



2015 Babine Lake Sockeye Smolt Enumeration - Hydroacoustic Feasibility

Prepared for the Pacific Salmon Commission by:
Janvier Doire

May 2016

Skeena Fisheries Commission
3135 Barnes Crescent
Kispiox, BC
V0J 1Y4

ABSTRACT

Skeena Fisheries Commission (SFC) conducted a study to investigate the feasibility of using an up-looking hydroacoustic methodology to enumerate outmigrating sockeye smolts at the outlet of Nilkitkwa Lake in the spring of 2015. Hydroacoustic techniques have the potential to produce accurate data and be less invasive, less labour intensive, and more cost effective than the mark-recapture method currently used to estimate the abundance of sockeye smolts during the annual seasonal migration from the Babine Lake Watershed.

The specific goal of this project was to test two 200kHz Simrad EK15 echosounders and three different 200 kHz Simrad transducer models (200-7C, 38/200 Combi D, and 200-28CM) on the Babine River, at the outlet of Nilkitkwa Lake, in combination with the up-looking hydroacoustic technique that has been successfully used on some rivers of the Bristol Bay area to estimate the seaward migrating sockeye smolt population abundance. Here we report the results from this project.

Acoustic data from migrating sockeye smolts were successfully collected using the three transducers tested on the Babine River. The acoustic data collected at the outlet of Nilkitkwa Lake in late May to early June 2015 showed similar vertical, lateral, and temporal distributions as were observed during the Bristol Bay area studies and also correlated well with the daily sockeye smolt population estimates using mark-recapture.

Near-surface resolution tests were also conducted with each of the transducers tested, and showed that narrow beam transducers were more appropriate to sample migrating sockeye smolt than wide beam transducers because of their finer near-surface resolution.

TABLE OF CONTENTS

ABSTRACT	ii
TABLE OF CONTENTS.....	iii
LIST OF FIGURES	iv
INTRODUCTION	5
METHODS	9
Study area.....	9
Hydroacoustic equipment and acoustic sampling of migrating sockeye smolt	10
Transducer calibration and near-surface resolution test	13
Hydroacoustic data post-processing	14
RESULTS AND DISCUSSION	15
Acoustic sampling of migrating sockeye smolt	15
Transducer calibration and near-surface resolution test	16
CONCLUSION.....	21
ACKNOWLEDGEMENTS	22
REFERENCES	23
APPENDIX I	25

LIST OF FIGURES

Figure 1. Trends in annual Babine Lake sockeye returns (catch plus escapement), 1970-2015.....	6
Figure 2. Map showing the Babine Lake Watershed, and the location of the Babine Sockeye Smolt Enumeration Facility.....	8
Figure 3. Satellite view of the acoustic feasibility study area.....	9
Figure 4. Cross-sectional depth profile of the Babine River channel, positioning of the three transducers, and representation of the acoustic beams for each of the transducers at the acoustic feasibility study site located at the outlet of Nilkitkwa Lake. May 29, 2015.	10
Figure 5. View of the acoustic equipment: laptop computer, Ethernet switch, two Simrad EK15 transceivers, 12v marine deep cycle battery, and the 200-7C (top) and 38/200 Combi D (right) transducer assemblies.....	11
Figure 6. View of the 200-28CM transducer assembly.	11
Figure 7. View of the acoustic shore station.....	12
Figure 8. Example of the transducer mount assembly, comprised of an aluminum plate, a structural steel I-beam piece, four stainless steel eye-bolts, and levels.....	12
Figure 9. View of the two buoys indicating the position of the 200-7C and 38/200 Combi D transducers in the Babine River, at the outlet of Nilkitkwa Lake.	14
Figure 10. Approximately 5 minutes of echograms from the 200-7C, 38/200 Combi D, and 200-28 CM transducers showing schools of sockeye smolt migrating through the Babine River, at the outlet of Nilkitkwa Lake, and data from a rain event collected by the 200-7C transducer.....	17
Figure 11. Hourly Area Backscattering Coefficient (ABC) measured by the 38/200 Combi D, 200-7C, and 200-28CM transducers (left y axis) compared to daily sockeye smolt abundance estimated using the mark-recapture method (right y axis) from May 23 rd , 2015 to June 9, 2015 on the Babine River, at the Nilkitkwa Lake outlet. Mark-recapture daily sockeye smolt estimates from Doire and Macintyre (2015)......	18
Figure 12. Vertical distribution of the Average Area Backscattering Coefficient measured by the 200-7C, 38/200 Combi D, and 200-28 CM transducers on the Babine River.	19
Figure 13. Single target (ST) target strength (TS) percentage frequency distribution for the 200-7C, 38/200 Combi D, and 200-28CM transducers.	20
Figure 14. Results from the near-surface resolution test for the 200-7C, 38/200 Combi D, and 200-28CM transducers.	20

INTRODUCTION

The Babine Lake Watershed is the principal sockeye salmon (*Oncorhynchus nerka*) rearing area for Skeena sockeye, producing up to 90% of the sockeye returns to the Skeena River. The Skeena watershed supports an average yearly harvest of 1.5 million sockeye in commercial (Canada and United States), recreational, and First Nations fisheries and an average spawning escapement of 1 million sockeye.

Sockeye salmon returns to Babine Lake have declined significantly during the past two decades (Figure 1). The outmigrating sockeye smolt population from the Babine Lake Watershed was not estimated from 2002 (brood year 2000) until 2013 (brood year 2011), and it is therefore not known to what extent the decreasing returns are due to limitations in freshwater versus marine productivity. In the spring of 2013, the Skeena Fisheries Commission (SFC) in collaboration with the Lake Babine Nation (LBN) successfully resumed the sockeye smolt mark-recapture population estimation program (Doire and Macintyre, 2014) previously carried out by the Department of Fisheries and Oceans from 1959 to 2002. The reactivation of the mark-recapture sockeye smolt program for the Babine Watershed adds an important dimension to a suite of Babine sockeye enumeration projects at different life history stages including a long history of accurate adult counts through a weir, an accurate run-reconstruction process to estimate the catch component of the stock, fry estimates from sockeye salmon enhancement facilities at Pinkut and Fulton creeks, and detailed past lake productivity studies. However, mark-recapture methods generally tend to over-estimate populations size, especially when tag retention, and tagged fish mortality (e.g. from predation) rates are unknown. The precision of the daily estimates in the first few days of the smolt outmigration is greatly reduced by low number of marked fish released in the system. The first smolts to migrate out of the Babine Lake Watershed (“early smolt migrants”) are from the Late Wild Babine River population which has declined substantially during the last few decades. An abundance estimation method that would increase the precision in the estimate of the abundance of the “early smolts migrant” would improve our understanding of the causes of decline for the Late Wild Babine River sockeye population.

Hydroacoustic methods are commonly used in fisheries science, notably to estimate fish populations and fish biomass (Simmonds and MacLennan, 2005). The main advantages of hydroacoustic methods compared with other fish sampling methods include the ability to efficiently sample large volumes of water, and to remotely sample fish without handling or other manipulations. SFC has gained significant expertise using hydroacoustic technology to estimate juvenile sockeye populations in small lakes. SFC has conducted over 50 successful mobile hydroacoustic surveys on small sockeye lakes in the Skeena and Nass Watersheds and on the British Columbia Central Coast since 2005. During mobile lake surveys, the acoustic equipment samples the water column vertically from a boat following pre-determined transects. It is also possible to use acoustic equipment in an up-looking, stationary position to sample a portion of the volume of water flowing down a river. Beginning in 2008 on the Kvichak River, and other rivers in the Bristol Bay area of Alaska, several studies have tested and successfully utilized acoustic equipment in an up-looking configuration to estimate the population abundance of out-migrating sockeye smolts. These studies concluded that the stationary, up-looking hydroacoustic method was feasible and precise (Wade *et al.* 2010, Nemeth *et al.* 2014, and Priest *et al.* 2015).

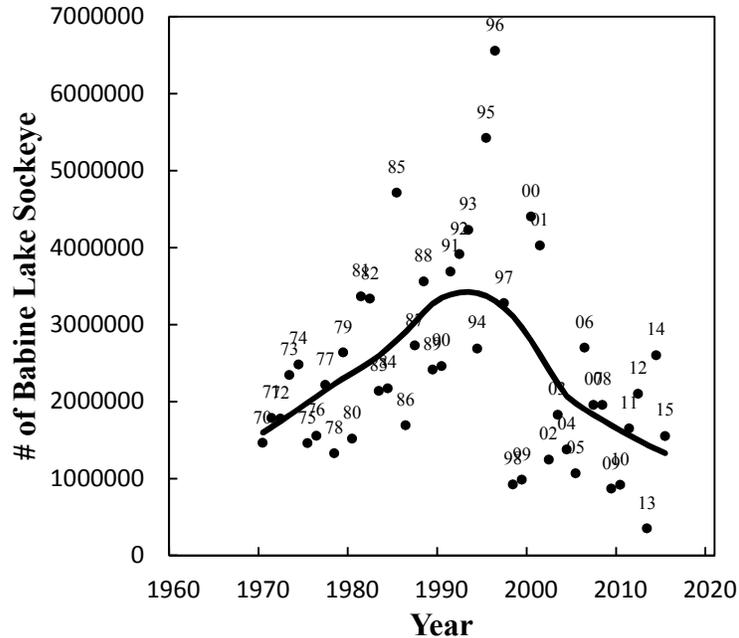


Figure 1. Trends in annual Babine Lake sockeye returns (catch plus escapement), 1970-2015. The trend line is fitted by LOWESS (F=0.5). Updated data from Cox-Rogers and Spilsted (2012). The 2013, 2014, and 2015 data points are interim values.

