AOS PROTOCOL AND PROCEDURE: BAT – BATHYMETRY AND MORPHOLOGY OF LAKES AND NON-WADEABLE STREAMS

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See configuration management system for approval history.

Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	06/02/2014	ECO-01129	Initial release
B	01/26/2015	ECO-02636	Migration to new protocol template
C	08/27/2015	ECO-03158	Updates for clarification, added figures.
D	02/29/2016	ECO-03680	Updates for clarification, and edits based on FOPS review; added figures.
E	04/10/2017	ECO-04483	CM updated with new template and changes based on feedback from FOPS; Major changes include removal of the need to sketch field observations on datasheets, removal of measuring discharge and inlet/outlet locations at lakes, and clarification of equipment setups with more figures. Sampling dates now coincide with peak greenness.
F	04/27/2018	ECO-05697	Bathymetric surveys take place within the site-specific biological sampling bout 2 (summer), or +/- 2 weeks of the Aquatic Plant survey, and overlaps with the period of peak greenness. Removed GPS spot-checking. Will collect ground-truthing data using random and targeted locations. Shoreline and in-water features are collected with a Trimble handheld unit. Ground-truth points identified in the field are recorded with the Humminbird GPS. Updated figures. Updated FOPS data entry and verification steps using Humminbird PC and HumViewer programs; removed converting the sonar files to .csv. Included references to the use of the mobile application and device. Revised data entry and validation section. No longer recording many of the sonar settings. Updated mobile application and datasheets with these changes.
G	01/29/2019	ECO-05998	Clarified the sampling timing contingency data product impacts if a survey occurs 5 days beyond the scheduled date or is outside of the +/- 2 week plant sampling window. Updated the Sampling Timing Contingency Outcome for Data Products in the event that the survey cannot be completed. Included a reference to the Humminbird Helix sonar unit in use at Domain 08. Updated the guidance for collecting shoreline/in-water

			features with the GPS. Minor updates to clarify the ground-truthing procedures. No datasheet or mobile application updates.
H	11/26/2019	ECO-06284	• Updated for use with the Biosonics MX Habitat echosounder and new template
J	03/22/2024	ECO-07066	• Migrated to protocol template rev L • Updated NEON logo • Integrated KBAs into protocol • Updated SOP's A and B for clarification • Added multiple figures to better illustrate steps • Fixed formatting issues

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1 OVERVIEW

1.1 Background

Bathymetry and morphology are key parameters for defining the hydrological, physical, chemical, and biological characteristics of lakes and non-wadeable streams. Water level, volume, and area relationships provide spatial quantitative information. They also impart a governing role on hydrodynamics, chemical reactions and biotic distribution and productivity. Furthermore, temporal comparisons between bathymetries can be used as an indicator of environmental change by providing information on ecosystem functioning, changes in water turnover times and storage, and catchment erosion-sedimentation rates (Dost and Mannaerts, 2008). Obtaining baseline characteristics, hence, becomes imperative in light of future activities aimed at a better understanding of lake and non-wadeable stream (river) dynamics as well as health through time.

This protocol describes the steps required to collect data for bathymetric and morphological maps utilizing an acoustic sonar system. Bathymetric and morphological data are collected to produce 2D and 3D bathymetric maps and to characterize the structure of the waterbody by creating morphological maps of the underwater environment. Bathymetric and morphometric data add another dimension to geographic mapping and modeling and can be used either as a background layer or as a 3D surface for draping thematic maps such as benthic habitats, organism habitats or geologic data.

1.2 Scope

This document provides a change-controlled version of Observatory protocols and procedures. Documentation of content changes (i.e. changes in particular tasks or safety practices) will occur via this change-controlled document, not through field manuals or training materials.

1.2.1 NEON Science Requirements and Data Products

This protocol fulfills Observatory science requirements that reside in NEON's Dynamic Object-Oriented Requirements System (DOORS). Copies of approved science requirements have been exported from DOORS and are available in NEON's document repository, or upon request.

