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## **SAVEWS Jr. User's Manual, Version 1.0**

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### **Introduction**

Automated processing of digital echo sounder data has proven to be useful for depth and canopy characterization in beds of submersed aquatic vegetation (SAV). The first version of this capability, SAVEWS (Submersed Aquatic Vegetation Early Warning System), released in 2001<sup>1</sup>, required an expensive calibrated scientific echo sounder that was beyond the financial means of many resource agencies. Consequently, the system was underutilized by agencies that would have benefited from SAVEWS data. Since then, consumer-grade marine electronics have advanced to the point they have many of the same features as the high-cost scientific echo sounders for a fraction of the cost. We surveyed the low-cost marine electronics market and selected a widely used echo sounder/GPS system (HDS-x, Lowrance Electronics, Tulsa, OK) with digital recording capability that we considered a good candidate for automated processing. The primary difference between this effort and the previous SAVEWS code is that the low cost systems are not calibrated and simultaneously use two different frequencies. This necessitated a fundamentally different approach to the processing. The signal processing code we developed was necessarily written around the data formats and characteristics of the Lowrance HDS system. Selection of this system does not constitute endorsement by the government. Potentially, other vendor's equipment could also be used although required code modification may be significant. The current version of the processing software is written in MatLab to facilitate rapid code development, at the expense of slightly slower execution times. As the code matures we will either optimize the final MatLab version for faster execution or rewrite it in a different language. These modifications will correspond to subsequent software releases beyond version 1.0.

<sup>1</sup> Sabol, B., R.E. Melton, R. Chamberlain, P. Doering, and K. Haurert. 2002. Evaluation of a digital echo sounder for detection of submersed aquatic vegetation. ESTUARIES 25(1):133-141.

This user's manual describes components, assembly, system configuration, data collection procedures, and data processing. Our goal is to make this a stand-alone technology that can be operated by scientists and field personnel involved with SAV mapping. The system uses two frequencies (200-and 800-kHz) from a downward-aimed echosounder. These are processed to determine the bottom depth, presence/absence of SAV, and if present, to estimate the canopy height and vegetation percent coverage. The key to processing acoustic data for SAV is to correctly locate the bottom, particularly when SAV is present. Using two frequencies resulted in better bottom tracking relative to the earlier 1-frequency SAVEWS. Once collected, the digital data (Lowrance proprietary .SL2 files) are displayed, using the SAVEWS Jr. software. The user will then select a configuration file that is appropriate to the environment sampled. This file will set a host of algorithm parameter values used within the software. We provide a general version of this file with the installation software. This will serve as a starting point for users to develop their own customized files. We provide some examples of how configuration files are set and we can provide assistance in developing these files in particularly difficult cases.

After initial processing, a display of classified output (bottom depth and canopy top) is superimposed on the colorized echogram for review by the user. This is aligned with data plots of canopy height and percent coverage. The user then ascertains whether these outputs reasonably represent conditions evident in the colorized echogram file. If not, then the file can be rerun after selecting different configuration values. Beyond quality assurance graphics, the primary output is the .SDF file (SAVEWS data file) which is an ASCII, comma delimited file containing position referenced classified output. This can be used directly in statistical analyses or mapping software. All steps in this process are described in the following sections.

## **Components**

Required components for the SAVEWS Jr system are listed in Table 1 and illustrated in Figures 1 -3. All except the external GPS and its supporting network cable are mandatory. This set of components allows a relatively wide-beam 200 kHz and the narrow-beam downlooking 800 kHz (or 455 kHz) signal to be simultaneously collected. The HDS system has an internal GPS but the external GPS provides greater positional accuracy and data rate, and allows the antenna to be positioned independent of the HDS system. This makes it possible to position the GPS antenna directly over the transducer and to more precisely navigate planned transects since the output rate is five times as fast resulting in less lag in navigation guidance.

**Table 1.** Hardware components required for SAVEWS Jr.

Component	Description	Part #A	Costs	Note
Echo sounder with internal GPS system	Lowrance HDS-10 (or HDS-7 or 8 w/ smaller screen and lower cost) with 200 KHz (20-deg) skimmer transducer with built-in temperature sensor	000-0140-00	\$2,500	Available from multiple sources
SDHC cards	8 GBytes			
External SDHC card reader				If not on PC
Side scan transducer	Lowrance 132-06 StructureScan Sonar option for HDS with 455 and 800 KHz transducers	LSS-2	\$600	
External GPS	Lowrance High sensitivity GPS Receiver Antenna w/ N2K cable and T connectors	LGC-4000-CE (000-0125-28)	\$200	
A. <a href="http://store.navico.com">http://store.navico.com</a> part numbers B. Approximate cost as of May 2012				

**Figure 1.** Lowrance HDS-10 console and 200 kHz skimmer transducer.





**Figure 2.** StructureScan sonar and transducer.



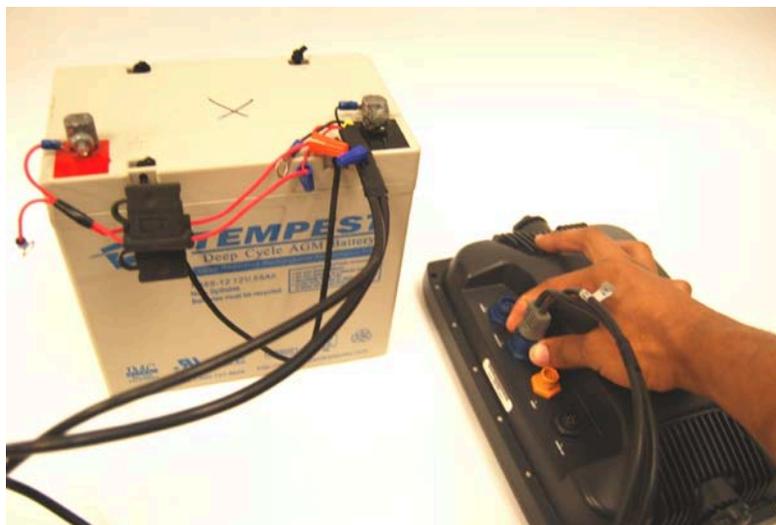
**Figure 3.** External GPS antenna and cabling.

## Installation, Setup, and Operation

We provide a brief set of instruction for equipment setup. Users are encouraged to download and read detailed installation and setup instructions available for each recommended component from the Lowrance website ([www.Lowrance.com/en/Downloads/Manuals/](http://www.Lowrance.com/en/Downloads/Manuals/)). Transom mounting, as suggested in the Lowrance manual, is very convenient because the transducers are permanently affixed to the boat and the only thing needed to conduct a survey is a fresh SDHC data card. However, two problems can be created with this technique: 1) the side lobe of the Structure Scan can “see” the lower unit of the outboard motor, if not trimmed properly, creating an artifact in the recorded data, and 2) the two transducers are not laterally aligned, therefore they sample different bottom areas during data collection. If not yet installed, we encourage users to consider another mounting technique, such as the transducer mount system illustrated in Figure A5, mounted on the bow. Instructions for assembling the entire system in a self-contained field-portable container, ideal for rapid deployment to any boat, are contained in Appendix A. The advantage of this self-contained unit is that it will not be necessary to do any assembly or connections each time the system is used.

## Connecting components:

- 1) Connect HDS power cable to the blue PWR/DATA plug on back of HDS (Figure 4) and a +12V battery. Recommend avoiding cigarette lighter connectors as they can flicker requiring that the entire system be reset.
- 2) Connect skimmer transducer cable to blue SONAR plug on back of HDS (Figure 5).
- 3) Connect StructureScan power cable to 12V source and to black POWER plug on back of LSS-2 sonar module (Figure 6). Make sure yellow wire on StructureScan power cable at battery is connected to yellow wire on HDS power cable at battery (Figure 7). This will allow the StructureScan to be turned on with the main HDS power button.
- 4) Connect StructureScan transducer cable to black SONAR plug on the back of the LSS -2 sonar module (Figure 8).
- 5) Connect the communication link between the LSS-2 sonar module and the HDS. The cable with the yellow plugs gets connected to ENET port #1 on the LSS -2 module and the yellow ENET plug on the back of the HDS (Figure 9).
- 6) Connect pre-configured GPS network cable (see Lowrance NMEA 2000 Network Installation Instructions [[www.lowrance.com/Downloads/Manuals](http://www.lowrance.com/Downloads/Manuals)]) to GPS antenna and to black NMEA 2K plug on back of HDS (Figure 10).
- 7) Attach power connections on pre-configured GPS network cable to battery.
- 8) System components are now correctly connected. Before proceeding to next step (power up and configuration) submerge the transducers in water. While this step is not required by Lowrance, it is a generally recommended practice to protect hydroacoustic transducers from damage.



**Figure 4.** Connecting power to HDS console.



**Figure 5.** Connecting skimmer transducer cable to HDS console.



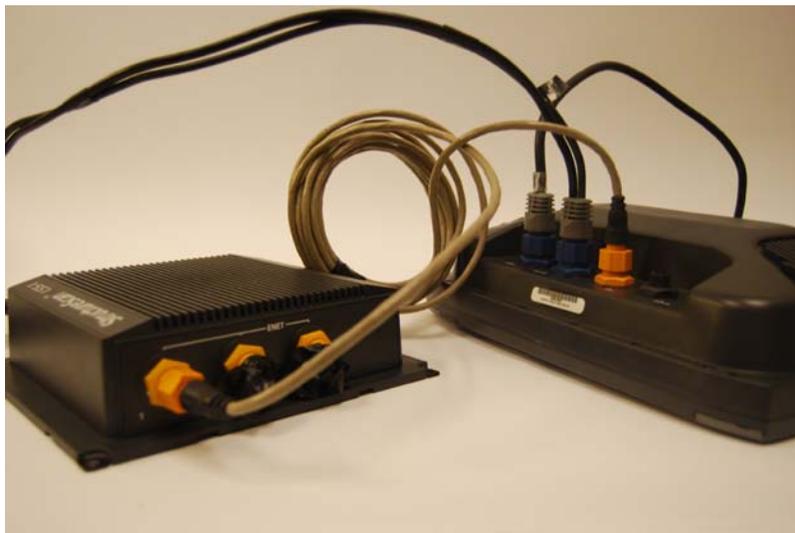
**Figure 6.** Connecting power to LSS-2 sonar module.



**Figure 7.** StructureScan power cabling; note connected yellow wires.



**Figure 8.** Structure Scan transducer cabling.



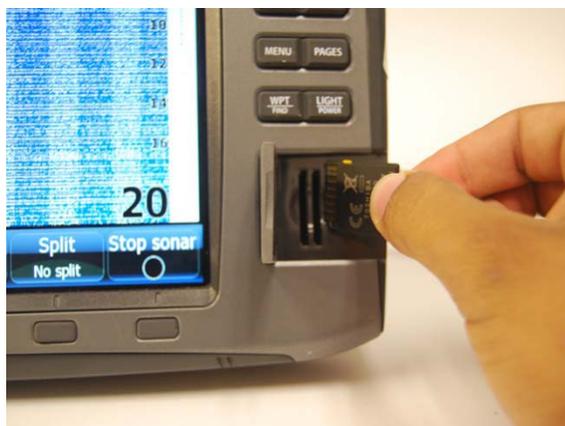
**Figure 9.** Connecting LSS-2 sonar module with HDS.



**Figure 10.** Connecting external GPS to HDS.

**System power-up and memory card insertion:**

- 9) All configuration required to initialize the system for use is performed from the HDS console (Figure 1).
- 10) Power on the HDS by pressing LIGHT/POWER button on lower right corner of HDS front
- 11) Dismiss warning (button on bottom row under “Accept”)
- 12) Insert one or more SDHC memory cards into the slots under door at lower right of HDS front (Figure 11). Card #1 goes on right and card #2 goes on left, with notch side down.
- 13) Press “Pages” button on right side of HDS face
- 14) Use multi-directional pad to page over to “Waypoints, routes, trails” then move to “Files”
  - a. Press Enter button on right side of HDS
  - b. Make sure memory card(s) is recognized by HDS. Card listings will be at the top of the screen. If a card is not listed, eject and reinsert until HDS recognizes the card.
- 15) Press Exit on right side of HDS. Memory card(s) are now inserted and ready to receive data.



**Figure 11.** Inserting memory card (notch down)

## System configuration:

### 200 kHz transducer

- 16) Press “Page” then scroll over to top heading “Sonar”, then down to subheading “Sonar”; press Enter. Sonar echogram display will be activated.
- 17) Press Menu (right side of HDS)
  - a. Set “Range” to maximum depth expected in survey (system actually records to twice user-set depth), **do not use Auto Range for recording**
  - b. Set “Frequency” to 200 KHz
  - c. Set “Ping Speed” to 10
  - d. Click (press Enter) at “Sonar Options”
    - i. Fish ID – off
    - ii. Fish ID beeps – disabled (circle not filled in)
    - iii. Click “Exit” to return to Sonar window
  - e. Click on “Settings” at bottom of menu
    - i. Press Enter
    - ii. Go to “Sonar” (press Enter) and configure as follows
      1. Network Sonar – enabled (circle filled in)
      2. Noise Rejection – off
      3. Surface Clarity – off
      4. Manual Mode – enabled (circle filled in)
      5. Fishing Mode – general use
- 18) Press “Exit” twice
- 19) Verify that sonar is in operation (data scrolling), if not scrolling make sure “Stop sonar” is not highlighted. Transducer configuration is now complete.

### StructureScan transducer

- 20) Press “Pages” button on right side of HDS face
- 21) Use multi-directional pad to page over to “Structure”, then down to “Structure and Sonar”, press Enter. Verify sidescan echogram is on and scrolling on the screen. If it is not, make sure SONAR STOP (from Menu) has not been activated. If still no scrolling, recheck cabling and battery power.
- 22) Press Menu then configure as follows:
  - a. Set RANGE to expected maximum depth (**do not use Auto Range for recording**)
  - b. Set FREQUENCY to 800 kHz.
  - c. Set VIEW to Down.
  - d. Press Structure options, then configure as follows:
    - I. Set Structure surface clarity to OFF
    - II. Set Structure noise rejection to OFF
    - III. Press EXIT twice to return to data screen
- 23) Configuration complete, press Exit on right side of HDS

### External GPS

- 24) On the HDS panel press MENU, then SETTINGS, then NETWORK, then Device List to verify that HDS recognizes external GPS (LGC4000 High Sensitivity Antenna). If LGC 4000 not listed on device list, recheck connections. Then EXIT

- 25) Go to MENU/SETTINGS/NETWORK/DATA SOURCE SELECTION/GPS (right arrow)/ALL DATA (right arrow). Highlight either AUTO (selects strongest GPS signal between internal and external GPS), or LGC4000 (uses ONLY external antenna). The press SELECT followed by CLOSE.
- 26) GPS output and healthy status can be seen by going to MENU/SETTINGS/SYSTEM/SATELLITES.
- 27) Suggest positioning GPS antenna directly over StructureScan transducer.

