Sampling 10 minutes per hour produced confidence limits of ± 10%. The width of the confidence intervals declines exponentially between 0 and 10-min sampling time. Further increases to sampling times beyond 10 minutes resulted in minimal increases in precision. There was not much difference between sampling the first or second 10-minute sample of each hour.

Lilja concluded that hourly sampling was justified, that diurnal and semi-diurnal rhythms were observed, and that hour-to-hour variation increased as the number of fish increased. Further increase to the precision of overall estimates could be obtained by increasing the sampling time during periods of high passage.

Discussion

- The sunrise/sunset times were based on actual Vancouver times, which changed slightly over the study period.
- Holmes said this analysis suggested sampling strategies such as increasing sampling for diurnal peaks and run peaks. This work would also facilitate cost-benefit analyses.
- With enough data storage, it would be possible to record all the time and to just count sub-samples as needed.

4. Hydroacoustic Lake surveys of Juvenile Sockeye

Jeremy Hume

This presentation gave an overview of the Lakes program, which involves ecosystem studies of juvenile sockeye and their rearing lakes. Acoustic/trawl surveys are used to verify empirical models of lake rearing capacity, to assess stock status (especially where no adult escapement is done) and to develop pre-season forecasts of adult returns (though this hasn't been a good predictor in recent years).

Sockeye fry spend a year or two in rearing lakes. During the day they school at depths of 65 metres, but they come to the surface to feed at sunset and disperse at a depth of around 25 metres at night. The lake is stratified into sections for trawling at night, with acoustic data used to target trawl depth and duration. Acoustic data is analysed with Echoview and acoustic population estimates are apportioned to species using samples from trawl catches. The equipment used is a Biosonics DE6000 Split Beam.

The program has 20-year data sets for Quesnel and Shuswap lakes. Surveys have been done on 23 lakes in the Fraser watershed, 18 lakes in the Skeena system, and seven lakes for coastal stocks. The data are used by fisheries managers, First Nations, biologists working on species at risk and others.

Plans include continuing long-term data collection for Quesnel and Shuswap lakes, a joint project with the Province on Sockeye/Kokanee/Rainbow Trout interactions, complete surveys of all rearing lakes in the Fraser, monitoring the success of recovery operations in Cultus and Sakinaw lakes and similar work on the north and central coasts, where little sampling has been done.

Discussion

- Has this program been used to assess adult spawners? No, Hume replied, though others have done it successfully elsewhere. Species identification is an issue.
- What is the usefulness of juvenile counts in predicting returns? It is quite good, Hume replied, but naïve models work just as well, if not better. Looking at biomass, fry size, etc. might improve this.
- Is the technology easily transferable? Hume said the program involves First Nations in the Skeena and the technology is transferable.

5. Hydroacoustic estimation for salmon in marine waters

Svein Vagle

Managers have historically relied on catch data for estimating passage of salmon in marine waters, but the challenge is that these data are no longer available due to reduced fishing. Hydroacoustic technology is currently the only real alternative and Johnston Strait provides an ideal "fence" location for this tool.

The simplest and least expensive hydroacoustic systems make use of single- and multi-frequency backscatter. Multi-frequency sonars have the potential to separate fish from plankton and also provide species classification. Dual- and split-beam backscatter systems are more complicated and a bit more expensive but are established as valuable tools in fish detection and counting. Multi-beam systems are costly and complicated at present mostly used for bottom mapping, even though they have the potential for water column measurements as well. Doppler systems are reasonably priced, quite feasible and might help with behaviour and classification. Future techniques may include acoustic daylight systems that use natural sound at a range of frequencies at once. However, these techniques don't work for calm water and still need a lot of refinements.

Other options include bottom-mounted active intermediate range sonar such as the 40 element 12 kHz array used in Denmark to track schools of herring for more than 2 km. Such an array towed behind a ship has been used to detect fish at ranges greater than 7 km. However, in its present configuration it is not possible to identify the targets. Ocean acoustic waveguide remote sensing (OAWRS) systems emit sound in all directions and are powerful tools for large area surveys of fish schools in shallow waters with the right sound propagation characteristics. Using a towed array that can be steered to map the range and direction of the scattered sound

allows for mapping of large areas in a relatively short time. However, the frequency range used (300-500Hz) may be problematic for marine mammals.
Cabled observatories are another option that can be cost effective and provide reliable real-time seasonal coverage close to the shoreline. The Ocean HUB is a bottom-mounted system deployed in a Norway fjord to monitor dynamic schools of herring over the entire winter period. It is also possible to combine systems that scan vertically and horizontally.

Issues to consider in setting up a system in Johnstone Strait include best location, appropriate equipment, whether it can actually detect salmon, comparisons with other counts and other systems. Only after doing this and testing the system for one or two seasons should a decision be made on whether a permanent system is feasible.

In summary, technology and expertise are now available and affordable enough to consider the feasibility of establishing fixed hydroacoustic installations on the B.C. coast to provide timely data for estimating returning salmon abundance. However, studies are needed to address the above-noted issues and others, such as species classification.

Discussion

- How transferable is this to a non-technical group? Vagle said interns could be trained to use this and it could all be run through the Internet.
- What is needed to permit species identification? Vagle said these studies are just starting.

Round table I: information gaps for Fraser sockeye

Facilitator Mike Lapointe assigned participants to three breakout groups, explaining the goal of these discussions is to help managers, scientists and others match the needs that exist to available tools, and to understand opportunities and limitations. He reviewed the questions presented for discussion: (see Appendix 2)

1. Canada is in the initial stages of implementing its Wild Salmon Policy (WSP). This policy focuses on conservation units (CU's) which have yet to be specified but will likely be associated with lake units for Fraser River sockeye. What is the required level of population assessment under the WSP? For in-season management? For assessment of CU's? For assessment of diversity within conservation units (CU's)?

2. Are there cost effective alternatives for the estimation of spawner abundance at the system level and at the terminal streams?

3. Can managers comment on the utility of assessments in the marine areas for the purposes of in-season management?

4. Can managers comment of the utility of assessment of juveniles in lakes?

Group 1

The group discussion covered the following key points:

Question 1:

- An overview of the WSP, which produced more questions than answers (e.g. How to define CUs? What are the assessment needs, benchmarks, etc.?), though a role was seen for hydroacoustic technology in assessing adult and juvenile abundance.
- Would stocks in poor condition be a higher priority for assessment?

Question 2

- Having more than one assessment site in the mainstem Fraser to address recent issues.
- Efficiency of mark/recapture vs. hydroacoustics in terminal areas. The latter can be more effective in larger systems. Accuracy and precision needs may affect the choice. Hydroacoustics can provide a cost-effective alternative but the answer is site specific.

Question 3

- Hydroacoustics could be cost effective in marine areas and could provide a more consistent picture of what's going by. But questions remain regarding feasibility, cost and species identification. There was support for a feasibility study.

Question 4

- This is very important for the WSP, in terms of assessing productivity at various life stages and bottlenecks. There have been questions recently in terms of the utility in forecasting abundance of returning salmon, but assessment of juveniles is useful for sorting out freshwater and marine survival issues. Lakes with more intensive surveys have been very helpful in explaining cyclic dominance, for example. There was some support for increasing juvenile lake surveys, on a case-by-case basis.

Group 2

This group had a similar discussion, covering the following key points:

Question 1:

- What does development of CUs mean and how might DFO go forward? Hydroacoustic technology will have application for both juvenile and adult stages and will be key for the WSP. Questions include: What level of assessment is required for CUs? Would the priority be for stocks in poor health or those with highest harvest? Options include spot checks for less abundant stocks every few years.

Question 2:

- Different technologies: Blueview may be more cost effective than DIDSON and there are plans to test it this year.
- Use juvenile estimates and back-calculate to get spawning populations?
- Use longer-range DIDSON for larger systems
- Another option is to combine resistivity counters and video cameras
- The KISS principle: concentrate on easily transferable technology that doesn't require extensive expertise—growing reliance on client groups.

Question 3:

- There is interest in improving the ability to assess returning stocks in-season, but there are concerns about the feasibility of implementing this in marine areas, especially re species identification. Issues include the influence of tidal flow on different species. This is the area where the least amount of work has been done and there is significant potential for improving estimates of abundance in marine areas that are currently subject to large variations due the reliance on indices of abundance derived from test fishery catches that sample only a small fraction of the migration.

Question 4:

- There was desire for and potential utility in testing DIDSON and other hydroacoustic technologies for smolt out-migration.
- Juvenile lake programs: a fairly developed program exists, but it is being scaled back due to funding constraints. The critical issue is funding. Shallow lakes present a problem for

hydroacoustics, so future testing for side-scanning systems might be helpful. It will be a challenge to assess non-lake rearing stocks in future.

Group 3

Discussion covered the following key points:

Question 1:

- Discussion of the WSP, including the CU concept, assessment needs and what would be the size of populations in a CU.

Question 2:

- The type of assessment would depend on the type of population. Hydroacoustics might be more cost effective in larger systems and useful in terminal areas. Would it be more useful to position the counter in the Quesnel River itself or in component systems (total system or index group)?
- There was general support for continuing the fall fry programs and expanding them if possible. This is being used for forecasts and evaluation of cyclic dominance.
- Discussion of precision and accuracy required for in-season management.
- Are key programs like Mission accurate enough and should additional efforts be deployed elsewhere.
- Hydroacoustics will be required for in-season management but it will be ancillary for the WSP.
- Hydroacoustics could be a cost-effective alternative to mark-recapture, with more stock identification at Mission.

Question 3

- Reduced fishing has meant reduced information for management. Participants saw real utility in assessing the feasibility of a marine program. There are concerns about species composition, although test fishing could help address that.

Question 4:

- The group had similar findings on the assessment of juveniles in lakes.

Discussion

- Population specific estimates could be done at Mission using DNA.
- There may be need for a portable acoustic system that could be positioned to evaluate particular stocks when the need arises
- There is no effort to estimate en route losses and hydroacoustic technology has some potential to achieve that. The technology is there. Having stations in sequence could address that large gap. In that way, Mission could play a role.

Round table II: possible future developments in hydroacoustic technology

Discussion began on the benefits and challenges of automated counting. Holmes explained that improving image analysis for DIDSON is not a trivial undertaking. Cronkite didn’t see major cost savings from this, as two people must still be onsite at all times. It takes about five hours to count the previous 24 hours of data. It was suggested, though, that this might permit more extensive sampling and thus more precision. Xie added that significant progress has been made and he expects this to continue to permit the operation of DIDSON with very minimal human supervision. However, he noted, it will never be perfect. It will work differently at different sites, given a dynamic subject and different signal to noise ratios. Xie agreed, noting the importance of site selection.

Biosonics, which makes split beams, is focusing efforts on the automation process: e.g. systems that automatically count and report results on a Web page. The level of precision and accuracy depends on whether managers want the results now, with ± 20% errors, or in three days, with ± 5%. At some sites, where behaviour is uniform enough, it can be automated, so the answer is site specific. It was noted that the ability to automate changes the cost-benefit analysis. It's important not to over-estimate what the system can do or to throw the baby with the bathwater. Holmes noted that their investigations of the tracking software that has been developed for the Didson system indicated that at densities of *200* fish/10 minute DIDSON file, there were real problems with the current version of automated counting software. However, no formal tests have been undertaken.

Regarding technology that can show the vertical distribution of fish in the water column, Holmes indicated that a DIDSON system on its side (oriented 90° relative to normal horizontal deployment configuration) would provide vertical distribution of fish, though it would lose upstream/downstream distribution, and direction of travel information.

Participants also discussed echo-integration. A recent paper was presented in Alaska on using this to address higher densities. Holmes said it works best with single species of salmon.

Asked about the success of hydroacoustics for counting out-migrating smolts, Xie said this had not been tried at Mission yet. Cronkite added that this would require a very clean system, whereas Mission is too noisy. It would also need to be stock-specific. There is still some debate about whether this can be done. The size of the fish (i.e. signal to noise ratio) is important. Another participant said echo-integration is the fallback technique and should not be abandoned, though the downsides are severe in terms of biasing the results, especially when dealing with small fish.

The issue of calibration was examined at Wood River, Alaska, next to the counting tower. Echo counting, trace formation and echo integration were tested. Trace formation was very linear to the tower count, up to a certain rate. Echo-integration assumes all fish are even in the beam but in this case, they were all at the bottom. A correction factor was introduced and the results were then linear to the tower count for very high volumes, but this was a very ideal site. At a critical density, one technique failed in an ideal site. It was noted that at Mission, distribution tends to shift during the day from uniform to the bottom, so the correction factor would vary accordingly.

Participants also discussed the value of being able to access raw data in the future. Xie explained that in a high-density scenario, with reasonable access to these data, it would be possible to quickly check on bias. In recent years, the inability to reach escapement targets has severely constrained fisheries, so fish have been passing in unprecedented numbers. It was clear that the system was saturated but without access to the raw data for comparison to the trace count, it was not possible to quickly estimate bias. This scenario will be more common in the future, so further discussion on resolving this issue was suggested.

A final question related to the feasibility of designing tags that the system could pick up. The response was that it's not easy because it's not just a matter of detecting a tag but also of identifying a particular tag. If cost were no object, it would be easier to use a parallel system for tag detection purposes.

6. Hydroacoustic estimation of salmon passage at Mission

Yunbo Xie

In estimating the daily passage of salmon, the hydroacoustic site at Mission is supported by two gillnet test fisheries downriver sites, that provide information on species and stock composition. Visual counts are also done at Hells Gate. Mission is the only site that provides ongoing quantitative data, though the hydroacoustic system cannot distinguish pink salmon from sockeye salmon. DFO operated an experimental hydroacoustic site at Qualark in the 1990s and the PSC examined another site at Boston Bar in 2005. These two upriver sites have potential for the future, if additional sites are desired to address the large gap between downriver and terminal enumeration sites.

The initial hydroacoustic program at Mission consisted of a boat crossing the river 160 – 180 times a day with a mobile single-beam sampling system (1977-2003). The program has operated well over the years, however in until a large number of expected sockeye failed to arrive on the spawning grounds, sparking a public enquiry. A joint working group found and corrected mathematical errors in the estimation model for the single-beam data. The sampling design optimized in 1999 through an attempt to minimize the variance in the estimates and an improved sampling methodology was implemented for the single-beam system during that season. In 1995, a split beam system was installed at the site to examine fish behaviour, providing direct measurements of swimming speed and direction of travel of insonified targets. While it important hydroacoustic results in some circumstances may be verified with visual counts, this cannot be done at Mission due to high turbidity of the water.

Since 2004, a new split-beam hydroacoustic estimator at Mission has been used as the in-season management tool. The program combines a side-looking system based on the left (south) bank and a vessel-based downward looking system. Some aspects of this program have been verified by DIDSON technology. The predominance of the migration occurs on the left bank (approximately 60%) and the system installed on this bank samples 10% of migrating fish in the coverage area, while the mobile system samples 0.5%. However, acoustic blind zones remain in the left-bank coverage area. The number of fish migrating in the blind zones has to be estimated by a geo-statistical extrapolation model. Another constraint of the system is that the vessel-based system cannot provide reliable measurements of swimming speed and direction of travel of insonified fish. As a result, the estimation model relies on a key assumption that migration behaviour is uniform across the river-width in order to estimate net-upstream salmon flux beyond the left-bank coverage area

Since visual counting is not possible for verifying the hydroacoustically estimated salmon abundance in the Fraser River at Mission, a 36-hour experiment in 2004 compared estimates from the left-bank split-beam and DIDSON systems for a limited area up to 40m from the left-bank split-beam system. Hourly counts varied somewhat but hourly means from the two systems were highly correlated, and of very similar magnitude Based on the DIDSON comparisions it appears that the left bank split beam system can provide accurate estimates over this limited area over the range of passage rates examined (approximately 2500 fish/day in the commonly insonified area).

Two challenges emerged in 2005. The first was record high daily fish passage, due to fishing constraints and the abundance of pink salmon, with a maximum of 767,000 salmon passing Mission on September 1. The second was the late arrival of sockeye and early arrival of pinks, which led to significant overlap in their upstream migrations. Furthermore the test fisheries used to apportion the hydroacoustics estimates to the two species over sampled the sockeye salmon because pink salmon are more shore oriented and less vulnerable to the gear.

Most but not all potential sources of bias in the salmon estimation model have been determined to be negative. Problems include saturation densities, detection problems due to pink salmon tending to swim too close to the transducer, assumptions about fish travelling up the far bank and fish avoidance of the boat that provides mobile sampling mid-river. DIDSON tests clearly showed fish scattering to avoid the boat. In the absence of other competing biases boat avoidance is believed to cause significant under-estimation.

Summing up, the new split-beam system at Mission produced more robust and precise estimates of daily total salmon abundances past Mission in comparison to the old single-beam system. Split-beam estimation of salmon flux off the south bank was verified with the fish counts using DIDSON. Potential biases have been identified and analysis is ongoing to quantify these biases. Another split-beam system will be tested this summer on the opposite shore to measure fish flux off the north (right) bank.

Discussion

- Xie said efforts are underway to quantify the boat avoidance bias. If there is more uniform distribution of fish across the river, this would suggest a lower bias than if the fish are concentrated along the shorelines. This pattern is known to vary as tides go in and out. Also, if more fish are close to the surface, this would increase the bias.
- Is the intent to have systems on the north and south shores providing most of the coverage? Xie said this depends on fish distribution vertically and across the river. The plan is to have shore-based units on both banks, minimizing the need for sampling of the offshore area by the mobile system.
- Is there technology that can avoid the need for the boat? Xie said the potential exists, with alternatives described the previous day, such as a cabled system across the river bottom. Another option is to anchor the boat in offshore areas and use a side-scanning sound-beam to sample off-shore fish.

7. Ideal site characteristics – Qualark site

Hermann Enzenhofer

This presentation elaborated on the ideal site characteristics for hydroacoustic enumeration of salmon passage. These include a straight single channel with laminar flow, a planar bottom (i.e. a straight bottom free of obstructions that create blind zones), no large boulders, an area free of human activity that would alter fish behaviour or introduce noise, fish actively migrating, and site accessibility.

Sample echograms were shown for single and split-beam systems to show actively migrating fish passage. The latter can produce 3-D information; editing software can provide further analysis of each migrating fish detected.

Qualark Creek is the first site on the mainstem Fraser that is amenable to acoustic detection of migrating fish. It's an 800-metre stretch of laminar flow, 150 metres wide, 95 kilometres upstream of Mission (2 - 3 days migration).

The site was established as a research station to develop acoustic methods for counting migrating fish. Work was undertaken to remove obstructions, to smooth the bottom profile and to install the necessary in-river equipment. Fish passage was near shore and was forced offshore around a weir to pass through the acoustic beam where detection is optimized. Drift gill-net sampling was performed to estimate species composition for apportioning the acoustic estimate and to collect biological data. A similar acoustic sampling design was tested at a site on the Thompson River at Spences Bridge. To measure bias at the Spences Bridge site, acoustic estimates were compared to a visual count over a delineated sample area, aided by overhead and underwater cameras These comparisons also aided the selection of a more appropriate transducer and provided a direct comparison of acoustically tracked fish to simultaneous video tracked fish over the sample area.

The research also identified issues with the tracking algorithms. The "ping" rate can affect accuracy of detection and tracking. If a faster ping rate is needed to cover near shore passage, then the detection range is shortened. Multiple aim strategies with slower ping rates are required to cover deeper water and longer range migrating fish, as is the case at Mission. As the number of returned echoes increase in a given ping with range it can confuse the tracker. As passage increases, recognition of the direction of travel by the acoustic system is impacted. Thus the technology is more suitable at sites where fish are actively migrating. The lessons learned at Qualark have been applied at other sites, including Mission, Rivers Inlet and the Michipicoten River in Ontario.

Summing up, Qualark can provide reliable estimates because fish passage is near shore. It remains a prime location for hydroacoustics because fish are committed to migrating upstream. Site selection remains a crucial component for hydroacoustic enumeration and DIDSON will work at this site. This site can also provide early warning of passage problems, as occurred in 1997 during the Early Stuart sockeye migration period.

