# Installation and use of a sonar (ARIS Explorer 1800) in the Kedgwick River during the 2019 summer 

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## Canadian Technical Report of Fisheries and Aquatic Sciences

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Installation and use of a sonar (ARIS Explorer 1800) in the Kedgwick River during the 2019 summer

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#### Abstract

Daigle A. and Dauphin, G.J.R. 2022. Installation and use of a sonar (ARIS Explorer 1800) in the Kedgwick River during the 2019 summer. Can. Tech. Rep. Fish. Aquat. Sci.. 3485: vii +45 p.

In 2019, a sonar was installed in the Kedgwick River (Restigouche watershed) to evaluate the feasibility of using such technology to provide a count of adult Atlantic salmon (Salmo salar) swimming through the sonar field of view. This report summarises the methodology used, the challenges encountered, and the data collected during this experiment. To use this technology in a monitoring program, this exercise illustrates the need for i) a suitable location for the installation of a sonar, mainly access to direct power and a riverbed profile favouring straight swimming behaviour and ii) the need for a dedicated person for maintaining the sonar during its operation and the processing of sonar data.


## RÉSUMÉ

Daigle A. and Dauphin, G.J.R. 2022. Installation and use of a sonar (ARIS Explorer 1800) in the Kedgwick River during the 2019 summer. Can. Tech. Rep. Fish. Aquat. Sci.. 3485: vii +45 p.

En 2019, un sonar a été installé dans la rivière Kedgwick (bassin versant de la Ristigouche) pour évaluer la faisabilité de l'utilisation de ce type de technologie pour obtenir un décompte de saumon Atlantique (Salmo salar) nageant a l'amont ou l'aval du sonar. Ce rapport résume la méthodologie utilisée, les difficultés rencontrées ainsi que les données collectées durant cette expérience. Si cette technologie devait être utilisée dans un programme de suivi, cette expérience illustre le besoin d'avoir i) un site qui convient à l'installation d'un sonar, c'est-à-dire avec un accès a une source de courant continue ainsi qu'un fond de rivière favorisant un comportement de nage directe au travers du champ du sonar et ii) une personne dédiée à la maintenance du sonar durant son utilisation ainsi qu'à l'analyse des larges quantités de données générées par le sonar.

## INTRODUCTION

In the Gulf Region of Atlantic Canada, three index rivers (Margaree, Miramichi, and Restigouche) for Atlantic salmon have relied on historical data collection methods to estimate population abundances. The most commonly used methods in the Gulf Region include the use of trap net data, snorkel counts, voluntary angler logbook returns, and angling license sales among others. These methods all produce indices of abundance for the salmon population which can be used to produce river-specific population estimates. As new technologies develop, it is important to explore their possible addition into a field program and determine if index of abundance obtained using these technologies can be used to complement, strengthen and/or replace existing population estimates.

Advancements in sonar technologies have led to the creation of new imaging sonars suitable for use in shallow water environments, such as rivers. Of particular note was the creation of the dual frequency identification sonar (DIDSON, Sound Metrics Corp.; www.soundmetrics.com) and its successor, the adaptive resolution imaging sonar (ARIS). ARIS units offer camera-like imaging when submersed in aquatic environments. However, where cameras rely on light waves to capture an image, sonars utilize soundwaves. This novel use of soundwaves in aquatic environments is beneficial, as it allows for images to be captured under low-light (including night time) and turbid conditions.

Since coming to the commercial market, imaging sonars have been used to enumerate fish and determine net upstream flux (upstream - downstream fish; Holmes et al. 2006; English et al. 2017; Egg et al. 2018; Lankowicz et al. 2020), describe fish behaviour (Xie et al. 2005; Gallagher et al. 2013; Enders et al. 2017; Shahrestani et al. 2017), and measure fish length (English et al. 2018; Cook et al. 2019; Helminen et al. 2020). In many of these studies, the enumeration of the number of fish and descriptions of movements is done using manual and observer specific methods. This decision likely reflects the fact that specialized software allowing for automated processing of sonar data is a niche market, with well supported software having relatively high costs. In addition to the limiting factor of cost, the software often requires a trained individual to develop the workflow and create a script to automate the processing of sonar files, which can be a time consuming task depending on the level of one's experience. This creates an added issue of relying on trained individuals, and costs associated with training new people. Regardless of the investment, if a study requires the collection of a long term imaging sonar dataset, then the automation of data processing becomes an advisable pursuit.

In 2019, an ARIS system was set up on one of the five large tributaries of the Restigouche River in order to evaluate the feasibility of adding an ARIS salmon counting program to the annual salmon stock assessments in the Fisheries and Oceans Canada's Gulf Region. An ARIS salmon counting program would complement existing indices of abundance and/or provide an index in rivers that currently do not have a monitoring program. As a first step toward this goal, the ability of the data processing software to accurately detect and count individual fish from ARIS footage needs to be assessed. While this study focuses on an installation in a Gulf River, some of
the general conclusions can be applied more broadly. With this in mind, the objectives of this study were to:

1. Collect a large ARIS dataset in a Gulf river.
2. Create a workflow to process all ARIS files and detect fish.
3. Create a script that automates reading an ARIS file into the processing software, having the data processed by the tailored workflow, and exporting fish detections.
4. Validate if automated fish detections correspond to manual fish detections.
5. Assess the costs, challenges, and benefits of an ARIS salmon counting program in a Gulf river.

## MATERIALS AND METHODS

## SITE LOCATION AND INSTALLATION

The Kedgwick River is a tributary of the Restigouche River, which is located in northern New Brunswick, Canada. The installation site was in the Kedgwick River slightly up river from the confluence of the Kedgwick and Little Main Restigouche rivers (Figure 1).

On July 3, 2019, an ARIS Explorer 1800 (Sound Metrics Corp.; www.soundmetrics.com) attached to a rotator arm (AR2) was installed in the Kedgwick River. The ARIS and AR2 were mounted to an H -stand and secured to the river bed using rebar and bags of gravel. The ARIS cable ( 150 m ) was run from the installation site to a small, well-protected shed where the remainder of the ARIS equipment (command module, Toughbook, and 5TB external hard drive) was stored with access to a 120 AC power supply (Figure 2).

The river installation site was selected for several reasons:
i. The bottom profile was observed to be flat up until reaching the incline towards shore (Figure 3). The approximate maximum depth at time of installation was 90 cm . Bottom substrate was mainly cobble and pebble (no large rocks and boulders), which suggested that this would prevent fish from holding in the sonar field. When a fish holds within the field of view of the ARIS, it can later create tracking problems during data processing.
ii. The river width at this site was narrow (about 25 m ) relative to other potential locations. A narrower river width is desirable as the resolution of the ARIS output decreases at longer range.
iii. The site was located upstream of a large salmon holding pool (about 100 m ). It was believed that being close to a salmon pool would provide opportunities to record numerous up- and downstream movements of Atlantic Salmon during the season.
iv. The site was close to a direct power source and a warden monitoring a nearby pool, which eliminated the need for a solar power station or generator, both of which would increase the cost, require more attention and maintenance, and present additional theft threats.

## DATA COLLECTION

Raw data were collected from July 3 to September 27, 2019. On July 22, 2019, a $3^{\circ}$ concentration lens was attached to the lens of the ARIS to improve imaging for this shallow water site. This modification provided a great amount of noise reduction, particularly from the near-lens surface water. Because of the significant improvement of the footage, it was decided to discard data collected prior to the use of the concentration lens. Due to a power outage, no data were collected from July 30, 2019 12:00 PM to August 14, 2019 3:30pm. When a power outage occurs, the sonar needs to be reset. Since the site was only visited every two weeks, the sonar was not in a recording position for several days after the power outage.

