Comparison of Paper- and Electronic-Formatted Hydroacoustic Data Charts used for Salmon Enumeration on the Yukon River near Pilot Station

by
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Table of Contents:

Abstract:

The Yukon River Sonar Project estimates salmon passage through the river near Pilot Station, Alaska. The hydroacoustic data collected by the sonar is currently printed on paper charts in a series of grey marks called "traces." Technicians count traces that were generated by fish, and these numbers are used to calculate daily abundance estimates. New technology allows the hydroacoustic data to be presented on electronic charts viewed on a computer. The electronic charts also present the data in a series of grey marks, and fish traces must be identified manually by technicians. However, the electronic charts present the data in greater detail, and settings that are used to optimize the visibility of fish traces are more easily adjusted. Both of these features may improve fish detection, which would result in more accurate estimates. Project leaders are planning to make a complete switchover from paper to electronic charts. The principle aim of this study was to compare the fish counts produced by the paper and electronic formats in order to expose any biases and explain why they occur. Due to variation in the slope of the river bottom, the area of river covered by the sonar is divided into several horizontal strata by distance from the transducer. Due to the properties of sound and the variation in the shape of fish traces at different ranges, it is possible that the level and direction of bias may differ among strata. A sample of 150 electronic files, out of approximately 1,700, from the 2008 season was selected for this comparison. Files were counted using Echotastic, a program written by AYK Regional Sonar Biologist, Carl Pfisterer. The electronic chart counts were higher than the paper chart counts for strata one through four, while the electronic counts were lower than the paper counts for stratum five (linear regression output: stratum one: slope=1.112, y-intercept=44.662, stratum two: slope=1.344, y-intercept=13.615, stratum three: slope=1.098, y-intercept=-7.052, stratum four: slope=1.077, y-intercept=-8.566, stratum five: slope=0.827, y-intercept=-0.688). Both the

positive and negative biases are likely a result of improved fish detection on the electronic charts and a high level of subjectivity associated with counting fish using sonar. If project leaders conclude that these biases are acceptable, a transition from paper to electronic charts would be advantageous, although correcting for differences will be necessary to make past and future fish estimates comparable.

Introduction:

The Yukon River Sonar Project estimates fish passage through the river near Pilot Station, Alaska. The project targets the runs of Chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*Oncorhynchus keta*), and coho salmon (*Oncorhynchus kisutch*), and has aided in fishery management decisions since 1986 (Carroll and McIntosh 2007). At the Yukon River Sonar Project, the sonar equipment transmits an acoustic signal that is used to detect objects and determine their location in the water column. The hydroacoustic data collected by the sonar equipment is printed on paper charts in a series of grey marks of varying shades, called "traces." Technicians examine these charts, determine which traces were generated by fish, and record the numbers. These numbers are entered into a database and run through a statistical package, which produces an estimate of fish abundance. A new upgrade to the sonar software allows the hydroacoustic data to be saved in digital files, and newly developed programs allow the data to be presented on electronic charts, viewed on a computer. The electronic charts are similar to the paper charts in that they present the same set of data in a series of grey marks, and fish traces must be identified manually by technicians. However, the electronic charts have the ability to present the data in greater detail, and settings that are used to optimize the visibility of fish traces are more easily adjusted, both of which may improve fish detection.

There are many potential advantages to using electronic charts over paper charts. Due to the improved fish detection, it is possible that the electronic charts may allow for more accurate enumeration of fish at Yukon River Sonar. With the current system, printer jams occur often, which results in lost data. This problem would be eliminated with the electronic charts. The equipment currently used with the paper chart system is outdated, and replacement parts may not be available in the future. The electronic chart system has smaller components that are more

5

easily transported in the field, and overall is more user-friendly. Also, the current paper chart system requires large quantities of paper, and it would be preferable to minimize this use. For these reasons, project leaders are planning to make a complete switchover from paper to electronic charts. The principle aim of this study was to compare the fish counts of the paper and electronic charts in order to assess any biases that exist. Exposing the biases and understanding why they occur may help project leaders validate the decision to make the transition between these two systems of data collection, and make past and future data comparable for monitoring purposes.

At Yukon River Sonar, it is assumed that 95% of the fish that swim through the river are bank-oriented, and therefore, the sonar does not cover the middle section of the river (H. Carroll, personal communication). Also, it is assumed that the river bottom forms a linear profile, which is often not the case (H. Carroll, personal communication). Depressions or bumps in the river bottom may allow fish to pass, undetected by the sonar. In addition, human error may result in missed fish traces on the charts. For these reasons, it is possible that there is a negative bias associated with fish enumeration at Yukon River Sonar. Project leaders accept this potential underestimation because with fisheries management, it is often better to be conservative; however, greater accuracy would be preferable. Since there is likely greater fish detection on the electronic charts, I hypothesized that there would be a positive bias associated with the electronic chart counts as compared to the paper chart counts. If this is the case, the counts obtained using the electronic charts may be closer to the actual fish numbers, thus it would be preferable to use the electronic format in future seasons.

Due to variation in the slope of the river bottom, the section of river covered by the sonar is divided into several horizontal strata by distance from the transducer. Due to the properties of

sound and the variation in the shape of fish traces at different ranges, it is possible that the level and even direction of bias may vary among strata. For example, sound attenuates over distance; therefore, fish traces on the charts generated for the offshore strata are often less clear than those on charts generated for the nearshore strata. In addition, the length of fish traces tends to increase with increasing range. On charts generated for the offshore strata, it can often be difficult to judge whether exceptionally long traces were generated by a single fish or multiple fish. Also, when fish passage rates are high, long traces that cross one another can be difficult to separate. Comparing the paper and electronic chart counts for each stratum will provide project leaders with a more detailed assessment of where biases are occurring, and for what reasons.

Methods:

Yukon River Sonar Overview / Fish Counting Theory

Yukon River Sonar runs from the beginning of June through the first week of September. This project currently uses HTI (Hydroacoustic Technologies Inc.) split beam sonar to collect hydroacoustic data. The sonar runs during three periods per day, for three hours each. Two three-hour periods of test fishing with drift gill nets of six mesh sizes are used to sample all species present. The proportions of each species caught are applied to the number of fish targets counted on the sonar. The counts from the three sonar periods are expanded out for a 24-hour period to create a daily fish abundance estimate for each species (e.g., Carroll and McIntosh 2007).

The main components of the current sonar system at Yukon River Sonar include a transducer, two rotators, sounder, computer, and printer. The transducer is mounted to two rotators that control its horizontal and vertical angles. These components are mounted to a tripod positioned slightly offshore in the water column. Cables connect the transducer and rotators to

the control equipment that is housed in a tent. There are two of these systems at Yukon River Sonar, one on each bank of the river. The river banks are termed "right bank" and "left bank" according to their position when facing downstream.

A simplified explanation of how sonar works is as follows: Electricity is sent from the sounder to the transducer, where it is converted to sound and sent out into the water column in a cone-shaped beam. These sound waves are sent out in pulses at regular intervals, called "pings." At Yukon River Sonar, the pulse rate ranges from 2.5 pings per second to 8 pings per second. When a ping hits an object, such as the river bottom, a fish, or a log, it bounces back and is received by the transducer. These data travel back to the sounder for processing and are then sent to the computer for storage. Lastly, the data are sent to the printer, which prints the information on a paper chart. The electronic system is an identical set-up, except the printer unit is replaced by a computer with the electronic chart program. Each ping that is received by the transducer is printed on the chart as a dot. Multiple pings generated by a single object show up as a grouping of dots, called a "trace." The location of the trace on the chart corresponds to the distance that the object was from the transducer, i.e., range, and the length of the trace corresponds to the time the object entered and exited the sonar beam.