Discussion

- What were the dates of operation? From 1993 to 1998.
- What annual maintenance was needed? Someone was always on site, so maintenance was constantly done as the river level dropped. Boulder removal was only done at the outset but damaged sandbags were replaced periodically.
- How practical is DIDSON, given high densities anticipated? It's not yet clear what the limits are for DIDSON. The impact of high density is reduced at Qualark due to the need for two systems, one on each bank, but it's not clear what the maximum migration numbers would be and what the limits are for the DIDSON. Multiple aims may be a possibility but there are some technical issues with this approach that need to be addressed for proper implementation.
- Why DIDSON and not split beam? Mainly due to ease of transfer of the technology. Split beam could be used, but this requires more training. Range is not an issue at Qualark as fish passage occurs within 10 m of the shore.
- How were the passage problems identified in 1997? The river was high, with warm water and high sediment loads, and the fish which normally travel near the bottom where current flows are less didn't seem to know where to go. Fish were stacking in creek mouths and back eddies and were observed, milling upstream of the weir. Fish passage observed by the split-beam acoustic system during this period indicated milling behaviour and not actively migrating fish tracks. Significant mortality was eventually seen but any carcasses washed downriver.
- Were other upstream sites evaluated? Other sites were looked at such as Boston Bar, Lillooet area and Spences Bridge to determine the background noise characteristics introduced to the acoustic system and to determine logistical problems for developing the site.
- When using a DIDSON system, stratifying sampling over range from the transducer would help for large passage numbers at some sites. This approach was successfully used during the Horsefly project in 2005 during playback of high passage rate files.

8. Hydroacoustic enumeration – Boston Bar

Andrew Gray

Various discrepancies exist in stock estimates over the years between Mission and the terminal areas. Currently, the only in-season assessment site on the mainstem of the Fraser River upstream of Mission is a daily visual count made by the PSC at Hells Gate. However these visual counts are only made for one shore during daylight hours and thus this site only provides index information on daily passage rates. An acoustic site at Boston Bar a short distance upstream of Hells Gate could provide useful quantitative information on passage rates. Technological limitations that had weighed against Boston Bar as an appropriate site in the past have been overcome Therefore, a grant from the Southern Endowment Fund was used to evaluate a site using a DIDSON sonar just downstream of the North Bend Bridge in a "wet test" in September 2005.

The study site at Boston Bar was at narrow section of the river, with smooth flow and easy site access. The substrate is made mainly of 30 – 60 cm sized rocks, and any large rocks on the opposite bank could be cleared. The bottom slopes quite steeply. We began scanning the entire water column by aiming the DIDSON horizontal beam at 0° , -6° and -18° pitch-angles, but no fish were detected after four hours of sampling in this configuration. When the sonar-beam was aimed further down to -20°, strongly insonifying many of the larger rocks at the site, we began to see larger numbers of fish targets migrating through the rocks. Many fish were detected over the 19-hour test period with this new configuration.

It was concluded that this site would allow fish detection. Next steps in following up this preliminary test would include verifying the river profile, conducting an extended test, testing the fish detection on the left bank, confirming river height fluctuation and developing a sampling plan.Since Boston Bar is above Hells Gate, this site can be used to monitor passage above the most difficult stretch of river.

Discussion

- How would you cover the mid-river section? A longer-range system could be used. You would not expect many fish in the middle, but it would be important to cover it.
- Multi-aim schemes can raise issues (e.g. double sampling). A narrower beam may also not help. Gray agreed, noting that an extended test would be helpful.
- What about species identification? The Boston Bar band fishes there, so similar test fishing to that used at Qualark in the past should be feasible. There is set net fishing nearby but it is near shore and would cause minimal disruption.
- What is the time lag from Mission? This site is 4 to 5 days from Mission.

9. Feasibility of Upper Fraser River hydroacoustic site

David Levy

This presentation described a project to scope out a sampling program to deliver on treaty requirements for the L'heidli T'enneh Band in Prince George. This program would support a domestic allocation of 5,000 sockeye per year and a commercial harvest of up to 12,500 sockeye per year. Given the limited commercial value of this harvest, cost is a significant factor in determining an appropriate assessment program. The Yale band recently agreed on a treaty that provides for a potentially significant share (0.9097% of Canadian TAC) and many other treaties are on the way, so this has important implications for the design of stock assessment programs.

Requirements for Upper Fraser River stock assessment programs include the ability to produce estimates to trigger or close fisheries, to address conservation concerns for several key Upper Fraser sockeye stocks and to provide in-season estimates for management (near real-time). Reliability and cost effectiveness are both key attributes. The program would assess five Upper Fraser sockeye stocks (early and late Stuart, Nadina, Stellako, and Bowron), plus many Upper Fraser Chinook stocks.

A successful 2004 workshop was held with agency scientists to obtain their input, reach consensus on run size estimation methodology and to explore future partnerships, which will be critical in addressing cost concerns. It quickly became clear that mark-recapture would be impractical and too invasive. CPUE has been used elsewhere to provide a predictor of run size but requires a series of annual observations in the upper river which can be compared to other estimates of abundance from stock assessment programs to establish the utility of this method for L'heidli T'enneh purposes.

In selecting an appropriate hydroacoustic site, the preference was for a location near the southern territorial boundaries, which could provide data for all incoming stocks on their approach. Based on physical characteristics, a site at Woodpecker was selected for testing, and a fish wheel and set net sites were located nearby. The bottom profile at this location is compatible with the hydroacoustic technology but river discharge is very dynamic, which creates challenges.

Standardized test fishing was done over the season, which revealed important information about daily run patterns. DNA testing of the catches showed a very smooth progression of runs for different populations. Set netting and DNA analysis provided a good predictor of escapement for the five sockeye stocks.

Although testing of the fish wheel was complicated by fast rising water, it suggested feasibility for selective fishing.

The hydroacoustic equipment used was a split-beam echo sounder and a 2° x 10° elliptical transducer on the left (eastern) bank. This gear could not sample the entire water column, but was aimed close to the bottom where the majority of fish were expected to be located. Also, this deployment, which was 15 m off the left bank, sampled a 65 m range, i.e., to about the mid-point in the river cross-section at this site, leaving a large blind zone in the deepest portion of the river near the right (western) bank. The test data showed that fish migration peaked during morning hours and most fish passed the site at ranges more than 40 metres offshore. Split-beam data showed large fish moving upstream and smaller fish swimming downstream. However, the trend in net daily upstream escapement produced by the hydroacoustic gear differed from the trends for the same period produced by set nets.

In conclusion, the set netting and DNA analysis were very useful. Hydroacoustic enumeration at this site shows promise and needs additional work, as does the fish wheel. It is expected that it could take a few years to make it all work. A second hydroacoustic system on the opposite bank would help address a blind spot due to bottom irregularity. It will also be very important to develop partnerships with DFO, PSC and upstream First Nations.

In terms of future project activities, set netting can continue along with DNA analysis for stock identification. The hydroacoustic equipment, on loan from Alaska, will be used for further sampling to estimate daily fish passage. Cross-river coverage is needed to obtain an absolute estimate and DFO daily sampling upriver can provide verification. If the split-beam hydroacoustic technology is to be used for management, the estimation must be produced near real-time.

Hydroacoustic enumeration upriver may be less complex than it is downriver. A series of such sites at Woodpecker, Thompson, Chilko, Quesnel and Lillooet could provide very useful information for stock assessment.

Discussion

- There are very few good acoustic sites along the river.
- What was the limiting factor for the transducer used? A 200 kHz. transducer was used, with a slightly wider angle. Testing the coverage limits would be the next step.

- What calibration was used for downstream/upstream movement? A tungsten carbide sphere was used and Target strength measurements taken in the field were consistent with theoretical values.
- What was the cross-river distribution of fish? Flow dynamics are not yet clear, but most were at lower depths.
- The high numbers for downstream movement seem unusual. Were fish moving downstream observed? No, but there was confidence in the results.
- Were the hydroacoustic results compared to set net results? The estimates were very coarse, so it was not really useful to compare them.

Round table III

Lapointe reviewed the discussion topics. A key issue is whether another upstream site could help resolve discrepancies between the Mission and terminal counts. Are there other programs and technologies, such as radio tagging, that might replace or complement hydroacoustics? First Nations treaties may require in-season stock assessment information for specific sections of the Fraser River. Under the Pacific Salmon Treaty, Canada is obliged to collect data on spawning escapements following standardised protocols. What programs will be needed for First Nations treaties? What sites might help answer questions about success of passage and meet the needs of First Nations treaties? What level of information is required between Mission and spawning grounds?

Discussion

- Accounting for numbers lost is not enough. It's also important to know the reasons for those losses—whether fish were caught, died etc.
- The inability to provide reliable estimates on species composition seems to be a significant problem. Pinks are the other big species downriver and that's an issue every other year. They go way upriver, and there are no terminal estimates for them. It's not an inconsequential problem. It might be better to put the second site above the pink spawning sites.
- Currently, it's necessary to wait until late in the season to know if there is a problem. It would be useful to have real-time information, especially if the information warranted a change in management. Having acoustic monitoring at a second site to provide the total number of fish, along with some sort of test fishery to address species composition, would give more comfort. This is assuming no species-specific bias in the gear used.
- The two sites might provide conflicting information, but it would at least raise warning flags if the counts disagree significantly. Under the current allocation structure, it takes sockeye salmon about 1 week to migrate from the major fishing areas to Mission. Thus depending on where the upstream site is located there could be a two-week time lag between marine harvest locations and feedback from the upstream site by which time the major commercial fisheries could be over.
- Preliminary results of radio tagging gave a preliminary indication of where losses were occurring in-river, so the second site should be located above that. Could using radio tags alone provide just as useful information at the same cost? Last year it cost about $200,000 for the radio tagging, comparing that to operational costs of $35,000/month plus one-time capital costs for Qualark hydroacoustic program. Radio tagging can't provide population estimates but it can provide information on rates of loss. You can get real-time information but the sample size is small so there is not the same level of confidence.
- Another idea is to have a series of fish wheels and mark-recapture estimates en route. This technique has been quite successful in the Nass and may be worth exploring for the Fraser. Holmes pointed out that fish wheels are often very site-specific in their performance and so may not provide a scientifically defensible approach. For example, the DIDSON system was used to look at fish behaviour around a fish wheel at Siska (the upper part of the Fraser canyon near Lytton) and it showed that fish were avoiding the fish wheel.

- Size selectivity was found in the Nass and Taku rivers. Success in the Nass was due to tagging a lot of fish; it's not clear how this would be done in the Fraser.
- Do you really want to handle 25% of fish that are already stressed by migration and environmental conditions in the Fraser River? This could work if you wait for terminal recovery but that's too late.
- What are the requirements for treaties now under negotiation? Current information suggests Mission would be the key source of information. If there are discrepancies, especially if Mission is under-estimating gross escapement, there would be a desire for something in the Upper Fraser to permit additional fisheries (or if there is significant en route loss, to stop fisheries). It's not a treaty requirement but this will be important in future for allowing fishing on any potential surpluses. The Yale band is interested in restarting Qualark program.
- Will there be more interest in dynamic management to take advantage of regional differences in future, i.e., is there benefit in having multiple hydroacoustic sites? It's expected that the different groups will want a better sense of what's coming into their respective territories. First Nations are very interested in getting more involved in salmon assessment, so expect requests for additional programs, although this will differ across the watershed.
- Higher radio tagging mortality might be seen in other years. Hydroacoustics may give a truer picture of fish passage. On the other hand, radio tagging can show choke points, which may vary from year to year. Tagged fish may have higher mortality vs. untagged fish and there is no way to tease that out. In the Nass, mortality of 30% was found due to handling.

Are there other logical sites suitable for hydroacoustics or for treaty and First Nations needs?

- Suggestions included Spences Bridge on the Thompson River, something above Hells Gate at Boston Bar, something above the confluence with the Thompson (or at Lillooet), another above the Chilko and Quesnel confluences and then Woodpecker.
- A number of key personnel in this field are retiring but many First Nations along those routes would be interested in getting involved. The preferred locations for First Nations would potentially coincide with the above suggestions. The Fraser River serves as the territorial boundary between the Chilcotin and Shuswap people, from the Thompson to Quesnel. It was made clear in the Woodpecker study that First Nations don't have the resources to run such sites locally, so partnerships will be needed, Levy stressed. What are the objectives? Cave said a key goal is to get better information about fish passage, especially above the difficult Fraser Canyon stretch.
- Xie added that a further goal is having an upstream site to verify the gross escapement estimates at Mission in-season. Mission is a good site in terms of timing for management, but it's a very challenging site for hydroacoustics. It was noted that Qualark is the first amenable site on the mainstem Fraser from a hydroacoustic perspective.
- It was noted that treaties would be another objective. Information is needed for treaties, but it shouldn't be done on a treaty-by-treaty basis, a participant added—it should be done through the PSC.
- In tests, the Mission and Qualark results tracked each other very well, so this might suggest going higher up-river.
- There was a big problem with the estimates in 2005 as a result of delayed sockeye entry and early pink entry into the Fraser, i.e., a species composition issue. Canada has obligation to estimate pink escapements under the Pacific Salmon Treaty—this is not for in-season management.
- Two issues arise with pinks: they tend to be more near-shore and, even in marine areas, they react differently to fishing gear.
- POST has a proposal to do acoustic tagging and to install a hydrophone at Mission. Tests showed that this could also provide useful information on travel speed.
- For 2006, it's known that sockeye will dominate, Xie noted. The newly adopted split-beam system is more robust but it's lacking independent comparison from another site. So it's urgent to consider having another station. It's like having a second clock to alert you if your

own watch is wrong—a discrepancy suggests the need for further study to determine which count is wrong.

- Qualark did show differences from Mission, some very significant, though the results mostly tracked very closely.
- Half of the pink population spawns below Qualark so there will be a significant difference in the total number of salmon counted there.
- Tagging has provided a lot of information on sockeye behaviour. Can this also be used to better understand the behaviour of pinks?
- There is way more "bang for the buck" in setting up another site vs. investing more in Mission. Participants discussed what would be needed to revive the Qualark site. It would cost about $70,000 in capital costs to reactivate the site. . The equipment is still at Cultus Lake. A revived Qualark could be operated with a DIDSON system on each bank. Several participants supported the idea of an independent site to corroborate Mission. But if there are two conflicting estimates, one asked, which do you choose for in-season management? What happens when there is disagreement about the spawning estimates? There should be reasonable expectations for accuracy and precision. It also should be clear if the objective is simply to calibrate Mission or something else.
- After a few years, it would be clear if the difference is systematic. It's necessary to go through this process for any new technology—you need the data before you can start looking for causes.
- Protocols should be established in advance for how close the two counts can be expected to match and how management should address any differences.
- Verifying Mission is a short-term objective. After that, is Qualark the best site? It's necessary to verify Mission before setting up another site upriver, or there will be too many moving parts.
- You can have a site every 10 feet, but if you don't know the cause of the difference, what's the point? Xie replied that it's not known whether there is a difference, and if so, whether it's statistically significant. If a second site finds a 50 percent difference and radio tags suggest there should only be about 10 percent en-route losses, then this would confirm that there's an issue with Mission.
- It's still necessary to satisfactorily explain what happened to the fish. While there is no guarantee that a second site can explain causes, it's necessary to take the first step.
- DIDSON is affordable and the ground has been laid already, so make use of it.

Priority information matrix

Following the 3 round table discussion on the general topic of the roll of hydroacoustics in the fisheries management of Fraser River sockeye, participants were asked to assign priority rankings in a matrix that listed assessment activities vs. different assessment objectives. Several changes were proposed to the matrix and it was agreed to ignore the time horizon aspect.

The following table was completed based on the consensus of the participants.

Relevant assessment category
priority rating for each category: H=high, M=medium, L=low

Assessment activity	Fisheries mgt.	WSP[1]	losses/DBE[2]	PST[3] needs	Future Treaty needs	Population Dynamics
a. Juvenile lake/smolt surveys	M	H	L	M	L	H
b. Spawning ground assessment	H	H	H	H	H	H
c. Lower river assessment for in-season management	H	H	H	H	H	L
d. Main-stem Upper River assessments	M	L	H	M	M	L
e. Run entering marine areas	H	L	L	H	H	L
f. Fish Behaviour	H	L	H	H	L	L

[1] WSP-Wild Salmon Policy
[2] DBE-Differences between Mission and Upstream accounting based estimates of abundance
[3] PST - Pacific Salmon Treaty.

Closing comments

Rutter was asked to comment on whether the discussion had addressed the central questions for the Southern Endowment Fund(SEF). He noted that the Fraser Panel prioritised assessment activities and received a number of proposals but the SEF committee had no way to prioritise them. DFO also has limited resources and therefore must set priorities for funding efficiency.

Rutter was also struck by the implications of the percentages of TAC under discussion in negotiations over First Nations treaties. “How thin are we going to slice this pie and to what extent can we anticipate how many slices we’re going to have?” This will require collaboration and agreement on the “clocks” to be used. It’s not clear yet where the workshop will fit in to that, but it’s clearly going to be a lot more complicated than in the past.

Rutter compared the limited benefits of spending another million dollars at Mission vs. spending that amount on a second site and wondered why there were no proposals for upstream sites yet. Bolstering confidence in Mission seems to be a top priority, so there should be resolve to get a second site going as soon as possible. If Qualark can be set up quickly and offers so many benefits, it seems we should do it, he concluded.

Cave thanked all the participants noting that proceedings would be distributed in a month, along with copies of all the presentations.

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Appendix I. List of Participants and Affiliations.

Participant Name	Affiliations
Dave Levy	
Kyle Adicks	
Li Ding	
Mike Staley	
Pete Nicklin	
Svein Vagle	
Jim Dawson	BioSonics, Inc.
Mike Burger	BioSonics, Inc.
Ann-Marie Huang	Fisheries and Oceans Canada
Jeff Grout	Fisheries and Oceans Canada
Les Jantz	Fisheries and Oceans Canada
Paul Ryall	Fisheries and Oceans Canada
Ron Goruk	Fisheries and Oceans Canada
Herman J. Enzenhofer	Fisheries and Oceans Canada – Cultus Lake
Jeremy Hume	Fisheries and Oceans Canada – Cultus Lake
Steve MacLellan	Fisheries and Oceans Canada – Cultus Lake
Keri Benner	Fisheries and Oceans Canada – Kamloops
Teri Ridley	Fisheries and Oceans Canada – Kamloops
Pieter Van Will	Fisheries and Oceans Canada – Port Hardy
Bruce Ransom	Hydroacoustic Technology Inc
Doug Wilson	Imagenex Technology Corp
Helmut Lanziner	Imagenex Technology Corp
Colin Smith	Kongsberg Mesotech Ltd.
Larry Rutter	National Marine Fisheries Service
Gary Graves	NWIFC
Marcel Pellegrini	OMNR
Andrew Gray	Pacific Salmon Commission
Fiona Martens	Pacific Salmon Commission
Ian Guthrie	Pacific Salmon Commission
Jacqueline Boffey	Pacific Salmon Commission
Jim Cave	Pacific Salmon Commission
Keith Forrest	Pacific Salmon Commission
Mike Lapointe	Pacific Salmon Commission
Yunbo Xie	Pacific Salmon Commission
George Cronkite	PBS Fisheries and Oceans Canada
Juha Lilja	PBS Nanaimo
Al Cass	PBS, Nanaimo
Chuck Parken	PBS, Nanaimo
John Holmes	PBS, Nanaimo
Steve Baillie	South Coast – Nanaimo
Linda Thompson	T. Thompson Ltd.
Chief Robert Hope`	Yale First Nation
Evert Hope	Yale First Nation
Kathy Hope	Yale First Nation

Appendix II. Round Table discussion points.

Points for Facilitator to direct Round Tables.

Round Table I on information gaps in Fraser River sockeye management.

In consideration of each of these questions please include the role hydroacoustics could play in providing information in these key areas?

1. Canada is in the initial stages of implementing its Wild Salmon Policy. This policy focuses on conservation units (CU's) which have yet to be specified but will likely be associated with lake units for Fraser River sockeye. What is the required level of population assessment under the WSP? For in-season management? For assessment of CU's? For assessment of diversity within conservation units (CU's)?

2. Are there cost effective alternatives for the estimation of spawner abundance at the system level and at the terminal streams?

3. Can managers comment on the utility of assessments in the marine areas for the purposes of in-season management?

4. Can managers comment of the utility of assessment of juveniles in lakes?

Round Table II discussion on the possible future developments in hydroacoustic technologies and their potential contribution to our understanding of the abundance and behaviour of fish populations.