In the spring of 2014, we tested the feasibility of using a stationary side-looking hydroacoustic technique to estimate the sockeye smolt population migrating out of the Babine Watershed. While a location with a deep U-shape channel suitable for hydroacoustic sampling was identified at the outlet of Nilkitkwa Lake, the side-looking hydroacoustic test demonstrated that two 6 degree beam transducers positioned on either side of the Babine River would sample less than 2/3 of the river’s cross-section, leaving the middle of the channel un-sampled, making it impossible to produce a robust statistical estimate of the migrating smolt population (Doire 2015). Furthermore, the acoustic data collected in 2014 contained a significant amount of noise that could not be edited to allow for accurate data analysis (Doire 2015). The side-looking hydroacoustic technique was determined to be too sensitive to acoustic noise caused by rain and wind at the water surface, and not appropriate to estimate migrating sockeye smolts at the outlet of Nilkitkwa Lake (Doire 2015), however the deep-U-shaped channel identified at the outlet of Nilkitkwa Lake was determined to be suitable for similar up-looking hydroacoustic methodology as used in the Bristol Bay area since 2008 (Wade *et al.* 2010, Nemeth *et al.* 2014, and Priest *et al.* 2015).

In the spring of 2015, SFC began testing the feasibility of using a stationary up-looking hydroacoustic technique in the deep U-shaped channel identified in 2014 at the outlet of Nilkitkwa Lake to estimate the population of sockeye smolts migrating out of the Babine Watershed. Because the acoustic equipment used in the Bristol Bay studies (Wade *et al.* 2010, and Priest *et al.* 2015) is no longer available, our objective in 2015 was to test the up-looking technique using a 200kHz single beam echosounder made by Simrad, and three different models of 200kHz single beam transducers, which are also made by Simrad.

This report explains the methodology used, presents the results obtained, and discusses the feasibility of estimating the abundance of sockeye smolt migrating through the Babine River at the outlet of Nilkitkwa Lake using an up-looking acoustic system. Some of the acoustic data collected during the study was sent to Don Degan (Principal of Aquacoustics, Inc.), who oversees the up-looking acoustic program and data analyses for sockeye smolt acoustic population estimation studies in the Bristol Bay area (Wade *et al.* 2010, Nemeth *et al.* 2014, and Priest *et al.* 2015). A note from M. Degan on the analysis of the data, and on his opinion of the feasibility of estimating the abundance of sockeye smolt migrating through the outlet of Nilkitkwa Lake using up-looking hydroacoustic is appended to this report (Appendix 1).

If feasible, the up-looking hydroacoustic technique has the potential to improve the accuracy and precision of the Babine sockeye smolt estimate because it is not dependent on a number of variables related to mark-recapture method (tag retention, mortality, predation rates, etc.), and has the potential to sample a greater portion of the sockeye smolt population. The trap currently used for the mark-recapture program usually samples approximately 1% of the out-migrating sockeye smolt population, and the mark-recapture estimate is based on this small sample. If the hydroacoustic technique is determined to be feasible and effective, it may not only be a more accurate than the standard mark-recapture method, but potentially less labour intensive, more cost effective, and will require no handling of the smolts. As a result, the hydroacoustic method may be a more efficient, cost-effective, and viable method to enumerate Babine Lake Watershed out-migrating sockeye smolts over the long term.



Figure 2. Map showing the Babine Lake Watershed, and the location of the Babine Sockeye Smolt Enumeration Facility. Map by Gordon Wilson - Gitksan Watershed Authorities.

METHODS

Study area

The Babine Lake Watershed is located in the eastern part of the Skeena River Watershed, approximately 70km northeast of Smithers, British Columbia (Figure 2). All of the juvenile sockeye rearing within the Babine Lake Watershed travel through the outlet of Nilkitkwa Lake before entering the Babine River during their seaward migration. The Department of Fisheries and Oceans (DFO) operated a smolt enumeration facility (including a trap, and associated leads, a working platform, and sheltered working sheds) at the outlet of Nilkitkwa Lake from 1959 until 2002. We used this facility in the spring of 2015 to conduct the Babine Lake Watershed Sockeye Smolt Mark-Recapture project.

A section of the Babine River immediately downstream of the smolt enumeration facility was selected as the site for the 2014 and 2015 hydroacoustic feasibility studies because it has appropriate physical characteristics including a narrow, deep, and steep channel cross-section configuration (Figure 3). The site is easily accessible from the smolt fence infrastructure with sufficient level terrain on the East bank to accommodate the hydroacoustic installation.

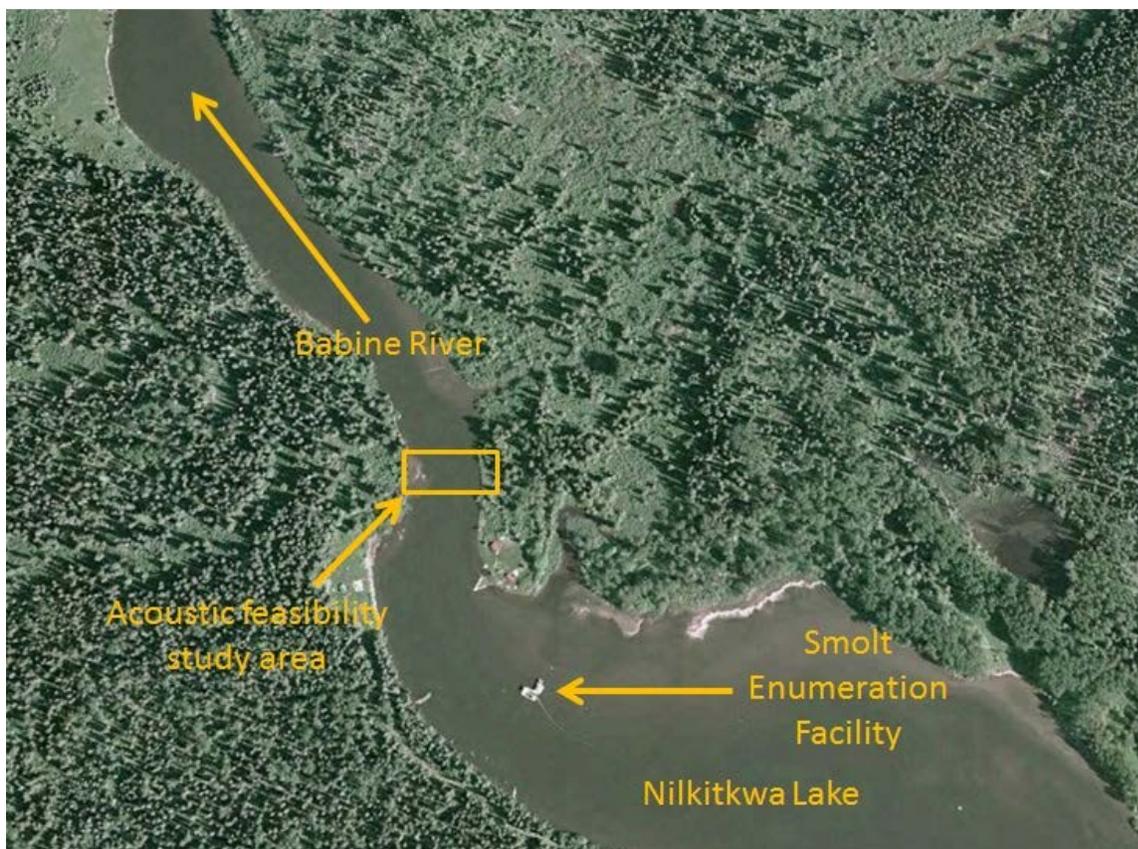


Figure 3. Satellite view of the acoustic feasibility study area.