### Recording:

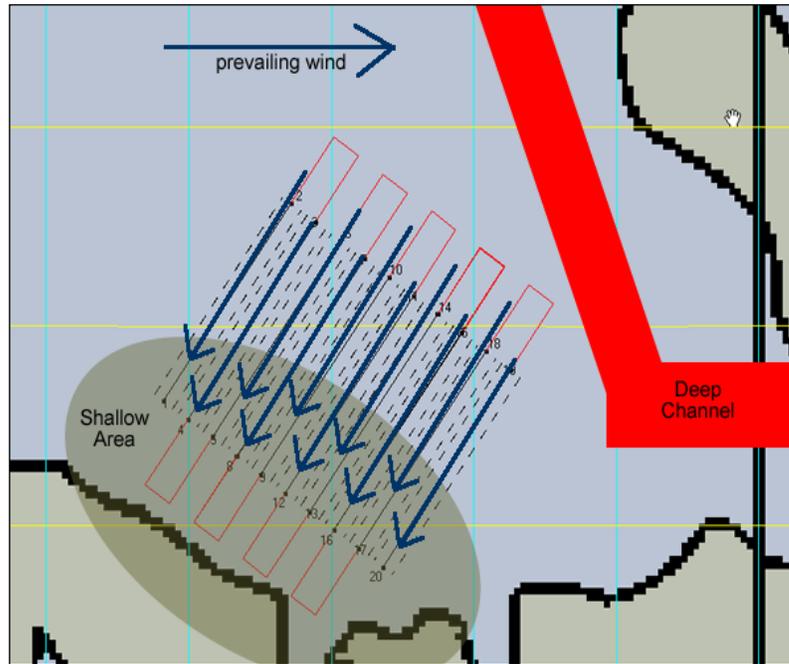
- 28) To begin recording:
  - a. Press “Menu”
  - b. Go to “Log Sonar”, press Enter
  - c. Set up recording session (HDS will reset options if the steps are not followed in this order)
    - i. Choose save location (Memory card 1 or 2, **NOT Internal**)
    - ii. Set “Bytes per sounding” to 3200 (we are investigating algorithm response to lower data rates, but version 1.0 requires the full 3200 bytes per sounding).
    - iii. Select “Log all channels”. This will record the 200 kHz skimmer, and all three channels of the StructureScan transducer (left, right, and down), using the frequency selected in step 21 b). An .sl2 file will be generated. It is OK to use the default file names offered by the HDS system – SONARxxxx. These file names will need to be renamed, using a date/time format as described later, before processing is done (see section **Data File Naming Convention**).
    - iv. Press Record to begin recording session
    - v. WRITE FILENAME, MEMORY CARD NUMBER, AND TIME/DATE IN FIELD BOOK (for use in renaming files)
- 29) Stop recording by pressing “Stop” twice
- 30) At end of recording session verify that files are present
  - a. Go back to “Waypoints, routes, files” from steps 13 and 14
  - b. Go to “Files”
    - i. Select the Memory card number used to store files
      1. Verify file presence
      2. View file if desired
        - a. Sensitivity parameter on far left of bottom row of buttons may need adjusting before data will appear
- 31) Press Exit twice
- 32) Shutting down: Press “Light/Power”
- 33) Select Power Off and Press Enter

## Designing and Conducting a Survey

A successful operational SAV survey requires some preliminary planning. The user should select a series of parallel transects, at some fixed spacing, to be surveyed. We have found that it is best to orient transects roughly perpendicular to the local depth contours (or shoreline) when there is considerable depth variation in the survey area. This orientation very precisely determines the depth at which SAV first occurs and make for more accurate maps when spatial interpolation (gridding) is involved. Points needed to define these transects should be determined and entered into the HDS as GPS waypoints (see section **Setting Waypoints**, ahead). Each transect can be specified by 2 points (beginning and ending points), or 3 collinear points (line up point, begin recording point and end recording point). The CHART capability of the HDS can be used to select these points and to navigate transects. During the survey the operator should manually record filenames, transducer depth, and times and dates associated with each logged file. This will be needed in post-processing to correct for tides and generate files ready for GIS mapping. A example datasheet for logging such information is contained in Appendix C. If operating in a tidally influenced area a measured time history of tides relative to the local vertical reference (usually Mean Lower Low Water – MLLW) will also be needed. Tidal measurements will need to be collected before, during (at least once an hour), and after the survey for each site. Vertical tidal references should be identified during the survey site selection stage.

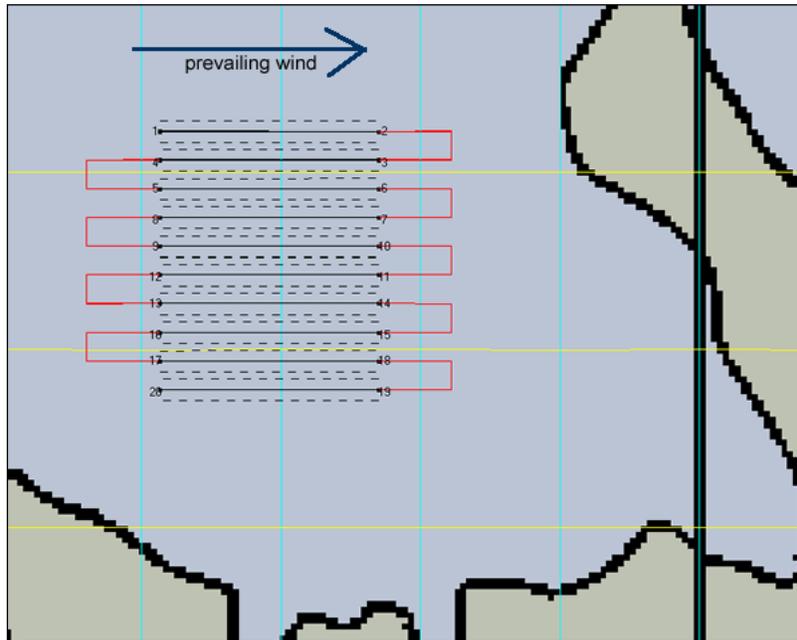
We also suggest that transects should not be too long. Using the required settings, data accumulates at a rate of 8 Mb/minute, thus a 5 minute transect will result in a 40 Mb .SL2 file. Shorter files have several advantages. First, long recording sessions are more susceptible to data loss, such as from a power flicker. Second, it will probably be necessary to process a file multiple times before the optimum configuration parameters are determined. Shorter files will save time here. Lastly, the algorithm dynamically computes thresholds needed for processing based on the acoustic conditions of the individual file. If the file is so long that conditions, such as bottom composition, appreciably change over the length of the transect, the resulting parameter settings may not be ideal for either condition. We recommend that transects be limited to no more than 5 minutes recording time. This corresponds to roughly 600m length at a well-suited boat speed of 4 knots. If more time is required to complete a longer transect, one file can be closed and the next opened up quickly. Guidance is offered for two types of survey designs -repeated parallel lines in the same direction and repeated parallel lines in opposing directions.

**Uni-directional parallel transects** (Figure 12) are best suited for areas where one end of the transects terminates in the shallows. A site that is bounded by a navigable channel or deeper slough to one side, and a shoreline or shoal to the other is an example where uni-directional parallel transects should be employed. This prevents needing to maneuver the survey boat in the shallows, to line up for the next transect, and possibly damaging shallow water SAV beds.



**Figure 12.** Uni-directional parallel transects.

**Bi-Directional parallel transects** (Figure 13) approaches work well in areas where spatial restrictions are less significant (i.e. an area within a larger SAV bed that has little depth change and is not restricted by shoreline, shoals or other obstacles). When designing a bi-directional survey consider the vessel's turning capabilities and the expected local conditions (tidal flow), two factors which will help determine how far past the final collection point the vessel operator should travel before setting up for the next transect. The longer time spent approaching the start-recording waypoint, the straighter the transect will be. Straight transects on a pre-planned path are particularly important for repeated surveys in the same location.



**Figure 13.** Bi-directional parallel transects are surveyed in opposing directions.

Regardless of method, keep the following guidance in mind:

1. End the survey line at a point that allows sufficient turning around of the vessel (i.e. not right up to a shoreline or restrictively shallow water).
2. Where a shoreline is the inside boundary of a set of lines carefully idle back to the offshore end of the transect (i.e. conduct each line in the same direction).
3. Suggest allowing approximately 50m prior to beginning your survey of the transect line to be sure the vessel operator has a correct heading given the local conditions.
4. In the case below, consider the prevailing wind direction when establishing your track (see environmental conditions below).
5. Avoid crossing the path of your boat while recording since the propeller entrains small bubbles in the wake that are highly reflective acoustically and can mask the intended signal (plants and bottom).

### **Environmental conditions:**

Conditions play a large role in an operator's ability to keep their vessel on track. In coastal areas tides and wind need to be taken into account prior to conducting the survey.

### Tidal Effects:

1. If you are unfamiliar with an area, deploy an anchor attached to a floating crab trap type buoy to visually observe the direction of the tidal flow.
2. If the flow is perpendicular to the transect lines, account for this in the vessel heading and angle the vessel along the line with the bow turned into the tide. Following the GPS navigation guidance on the HDS CHARTS window will show the true track of the boat and allow the operator to make needed corrections.
3. If possible run the transect line either into (preferred) or with the tide.
  - a. Adjust vessel power to maintain a nearly constant speed over ground (SOG) – suggest staying in the range of 2 -6 knots.
    - i. Decrease engine RPM when with the tide.
    - ii. Increase engine RPM when against the tide.
4. Strong tidal flow causes SAV canopies to lay down in the direction of flow, greatly reducing the in situ canopy height. If accurate measures of in situ canopy height are important, then it would be highly desirable to schedule the survey during high slack tide. Vegetation percent coverage is not too sensitive to plants laying over due to tidal currents.

### Wind Effects:

Depending on the survey vessel's susceptibility to wind (cabin vs. non-cabin vessels), wind may affect the path along the given transect line.

1. If possible, run the transect line either into (preferred) or with these forces.
  - a. Adjust vessel power to maintain a nearly constant speed over ground (SOG)
    - i. Decrease engine RPM when with the wind.
    - ii. Increase engine RPM when against the wind.
2. For those not familiar with handling characteristics of the vessel, several practice transects are recommended.
  - a. Note speed and direction of deviations from transect lines and record in field notebook.
  - b. Correct for deviations while conducting the survey by adjusting speed.

In addition to navigational challenges wind affects acoustic conditions within the upper water column. Wind, and resulting waves, entrain small bubbles in the upper water column. These highly reflective bubbles may mask the "quiet zone" necessary for detecting submersed vegetation. This is not a problem in deep waters, except for the boat heave effects on the detected bottom depth. In shallow waters, the loss of the quiet zone may make plant detection impossible. Strong (>10 kts), steady winds may make it necessary to reschedule sampling activities.

### **Setting Waypoints:**

Transect waypoints are specified by latitude/longitude pairs. Two waypoints are minimally needed to define each transect. It may be desirable to specify each transect using three waypoints - the first being a line-up point, followed by the start-recording and the stop-recording points. Transect points may be selected in two ways – using digital (or paper) maps (including the HDS CHART), and field selection during a preliminary site visit. If time is available, the second method is of course preferred

because it's possible to see conditions that may not be evident from a map. All waypoints should be entered and saved into the HDS as GPS waypoints.

Map selection of waypoints: Prior to field work attain a chart or use the HDS chart to select field sites.

1. If using the HDS chart open the Chart page.
2. Place the cursor on the Chart page where you want to set the waypoint, select New Waypoint.
3. When the New Waypoint menu appears, select Save.

If using latitude and longitude selected from an external chart go to the Utilities page.

1. Go to the Waypoints screen.
2. To open the Waypoints screen menu, press the MENU key from the Waypoints screen.
3. Select New.
4. From this screen type in latitude and longitude as well as the waypoint name. Hit enter.
5. Double check the position of the Waypoint on the Chart screen.

Field selection of waypoints:

1. Position survey vessel 50 m away from selected waypoint position. Motor towards the beginning of the survey transect.
2. Press the MENU key (soft key). From the Chart menu, select New Waypoint.
3. When over the beginning of the transect begin the process to save the Waypoint. When the New Waypoint at Vessel menu appears, select Save.
4. Record site name, transect number, waypoint number, and GPS position in a field notebook.
5. Repeat step for all waypoints.

To delete waypoints:

1. From the Pages screen select Waypoints, routes, trails, press ENTER.
2. When the waypoints screen appears select the waypoint you want to navigate to from the waypoints list and press MENU.
3. The waypoints screen will appear. Press the Edit softkey.
4. From the edit Waypoint menu, select Delete.

### **Navigating Transects:**

Key Concepts to remember when conducting a survey.

1. Do not run the survey as one file. Save the data for individual (preferably straight) survey lines by saving and renaming each line of the survey individually.
2. While running the transect, avoid over-compensating course corrections which may occur due to the short lag time between GPS updates and the visual tools on the HDS screen.
  - a. Make subtle changes when off track.
  - b. Allow updates of the screen to occur before making additional adjustments (the external GPS helps here because it updates position 5 times as fast as the internal GPS in the HDS unit).
  - c. To avoid over-compensating, select a distant object to steer toward when on track, only occasionally check your positing on the HDS.

3. Make sure to be zoomed in on the screen to the appropriate range – this may be all the way in to follow the line, or some operators prefer to be able to see the end point on the screen at all times.
4. Maintain a constant speed when on recording transects. This should be within the range of 2-6 knots.