Execution of this protocol procures samples and/or generates raw data satisfying NEON Observatory scientific requirements. These data and samples are used to create NEON data products, and are documented in the NEON Scientific Data Products Catalog (RD[03]).

1.3 Acknowledgments

The field protocol used by NEON for producing bathymetric and morphometric maps of the lakes and non-wadeable streams follows the general requirements set forth by the U.S. Army Corps of Engineers (2002) and Heyman et al. (2007).

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

Applicable documents contain higher-level information that is implemented in the current document. Examples include designs, plans, or standards.

AD[01]	NEON.DOC.004300	EHS Safety Policy and Program Manual
AD[02]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD[03]	NEON.DOC.000724	Domain Chemical Hygiene Plan and Biosafety Manual
AD[04]	NEON.DOC.050005	Field Operations Job Instruction Training Plan
AD[05]	NEON.DOC.004104	NEON Science Data Quality Plan
AD[06]	NEON.DOC.001152	NEON Aquatic Sampling Strategy

2.2 Reference Documents

Reference documents contain information that supports or complements the current document. Examples include related protocols, datasheets, or general-information references.

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms
RD[03]	NEON.DOC.002652	NEON Data Products Catalog
RD[04]	NEON.DOC.001271	AOS/TOS Protocol and Procedure: DMP – Data Management
RD[05]	NEON.DOC.001646	General AQU Field Metadata Sheet
RD[06]	NEON.DOC.003282	NEON Protocol and Procedure: SIM – Site Management and Disturbance Data Collection
RD[07]	NEON.DOC.004257	Standard Operating Procedure: Decontamination of Sensors, Field Equipment, and Field Vehicles
RD[08]	NEON.DOC.005247	AOS/TOS Standard Operating Procedure: NEON Aquatic and Terrestrial Site Navigation
RD[09]	NEON.DOC.004856	AOS Standard Operating Procedure: BAT – Post-Processing of Bathymetric and Side Scan Sonar Data from NEON Lakes and Non-Wadeable Streams
RD[10]	NEON.DOC.001085	AOS Protocol and Procedure: Stream Discharge
RD[11]	NEON.DOC.003039	AOS Protocol and Procedure: APL – Aquatic Plant, Bryophyte, Lichen and Macroalgae Sampling
RD[12]	NEON.DOC.002494	Datasheets for AOS Sample Shipping Inventory
RD[13]	NEON.DOC.003104	Datasheets for AOS Protocol and Procedure: BAT – Bathymetry and Morphology of Lakes and Non-Wadeable Streams

2.3 Acronyms

Acronym	Definition
CI	Cyberinfrastructure
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System

LCD	Liquid Crystal Display
MMC	Multi-Media Card
NAD83	North American Datum of 1983
P&P	Procedure and Protocol
PVC	Polyvinyl Chloride
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WAAS	Wide Area Augmentation System
YSI	Yellow Springs Instrument Co.

2.4 Definitions

Bathymetry: Underwater depth of an aquatic ecosystem.

Fulcrum: Software tool used to create NEON electronic data entry applications.

Morphology: Structure and arrangement of features within the lake watershed and lake bottom. It can include the shape of the surface of a lake and the arrangement of rocks and sediments.

Sonar: Technique that uses sound propagation. The active sonar emits pulses of sounds and records echoing returns. When used in water it is more frequently known as hydroacoustic and involves the use of an echosounder.

ServiceNow: Software tool used for problem/incident tracking and resolution.

3 METHOD

A vessel is mounted with the DGPS and echo-sounding equipment and driven across the lake or non-wadeable stream surface. The field protocol used by NEON for producing bathymetric and morphometric maps of the lakes and non-wadeable streams follows the general requirements set forth by the U.S. Army Corps of Engineers (2002) and Heyman et al. (2007). While the equipment is not the same, the assumptions remain valid. The U.S. Army Corps approach entails the use of a dual-beam echosounder that is mounted on a large research vessel and capable of mapping large areas. The equipment utilized here also uses an echosounder, but it is a single beam high frequency system that is able to accurately (<1 cm) detect bathymetry of shallow systems (>= 0.5 m depth below the transducer face). The echosounder transmits at a frequency of 204.8 kiloHertz with a canonical beam angle of 8.5°. Water depths are determined by the echosounder based on post-processing review and the speed of sound in water and compensated for temperature.

