DIDSON ABSTRACTS
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1. Title: Creation of river bottom profiles from a dual-frequency identification sonar (DIDSON) to reliably aim fish-counting sonars and a comparison with other profiling methods

Running Title: Creating river bottom profiles using DIDSON

Authors: Suzanne L. Maxwell and April V. Smith

Counting fish in rivers with fixed, shore-based sonars relies on carefully positioning the transducer to maximize detection. Relying only on reflections from the river bottom or targets to aim a sonar transducer may result in a beam angle that poorly detects fish. We developed a robust aiming protocol using the transducer's absolute tilt angle and river bottom profiles generated from standard and long-range dual-frequency identification sonars (DIDSONs). The DIDSON profiles compared well with profiles generated from range and depth measures or bathymetry methods when the river bottoms were linear, or changed from a steeper slope near shore to a flatter slope offshore. If the secondary slope was steeper, the DIDSON profile displayed shallower depths. Actual differences in depth between DIDSON profiles and profiles from other methods were often considerably less than the potential beam-spreading error. Maximum depth differences between the same DIDSON profiles marked independently multiple times ranged from 0.08 m for the DIDSON's highest frequency to 0.5 m for the lowest. A model of the fish-counting transducer beam was plotted in the same coordinate system as the river bottom profile. Excel macros enabled us to 'rotate' the beam and determine the optimal tilt angle for each river bottom profile. With these tools, an aiming protocol was developed to maximize fish detection. We have begun testing the vertically-positioned DIDSON to obtain vertical fish distributions, and mobile DIDSONs to obtain cross-river fish distributions. The aiming protocol and fish distributions will increase our confidence in fish counts obtained using the DIDSON technology.

2. Title: Evaluation of a Dual-Frequency Imaging Sonar (DIDSON) for Estimating the Size of Migrating Salmon

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Fixed-location, side-looking sonar techniques are often the only way to obtain in-season abundance estimates for anadromous fish stocks in rivers that are too wide for weir structures and too occluded for visual observations. One of the primary barriers to wider use of sonar assessment has been the difficulty in acoustically discriminating among fish species. Experiments were conducted with a DIDSON (Dual frequency IDentification SONar) acoustic system to evaluate the potential for estimating fish size from images of tethered and free-swimming fish in two Alaskan rivers. In the first experiment, DIDSON images were collected from six Chinook salmon *Oncorhynchus tsawytscha* and four sockeye salmon *O. nerka* tethered in the center of the DIDSON's multibeam array. In the second experiment, 130 Pacific salmon *Oncorhynchus* spp and Dolly Varden *Salvelinus malma Walbaum* were allowed to swim freely through the DIDSON multibeam array after being released from a weir live-box. DIDSON length measurements differed greatly depending on whether they originated from tethered or free-swimming fish. Length estimates from DIDSON images of tethered fish were subject to a positive bias that increased with range of the fish from the transducer (approximately 1.3 cm/m of range). Measurements from free-swimming fish did not demonstrate the same size bias with range. Given that DIDSON measurements of free-swimming fish were not subject to substantial bias, we conclude that reasonably good estimates of fish length can be extracted from DIDSON images of free-swimming fish at close distances (<12 m) in the high frequency (1.8 MHz) mode.

3.Title: Use of dual frequency identification sonar to estimate adult salmon escapement in the Secesh River, Idaho: an Endangered Species Act application.

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Abstract: Dual Frequency Identification Sonar (DIDSON) was experimentally tested in the Secesh River to monitor adult escapement in a wild salmon population. DIDSON technology provided a passive method that avoids incidental trapping and handling mortality of this threatened species. High frequency DIDSON sonar files that sampled the entire water column were continuously collected in the Secesh River during the salmon migration period. DIDSON estimated salmon escapement at the Secesh River monitoring site, with 95% confidence intervals in parenthesis were: 914 salmon (± 194) in 2004, 336 salmon (± 59) in 2005, and 209 salmon (±24) in 2006. To obtain accurate and precise escapement information it was crucial to adjust the raw daily salmon passage data. DIDSON generated salmon escapement estimates in 2005 and 2006 would have been positively biased by 53.3% and 20.7% without adjustment for file reader error and CSOT processing error. Validation monitoring occurred over the three year period through use of underwater optical cameras to determine whether fish targets identified by the DIDSON technology were actually salmon. A subsample of days revealed that 1,470 optical camera recorded salmon passages were observed in the validation zone, and all of the passages were recorded as salmon during DIDSON file review.