### Conducting a survey:

1. Display Sonar and Chart pages as a combo page.
  - a. Prior to selecting the active page adjust the zoom on the chart page to the appropriate scale. Once you have selected the Sonar Page as the active page you will not be able to adjust the zoom on the chart without switching the active page.
  - b. Use the keypad to select the Sonar page as the first page for the combo display. This is the primary page which can be edited during processing (left side of the screen).
  - c. Select the Chart pages from the primary pages combo display list. This is the secondary page (right side of the screen). Press ENTER.
  - d. Pressing the MENU key will open the active panel's context menu.
  - e. If switching the active page becomes necessary press and hold the PAGES key down for 1 second.
2. Approximately 50m prior to beginning your survey of the transect line to be sure the vessel has a correct heading given the local conditions.
3. 20 m before the first Waypoint access the Sounder Logging Menus to begin recording:
  - a. Press "Menu"
  - b. Go to "Log Sonar", press Enter
  - c. Set up recording session (HDS will reset options if step are not followed in order)
    - i. Choose save location (Memory card 1 or 2, NOT Internal)
    - ii. Set "Bytes per sounding" to 3200
    - iii. Select "Log all channels". This will record the 200 kHz skimmer, and all three channels of the StructureScan transducer (left, right, and down), using the frequency selected in step 22 b). An .sl2 file will be generated. It is OK to use the default file names offered by the HDS system – SONARxxxx. These file names will need to be renamed, using a date/time format as described later, before processing is done.
    - iv. Press Record to begin recording session
    - v. **WRITE FILENAME, MEMORY CARD NUMBER, AND TIME/DATE IN FIELD BOOK** (for use in renaming files)
4. Stop recording by pressing "Stop" twice
5. At end of recording session verify that files are present
  - a. Verify the file has been recorded by performing step 30 (section **Recording**).
  - b. Go to "Files"
    - i. Select the Memory card number used to store files
      1. Verify file presence
      2. View file if desired
        - a. Sensitivity parameter on far left of bottom row of buttons may need adjusting before data will appear
6. Press Exit twice
7. Repeat at the beginning of each transect.

8. Shutting down: Press “Light/Power”
9. Select Power Off and Press Enter

Various types of data should be manually recorded during a survey for later use. Appendix C contains an example field data sheet that can be copied and used.

#### **Data File Naming Convention:**

Default filenames generated by the HDS have the format SONARxxxx (where xxxx are sequential numbers added by the HDS operating system). This is adequate for field data collection, given that typing in different names on the HSD during data collection can be slow and awkward. However these files should be renamed after data collection and prior to processing to avoid possibly losing data due to duplicated filenames. All post-processing steps will require filenames in a date/time format:

*yyyymmdd\_hhmmss.SL2*

example:

20110612\_133200.SL2

corresponds to June 12, 2011 at 1:32:00 PM (13:32:00 is 24-hr time format)

Time and date are not available within the .SL2 files so the filename is the only means of recording date and time for tidal correction and archival purposes.

## **Software Distribution, Installation, and Setup**

The required software and files, and this manual, may be downloaded free of charge. Go to <http://el.erdc.usace.army.mil>, then click on **Products** followed by **Aquatic Plants** (under **Models and Tools**). Products that must be downloaded include SAVEWS\_Jr (32-bit or 64-bit code and user manual), FINALIZE\_Jr (contains installer for FINALIZE-3), MCR (installer for 32-bit and 64-bit MatLab runtime libraries), and TestFiles (contains all associated test files needed to verify the correct installation). Installing the MCR is the most time consuming step. If you have previously installed this or have working version of MatLab on your computer, this step is not necessary. If you encounter difficulties downloading or installing these files contact the Points of Contact identified at the end of this document. Files can be mailed via CD or sent by a file transfer utility. SAVEWS Jr. version 1.0 is written in MATLAB and requires the system to have MATLAB R2011b installed or the MATLAB Compiler Runtime (MCR) version 7.16. We only support 32-bit and 64-bit Microsoft Windows platforms.

1. If you have MATLAB or the MCR installed on your system, skip to step 3.
2. SAVEWS Jr. requires the MCR to be installed on computers that are not running MATLAB. Run the MCRInstaller.exe file located on the SAVEWS Jr. distribution disk (**this will require Administrator permissions**). Follow the installation instructions on the screen.
3. Copy the SAVEWS Jr. program to the folder (directory) of your choice. The 32-bit distribution uses the filename SAVEWS\_Jr\_32.exe and the 64-bit distribution uses the filename SAVEWS\_Jr.exe. Note: The phrase “the folder (directory) of your choice” means that you can put the executable anywhere on your computer. But you will need to know where you put it so you can run the program by double clicking the icon or program name. Most users will put the executable on their desktop and run it from there. Others may separate their work into project directories. If you do, place the executable in a project directory with your data files. There is no right answer, it is a personal preference.
4. If you don't use the Finalize Jr. program, skip to step 8.
5. If you have the Microsoft .NET Framework 2.0 Service Pack 2 installed on your system, skip to step 7.
6. Install Microsoft .NET Framework 2.0 Service Pack 2. This can be found at the Microsoft Download Center. (<http://www.microsoft.com/en-us/download/details.aspx?id=1639>)
7. Run the Finalize.msi installer (**this will require Administrator permissions**). The installer will walk you through installing Finalize Jr. on your system.
8. Verify your installation and the operation of SAVEWS Jr. Copy the test files (20010101\_010101.SL2 and DEFAULT.sjrcfg) from the SAVEWS Jr. distribution and place them in a working folder (directory) of your choice.
9. Run the SAVEWS Jr. program (double click on the icon or program name) and select the 20010101\_010101.SL2 file as your data input and DEFAULT.sjrcfg as the configuration file.
10. Press the “Process File” button. The program will take several minutes and it will generate a 20010101\_010101.jpg file when the program finishes. The 20010101\_010101.jpg file will be in the same folder (directory) as the 20010101\_010101.SL2 file. Graphically compare the 20010101\_010101.jpg file with the VERIFY.jpg file that is in the SAVEWS Jr. distribution. If they appear the same, the program is operating correctly.

Users experiencing difficulty installing this software should contact Mr. Eddie Melton at ERDC (601-634-3498).

## Version Notes (version 1.0)

Version 1.0 is the initial release of the SAVEWS Jr. code. This version uses dual frequency (200 kHz, and 800 kHz down-looking channel of StructureScan) processing. Training data for this version was obtained from a limited amount of sampling of estuarine eelgrass (*Zostera marina*) in New Jersey and Massachusetts, various freshwater macrophytes (pondweed, milfoil, and others) in Michigan and Wisconsin, and hydrilla in central Florida. This initial version has not been optimized for execution speed and is not capable of running in batch mode, i.e. the user must enter and process one file at a time. We fully expect that as additional environments are sampled and different conditions encountered further modification to the code will be needed, resulting in subsequent versions. We solicit feedback from users in identifying shortcomings and get suggestions on how the code may be improved.

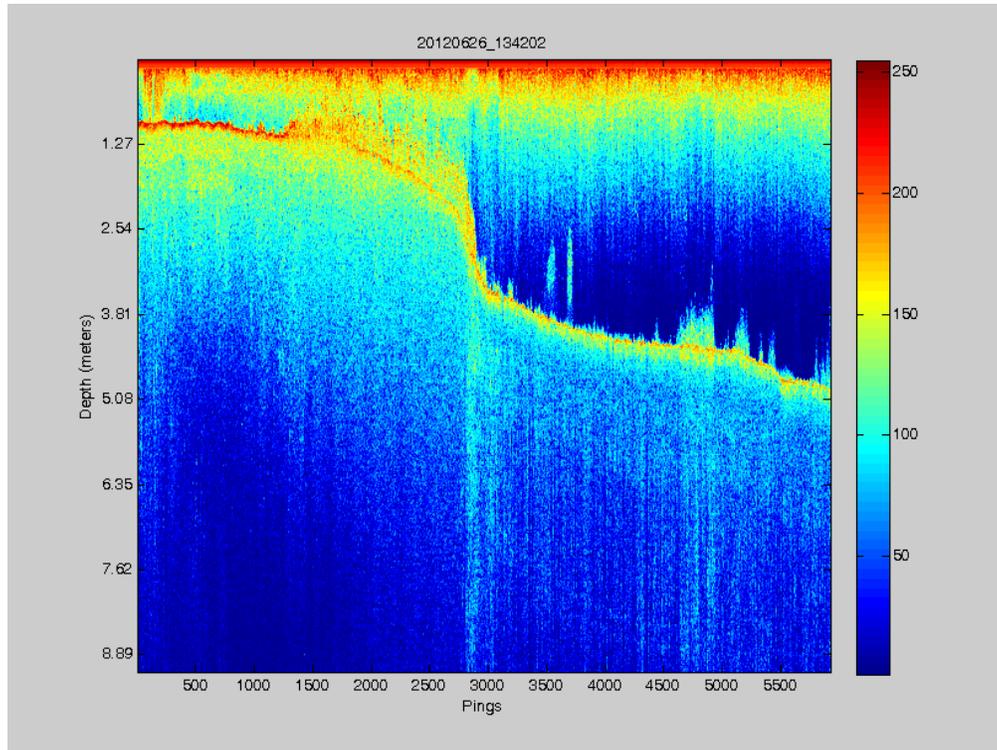
## Processing

The general sequence of steps the user follows in processing data includes:

- 1) Running a single (preferably small, <20 Mb) file with an unturned configuration file (CF).
  - 2) A colorized echogram of the file is generated along with the processed output graphic and ASCII file.
  - 3) The initial processing will probably not generate satisfactory results, but will help guide the user in modifying the CF to achieve best results.
  - 4) The user will iteratively change the CF, preferably one variable at a time until results appear in agreement with the colorized echogram.
  - 5) The resulting modified CF will then be used to process all transects taken in this sampling site.
  - 6) The user will review each one to verify that no further modification are needed to the CF.
  - 7) Once all transects have been processed and accepted they are run through a post-processing program (FINALIZE) that concatenates all files, correct for tides (if necessary) and transducer depth, and converts geographic coordinates (latitude and longitude) to a user-selected Cartesian coordinate system (UTM, state plane, etc).
  - 8) The output of FINALIZE is then ready for entry into a mapping or statistical analysis package.
- In this section we process two file to illustrate each of the steps in the process above.

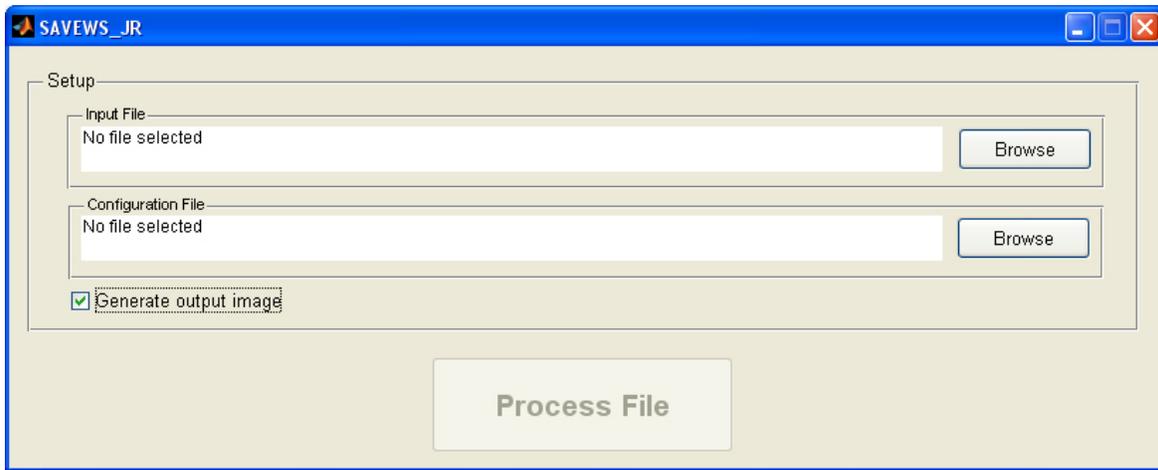
### SAVEWS Jr. Processor:

Our first example file (Figure 14, file 20120626\_134202.SL2, using the required file nomenclature described above) is from Cuttyhunk Harbor, MA, and was sampled from a high energy, sand bottom locations near the harbor entrance. The graphic is generated by the processor and represents the 8-bit echo return intensity generated from the downlooking channel of the 800 kHz StructureScan transducer. Hot colors (red and orange) representing high reflectivity (high values) and cool colors (blue and green) representing low reflective “quiet” conditions (low values). The roughly 4 -minute recording, which traversed 440 m generated 34.6 Mb of data and almost 6000 pings, began in the shallows (~1 m depth) and ended in the deep (~5m) area. Along the top edge of the figure is high return generated by transducer residual ringing and surface “noise” (micro bubbles near the surface). Below that, the water column becomes progressively quieter (cool colors) with increasing depth. The sand bottom is revealed as a narrow red/orange line beginning at around 1 meter, rapidly getting deeper at around ping 3000, and ending near 5 m depth. SAV is evident beginning near ping 1300 and extending to around ping 3000 at a depth around 3.5 m (note that depth here is specified as the distance between the transducer face and the bottom, and that the transducer face is submersed at least 0.25 m in the water). In this region plants, known to be dense eelgrass (*Zostera marina*), are highly reflective, and the open water above these plants is not very “quiet” before it reaches the near surface noise. Beyond ping 3000, the near bottom waters are very quiet and there are several occurrences of what appears to be low reflectivity plants (between pings 4700 and 5300). We aren’t sure if these are plants or what species they are, but they are growing at considerably deeper depth than the known eelgrass bed and they exhibit relatively low reflectivity. Figure 14 is actually generated by the first processing of the file described below – we’ve jumped ahead of ourselves for illustrative purposes.