## DATA STORAGE AND BACK-UP

Raw ARIS files were recorded $24 / 7$ for the duration of the project, with a new file being created every 10-minute. Files were stored on a 5 TB external drive. Every two weeks, a crew member would swap out the external drive for an empty one. This was done for two reasons:
i. To minimize the amount of data that would be lost if some event occurred that led to the damage of the equipment. With the two week external drive rotation, a maximum of two weeks of data would be lost if such an event occurred.
ii. To allow storage of back-up data files to a more secure location. For this, a 10-bay Network Attached Storage (NAS) system was purchased and fitted with four 5 TB external drives. Using such a data storage design creates data redundancy and more security.

## DATA PROCESSING

All data were processed using the Echoview 11 software, as it is one of the only sonar software companies that regularly update their product and provide user support. To detect fish tracks, an Echoview dataflow template was created by following the Echoview tutorial titled Introduction to Multibeam Target Data Processing (Echoview 2018a). All settings were adjusted and tuned based on the specifics of the data collected at the Kedgwick River location (e.g., accounting for the physical properties of the site) and the objective of the experiment (i.e., counting fish moving through the sonar field). Some helpful definitions of Echoview terminology are provided in Table 1.

## Echoview dataflow

The Echoview dataflow window (Figure 4) was used to display and manage each step of the data cleaning and detection process. The window displays the relationship between variables and operators, and indicates the flow of data from initial input to final output. The following steps outline how the data were processed for this project:

## 1. Raw data

When multibeam raw data files are opened in Echoview, the $S_{v}$ frames variable is generated automatically. $\mathrm{S}_{\mathrm{V}}$ is defined as the volume backscattering strength (in dB referenced to $1 \mathrm{~m}^{-1}$; Table 1). Opening the $S_{v}$ frames variable will produce a new window displaying a multibeam echogram. This echogram allows the user to visually inspect the raw data recordings.

## 2. Calibration

Before beginning the data cleaning process, a calibration file is required. In a freshwater installation, the variables required are absorption coefficient and speed of sound. Both variables can be calculated by Echoview with the use of the Sonar Calculator. Required inputs for the Sonar Calculator are water temperature, transducer frequency, and depth/range. The calculator determines sound speed following Del Grosso and Mader (1972) and absorption coefficient following Francois and Garrison (1982).

## 3. Background removal

The background removal operator automatically removes stationary single targets (e.g., river bottom substrate like sand, cobble, pebble) from the echogram.

## 4. Data smoothing

The purpose of data smoothing is to improve the definition of the targets, making them easier to detect at a later stage. For the current workflow, data was smoothed using a combination of $3 \times 3$ beam median and beam dilation filters. The $3 \times 3$ beam median filter replaces each data point with the median of the data points in the surrounding cells, while the dilation filter replaces each data point with the maximum of the data points in the surrounding cell.

## 5. Multibeam target detection

This operator detects targets (objects) using a multibeam target detection algorithm.

## 6. Data filtering

The target property threshold operator allows targets that are not of interest to be excluded from further analyses based on a given threshold for a particular property (e.g., length, thickness, area, intensity). Although this operator has been included in the workflow, no property threshold has been applied.

## 7. Data conversion

The data conversion operator takes multibeam data and converts it into a single beam format. This single beam format is necessary for detecting fish tracks.

## 8. Fish track detection

When fish track detection is selected, an algorithm is applied to all data within the data conversion echogram. The algorithm settings (Appendix A) can be adjusted to optimize fish track detections for any given data set.

## 9. Exporting fish track metrics

Once fish tracks have been detected, the data are exported as a comma separated value (*.csv) file format. Each row represents a single detection. An example of relevant information provided per detection is date, time, target length, and number of single targets comprising the fish track.

## Automation

Given the large volume of raw data files that required processing, it was necessary to automate data cleaning, fish detection, and region exportation. This was completed by following the Echoview tutorial titled Intro to COM Scripting (Echoview 2018b), as well as utilizing the Echoview example script titled EV script 007 - New EV file using template, detect and export fish tracks (Echoview n.d.). The example script was adjusted accordingly to reflect the appropriate files, file pathways, and naming structure for our dataset (Appendix B). Running the automation script led to the creation of 305 csv files containing all fish track regions detected by the algorithm for the whole duration of the experiment. These files were then consolidated in a single file using R (R Core Team 2021).

## Checking algorithm accuracy

To validate the accuracy of the fish track detection algorithm, a subsample of 103 10-minute files extracted from the cleaned data files were manually analysed. That is, using Echoview, a 10minute file was opened and fish tracks were manually identified. The total number of fish tracks per file was recorded. Manual fish track counts were then compared to the track counts generated by the Echoview script for the same 10-minute file to assess the accuracy of the automated process. This procedure was repeated for each of the 103 10-minute files.

A preliminary assessment of the Echoview dataset identified differences in the number of tracks detected at different times of the day (Figure 5). Typically, a large number of tracks were detected during night-time between 21:00 and 5:00 h (high-movement hours) and a small number of tracks were detected from 5:00 to 21:00 h (low-movement hours). To reflect this apparent dichotomy in diel activity, the random sub-sampling of 10 -minute files was focused on high-movement hours. Therefore, for each day with available data, three 10 -minute files were randomly chosen within the high-movement hours and one file was randomly chosen from the low-movement hours.

## RESULTS

Scouting a suitable location for sonar installation, i.e., a portion of river that had a narrow width ( 30 m at maximum, but preferably narrower), a relatively flat bottom, and no bottom obstructions (boulders, vegetation, logs, etc.), was a time consuming process. The presence or absence of bottom obstructions often had to be verified by using a partial sonar installation and examining at the sonar image in real time. Direct power was available at the site chosen for this experiment which saved time and effort as it eliminated the need to install an off-grid solar power station (solar panels attached to a battery bank and inverter). However, a downside of relying on the direct power is that power outages, even when brief, resulted in the ARIS shutting off. When a power outage occurs, the unit needs to be manually turned back on and the viewing angles need to be re-set. Such a power outage occurred during this experiment and it resulted in losing approximately two weeks of data (see discussion).

The in-river installation was straightforward: securing the H -stand in place with rebar and gravel bags worked well and no issues arose from H -stand movement during the experiment. Variations in water level throughout the season does not appear to have impacted the data collection (Figure 6). However, the experiment was ended and sonar removed when the forecast began calling for large amounts of rain. Heavy precipitation can lead to high water events, often bringing debris (logs, branches, etc.) down the river. This has the potential to damage and/or dislodge the sonar or H-stand. Like other similar projects, a large amount of data were generated: data were collected in 10-minute files, adding up to a total of 3.54 TB of raw data collected through the course of the experiment.

## OBSERVED SWIMMING PATTERNS

Various types of fish behaviour were observed over the course of this project. The following section describes the four most commonly encountered behaviours and how they are interpreted by the fish track detection algorithm. To illustrate these behaviours, screenshots from Echoview showing a synchronized split screen of the raw ARIS echogram (A) and the single target echogram used for detecting fish tracks (B) are presented (Figure 7 to Figure 15). In each figure, the left panel (A), has a single echogram at a specific point in time with the narrow end of the cone indicating the ARIS lens location that emits and receives the sound waves, forming the overall image captured and represented by the blue cone. This view is the equivalent of a snapshot in time of a bird's-eye view (top) of the sonar field. In the right panel (B), on the vertical axis moving from bottom to top of the echogram represents distance away from the lens of the ARIS. On the horizontal axis, moving from left to right in the echogram represents moving through time. The vertical black dotted line in the right panel corresponds to the time instance synchronized between the two screen views. Single targets are grouped into fish track regions based on the fish track detection algorithm. Fish track regions are named (fish) and a bright border is generated around the single targets comprising the complete fish track. In Figure 7 to Figure 15, the yellow circle in the left panel outlines the location of a fish, while the yellow circle in the right panel highlights the single targets corresponding to that fish.