Hydroacoustic technology has provided a vital contribution in the assessment of fish populations. However there continues to be uncertainty in our understanding of fish migration and needs for new information.

1. In addition to items already discussed, list some keys problems/questions that might be addressed by hydroacoustics? (e.g. species identification, assessment at high passage rates)

2. Are there new developments in hydroacoustic technologies on the horizon that may help address some of these concerns?

Round Table III Discussion on the need to develop programs to obtain estimates of sockeye abundance at sites upstream of Mission on the mainstem of the Fraser River.

Since 1992, there have been several costly inquiries into the differences between the abundance of sockeye that was identified to have past Mission, and what actually showed up on the spawning grounds. The lack of quantitative information on passage success between Mission and the spawning grounds has prompted finger pointing and speculation about causes of differences. Beginning with the conclusions of Pearce and Larkin in 1992, recommendations have included the investigation and institution of hydroacoustics sites upstream of Mission. A program was operated at Qualark Creek during the mid 1990's, but as Herman has reported but the program has since been discontinued.

Hydroacoustics can provide information on the success of upstream passage of the entire migration and may provide a better understanding of potential en-route loss and an opportunity to adjust in-season fishery management accordingly. Radio tagging programs have provided valuable insights on the locations of loss, passage rates, and loss rates for a small subset of individuals.

The following questions were intended to guide discussion for this round table topic:

1. What level of information between Mission and the spawning grounds is required to provide a better understanding of potential en-route loss?

2. What level is needed to permit in-season adjustment to fisheries to help ensure escapement targets are met?

3. Are hydroacoustics sites upstream of Mission essential to fisheries management?

4. What are the key locations for upstream hydroacoustics sites?

5. Would information from a radio tagging program augment information from multiple hydroacoustic sites or could it potentially substitute for hydroacoustics information.

Treaties with First Nations may require in-season salmon stock assessment information for specific section of the Fraser River to assist with fisheries planning. In addition, Under the Pacific Salmon Treaty (PST), Canada is obliged to collect information on spawning escapements following similar protocols to those followed by the by the IPSFC (coverage of all streams, accuracy of program delivery related to expected size of return). Furthermore, the PST specifies management of four run timing groups (Early Stuart, Early Summer, Summer and Late-run).

1. List the current and new assessment programs required to address the requirements for these Treaties?

2. For each program identify where hydroacoustics techniques are currently being applied, where hydroacoustics could be applied and where hydroacoustics techniques are unlikely to be applicable.

Workshop conclusions

There are limited resources to fund assessment activities in general and hydroacoustics applications more specifically. List the following assessment activities in order of priority in terms of need for information and for development or continued use of hydroacoustics (1=highest)

Juvenile lake surveys

Spawning ground assessment

Lower river assessment for in-season management

Fraser river mainstem assessments for en-route loss and difference between estimates

Fraser river mainstem assessments to meet future Treaty obligations

Marine assessment

Others? (please specify)

Appendix III. Copies of Powerpoint presentations made at the Workshop.

Integrating the DIDSON imaging sonar into salmon stock assessment in the Fraser River: An Overview

Riverine Acoustics Group

Applied Technology Section

MEAD/DFO

Fisheries and Oceans Canada / Pêches et Océans Canada

Riverine Acoustics Group

- Research to find, develop, evaluate and transfer new technology for stock assessment (DIDSON, fixed aspect side-looking split-beam sonar; Blueview?)
- Provide support to stock assessment (training, data interpretation, technical issues)
- Collaborate with PSC on technical issues at Mission hydroacoustic facility

Outline

- Overview of the DIDSON technology
- Our evaluation – sites and data quality
- Our experience with the DIDSON system
  - What the DIDSON system can do
  - What the DIDSON system cannot do (at present)
  - What we are working on

Technology Overview

Why Consider Acoustic Technology in Terminal Areas?

- Number of stocks assessed by mark-recapture programs has increased in last 2 decades
- Costs of mark-recapture programs have increased due to inflation as well as need for more MRPs.
- Gap between needs and delivery growing prompting search for cost-effective and reliable alternatives

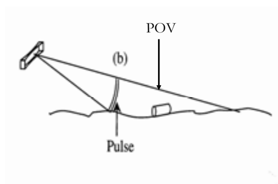
Standard Version DIDSON

- Produces images using sound and a lens system to focus sound waves, similar to a camera
- Images in video format at a rate of 5-20 frames/sec, depending on range
- At low frequency (1.1 MHz), detects objects up to 40 m away
- At high frequency (1.8 MHz), resolution is sufficiently good that objects can be identified up to 15 m away

Development History

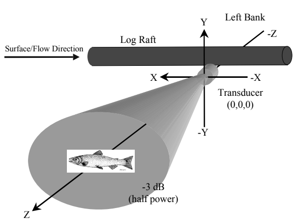
- Developed by APL for U.S. Navy - mine detection by divers; manufactured by Sound Metrics in Seattle
- Two versions: Standard (1.1 and 1.8 MHz); Long-range (700 kHz and 1.2 MHz)
- Pacific Region currently has 2 standard version DIDSONS
  - DFO (Whitehorse) has access to a long range version

Aiming is Important for Data Interpretation



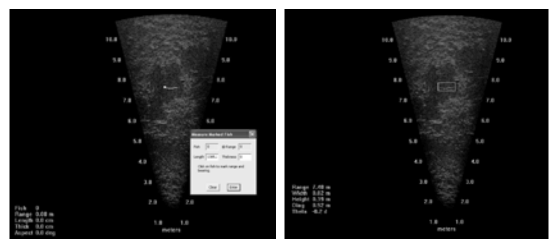
- DIDSON must be oriented with a slight grazing angle to properly interpret surfaces of targets of interest.
- Observer POV is as if viewed from directly above the target.

Target Position



- DIDSON cannot determine the position of a target with respect to the bottom and surface of the water column (Y coordinate).
- Targets at the same range, but different elevations cannot be distinguished as separate targets (e.g., could occur during high fish passage rates).
- Must aim carefully and manually check aim to make sure no blind zones at surface or bottom

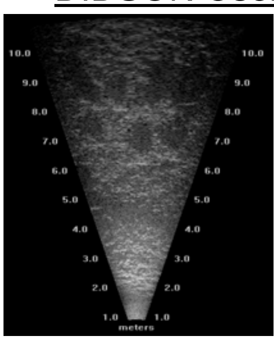
Length Measuring Tools



Zoom image, data stored in text file   Zoom image, data on screen

Length is based on number of beams occupied by a fish image

DIDSON User Advantage



Horsefly River: 13 Sept 2005 @ 1600 (7,332 fish/hr)

- Visual, intuitive interpretation
- Uses image analysis, interpolation, and tracking capabilities of eyes and brain

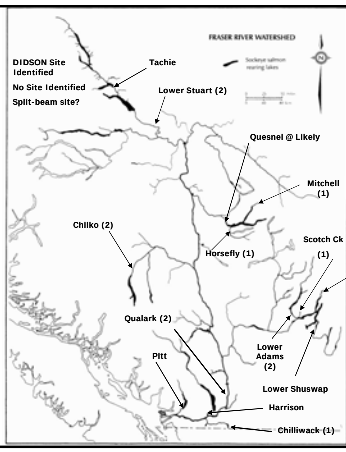
Our Evaluation of the DIDSON

Key to Success is Site Selection

- **Cross-section of the river** – wider river, lower water velocities, variable fish behaviour
- **Convolution of the river** – more than one channel increases complexity of estimation
- **Fish behaviour** - avoid sites with milling/holding; can bias escapement estimates and be difficult to correct post-processing
- **Fish density** - high density passage events degrade counting performance of individuals/tracking software
- See Hermann Enzenhofer's presentation on site selection and Qualark

Site Characteristics

- Single channel
- Laminar flow
- Planar bottom configuration
- Fish actively migrate through site
- Below known spawning areas
- Site access



First Cut: only systems in which mark-recapture programs for sockeye salmon used

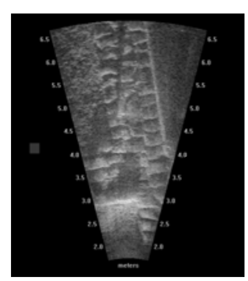
Holmes et al. (2005). Can. Tech. Rep. Fish. Aquat. Sci. 2592

Some of the Sites Identified

Site Types

- Wide, high velocity; e.g., mainstem @ Qualark, Chilko, Adams
- Narrow, fish constricted by weirs; e.g., Horsefly, Mitchell, Seymour

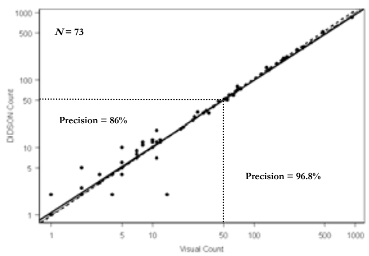
Accuracy and Precision



Calibration at Stellako River Fence: Sept 2004

Passage rates of 1-932 fish/hr

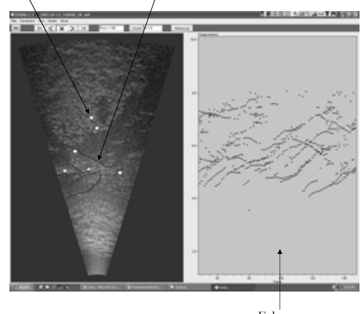
Data Quality



- Two regression lines statistically same as $y = x$ (dashed line)
- ∴DIDSON data as accurate as enumeration fence counts

Holmes et al. (2006): ICES J. Mar. Sci. 63(3): 543-555

Automated Counting



Horsefly River – 13 Sept 2005 @ 1600

- Problem: program computer to do what eyes and brain do subconsciously at high rate of input
- Requires improved image analysis to define targets and tracking to follow multiple targets across consecutive frames
- Work in progress; can track up to passage rates of about 1,200 fish/hr.

Evaluation Summary

- Identified sites on most tributary systems that were examined (13 sites on 12 systems)
  - Early Summer: Pitt, Chilliwack, Seymour, Scotch
  - Summer: Chilko, Quesnel (Mitchell, Horsefly)
  - Late: Adams
- Count data are accurate and precise as long as all fish passing site are detected acoustically
- Manual counting of files works well at all passage rates observed (max 7,300 fish/hr – see George Cronkite's presentation on the 2005 Horsefly run)

Our DIDSON Experience

DIDSON Can…

- Monitor spawning escapement 24 hr per day throughout entire spawning run in turbid/clear, light/dark viewing conditions
- Monitor spawning escapement in tributaries not amenable to other sonar technology
- Estimate net upstream flux of fish manually up to rates of at least 7,300 fish/hr
- Derive run-timing curves for spawning areas

DIDSON Cannot…

- Detect fish beyond 15 m (HF) or 40 m range (LF)
- Collect biological information such as sex, state of maturity, weight, health, spawning success
- Detect tags on tagged fish
- Automatically count fish, except under very simple circumstances, i.e., low passage rates, no unusual behaviour; these conditions are the exception in the Fraser watershed
- Reliably identify different salmon species in a mixed assemblage
  - But, potential to identify different species if clear and consistent size behaviour differences and range of sizes do not overlap (e.g., *Catostomus* spp. & *Oncorhynchus* spp.); reliability unknown

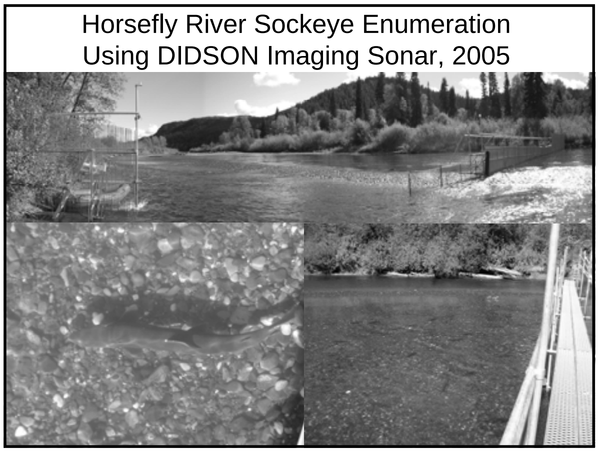
Ongoing DIDSON Work

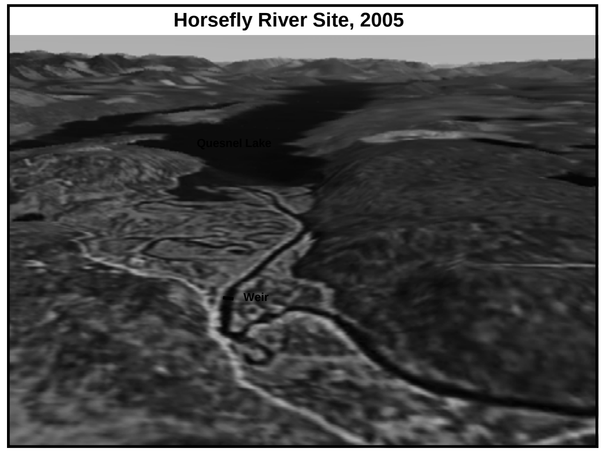
- Experimental
  - Effect of fish density (i.e., fish/m^3 ensonified volume) on counting performance (saturation)
  - Relationship of intensity values to surface texture and density
  - Effect of acoustic shadows on counting performance
- Sampling strategy – see Juha Lilja's presentation based on Horsefly 2005
- Benefit-cost comparison of escapement estimation with DIDSON and mark-recapture program (based on Horsefly 2005)
- Software development – external to DIDSON system software
  - Image analysis and Tracking
    - Automated counting
    - Species identifiers – improved performance mixed-species assemblage
- New locations for deployment
  - Sockeye salmon (only looked at stocks assessed with MRP)
  - Other salmon species, especially chinook, coho
- Provide technical support to stock assessment programs

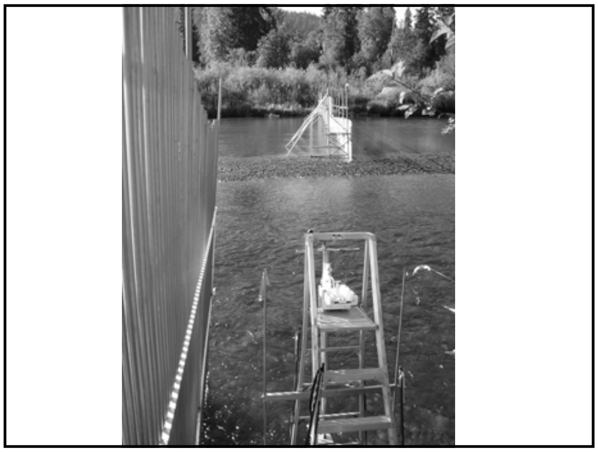
Take-Home Messages

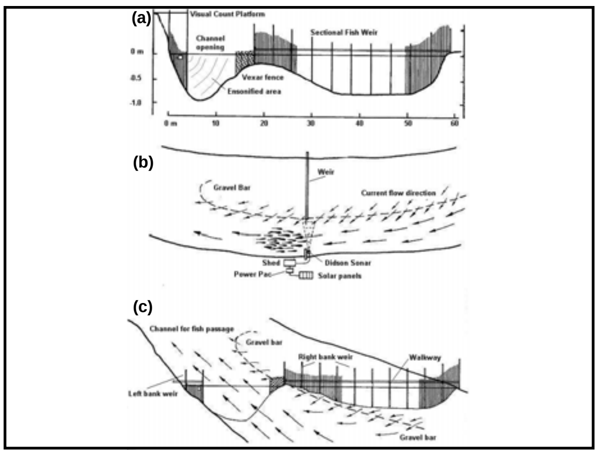
- DIDSON imaging system is versatile and easy-to-use technology; field staff need to be trained and follow appropriate procedures (see George Cronkite's presentation on Horsefly River)
- DIDSON system seems to be a practical alternative to mark-recapture programs and can help stock assessment program delivery
- Implementation of DIDSON system will provide more timely escapement data to managers (see George Cronkite's presentation)

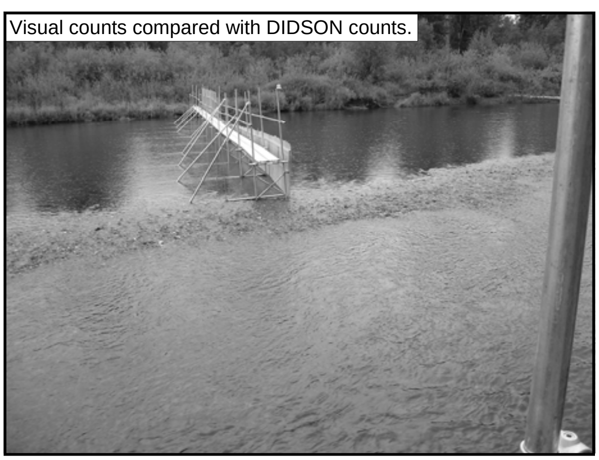
DIDSON Attack Team (DAT)


Horsefly River Sockeye Enumeration
Using DIDSON Imaging Sonar, 2005


Horsefly River Site, 2005
Quesnel Lake
Weir

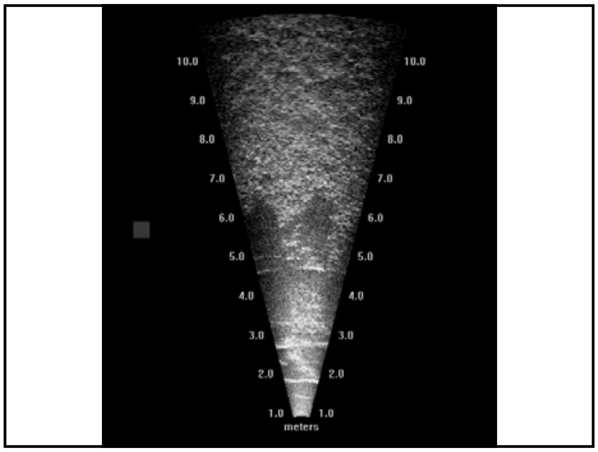






Files collected varied in length from 10 to 60 min. out of the hour, but most were 20 min.