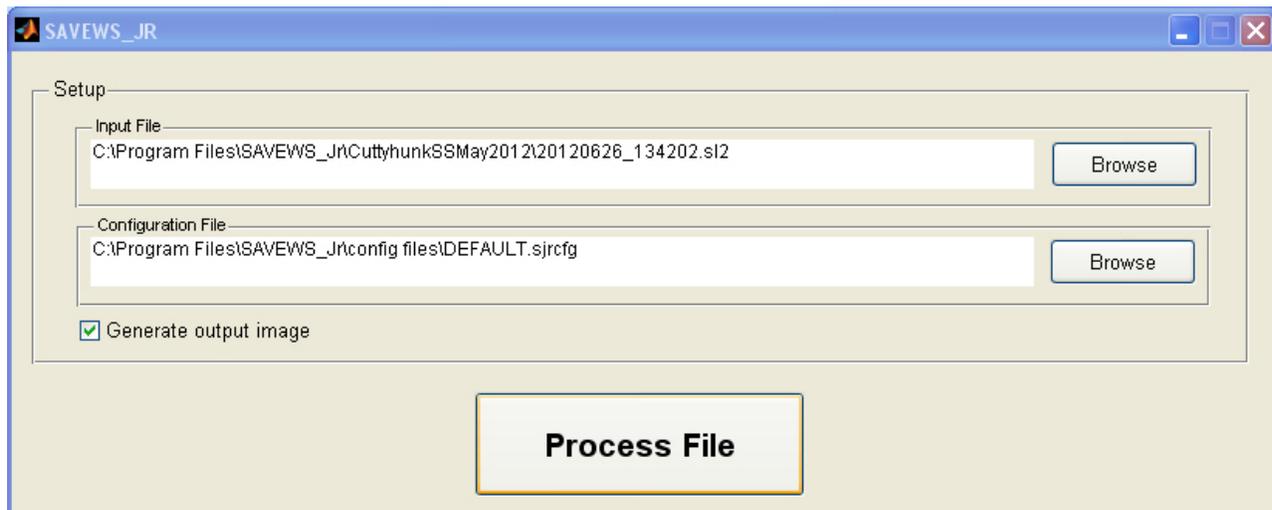


**Figure 14.** Colorized echogram of acoustic transect at Cuttyhunk Harbor, MA.

The process begins by initiating program `SAVEWS_Jr.exe`, which produces the main graphic user interface (GUI) window (Figure 15). The user clicks browse and selects a `.SL2` file from the subdirectory created to contain the survey data. Next the user clicks browse to select a CF. We recommend having a separate subdirectory containing just CFs (file type `.sjrcfg`). A generic starter CF is picked for the initial run. We don't expect these configuration settings to produce the best output, but obvious errors in the output will help determine what parameters need to be modified. To execute the program the user then clicks **Process file** (Figure 16). A number of large libraries are read into memory at this point which may take a minute or two.

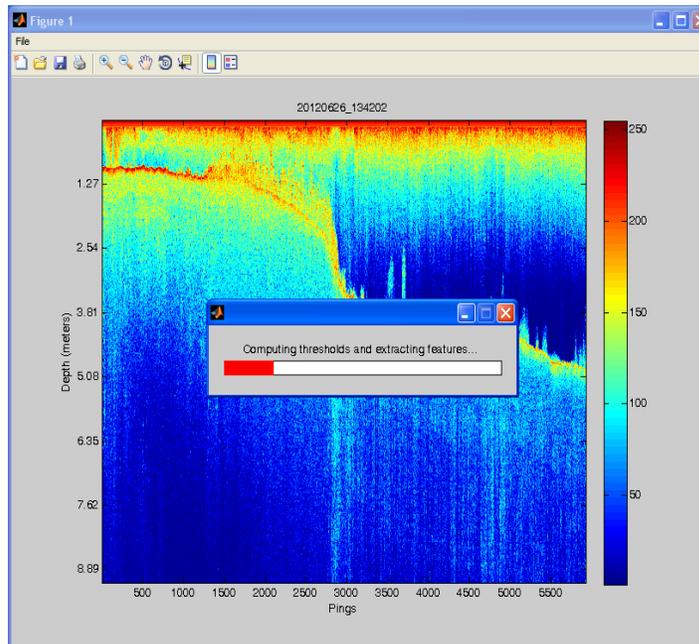


**Figure 15.** SAVEWS\_Jr data processing window, *Generate output image* is on by default.



**Figure 16.** Processing GUI filled in and ready to start program.

When a particular file is run for the first time the program parses the .SL2 file and reads it into memory while displaying the message *Reading Data File [filename]*. This is a relatively slow process so be patient. Once this step is complete the colorize echogram (Figure 14) appears overlain by a series of progress bars (Figure 17) indicating the stage and progress of processing. The sequence of progress bars is: *Computing Thresholds and Extracting Features*, *Finding Biggest Peaks*, *Finding Falling Edges*, and *Determining Canopy Tops*. All after the data reading are relatively quick, and if a given file is reprocessed the read in step is skipped.

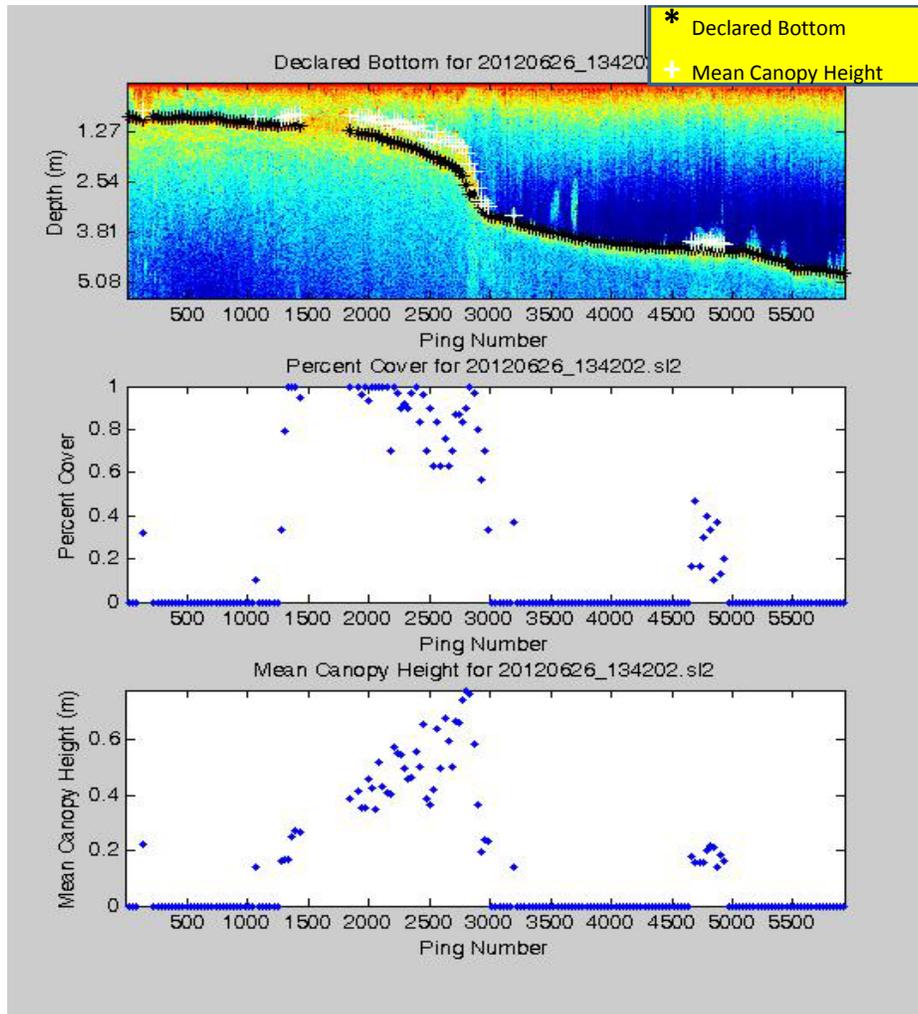


**Figure 17.** Display during processing.

At the completion of processing three files are placed into the data subdirectory (location of .SL2 files):

- a. *filename.\_chart.bmp* – colored echogram of .SL2 file (e.g. Figure 14)
- b. *filename.jpg* – graphic of processed output (Figure 18)
- c. *filename.sdf* – comma-delimited ASCII file of processed output (Figure 19)

The graphic of processed output (Figure 18) contains 3 panels. The top panel overlays bottom and mean canopy height declarations onto the colored echogram. The middle panel is a co-aligned data plot of SAV coverage, and the bottom panel is a similarly aligned data plot of mean canopy height. These plots are intended to make it easy for the user to readily evaluate the goodness of the output and to rapidly detect output changes with subsequent runs using different configuration inputs. The final output (Figure 19) is a text version of the graphic output (Figure 18) that is used for post-processing or analyses. Variables used in the text output (Figure 19) are defined in Table 2. Before processing another file the user must close the .SDF file (opened in Excel) or not output will be generated from subsequent runs.



**Figure 18.** Graphic of processed output generated from a non-optimized CF (DEFAULT.sjrcfg).

a. Processing information from top of .SDF file.

	A	B	C
1	Input Parameters		
2	File Name	20120626_134202.sl2	
3	Date	6/26/2012	
4	Time	13:42:02	
5	Pings Per Report Cycle	30	
6	Minimum Gap for Ping Thresholds (m)	0.1	
7	Noise Threshold	149.1708	
8	Minimum Vegetation Height (m)	0.1	
9	Minimum Vegetation Standard Deviation (m)	0.03	
10	Maximum Vegetation Depth Limit (m)	5	
11	Configuration File used:	DEFAULT.sjrcfg	
12			

b. Output data from bottom of .SDF file.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Rpt	Latitude	Longitude	Times(hr)	Day	Month	Year	Center Ping	Bottom(m)	Canopy Height(m)	Percent Cover	Depth to Canopy/Bottom (m)
2	1	41.424656	-70.91875	13.7008	26	6	2012	15	0.883	0	0	0.883
3	2	41.42466	-70.91874	13.7011	26	6	2012	45	0.876	0	0	0.876
4	3	41.424663	-70.91872	13.7013	26	6	2012	75	0.908	0	0	0.908
5	4	41.42467	-70.91869	13.7019	26	6	2012	135	0.946	0.22	32	0.726
6	5	41.424683	-70.91864	13.7027	26	6	2012	225	0.876	0	0	0.876
7	6	41.42469	-70.91863	13.7029	26	6	2012	255	0.876	0	0	0.876
8	7	41.424697	-70.91862	13.7032	26	6	2012	285	0.895	0	0	0.895
9	8	41.424704	-70.9186	13.7034	26	6	2012	315	0.902	0	0	0.902
10	9	41.424711	-70.91858	13.7037	26	6	2012	345	0.902	0	0	0.902
11	10	41.424717	-70.91856	13.704	26	6	2012	375	0.908	0	0	0.908
12	11	41.424724	-70.91855	13.7042	26	6	2012	405	0.889	0	0	0.889
13	12	41.424731	-70.91854	13.7045	26	6	2012	435	0.876	0	0	0.876
14	13	41.424734	-70.91852	13.7048	26	6	2012	465	0.883	0	0	0.883
15	14	41.424738	-70.9185	13.705	26	6	2012	495	0.857	0	0	0.857
16	15	41.424744	-70.91848	13.7053	26	6	2012	525	0.895	0	0	0.895
17	16	41.424748	-70.91846	13.7056	26	6	2012	555	0.902	0	0	0.902
18	17	41.424751	-70.91844	13.7058	26	6	2012	585	0.895	0	0	0.895
19	18	41.424754	-70.91843	13.7061	26	6	2012	615	0.895	0	0	0.895
20	19	41.424758	-70.91841	13.7063	26	6	2012	645	0.914	0	0	0.914
21	20	41.424761	-70.91839	13.7066	26	6	2012	675	0.908	0	0	0.908
22	21	41.424761	-70.91838	13.7069	26	6	2012	705	0.889	0	0	0.889
23	22	41.424765	-70.91836	13.7071	26	6	2012	735	0.914	0	0	0.914
24	23	41.424768	-70.91834	13.7074	26	6	2012	765	0.908	0	0	0.908
25	24	41.424768	-70.91832	13.7077	26	6	2012	795	0.94	0	0	0.94

Figure 19. Raw output file (.SDF); a. processing parameters, b. processed data.

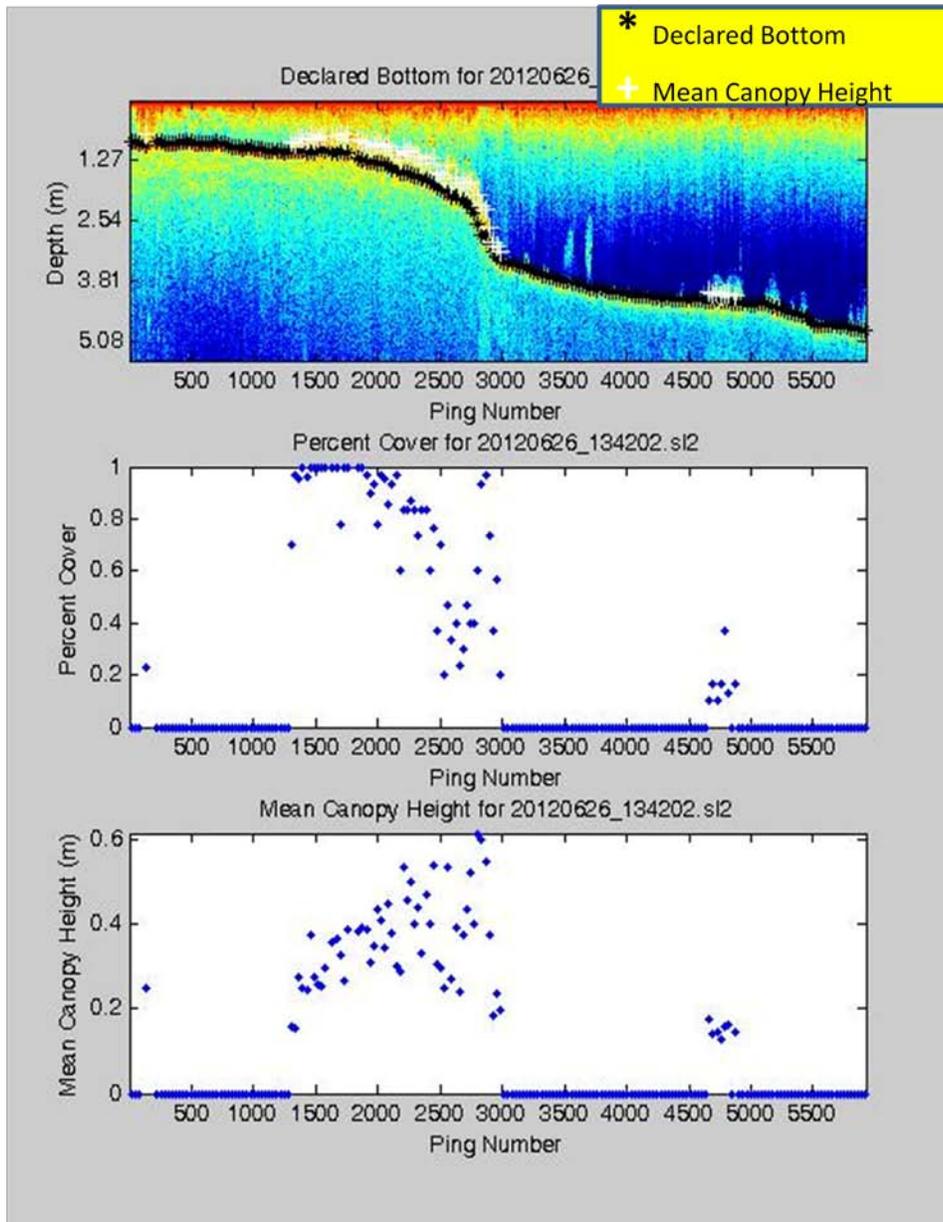
Table 2. Definition of output variables form raw output file (.SDF).