The four behaviours are coarsely grouped into the following:

## Straight Shooter (Figure 7 to Figure 10):

The fish moves upstream or downstream, straight through the sonar field. This is the ideal scenario, as the algorithm is tuned to recognize this type of movement. In Figure 7, the fish swims upriver with minimal meandering. In Figure 8, the fish is moving downstream but facing upstream, with minimal meandering. In Figure 9, three individual fish are detected moving upstream during the 260 s of the echogram plot. In Figure 10, one fish located near the transducer lens moves quickly upstream and another fish shortly after ( 140 second) moves downstream.

## Holding (Figure 11 and Figure 12):

A fish is described as holding when it stays within the sonar beams for a prolonged period of time, displaying little or no movement. There are a few Echoview interpretation issues associated with holding behaviour of a fish. First, it generates an abundance of single target detections over a long period of time. These targets are rarely grouped by the fish track detection algorithm as one fish. Instead, single targets coming from one fish are categorized as having come from many fish, thus overinflating the fish count. Second, the acoustic shadow created by a holding fish can prevent the detection of other fish swimming within the shadow, or can break what should be one fish track into two, by preventing the detection of any single target where the shadow occurs. An acoustic shadow is created when the emitted sound waves encounter a target. These incident waves are reflected back, not propagated through the target. Since no sound travels through the target, the area behind the target cannot be 'seen'. Thus, this area is referred to as the acoustic shadow.

In Figure 11, the holding behaviour of a single fish causes the fish track detection algorithm to fail, classifying the single track as having come from several different fish. In Figure 12, two large fish are holding side-by-side for a long period of time (yellow circle) and a third fish (red circle) is holding in the acoustic shadow created by the other two fish. One of the two fish (yellow circle) holds in the same position for 50+ minutes (not displayed here).

## Group Swimming (Figure 13 and Figure 14):

Fish moving through the sonar field as a school, depending on how close the fish are to one another, can impact the accuracy of the track detection algorithm.

In Figure 13, Echoview interprets the single targets as coming from four fish tracks whereas the manual analysis interpreted the single targets as coming from six or seven fish. In Figure 14, Echoview interprets the single targets as coming from six fish whereas manual analysis interpreted the single targets as coming from a school of ten + fish.

## Camera Shy (Figure 15):

A fish is described as camera shy when it moves partially in and out of the sonar field. This behaviour can result in overinflated fish counts because they are repeatedly counted every time they come into view, without ever having crossed the field.

In Figure 15, the single target echogram shows an example of an individual fish entering the sonar field, never crossing the entire field, but instead dropping back out of view on the same side. Manual interpretation of the image file shows that pattern of incomplete movement across the beam.

## ACCURACY OF AUTOMATED TRACK DETECTION VS. MANUAL COUNTS

To assess the accuracy of the track detection algorithm, a total of 103 10-minute files (Appendix Table C1) were manually examined to identify the number of fish moving or holding in the sonar field during that time. Poisson and Negative-Binomial Generalized Linear Models (GLMs) were explored to understand the relationship between the manual counts and automated counts generated by the Echoview track detection algorithm data. Unfortunately, the large amount of structural zeros ( $\sim 25 \%$ of the manual counts) resulted in poor fits. To solve this, Poisson and Negative Binomial zero inflated GLMs were instead fitted to the data in order to deal with these structural zeros (Figure 16), the latter providing the best fit (AIC $=606$ for the zero-inflated Poisson GLM and AIC $=523$ for the zero-inflated Negative Binomial GLM). There was a reasonable positive association between manual and automated counts, quantified by a maximum likelihood pseudo r-squared of 0.65 which was calculated with the pscl package (Jackman, 2020) in R . The log odds of being an excessive 0 decrease by 0.57 for each additional automated count. Conversely the larger the automated count, the higher the probability that a fish was counted manually (Figure 16).

Overall, the automation process generated more tracks than the number of fish identified as such manually. This can likely be explained by the inadequacy of the detection algorithm to recognize the variety of behaviors displayed by fishes in the sonar field (see section above). The manual counts were higher than the automated counts in $9 \%(9 / 103)$ of the files. Note that when there were no fish swimming through the sonar field as interpreted manually, the Echoview algorithm overwhelmingly detected no tracks in $92 \%$ of those instances examined (23/25; Appendix C).

## DISCUSSION

The purpose of this experiment was to explore if information collected by an ARIS could be used to complement existing indices of Atlantic salmon abundance in Fisheries and Oceans Canada's Gulf Region. Practical objectives were set and achieved. These objectives included finding a location, installing the equipment in a natural river setting, running the sonar for two + months, having no equipment wash-outs, and automating fish detections. The main finding from this work was that in this experiment, the automated fish detections did not align well with the manual fish detections While this is somewhat disappointing, the bias between the manual fish counts and the automated detections is primarily due to particular fish swimming behaviours that are difficult to interpret with automated algorithms. The swimming patterns in and of themselves are not necessarily the issue. The main issue arises when trying to develop an algorithm that detects all four patterns simultaneously, using a single Echoview workflow. That is, instead of being able to closely tailor the Fish Track Detection algorithm parameters for one swimming pattern, the parameters need to be loosened and adjusted in such a way as to allow all swimming patterns to be detected. This trade-off leads to an algorithm that produces mediocre detection results, with single targets often being assigned to false fish tracks. To clarify, a false fish track would be a fish track identified by the Echoview algorithm, but is comprised of single targets that come from multiple objects (fish, debris, bottom, etc.) in the field of view.

Given the data processing and detection complexities that arise when multiple swimming behaviours are present, it is strongly recommended to, when possible, alter the environment within and around the field of view of the ARIS (e.g., laying large paving stones; S. Milne, pers. comm.) such that a single swimming pattern will be elicited by fish (ideally straight swim through). Tailoring the Fish Track Detection algorithm for a data set where a single type of swimming pattern is observed should result in a greater degree of agreement between manual fish counts and automated detections. Eliciting one 'right' type of swimming behaviour should increase the accuracy of automated detections. The issues of the swimming patterns observed during this study are discussed below.

Holding, as previously described, is when a fish stays within the ARIS field of view (i.e., in the sonar beams) for a prolonged period of time, in the same position, displaying little to no movement. This behaviour can cause several issues:
i) holding with little movement (movement is often from tail beats) results in the continuous deposition of single targets throughout the echogram. Because the movement is minimal, the single targets are often spaced apart, creating large gaps. These large gaps provide opportunities for misinterpretation by the Fish Track Detection algorithm, as a fish track might end too early, or a single target deposited by a different object might be incorrectly grouped into the fish track. Note that the degree of opportunity for mistakes is highly dependent on how well the echogram was cleaned prior to the fish tracking step. If minimal reverberation (echoes from unwanted targets; Simmonds and MacLennan 2005) is present, it is still possible for the tracking algorithm to overcome large gaps accurately.
ii) holding for periods of time with no movement. This will result in the fish being eliminated during the background removal step of data processing. Such a behaviour would inflate the overall number of fish tracks as each movement after a period of holding would result in single targets being deposited and grouped as a fish track. For example, if a single fish decided to hold in three different locations within the field of view during some period of time, that would result in a total of four fish tracks; (1) when the fish enters the field of view to hold in position one, (2) when the fish moves from position one to position two, (3) movement from second to third hold positon, and (4) when the fish moves from the third hold position to exit the field of view. Thus, at a minimum, a holding fish will be counted as two fish tracks, but has the potential to be counted as more if the fish holds at various locations within the field of view.
iii) the holding fish produces an acoustic shadow. As previously mentioned, an acoustic shadow is created when a target within the ARIS field of view reflects the incident sound waves, creating an acoustic shadow behind that target. Any other target that enters the acoustic shadow will not be observed because the ARIS sound waves (a basic requirement for building a sonar image) are being blocked by the first target. In terms of data processing, this means that no single target can be deposited by a target residing in the shadow, which can result in a gap between two sets of single targets deposited by a single fish that swims through the shadow. Large gaps, as explained previously, provide opportunities for misinterpretation by the Fish Track Detection algorithm (dependent on algorithm settings) and will often inflate the total number of automated fish detections.