4. Title: Development of Efficient Tracking Software for Fish Counting and Sizing with DIDSON Imaging Sonar

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Abstract: Recent development of the DIDSON imaging sonar system has found applications in monitoring and estimating abundance of salmon stocks in some major salmon production rivers in North America. Fish are generally visually identifiable in the resulting images from the system, and manual counting of imaged fish is feasible when dealing with a small amount of image data. Also possible is the visual measurement of fish size from DIDSON images via a user interface. Yet these manual operations become very labor intensive when processing a large amount of data, and in this case, the ability to perform these tasks with some automation is highly desirable. Automatic processing of DIDSON image data is considered very challenging, but is not impossible. Here we present a software system that allows automatic counting of fish with DIDSON data. The system has been tested with DIDSON data collected in the lower Fraser River in British Columbia and shows considerable promise. In addition, this system also allows the user to measure individual fish size with some automation. We will discuss the potential and limitations of the software at the present status, and new developments currently underway for improving the software.

5. Oral or Poster: Oral preferred; poster acceptable
First Topic Choice for Contributed Session: Marine Fish Ecology
Second Topic Choice for Contributed Session: Communities and Ecosystems

Title: Electronics in the prop-roots: application of multi-beam sonar and stereo video for fish community data collection in mangroves

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Abstract: Visual surveys have become the most commonly used method for estimating fish abundance and diversity in coral reef environments, and more recently in adjacent environments such as mangroves. Limitations associated with visual surveys (e.g., restricted to daylight hours and non-turbid conditions) have resulted in a potentially incomplete assessment of fish community assemblages. We examine the utility of a dual frequency, multi-beam sonar system (DIDSON) and a stereo-video system for underwater fish community assessment in mangrove environments. Under low-turbidity conditions, both systems provided similar fish length estimates; under high-turbidity conditions, DIDSON estimates were unaffected, but stereo-video produced smaller estimates. Stereo-video resulted in lower estimates of abundance, relative to DIDSON, in clear and turbid mangrove conditions. Both techniques resulted in the ability to collect fish community data at night. During both day and night DIDSON enabled the quantification and measurement of fish swimming within the prop roots of mangroves that were not visible or detected with stereo-video (or visual surveys). We demonstrate the applicability of DIDSON in surveying for a protected species (goliath grouper *Epinephelus itajara*) and of both systems for assessing predator use (including sharks) of mangrove environments. We discuss the benefits and limitations of each method for assessing fish communities.

6. Title: The practice of counting fish with DIDSON over a 3-month period -- How to find 1,400 fish in 2 Terabytes of data.

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Abstract: Development in hydroacoustic sampling gear often precedes data analysis software development and the DIDSON multibeam sonar follows this paradigm. A DIDSON multibeam sonar system was used in Mill Creek, California to enumerate Chinook salmon passage March through June 2006. The system collected over 1821 hours resulting in 2.1 Terabytes of data. This large dataset precluded us from visually reviewing the DIDSON images, and our expectation of a small number of salmon over the 3-month period, with no preliminary information on the temporal distribution, made us uncomfortable subsampling. Our analysis procedure in-season was to generate fish tracks from the image data, and review only those time periods when tracks occurred to confirm the tracks met our criteria for salmon. We feel that the data analysis procedure can evolve further. We propose collecting 100% of the data, and generating a second dataset with the selective recording option in the DIDSON software. We will store 5 to 10% of the original dataset for visual counting, but process the selectively recorded dataset. This procedure would result in a 77% reduction in the size and the time required for analysis of the Mill Creek dataset with a small but measurable loss in efficiency.