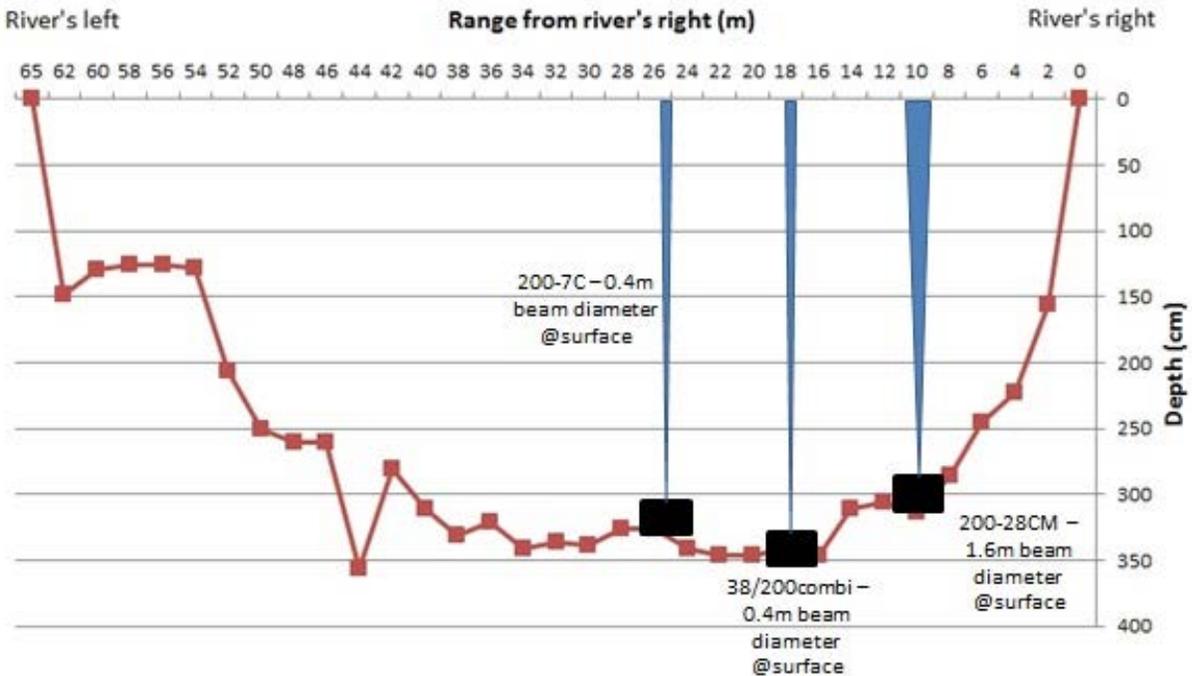


Figure 4. Cross-sectional depth profile of the Babine River channel, positioning of the three transducers, and representation of the acoustic beams for each of the transducers at the acoustic feasibility study site located at the outlet of Nilkitkwa Lake. May 29, 2015. Note different scales for x and y axes.

Hydroacoustic equipment and acoustic sampling of migrating sockeye smolt

The acoustic configuration that was field-tested during this feasibility project consisted of two 200kHz Simrad EK15 single beam echosounders coupled alternately with three different models of Simrad single beam 200kHz transducers: a 200-7C (7 degree beam), a 38/200 Combi D (7 degree beam), and a 200-28CM (28 degree beam) (Figures 5 and 6). The 200-7C and 38/200 Combi D transducers were installed with sufficient extra communication cable to allow both transducers to be installed up to 40m from the echosounders/computer station on shore. The 200-28CM transducer was used with the factory standard 25m communication cable. A covered shore station comprising of a laptop computer, the two echosounders, an Ethernet switch, batteries, and a power inverter was set-up on the river's right bank (Figure 7). The laptop computer was used to control the echosounders and store data. Communication and data transmission between the computer and the two echosounders were done via the Ethernet switch (Figure 5). With this set-up, one computer can control and store data from up to 15 EK15 echosounders/transducers. The acoustic system, laptop computer, and Ethernet switch were powered using four 12V marine deep cycle batteries in rotation, and a 500W power inverter (Figure 7). Two batteries powered the system for approximately 15 to 20 hours, while the other batteries were being recharged using a diesel generator.



Figure 5. View of the acoustic equipment: laptop computer, Ethernet switch, two Simrad EK15 transceivers, 12v marine deep cycle battery, and the 200-7C (top) and 38/200 Combi D (right) transducer assemblies.



Figure 6. View of the 200-28CM transducer assembly.



Figure 7. View of the acoustic shore station.



Figure 8. Example of the transducer mount assembly, comprised of an aluminum plate, a structural steel I-beam piece, four stainless steel eye-bolts, and levels.

The transducers were bolted to aluminum plates, which were in turn mounted to pieces of steel structural I-beam 40 cm in length, 30 cm in height and 15 cm in width (Figures 5, 6, and 8). Four eye-bolts held the transducers/aluminum plates attached to the steel I-beam pieces. Finally, ropes and buoys were attached to the eye-bolts to assist with installing and retrieving the transducers in and out of the water. The steel I-beams weighed approximately 30lbs and provided sufficient weight to keep the transducer anchored to the bottom of the river. Each transducer/I-beam assembly was secured to shore using a galvanised steel cable to minimize stress on the communication cable during installation and retrieval, and in the unlikely event the transducer/I-beam assemblies became dislodged from the bottom and drifted downstream.

The three transducers were positioned in a perpendicular line across the river channel. The 200-28CM transducer was approximately 10m from shore, with the 38/200 Combi D and 200-7C transducers positioned approximately 8 and 16m respectively further away (Figures 4 and 9). Levels which were glued to the transducer assemblies were intended to help positioning the transducers as level as possible on the bottom, however because of delays with reception of the equipment, and record high water levels in mid-May 2015 resulting in high water velocity and turbidity, it was impossible to immediately verify if the transducers were level during their initial installation in the river. After several days of observation of the acoustic data being recorded, and trial and error based adjustments to the transducer assemblies positioning using ropes, the transducers were as level as possible. All three transducers produced quality acoustic data starting in the evening of May 23, 2015. Installation of the transducer assemblies earlier in the season, when water level, velocity, and turbidity are lower would be much easier and more efficient. Considering the beam angle and depth of each transducers, the 200-28CM transducers had a beam diameter of approximately 1.6m at the surface, and both the 200-7C and 38/200 Combi D transducers had beam diameters of approximately 0.4m at the surface (Figure 4).

The acoustic system was operated at a 60ms ping interval and 0.08ms pulse duration using Simrad's EK15 software (v 1.2.4). The data collected were viewed in real-time and stored on a laptop computer. Data from only two of the three transducers could be collected at a same time because only two echosounders were available. The three transducers were alternately connected to the two echosounders. Data was collected mostly continuously, with some system shutdowns lasting at most a few hours caused either by loss of power or full internal laptop memory.

Transducer calibration and near-surface resolution test

Calibration of all three transducers was completed using a 36mm diameter tungsten-carbide hydroacoustic calibration sphere. The calibration corrections applied in Echoview for the analysis of the acoustic data are presented in Table 1. Additional tests to compare how well each transducer could resolve a target close to the surface were also conducted with the acoustic system positioned and operated similarly to during the acoustic smolt sampling in the Babine River. During these tests, the hydroacoustic calibration sphere was lowered directly above each transducer from the surface (depth of 0) to a depth of 40 cm, in 5 cm increments.

Table 1. Calibration corrections applied during analysis.

Transducers	Largest TS observed (dB)	Expected calibration sphere TS (dB)	Gain correction	Corrected Ek60TransducerGain	Sphere TS after correction (dB)
200-7C	-36.70	-39.6	1.45	26.95	-39.60
38/200 Combi D	-38.93	-39.6	0.33	25.13	-39.59
20-28CM	-38.34	-39.5	0.58	14.48	-39.50



Figure 9. View of the two buoys indicating the position of the 200-7C and 38/200 Combi D transducers in the Babine River, at the outlet of Nilkitkwa Lake.

Hydroacoustic data post-processing

Hydroacoustic data was imported into the Echoview software (v. 7.0.77) for editing and analysis. Acoustic data in the Sv domain were reduced using a TS threshold of -65 decibels, then noise events generated by boat passage, and rain and wind events were removed prior to analyses. The remaining data were stratified in intervals of one hour by 0.2 m of range, and the area backscattering coefficient (ABC) was integrated for each stratum for each transducer, using the same methodology applied by Wade *et al.* (2010), Nemeth *et al.* (2014), and Priest *et al.* (2015) in the Bristol Bay area studies.

RESULTS AND DISCUSSION

Acoustic sampling of migrating sockeye smolt

From May 23, 2015 to June 9, 2015, we collected and analyzed more than 692 hours and more than 26GB of good quality up-looking hydroacoustic data was collected from two of the three transducers being tested. The acoustic signal from migrating sockeye smolt schools were clearly observed with all three transducers (Figure 10). Approximately 17%, 11%, and 9% of the data from the 200-7C, 38/200 Combi D, and 200-28 CM transducers, respectively, was removed during data editing due to excessive acoustic noise. Most of the editing data loss was because of boat wake or air bubbles in the water caused by boat, rain or wind events (Figure 10). Data loss from boat passage was usually short in duration; however rain and wind events caused some extensive data loss at times. The data from all transducers should have been impacted similarly by rain events and passing boats, however the positioning of the transducers along the cross-section of the river seems to have influenced the amount of noise in the data. The data from the 200-7C transducer contained the most noise. This may have been because the dominating winds at the study location are mostly from the southeast, and the 200-7C transducer was positioned close to the middle of the Babine River channel. During wind events, winds from the South-East would create waves on Nilkitkwa Lake, which would affect the 200-7C transducer more than the two others which were closer to the east shore, and sheltered from the waves.