A second problematic swimming behaviour observed during this project was group swimming. This occurred when an aggregation of fish moved through the ARIS field of view. When counting fish manually, it is possible through careful review of the video to discern how many individuals comprise the aggregation. Conversely, the automated Fish Track Detection algorithm struggles at grouping together single targets into accurate Fish Tracks. This is because numerous single targets are deposited by all the fish in generally the same area. It is unlikely that the parameters of the Fish Track Detection algorithm could be adjusted to accurately classify these individual Fish Tracks.

The final problematic swimming behaviour observed was by camera shy fish. This term refers to fish that hold near the edge of the field of view, sometimes interspersed with short periods of meandering. Movements in their holding position cause them to come in and out of the field of view, making it difficult for both manual and automated detection. When counting fish manually, the camera shy behaviour can sometimes be identified with confidence, as part of the fish may remain just on the edge of the field of view. When this happens, the manual counter can wait until the camera shy fish finally exits fully, allowing it to be counted as a single fish. Other times, however, the fish disappears completely, but then reappears moments later around the same area. In these instances, one cannot be certain that it is indeed, the same fish. During automated counts, camera shy fish often inflate the overall count.

The ideal swimming pattern to document with an ARIS in a fish counting situation would be what was classified as the straight shooter. This pattern is observed when a fish moves through the ARIS field of view with a somewhat constant speed and minimal meandering. Such a
movement often leads to the deposition of single targets that can easily be grouped into a Fish Track after appropriate adjustments to the settings in the Fish Track Detection algorithm.

Options for eliciting a desired swimming pattern, while deterring other patterns vary. Choosing locations with no large boulders and removing small boulders can help avoid the holding behaviour. Strategic placement of counting fence material can help deter group swimming through the field of view. It has been suggested (S. Milne, pers. comm.) that placing slab patio stones onto shallow flat river bottom areas could promote straight shooter behaviour, as fish are thought to feel exposed and will quickly swim past the patio stones. Anything that can be done to help deter and reduce multiple swimming patterns from occurring in the ARIS field of view is advisable, as it will provide a greater chance of providing more unbiased automated fish detections.

Other information of interest for the use of these data in a population management context is the ability to identify species and lengths of the fish swimming through the sonar field. This goes a bit beyond the scope of this particular study and might be challenging to extract due to the nonoptimal nature of the data that were collected during this experiment, but several options to obtain this information could be investigated (e.g. Helminen et al. 2020, 2021 for some examples in New Brunswick rivers). While not explored in this study, it is worth noting that the popularization of machine learning algorithms is opening the door to new ways to analyse large datasets generated from sonars (e.g. Fernandez Garcia et al. 2021, Kandimalla et al. 2022). These models are not a silver bullet as the resources needed for the labelling of training data are still a limiting factor. However, with appropriate resources and expertise, these methods could eventually be used to analyse large sonar datasets.

Overall, this preliminary study assessed the potential of using an ARIS to count fish in a natural river environment. Of the issues we encountered (loss of power, resetting ARIS position, problematic swimming behaviours, etc.) many could have been addressed and potentially resolved during the study had a number of items been available. The most important of these items would be having at least one person close to the experiment location and responsible for regular maintenance of the sonar as well as regular data checks to address any issues occurring in real-time. This person would have to have, at a minimum, a beginner's understanding of sonar theory and sonar data processing. Having remote access to the laptop running the sonar would make regular maintenance more attainable, especially for installations in remote areas where daily physical presence is not always feasible. Unfortunately, for this study, it was not possible to set up remote access to the sonar laptop, and staff shortages meant that no single employee could be dedicated to sonar maintenance and data troubleshooting on a regular basis. Regarding the sonar site selection, discussion with local river users (e.g. indigenous communities, fishing guides) could help in finding a more suitable location that would favor only one type of swimming behavior.

## CONCLUSIONS

The main focus of this study was to provide a proof of concept that counts of fish-like objects moving through an imaging sonar field of view could be obtained in a moderate sized river with limited infrastructure. An ARIS unit was successfully deployed in the Kedgwick River and continuous fish movement data were collected over the period of July 3 to September 27, 2019. The largest amount of effort was spent creating an appropriate workflow in Echoview and then automating the data processing so that fish track detections were exported from each data file. By comparing manual fish detections to automated fish detections, it was found that the fish track detection algorithm can be tailored to detect fish tracks with a high level of accuracy, but only when fish are behaving similarly. The algorithm can be tailored to capture one type of fish swimming behaviour well, but is inefficient when having to detect fish with different swimming behaviours. The issue of identifying different species of fish swimming through the sonar field was not considered in this study but it is a complicating factor in natural settings such as the rivers of the southern Gulf of St. Lawrence with a diverse riverine fish fauna.

The time investment necessary to process sonar data manually is very variable: a 10 -minute file can take anywhere from 30 s (day time, with little to no activity) to 30-minute (night time, multiple fish entering and leaving the sonar field at the same time). It is therefore crucial to have automation as reliable as possible. In the light of this experiment, for future ARIS installations, we recommend altering the study area in such a way as to force fish to behave in the ideal swimming behaviour, which is most easily interpreted by automated methods. This would include:

- When the ARIS installation is in a shallow section of river, laying large paving stones across the river bottom (within the field of view) to stimulate active swimming and preclude fish from holding.
- Use of fish counting fence materials would aid in isolating where fish can enter or exit the beam. This would allow for greater image resolution, as it would decrease the distance the beams need to travel. Fencing material could also limit the number of fish entering the field of view at one time. The combination of increased resolution with decreased fish in the field of view would likely reduce the error in automated counting.


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## FIGURES



Figure 1: Location (red star) of the ARIS site in the Kedgwick River, upstream of the junction with the Little Main Restigouche River.


Figure 2: Upper panel: Underwater view of the ARIS, control arm, and H-stand. Bottom panel: Upstream view of the installation site, the red line shows the ARIS cable from the protected shed to the ARIS control arm.


Figure 3: Top panel: Profile of river bed from ARIS installation site. The ARIS was rotated $90^{\circ}$ in order to capture an image of the cross section of the bottom profile. The narrowest part of the cone indicates the location of the ARIS lens. The beams emitted by the ARIS expand with distance, hence why the cone becomes larger with distance from the lens. The river bed is comprised of cobble and pebble, creating a strong echo that can be followed towards shore (appears as a mostly solid white line). The surface water also creates a strong echo, but the line appears smudged relative to the bottom line. This is because the surface water is flowing, creating turbulence. Bottom panel: Depth profile extrapolated from the ARIS image in the top panel. Measurement were taken every meter, while not precise (the ARIS mage is very pixelated) it provides a reasonable representation of the depth encountered in the channel at the sonar location. The grey area indicates the zone where it was not possible to extract a depth measurement.


Figure 4: Screenshot of an Echoview dataflow designed to detect fish tracks from multibeam data files. Black arrows indicate the direction of the workflow. The orange arrow indicates the raw data coming from the ARIS. The swath shape represents multibeam acoustic variable, while the rectangle shape represents single beam acoustic variables. Blue indicates $S_{\mathrm{V}}$ data and green indicates target data. Bracketed numbers are for labelling purposes only.


Figure 5: Number of fish tracks detected (Echoview) by hour of the day and grouped by week (approximately seven days per week, when possible) from July to September at the Kedgwick River sonar location. Orange bars indicate the number of fish tracks detected in a given hour. Dark and light grey areas represent night and day time, respectively. Average sunrise and sunset were calculated for each week and rounded to the closest hours. Note: as previously mentioned, no data are available for the period July 30 to August 14 m 2019 due to a power outage.