7. Title: Classifying acoustic targets using DIDSON images -- How to distinguish eels from debris

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Abstract: The purpose of this study was to test the feasibility of developing a hydroacoustic monitoring system for the automatic detection of downstream migrating adult eels. We used a DIDSON multibeam sonar to record the movement of acoustic targets. Visual inspection of the DIDSON acoustic video allowed confident identification of eels out to a maximum range of 20 m. The unique shape and swimming motion of eels and the fact that DIDSON images have enough resolution to show these characteristics make this dataset a good candidate for the development of a classification algorithm. The challenge we faced was that the algorithm needs to be able not only to positively identify eels, but also be accurate enough to reject more than 99% of debris and other targets, which outnumbered eels by a ratio of ~100:1. The key step was to identify features of the DIDSON images that quantified the size, shape and motion of the detected targets and find image processing techniques that enhanced eel-specific characteristics. These features were then used in a pattern recognition program, which calculated each target's probability of membership in two categories: eels and non-eels. The outcome was compared to the results obtained by visual identification.

8. An analysis pathway for obtaining fish size and abundance estimates from DIDSON data

K.M. Boswell, M.P. Wilson, and J.H. Cowan

We present an analysis of several techniques for processing dual-frequency identification sonar (DIDSON) data within the existing Echoview framework. Our objectives were to develop a semi-automated analysis pathway to reduce the effort of counting and measuring fish targets and to obtain estimates of basic target information (e.g. size, abundance, speed, and direction of travel). Analyses were conducted on DIDSON data collected at three different locations (Kenai River, AK; Mobile River, AL; and Port Fourchon, LA) with different equipment and deployment configurations. We integrated both image and acoustic analysis techniques to yield an efficient post-processing approach that can be applied to a variety of data sets, independent of user and deployment method. Estimates of fish abundance were consistent when comparing between methods presented. Mean fish size, direction and speed of travel, and target surface were derived for each data set analyzed. Estimates of fish size and surface area can be used to calculate fish biomass while direction and speed of travel can provide information on fish behavior and associations with ensonified habitats. Results further demonstrate the usefulness of DIDSON technology in fisheries applications.

9. Dual Frequency Identification Sonar Opening a Door to Fishing Opportunities on Anchor River Chinook Salmon through Careful Management for Sustainability

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A Dual Frequency Identification Sonar (DIDSON) has enabled fisheries managers for the first time to estimate the Chinook salmon *Oncorhynchus tshawytscha* escapement on the Anchor River, resulting in more fishing opportunities. While before the DIDSON was used, aerial surveys were used to index escapement and fishing opportunities were becoming more restrictive. The Anchor River is located on the Kenai Peninsula in Alaska and supports the largest native Chinook salmon return in the Lower Cook Inlet Management Area. We have used a DIDSON since 2003 to collect Chinook salmon escapement counts during May and June, when conventional weir methods are prohibited due to high river discharge. Beginning in 2004 the DIDSON was replaced with a full weir when river discharge became favorable. The resulting escapement estimates are higher than anticipated, ranging between nine and twelve thousand during 2003-2006. Fresh water harvests during the same period have been less than two thousand, with exploitation rates less than 11%. The sport fishing season was extended by one weekend from 2004 to 2006. Because our objective has always been to manage the fishery to ensure sustainable yield, cautious liberalization of sport fishing regulations is proposed as we develop an escapement goal for Anchor River Chinook salmon.

10. Title: Using DIDSON (dual-frequency identification sonar) as a tool to estimate steelhead (*Oncorhynchus mykiss*) escapement in a small coastal basin in Central California

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Steelhead (*Oncorhynchus mykiss*) in central and southern California are listed as Threatened and Endangered under the Endangered Species Act. Obtaining escapement estimates is critical for the recovery planning process. Population estimates are difficult to obtain due to the rare and widely-spaced nature of steelhead in these regions and turbid stream conditions typical during winter spawning. These factors make traditional escapement surveys impractical and require complete censuses of the populations be made. We are using DIDSON to determine the feasibility of monitoring adult steelhead migration in Big Creek (Monterey County, California) in an attempt to estimate escapement. DIDSON produces high-quality images in turbid water, which allows for detection and enumeration of fish, as well as estimation of fish size and swimming direction. Images were recorded continuously over the entire steelhead run season, January through April 2007. Over 3000 gigabytes of data were generated, stored and analyzed. The DIDSON software feature 'Convolved Samples over Threshold' was used to shorten large file sizes to a smaller subset of frames during which movement was detected, significantly reducing the time required to review files manually. We will present our findings from the 2006-07 season, including escapement estimates, observer error and efficiency of data analysis tools.