Figure 11 presents the hourly ABC measured by the 38/200 Combi D, 200-7C, and 200-28CM transducers from May 23rd, 2015 to June 9, 2015 on the Babine River, at the Nilkitkwa Lake outlet. The hourly ABC varied greatly between transducers and also temporarily. The hourly ABC measured by the 200-7C transducer was almost always greater than the hourly ABC measured at the same time by both the 38/200 Combi D or 200-28CM transducers, and the hourly ABC measured by the 38/200 Combi D transducer was also mostly always greater than the hourly ABC measured simultaneously by the 200-28CM transducer. Considering the 200-28CM transducer was the closest to shore (Figure 4), where the water flow is slowest, the 200-7C transducer was almost in the middle of the Babine River channel, where the water flows the fastest, and the 38/200transducer was between the other two transducers, the differences in hourly ABC measured by the three transducers are consistent with observations made during the up-looking sockeye smolt hydroacoustic estimation studies in the Bristol Bay area (Wade *et al.* 2010, Nemeth *et al.* 2014, and Priest *et al.* 2015). Indeed, Wade *et al.* (2010), Nemeth *et al.* (2014), and Priest *et al.* (2015) also observed that the transducers positioned in the thalweg of the rivers, where the water flow is the fastest, were always the transducers which were measuring the greatest ABC values, or smolt flux, and the transducer closer to shore, where the water velocity is slower, always measured the lowest ABC values.

Figure 11 also compares the data collected by the three transducers to the daily sockeye smolt abundance estimated using the mark-recapture method (Doire and Macintyre, 2015). The hourly ABC values measured by each transducer seem to follow a similar temporal pattern which correlates well with the mark-recapture daily smolt abundance estimates (Figure 11). The greatest hourly ABC values for each transducer were measured between May 24th, and May 28th, when the daily sockeye smolt abundance mark-recapture estimates were also the greatest. The opposite was also observed between June 1st and June 8th, when the daily sockeye smolt

abundance mark-recapture estimates were low, the hourly ABC values measured by the transducers were also low.

The ABC is a relative acoustic representation of the aerial density of targets, in this case sockeye smolt, within a given stratum of the acoustic beam produced by a transducer. The ABC can be divided by the mean on-axis sigma (target strength -TS- in the linear domain) of the single targets (smolts in this case) being sampled to calculate the smolt aerial density (smolt/m²) at each transducer location (Simmonds and MacLennan, 2005). This was not done as part of the present feasibility study, but the mean on-axis single target sigma can be estimated using the process of “expectation, maximization, and smoothing (EMS) to correct for off-axis targets (Hedgepeth *et al.*, 1999), as Wade *et al.* (2010), Nemeth *et al.* (2014), and Priest *et al.* (2015) did, if only data from single beam transducers are available. The mean on-axis single target sigma can also be calculated using the single target TS data from a split-beam transducer. The aerial smolt density (smolt/m²) may then be multiplied by the water velocity (m/hr) measured at each transducer location to estimate the hourly smolt flux per meter of river cross-section (smolt/hr/m) (Wade *et al.* 2010, Nemeth *et al.* 2014, and Priest *et al.* 2015). In the Bristol Bay area studies, linear interpolation between each transducer location, and between the transducers closest to shore, and the river banks (value of zero) was used to estimate smolt passage for areas of the river’s cross-sections not sampled. This method allowed an estimate of the daily river-wide migrating smolt abundances (Wade *et al.* 2010, Nemeth *et al.* 2014, and Priest *et al.* 2015). This was not done as part of this feasibility study as only two transducers at a time could sample the migrating smolt because only two echosounders were available. A minimum of 4 to 5 transducers and related echosounders would be needed to adequately sample the full width of the Babine River channel at the outlet of Nilkitkwa Lake so a reliable estimate of the migrating sockeye smolt abundance could be calculated. It appears that daily estimates of the migrating sockeye smolt population abundance calculated using the up-looking hydroacoustic technique on the Babine River at the outlet of Nilkitkwa Lake would correlate well with the daily mark-recapture sockeye smolt population estimates.

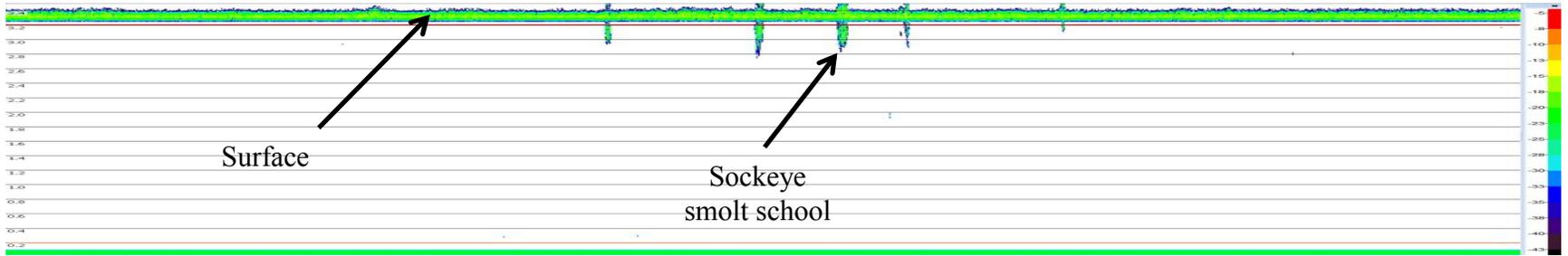
The average ABC values measured by all three transducers were the greatest close to the surface and within 1 m of the surface (Figure 12). Below 1 m depth, the ABC values were mostly insignificant. This shows most of the smolt migrate within 1 m from the surface. This is consistent with observations made at the Babine smolt trap, and also observations made by Wade *et al.* 2010, Nemeth *et al.* 2014, and Priest *et al.* 2015.

Transducer calibration and near-surface resolution test

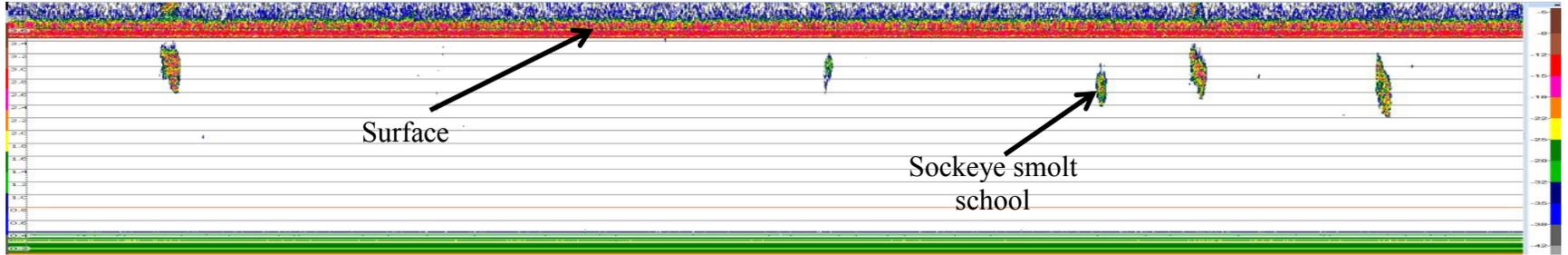
Figure 13 presents the single target (ST) target strength (TS) relative frequency distribution for the three transducers used in this feasibility study. The TS percentage frequency distributions are similar for each of the transducers, with peaks at -64dB (Figure 13). Because the three transducers were all sampling similar targets, this shows that the calibration corrections applied to the data from each transducer were appropriate.