Figure 6: Upper panel, discharge profile (in $\mathrm{m}^{3} \cdot \mathrm{~s}^{-1}$ ) as observed at hydrometric station 01BC001 (Restigouche River below Kedgwick River) from July 22, to September 27, 2019. Lower panel, daily track detection (Echoview) during the same time period. The greyed area correspond to the periods during which the sonar was not operational.


Figure 7: Left panel, $S_{v}$ echogram; right panel, single target echogram. The amount of time shown in the right panel is 260 s . Time at dotted vertical line is $01: 29$. The single target echogram shows a fish swimming upriver with minimal meandering, over a time span of 17 s . The yellow circle in each panel circumscribes the fish target in both echograms at that time. The white arrow indicates up river.


Figure 8: Left panel, $S_{v}$ echogram; right panel, single target echogram. The amount of time shown in the right panel is 260 s . Time at dotted vertical line is $05: 01$. The single target echogram shows a fish facing upriver, but falling back down river, over a period of 12 s . There is some meandering, but the algorithm accurately groups single targets into the fish track region. The yellow circle in each panel circumscribes the fish target in both echograms. The white arrow in the left panel indicates up river.


Figure 9: Left panel, $S_{\mathrm{v}}$ echogram; right panel, single target echogram. The amount of time shown in the right panel is 260 s . Time at dotted vertical line is $23: 39$. The single target echogram shows three fish moving straight through the beams. The yellow circles indicate the same fish target in both echograms. Later, two additional fish (red circles) are also observed moving relatively straight through the beams at different ranges. The algorithm accurately groups single targets into the fish track regions. The white arrow in the left panel indicates up river.


Figure 10: Left panel, $S_{V}$ echogram; right panel, single target echogram. The amount of time shown in the right panel is 260 s . Time at dotted vertical line is 23:54. The single target echogram shows a fish moving quickly up-river through the beams, near the lens (yellow circle). Later, another fish drops down, again moving quickly through the beams (red circle). Both movements were accurately tracked by the fish track detection algorithm. The yellow circle indicate the fish target in both echograms. The white arrow in the left panel indicates up river.


Figure 11: Left panel, $S_{V}$ echogram; right panel, single target echogram. The amount of time shown in the right panel is approximately 260 s , from left to right. Time at dotted vertical line is $22: 30$. The single target echogram shows a holding behavior causing the fish track detection algorithm to fail by classifying the tracks as having come from several different fish. The yellow circles indicate the fish target in both echograms. The white arrow in the left panel indicates up river.


Figure 12: Left panel, $S_{v}$ echogram; right panel, single target echogram. The amount of time shown in the right panel is approximately 260 s , from left to right. Time at dotted vertical line is $04: 45$. The single target echogram is an example of an echogram with a large amount of activity. Two large fish are holding side-by-side for a long period of time (yellow circle) and, a third fish (red circle) is holding partially in the acoustic shadow created by the other two fish. One of the two fish (yellow circle) holds in the same position for $50+$ minutes (not displayed here). The yellow and red circles indicate the same fish targets in both views. The white arrow in the left panel indicates up river.


Figure 13: Left panel, $S_{v}$ echogram; right panel, single target echogram. The amount of time shown in the right panel is approximately 260 s , from left to right. Time at dotted vertical line is $21: 15$. The single target echogram is an example of the fish track detection algorithm interpreting the echoes as four fish tracks when manual analysis interpreted the echoes as six or seven fish. The yellow circles indicate the fish targets in both echograms. The white arrow in the left panel indicates up river.


Figure 14: Left panel, $S_{v}$ echogram; right panel, single target echogram. The amount of time shown in the right panel is approximately 260 s , from left to right. Time at dotted vertical line is 21:04. The single target echogram is an example of the fish track detection algorithm interpreting the echo sequences as six fish whereas manual analysis interpreted the echo sequences as a school of ten+ fish. The yellow circles indicate the fish targets in both echograms. The white arrow in the left panel indicates up river.


Figure 15: Left panel, $S_{v}$ echogram; right panel, single target echogram. The amount of time shown in the right panel is approximately 260 s , from left to right. Time at dotted vertical line is $02: 16$. The single target echogram is an example of an individual fish entering the sonar field, never crossing the entire field, but instead dropping back out of view on the same side. The yellow circles indicate the fish target in both echograms. The white arrow in the left panel indicates up river.


Figure 16: Top left panel: Zero-inflated Negative Binomial GLM fit (blue line) between manual and automated counts. Each dot corresponds to one 10 -minute file. The colours indicate the month during which the file was recorded. The grey dashed line correspond to the one to one relationship. Note: some jitter was added to visualize the large number of 10 -minute files with a null amount of manual and / or automated counts. Bottom left panel: Probability of observing an excess/structural zero. Top right panel: Pearson's residuals versus fitted values from the Zero-inflated Negative Binomial GLM.

## TABLES

Table 1. Echoview terminology defined. The following terms are used when explaining how sonar data are processed using Echoview. Definitions come from the online Echoview Help file (Echoview 2020) unless stated otherwise.

| Term | Definition |
| :--- | :--- |
| Raw variable | A raw variable is a variable that has been derived directly from a <br> sonar data file. |
| Virtual variable | A virtual variable is created by applying an operator. |
| Operator | An operator is an algorithm which acts upon a variable (raw or <br> virtual) to produce a virtual variable. |
| Mean volume back <br> scattering strength <br> (MVBS or Sv) | The volume backscattering strength is averaged over a specified <br> depth interval and over several transmitted pulses (Johannesson and <br> Mitson 1983). Sv (dB re 1 m <br> -1 $)$ is defined as the Mean Volume <br> Backscattering Strength (MVBS). |
| Backscattering <br> Strength | The back scattering strength is determined from the object echo and <br> the instrument parameters (Do 1987). This variable is used for echo <br> integration. |
| Echogram | An echogram is a visual representation of a variable (raw or virtual). <br> It is the principal window for quality control, editing, and analysis of <br> data. |
| Regions | Regions in Echoview are a feature of the Echoview file and once <br> defined, a region can be applied to all echograms in the file. They are <br> a versatile tool. Regions can be used to broadly define areas of the <br> water column (e.g., benthic vs. pelagic) which is useful when dealing <br> with species that favour different habitats. Alternatively, regions can <br> be created to group single targets coming from the same object (e.g., <br> fish track regions). |
| Fish track | Fish track is a type of region. An individual fish track region is <br> created around one or more single targets that show a pattern of <br> systematic movement, as defined by the fish track detection <br> algorithm. |
| Single target | A single target is the representation of an acoustic echo attributed to a <br> single backscattering target detected within the beam of a sonar unit. |

## APPENDIX A: FISH TRACK DETECTION SETTINGS

To access the Track Detection Properties, the EV File Properties window must be opened, and the Fish Tracks tab selected. Adjusting settings within the Track Detection Properties is advisable as it can produce more accurate detections than if the settings remain at their default values. Adjustments made are often iterative, and are dependent on the swimming behaviour observed. Note that three tabs exist within the Track Detection Properties dialogue box: Algorithm, Weights, and Track Acceptance. Images of each or these tabs are provided below, with the settings that were used for the analysis presented in this report.


Figure A1 - Track Detection Properties, Algorithm tab. This tab is used to identify candidate single targets for inclusion into a fish track. Further description of the settings within the Algorithm tab can be found in the Echoview help file (Echoview 2020).


Figure A2 - Track Detection Properties, Weights tab. When a single target is determined to be a candidate for a fish track, its suitability is then determined by settings in the Weights tab. Further description of the settings within the Weights tab can be found in the Echoview help file (Echoview 2020).


Figure A3 - Track Detection Properties, Track Acceptance tab. This tab outlines the criteria required by a candidate fish track in order to be included in the final fish track detection. Further description of the settings within the Weights tab can be found in the Echoview help file (Echoview 2020).