11.Title: Comparison of split-beam and DIDSON hydroacoustic gears for conducting sturgeon Surveys

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Abstract: Population estimates are valuable for managing fisheries and assessing the status of rare species. In large rivers, one common approach for estimating population size of anadromous fish is to count upstream-migrating fish at a fixed site, using split-beam hydroacoustic equipment. Echoes produced as a fish passes through the beam can be used to estimate fish size, range, position in the water column, speed and direction of movement. One disadvantage of split-beam transducers is that they provide no information about species identification. A newer technology that can be used to count upstream migrants is the DIDSON, a high-definition imaging sonar that provides near-video quality images. When used at a range of 5-10 m, video files clearly show body shape including fin placement, size, and swimming behavior of individual fish. In hatchery pond experiments, two size classes of Atlantic sturgeon were differentiated with a high degree of certainty using split-beam and DIDSON technologies. Split-beam gear provides more precise information about fish position, but DIDSON data are much easier to interpret, can be used to identify sturgeon to genus, and allow for on-screen measuring of fish lengths. Initial field trials showed potential for utilizing these technologies to determine habitat, identify sturgeon, and estimate densities.

12. Title: Using a DIDSON Ultrasonic Imaging Sonar in a Groundfish Trawl

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Abstract: Underwater observations of fish behavior, in proximity to fishing gear, submersibles, ROVs, and other research tools, may be confounded by the presence of artificial visible light. The DIDSON, ultrasonic imaging system provides an image of both fish and surrounding structure without the use of artificial light in live-viewing or autonomous modes. We tested a DIDSON sonar in a selective flatfish bottom trawl to learn whether it could provide a clear view of fish behavior and net structure. A novel mounting frame design provided a stable platform for ultrasonically imaging areas in front of and in the mouth of the trawl (e.g., footrope, headrope, wings, mud cloud). We obtained images of large portions of the trawl, and of fish movements in relation to the gear, up to 17 m from the sonar. Video cameras were used simultaneously, and the resulting paired images were used to confirm which species were observed on the sonar. The strengths of the new sonar are increased viewing range and the ability to see beyond moderate turbidity and obstacles. The weaknesses are insufficient resolution to reliably identify species and the limited ability to distinguish fish in close proximity to the bottom when both are in relative motion.

13. Title: The sensitivity of clupeids to a high resolution imaging SONAR: Acoustic monitoring of shad just got harder.

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Abstract: This paper describes some unusual responses of an anadromous species of clupeid in a riverine environment to a sonar system transmitting sound at 1.8 MHz and 1.1 MHz. It establishes that only twaite shad, Alosa fallax fallax were able to detect these transmissions and that these responses were not replicated in a "closed", captive environment.

In 2005 and 2006, shad were monitored at two different sites on the River Wye in Wales, using an imaging sonar system (the Dual Frequency Identification Sonar or DIDSON) operating at both 1.1 and 1.8 MHz. The data revealed that shad repeatedly and consistently swam away from the DIDSON transducer, changing direction as they moved upstream by between 45 and 90 degrees as they approached the centre beams. This is shown to be directly attributable to the DIDSON transmission. The behavioural characteristic observed could be described as mild avoidance rather than the startle and flee response observed during 200 KHz transmission. Data collected clearly indicates twaite shad are capable of detecting a directional pulsed sound generated by an imaging sonar system operating at both 1.1 MHz and 1.8 MHz in a natural river environment.

To examine fish behaviour in a controlled environment, shad were captured and
This reaction to 200 KHz occurred, although with variable intensity, across a range of power and pulse rate combinations.