Figure 14 presents the results from the near-surface resolution tests conducted with each of the three transducers. The 200-7C transducer could resolve the calibration sphere signal from the surface signal when the sphere was 10 cm below the surface, whereas the 38/200 Combi D and

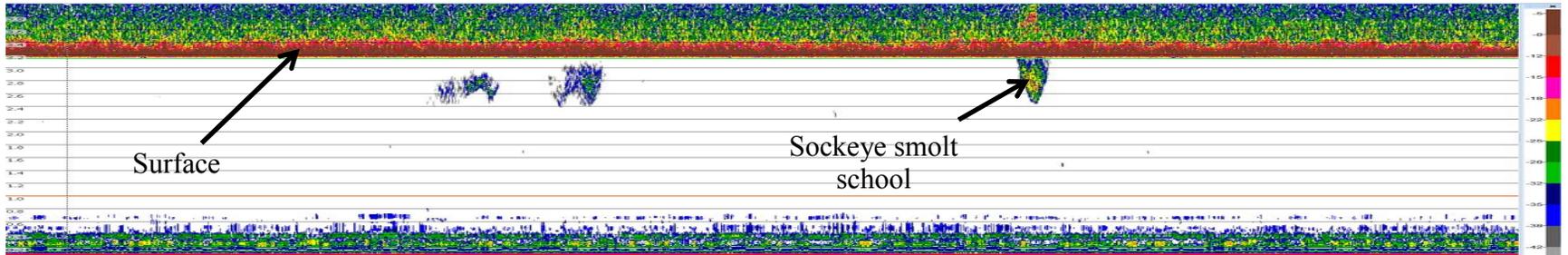
200-7C
Transducer
Echogram



38/200
Combi D
Transducer
Echogram



200-28CM
Transducer
Echogram



200-7C
Transducer
Echogram

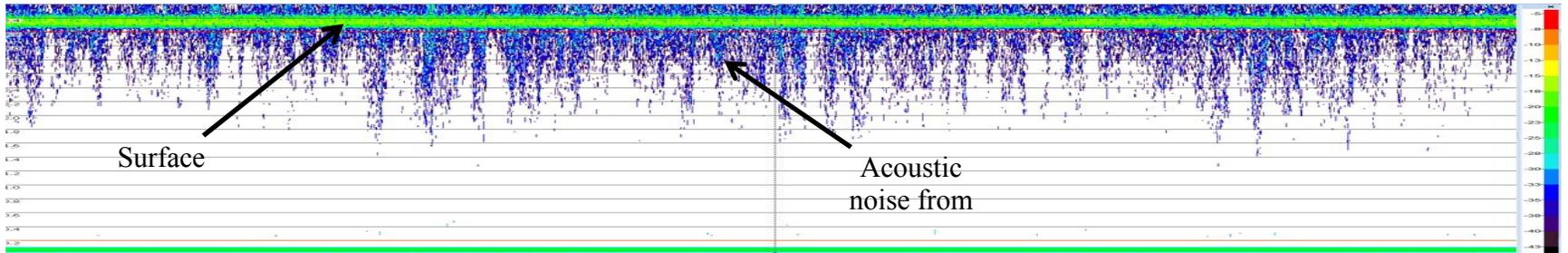


Figure 10. Approximately 5 minutes of echograms from the 200-7C, 38/200 Combi D, and 200-28 CM transducers showing schools of sockeye smolt migrating through the Babine River, at the outlet of Nilkitkwa Lake, and data from a rain event collected by the 200-7C transducer.

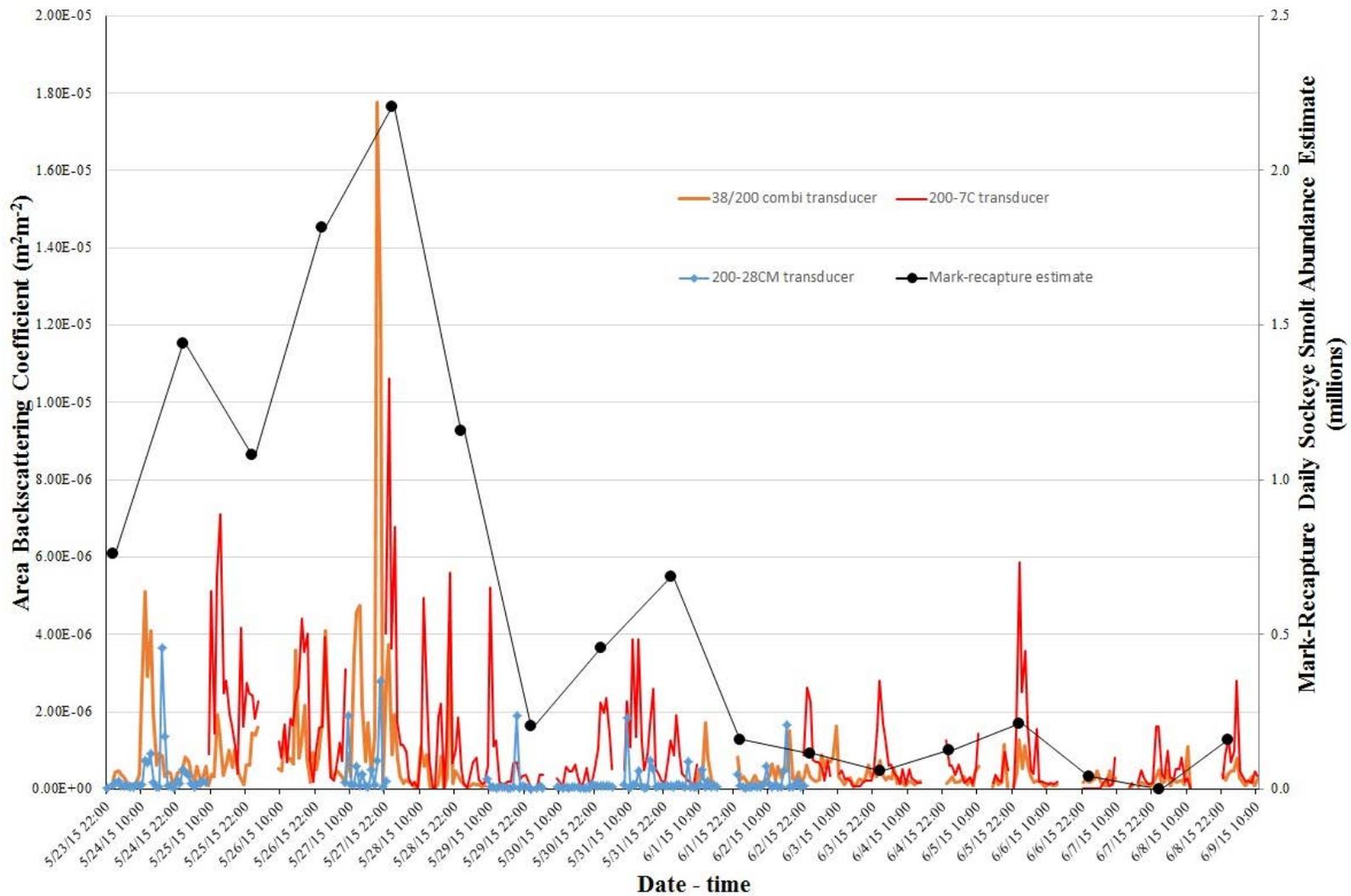


Figure 11. Hourly Area Backscattering Coefficient (ABC) measured by the 38/200 Combi D, 200-7C, and 200-28CM transducers (left y axis) compared to daily sockeye smolt abundance estimated using the mark-recapture method (right y axis) from May 23rd, 2015 to June 9, 2015 on the Babine River, at the Nilkitkwa Lake outlet. Mark-recapture daily sockeye smolt estimates from Doire and Macintyre (2015).

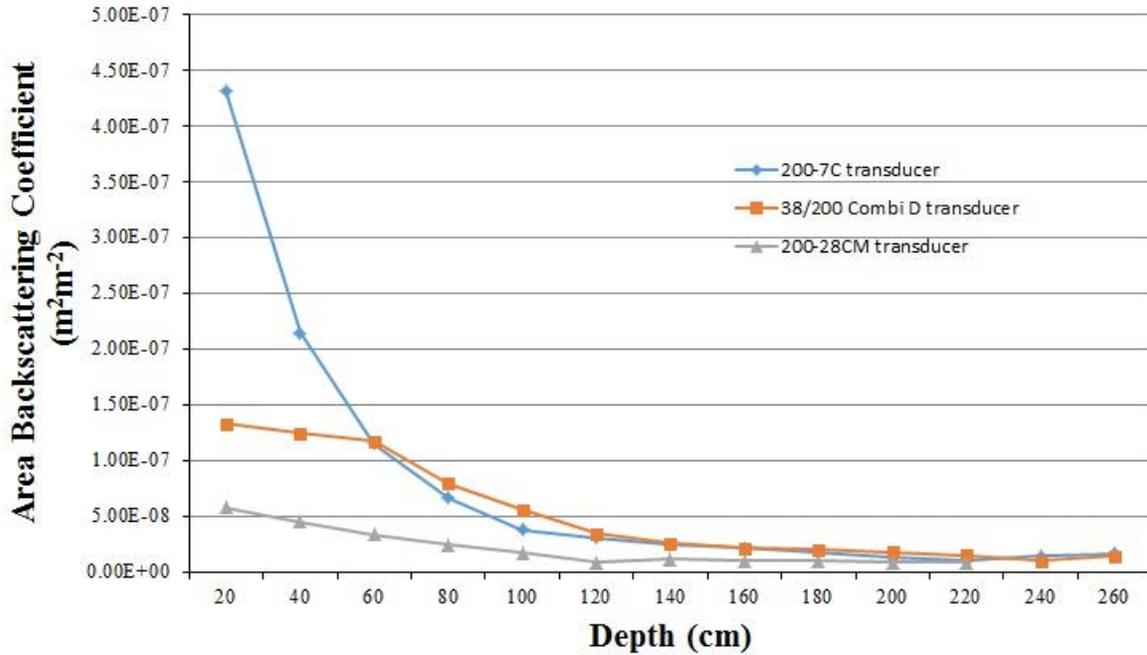


Figure 12. Vertical distribution of the Average Area Backscattering Coefficient measured by the 200-7C, 38/200 Combi D, and 200-28 CM transducers on the Babine River.