For accurate fish detection, the sonar beam must cover the river bottom and water column; however, the slope of a river bottom can be quite variable. Oftentimes, the bottom slope is more gradual near shore, and then drops off at a point where water velocities increase. For this reason, the region of data collection on each bank is divided into several horizontal strata (Figure 1). This allows the beam to be projected at multiple angles, which maximizes the area of river covered by the sonar. For example, on right bank, data are collected from two strata. Stratum one ranges from 0 to 50 meters and the transducer is tilted down at a greater angle to better cover the

nearshore region. Stratum two ranges from 50 to 100 meters, and the transducer is tilted up, to better match the slope of the offshore region. Due to high silt deposition and erosion, river bottom profiles can change significantly in a relatively short period of time – weeks, or even days. For this reason, the strata ranges were adjusted seven times on right bank and three times on left bank over the course of the summer. For example, at the beginning of the summer, stratum one ranged from 0 to 50 meters, but due to changes in the slope of the river, the range was adjusted to 0 to 40 meters later in the season.
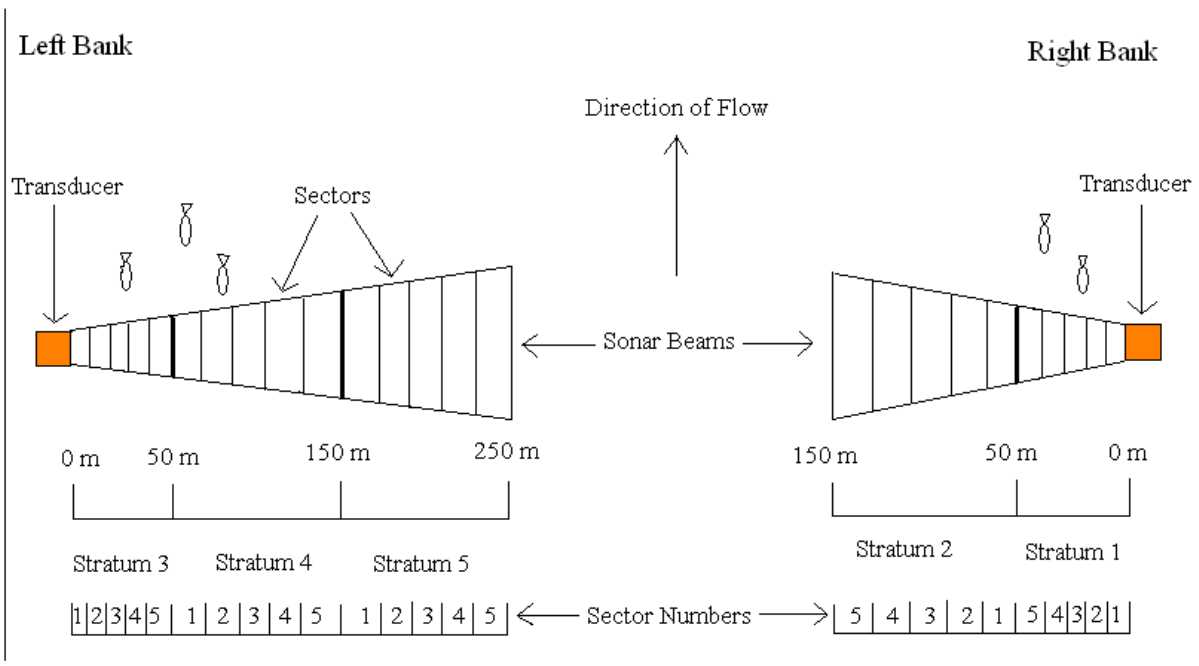

Figure 1. Illustration of the relationships between banks, strata, sectors and approximate sonar ranges (not drawn to scale).

Paper charts (Figure 2) are printed continuously throughout the three-hour sonar period. Data collection rotates between strata every half hour. On right bank, data collection alternates between strata one and two, resulting in 1.5 hours of data per strata, and on left bank, data

collection rotates between strata three, four, and five, resulting in 1 hour of data per strata. Both the paper and electronic charts are organized with range on the x-axis and time on the y-axis. On the paper charts, the range is divided into five equal sectors. Technicians count the number of fish in each sector, marking each trace with a highlighter, and tally their counts in two 15-minute sections. These numbers are then recorded on data sheets and manually entered into the main database. In addition to simplifying the counting process, tallying the counts by sector allows biologists to calculate with greater specificity the range at which fish are passing through the river. Both the paper and electronic charts display information on a grey scale. On the paper charts, objects that are detected by the sonar appear as black ink on a white paper.

For this study, electronic files were counted using Echotastic, a program written by AYK Regional Sonar Biologist, Carl Pfisterer (Figure 3). The electronic files are approximately 30 minutes long, corresponding to each change in stratum. With Echotastic, a mouse click places a small square marker on the chart, which is used to indicate a fish trace. The total number of marks for each electronic file is recorded automatically in a corresponding text file. The counts in the text files are automatically transferred to the main database. Echotastic does not divide the range into sectors. Instead, the exact range of each mark is recorded in the text file, which allows biologists to assess the range at which fish are passing through the river with high specificity. The exact time of each mark is recorded in the text file as well. Echotastic can present the data as a black-on-white or a white-on-black image. For this study, the white-on-black option was selected.
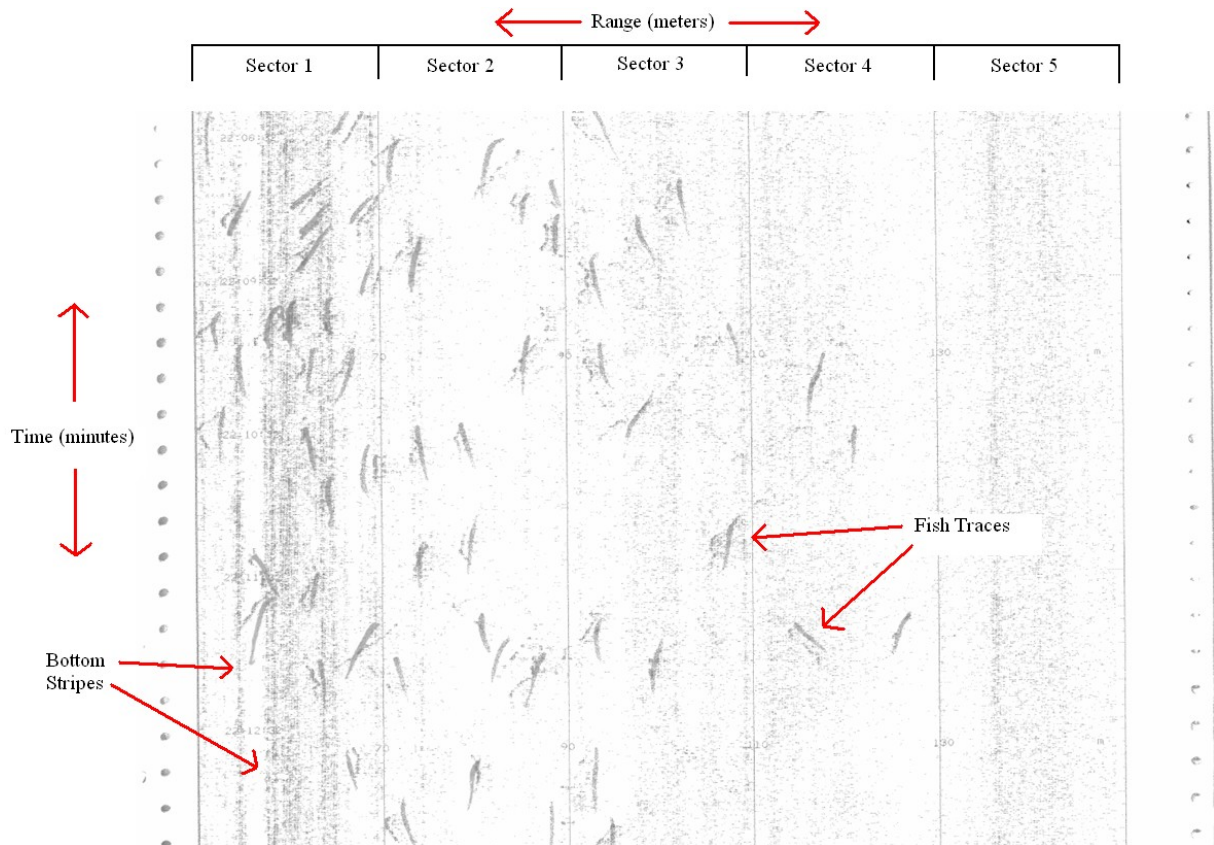
Figure 2. A five-minute section of a paper chart printed during the 2008 field season. The range is divided into five equal sectors. Features on the river bottom appear as continuous dark stripes. Fish appear as short, irregular dark traces.
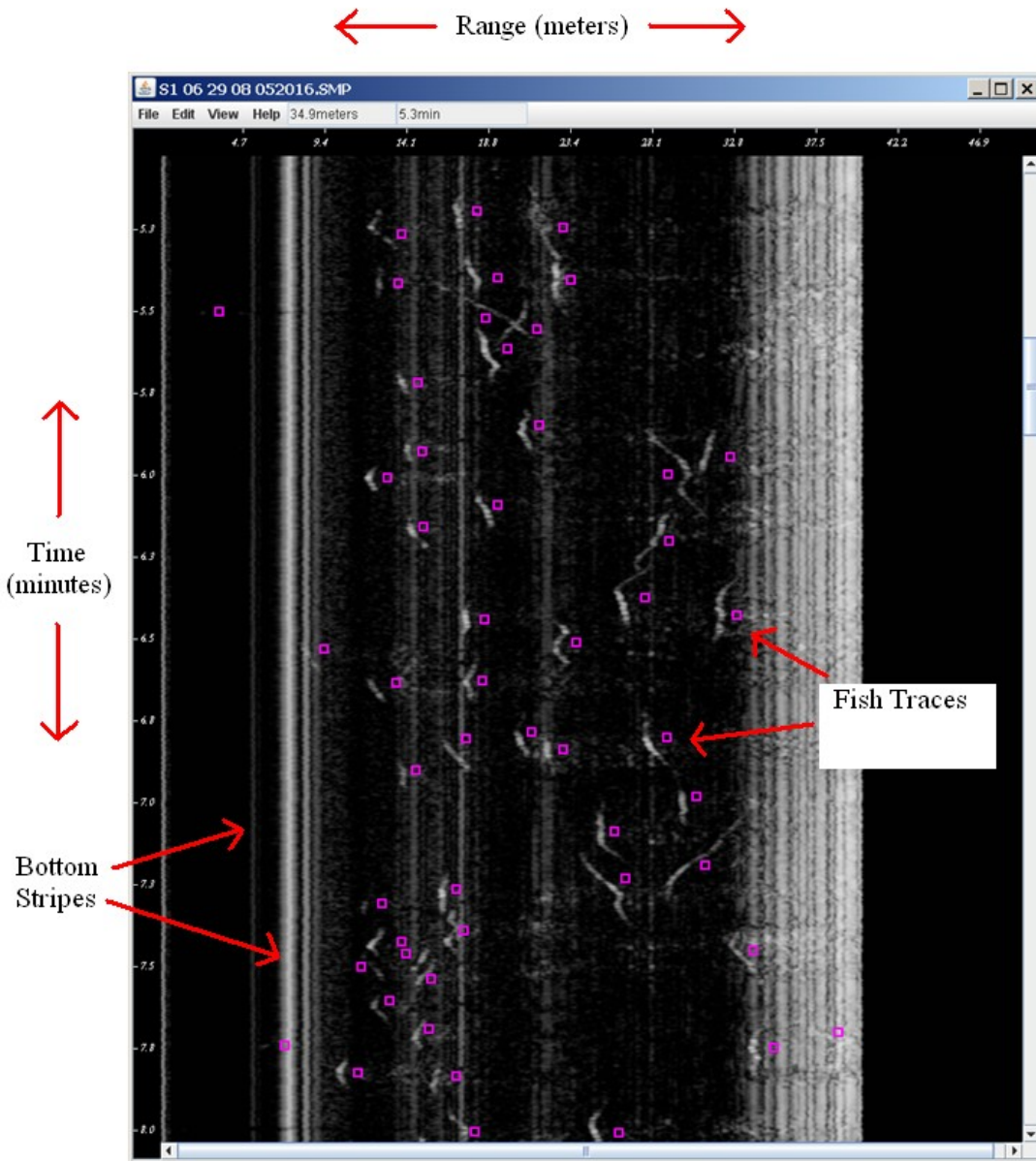
Figure 3. A three-minute section of an electronic chart configured by the Echotastic program. Echotastic does not divide the range into sectors. Features on the river bottom appear as continuous light stripes. Fish appear as short, irregular light traces.