Recent advances in echo-sounding equipment provide information regarding bathymetry (depth), as well as recording the strength of sound energy that bounces back (called "backscatter"). Backscatter is used to identify the composition of the underwater sediments. This technology facilitates the identification of changes in the morphometry of water bodies over time that may result from high impact events or long-term changes in the environment. The shoreline and large in-water features are recorded at the time of sampling with a handheld GPS receiver with decimeter accuracy (e.g. Trimble) in continuous mode. The use of a handheld GPS receiver antenna is preferred if available but not necessary. Other in-water ground-truthing feature locations identified while surveying will be collected using the Biosonics sonar and GPS. Types of features that are important to record are those that can't be driven over, and therefore won't be detected by the sonar unit. These include floating vegetation mats and large woody debris or boulders that are too close to the surface to drive over. These data are imported into GIS and used during post-processing. Data collected in the field are formatted and downloaded into formats required for post-processing and data product creation (RD[09]).

Standard Operating Procedures (SOPs), in Section 7 of this document, provide detailed step-by-step directions, contingency plans, sampling tips, and best practices for implementing this sampling procedure. To properly collect and process samples, field technicians **must** follow the protocol and associated SOPs. Use NEON's problem reporting system to resolve any field issues associated with implementing this protocol.

The value of NEON data hinges on consistent implementation of this protocol across all NEON domains, for the life of the project. It is therefore essential that field personnel carry out this protocol as outlined in this document. In the event that local conditions create uncertainty about carrying out these steps, it is critical that technicians document the problem and enter it in NEON's problem tracking system.

Quality assurance is performed on data collected via these procedures according to the NEON Science Data Quality Plan (AD[05]).

4 SAMPLING SCHEDULE

4.1 Sampling Frequency and Timing

Bathymetric surveys at lakes are completed at least every 5 years, except when an extreme event results in substantial physical change to the morphology or submerged habitat of a site. In that case, an out-of-cycle survey may be requested at a more frequent interval. At non-wadeable streams, bathymetric surveys are completed on an annual basis for at least 3 years to assess stability of the channel and then every three years unless there is a high flow event. Bathymetric surveys take place within +/- 2 weeks of the Aquatic Plant survey, and overlaps with the period of peak greenness, defined as the range of dates where MODIS NDVI is within 90% of the site maximum. It is advised that surveys are started as early in the day as possible to complete the survey. Refer to the Site-Specific NEON Aquatic Site Sampling Design documents for the biological bout 2 schedule for determining the bathymetry and morphology schedule.

Bathymetry and Morphology of Lakes and Non-Wadeable Streams is performed according to the schedule in **Table 1** and implementation of this protocol is scheduled during the peak greenness window and within 2 weeks of plant sampling. Synchronized protocols and SOPs include:

AOS Protocol and Procedure: APL – Aquatic Plant, Bryophyte, Lichen and Macroalgae Sampling (RD[11])

Table 1. Sampling frequency for Bathymetry and Morphology of Lake and Non-wadeable Streams procedures on a per SOP per site basis.

SOP	Site	Bout Duration	Expected Bout Frequency	Remarks
SOP A	River	1-2 hours	1 per 3 years	Building the mount should only need to be done once after receiving the sonar unit. Then preparations for sampling should take 1-2 hours the day before to charge batteries and pack supplies.
	Lake	1-2 hours	1 per 5 years	
SOP B	River	1 day	1 per 3 years	Collecting sonar data, water body perimeter GPS data, and ground-truth data.
	Lake	1-5 days	1 per 5 years	
SOP C	River	1-2 hours	1 per 3 years	QAQC and load data to CI Dropbox.
	Lake	1-2 hours	1 per 5 years	

Scheduling Considerations

1. Coordinating with plant sampling and the peak greenness window for Bathymetry and Morphology of Lakes and Non-Wadeable Steams should take place at all lake and river sites.