Variable name	Units	Definition
Report cycle	Integer	Sequential number of output report summarizing N pings
Latitude	Decimal degrees	Geographic coordinates in coordinate system set on GPS (typically NAD83)
Longitude		
Time	Decimal hours	24-hr time parsed from .SL2 filename and incremented with HDS clock time (seconds lapse since file start)
Day	Integer	Day of month, parsed from .SL2 filename
Month		Month of year, parsed from .SL2 filename
Year		Year, parsed from .SL2 filename
Center ping		Ping number at center location of N-ping report cycle output
Bottom	Meters	Distance between transducer face and algorithm-detected bottom
Canopy Height		Mean height of detected plants in report cycle
Acoustic Percent Cover	Integer	Percentage of valid processed pings in which plants were detected (0..100) (see Appendix D)
Depth to Canopy/Bottom	Meters	Distance between transducer face and first echo return above USERNOISE (set in configuration file)

Examination of the graphic processed output (Figure 18) reveals that bottom tracking appears reasonable and that much of the eelgrass bed (ping region 1400-3000) has been correctly declared, and some of the apparent sparse vegetation (ping region 4500 -5500) has also been detected. An obvious problem is the lack of bottom or plant declarations in dense eelgrass at ping region 1500-1800.

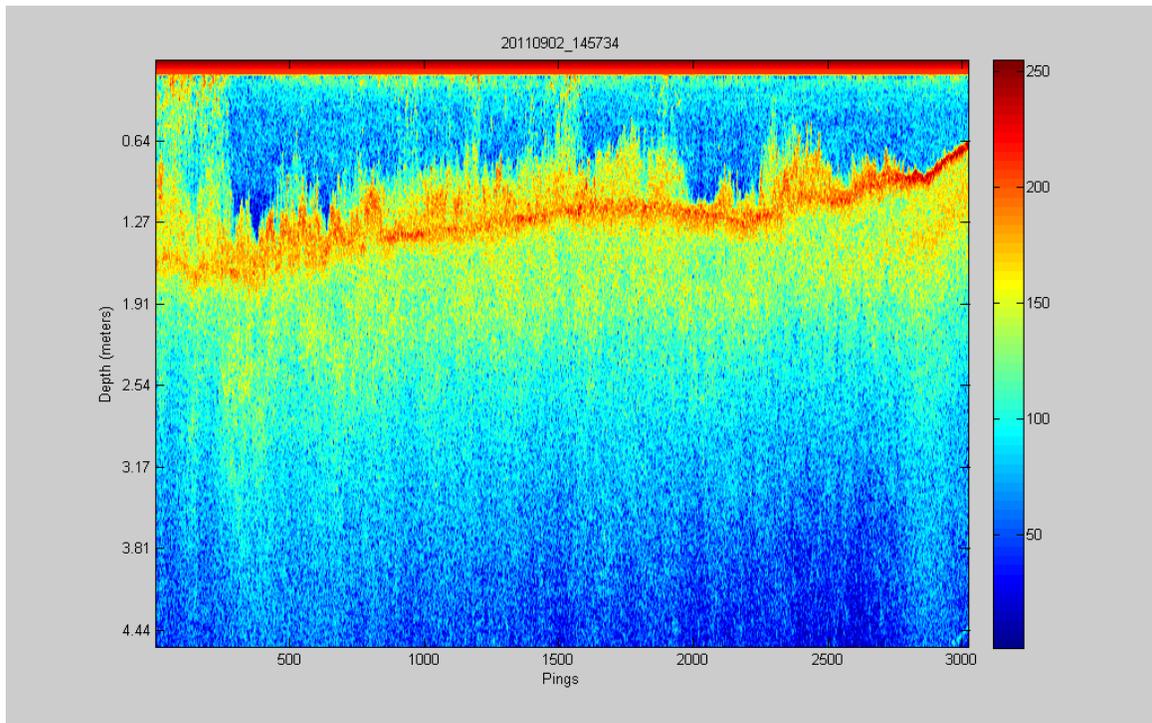
To understand how output problems can be fixed, it is necessary to understand the configuration parameters defined within the CF. A full listing of the CF (DEFAULT.sjrcfg), used to create our first example, is shown (Appendix B). Parameters are grouped into *Basic*, *Intermediate*, and *Advanced* categories. The *Basic* group contains parameters that we expect to change routinely. The *Intermediate* group consists of somewhat more advanced parameters that the user should have some familiarity with before changing. The *Advanced* group consists of parameters that require an in-depth knowledge of the algorithm to manipulate, and generally should not be changed. We encourage the user to read the description of each parameter in the example CF (Appendix B).

When a file is run for the first time, it is useful to allow the algorithm to automatically pick the **usernoise** parameter value. This was done by setting **usernoise=0** and **percentile=75** (Appendix B). The result was that the algorithm picked a **usernoise** value of 149 (line 7, Figure 19a). The key to the missing output is that this region is very “noisy”, i.e. there is not a clearly defined “quiet zone” between the top of the plants and the surface for the **usernoise** threshold selected. As the **usernoise** threshold increases, there will be less sensitivity to water column noise, and also less sensitivity to vegetation detection. We hypothesize that by increasing the **usernoise** threshold, we may be able to recover data from the missing region. This can be done by increasing percentile, or manually setting the **usernoise** threshold higher. We choose the second approach and change **usernoise** from 0 to 160. Improvement in the reprocessed output is evident (Figure 20) – the gap of missing output has been filled in, however, this has occurred at the cost of some plant detection sensitivity -there is a very slight decrease in canopy height and percent coverage in the detected vegetation. There is an unavoidable tradeoff between noise rejection and detection sensitivity.

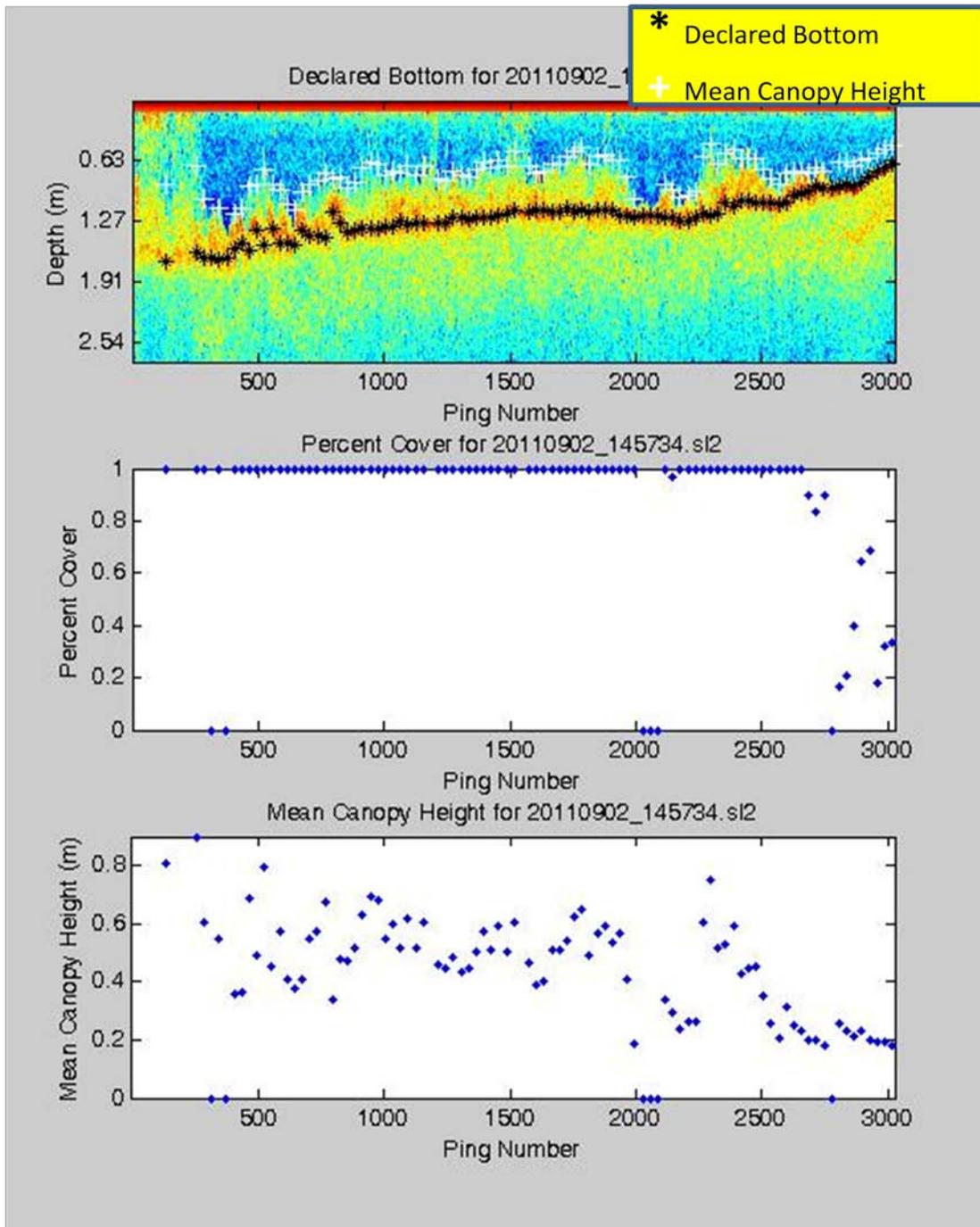


**Figure 20.** Reprocessing file 20120626\_134202 with `usernoise=160`.

We run a second example (Figure 21) to illustrate some other configuration parameters. The transect selected is of Eurasian watermilfoil in a northern Wisconsin lake. Several locations along the transect exhibit dense tall vegetation with a noisy water column above. Also, the bottom is not clearly evident at the beginning of the file and in ping region 2300-2500. We begin by processing with the starter CF (DEFAULT.sjrcfg, Appendix B) used in the previous example, and generate Figure 22. Several problems are immediately evident. Output data is missing from the start of the file (ping region 0-250); apparent false detects are occurring near the end (ping region 2700-3000) and bottom tracking is erratic in ping region 500-750. The automated threshold picker selected `usernoise = 95`.



**Figure 21.** Colorized echogram of acoustic transect of Eurasian watermilfoil in northern Wisconsin.



**Figure 22.** Graphic of processed output generated from a non-optimized CF (DEFAULT.sjrcfg).

There are two types of problems occurring – vegetation detection and bottom tracking. The first modification we make is to correct missing vegetation detections and false detections. The following parameter changes are made to improve vegetation detection performance:

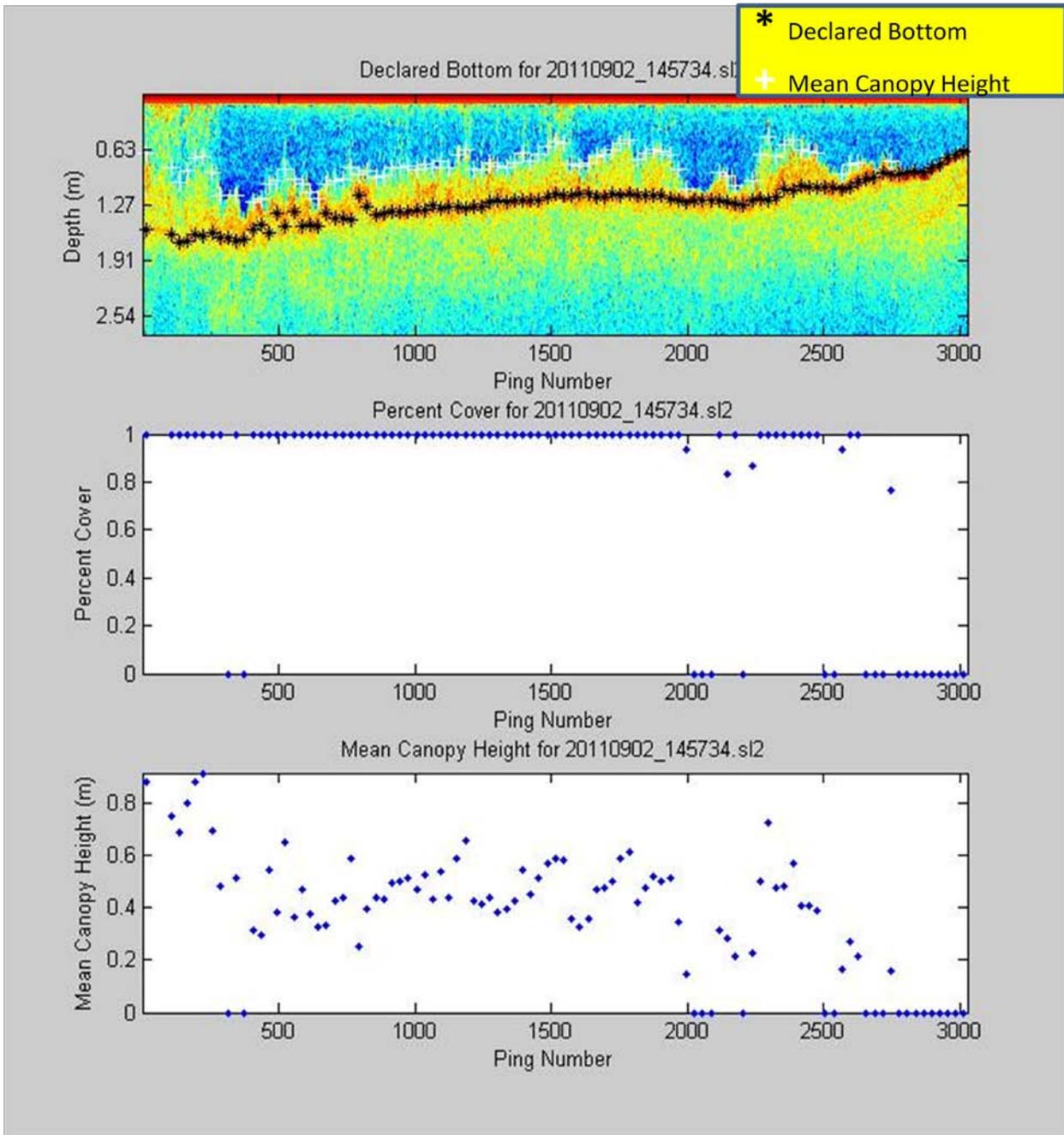
- 1) increase **usernoise** from 95 to 115. This will reduce sensitivity to water column noise evident in ping region 0-250, and possibly eliminate false detects near the file's end caused by hypersensitivity of a low threshold.