A subset of files were repeat counted by different observers to derive average percent error (APE)


10.0 10.0
9.0 9.0
8.0 8.0
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5.0 5.0
4.0 4.0
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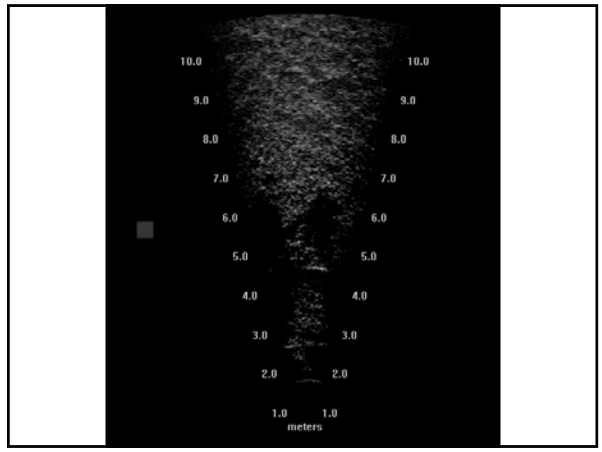
1.0 1.0
meters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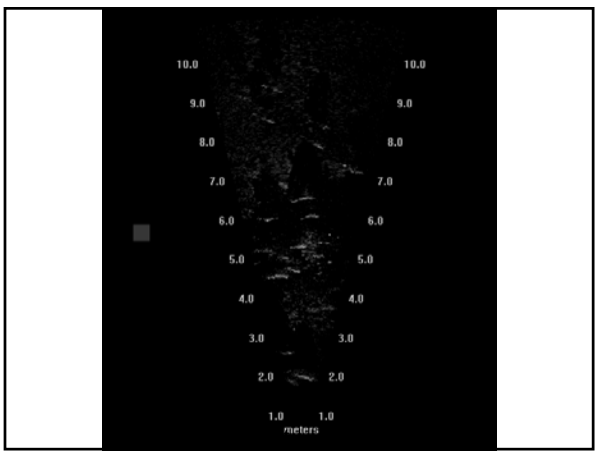
1.0 1.0
meters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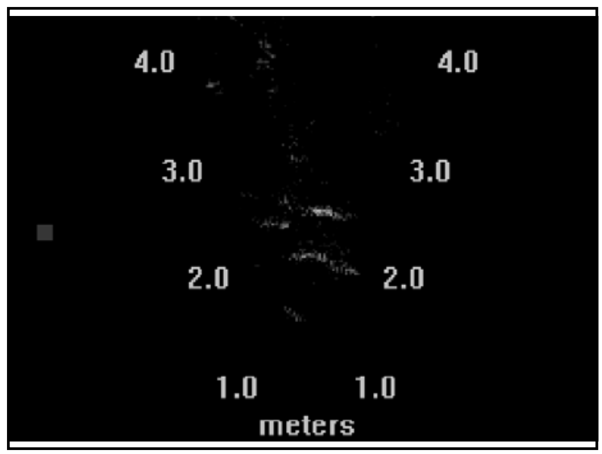
meters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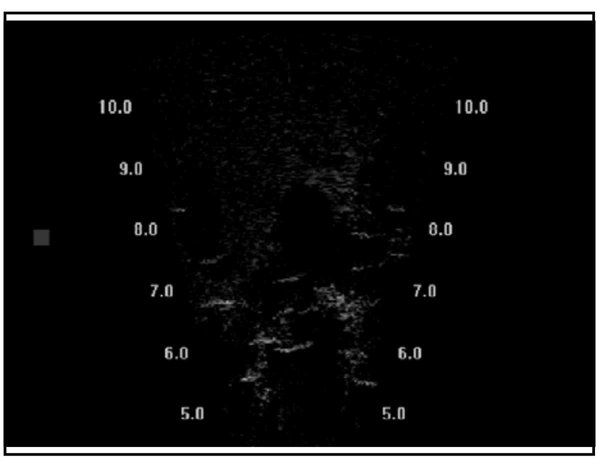
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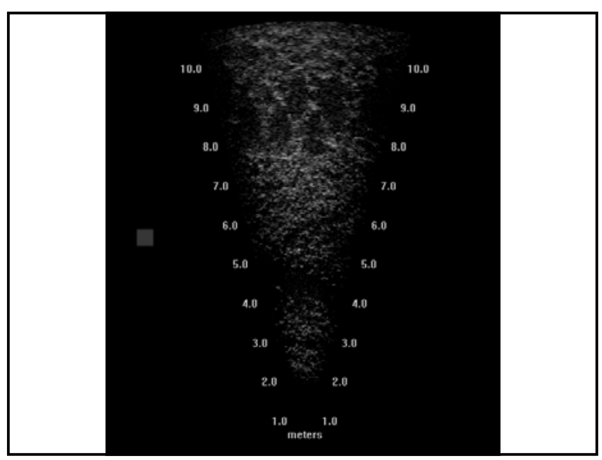
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4.0 4.0
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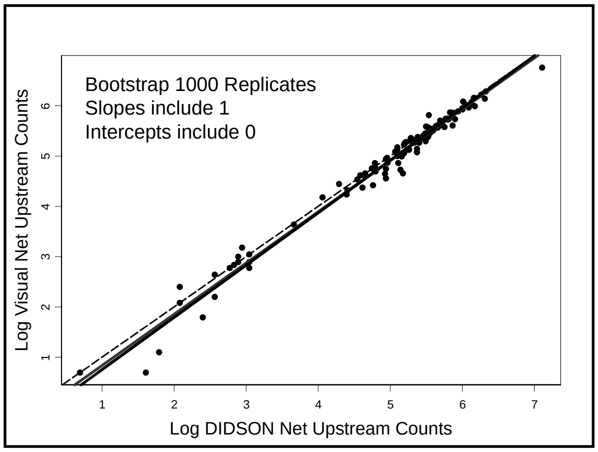
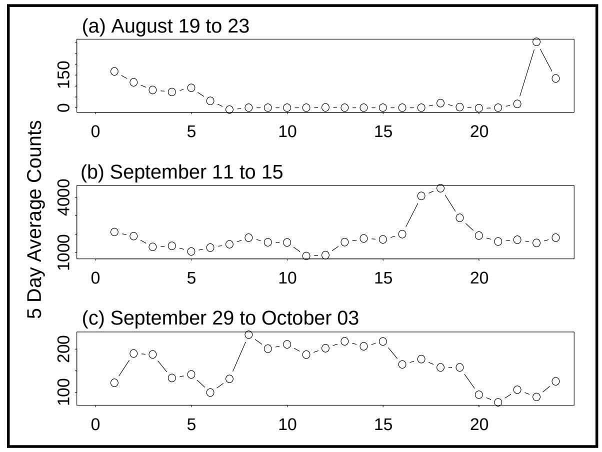
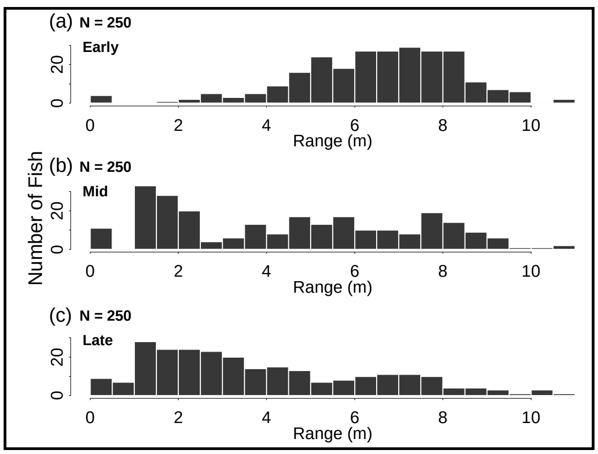
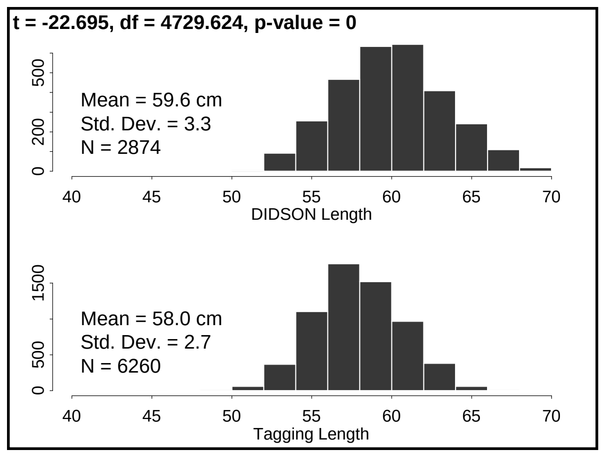
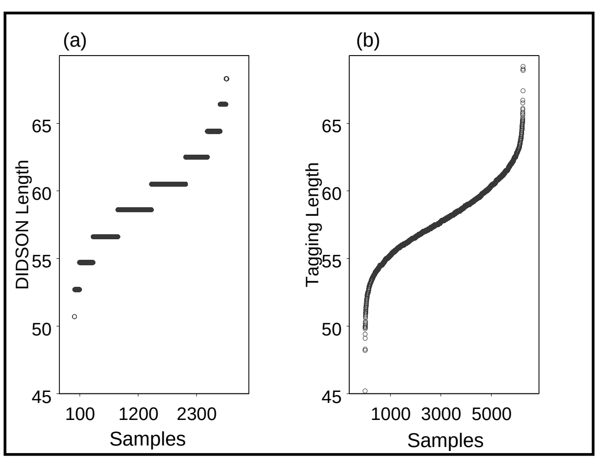
2.0 2.0
1.0 1.0
meters

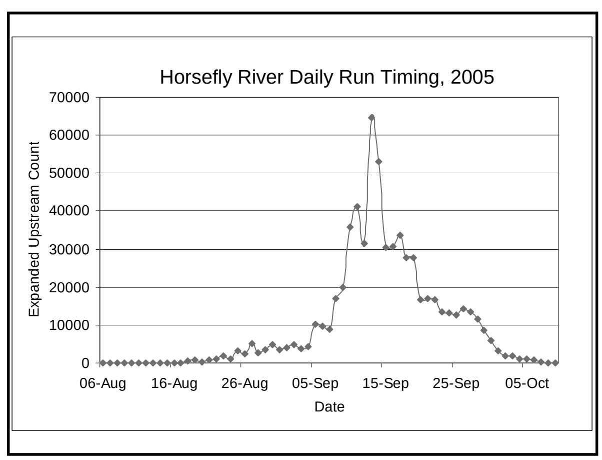

Bootstrap 1000 Replicates
Slopes include 1
Intercepts include 0
Log Visual Net Upstream Counts
Log DIDSON Net Upstream Counts

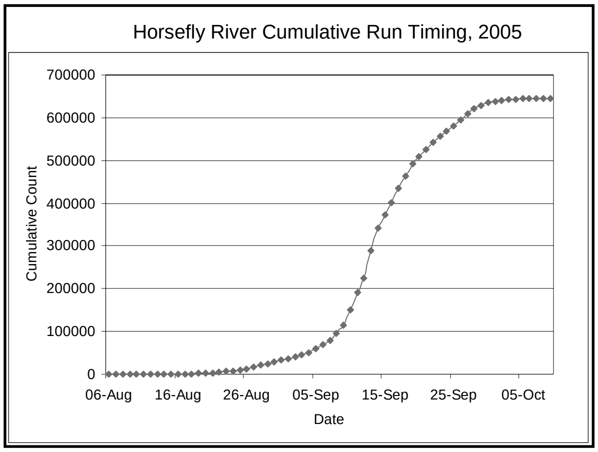

(a) August 19 to 23
(b) September 11 to 15
(c) September 29 to October 03
5 Day Average Counts

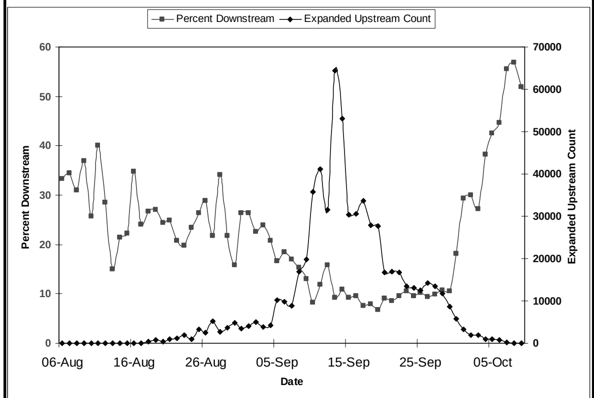

(a) N = 250
Early
(b) N = 250
Mid
(c) N = 250
Late
Number of Fish
Range (m)


t = -22.695, df = 4729.624, p-value = 0
Mean = 59.6 cm
Std. Dev. = 3.3
N = 2874
DIDSON Length
Mean = 58.0 cm
Std. Dev. = 2.7
N = 6260
Tagging Length


(a)
(b)
DIDSON Length
Tagging Length
Samples

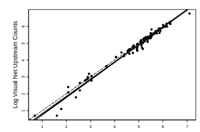

Horsefly River Daily Run Timing, 2005
Expanded Upstream Count
Date





Accuracy and Precision

Sources of Error:



1) Fish Detection Errors
± 0 %

2) Average Percent Error (APE) Between Observers
± 6 %

3) Temporal Error due to Sub-sampling in Time
± 0 % to ± 10 %
for 60 minutes to 10 minutes

- Most files counted for 20 minutes → 5 % error
- Juha will talk about his work on this

Accuracy and Precision

$$SD_{TotalCount} = \sqrt{Var(\hat{Y}_{10-\min}) + Var(\hat{Y}_{20-\min}) + Var(\hat{Y}_{30-\min}) + Var(\hat{Y}_{APE})}$$

+ Fish Detection Errors (0 %)

Overall Error = ± 14 % for 2005

Could be reduced to approximately ± 10 %
if all 20 minute sub-samples were used.
(If this were necessary)

However, this is unlikely to change the point estimate by a significant amount as one of Juha's plots will show.

When we incorporate our measures of accuracy and precision into the population estimate, we are 95% certain that the true population lies within the range of:

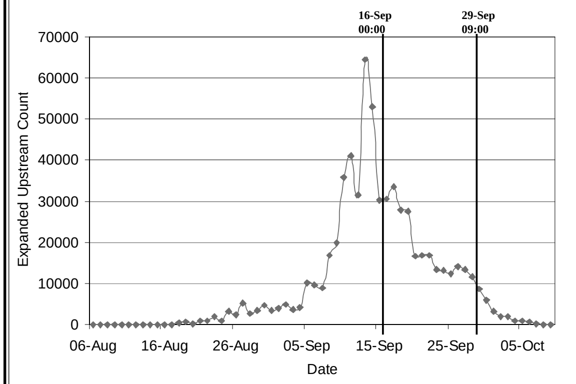
554,711 to 735,909 sockeye
(645,310 ± 90,599 or ± 14%)

SUMMARY

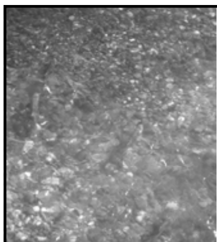
1. DIDSON Derived Population Estimate
2. Accuracy and Precision of the Estimate
3. Associated Confidence Limits
4. Defensible Estimate (Holmes et al, 2006)

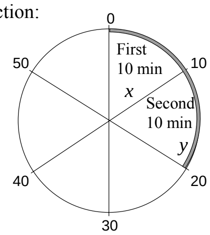
Temporal sampling strategy for making terminal area sockeye salmon escapement estimates

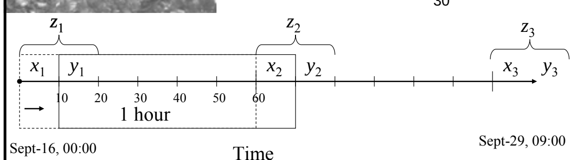
Juha Lilja
Fisheries and Oceans Canada
Post-doctoral Fellow
Academy of Finland



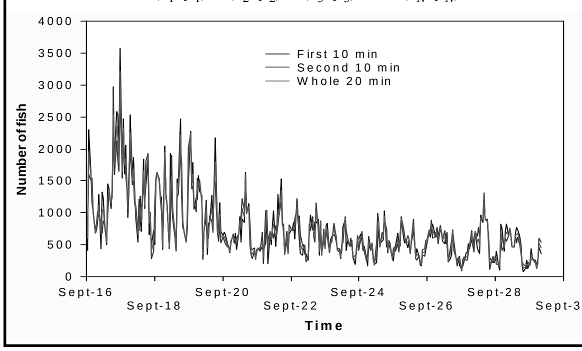
Data collection:





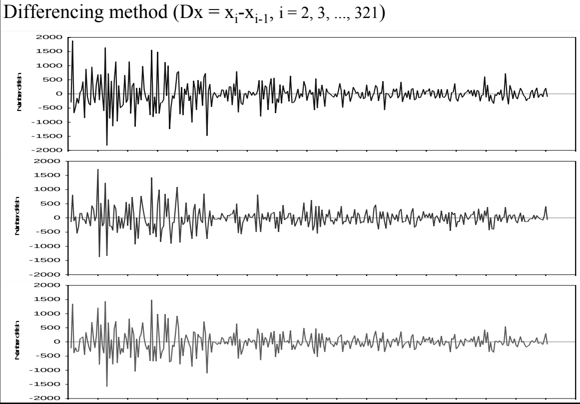


Three time series:
First 10 min = $6x_1, 6x_2, 6x_3, \ldots, 6x_N$
Second 10 min = $6y_1, 6y_2, 6y_3, \ldots, 6y_N$
Whole 20 min = $3(x_1+y_1), 3(x_2+y_2), 3(x_3+y_3), \ldots, 3(x_N+y_N)$



Short-term variation (hour-to-hour):

Differencing method ($Dx = x_i - x_{i-1}$, $i = 2, 3, \ldots, 321$)



Between hours

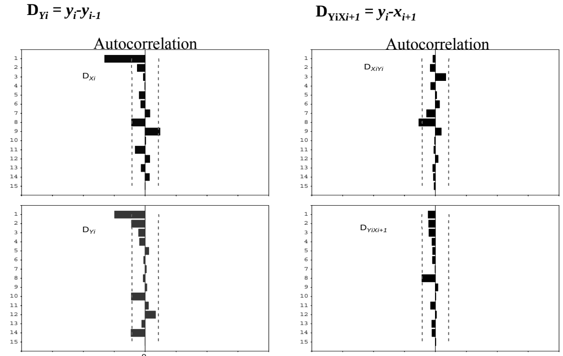
$D_{Xi} = x_i - x_{i-1}$

$D_{Yi} = y_i - y_{i-1}$

Within hours

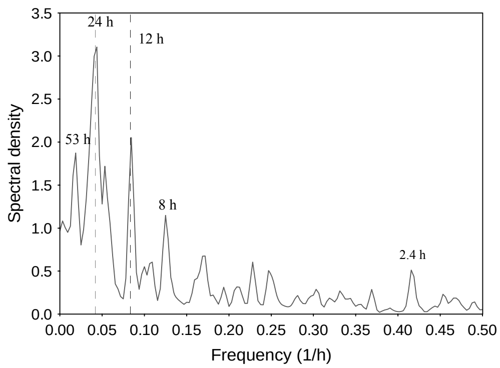
$D_{XiYi} = x_i - y_i$

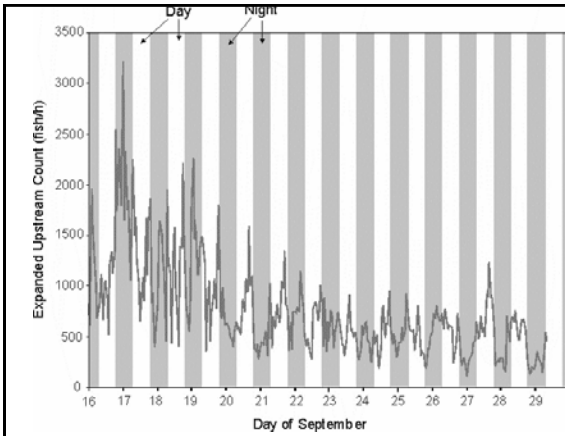
$D_{YiXi+1} = y_i - x_{i+1}$



Long-term variation (diurnal):

Spectral analysis (20-min count series)





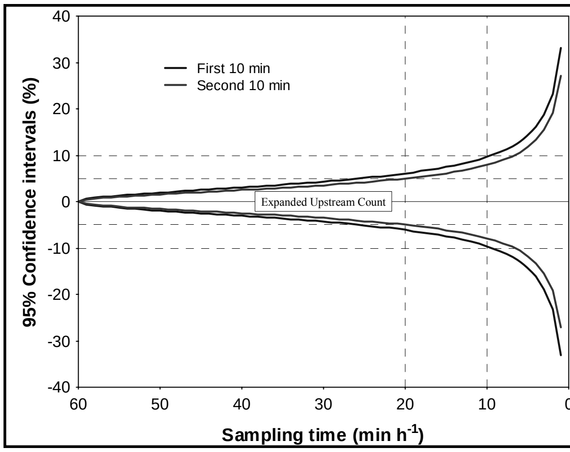
Precision of temporal expansion:

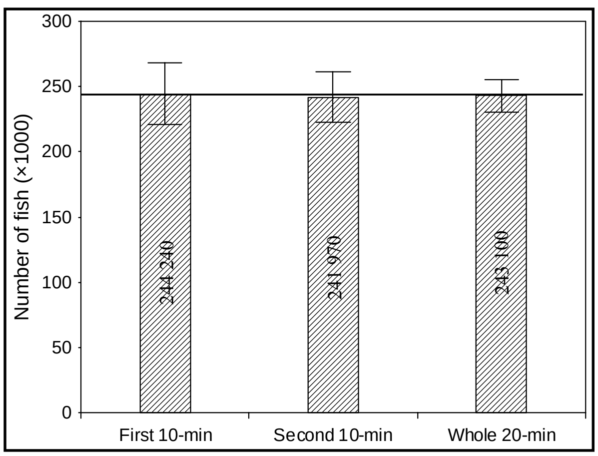
Systematic sampling

Systematic sample-variance estimator with the method of succesive difference.

$$Var(\hat{X}) = N^2 \frac{\left(1-\frac{n}{N}\right)}{n} \sum_{i=2}^{N} \frac{(X_i - X_{i-1})^2}{2(N-1)}$$