2. Environmental conditions may impact data collection.

   a. Wind speeds above 5 knots that cause waves to form create noise in the sonar data that cannot be corrected for in post-processing. Data collection should not occur during high wind conditions where the water surface is choppy.

      b. Precipitation or water inflow conditions that change the staff gauge height more than ±2 cm from the beginning to end of the day require review by HQ science prior to proceeding with data collection the next day to verify that changes in water level are accounted for in post-processing.

4.2   Criteria for Determining Onset and Cessation of Sampling

Baseline lake or non-wadeable stream bathymetric and morphological maps were generated during the first year of operations using a side-scan sonar unit at each site during the period of peak greenness as defined by maximum cumulative growing degree days. The annual timing of such bathymetric surveys shall remain the same for each individual site (within the site-specific peak greenness window), to have seasonal comparison at sites sampled at the same time of year each year at rivers or every 5 years at lakes and enable comparison to the airborne observation platform (AOP) images. Onset of sampling occurs with the peak greenness window and cessation of sampling occurs when the entire water body has been mapped according to this protocol.

4.3   Sampling Timing Contingencies

Bathymetric mapping requires calm conditions in order to improve the accuracy and precision of the data acquired. Pitch, roll and heave can affect the angle at which the acoustic beams are delivered in the water column and received by the transducer on the boat. Should the boat be at an angle the apparent depth will differ substantially from the actual depth. Data should only be collected during calm water conditions.

Table 2. Contingency decisions for Bathymetry and Morphology of Lakes and Non-Wadeable Streams.

Delay/ Situation	Action	Outcome for Data Products
Hours	Do not undertake bathymetric sampling if the water surface is choppy or has surface waves. This often occurs at wind speeds above 5 knots or when boat traffic produces a wake. Wait for the weather to change or wakes to pass and attempt a mapping session later in the day, or postpone to another day.	No adverse outcome.
	If equipment stops functioning during sampling, verify equipment and start sampling again as soon as possible.	
	If weather becomes unsafe during sampling, stop and resume when conditions are safe to continue sampling.	
1 Day or More	Should safety conditions change while on the water and in the middle of a mapping project, note this in the remarks section of the field datasheets and stop working. Save the data, turn off all equipment and start re-surveying as soon as conditions permit. If conditions have changed substantially so that more than 5 days have passed or the survey occurs outside of the	No adverse outcome if survey is completed. Surveys that cannot be completed will result in no data.

Delay/Situation	Action	Outcome for Data Products
	+/- 2 week plant sampling window, file a trouble ticket and contact HQ science.	

4.4 Estimated Time

The time required to implement a protocol will vary depending on a number of factors, such as skill level, system diversity, environmental conditions, and distance between sample plots. The timeframe provided below is an estimate based on completion of a task by a skilled two-person team (i.e., not the time it takes at the beginning of the field season). Use this estimate as framework for assessing progress. If a task is taking significantly longer than the estimated time, a problem ticket should be submitted. Please note that if sampling at particular locations requires significantly more time than expected, Science may propose to move these sampling locations. We estimate sampling for bathymetry and morphology in lakes requires two field scientists between 5 to 10 hours each sampling day (up to 5 days) plus travel to and from the site.

Table 3. Estimated staff and labor hours required for implementation of the of Bathymetry and Morphology of Lakes and Non-Wadeable Streams.

SOP	Estimated time	Suggested staff	Total person hours
SOP A.1: Preparing for Data Capture	0.25 h	1	0.25 h
SOP A.2: Preparing field equipment and charging batteries	0.25 h	1	0.25 h
SOPs B.2 & B.3: Transducer mounting	0.5 h (first sampling)	1	0.5 h (first sampling)
SOP B.4: Connecting power and communication	0.25 h	1	0.25 h
SOP B.5 & B.6 & B.7: Collecting Bathymetry Data	4-24 h	2	8-48 h
SOP B.8: Collecting Staff Gauge Readings	0.25 h	1	0.25 h
SOP B.9: Collecting Shoreline and In-water Features	4-16 h	2	8-32 h
SOP B.10: Collecting Ground-truthing Data	1-8 h	2	2-16 h
SOP C: Activities at the End of a Sampling Day	4-16 h	2	8-32 h per site

5 SAFETY

This document identifies procedure-specific safety hazards and associated safety requirements. It does not describe general safety practices or site-specific safety practices.