The transducer receives sound that bounces back from all objects, not just fish, including suspended sediment, logs, and boats. This return sound is called an echo. The size of an echo is described by a number called "target strength," and varies depending on volume and the material of which the object is composed (Simmonds and MacLennan 2005). For example, large, solid

objects such as rocks have greater target strengths than smaller, soft objects such as leaves. Most fish have gas-filled organs called swimbladders, which have a high ability to reflect sound due to the large difference in density between the gas and the water medium (Simmonds and MacLennan 2005). This is what gives fish relatively high target strength and why sonar is such an effective method for detection.

Threshold levels are used to differentiate between echoes of varying magnitude and their corresponding target strengths. The printer currently used at Yukon River Sonar has four threshold levels. Each threshold level corresponds to a certain target strength, which corresponds to one of four different grey levels. Depending on the target strength, it will fall above or below one of the four thresholds, and be printed at the corresponding grey level on the paper charts.

Background noise is unwanted sound that is generated by a source other than the transducer, such as wind, waves, and boat motors (Urick 1983). Background noise can be constant, and appears as a grey cloud on charts, making fish traces less noticeable. Threshold levels can be adjusted so that the sound generated by small non-target objects is filtered out. In this way, the grey clouds caused by background noise are reduced, making fish traces more distinct on charts. Continually adjusting the threshold levels higher increases the contrast between fish traces and background noise, although this may result in an overall loss of detail on charts. With the printer system, the threshold settings can only be adjusted before data collection starts and can not be changed once charts have been printed.

The Echotastic program does not permanently threshold out background noise. All of the information is available in each file, and the threshold settings can be adjusted continuously, including after the file has been processed. In this way, the visibility of fish traces can be optimized for each file, according to changes in background noise and environmental conditions.

Also, Echotastic has 256 threshold levels that allow for a more detailed representation of varying signal strengths (C. Pfisterer, personal communication). Both the increased detail and the ability to adjust thresholds according to changes in environmental conditions may result in a positive bias associated with the electronic chart counts.

Each object detected by the sonar produces a unique trace on the charts, and it is the technician's job to distinguish fish traces from those of other objects. Most charts contain several continuous vertical lines, or "bottom stripes." These traces are continuous because they are generated by fixed objects on the river bottom. Fish behavior helps distinguish a fish trace from those of other objects. Fish often do not swim in a straight line but may meander toward or away from shore. A change in the distance between the fish and the transducer as it passes through the sonar beam translates to a curved trace on the charts. Traces at greater ranges that form a mostly-straight line may be logs or debris passing downstream through the sonar beam, and not a fish, since it is unlikely for a fish to maintain the exact same range for a long period of time. Traces that are generated by boats often appear as wide grey clouds, and are easy to distinguish from fish traces.

Fish closer to the transducer pass through a narrower section of the cone-shaped beam, and therefore have a narrower time window during which they will be hit by pings. The speed at which the fish are swimming also determines how many pings with which they are hit. The number of pings that hit a fish and bounce back to the transducer translates to the length of the fish trace on the charts. In general, a fast-swimming fish at close range would result in a short trace on the charts, and vice versa. Extremely short traces that are composed of just a few grouped pings can often be difficult to judge. On the paper charts, one line of ink corresponds to one ping. At Yukon River Sonar, if the trace contains fewer than three lines, it is not counted as a

fish. Occasionally, two identical fish traces appear side by side on a chart. This effect is called backscatter or "mirroring" and is produced when the sound travels through the object and then bounces off the bottom or water surface before returning to the transducer. Since it is unlikely that two fish would swim in the exact same pattern, these traces are counted as a single fish.

High fish passage rates in the river result in a higher concentration of fish traces on the charts. At greater ranges, longer fish traces may cross each other, making the traces difficult to separate. Under these circumstances, technicians may tend to undercount. When fish passage rates are extremely low, technicians tend to "search" for traces, which may lead to overcounting. There is a high level of subjectivity associated with counting fish using sonar, and some technicians tend to count more traces than others. At Yukon River Sonar, it is assumed that over the course of the summer, the undercounting and overcounting likely cancel one another, and therefore, the small biases associated with fish passage rate and operator to operator differences are negligible.

Details of this Study:

Both paper charts and electronic files were collected throughout the 2008 summer sampling season. The paper charts were counted by 10 technicians during normal operation. A sample of electronic files was chosen for this comparison, and counted by the author. Electronic files were selected every third day throughout the summer, starting with June 11th, and ending with September 6th. Due to scheduling, some technicians always worked a specific sonar period. In order to minimize operator to operator bias, the sonar period from which the files were chosen was selected randomly. All 10 technicians were represented in the sample of electronic files. Operator to operator differences should be reflected as random "noise" in the data. On right bank, three 30-minute files were produced per stratum during each three-hour period, and on left

bank, two 30-minute files were produced per stratum. The first of these files was selected for sampling unless an error in data collection produced an incomplete file, then the second or third was chosen. Thirty files were counted per stratum, for a total of 150 files, out of approximately 1,700.