200-28CM transducers could only differentiate the calibration sphere signal when it was at least 20 cm, and 25 cm below the surface, respectively (Figure 14). Considering the geometry of the 28 degree beam produced by the 200-28CM transducer, it was expected this transducer would not be able to resolve targets located as close to the surface as the two other 7 degree beam transducers would. This is because for a transducer producing a 28 degree beam, the difference between the on-axis distance travelled by the sound wave produced by the transducer to the surface and the 14 degree off-axis distance traveled by the same sound wave to the surface is greater than for a 7 degree beam producing transducer. This is also demonstrated by the much wider surface signal produced by the 200-28CM transducer compared to the narrower surface signals produced by the 200-7C and 38/200 Combi D transducers (Figure 14).

The significant difference between the near-surface resolution of the 200-7C transducer (10 cm) and the 38/200 Combi D transducer (20 cm) is surprising given both transducers produce 7 degree beams. Perhaps the 38/200 Combi D may have been tilted during the near-surface resolution test, which would have decreased its near-surface resolution potential. The 200-7C is also significantly more expensive to purchase as it is built with better components than the 38/200 Combi D transducer. This may also explain the finer near-surface resolution of the 200-7C transducer compared to the 38/200 Combi D transducer.

Considering sockeye smolt have a tendency to travel close to the surface (Figure 12), transducers with finer near-surface resolution such as the 200-7C and potentially the 38/200 Combi D are more appropriate than transducers with poor near-surface resolution such as the 200-28CM for use to estimate migrating sockeye smolt population abundance using an up-looking hydroacoustic method.

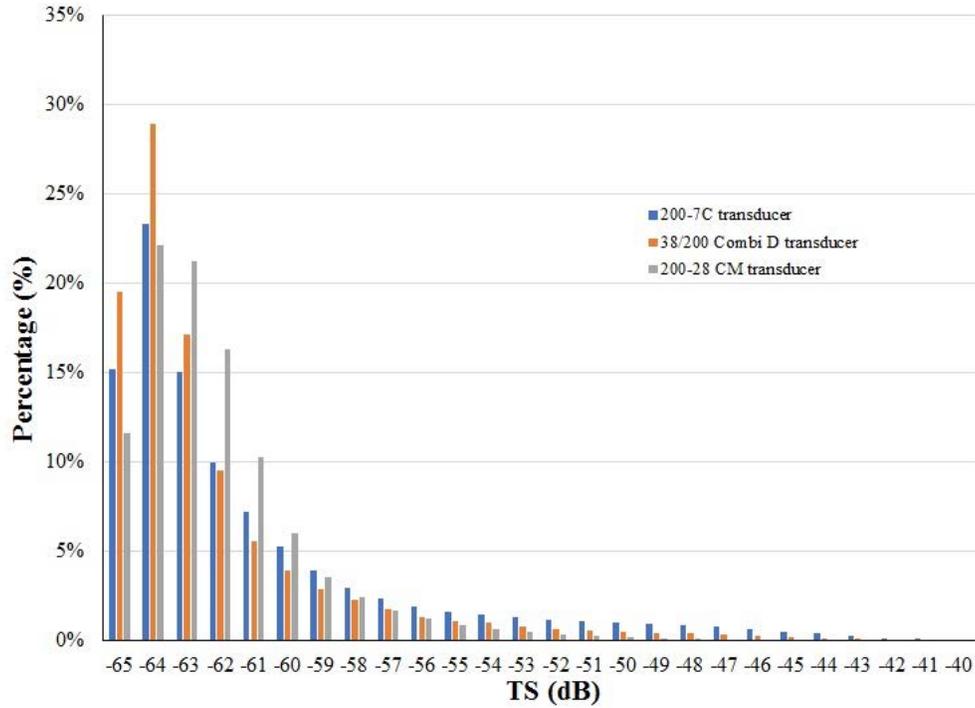


Figure 13. Single target (ST) target strength (TS) percentage frequency distribution for the 200-7C, 38/200 Combi D, and 200-28CM transducers.

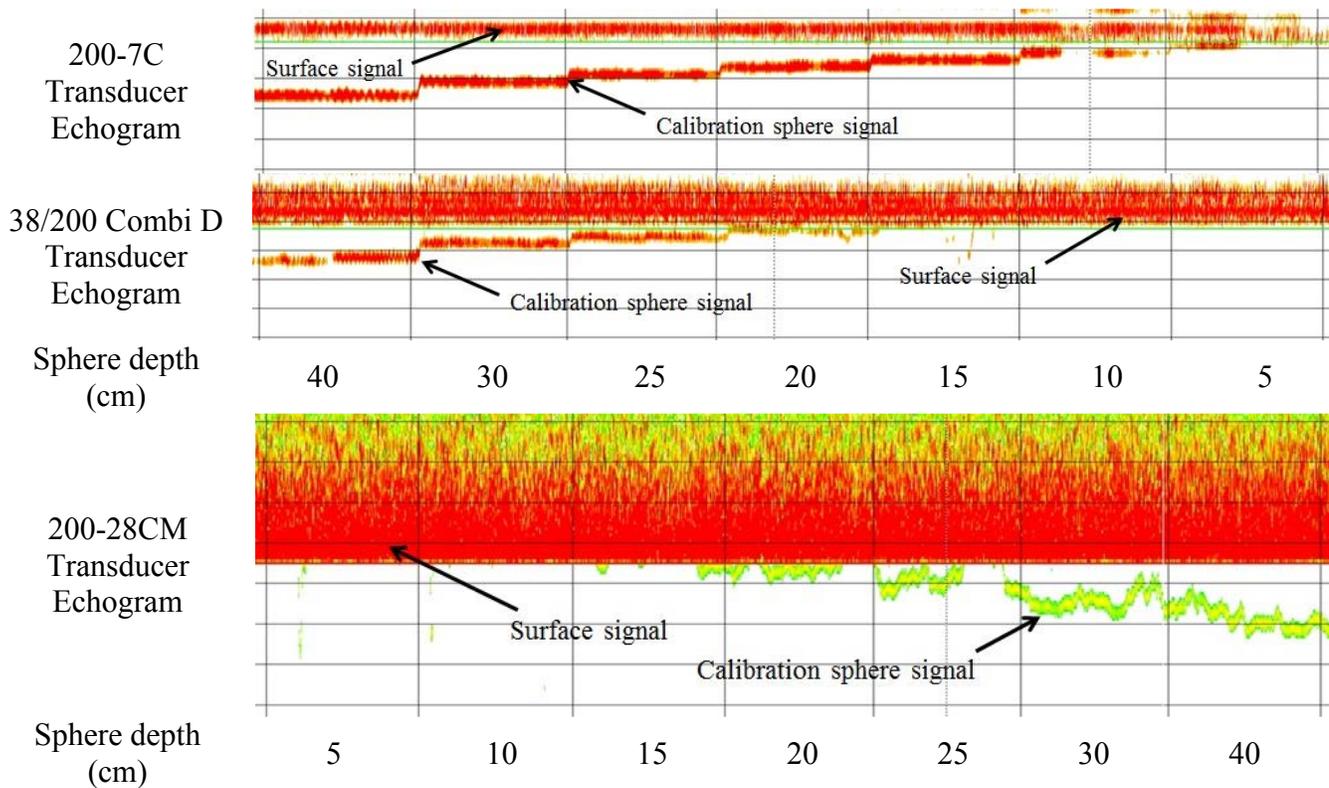


Figure 14. Acoustic results from the near-surface resolution test for the 200-7C, 38/200 Combi D, and 200-28CM transducers.

CONCLUSION

The specific goal of this project was to test two 200kHz Simrad EK15 echosounders and three different 200 kHz Simrad transducer models (200-7C, 38/200 Combi D, and 200-28CM) on the Babine River, at the outlet of Nilkitkwa Lake, while using the up-looking hydroacoustic technique successfully used on some rivers of the Bristol Bay area to estimate the seaward migrating sockeye smolt population abundance.