Personnel working at a NEON site must be compliant with safe field work practices as outlined in the Operations Field Safety and Security Plan (AD[02]) and EHS Safety Policy and Program Manual (AD[01]). Additional safety issues associated with this field procedure are outlined below. The Field Operations Manager and the Lead Field Technician have primary authority to stop work activities based on unsafe field conditions; however, all employees have the responsibility and right to stop their work in unsafe conditions.

In addition, the following safety guidelines are provided:

1. Due to site-specific hazards, the safest approach may be for the field scientist to perform GPS positioning and measurements for inflow and outflow (where applicable) in the boat without dismounting.

2. When alligators inhabit waters, the field scientist should not place hands or feet in river, lake, or pond.

3. The field scientist must wear personal flotation device (PFD) prior to entering boat and during work operation.

4. The field scientist must have communication with team members such as a two-way radio, satellite phone/pager, or cellular.

5. Safety briefing should include known hazards and any specific requirements or procedures for the location. Examples are navigation rules, deep or shallow areas, etc.

6   PERSONNEL

6.1   Training Requirements

All technicians must complete protocol-specific training as required in the Field Operations Job Instruction Training Plan (AD[04]). Additional protocol-specific required skills and safety training are described here.

All personnel required to operate a boat shall be trained through a program approved by NEON Environmental, Health, and Safety. All others shall be aware of boating safety procedures.

Personnel are to be trained in lake and non-wadeable stream bathymetry and morphometry measurements and safe working practices for lake and non-wadeable stream work.

6.2   Specialized Skills

Where applicable, personnel will be licensed to operate a boat and able to safely handle an electric motor and drive a boat safely.

7   STANDARD OPERATING PROCEDURES

SOP Overview
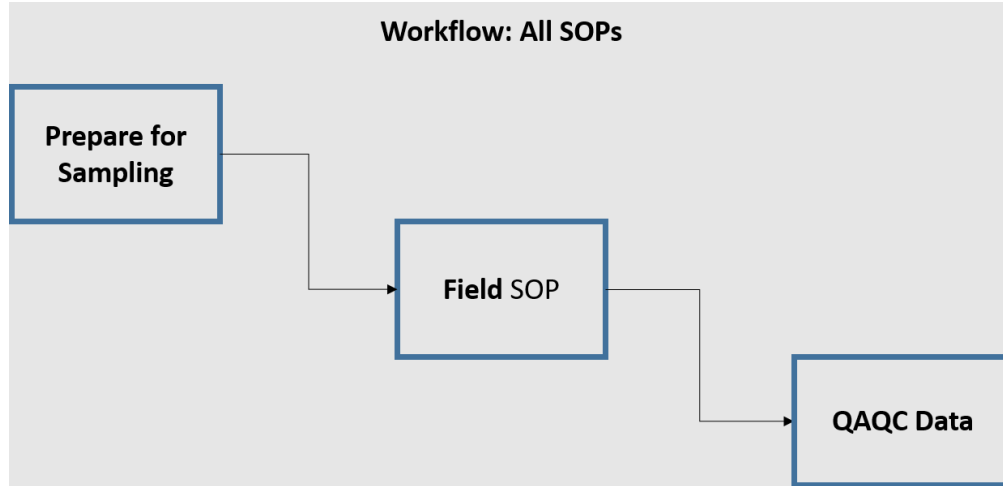
Figure 1. A high level workflow diagram that visually shows how the separate SOPs are sequentially connected. Each box represents an SOP within the protocol.