It was assumed that the author's bias, either negative or positive, was consistent for this study. This was a "blind" study in the sense that the author did not know how many fish were counted on the paper charts while counting the electronic charts. However, the author had previous experience counting fish using split beam sonar and worked with the Yukon River Sonar Project during the 2008 field season.

In general, the optimal threshold settings were similar amongst files of a single stratum. In a few instances, different optimal thresholds were apparent for the nearshore and offshore sections of a file. For the most part, all the files from a single stratum were counted consecutively to avoid repeated change of the threshold settings.

For 66 electronic files, the total time did not correspond precisely with the paper charts. In some instances, 31 minutes of paper charts were counted, whereas only 30 minutes of data were recorded in the corresponding electronic file. In other instances, printer jams resulted in several minutes of lost data on the paper charts. In order to make the counts of each format directly comparable, the rate of fish traces per hour was calculated and used for the analysis. The electronic and paper chart ranges did not correspond exactly in 37 instances. For example, on some paper charts, the range was 0 to 40 meters, whereas the electronic files ranged from 0 to 50 meters. When this occurred, the data recorded for each fish trace in the text files was sorted, and traces that were marked in the non-corresponding range (in this case, those marked between 40

and 50 meters) were removed from the counts. This adjustment also made it possible for the counts of each format to be directly compared.

The number of electronic traces per hour was plotted against the number of paper traces per hour for each stratum. The counts from the paper and electronic charts were compared for each stratum using a linear regression analysis on Microsoft® Excel. One outlier was observed in stratum four, likely resulting from a combination of poor environmental conditions when the file was recorded and operator error involving the threshold settings with the electronic file. This datum was removed for the analysis.

Results:

The paper chart counts and electronic chart counts closely corresponded for strata one through four (stratum one: $R^2=0.986$, $p<0.001$, stratum two: $R^2=0.950$, $p<0.001$, stratum three: $R^2=0.928$, $p<0.001$, stratum four: $R^2=0.950$, $p<0.001$; Figures 4, 5, 6 and 7). The correspondence between counts was the most variable for stratum five ($R^2=0.813$, $p<0.001$; Figure 8). The electronic chart counts were higher than the paper chart counts for strata one through four (linear regression output: stratum one: slope=1.112, y-intercept=44.662, stratum two: slope=1.344, y-intercept=13.615, stratum three: slope=1.098, y-intercept=-7.052, stratum four: slope=1.077, y-intercept=-8.566, stratum five: slope=0.827, y-intercept=-0.688). The electronic chart counts were lower than the paper chart counts for stratum five (linear regression output: stratum five: slope=0.827, y-intercept=-0.688).
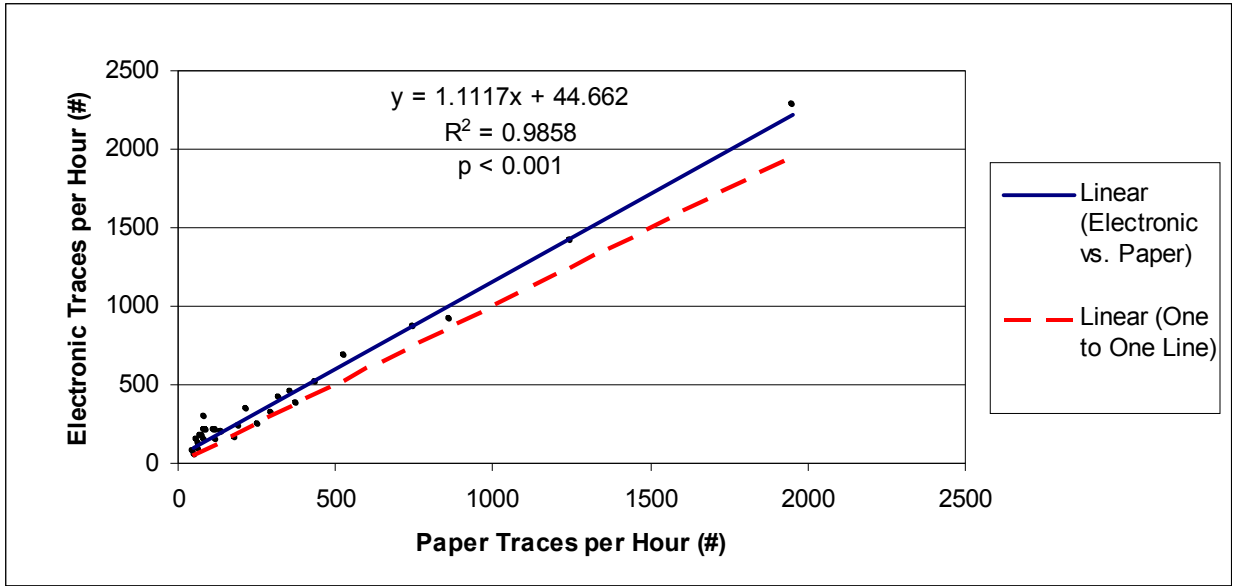
Figure 4. Relationship between electronic and paper chart counts for stratum one. The linear regression indicates that the electronic chart counts were higher than the paper chart counts for this stratum.

Figure 5. Relationship between electronic and paper chart counts for stratum two. The linear regression indicates that the electronic chart counts were higher than the paper chart counts for this stratum.

Figure 6. Relationship between electronic and paper chart counts for stratum three. The linear regression indicates that the electronic chart counts were higher than the paper chart counts for this stratum.
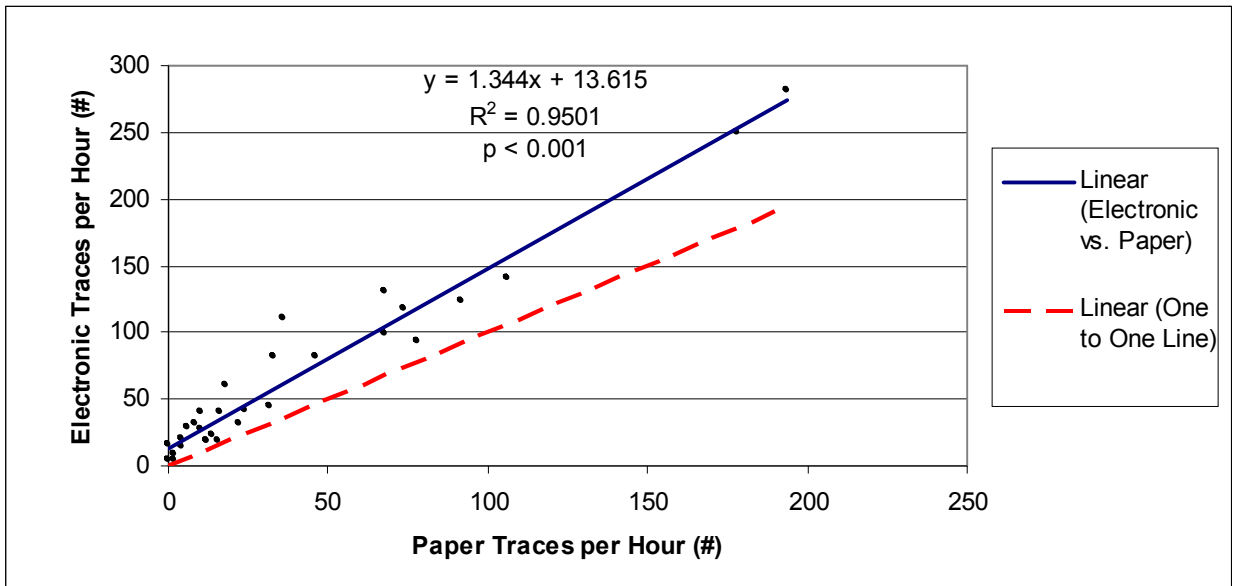