N = total number of one-hour sample periods
n = total sampled time in hours
X_i = estimated number of fish passing the sampling site during hour i



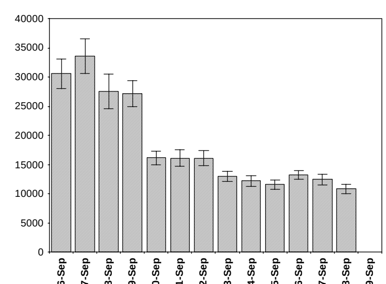


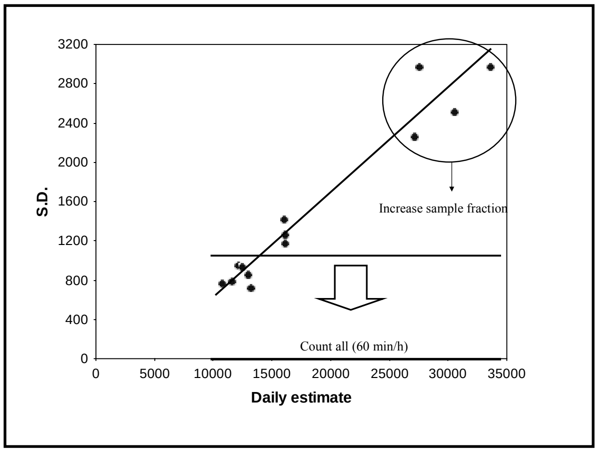
Conclusions:

Hourly sampling was justified

Diurnal and semi-diurnal rhythms were observed

Hour-to-hour variation increased as number of fish increased




3200
2800
2400
2000
1600
1200
800
400
0
S.D.
0
5000
10000
15000
20000
25000
30000
35000
Daily estimate
Increase sample fraction
Count all (60 min/h)

Surveying lake rearing juvenile sockeye

Lakes Program

- Ken Shortreed
- Jeremy Hume
- Steve MacLellan
- Kelley Malange
- Steve McDonald

Lakes Program

- Ecosystem studies of juvenile sockeye and their rearing lakes.
- Two major field approaches
  - Limnology
    - Physical, chemistry, nutrients, bacteria, phytoplankton, zooplankton
  - Limnetic fish
    - Hydroacoustics
      - Abundance
      - Distribution
    - Midwater trawls
      - Species and age composition
      - Size and growth

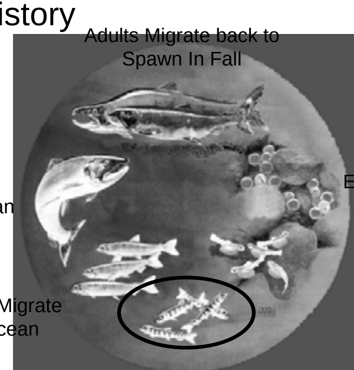
Lakes Program

- Productive capacity of sockeye lakes
  - Empirical models of rearing capacity based on primary production (PR model)
  - Tested against juvenile S/R data sets
  - Provides estimates of optimum escapement
    - Considered for WSP benchmarks

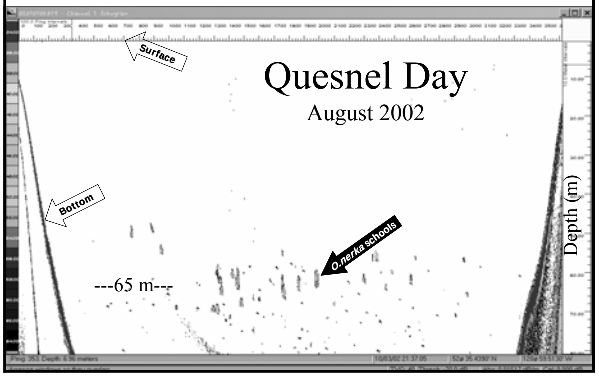
Lakes Program

- Acoustic / Trawl surveys are used for:
  - Stock status particularly where no adult escapement is done.
  - Preseason forecast of adult returns, used in Quesnel and Shuswap lakes but has not been the best predictor in recent years

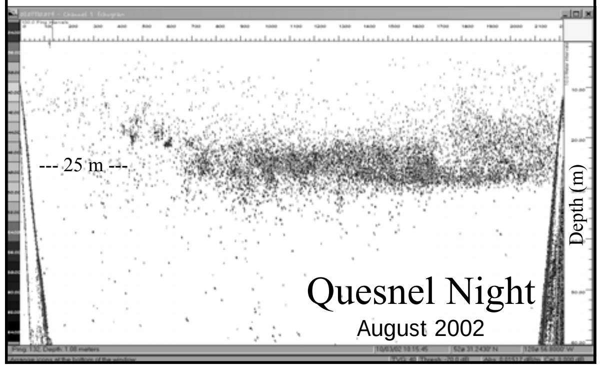
Life History



Juvenile Behaviour



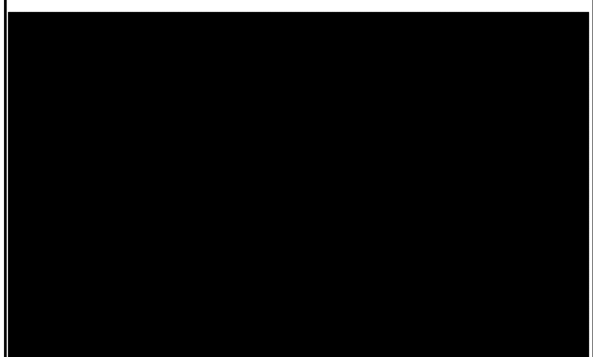
Juvenile Behaviour



Surveys

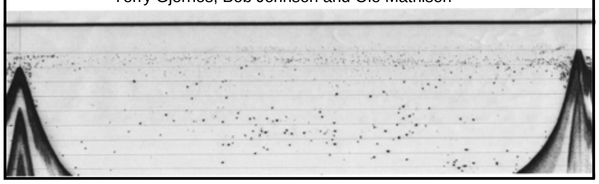
- Lake is stratified into trawling sections
- 2-4 acoustic transects -within each section
- Acoustic data used to target trawl depth and duration
- Acoustic data analyzed with Echoview
- Acoustic population estimates apportioned with trawl catch results.
- Surveys done at night.

Surveys



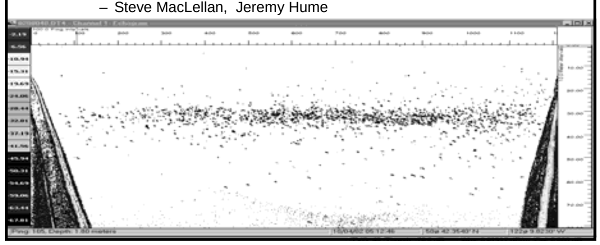
History -Sounder

- 1975 Furuno FM21/22
  - 200kHz, 5º beam @ -3dB
    - IPSFC
    - TVG!
    - Paper records
    - Target counting, Integration available but not used
    - Terry Gjernes, Bob Johnson and Ole Mathisen



History - Sounder

- 2002 Biosonics DE6000 Spit beam
  - 201 kHz, 6.4º beam @ -3dB
  - TS, digital data, primary processing TVG
  - Computer file data storage
  - Integration, single target, tracked target
  - Echoview
    - Steve MacLellan, Jeremy Hume



History - Our boats

- 1975
- Ski Barge

History - Our Boats

- 1978
- The Beaver!

History - Our Boats

- 1996
- Night Echo

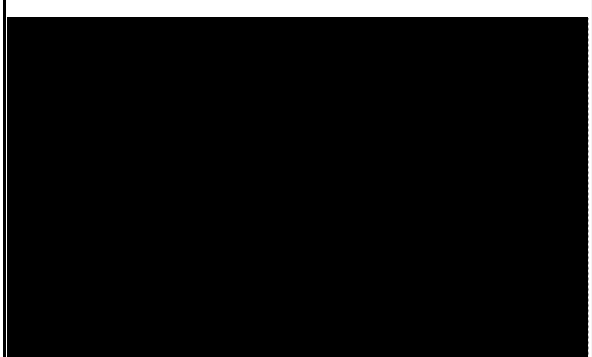
History - Our Boats and Planes

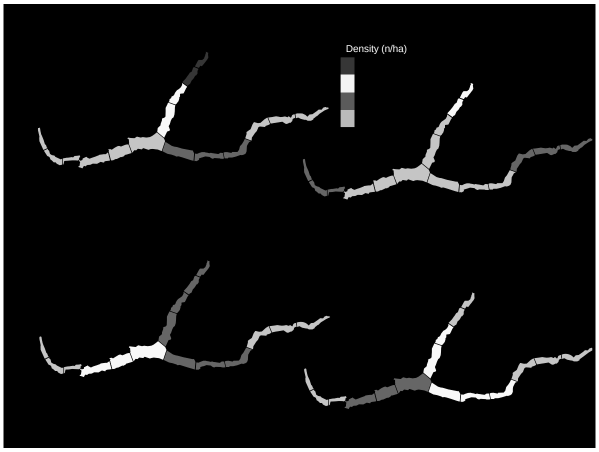
- 2001
- Little Echo
- Fly in

Low cost under investigation

Thanks to Jim Irvine for the suggestion.

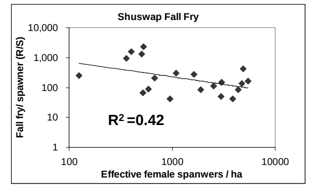
Surveys

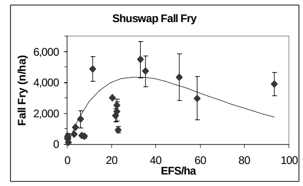




Results

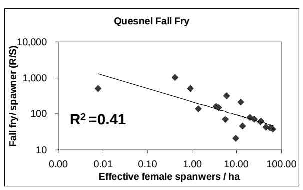
- Shuswap Lake

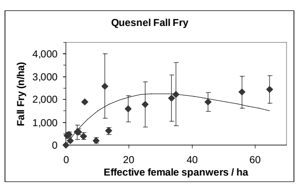




Results

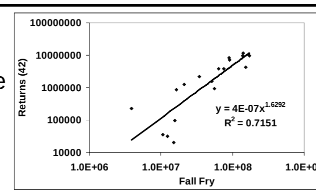
- Quesnel Lake



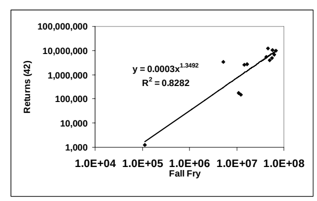


Results

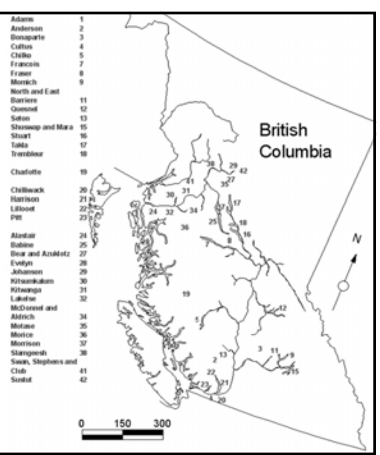
- Shuswap Lake



- Quesnel Lake



- Fraser River
  - 23 Lakes
    - Up to 20 yrs data
- Skeena River
  - 18 lakes
    - 1-3 years data
- Coastal Rivers
  - 7 lakes
    - 1 year of data



Lakes Program Clients/Partners/Funding

- Fishery managers DFO/PSC/PST
  - Sockeye Return forecasts
  - Determining escapement goals
  - SARA & WSP Issues
- HEB/ First nations / B. C. Hydro
  - Impediments to sockeye production
  - Enhancement opportunities including lake enrichment
  - Assessment of lake enrichment projects
  - Assessment of hydro impacts

Current and Future work

- Quesnel and Shuswap lakes
  - Maintain long term data collection to:
    - evaluate effect of escapement variations on sockeye production
    - the presence of cycle line interactions
  - Joint project with the province on Quesnel on sockeye/kokanee/rainbow trout interactions
- Complete surveys of all sockeye rearing lakes in the Fraser River system
  - Mable and Kamloops Lakes
- Cultus & Sakinaw Lakes
  - Assist and monitor recovery operations

Current and Future work

- North & Central Coast Management Area
  - On Skeena and coastal lakes
  - Stock status where adult escapements not done
  - Rearing area limits to production in individual lakes.

Surveys

- Lakes vary in size from
  - 461 - 270 km² (Babine, Shuswap, Quesnel)
    - 3 - 6 nights sampling
  - < 10 km² (Cultus, North Barrier)
    - One night each

Potential for hydroacoustic technology for the estimation of salmon passage in marine waters

By
Svein Vagle
Ocean Science Division, Institute of Ocean Sciences, DFO

Presented at PSC workshop 22-23 March 2006

Acknowledgments:
M.V. Trevorrow, K. Cooke, R. Kieser

Presentation Outline:

The Challenge

Why hydroacoustics?

Hydroacoustic Technology

Johnstone Strait salmon tracking

The challenge:

- **Historically the management of Fraser River sockey and pink salmon has depended on the fisheries to provide data for estimating returning abundance.**
- **Reduced fisheries has resulted in dependence on catch-per-unit-effort (CPUE) data from limited test fisheries. (Small sample size and high variability)**
- **Standardized surveys give a snapshot picture of the state of stocks.**
- **To secure comparability surveys avoid periods and areas of high dynamics.**
- **Need for new techniques and approaches that minimize these problems.**

Why hydroacoustics?

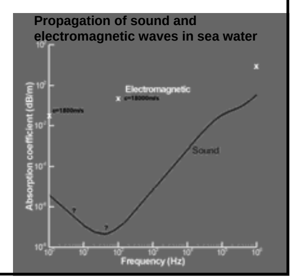
"The only alternative?"

Other approaches:

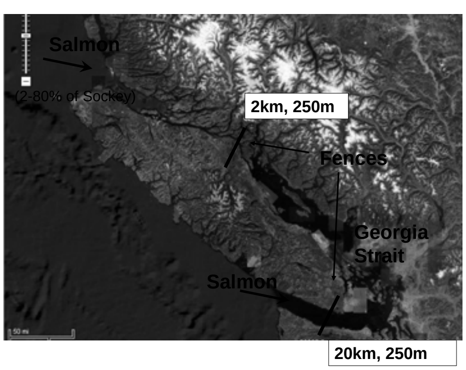
Electromagnetic sensors (e.g., cameras and lasers)

Scent?

Others?



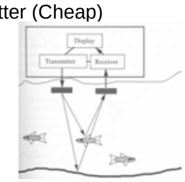
Dream Geography



Hydroacoustic Technology

Single- and multi-frequency backscatter (Cheap)

(Didson, Blueview)



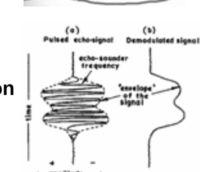
Multi-frequency sonar (chirp):

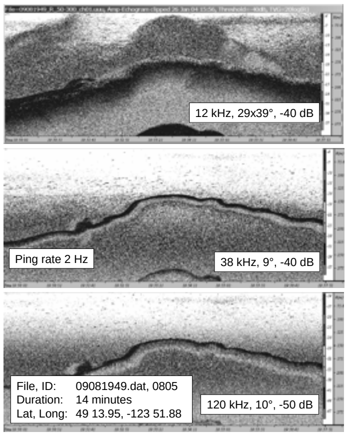
(70, 120, 200 & 400kHz)

(Scientific American, Jan 05)

- **Separate fish from plankton**
- **Species classification (echo pulse shape, width, kurtosis)**

(T. Mulligan)

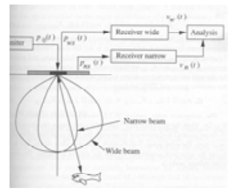


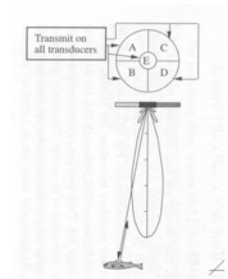


(R. Kieser)

Hydroacoustic Technology

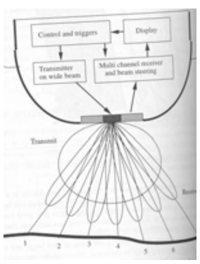
Dual- and split-beam backscatter (Reasonable)

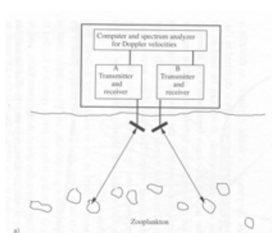




Hydroacoustic Technology

Multi-beam backscatter (Costly, Difficult to deal with data, volumetric data rare)

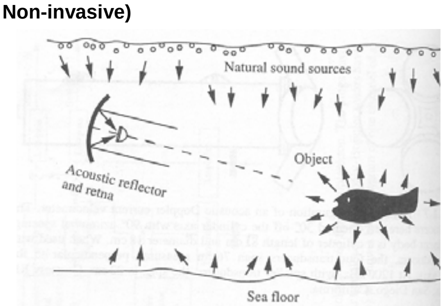




Doppler (coded data) (Reasonable)

Hydroacoustic Technology

Acoustic Daylight (New. Broad frequency range. Non-invasive)

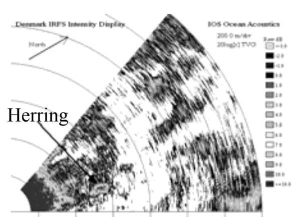


Hydroacoustic Technology

Bottom mounted Active Array

12 kHz steerable array

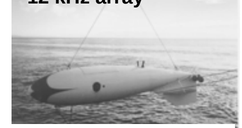
40 elements – 2.8º



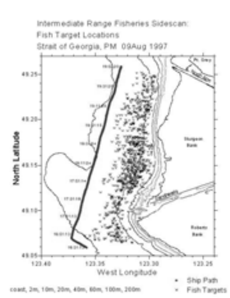
(M.Trevorrow)

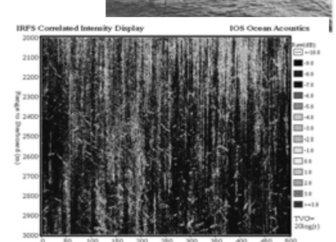
Hydroacoustic Technology

Towed Active Array



12 kHz array





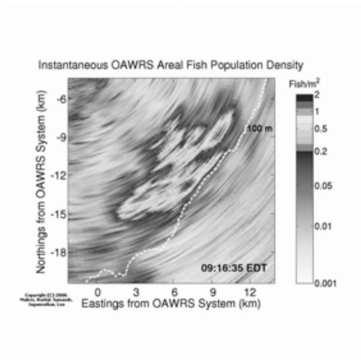
(M.Trevorrow)

Hydroacoustic Technology

Ocean-acoustic waveguide remote sensing (OAWRS)

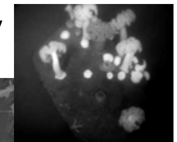
Broadband source (350-450 Hz)

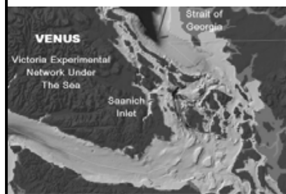
Steerable array behind ship



Hydroacoustic Technology

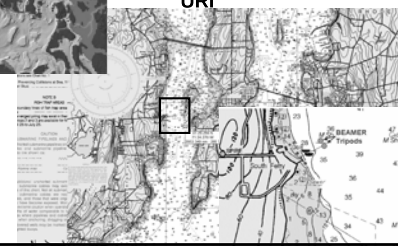
Cabled observatories



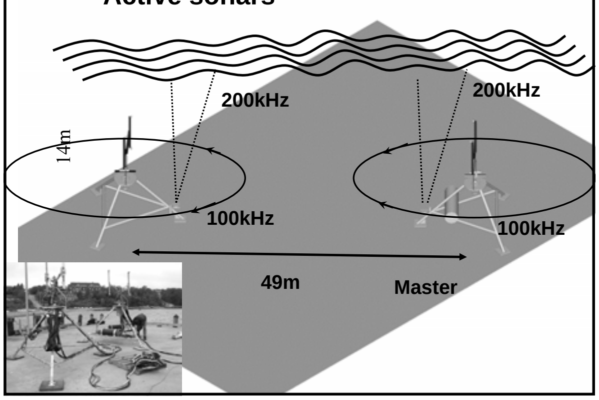


URI

VENUS



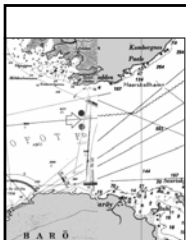
Active sonars

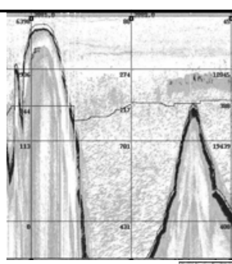


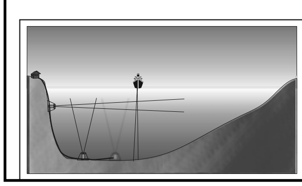
Ocean HUB

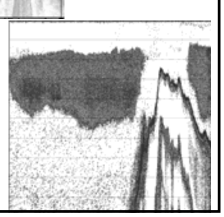
Ofotfjord Northern Norway

With Institute of Marine Research, Bergen, Norway







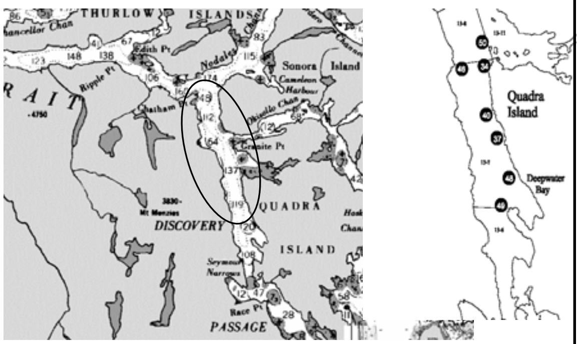


Johnstone Strait salmon tracking

- **Determine best location**

Talk to locals, fishermen, PSC/DFO personnel

Johnstone Strait salmon tracking



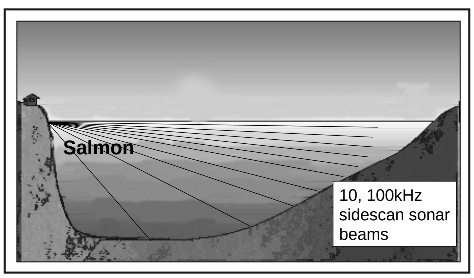
Johnstone Strait salmon tracking

- •Determine best location
  - Talk to locals, fishermen, PSC/DFO personnel
- •Decide on appropriate equipment
- •Determine whether we can actually detect salmon
- •Compare with Didson and/or Blueview
- •Compare with test fisheries and Mission counts
- •Operate for one or two seasons

Johnstone Strait salmon tracking

Equipment:

+Didson/Blueview+ CTD



Johnstone Strait salmon tracking

- •Determine best location
  - Talk to locals, fishermen, PSC/DFO personnel
- •Decide on appropriate equipment
- •Determine whether we can actually detect salmon
- •Compare with test fisheries and Mission counts
- •Compare with Didson and/or Blueview
- •Operate for one or two seasons

Then,

Decide whether a permanent system with feed to PSC is feasible and desirable.