Acoustic data from migrating sockeye smolt were successfully collected using the three transducers tested on the Babine River in late May to early June 2015. The analysis of the data showed that the up-looking hydroacoustic system tested could detect the horizontal, vertical, and temporal distribution variation patterns of the migrating sockeye smolt which were consistent with observations made during the Bristol Bay area studies. The capacity of the up-looking hydroacoustic system to detect variations in the smolt migration abundance across vertical, lateral, and time strata would make it possible to generate daily and seasonal abundance estimates of migrating sockeye smolt at the outlet of Nilkitkwa Lake if more echosounders and transducers were used to provide an appropriate coverage of the cross-section of the Babine River. Although daily sockeye smolt population estimates were not calculated as part of this project, it appears the acoustic data collected in late May-early June 2015 correlated well with the daily sockeye smolt population estimates using mark-recapture. As M. Degan concluded (Appendix 1), the uplooking hydroacoustic method using Simrad EK15 echosounders is a potentially effective and financially viable method to provide estimates of sockeye smolt population abundance migrating through the outlet of Nilkitkwa Lake, which could be used as a precise index of the seasonal sockeye smolt migration population abundance.

Key recommendations for future project using the Simrad EK15 echosounders with up-looking transducers on the Babine River, at the outlet of Nilkitkwa Lake are as follows:

1. A minimum of 4 to 5 transducers and related echosounders would be needed to adequately sample the full width of the Babine River channel at the outlet of Nilkitkwa Lake so a reliable estimate of the migrating sockeye smolt abundance can be calculated.
2. Use good quality narrow (at most 7 degree beam) single beam transducers which have near-surface resolution of at most 10cm.
3. Use at least one narrow beam split beam echosounder/transducer system to help determine the single target TS, which is used to scale the hourly ABC provided by the acoustic equipment, to estimate the smolt flux at each transducer location.
4. Install the hydroacoustic gear in late April, before sockeye smolts begin their migration out of the Babine Lake Watershed and before the water levels increase significantly. This will allow for easier and more effective positioning of the transducers.

ACKNOWLEDGEMENTS

Funding for this project was provided by the Northern Fund of the Pacific Salmon Commission (PSC). The field work at the Babine smolt enumeration facility was carried out by Clifford Aslin, Carole Marlowe, Jonathan Williams, Jason Balczer, and Cassie Seibert, under the leadership of the author. Thanks are due to the Lake Babine Nation for permission to conduct field work on their traditional territory. Analysis of the data and report preparation were by Janvier Doire, with mapping by Gordon Wilson, and editing by Charmaine Carr-Harris, and Kyla Warren. Thanks to all!

REFERENCES

- Cox-Rogers, S., and B. Spilsted. 2012. Updated assessment of sockeye salmon production from Babine Lake, British Columbia. *Can. Tech. Rep. Fish. Aquat. Sci.* 2956, viii + 65p.
- Doire, J. 2015. 2014 Babine Lake Sockeye Smolt Enumeration – Hydroacoustic Feasibility. Skeena Fisheries Commission.
- Doire, J., and Macintyre, D. 2016. 2015 Babine Lake Watershed Sockeye Smolt Population Estimation Project – Mark-Recapture. Skeena Fisheries Commission.
- Hedgepeth, J.B., Gallucci, V.F., O’Sullivan, F., and Thorne, R.E. 1999. An expectation maximization and smoothing approach for indirect acoustic estimation of fish size and density. *ICES J. Mar. Sci.* 56: 36–50.
- Nemeth, M. J., J. T. Priest, D. J. Degan, K. A. Shippen, and M. R. Link. 2014. Sockeye salmon smolt abundance and inriver distribution: results from the Kvichak, Ugashik, and Egegik rivers in Bristol Bay, Alaska, 2014. Report prepared by LGL Alaska Research Associates, Inc., Anchorage, AK, and Aquacoustics, Inc., Sterling, AK, for the Bristol Bay Science and Research Institute, Dillingham, AK, 81 pp.
- Priest, J. T., M. J. Nemeth, J. W. Bures, D. J. Degan, and M. R. Link. 2015. Sockeye salmon smolt abundance and inriver distribution: results from the Kvichak, Ugashik, and Egegik rivers in Bristol Bay, Alaska, 2015. Report prepared by LGL Alaska Research Associates, Inc., Anchorage, AK, and Aquacoustics, Inc., Sterling, AK, for the Bristol Bay Science and Research Institute, Dillingham, AK, 90 pp.
- Simmonds, J. and MacLennan, J. *Fisheries Acoustics: Theory and Practices.* 2005. Blackwell Publishing.
- Wade, G. D., D. J. Degan, M. R. Link, and S. W. Raborn. 2010. Evaluation of an up-looking sonar system designed to enumerate sockeye salmon smolts on the Kvichak River, 2008. Report prepared by LGL Alaska Research Associates, Inc., Anchorage, AK, and Aquacoustics, Inc. Sterling, AK, for the Bristol Bay Science and Research Institute, Dillingham, AK, 45 p + Appendix.

APPENDIX I

Feasibility of using an up-looking hydroacoustic system (Simrad EK15 with 200-7C, 38/300 combi, and 200-28 degree transducers) at the outlet of Nilkitkwa Lake (Babine River) to estimate the out-migrating sockeye smolt population

I have reviewed hydroacoustic data collected by Janvier Doire during May-June 2015 as part of a smolt estimation using hydroacoustic equipment feasibility project. The data were collected on the Babine River, at the outlet of Nilkitkwa Lake, with two Simrad EK15 200 kHz echosounders, using three single beam transducers: a 200-7C (7 degree beam), a 38/200 Combi D (7 degree beam), and a 200-28 (28 degree beam). The data included surface resolution tests and calibration tests for each transducers, and a block of data collected at the proposed hydroacoustic smolt population estimation site from May 28 to June 9, 2015 with the three transducers. Calibration corrections were entered for all three transducers using data collected with a 36 mm tungsten carbide sphere.

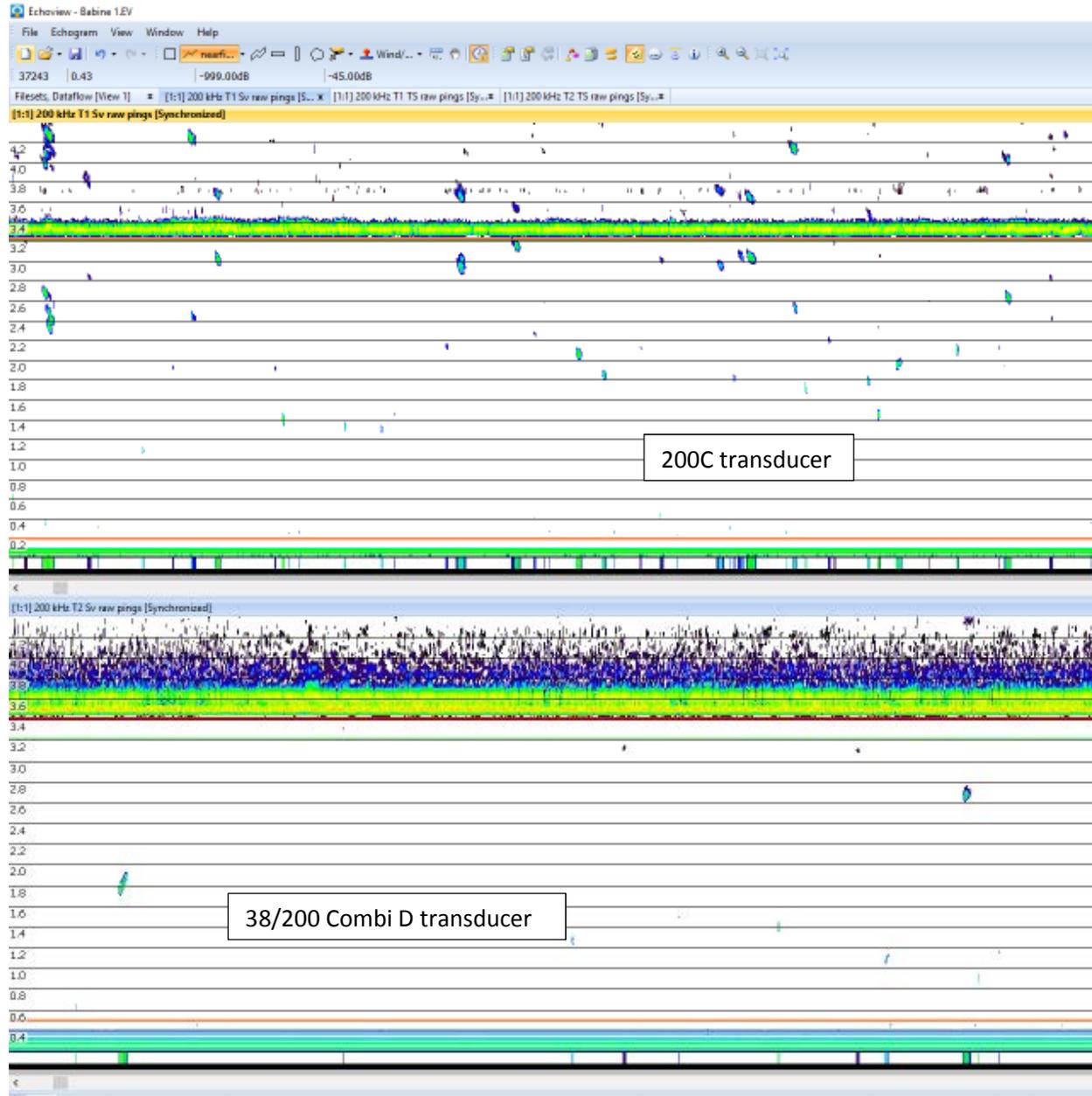
Transducer	Largest Observed	Expected at sample temp	Difference	Gain correction	New Ek60TransducerGain	TS after correction
200-7C	-36.7	-39.6	2.9	1.45	26.95	-39.6
38/200	-38.93	-39.6	0.67	0.33	25.13	-39.59
200-28CM	-38.34	-39.5	1.16	0.58	14.48	-39.5