Figure 7. Relationship between electronic and paper chart counts for stratum four. The linear regression indicates that the electronic chart counts were higher than the paper chart counts for this stratum.
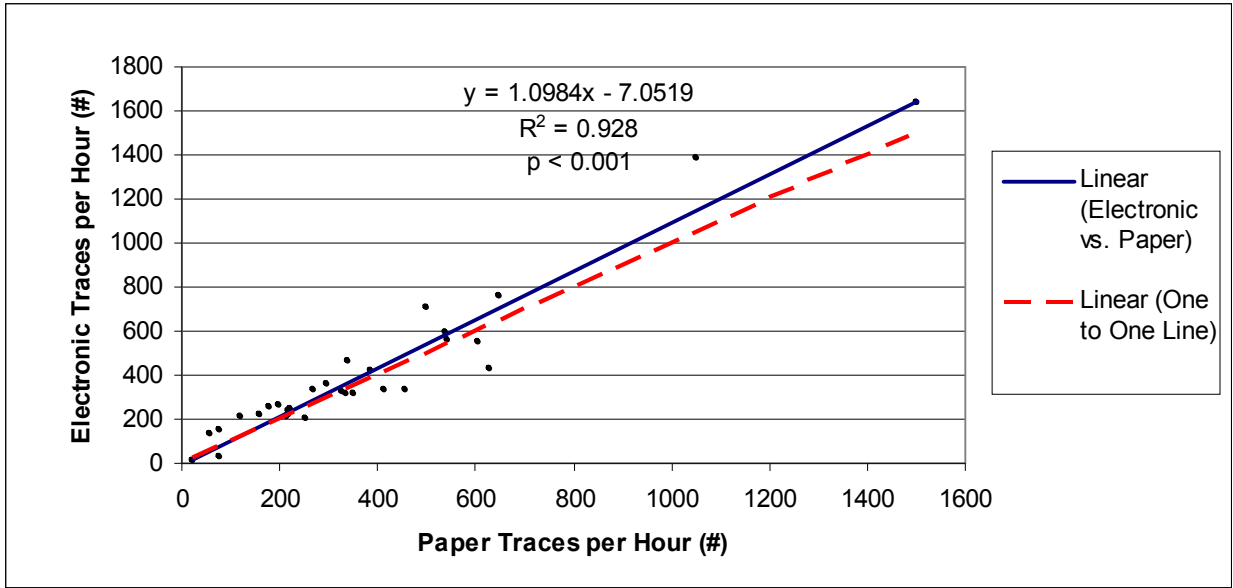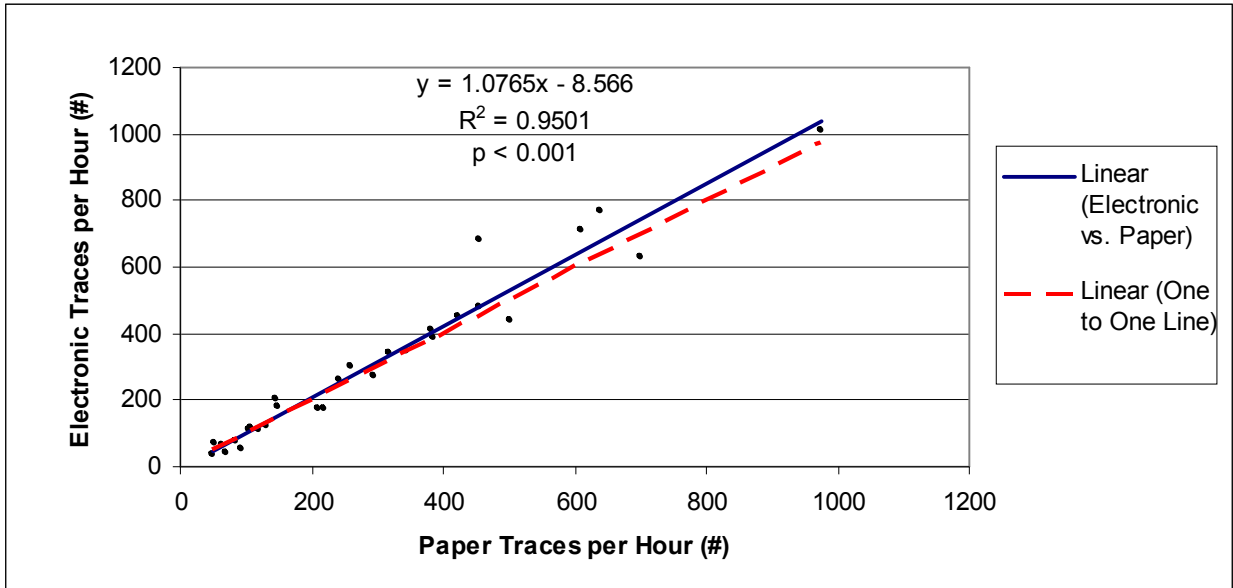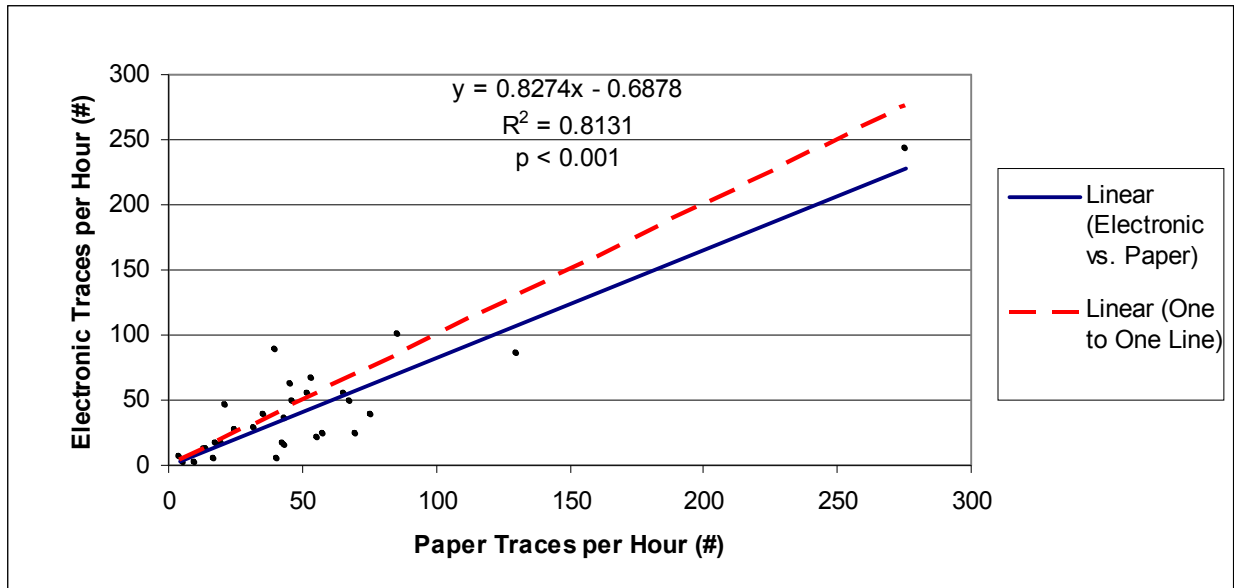
Figure 8. Relationship between electronic and paper chart counts for stratum five. The linear regression indicates that the electronic chart counts were lower than the paper chart counts for this stratum.

Discussion:

Results indicate that there are differences in biases associated with counting fish using the electronic format versus the paper format. Electronic chart counts were, in general, greater than paper chart counts for all strata, with the exception of stratum five. The two primary factors that likely resulted in this discrepancy were the thresholding capabilities of each system (the ability to represent varying target strengths in a range of grey levels on charts), and operator bias. The printer has just four threshold levels; therefore, each return signal can only be presented as one of four grey levels. Since Echotastic has 256 threshold levels, the return signals can be presented in a greater range of grey levels, which likely creates a more detailed image, making fish traces more detectable (e.g., Figures 11a and 11b). Also, the printer thresholds were adjusted a few times over the course of the summer, whereas the threshold settings on Echotastic could be adjusted for each file as the conditions changed to eliminate background noise and make fish traces more noticeable. It was also observed that the thresholds on the majority of the electronic

charts were adjusted lower to eliminate less background noise than on the paper charts. In many instances, adjusting the threshold levels higher increases the contrast between background noise and fish traces, making fish traces stand out more. However, this also decreases the overall detail of information presented. It is possible that with the electronic charts, adjusting the thresholds lower and allowing more information to be presented, rather than increasing the contrast, made traces more detectable, and therefore, may have resulted in higher electronic counts.

Operator bias is another factor that may have contributed to the discrepancy between the electronic chart counts and the paper chart counts for strata one through four. The author was not timed while counting the electronic charts, but in the field, technicians had approximately three and a half hours to count three hours of paper charts. It is possible that more time was spent examining the electronic charts, which may have increased fish detection. Also, counting fish using sonar is largely subjective. For strata one through four, the author may have marked more traces as fish than the other technicians.