- SOP A: Preparing for Sampling
- SOP B: Field Sampling
- SOP C: Post-Field Sampling Tasks

SOP A   Preparing for Sampling

A.1   Preparing for Data Capture

Mobile applications are the preferred mechanism for data entry. Mobile devices should be fully charged at the beginning of each field day, whenever possible.

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should be carried along with the mobile devices to sampling locations at all times.

In addition:

1. Ensure computer(s) have Visual Acquisition software installed and a minimum of 10 GB free hard drive space for storing sonar data. Software can be downloaded from the Biosonics website (https://www.biosonicsinc.com/support/customer-downloads/) or installed from the USB flash drive included with the sonar unit.

2. Ensure camera memory cards are blank or have sufficient space for additional photos. If files are present, confirm data and photos have been uploaded prior to deleting.

3. Ensure that you are able to set your computer's LAN connection manually to 192.168.1.9. Once the change has been made, your computer will not be able to connect to the internet via Ethernet (e.g. on a wired dock at the office) until you have changed your settings back to "obtain an IP address automatically". Wi-fi should work just fine, though. If the following steps do not work, please contact IT.

   a. Open settings and select network & internet

   b. Click Ethernet and then network and sharing center

   c. Click change adapter settings and double click on Ethernet (ignore any vEthernet options) and click on properties

   d. Double click on "internet protocol version4" and select "Use the following IP address"

   e. Enter 192.168.1.9 into the IP address field and 255.255.255.0 into the Subnet mask field, click ok (**Figure 2**).
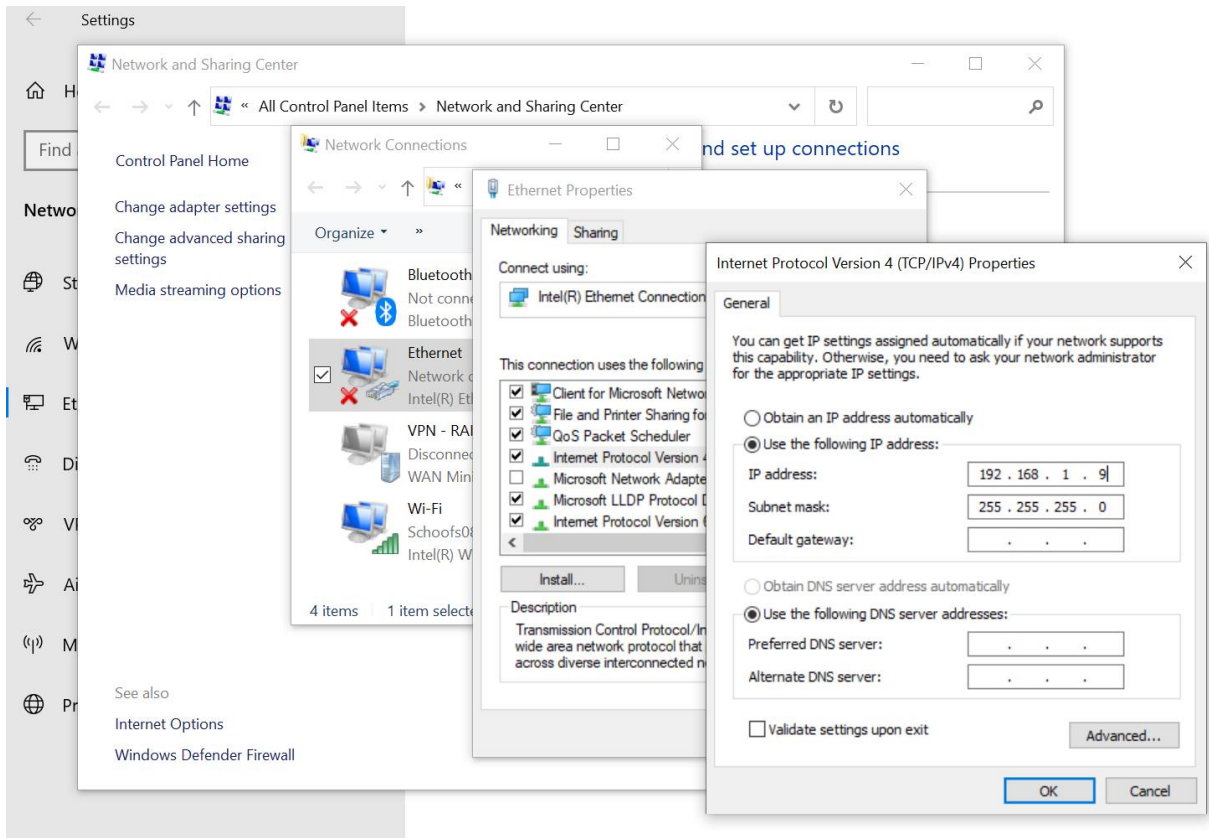
Figure 2. Shows pathway for manually changing LAN on laptop.