The data were processed using Echoview, V 7. When processing the data, I used the speed of sound and absorption for freshwater at 10° C. Data were output by range from the transducer in 0.2-meter range strata and one-hour time periods. I removed noise caused by boat wakes passing the site and wind/rain events.

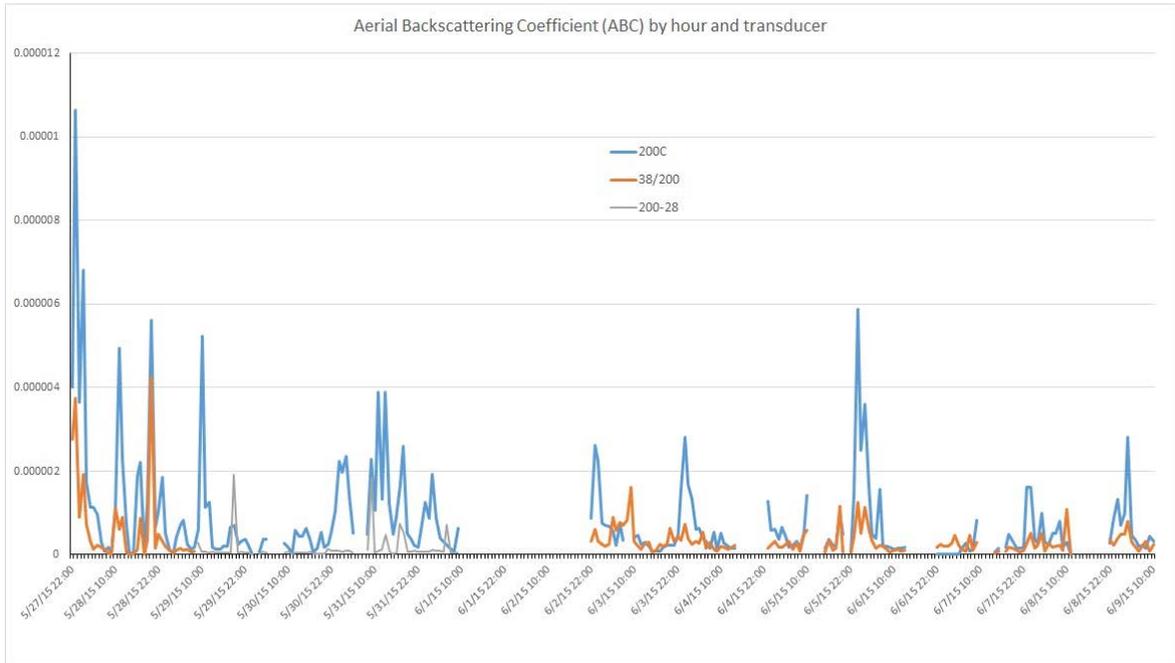
Transducer 200-7C had more wind/rain noise than the 38/200 Combi D or the 200-28 transducers, however, I am not sure this is due to the transducer calibration, or placement in the river. The system is near the outlet of the lake, and wind events could be likely driving micro-bubbles into the water column. Moving the system downstream further may alleviate this problem. The location of the 200-7C transducer relative to the thalweg may contribute to the elevated wind noise for this transducer, or it could be because it is more sensitive to micro-bubbles. There was no evidence of waves at the site from the echograms.



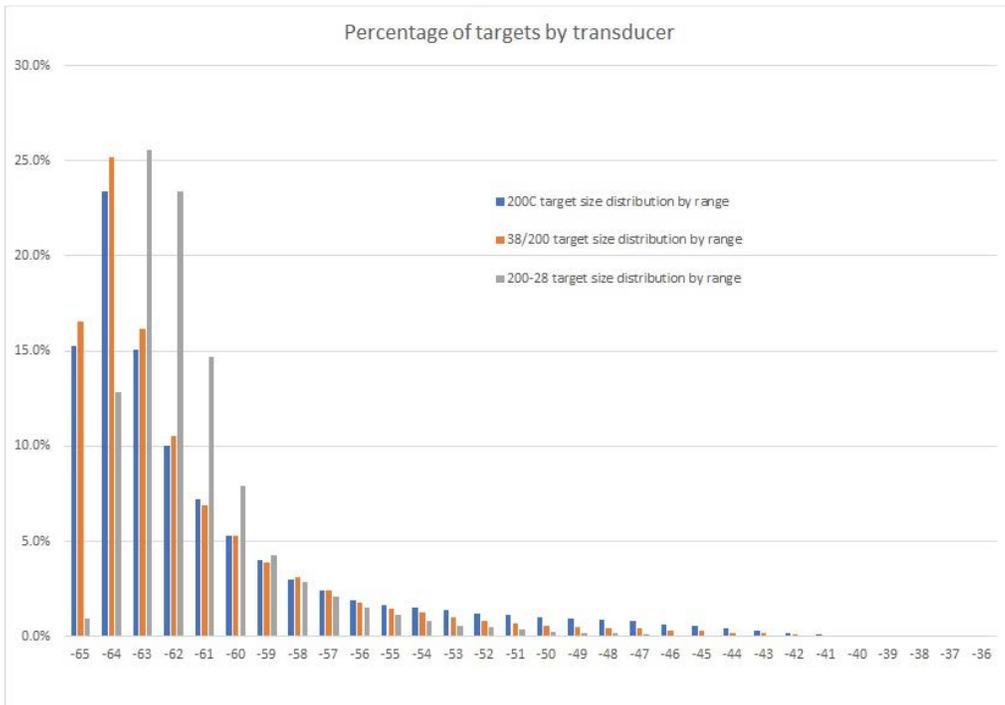
The 200-7C transducer provided better resolution as evidenced by the width of the surface reflection. It also had a shorter nearfield than the 38/200 Combi D transducer (less than 0.2 m vs. 0.5 m) where data could not be processed. The nearfield for the 200-28 CM was over 1 meter and the surface resolution was poor due to the 28° beam width.



The aerial backscattering coefficients (ABC), which can be scaled to calculate fish densities, appear to follow a similar pattern over time for all transducers. The unscaled density estimates indicate the 200-7C counted nearly 4 times the number of smolt as the 38/200 Combi D. The difference in density counts is likely due to location in the river. The 200-7C transducer was positioned at a location with higher water velocities, and generally, smolt out-migrate following the highest water velocities.



Looking at the TS distribution for single targets between the 3 transducers, it appears that there is a 1 dB difference in the TS mode. The 200-28 mode is -63 dB, compared to the 38/200 and 200C modes being -64 dB. I would expect the same TS mode for the 3 transducers as the systems are likely sampling the same targets, however the difference isn't concerning, and could be due to the small amount of data analysed for the 200-28 transducer.



The ABC can be converted to smolt counts by dividing by the mean sigma, based on the TS distribution using EMS deconvolution (by J. Hedgepeth) for each transducer individually and expanding for the water velocity at the transducer location.

The Simrad EK15 200-kHz system appears to be a viable hydroacoustic system for sampling sockeye salmon smolt in the Babine River at this site. Editing loss for the 200-7C was 20.6% and for the 38/200 was 15.4%. The 200-7C has a shorter nearfield making it better for sampling shallow areas. Single beam transducers (8-10° beam) from Airmar Technology have also proved to have good characteristics to sample smolt and may be a lower cost option to the 200-7C. The system should sample the river cross-section with 4-5 transducers spaced 7 to 10 meters apart. Areas shallower than 1 meter would not need sampling. A U-shaped river cross-section with the thalweg in the river center would provide the best estimates because the fish are not concentrated as they are in a river bend where the thalweg moves close to a river bank.

Donald Degan

A handwritten signature in black ink that reads "Donald J. Degan". The signature is written in a cursive style with a large initial 'D'.

Aquacoustics, Inc.