- 2) Decrease **startdepth** from 0.5 to 0.3 m. The near surface noise is minimal, relative to the previous example. This decrease may help reduce data rejection in ping region 0-250.

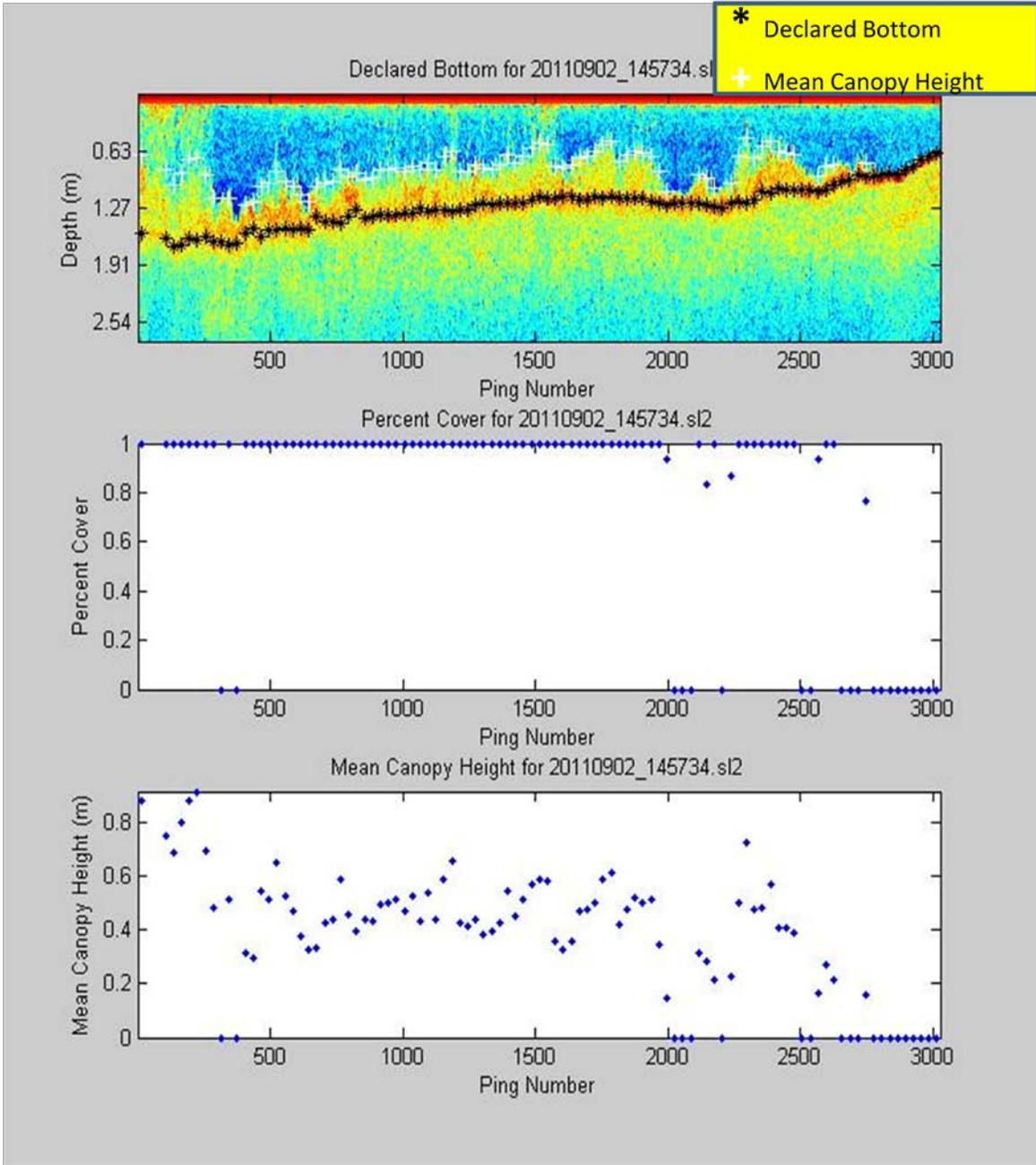
Output from these modifications is shown below (Figure 23). Reasonable vegetation detections are now being generated from ping region 0-250, and false detections near the end have been eliminated. Bottom tracking in ping region 500-800 is still erratic. We make a second parameter modification to improve bottom tracking:

- 1) Set **bot\_change\_tol** to 0.10 m (from 10m). This activates the median filtering of bottom depth declarations. In this case when the difference between the current bottom depth and the 9-element (**bot\_med\_filt\_size**) median value, centered at the current depth exceeds 0.10m, the bottom depth will be reset to the median value. This is more of a cosmetic fix than a true signal processing fix, but it can be handy in some situations.

The reprocessing results (Figure 24) exhibit the desired depth smoothing in ping region 500-800. In this case we do not know the cause of the original erratic bottom depth declarations – they may have a legitimate physical cause. However, the modification we made shows how median filtering can be used to smooth depths if desired. Median filtering preserves sharp discontinuities in the string of depth estimates – unlike use of a moving average filter. Frequently in very dense vegetation, bottom depths become erratic and use of median filtering would be warranted.



**Figure 23.** First reprocessing file 20110902\_145734 (**usernoise=115, startdepth=0.3**) to improve vegetation detection performance.



**Figure 24.** Second reprocessing file 20110902\_145734 (**bot\_change\_tol** = 0.10m) to smooth erratic bottom depth declarations.

The two processing examples above illustrate how the CF can be adjusted to align output of a single file with the user’s heuristic interpretation of the echo signal. When one conducts an acoustic survey typically there are many transects collected from a localized region. It would be unreasonably time consuming to optimize the CF for each transect in the survey, additionally, it would lead to inconsistent detection sensitivity among transects. Our recommendation is to select a “typical” and small (<20 Mb) file from within the localized region to iteratively adjust the CF to get best performance. Then use this optimized CF to process all other files collected in this region. The user should examine and evaluate the output graphic as a quality control step. If bottom or plant type

conditions change much over the spatial extent of the surveyed region it may be necessary to adjust some parameters further.

In the above examples we started with a generic starting CF (DEFAULT.sjrcfg, Appendix B) which had not been optimized for any particular set of environmental conditions. If your application is typically within some specific environment type (eg. Florida hydrilla, coastal eelgrass, etc), we recommend you develop your own customized starting CF, which is somewhat optimized for your conditions. This will save time arriving at the final CF.

### Post Processing:

The post-processing program FINALIZE combines transect files, makes depth corrections, and coordinate projection transformations to State Plane. The output file is a single, comma-delimited ASCII text file ready for entry into a mapping or statistical analysis program. In addition to the SDF files to be included, the program requires a data file of tide measurements and a file of SDF filenames. Steps in creating these files and running the FINALIZE program are described below.

1. Tide data file. An example tide file is contained in Figure 25. This ASCII space-delimited text file can be generated using any text-editing program, such as Microsoft Wordpad or Notepad. The first line is for documentation only. Each subsequent line contains the integer month, integer day of month, time (decimal hours local time, 24 hr), and tide (feet) relative to the selected reference plane. The first data line of the file must contain a tide measurement BEFORE the first recorded SDF file. The last data line must contain a tide measurement AFTER the last recorded SDF file. If this condition is not met, the program will give a warning message and halt execution. If a tide measurement was not made at the correct time during data collection, it will be necessary to estimate one and enter it.

```
{tide data: mm,dd,hh.hh,tide (ft)
8 01 11.55 9.4
8 01 11.75 9.3
8 01 11.90 9.2
8 01 12.06 9.0
8 01 12.24 8.9
8 01 12.56 8.6
8 01 12.74 8.2
8 01 12.90 7.9
8 01 13.06 7.6
8 01 13.24 7.2
8 01 13.40 7.0
8 01 13.56 6.5
8 01 13.73 6.1
8 01 13.90 5.6
8 01 14.07 5.2
8 01 14.35 4.5
```

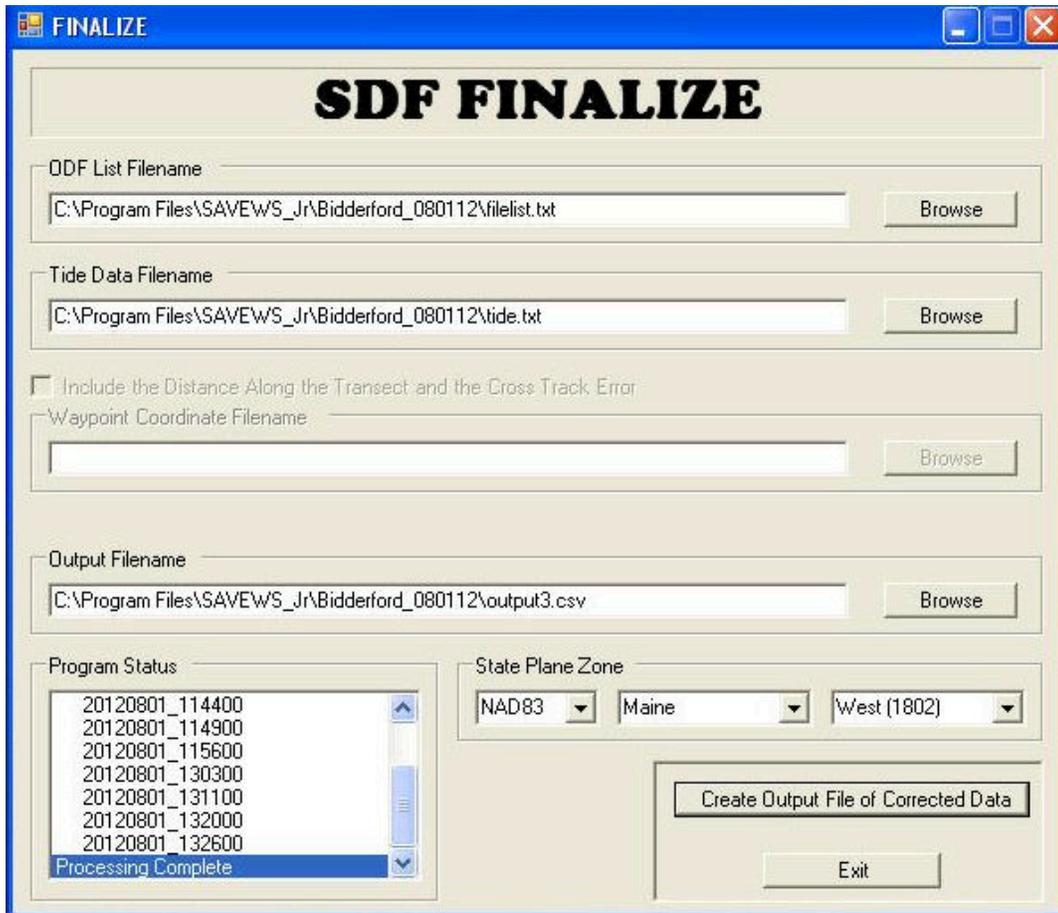
**Figure 25.** Tide data file must contain integer month and day, decimal hours local time, and tide (ft).

2. File listing SDF files. An example file is contained in Figure 26. Each line of the file corresponds to a single SDF file. It is not critical to have this list ordered in any particular way, but it may be convenient to order the files chronologically. The easiest way to generate this file without having to type all the 15-character filenames is to enter the COMMAND PROMPT program (DOS emulator) and type: **dir /B /ON \*.SDF > filelist.txt** from within the proper directory. This will make a list of the SDF files 15-character filenames. Be careful to eliminate any aborted files from the list.

```
20120801_114000 1 0.20 1
20120801_114400 2 0.20 1
20120801_114900 3 0.20 1
20120801_115600 4 0.20 1
20120801_130300 6 0.20 1
20120801_131100 7 0.20 1
20120801_132000 8 0.20 1
20120801_132600 9 0.20 1
```

**Figure 26.** The list file must contain SDF filenames, in date\_time format, transect ID #, depth of transducer face (m), and replicate #.

3. Running FINALIZE. Double click on the FINALIZE icon. The SDF FINALIZE window will appear (Figure27). The user then selects the SDF list, tide data, and output filenames using the browse button (direct typed entry will not work). If the user wants to include the distance along the transect and the cross track error in the output file, check the Include the Distance Along the Transect and the Cross Track Error box and select the waypoint coordinate file using the browse button. Then select the Datum, State, and the Zone for the State Plane projection. The Zone list is populated based on the selections made in the Datum and State boxes. This computation is embedded in FINALIZE using the commercially-available code ProLat.dll, version 3.01, by Effective Objects (<http://www.effectiveobjects.com>), which uses USGS computational methods. If the combination of Datum, State, and Zone do not correctly match, Zone will appear in the selection box and you will not be able to initiate the program. Then click Create Output File of Corrected Data button to initiate the program. If invalid data has been entered, the button will be deactivated until correct data has been entered. Status of the program, including any errors, will be noted within the Program Status window.



**Figure 27.** FINALIZE graphic user interface window after executing program; note that the grayed-out function (Include the distance along transect . . .) will be included in a later release.