Summary:

Technology and expertise now available and affordable to think about the feasibility of establishing fixed hydroacoustic installations on BC coast to provide timely data for estimating returning salmon abundance.

However,

Studies are needed to determine ultimate location, whether we can actually detect salmon in these areas reliably, equipment, and operating procedures (24 h/day? For how long? Processing algorithms, etc)

Species classification (Different acoustic characteristics, behaviour, timing, location in water column, etc)

Mission Hydroacoustic Program:

A Tool for In-season Management of Fraser River Sockeye and Pink Salmon from 1977-2005.

Stock Assessment Group

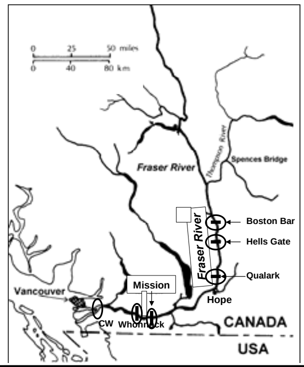
Pacific Salmon Commission

Acknowledgements:

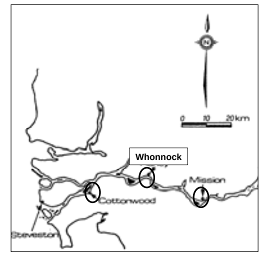
1. Applied Technologies Group, Dept. of Fisheries and Oceans, and
2. PSC Southern Boundary Restoration & Enhancement Fund

1

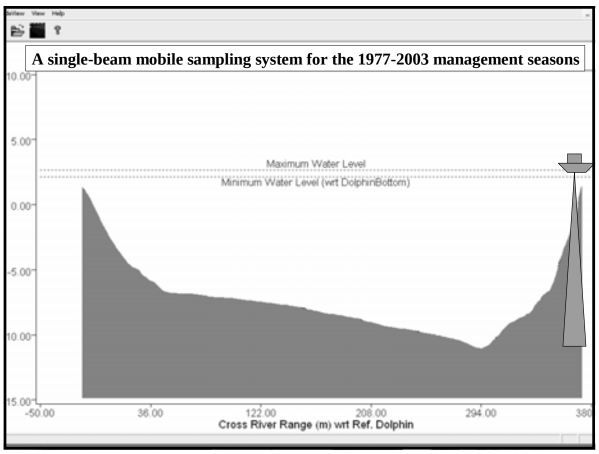
Operating & Tested assessment sites in the mainstem of the Fraser River

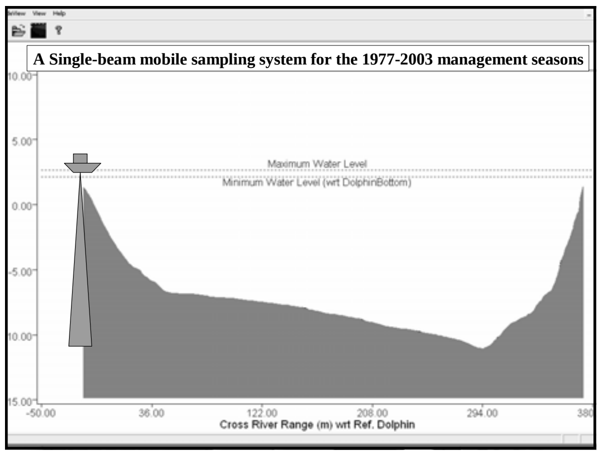


A detail map of PSC in-season assessment sites in the lower river

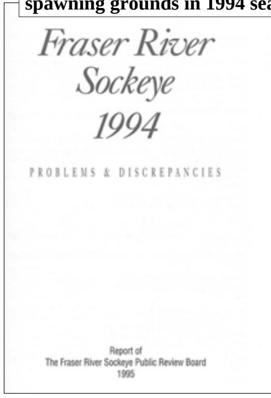


2





How did it start: the significant short-falls of expected arrivals at spawning grounds in 1994 season. Public Inquires Initiated.



Fraser River Sockeye 1994

PROBLEMS & DISCREPANCIES

Report of
The Fraser River Sockeye Public Review Board
1995

Report of the Mission Hydroacoustic Facility Working Group

(submitted to the Fraser River Sockeye Salmon Management Review Team)

Part 1: Main Report

David Farmer[1] *Chairman*
Jim Galloway[1]
Tim Mulligan[2]
Jim Cave[3]
Ian Guthrie[3]
Jim Woodey[3]

15 December 1994

1. Institute of Ocean Sciences, DFO
2. Pacific Biological Station, DFO
3. Pacific Salmon Commission

Refining the Single-beam Model and Optimizing Sampling Efforts

Estimation of in-river fish passage using a combination of transect and stationary hydroacoustic sampling

Sarath G. Banneheka, Richard D. Routledge, Ian C. Guthrie, and James C. Woodey

Available online at www.sciencedirect.com

SCIENCE @ DIRECT

ELSEVIER

Fisheries Research 47 (2004) 175-281

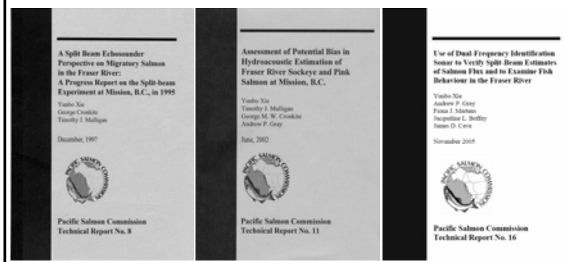
FISHERIES RESEARCH

Optimal partition of sampling effort between observations of fish density and migration speed for a riverine hydroacoustic duration-in-beam method

D.G. Chen, Y. Xie, T.J. Mulligan, D.N. MacLennan

Split-beam tracking and estimating of fish abundance (1995-2005)

Split-beam and DIDSON studies of Fish behaviour and flux (1995-2005)



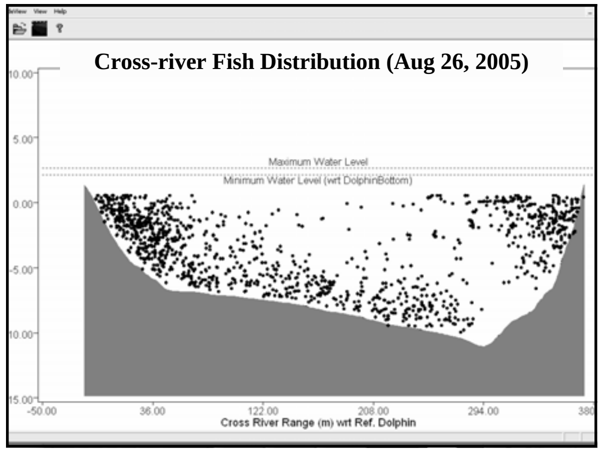
8

Mission Split-beam Hydroacoustic Estimator as an In-season Management Tool since 2004

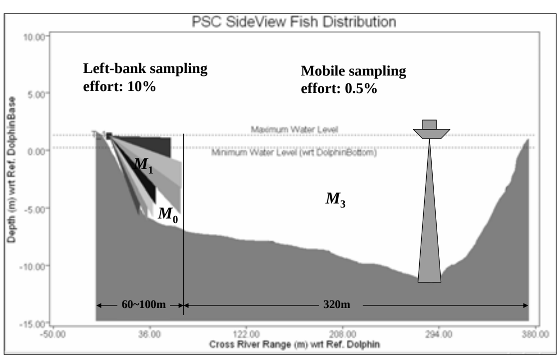
1. **Sampling Designs and Estimation Models for Daily Total Salmon Estimate:**
   - a) south-bank shore-based side-looking survey system,
   - b) vessel-based downward looking mobile survey system,
   - c) total salmon estimate,
   - d) Verification of estimates with image sonar (DIDSON).
2. **Challenges in Recent Years.**
3. **Potential Biases.**

9

Cross-river Fish Distribution (Aug 26, 2005)



Sampling geometry and efforts for fish-flux: *ρv*



11

Fish-flux Estimation Models for Left-bank and Mobile Systems

For left-bank sampled areas (*U- D*):

$$M_1 = 24\times\bar{y} = 24\times\frac{1}{24}\cdot\sum_{i=1}^{24}[(U_i - D_i)/0.1] = 10\times\sum_{i=1}^{24}(U_i - D_i)$$

[fish in 24hr]

For left-bank un-sampled areas:

M_0 estimated by a nearest-neighbour extrapolation model

For off-shore areas sampled by the transect vessel: ***behaviour factors***

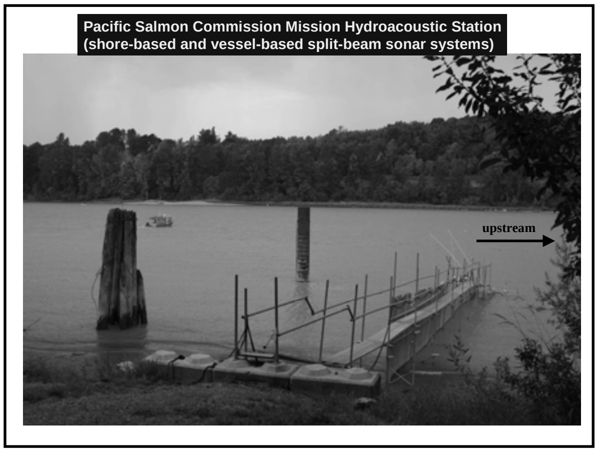
$$M_3 = \frac{m_T\cdot v_+}{L}\cdot\left[1-(1-\frac{v_-}{v_+})\cdot\frac{D}{D+U\cdot v_-/v_+}\right]\cdot\left[1-2\cdot\frac{D}{D+U}\right]\times(24\times3600)$$

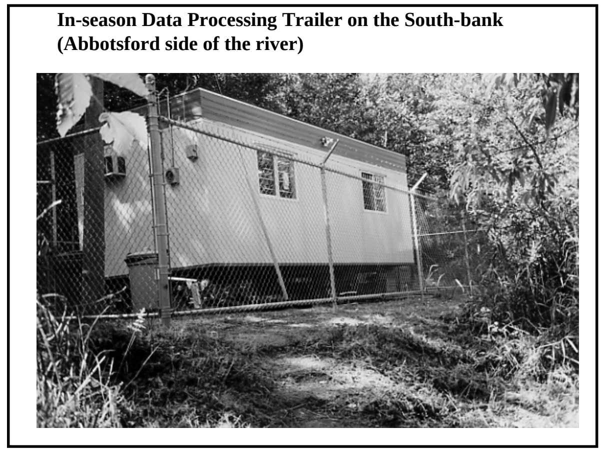
[fish in 24 hr]

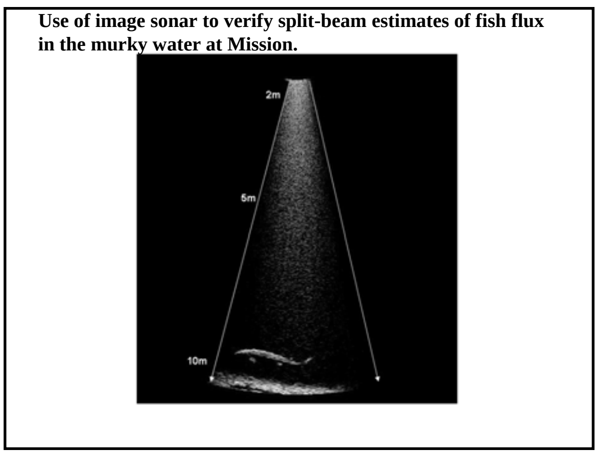
24-hr total net upstream salmon flux past Mission:

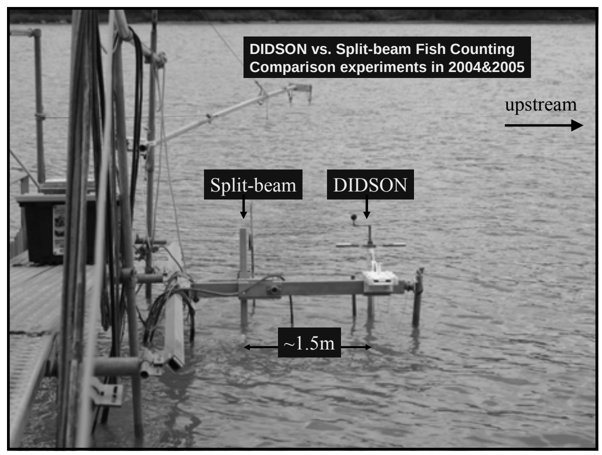
$$M = M_0 + M_1 + M_3(r > r_c)$$

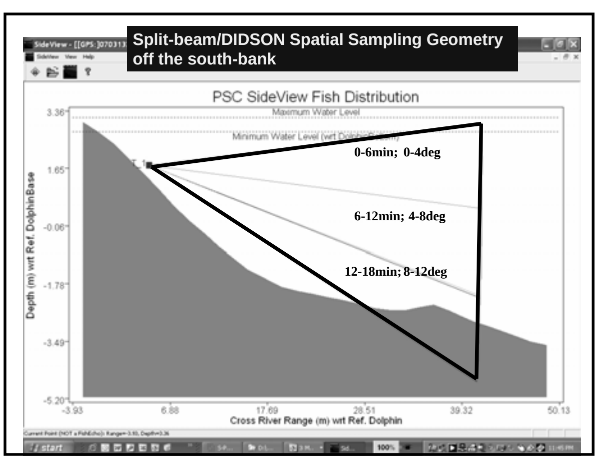
12

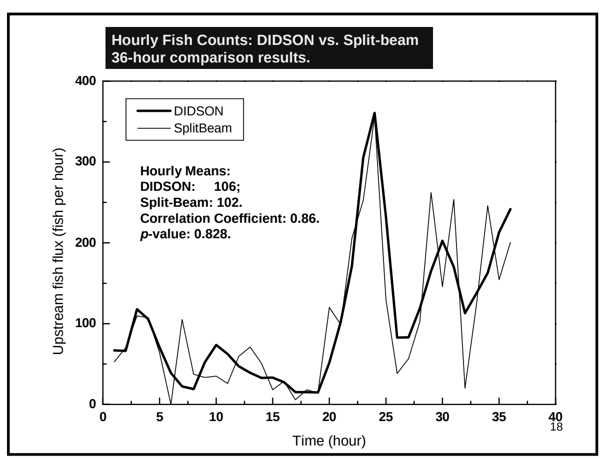

Pacific Salmon Commission Mission Hydroacoustic Station
(shore-based and vessel-based split-beam sonar systems)
upstream

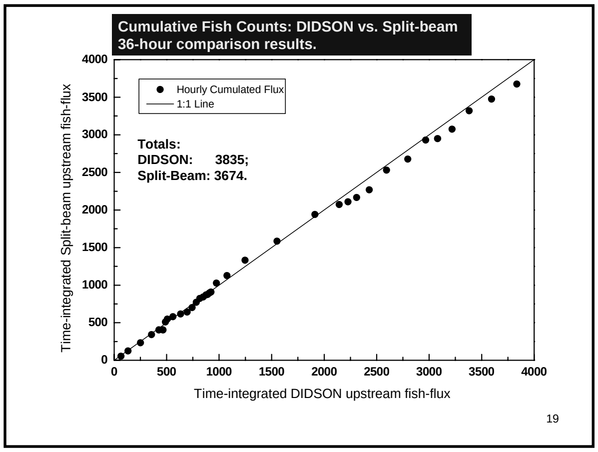

In-season Data Processing Trailer on the South-bank
(Abbotsford side of the river)

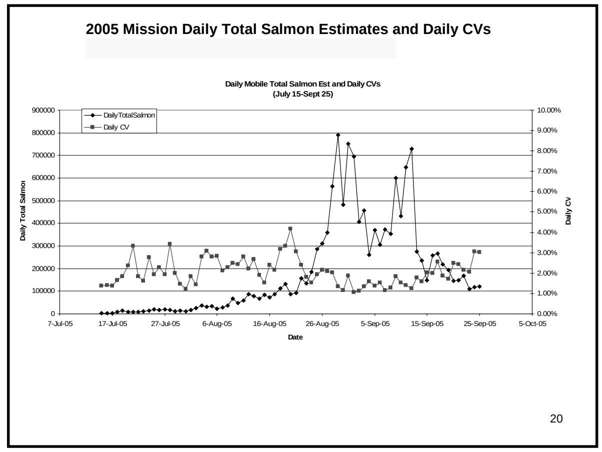

Use of image sonar to verify split-beam estimates of fish flux in the murky water at Mission.
2m
5m
10m


DIDSON vs. Split-beam Fish Counting
Comparison experiments in 2004&2005
upstream
Split-beam
DIDSON
~1.5m


Split-beam/DIDSON Spatial Sampling Geometry
off the south-bank
PSC SideView Fish Distribution
Maximum Water Level
0-6min; 0-4deg
6-12min; 4-8deg
12-18min; 8-12deg
Depth (m) wrt Ref. DolphinBase
Cross River Range (m) wrt Ref. Dolphin
3.36
1.65
-0.06
-1.78
-3.49
-5.20
-3.93
6.88
17.69
28.51
39.32
50.13


Hourly Fish Counts: DIDSON vs. Split-beam
36-hour comparison results.
DIDSON
SplitBeam
Hourly Means:
DIDSON: 106;
Split-Beam: 102.
Correlation Coefficient: 0.86.
p-value: 0.828.
Upstream fish flux (fish per hour)
Time (hour)
0
100
200
300
400
5
10
15
20
25
30
35
40
18





Challenges in 2005 Season for Mission Hydroacoustic System

1. Record high daily passages between late-Aug & mid-September 7 days of daily passage > 500,000 with a maximum of 767,000 on Sept 1st. In 2002, only 3 days of daily passages (Sept.) > 500,000.