## APPENDIX B: ECHOVIEW SCRIPT

The following is a modified version of an example COM script provided by Echoview titled $E V$ script 007 - New EV file using template, detect and export fish tracks (Echoview n.d.). The example script was modified to reflect the appropriate files, file pathways, and naming structure for the dataset used in this report.

```
' EV script 007 - New EV file using template, detect and export fish tracks
' Example Echoview COM script downloaded from www.echoview.com
' For support, contact the Echoview support team <support@echoview.com>
```


' Strict syntax checking
Option Explicit
'-----------------------------------------------------------------------------------
' Set default values for the script
Const TemplateFile = "E:\WFH\2_EV Files\2020_05_11_KedgwickTemplate.EV" 'Which template to
use to create new EV files
Const DataFilePath = "E:\WFH\RawData\ARIS_2019_08_14\" 'Where the data files are located
Const DataFileExt = "aris" 'Data file type e.g. raw, DT4, etc
Const OutputEvFilePath = "E:\WFH\Exports\EV_Files\" 'Where to save the EV files
Const OutputExportPath = "E:\WFH\Exports\FishTrackRegions\" 'Where to save the export
Const NumberDataFiles = 1 'The number of data files to add per EV file
Const EvFilePrefix = "ForReal_" 'EV files will be saved with this prefix then the name of the
first data file
Const FishTrackRegionClass = "Fish" 'The region class to export
Const VariableToExport = "Fish Tracking" 'The variable to detect and export fish tracks from
' We want these objects to be available all through the script
Dim FSO: Set FSO = CreateObject("Scripting.FileSystemObject")
Dim EvApp: Set EvApp = CreateObject("EchoviewCOM.EvApplication")
EvApp.Minimize()
Sub QuitWithError(ErrorMessage)
MsgBox ErrorMessage + vbCrLf + vbCrLf + "Exiting.", vbOk + vbError, "Error"
WScript.quit 1
End Sub

' Create the source folder object
Dim DataFileFolder
Set DataFileFolder = FSO.GetFolder(DataFilePath)
' Export, save and close the EV file
Sub SaveAndCloseFile
If EvFile.Filesets.Item(0).DataFiles.Count $=0$ Then
QuitWithError "Tried to save an EV file with no data files"
End If

```
    ' This is a good place to do any per-EV file work you want to do
    ' Find the specified variable
    Dim objVariable
    Set objVariable = EvFile.Variables.FindByName(VariableToExport)
    If objVariable is Nothing Then
    QuitWithError "Could not find the variable " & VariableToExport & " in the EV file."
    End If
    ' Now get the variableacoustic interface of the variable
    Dim objVariableAcoustic
    set objVariableAcoustic = objVariable.AsVariableAcoustic
    '------------------------------------------------------------------------------
    ' Now we get the file name
    Dim BaseFileNameExport
    Dim BaseFileNameEvFile
    Dim FirstDataFileName
    FirstDataFileName = FSO.GetBaseName(EvFile.Filesets.Item(0).DataFiles.Item(0).FileName)
    BaseFileNameExport = OutputExportPath & EvFilePrefix & FirstDataFileName
    BaseFileNameEvFile = OutputEvFilePath & EvFilePrefix & FirstDataFileName
    '-----------------------------------------------------------------------------
    ' Run the fish-tracking algorithm on the specified variable
    Dim iFishTracks
    iFishTracks = objVariableAcoustic.DetectFishTracks(FishTrackRegionClass)
    ' Pop up a warning if no fish tracks were found in the data file
    If iFishTracks = 0 Then
        ' Un-comment this line if you want a notification to pop up when no fish tracks are
detected in an EV file
        ' this may indicate that you need to tune your target detection or fish tracking
settings
' MsgBox "No fish tracks detected in variable " & VariableToExport & " in file:" &
vbCrLf & BaseFileNameEvFile & ".EV", vbOk + vbInformation
    Else
        Dim bResult
        bResult = objVariableAcoustic.ExportFishTracksByRegions(BaseFileNameExport & ".csv",
EvFile.RegionClasses.FindByName(FishTrackRegionClass))
        If Not bResult Then
            MsgBox "Unable to export from file " & BaseFileNameExport & ".csv"
        End If
    End If
    '-----------------------------------------------------------------------------
    ' Actually save the file to that name
    If EvFile.SaveAs(BaseFileNameEvFile & ".EV") = False Then
            QuitWithError "Could not save EV file " + BaseFileNameEvFile
    End If
    EvApp.CloseFile EvFile
End Sub
```

```
C The actual body of the script...
Dim File
Dim EvFile
Set EvFile = Nothing
For Each File In DataFileFolder.Files
    If StrComp(FSO.GetExtensionName(DataFilePath + File.Name), DataFileExt, vbTextCompare) = 0
Then
            ' We need a new EV file (haven't opened one, or we just closed it)
            If EvFile Is Nothing Then
                    Set EvFile = EvApp.NewFile(TemplateFile)
            End If
            EvFile.Filesets.Item(0).DataFiles.Add(DataFilePath + File.Name)
            If EvFile.Filesets.Item(0).DataFiles.Count >= NumberDataFiles Then
                    ' This file is full; any more data files are to be
                    ' added to a new file
                    SaveAndCloseFile
                    Set EvFile = Nothing
            End If
        End If
Next
If Not EvFile Is Nothing Then
    ' The last file needs to be saved and closed (wasn't full)
    SaveAndCloseFile
    Set EvFile = Nothing
End If
MsgBox "Script exiting successfully.", vbOk + vbInformation
```


## APPENDIX C: MANUAL VS. AUTOMATED FISH COUNTS

Table C1 - Number of manually detected fish tracks vs. the number of automated fish track detections, per Echoview file. Start time indicates when the file recording began, and end time indicates when the file recording ended. Duration indicates the total length of the file recording. Manual count was determined by having a trained individual count the number of fish they observed during the duration of a file recording. Auto count was determined using Echoview's Multibeam Fish Track Detection module. Due to the time consuming nature of manual fish counts, only a subset of all data files were manually counted.

| EV File Name | ID | Year | Month | Day | Start <br> Time | End <br> Time | Total Time | Manual Count | Auto Count | Notes |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{gathered} 2019-07- \\ 22 \_232000 \\ \hline \end{gathered}$ | 1 | 2019 | 7 | 22 | 23:20:00 | 23:29:59 | 0:09:59 | 7 | 8 |  |
| $\begin{gathered} \text { 2019-07- } \\ 22 \_212000 \end{gathered}$ | 2 | 2019 | 7 | 22 | 21:20:00 | 21:29:59 | 0:09:59 | 27 | 25 |  |
| $\begin{gathered} 2019-07- \\ 22 \_234000 \end{gathered}$ | 3 | 2019 | 7 | 22 | 23:40:00 | 23:49:59 | 0:09:59 | 3 | 0 |  |
| $\begin{gathered} \hline 2019-07- \\ 23 \_000000 \\ \hline \end{gathered}$ | 4 | 2019 | 7 | 23 | 0:00:00 | 0:09:59 | 0:09:59 | 1 | 0 |  |
| $\begin{gathered} \text { 2019-07- } \\ 23 \_043000 \end{gathered}$ | 5 | 2019 | 7 | 23 | 4:30:00 | 4:39:59 | 0:09:59 | 10 | 40 |  |
| $\begin{gathered} \text { 2019-07- } \\ 23 \_023012 \\ \hline \end{gathered}$ | 6 | 2019 | 7 | 23 | 2:30:00 | 2:39:59 | 0:09:59 | 17 | 23 |  |
| $\begin{gathered} \text { 2019-07- } \\ 23 \_182000 \end{gathered}$ | 7 | 2019 | 7 | 23 | 18:20:00 | 18:29:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \text { 2019-07- } \\ 24 \_210000 \\ \hline \end{gathered}$ | 8 | 2019 | 7 | 24 | 21:00:00 | 21:09:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} 2019-07- \\ 24 \_012000 \\ \hline \end{gathered}$ | 9 | 2019 | 7 | 24 | 1:20:00 | 1:29:59 | 0:09:59 | 7 | 74 |  |
| $\begin{gathered} \text { 2019-07- } \\ 24 \_042012 \\ \hline \end{gathered}$ | 10 | 2019 | 7 | 24 | 4:20:00 | 4:29:59 | 0:09:59 | 15 | 79 |  |
| $\begin{gathered} \text { 2019-07- } \\ 24 \_181012 \\ \hline \end{gathered}$ | 11 | 2019 | 7 | 24 | 18:10:00 | 18:19:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \text { 2019-07- } \\ 25 \_030000 \end{gathered}$ | 12 | 2019 | 7 | 25 | 3:00:00 | 3:09:59 | 0:09:59 | 6 | 7 |  |