4. Output file format. The output is in an ASCII comma delimited (.CSV) format. An example is illustrated (Figure 28). Definition of variables contained in this file is contained in Table 3.
5. Further processing. Some users may find it useful to generate additional summary variables based on the outputs provided. One such variable is Biovolume. This is defined as the portion (percentage) of the water column occupied by vegetation and is computed as:

$$\text{Biovolume} = \text{acoustic\_percent\_cover} * \text{Height\_m/Depth\_bottom}$$

Lon	Lat	X_stpln	Y_stpln	Year	Day	Time	Trans	Depth_Bottom	Depth_Canopy	Cover	Height_m
70.35202	43.45018	2903529	224880	2012	214	11.6671	1	-3.93	-3.5	66.67	0.43
70.35203	43.45021	2903526	224889	2012	214	11.6675	1	-4.79	-4.16	73.33	0.63
70.35204	43.45023	2903524	224898	2012	214	11.6679	1	-5.42	-5.42	0	0
70.35205	43.45026	2903521	224907	2012	214	11.6684	1	-5.51	-5.51	0	0
70.35206	43.45029	2903519	224918	2012	214	11.6688	1	-5.5	-5.5	0	0
70.35207	43.45032	2903517	224929	2012	214	11.6693	1	-5.52	-5.23	13.33	0.29
70.35208	43.45035	2903514	224940	2012	214	11.6698	1	-5.39	-5.39	0	0
70.35209	43.45038	2903512	224950	2012	214	11.6702	1	-5.33	-5.33	0	0
70.35209	43.4504	2903510	224960	2012	214	11.6707	1	-5.32	-5.32	0	0
70.35211	43.45043	2903506	224971	2012	214	11.6711	1	-5.3	-5.3	0	0
70.35212	43.45046	2903502	224981	2012	214	11.6716	1	-5.15	-5.15	0	0
70.35213	43.45049	2903499	224991	2012	214	11.672	1	-5.13	-5.13	0	0
70.35215	43.45051	2903495	225001	2012	214	11.6724	1	-5.08	-5.08	0	0
70.35216	43.45054	2903492	225009	2012	214	11.6729	1	-5.04	-5.04	0	0
70.35218	43.45056	2903488	225018	2012	214	11.6733	1	-4.86	-4.86	0	0
70.35219	43.45059	2903485	225027	2012	214	11.6737	1	-4.75	-4.75	0	0
70.3522	43.45061	2903481	225036	2012	214	11.6741	1	-4.71	-4.71	0	0
70.35221	43.45063	2903479	225045	2012	214	11.6745	1	-4.59	-4.59	0	0
70.35222	43.45066	2903475	225053	2012	214	11.6749	1	-4.43	-4.59	0	0
70.35224	43.45068	2903472	225063	2012	214	11.6754	1	-4.21	-4.21	0	0
70.35225	43.45071	2903468	225072	2012	214	11.6758	1	-4.04	-4.04	0	0
70.35227	43.45073	2903464	225080	2012	214	11.6762	1	-3.96	-3.96	0	0
70.35228	43.45076	2903461	225090	2012	214	11.6766	1	-3.89	-3.4	20	0.49
70.35229	43.45078	2903457	225098	2012	214	11.677	1	-3.81	-3.41	40	0.4
70.35231	43.45081	2903454	225108	2012	214	11.6774	1	-3.8	-3.38	93.33	0.42

**Figure 28.** Example output of FINALIZE program (Output.CSV).

**Table 3.** Definition of output variables from FINALIZE program.

Variable name	Units	Definition
Lon	decimal degrees	Geographic coordinates in selected datum
Lat		
X-stpln	feet	Easting in state plane coordinates
Y-stpln		Northing in state plant coordinates
Year	integer	4-digit year
Day		3-digit, day of year
Time	hours	Local time, 24-hr clock
Transect	integer	Transect number
Depth_Bottom	meters	Distance between water surface and detected bottom (corrected for transducer depth and tides)
Depth_Canopy_Bottom		Distance between water surface and first object (contiguous with detected bottom) above threshold ( <b>usernoise</b> )
Acoustic_Percent_Cover	percent	Estimate coverage, computed as percentage of pings in reporting cycle in which plants were detected (see Appendix D)
Height_m	meters	Average estimated plant height in pings detected with plants in reporting cycle

## Caveats and Limitations

We are currently aware of a number of performance limitations to the version 1.0 processing under certain conditions. These known limitations and associated caveats are listed below.

- a. **Soft, highly absorptive bottom.** When a very light bottom, such as floc, or very light organic mud is encountered, the acoustic pulse may be absorbed instead of reflected. When this occurs, no bottom detection will be registered by the algorithm. If SAV is present, the top of the canopy will probably register as the bottom, but SAV will not be declared present. We do not presently have an approach for handling this situation.
- b. **Short/low density SAV.** We have not yet quantitatively established the detection limit for version 1.0. We expect to do so as additional ground truthed data becomes available. Experience with the original SAVEWS showed that detections fell to zero as SAV became shorter and sparser. The computed detection limit for this system was 7 cm height and a density of 60 g m<sup>-2</sup> (wet weight). Sparse beds of *Halodule wrightii* frequently were below this detection limit. We expect that SAVEWS Jr. detection limits may be similar.
- c. **Acoustically impenetrable canopy.** When a submerged canopy is so dense that all acoustic energy is reflected from it, none is left to reflect from the bottom. When this occurs for many adjoining pings, the canopy top will probably be declared to be the bottom and SAV will either not be detected or will be mischaracterized. We have seen this situation with very dense Eurasian watermilfoil canopies that form below the surface. These can become colonized with filamentous algae that trap gas, further increasing the acoustic reflectivity of the canopy top. The use of dual frequencies within the current code greatly reduced this occurrence, however, it will still occur under very dense canopy conditions. We are developing a work-around for this situation that involves subtracting a bathymetric grid from the top-of-canopy depth grid generated by acoustic mapping. Significant differences in depth would indicate plants presence. The bathymetric grid may be obtained from a separate data source, or generated by acoustic mapping during a period of minimum SAV biomass.
- d. **Species discrimination.** The algorithm generates data that characterized SAV canopy geometry. There is currently no general capability to discriminate SAV species or even general classes of SAV. There are however, a number of specific conditions when limited discrimination is possible. When species present in a body of water are known and there are large difference in characteristics measured by the acoustic system (height for instance), then discrimination is possible. Using a height discriminator we demonstrated the ability to differentiate eelgrass (*Zostera marina*) from marine macroalgae in a New England estuary during summer<sup>1</sup>.

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<sup>1</sup> Sabol, B. E. Lord, K. Reine, and D. Shafer. 2008. Comparison of acoustic and aerial photographic methods for quantifying the distribution of submersed aquatic vegetation in Sagamore Creek, NH, report ERDC TN-DOER-E23. U. S. Army Engineer Research and Development Center, Vicksburg, MS.

- e. **Debris in bottom.** The signal processor detects SAV by looking for contiguous signal above and connected to the bottom. Many things other than SAV can cause such a signal. Sunken debris, branches, and drowned trees can generate an acoustic signal that is indistinguishable from SAV. The proper way of assessing the accuracy of the processor output is with a statistically sound ground truth sampling effort, which is not covered in this document. A means of mitigating false SAV detections due to debris is to set the **maxplantdepth** variable in the configuration file to the observed maximum depth of plant growth. This will disallow plant detection of plant-like signatures at depths too deep to be plants.
- f. **Rocky irregular bottom.** The bottom tracker within the algorithm makes the assumption that the depth of the true bottom changes very little between adjoining pings. This is true for virtually all sediment bottoms. When the bottom consists of large rocks and cobbles it becomes irregular and this assumption is violated, resulting in incorrect bottom tracking. We are in the process of developing a separate algorithm to handle this situation which will be incorporated into a subsequent version.
- g. **Boat wakes and choppy water.** Boat propellers, breaking waves, and choppy water act to incorporate small bubbles into the water column. These bubbles are very reflective acoustically and can exceed thresholds used within the algorithm (**usernoise**). This can lead to false or missed SAV detections. It is best to avoid boat wakes (particularly your own) when executing survey transects, and if conditions get too choppy it is best to suspend operations until calmer conditions occur.
- h. **Topped vegetation.** The software is designed to detect bottom-attached vegetation that has not reached the surface. The algorithm looks for a zone of “quiet water” with echo intensity below **usernoise** that is at least **mingap** meters in depth between **startdepth** and the first detected returns above **usernoise**. If this condition is not found the ping data is declared to be noisy (i.e. bad) and not output. If the percentage of pings in a report cycle is below **required\_good** then output of that report cycle is suppressed. If working in near topped vegetation, careful setting of these parameters may allow the output of some or all of these ping samples.
- i. **Final caveat – VERIFY OUTPUT.** If the software described here declares that vegetation of a certain density and height is detected it is only indicating that the acoustic returns are consistent with the unknown source of the echoes being submersed vegetation of that specified density and height. Conversely, if output declares a location to be unvegetated it is only indicating that no signals consistent with submersed vegetation were detected. Vegetation may be present but below the detection limit of the echosounder, or below the detection settings of the configuration file. We always recommend that output be verified with at least a limited ground truth sampling or observation effort.

## Points of Contact

We request feedback and comments from users to identify needed improvements to the code.

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To send files over 8 Mb, use the AMRDEC/SAFE utility (<https://safe.amrdec.army.mil/SAFE2/>).

## Appendix A: Assembling a Self Contained SAVEWS Jr. Field Unit

This appendix describes the necessary parts needed to construct a portable, self contained SAVEWS Jr. system. The system described in this section is an example of a functioning and tested system used by the New England District of USACE. Please note that damage to the Lowrance HDS system or LSS2 StructureScan unit resulting from modification of factory components or incorrect wiring procedures is your responsibility. The Lowrance factory wiring diagram provided with your HDS system and appropriate in-line fuses should be used in assembly of the system.

The system (Figures A1) consists of a Lowrance LSS-2 structure scan module and a 12-V DC power source housed in a waterproof case (Figure A2), a quick disconnect swivel mount for the HDS unit, and a water proof through-deck fitting for transducer and power connections (Figure A3). The system includes provisions for external power through the use of a 12-V water resistant male trolling motor socket built into the case (Figure A4) which is paired with a female trolling motor plug wired ring terminals to receive power from an external 12-V battery. The pictured system also includes a male serial connector wired to the NMEA output on the HDS power/data cable. The transducers (455/800KHz StructureScan and 200 kHz skimmer) and external GPS antenna are mounted to an adjustable bracket (Figures A5 and A6) which clamps on to the bow or rail of the survey vessel. The external GPS antenna (not pictured) should be mounted to a pole which can be clamped to the transducer bracket. This allows the user to overlay position data on a paired video system recording in real time or to another external source. A parts list for the example system is provided in Table A1.

**Table A1.** Components Used for Example Self Contained SAVEWS Jr. System

Component	Description	Part #
Integrated echo sounder with internal GPS system	Lowrance HDS-10 with 50/200kHz skimmer transducer	Lowrance 000-0140-02
Structure Scan module and transducer	Lowrance LSS-2 StructureScan module for HDS systems with 455/800 KHz transducer	Lowrance 000-0132-06
Structure Scan transducer extension cable	Lowrance extension cable for LSS-2 transducer	Lowrance 99-006
External GPS	Lowrance LGC-4000 High sensitivity GPS Receiver Antenna	Lowrance 000-0125-28
NMEA 2000 network	Lowrance NMEA 2000 Network	N2K-EXP-RD-2
Waterproof Case	Pelican Case 1450 with Pick 'N Pluck Foam Case	Pelican 1450

<b>Component</b>	<b>Description</b>	<b>Part #</b>
Removable mount for HDS unit	Johnny Ray swivel mount for electronic instruments with push-button release	Jonny Ray JR-300
Waterproof through-deck fitting	Large CableClam waterproof fitting	Blue Sea Systems 1003
Adjustable transducer mounting bracket	Sully transducer mounting bracket for pontoon and thick-transom boats (selected for versatility)	Sully 8001P
Internal power source	12-V/7.5 Amp rechargeable battery	NA
Optional 12 volt external power connection	12-V 2 wire trolling motor connectors  -male boat side socket (case)  -female plug (wire with ring terminals or alligator clips to external battery)	Sierra WH10520 (male)  WH10530 (female)
Power switch for running the HDS unit without the LSS-1 module	Chrome-plated 12-V DC SPST toggle switch with water resistant switch boot	NA

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**Figure A1.** Portable SAVEWS Jr. System



**Figure A2.** LSS-2, 12 V Power Source, and Wiring



**Figure A3.** Quick Disconnect Mount External Connections



**Figure A4.** External Power Connection



**Figure A5.** Transducers, mounted on pivot arm, and GPS antenna mounting bracket.



**Figure A6.** Transducer and GPS bracket in use.



## Appendix B: Configuration File -DEFAULT.sjrcfg

Configuration file testing on May 2012 Cutty Hunk data collected by Ben Loyd  
file created 07/19/12

The values for the parameters in this file may be edited.

WARNING! CHANGING ANYTHING BESIDES THE NUMERIC VALUES FOR THE PARAMETERS WILL CAUSE THE CONFIGURATION FILE TO BECOME INVALID!

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### Basic Parameters - change as needed

\*\*\*\*\*

n	30	The number of StructureScan pings used per report cycle. Structure-Scan operated as a fixed rate of 30 Hz.
heightmin	0.10	Minimum plant height (m) (distance between declared bottom and shallowest above-threshold signal) required for a candidate plant detection declaration.
stdmin	0.03	Standard deviation (m) of difference between plant height of adjoining pings. Both STDMIN and HEIGHTMIN must exceed this minimum for a declared plant detection (AND function). To use only one feature set the other to zero.
maxplantdepth	5	The maximum bottom depth (m), uncorrected for transducer depth or tides, at which plants are found. This eliminates any candidate detection below this depth, and output is declared unvegetated.

\*\*\*\*\*

### Intermediate Parameters - change with caution

\*\*\*\*\*

startdepth	0.5	The depth (m) below transducer (zero depth) to start processing. This value can be set to higher value if it is necessary to read past an interference such as reflection from the motor lower unit. All data prior to this depth is ignored.
usernoise	0	Setting this value to zero will activate automated determination of noise threshold using Percentile value below. If set to a non-zero value, that number will be used as the noise threshold value.
percentile	75	The percentile of program-generated noise threshold data to be represented by the program-determined overall noise threshold. Higher percentile values result in higher thresholds, with less sensitivity to noise and to plant detection.
mingap	0.10	The minimum quiet zone distance (m) that must be below noise threshold in order to detect vegetation. If this quiet zone minimum is not met the ping is rejected as bad data. Only decrease this value from 0.10 m if working in extremely shallow water or inherently "noisy" water. In this situation, an alternate approach would be to increase the usernoise value.

bot_med_filt_size	9	Parameter for smoothing bottom declarations. Size of median filter (number of elements) used in median filter. Current value is the center element of this filter. Use only odd numbers between 5 and 13.
bot_change_tol	10	Parameter for smoothing bottom declarations. If deviation (m) between current value and the median determined by median filter of size bot_med_filt_size exceeds this value, then the current value will be replaced by the median. Deactivate this feature by setting it to a very large value, such as 10 m.
cand_veg_amt	5	The minimum percentage of pings in a report cycle that must be candidate vegetation before output is declared to be vegetation. If this percentage is not met, the report is declared unvegetated.
required_good	30	Minimum percentage of pings in report cycle (set as n above) that must be valid data before that report cycle is output. 30 is considered the minimum recommended value.