Stratum five was the only case in which the electronic charts counts were lower than the paper chart counts. Thresholding and operator bias may contribute to this discrepancy as well. Since stratum five covers the most distant range of all strata, it generally takes fish a longer period of time to pass through the sonar beam, which translates to longer traces on the charts. Because sound attenuates with distance, signals that return from stratum five are generally weaker than those returning from other strata, and this translates to overall lighter traces on the charts. Depending on the orientation of the fish and the section of the sonar beam through which it is passing, the target strength may vary over the time that the fish is swimming through the beam. On the charts, this usually translates to a trace that has lighter grey sections, or even gaps. It is often difficult to discern whether the trace was generated by a single fish, or by multiple

fish. Because Echotastic is able to produce a more detailed image, in many instances, the gaps in long fish traces were filled in. Also, as previously mentioned, it was observed that the thresholds on the electronic charts were adjusted lower to reduce contrast and allow more information to be presented. This also may have resulted in fewer gaps, and, in many instances, what appeared to be several fish on the paper chart, appeared as a single fish on the electronic chart (e.g., Figures 12a and 12b).

Operator bias may also be a reason for the lower electronic counts observed for stratum five. It is possible that the author detected fewer traces than the other technicians in this particular stratum. Also, the lighter, longer traces observed in stratum five may result in increased subjectivity associated with counting fish, potentially why the correspondence was more variable between the counts for this stratum.

The rate of salmon passage through the Yukon River is not always steady throughout the summer. Salmon often return to the river in pulses, resulting in a wide range of counts on charts. For example, the electronic chart counts for stratum three ranged from 6 fish per hour on June11[th] to 1,634 fish per hour on July 8th. For all strata, one or two files were selected from days with exceptionally high fish passage rates, and these data points strongly influence the relationships generated by the linear regression analyses. This is especially important to note for stratum five, given the variable correspondence, and the relationship observed may change substantially with the removal of a single data point.

If project leaders conclude that the counts produced by the electronic charts are more accurate than those produced by the paper charts, it may be possible to make the switchover without adjusting the project's statistical package to correct for biases. However, the estimates obtained in future seasons once the electronic format is implemented can not be directly

compared to past estimates without first correcting for these differences. In addition to considering the biases, it will be important for project leaders to weigh the advantages and disadvantages of the electronic system before making the switchover. As previously mentioned, some of the advantages include the ability to more accurately estimate fish abundance, eliminate out-dated, bulky equipment, minimize the use of paper, and eliminate data lost to printer jams. Several features also make the electronic system more user-friendly, such as the ability to change the threshold settings at any time. With the paper charts, a permanent record is left of what was collected at a specific setting. With the electronic system, project leaders can go back and change the settings to see if any fish targets were missed. The electronic system also allows automatic recording of fish counts into the project database, eliminating transcription errors. At the beginning of the field season and periodically throughout the summer, project leaders must aim the sonar beam to provide the best coverage of the river bottom and water column. These aiming procedures may be more difficult with the electronic system. Another drawback of the electronic format is that more expensive equipment may be needed to store a large quantity of data. It is likely that the advantages of the electronic format outweigh the disadvantages, making it the preferable format.

For future studies, it would be useful to have all technicians count a sample of corresponding paper and electronic files during the normal operating season. This may be an insightful comparison to see if the biases observed in this study were primarily due to the enhanced capabilities of the electronic system to present the data, or due to the author's biases. Future analyses may also examine differences in bias related to the rate of fish passage in the river, and different environmental conditions. It is likely that technicians alter their counting methods depending on the density of fish traces on the charts. Also, changes in environmental

conditions, such as silt content and wave size, may affect the visibility of fish traces, which could also lead to differences in bias. Each of these studies would serve to further explain any sources of bias associated with the electronic chart format as compared to the paper chart format. Salmon enumeration on the Yukon River is a daunting task, but fish counting methods continue to evolve. By testing and incorporating new ideas and technology, it is hoped that the Yukon River Sonar Project will be able to produce ever more accurate estimates of salmon abundance to better manage this valuable resource.

Figure 11a. Example of a stratum one paper chart highlighting discrepancies between the paper and electronic counts. Traces circled in blue were marked on both the paper and electronic charts. Traces circled in red were marked on the electronic chart, but not the paper chart.