| EV File Name | ID | Year | Month | Day | Start <br> Time | End <br> Time | Total Time | Manual Count | Auto Count | Notes |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{gathered} \hline 2019-07- \\ 25 \_220000 \end{gathered}$ | 13 | 2019 | 7 | 25 | 22:00:00 | 22:09:59 | 0:09:59 | 18 | 18 |  |
| $\begin{gathered} \text { 2019-07- } \\ 25 \_023000 \end{gathered}$ | 14 | 2019 | 7 | 25 | 2:30:00 | 2:39:59 | 0:09:59 | 8 | 12 |  |
| $\begin{gathered} \hline 2019-07- \\ 25 \_110000 \\ \hline \end{gathered}$ | 15 | 2019 | 7 | 25 | 11:00:00 | 11:09:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \hline 2019-07- \\ 26 \_032000 \\ \hline \end{gathered}$ | 16 | 2019 | 7 | 26 | 3:20:00 | 3:29:59 | 0:09:59 | 2 | 0 |  |
| $\begin{gathered} \text { 2019-07- } \\ 26 \_210003 \\ \hline \end{gathered}$ | 17 | 2019 | 7 | 26 | 21:00:00 | 21:09:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} 2019-07- \\ 26 \_221000 \\ \hline \end{gathered}$ | 18 | 2019 | 7 | 26 | 22:10:00 | 22:19:59 | 0:09:59 | 17 | 49 |  |
| $\begin{gathered} \hline 2019-07- \\ 26 \quad 202003 \\ \hline \end{gathered}$ | 19 | 2019 | 7 | 26 | 20:20:00 | 20:29:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \hline \text { 2019-07- } \\ 27 \_213003 \\ \hline \end{gathered}$ | 20 | 2019 | 7 | 27 | 21:30:00 | 21:39:59 | 0:09:59 | 24 | 22 |  |
| $\begin{gathered} \hline 2019-07- \\ 27 \_224000 \\ \hline \end{gathered}$ | 21 | 2019 | 7 | 27 | 22:40:00 | 22:49:59 | 0:09:59 | 27 | 119 |  |
| $\begin{gathered} \hline 2019-07- \\ 27 \_225000 \\ \hline \end{gathered}$ | 22 | 2019 | 7 | 27 | 22:50:00 | 22:59:59 | 0:09:59 | 15 | 60 |  |
| $\begin{gathered} \text { 2019-07- } \\ 27 \_125000 \\ \hline \end{gathered}$ | 23 | 2019 | 7 | 27 | 12:50:00 | 12:59:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \hline 2019-07- \\ 28 \_233000 \\ \hline \end{gathered}$ | 24 | 2019 | 7 | 28 | 23:30:00 | 23:39:59 | 0:09:59 | 14 | 116 |  |
| $\begin{gathered} \text { 2019-07- } \\ \text { 28_213000 } \\ \hline \end{gathered}$ | 25 | 2019 | 7 | 28 | 22:30:00 | 22:39:59 | 0:09:59 | 18 | 60 |  |
| $\begin{gathered} \hline \text { 2019-07- } \\ \text { 28_030000 } \end{gathered}$ | 26 | 2019 | 7 | 28 | 3:00:00 | 3:09:59 | 0:09:59 | 13 | 80 |  |
| $\begin{gathered} \text { 2019-07- } \\ 28 \_062000 \\ \hline \end{gathered}$ | 27 | 2019 | 7 | 28 | 6:20:00 | 6:29:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \hline 2019-07- \\ 29 \_223000 \\ \hline \end{gathered}$ | 28 | 2019 | 7 | 29 | 22:30:00 | 22:39:59 | 0:09:59 | 10 | 61 |  |


| EV File Name | ID | Year | Month | Day | Start <br> Time | End <br> Time | Total Time | Manual Count | Auto Count | Notes |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{gathered} \hline \text { 2019-07- } \\ 29 \_014000 \end{gathered}$ | 29 | 2019 | 7 | 29 | 1:40:00 | 1:49:59 | 0:09:59 | 11 | 128 |  |
| $\begin{gathered} \text { 2019-07- } \\ 29 \_023000 \\ \hline \end{gathered}$ | 30 | 2019 | 7 | 29 | 2:30:00 | 2:39:59 | 0:09:59 | 11 | 76 |  |
| $\begin{gathered} \hline \text { 2019-07- } \\ 29 \_193000 \end{gathered}$ | 31 | 2019 | 7 | 29 | 19:30:00 | 19:39:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \hline \text { 2019-08- } \\ 17 \_001000 \\ \hline \end{gathered}$ | 32 | 2019 | 8 | 17 | 0:10:00 | 0:19:59 | 0:09:59 | 3 | 30 |  |
| $\begin{gathered} \hline 2019-08- \\ 17 \_220000 \end{gathered}$ | 33 | 2019 | 8 | 17 | 22:00:00 | 22:09:59 | 0:09:59 | 6 | 42 |  |
| $\begin{gathered} \hline \text { 2019-08- } \\ 17 \_033000 \end{gathered}$ | 34 | 2019 | 8 | 17 | 3:30:00 | 3:39:59 | 0:09:59 | 5 | 10 |  |
| $\begin{gathered} \text { 2019-08- } \\ 17 \_094000 \\ \hline \end{gathered}$ | 35 | 2019 | 8 | 17 | 9:40:00 | 9:49:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} 2019-08- \\ 20 \_035000 \\ \hline \end{gathered}$ | 36 | 2019 | 8 | 20 | 3:50:00 | 3:59:59 | 0:09:59 | 13 | 30 |  |
| $\begin{gathered} \text { 2019-08- } \\ 20 \_232000 \end{gathered}$ | 37 | 2019 | 8 | 20 | 23:20:00 | 23:29:59 | 0:09:59 | 19 | 96 | In addition to holding, there is a fair amount of meandering in this file. Meandering also causes detection issues. |
| $\begin{gathered} \hline 2019-08- \\ 20 \_022000 \\ \hline \end{gathered}$ | 38 | 2019 | 8 | 20 | 2:20:00 | 2:29:59 | 0:09:59 | 9 | 12 |  |
| $\begin{gathered} \hline 2019-08- \\ 20 \_200000 \\ \hline \end{gathered}$ | 39 | 2019 | 8 | 20 | 20:00:00 | 20:09:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \hline 2019-08- \\ 22 \_234000 \\ \hline \end{gathered}$ | 40 | 2019 | 8 | 22 | 23:40:00 | 23:49:59 | 0:09:59 | 7 | 35 |  |
| $\begin{gathered} \hline 2019-08- \\ 22 \_225013 \\ \hline \end{gathered}$ | 41 | 2019 | 8 | 22 | 22:50:00 | 22:59:59 | 0:09:59 | 7 | 9 |  |
| $\begin{gathered} \hline 2019-08- \\ 22 \_223013 \\ \hline \end{gathered}$ | 42 | 2019 | 8 | 22 | 22:30:00 | 22:39:59 | 0:09:59 | 6 | 13 | holding and meandering |
| $\begin{gathered} \hline 2019-08- \\ 22 \_051000 \\ \hline \end{gathered}$ | 43 | 2019 | 8 | 22 | 5:10:00 | 5:19:59 | 0:09:59 | 6 | 26 | holding is the main problem |