14. Title: Automated tracking of fish in trawls using a dual-frequency identification sonar (DIDSON)

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Abstract: An automated method to track individual fish using a dual-frequency identification sonar (DIDSON) was developed and tested on observations taken in midwater trawls. This process consists of target detection and isolation at each observation instance, multiple target tracking across time, and the estimation of behavioural parameters from the track data such as target speed and direction. The automated algorithm was evaluated by comparison with manually derived tracks as a validation standard. Three test-data sets with different target sizes, observation ranges, and densities were compared. In two data sets where the targets were less dense and smaller, the automated tracking performed well compared to the case where targets were dense and appeared large due to the shorter observation range. Target speed and direction, derived from the tracking data, showed good agreement between the manual and automatic methods for all three test cases. In an ongoing study of survey gear selectivity, automated tracking is being used to quantify escapement behaviour of walleye pollock (Theragra chalcogramma) in a midwater trawl. Some preliminary results from this study are presented.

15. Title: Observations of avoidance behavior of migrating salmon using dual-frequency identification sonar (DIDSON)

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Abstract: Use of vessel-based mobile acoustic surveys to estimate fish abundance in rivers and lakes is subject to potential bias due to avoidance behavior of the fish. To quantify the impact of such bias on the estimation, we must utilize effective tools and methods that enable us to observe and quantify avoidance behavior fish may exhibit in response to the presence of a survey vessel. In this paper, we present sonogram images obtained with a dual-frequency identification sonar (DIDSON) system from a vessel-avoidance experiment conducted during the 2005 salmon migration season in the lower Fraser River. These images captured detailed avoidance behavior of upstream migrating adult sockeye and pink salmon in response to a mobile echo sounding vessel. The information revealed by the image data allowed for a quantitative analysis of behavioral responses of fish to the vessel as it approached the fish in near-shore shallow water areas where heavy migrations took place.

16. Title: Effectiveness of Light and Sound Behavioral Deterrent System for the Reduction of Fish Impingement

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Abstract: Alabama Power Company and the Electric Power Research Institute (EPRI) have pursued a cooperative research effort in order to test the efficacy of a light and sound fish deterrent system at Plant Barry, Alabama for the reduction of fish impingement. A full array of light and sound deterrents were installed in Units 4-5 cooling water intake structure (CWIS) during the spring of 2006. This system was designed so that the approach bay immediately upstream from the entire CWIS could be affected by both of the light and sound deterrents. The evaluation of the effectiveness of the deterrents was two-fold: (1) perform conventional impingement collection from traveling screens and (2) utilize hydroacoustics monitoring techniques (split-beam and multi-beam sonar). The traditional impingement collection data showed no significant reduction in impingement with the deterrent system on. In addition, the hydroacoustics data supported the impingement data. The split-beam sonar (Biosonics DTX), located in the intake screen pit, did not show a significant difference in fish density with or without the operation of the deterrent system. The multi-beam sonar (DIDSON), located in front of the CWIS trash racks, also did not show a significant difference in fish counts with or without the deterrent system.

17. Title: Using a Dual Frequency Identification Sonar (DIDSON) to enumerate the spawning migration of kokanee salmon into the Metolius River, Oregon.

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Kokanee salmon *Oncorhynchus nerka* in the Lake Billy Chinook / Metolius River system in Central Oregon support an important sports fishery, and may be used to develop an anadromous population of sockeye salmon in the Deschutes River. However, managers have been unable to obtain estimates of spawning adult escapement of desired accuracy and precision. In 2006, we tested the use of a long range Dual Frequency Identification Sonar (DIDSON-LR™, Sound Metrics Corp) to estimate spawning escapement. The DIDSON-LR was deployed in the Metolius River near its confluence with Lake Billy Chinook, and files were recorded between September 5 and November 4. Counts of in-migrating fish were obtained from a sample of these files, concentrated on the first 3-5 hours after sunset, after it was observed that the majority of kokanee migrated during these hours. Images on the files were identified as kokanee based on size and behavior. We observed that kokanee tended to move in groups of 10-30 fish or more, and preferred the shallow side of the river where the current was less strong. The sample counts were expanded to produce estimates of hourly, daily, and total escapement. Plans are underway to repeat this sampling in 2007.