Figure 11b. Example of a stratum one electronic chart highlighting discrepancies between the paper and electronic counts. Traces circled in blue were marked on both the paper and electronic charts. Traces circled in red were marked on the electronic chart, but not the paper chart.
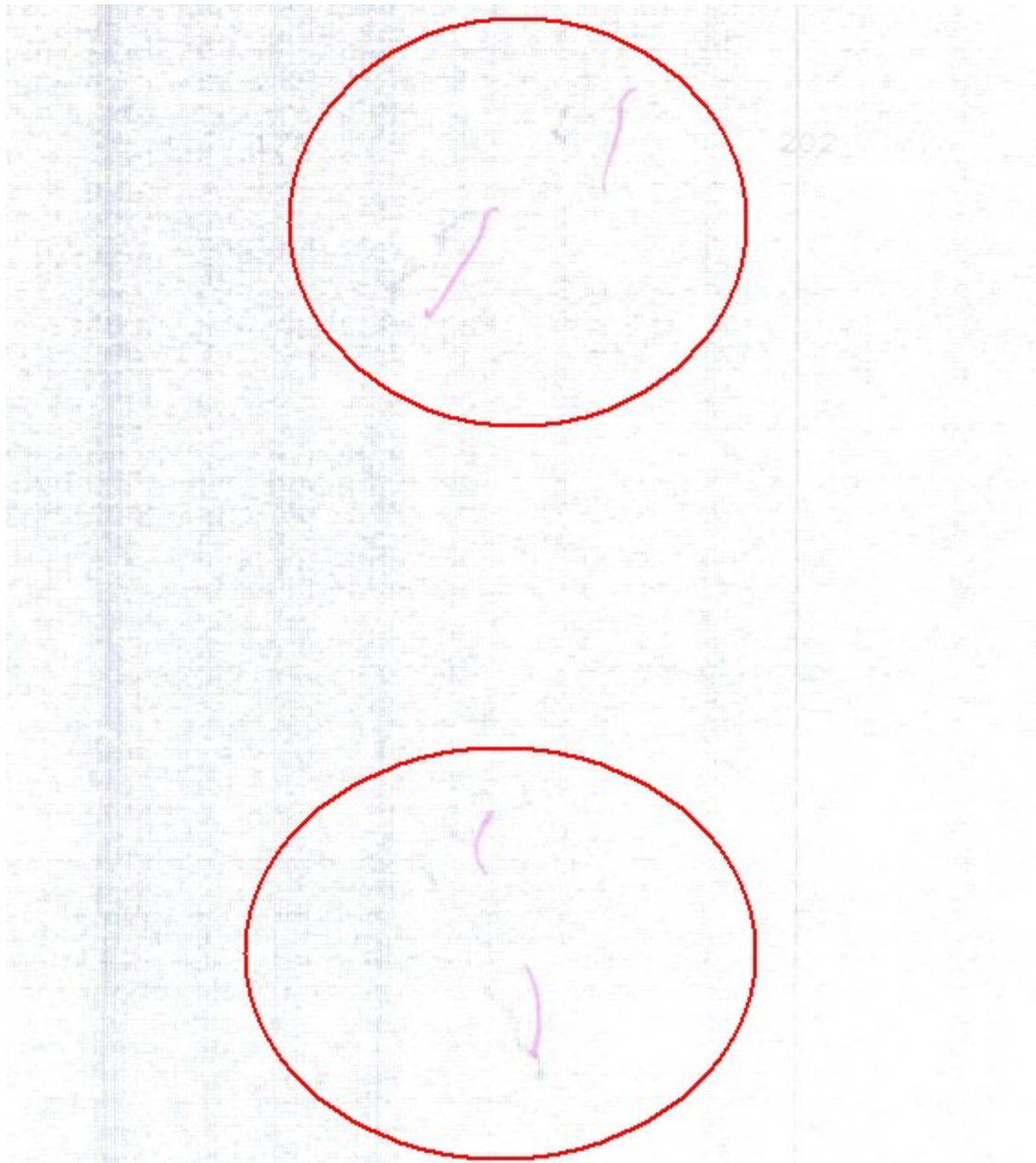
Figure 12a. Example of a stratum five paper chart highlighting discrepancies between the paper and electronic counts. Traces circled in red were counted as two fish on the paper chart and one fish on the electronic chart.
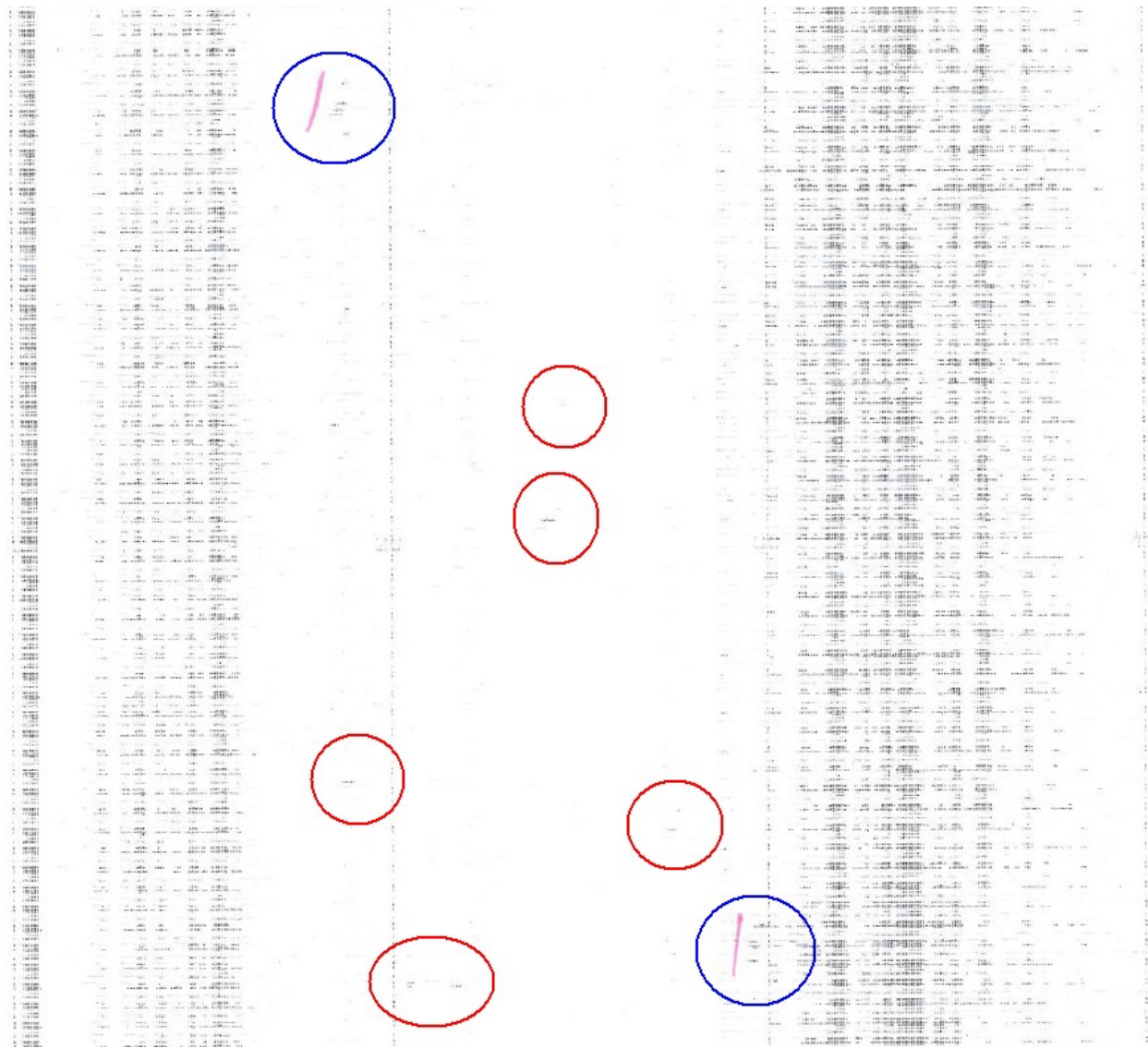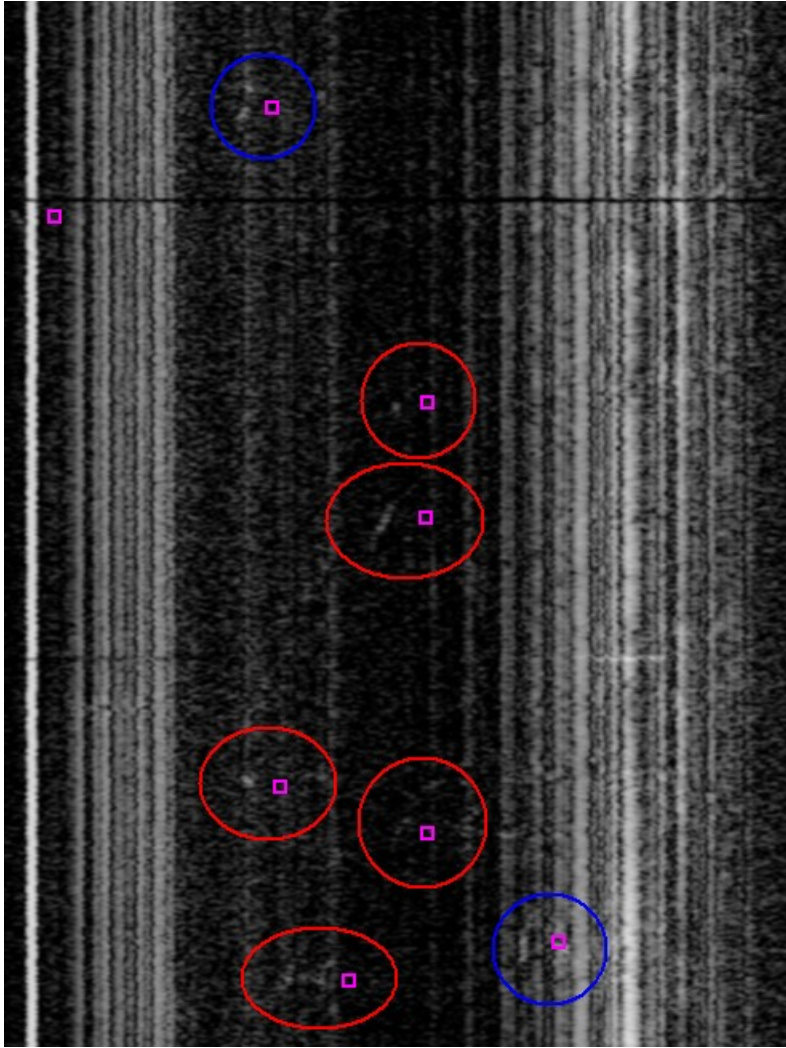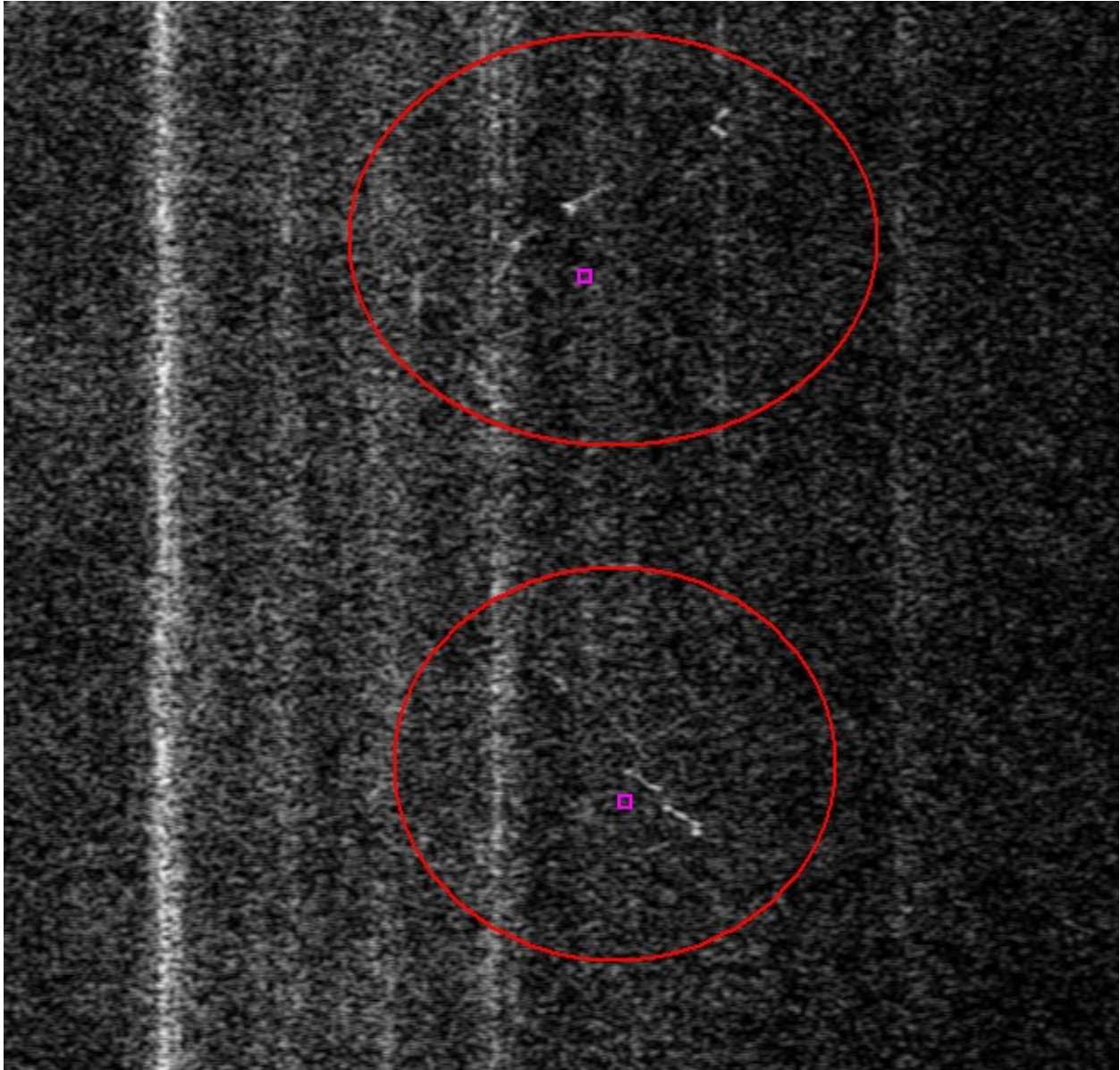
Figure 12b. Example of a stratum five electronic chart highlighting discrepancies between the paper and electronic counts. Traces circled in red were counted as two fish on the paper chart and one fish on the electronic chart.