| EV File Name | ID | Year | Month | Day | Start <br> Time | End <br> Time | Total <br> Time | Manual <br> Count | Auto <br> Count | Notes |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |


| EV File Name | ID | Year | Month | Day | Start <br> Time | End <br> Time | Total <br> Time | Manual <br> Count | Auto <br> Count | Notes |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :--- |


| EV File Name | ID | Year | Month | Day | Start <br> Time | End <br> Time | Total Time | Manual Count | Auto Count | Notes |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{gathered} \hline \text { 2019-09- } \\ 08 \_032000 \\ \hline \end{gathered}$ | 74 | 2019 | 9 | 8 | 3:20:00 | 3:29:59 | 0:09:59 | 11 | 11 |  |
| $\begin{gathered} \text { 2019-09- } \\ 08 \_125000 \end{gathered}$ | 75 | 2019 | 9 | 8 | 12:50:00 | 12:59:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \hline 2019-09- \\ 10 \_224000 \\ \hline \end{gathered}$ | 76 | 2019 | 9 | 10 | 22:40:00 | 22:49:59 | 0:09:59 | 5 | 58 | Single holding fish is main issue |
| $\begin{gathered} \hline \text { 2019-09- } \\ 10 \_230000 \\ \hline \end{gathered}$ | 77 | 2019 | 9 | 10 | 23:00:00 | 23:09:59 | 0:09:59 | 4 | 60 | Single holding fish is main issue |
| $\begin{gathered} \hline \text { 2019-09- } \\ 10 \_043000 \end{gathered}$ | 78 | 2019 | 9 | 10 | 4:30:00 | 4:39:59 | 0:09:59 | 4 | 23 | Single holding fish is main issue |
| $\begin{gathered} \text { 2019-09- } \\ 10 \_153003 \end{gathered}$ | 79 | 2019 | 9 | 10 | 15:30:00 | 15:39:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \text { 2019-09- } \\ 11 \_033000 \\ \hline \end{gathered}$ | 80 | 2019 | 9 | 11 | 3:30:00 | 3:39:59 | 0:09:59 | 3 | 6 |  |
| $\begin{gathered} \text { 2019-09- } \\ 11 \_035000 \\ \hline \end{gathered}$ | 81 | 2019 | 9 | 11 | 3:50:00 | 3:59:59 | 0:09:59 | 9 | 12 |  |
| $\begin{gathered} \hline \text { 2019-09- } \\ 11 \_230000 \end{gathered}$ | 82 | 2019 | 9 | 11 | 23:00:00 | 23:09:59 | 0:09:59 | 18 | 136 | A few holding fish causing the main detection issues |
| $\begin{gathered} \hline \text { 2019-09- } \\ 11 \_085000 \end{gathered}$ | 83 | 2019 | 9 | 11 | 8:50:00 | 8:59:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \hline \text { 2019-09- } \\ 15 \_213004 \\ \hline \end{gathered}$ | 84 | 2019 | 9 | 15 | 21:30:00 | 21:39:59 | 0:09:59 | 18 | 43 |  |
| $\begin{gathered} \hline \text { 2019-09- } \\ 15 \_020000 \end{gathered}$ | 85 | 2019 | 9 | 15 | 2:00:00 | 2:09:59 | 0:09:59 | 7 | 34 |  |
| $\begin{gathered} \hline \text { 2019-09- } \\ 15 \_040000 \end{gathered}$ | 86 | 2019 | 9 | 15 | 4:00:00 | 4:09:59 | 0:09:59 | 6 | 37 |  |
| $\begin{gathered} \text { 2019-09- } \\ \text { 15_144003 } \end{gathered}$ | 87 | 2019 | 9 | 15 | 14:40:00 | 14:49:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \hline \text { 2019-09- } \\ 19 \_044000 \\ \hline \end{gathered}$ | 88 | 2019 | 9 | 19 | 4:40:00 | 4:49:59 | 0:09:59 | 10 | 21 |  |
| $\begin{gathered} \hline \text { 2019-09- } \\ 19 \_004013 \\ \hline \end{gathered}$ | 89 | 2019 | 9 | 19 | 0:40:00 | 0:49:59 | 0:09:59 | 8 | 18 |  |


| EV File Name | ID | Year | Month | Day | Start <br> Time | End <br> Time | Total Time | Manual Count | Auto Count | Notes |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\begin{gathered} \hline \text { 2019-09- } \\ \text { 19_010013 } \end{gathered}$ | 90 | 2019 | 9 | 19 | 1:00:00 | 1:09:59 | 0:09:59 | 6 | 15 |  |
| $\begin{gathered} \text { 2019-09- } \\ 19 \_174000 \end{gathered}$ | 91 | 2019 | 9 | 19 | 17:40:00 | 17:49:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} 2019-09- \\ 21 \_043000 \end{gathered}$ | 92 | 2019 | 9 | 21 | 4:30:00 | 4:39:59 | 0:09:59 | 13 | 60 |  |
| $\begin{gathered} \hline \text { 2019-09- } \\ 21 \_003000 \\ \hline \end{gathered}$ | 93 | 2019 | 9 | 21 | 0:30:00 | 0:39:59 | 0:09:59 | 14 | 70 |  |
| $\begin{gathered} \text { 2019-09- } \\ 21 \_225000 \end{gathered}$ | 94 | 2019 | 9 | 21 | 22:50:00 | 22:59:59 | 0:09:59 | 8 | 17 |  |
| $\begin{gathered} \text { 2019-09- } \\ 21 \_131000 \end{gathered}$ | 95 | 2019 | 9 | 21 | 13:10:00 | 13:19:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \text { 2019-09- } \\ 23 \_045000 \\ \hline \end{gathered}$ | 96 | 2019 | 9 | 23 | 4:50:00 | 4:59:59 | 0:09:59 | 17 | 59 |  |
| $\begin{gathered} \text { 2019-09- } \\ 23 \_225000 \\ \hline \end{gathered}$ | 97 | 2019 | 9 | 23 | 22:50:00 | 22:59:59 | 0:09:59 | 11 | 88 |  |
| $\begin{gathered} \hline 2019-09- \\ 23 \_050000 \end{gathered}$ | 98 | 2019 | 9 | 23 | 5:00:00 | 5:09:59 | 0:09:59 | 6 | 61 |  |
| $\begin{gathered} \text { 2019-09- } \\ 23 \_184000 \end{gathered}$ | 99 | 2019 | 9 | 23 | 18:40:00 | 18:49:59 | 0:09:59 | 0 | 0 |  |
| $\begin{gathered} \text { 2019-09- } \\ 24 \_051000 \end{gathered}$ | 100 | 2019 | 9 | 24 | 5:10:00 | 5:19:59 | 0:09:59 | 10 | 21 |  |
| $\begin{gathered} \text { 2019-09- } \\ 24 \_003000 \end{gathered}$ | 101 | 2019 | 9 | 24 | 0:30:00 | 0:39:59 | 0:09:59 | 18 | 56 |  |
| $\begin{gathered} \text { 2019-09- } \\ 24 \_230000 \end{gathered}$ | 102 | 2019 | 9 | 24 | 23:00:00 | 23:09:59 | 0:09:59 | 20 | 66 |  |
| $\begin{gathered} 2019-09- \\ 24 \_090000 \end{gathered}$ | 103 | 2019 | 9 | 24 | 9:00:00 | 9:09:59 | 0:09:59 | 0 | 0 |  |