2. Heavily overlapping of pink-migration with sockeye-migration. In the past, either little overlapping or terminating the program (2003) when pink migration becomes pronounced.

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Source of potential biases and the corresponding mechanisms in the daily total salmon estimation

(1) Saturation of split-beam tracking system of individual fish (-).

(2) Rejection of echoes from closely spaced fish: multiple-targets (-).

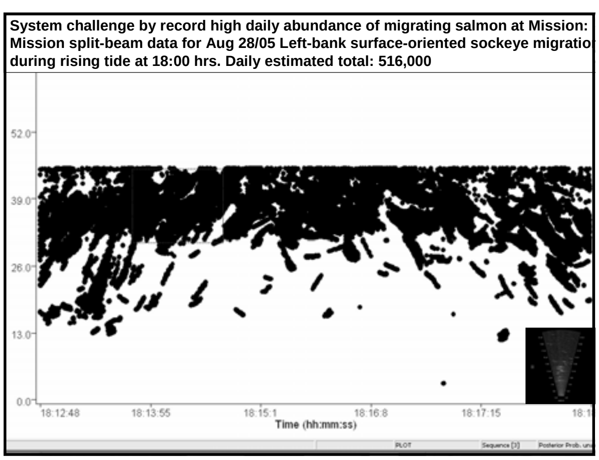
(3) Avoidance reaction in shore areas to the sounding vessel (-).

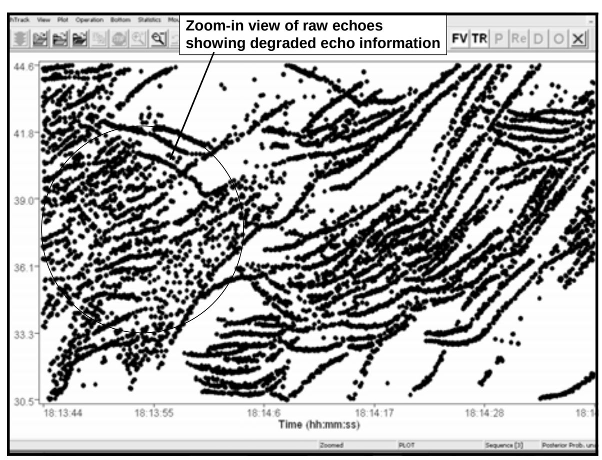
(4) Reduced sampling volume in shallow waters near north-bank (-).

(5) Blanking/distortion of shore-based sonar-beams by extremely shore-oriented pink salmon (-).

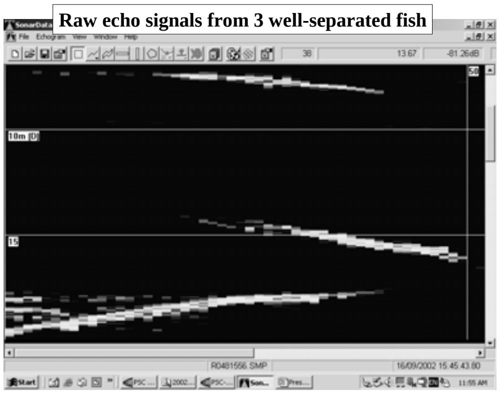
(6) Application of south-bank fish speed to migration speed off the north-bank (+).

22





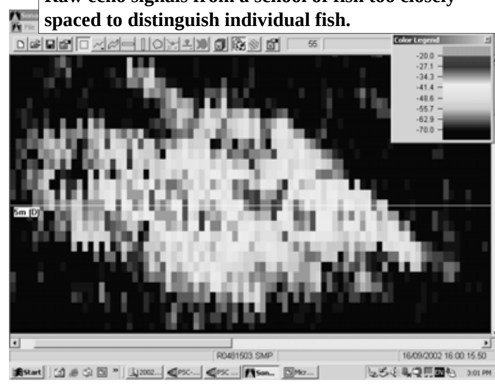
Raw echo signals from 3 well-separated fish



Echoview, R0481556.smp, Event 25, ping 0-50, 6.95-19.9m, 3 targets, 2x10 degree transducer

25

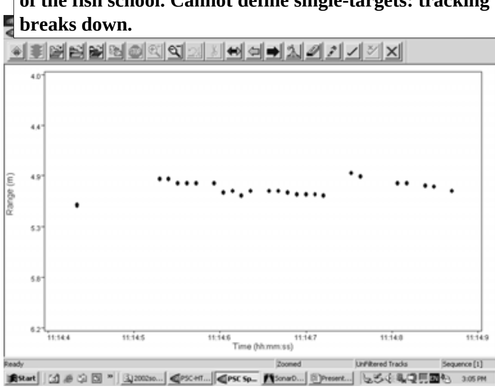
Raw echo signals from a school of fish too closely spaced to distinguish individual fish.



Echoview, R0481503.smp, event 5, ping 6-92, 4.09-5.76m, 5 targets, 4x10 degree transducer

26

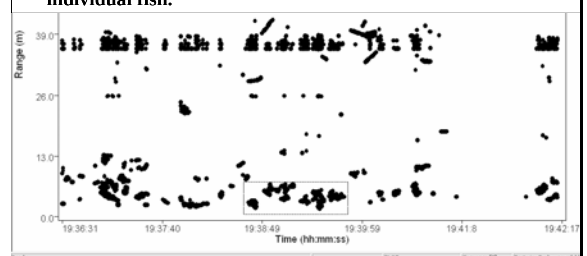
Split-beam filtered tracking echoes from the raw echoes of the fish school. Cannot define single-targets: tracking breaks down.



27

Challenges from pink salmon behaviour: swimming extremely close to shore in upstream migration.

1. Near-field scattering/distortion/absorption of the sound-beam by pinks: seeing bottom/surface echoes from re-scattered sounds;
2. Significant loss of fish echoes: too few echoes for tracking individual fish.



28

Estimation bias due to using south-bank fish behaviour for fish migrating off the north-bank

Mobile split-beam flux estimation model:

+16% +1.8% -2.8%

$$B = \frac{m_T \cdot v_+}{L} \cdot \left[1 - \left(1 - \frac{v_-}{v_+}\right) \cdot \frac{D}{D + U \cdot v_- / v_+} \right] \cdot \left[1 - 2 \cdot \frac{D}{D + U} \right]$$

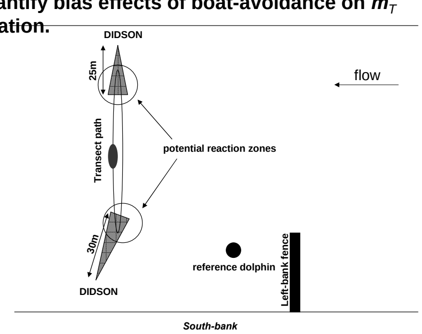
Combined: +15%

Mainly from overestimation of upstream speed of north-bank fish

Estimation bias due to fish avoidance of the vessel: underestimation of m_T.

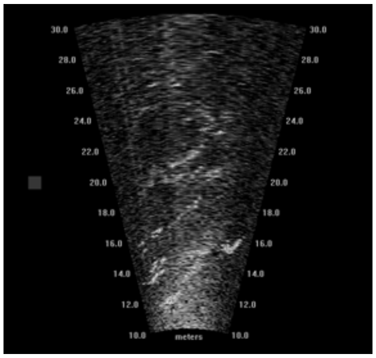
29

1. Collect information on avoidance behaviour in shore areas (shallow waters) with DIDSON.
2. Quantify bias effects of boat-avoidance on m_T estimation.

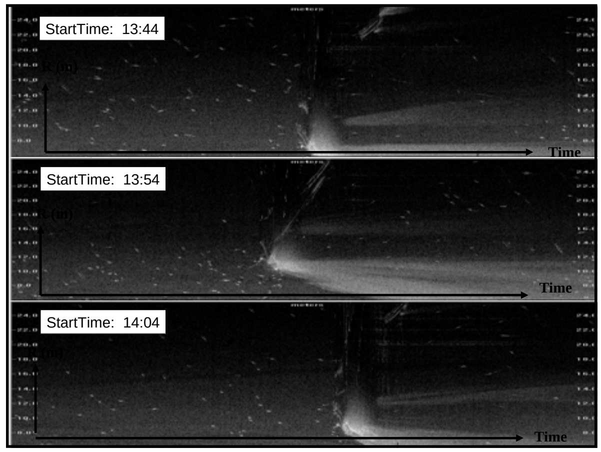


30

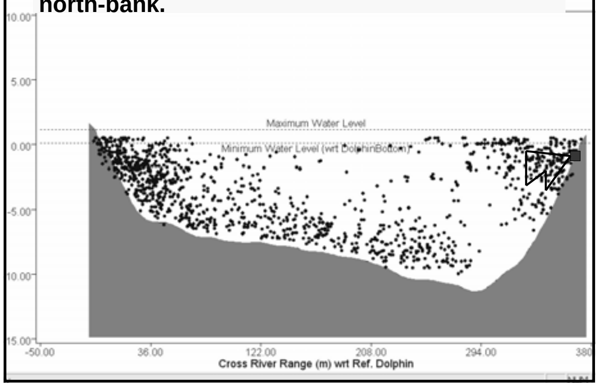
Fish Avoidance of the vessel on the left-bank during low water



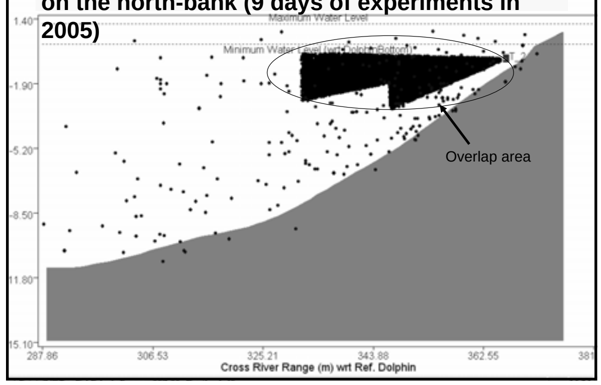
31

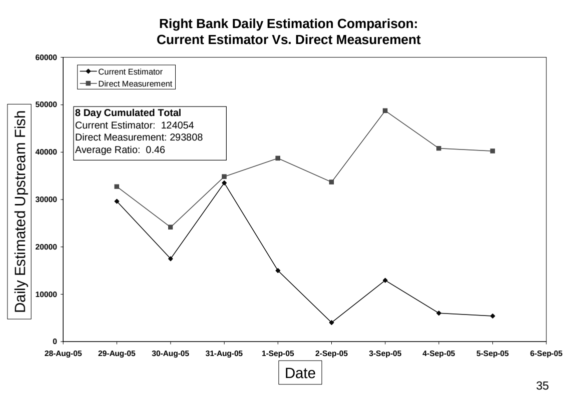


Direction and magnitude of bias in the estimation of upstream migrating fish off the north-bank.



fish-flux by a shore-based side-looking split-beam system on the north-bank (9 days of experiments in 2005)



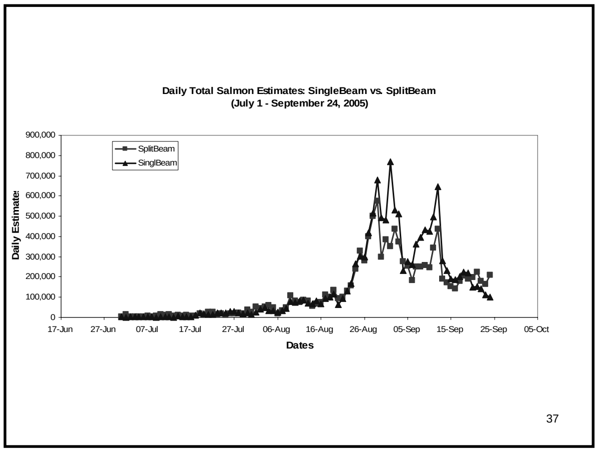


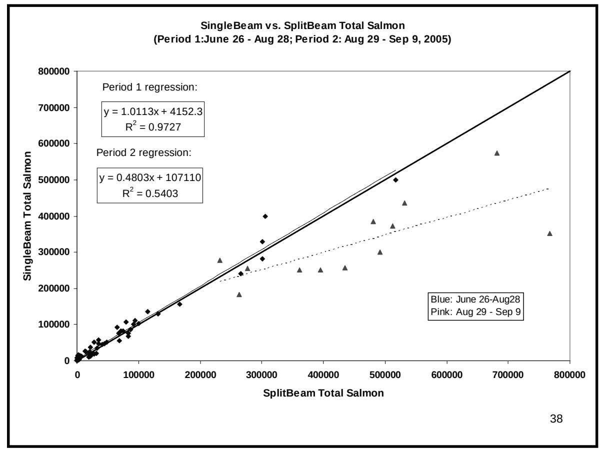
35

Summaries

1. In comparison to the single-beam estimator, the newly implemented split-beam estimator produces robust more and precise estimates of daily total salmon abundance past Mission.
2. We have verified split-beam estimation of salmon-flux off the south-bank with the fish counts by a DIDSON image sonar.
3. We have identified 6 mechanisms of potential biases in the current estimator: 5 negative and 1 positive.
4. Analyses have been on-going to quantify magnitudes of biases from these mechanisms.
5. Preparation is underway to install a shore-based split-beam system on the north-bank to measure fish-flux off the north-bank.

36


Daily Total Salmon Estimates: SingleBeam vs. SplitBeam
(July 1 - September 24, 2005)
SplitBeam
SinglBeam
Daily Estimate
Dates
37


SingleBeam vs. SplitBeam Total Salmon
(Period 1:June 26 - Aug 28; Period 2: Aug 29 - Sep 9, 2005)
Period 1 regression:
y = 1.0113x + 4152.3
R2 = 0.9727
Period 2 regression:
y = 0.4803x + 107110
R2 = 0.5403
Blue: June 26-Aug28
Pink: Aug 29 - Sep 9
SingleBeam Total Salmon
SplitBeam Total Salmon
38

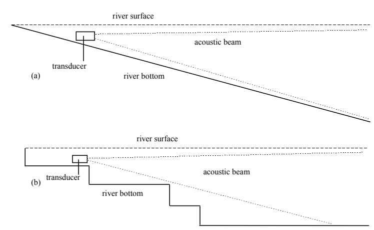
Enumerating migrating fish from an acoustic point of view

What makes a good acoustic site

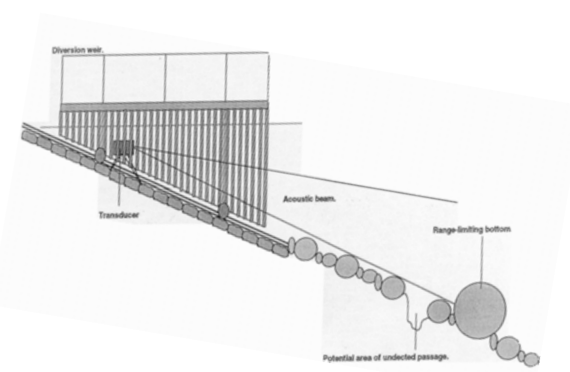
- Need a straight single channel with laminar flow
- Planar bottom profile
- Bottom substrate free of obstructions
- Minimal human activity which could alter fish behaviour
- Fish actively migrating

Straight singular channel with laminar flow

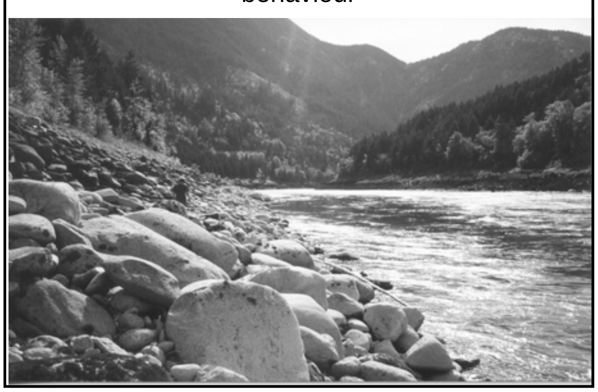
Planar bottom profile



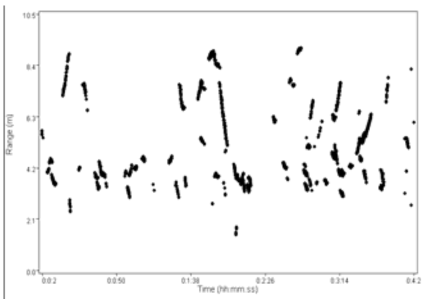
Bottom substrate free of large boulders



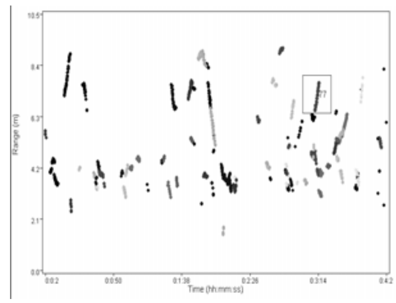
Minimal human activity to alter fish behaviour



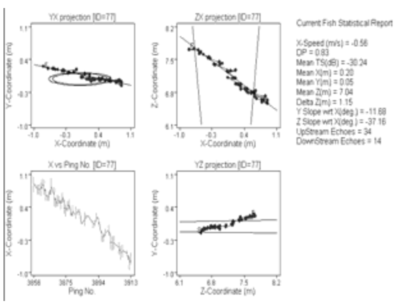
Fish actively migrating



Fish passage near shore



Fish passage committed to migrating upstream



Qualark Creek

- Qualark Creek is the first site on the mainstem Fraser River that is amenable to acoustic detection of migrating fish

HISTORY

- Initiated by the Fisheries Minister through the Pearse-Larkin Commission
- Mandate was to develop acoustic methods that provide reliable estimates of numbers of migrating fish

Qualark Creek Hydroacoustic Site

Location

- 5 km downstream of Yale and 95 km upstream of Mission site
- If you are a fish it takes 2 days to get to Yale in early and mid summer from Mission
- As river drops to low flow rate in September the tendency is for a 3 day lag

Why was Qualark successful?