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Appendix: Number of electronic and paper traces per hour by date for each stratum.

Date	Stratum	Electronic Traces per Hour (#)	Paper Traces per Hour (#)	Date	Stratum	Electronic Traces per Hour (#)	Paper Traces per Hour (#)
6/11	1	53.8	54.0	6/11	2	18.0	15.5
6/14	1	89.0	68.0	6/14	2	32.0	22.0
6/17	1	246.2	258.0	6/17	2	82.0	46.5
6/20	1	372.4	374.4	6/20	2	94.0	78.0
6/23	1	144.8	122.0	6/23	2	82.0	32.9
6/26	1	871.0	746.0	6/26	2	140.0	106.0
6/29	1	2282.1	1952.0	6/29	2	250.0	178.0
7/2	1	912.0	866.3	7/2	2	282.0	193.5
7/5	1	686.0	532.0	7/5	2	124.0	92.0
7/8	1	1420.0	1248.0	7/8	2	130.0	68.0
7/11	1	509.0	438.0	7/11	2	117.9	74.0
7/14	1	320.7	296.0	7/14	2	99.3	67.7
7/17	1	163.4	183.9	7/17	2	22.8	13.5
7/20	1	70.3	50.0	7/20	2	14.5	4.0
7/23	1	209.0	114.0	7/23	2	26.9	10.0
7/26	1	174.2	76.0	7/26	2	4.1	0.0
7/29	1	206.0	88.0	7/29	2	4.1	2.0
8/1	1	290.0	88.0	8/1	2	28.5	6.0
8/4	1	451.0	358.0	8/4	2	60.0	18.0
8/7	1	213.1	122.0	8/7	2	32.0	8.6
8/10	1	140.7	60.0	8/10	2	16.0	0.0
8/13	1	167.6	78.0	8/13	2	18.0	12.0
8/16	1	409.7	322.0	8/16	2	110.0	36.0
8/19	1	190.3	142.0	8/19	2	44.0	32.0
8/22	1	192.4	140.0	8/22	2	18.0	12.0
8/25	1	209.0	93.1	8/25	2	42.0	24.0
8/28	1	343.4	220.0	8/28	2	40.0	10.0
8/31	1	229.7	194.0	8/31	2	40.0	16.0
9/3	1	115.9	66.0	9/3	2	8.0	2.0
9/6	1	146.9	86.0	9/6	2	20.0	4.0

Date	Stratum	Electronic Traces per Hour (#)	Paper Traces per Hour (#)	Date	Stratum	Electronic Traces per Hour (#)	Paper Traces per Hour (#)

Date	Stratum	Electronic Traces per Hour (#)	Paper Traces per Hour (#)		Date	Stratum	Electronic Traces per Hour (#)	Paper Traces per Hour (#)
6/11	3	6.0	22.0		6/11	4	700.0	102.0
6/14	3	28.0	80.0		6/14	4	110.0	106.0
6/17	3	262.0	200.0		6/17	4	476.0	456.0
6/20	3	314.0	336.8		6/20	4	680.0	456.8
6/23	3	560.1	544.0		6/23	4	626.0	702.0
6/26	3	588.1	540.0		6/26	4	712.0	609.7
6/29	3	1384.0	1054.0		6/29	4	1010.0	974.0
7/2	3	708.0	500.0		7/2	4	440.0	502.0
7/5	3	334.0	457.5		7/5	4	274.0	296.1
7/8	3	1634.0	1504.0		7/8	4	768.0	638.7
7/11	3	550.0	607.7		7/11	4	452.0	421.9
7/14	3	414.0	388.0		7/14	4	342.0	318.0
7/17	3	334.0	416.0		7/17	4	172.0	218.0
7/20	3	234.0	218.0		7/20	4	64.0	64.0
7/23	3	246.0	224.0		7/23	4	118.0	108.0
7/26	3	250.0	178.0		7/26	4	180.0	150.0
7/29	3	316.0	350.3		7/29	4	202.0	147.1
8/1	3	318.0	327.1		8/1	4	258.0	241.9
8/4	3	426.0	628.1		8/4	4	348.0	344.5
8/7	3	218.0	219.4		8/7	4	74.0	83.2
8/10	3	332.0	270.0		8/10	4	70.0	52.0
8/13	3	216.0	162.0		8/13	4	32.0	50.0
8/16	3	754.0	648.0		8/16	4	410.0	382.0
8/19	3	144.0	80.0		8/19	4	108.0	120.0
8/22	3	210.0	216.0		8/22	4	124.0	132.0
8/25	3	356.0	298.0		8/25	4	300.0	260.0
8/28	3	458.0	342.0		8/28	4	384.0	384.0
8/31	3	212.0	120.0		8/31	4	172.0	210.0
9/3	3	128.0	58.0		9/3	4	42.0	70.9
9/6	3	202.0	253.1		9/6	4	52.0	92.0

Date	Stratum	Electronic Traces per Hour (#)	Paper Traces per Hour (#)
6/11	5	16.0	20.0
6/14	5	2.0	6.0
6/17	5	2.0	10.0
6/20	5	4.0	40.6

6/23	5	14.0	44.0
6/26	5	48.0	68.0
6/29	5	54.0	66.0
7/2	5	86.0	130.0
7/5	5	66.0	54.0
7/8	5	46.0	21.3
7/11	5	54.0	52.3
7/14	5	62.0	46.0
7/17	5	20.0	56.0
7/20	5	4.0	17.4
7/23	5	6.0	4.0
7/26	5	16.0	18.0
7/29	5	26.0	25.2
8/1	5	48.0	46.5
8/4	5	38.0	36.0
8/7	5	12.0	13.5
8/10	5	12.0	14.0
8/13	5	24.0	58.0
8/16	5	242.0	276.0
8/19	5	36.0	44.0
8/22	5	28.0	32.0
8/25	5	100.0	86.0
8/28	5	88.0	40.0
8/31	5	38.0	76.0
9/3	5	16.0	43.2
9/6	5	24.0	70.0