\*\*\*\*\*  
 Advanced Parameters - recommend not changing  
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swin	9	The width of the median filter to be used in smoothing the pings. If changing this parameter, refer to filterflag in the "Intermediate Parameters" section to complete parameter setup.
th_limit	230	The maximum allowable noise threshold for a ping.
use_all	1	Set this value to 1 for all data to be used, or 0 for only half of the data (depth-wise) to be used. This is a data reduction option that achieve processing time cost savings if depth recording is > 2x bottom depth.
hist_width	0.02	The width (m) of the bins to use in the histogram analysis that is used to make bottom declarations. This represents the bin widths into which bottom candidates are placed in order to make accurate bottom declarations.
bot_wid_percent	1	The percentage of bottom widths that can have a width of 0. This is used to set the threshold value to calculate the width of the bottom. The threshold value is increased until (bot_wid_percent) percent of pings have no bottom width.
filterflag	0	Set this value to 1 if median filtering of the original ping data is desired, or 0 is median filtering is NOT desired. For 200khz input data, this filtering must always be used. If using median filtering, refer to "swin" in the "Advanced Parameters" section.

\*\*\*\*\*  
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 If sending us files to troubleshoot, always send the .SJRCFG file used.  
 \*\*\*\*\*



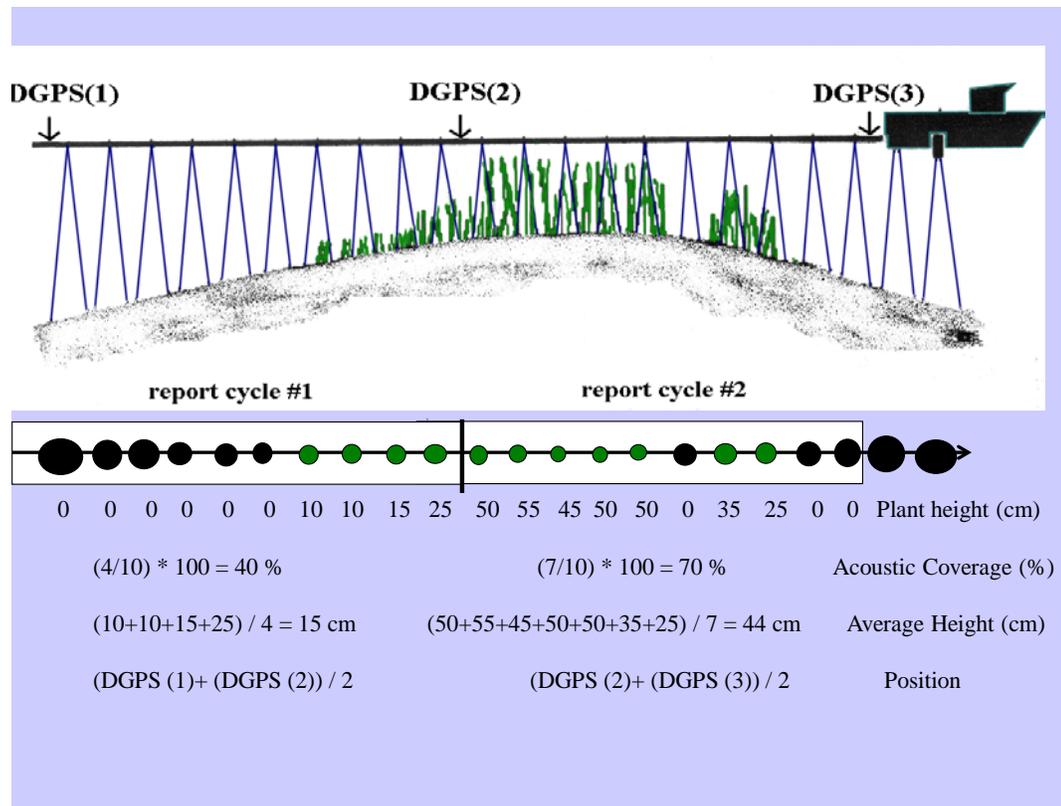
## Appendix D. Description of *Acoustic Percent Coverage*.

Percent coverage is a widely used quantitative metric to characterizing plant stands, both terrestrial and aquatic. Measurements of plant percent cover may be more ecologically meaningful than numbers of individuals, since cover is likely to provide a better measure of plant biomass than abundance (Mueller-Dombois and Ellenberg 1974). Visual estimates of seagrass percent cover using quadrats has been shown to require fewer replicates and less sampling effort for detecting differences than estimates of shoot count or biomass, making percent cover estimates more cost effective (Heidelbaugh and Nelson 1991). However, it is not practical to sample large areas using this technique. Alternatively, underwater videography has also been used to estimate seagrass basal area coverage over larger areas, but these methods are limited to areas with good water clarity (Norris et al. 1997). Both quadrat and underwater videography methods involve imposing a frame of a known size over the bottom, followed by estimating the proportion of the surface area within the frame that is occupied by vegetation.

In some ways, the acoustic technique presented here is analogous to a series of visual estimates of percent cover. For example, each individual sample (single ping) of the SAVEWS Jr system could be likened to a small quadrat; SAVEWS Jr transects would thus be similar to a series of contiguous small quadrats arranged in a belt transect. In this case, overall seagrass cover within the area occupied by the belt transect would be computed as the average cover of all quadrats within that transect, and as pointed out by Mueller-Dombois and Ellenberg (1974) continuous transects of evenly spaced points should result in more accurate estimates of plant cover than random placements of grouped points. However, the way in which seagrass cover is detected and estimated in the hydroacoustic technique is fundamentally different. In the visual methods, the percent cover of seagrass within each quadrat is estimated as the proportion of the bottom that is covered by vegetation. In contrast, the acoustic technique classifies each individual sample (single ping) as either detecting or not detecting SAV. The requirement for detection is that acoustically reflective material occurs contiguously above the bottom for some minimum distance. As noted in this manual, the sensitivity of the acoustic echo and minimum distance above the bottom required for detection can both be set by the user to be more or less sensitive, based on conditions and survey objectives. We then estimate coverage as the percentage of pings within a localized area (settable as a reporting cycle using parameter **N** in CF, see Appendix B). Each ping within the reporting cycle either represents a detection or not (binary). While this seems a reasonable approach given the constraints of the acoustic system, it is a fundamentally different measure from the physical and visual measured. For this reason we have labeled this measure as *Acoustic Percent Coverage*. The resulting acoustic percent coverage summarizes results from a linear string of binary detection samples<sup>2</sup>. This is illustrated below along with an example of the calculations for coverage and mean height (Figure D1).

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<sup>2</sup> Because a linear transect is summarized and output as a point, users should be aware that intersecting (non-parallel) transects may have outputs at the same location that have different values. This may seem counterintuitive but it is because each output represents a different area surveyed, except for the midpoint of the reporting cycle. For this reason we recommend that surveys consist of parallel, non-intersecting transects.

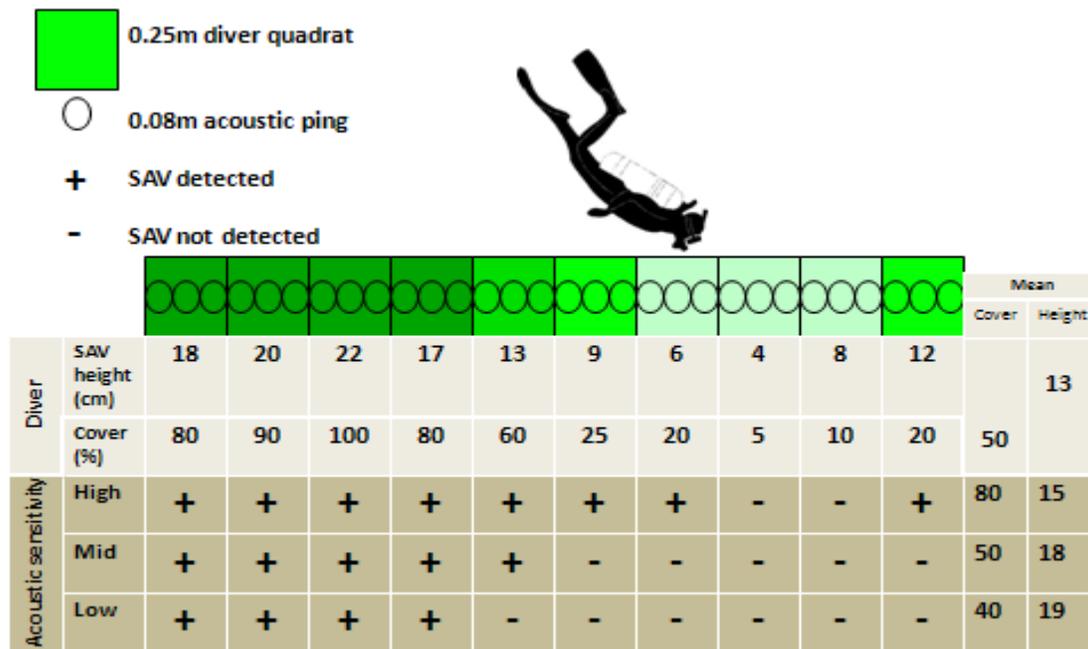


**Figure D1.** Cartoon of acoustic survey and computation of outputs using 10 pings per report cycle.

The flexibility in setting processing parameters, the binary nature of detection, and the fact that there will always be an inherent (and variable) detection limit makes acoustic coverage different from the standard coverage measure. This is illustrated in the hypothetical example below (Figure D2). A 2.5-m segment is acoustically surveyed (1 second at 5 knots boat speed and 30 pings/sec) and sampled by a diver. We will assume that depth is around 1.6 m, thus the acoustic area sampled has a diameter of approximately 8 cm (roughly 5% of depth for 800 kHz downward facing channel) so that the sampled circles are almost contiguous ( $30 \times 0.08\text{ m} = 2.4\text{ m}$ ). Diver measurements (quadrat coverage and plant height) for 10 contiguous 0.25-m quadrats show an average coverage of 50% and an average plant height of 13 cm. Acoustic data are processed with three levels of sensitivity, controlled by the sensitivity threshold **usernoise** and the height threshold **heightmin**. For this example we assume that adjustments of these thresholds translate to the following detection performance.

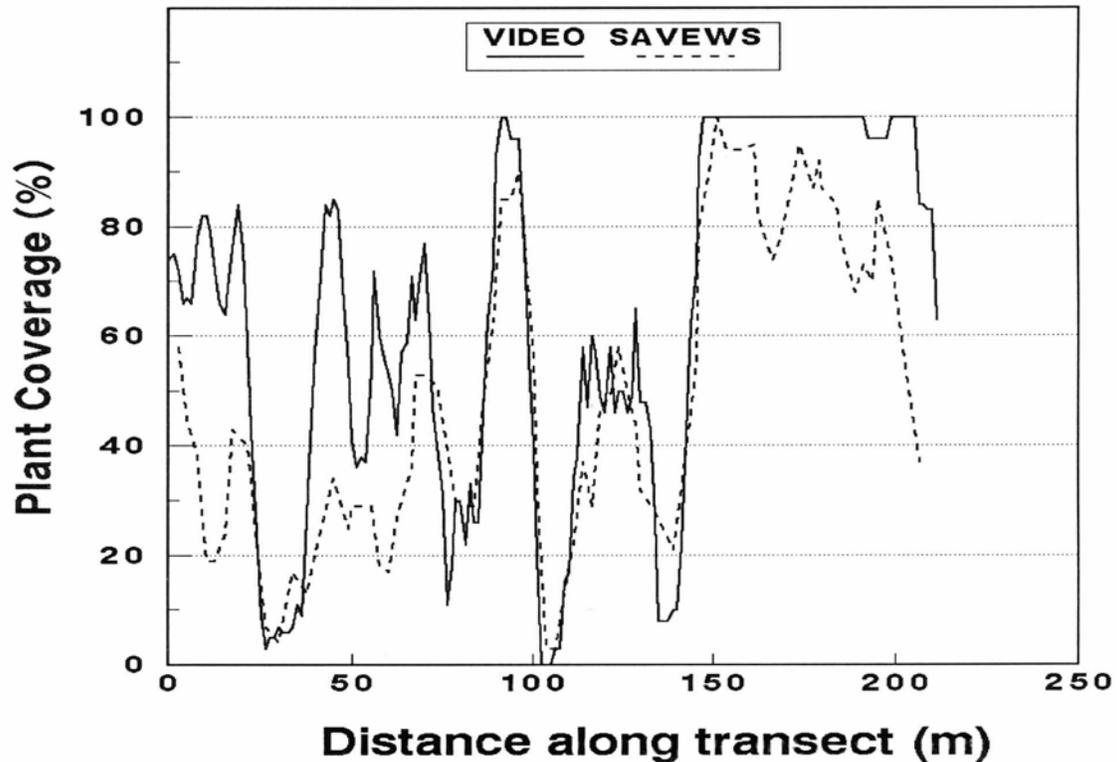
1. Highest sensitivity: plant height > 5 cm **and** coverage > 15%;
2. Intermediate sensitivity: plant height > 10 cm **and** coverage > 20%;
3. Lowest sensitivity: plant height > 15 cm **and** coverage > 25%.

Corresponding detection performance for the acoustic survey with the diver survey shows general agreement but also illustrates the effect of user-defined sensitivity (for purposes of graphic simplicity we only show acoustic detection for every third ping).



**Figure D2.** Hypothetical comparison of diver and acoustic measurements for a 2.5-m linear segment of SAV

One could easily envision scenarios where there are dramatic difference between diver and acoustic survey technique results. An example of this would be surveys in sparse vegetation below the detection limit of the acoustic system – such as sparse and short *Halodule* spp. or *Halophila* spp. We have found that when operating in vegetation within the performance bounds of the acoustic system, results are generally similar. We have not yet collected or analyzed simultaneous diver and acoustic data for the SAVEWS Jr system but have done so for the predecessor system, SAVEWS (Figure D3). These data compare SAVEWS with simultaneous interpreted underwater video for a southwest Florida site containing a mixed bed of *Halodule*, *Syringodium*, and *Thalassia* (Sabol et al. 2002). We found that the acoustic system generated coverage estimates that were highly correlated, but slightly below, that of the videographic technique, but that there was very good agreement on boundaries. While we do not yet have similar validation data for the SAVEWS Jr. system, we have acquired simultaneous comparisons with the SAVEWS and found a high level of agreement. We expect that SAVEWS Jr would exhibit at least a similar level of agreement the standard coverage measures as did the SAVEWS.



**Figure D3.** Comparison of interpreted underwater videography and SAVEWS acoustic system in mixed seagrass bed in southwest Florida.

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