- Met all criteria when choosing an acoustic site
- Equipment and methodology developed over time
- Fish passage was near shore
- Measure of validity to the acoustic estimate (Groundtruthing)
- Technology applied to other sites

Planar bottom profile

Bottom substrate free of obstructions

Removal of obstructions for low water operation

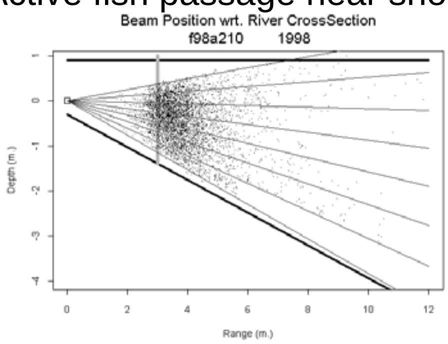
Equipment development

- In-river accessory equipment designed to assist the acoustic measurement
- Equipment designed to measure the performance of the acoustic system

Installing In-River Accessory Equipment

Fish passage was near shore

Active fish passage near shore



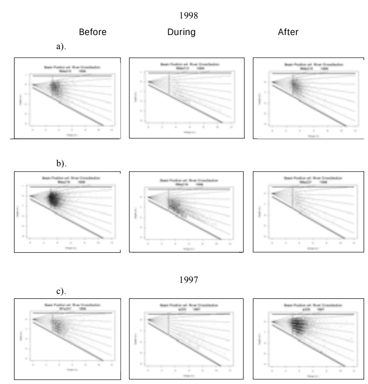


Fig. 16. Daily Fan plots of fish passage detected at Qualark Creek for three selected Julian days (a, b, and c) in 1997 and 1998. Each time sequence shows the distribution before, during and after the gillnet fishery. Each fan plot represents a composite of all transducer positions in the water column delineated with radiating lines. The solid vertical line represents the end of the fish deflection weir

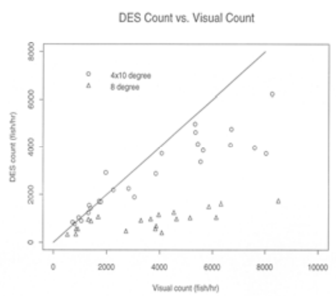
Shore orientation simplifies apportioning estimate

Measure of Bias (Groundtruthing)

- Acoustic estimate compared to a visual count
- Direct comparison with a non-acoustic estimate for the same fish over a delineated sample area
- Performance of the acoustic tracking algorithm

Groundtruthing the acoustic estimate

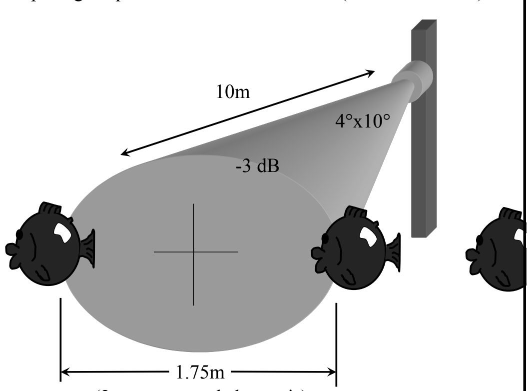
Selection of an appropriate transducer



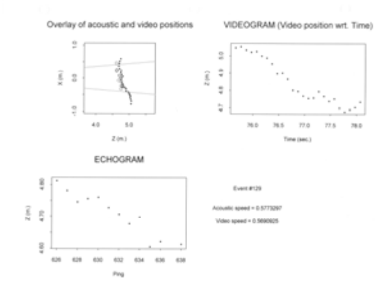
Acoustic tracking compared to video

- Problems associated with acoustic tracking when multiple fish are in the beam at the same time

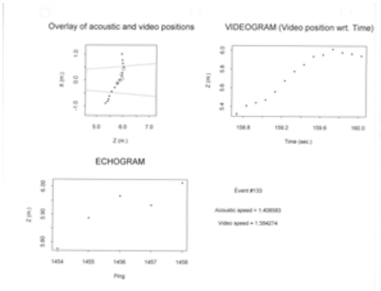
Target Spacing Required to Avoid Interference (Ideal Conditions)



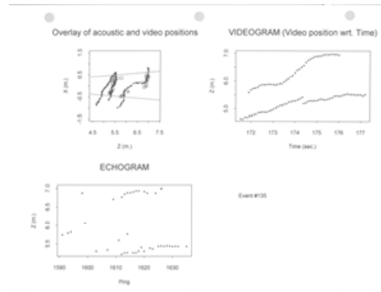
When one fish appears



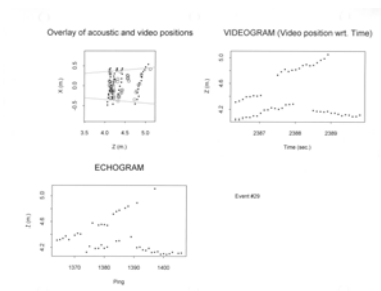
Fast moving fish



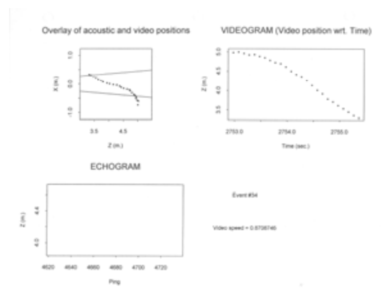
(3) Fish are counted correctly but tracked incorrectly



Lose reliance on direction but still get the number of fish



Fish not acoustically tracked due to aspect angle



What does this mean to estimation?

- As number of echoes increase within the beam per ping there is an impact on tracking.
- The impact would increase as the range increases.
- As passage increases direction of travel is impacted.

What was learned at Qualark was applied at other locations

Mission

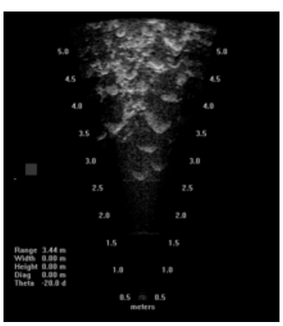
Rivers Inlet

Michipicoten River

Conclusion

- Reliable estimates of passage can be achieved at Qualark simply because passage is near shore.
- Qualark from an acoustic point of view still remains a prime location because fish are committed to migrating upstream.
- Site selection remains crucial component.
- DIDSON will work at Qualark.

DIDSON imaging sonar at Qualark



Early warning of passage problems

Riverine Acoustics Group

George Cronkite

Tim Mulligan

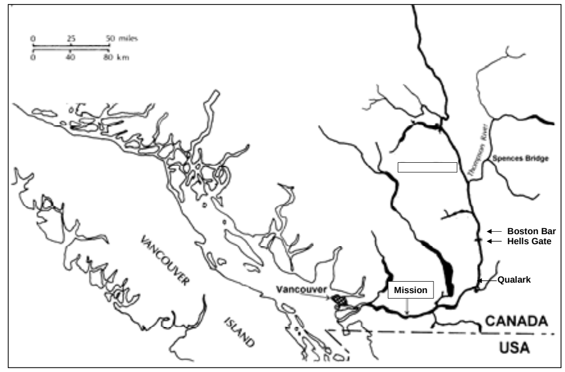
Juha Lilja

Hermann Enzenhofer

John Holmes

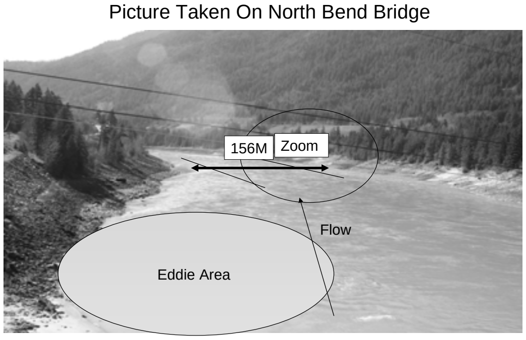
The Application of Enumerating Fish Passage Using Hydro-acoustics at An Upstream Main-stem Fraser River Monitoring Site

Andrew Gray, Fiona Martens, Hermann Enzenhofer, Jacqueline Boffey, Yunbo Xie, Jim Cave, John Warren, Larry Florence, SEF

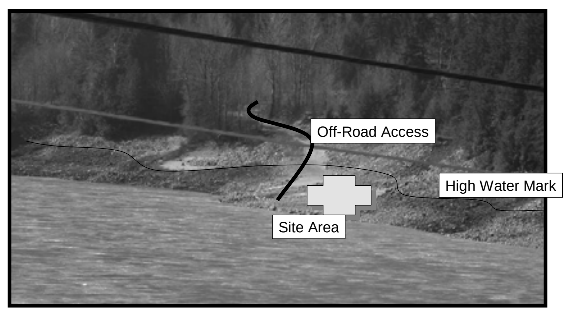


Boston Bar Site Selection

Picture Taken On North Bend Bridge



Area Selected For Wet Test



Boston Bar DIDSON Deployment Site (September 6-7, 2005)

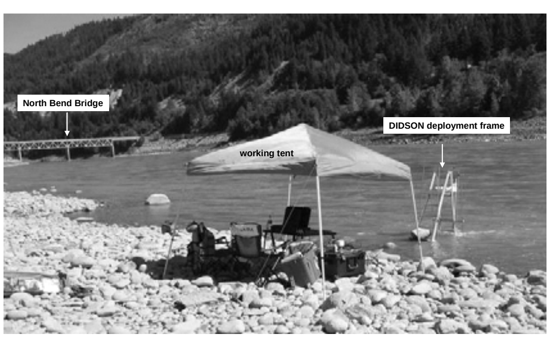
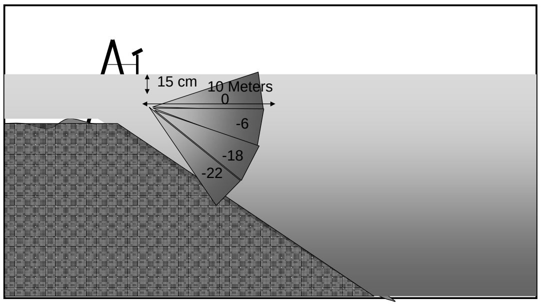
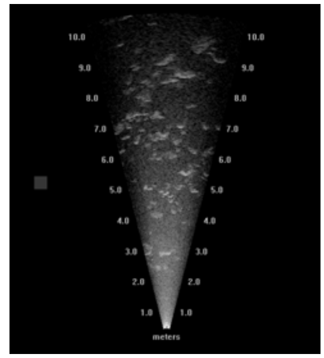


Photo of 2005 Boston Bar Deployment of Ladder and Mount for Didson Unit

Schematic of Didson Ladder and Mount



Fish Distribution – Shore Orientation of Fish



Further Work

- Cross River Profile; Develop a profile of the river bottom across the entire test area to determine coverage areas and possible dead zone areas.
- Extended Wet Test; Conduct a 10 day sampling experiment during peak migration periods to better understand fish behavior in that area.
- Test the left-bank; Conduct a Wet Test on the opposite bank to monitor fish passage on the left-bank.
- Determine River Height fluctuation; Monitor the river levels over a one year period to determine the amount of change over the period of salmon migration.
- Develop Sampling Plan; Using the above information develop a sampling scheme that would allow us to come up with an estimate of fish passage.

Feasibility of estimating sockeye salmon in the Upper Fraser River by fixed aspect hydroacoustics

L'heidli T'enneh Band, Prince George

Treaty Requirements for Salmon Population Estimates

e.g. Yale First Nation: March 9, 2006 Agreement-in-principle

Domestic allocation for sockeye of 0.9097% of the Canadian TAC

Yale First Nation will have a commercial fishing opportunity of up to 1.15% of commercial TAC for sockeye

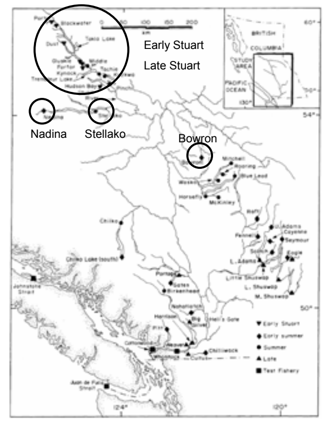
Salmon Stock Assessment in the Upper Fraser River

Estimates required to trigger or close fisheries

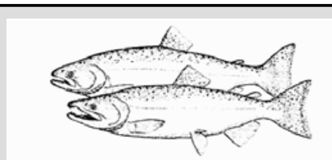
Conservation concerns for Upper Fraser sockeye:
- Early Stuart
- Late Stuart
- Bowron

In-season estimates required for management (near real-time)

Reliability is key



Five Upper Fraser sockeye stocks



Fraser River Chinook Salmon

Many Upper Fraser chinook populations (each supporting thousands or hundreds of spawners).

During 2004, we captured chinook returning to Dome, Holmes, Salmon, Slim, Tete Jaune, Torpy, Nechako, Stuart, and Westroad Rivers.

March 17, 2004 Workshop Objectives

- obtain critical feedback from agency scientists involved in Fraser River sockeye and chinook stock assessment
- consensus on run size estimation methodology
- explore partnerships for the future

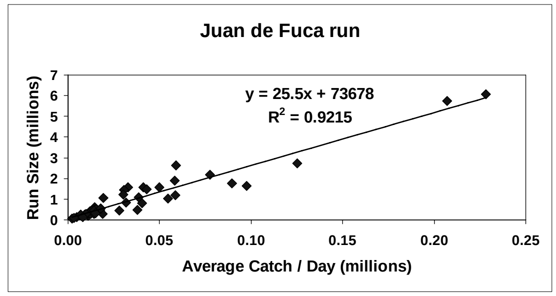
Mark-recapture estimation

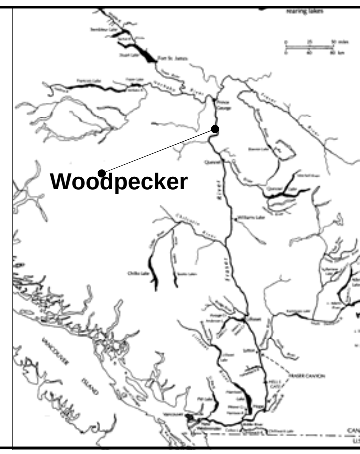
If escapement is 1 million fish, need to tag 10,000 and sample 50,000 <u>minimum</u> to obtain an estimate.

This estimate would not be precise enough for management.

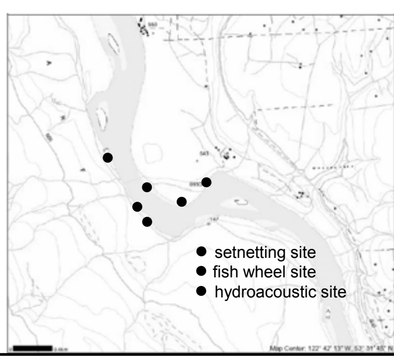
Approach is impractical and too invasive.

CPUE methods require a series of annual observations

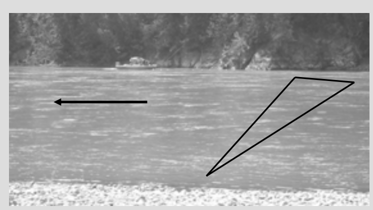


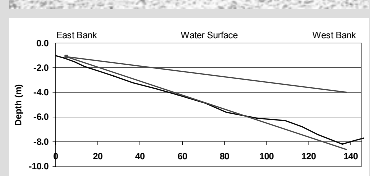


Woodpecker Sampling Locations

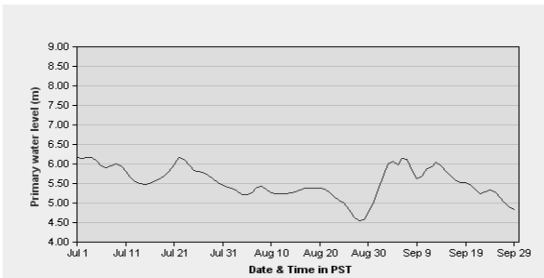


Woodpecker Sampling Site

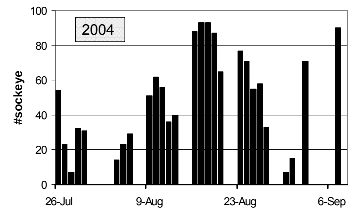




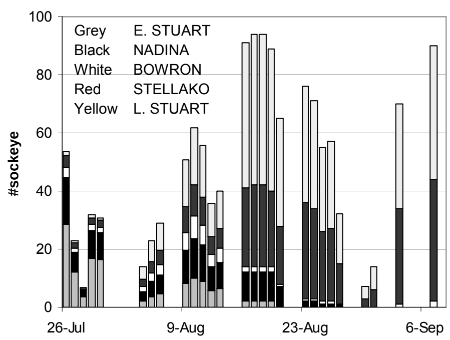
2004 Fraser River Discharge



Quantitative sampling by means of LT Fishing Methods



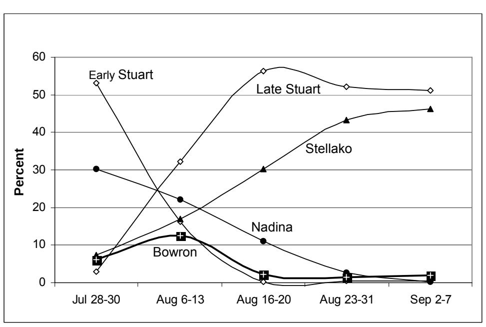
Set-net catches by stock of origin



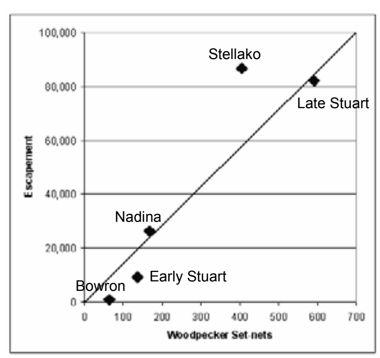
Lheidli T'enneh Fish Wheel

Woodpecker site is fishable; additional testing required.

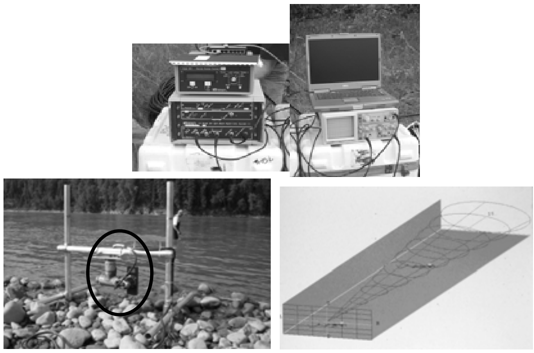
Stock Composition at Woodpecker



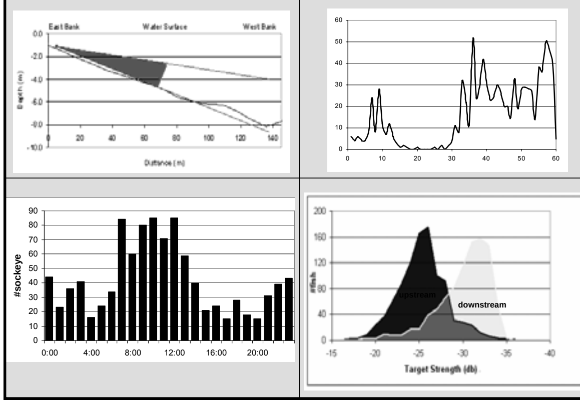
Set-netting and DNA analysis provide a good predictor of escapement for 5 Upper Fraser sockeye stocks



Quantitative estimation using split-beam echosounder and elliptical transducer



Woodpecker Hydroacoustic Results 2004



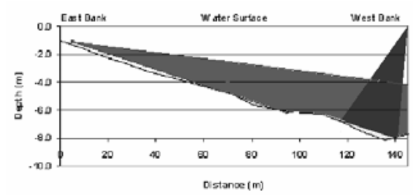
Conclusion:

Setnetting, DNA analysis, hydroacoustics and fish wheels are relevant salmon assessment techniques in the Upper Fraser River.

Additional development work is required.

Next Steps

Hydroacoustics: need cross-river coverage and real-time estimation



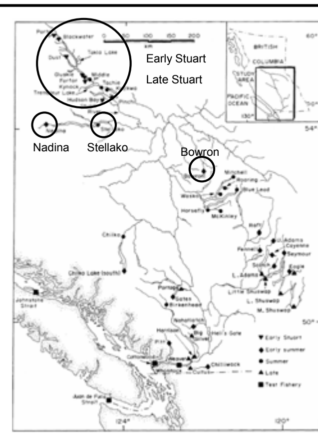
Setnetting and DNA analysis: can be used routinely

Fish wheel: more testing required

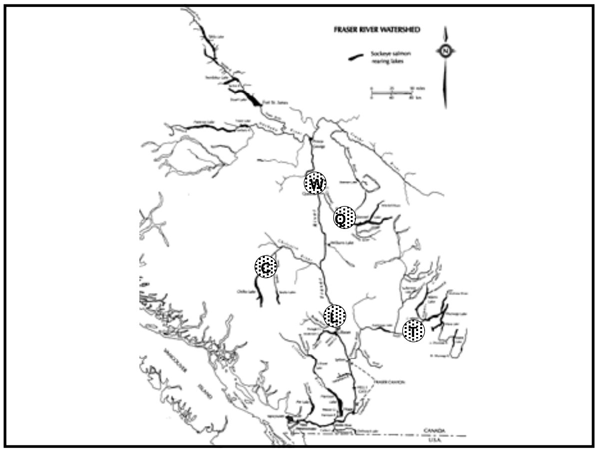
Partnerships: develop in parallel with technical assessment
Need upstream FN's DFO and PSC as partners

Future Project Activities

- Set-netting/fish wheel by LT Fishery Technicians
- DNA analysis for stock identification
- Hydroacoustics: loan of ADF&G equipment
  - Sampling to be undertaken in specific time blocks to estimate daily fish passage
  - Emphasis on cross-river coverage to obtain an absolute estimate
  - Ground truth provided by DFO daily escapement estimates and run reconstruction
  - Develop procedures for near-real time estimation



Five Upper Fraser sockeye stocks


FRASER RIVER WATERSHED
Sockeye salmon rearing lakes
N
W
Q