  f. Click ok and then close and you should be back at the network connects window and you should be all set. As a check to see if your computer saved the new LAN connection, try connecting to the internet via an ethernet connection. It will be unable to connect once the LAN change happens. If it does connect you know that you will need to try again.

A.2 Preparing Field Equipment and Charging Batteries

The following section describes activities that may need to take place the day before each planned field day:

1. Fully charge the 12V DC marine deep-cycle battery that will be connected to the sonar instrument.

2. Fully charge the laptop that will be connected to the sonar instrument.

3. Fully charge any batteries needed for electric trolling motors or make sure that fuel tanks are adequately full for the day.

4. Ensure all equipment is decontaminated according to NEON Decontamination Protocol (RD[07]).

SOP A

5. Generate random ground truthing points. ArcGIS step by step instructions are available in the "Determining Sampling Locations" presentation in the Training Center.

   a. Navigate to Training Center

   b. Click on Course Catalog

   c. Select APL from Categories

   d. Click on "APL Non-wadeable Field Methods Training Plan"

   e. Click on "APL Non-wadeable Presentation – Field Sampling"

   f. Select and review "APL Presentation – Determining Sampling Locations"

NOTE: *You will be randomly sampling the entire body of water for your random ground truth points so do not use a plant colonizable depth when determining area to generate your points. Skip slides 13 through 22.*

6. Review NEON.DOC.005221, *AOS/TOS Standard Operating Procedure: Trimble GEOXH Receivers Setup and Use* and familiarize yourself with using a Trimble.

7. Download **Visual Acquisition** and **Visual Aquatic** software to laptop used to the bathymetry survey. They can be found on flash drives stored with the Biosonics sonar case. Contact your Domain Manager and/or Science if they are misplaced.

A.3   Preparing for Field Sampling

1. Plan and save sampling routes for field teams using standard site navigation procedures (RD[08]). Route planning enhances sampling efficiency and helps avoid accidental foot traffic within NEON plots.

SOP B   Field Sampling

Ensure the General AQU Field Metadata Sheet (RD[05]) is completed.

B.1   Temporally Linked Protocols

Aquatic Plant, Bryophyte, Lichen and Macroalgae Sampling is temporally linked to bathymetry so that plant community structure and composition can be compared between the two protocols.

- Bathymetry should be scheduled within +/- 2 weeks of the aquatic plant sampling that will be completed in the same year as a bathymetry bout.

- This should coincide with a timeframe within the peak greenness window as well.

⚠️ *The face of the sonar transducer is extremely sensitive to scratches and pitting. Do not hit, bump, or scratch the transducer face while mounting the sonar to the pipe reducer or boat mount.*

B.2   Transducer and Boat Setup – Non-wadeable Streams and Rivers

At Non-Wadeable Streams, the Kentucky 2 mount will be used for mounting the sonar unit. The vertical 2" aluminum pole needs to be threaded in order to accommodate a reducer that goes from 2" to 0.5" to match the threads of the Biosonics unit (see **Table 6** for part numbers). So, the pole used for the ADCP mount cannot be used since it isn't threaded. The following steps are a guide and can performed in a different order as long as the transducer face is protected from damage along the way and the transducer ends up securely mounted to the boat.

1. Remove the reducer that ships with the Biosonics unit, if needed (**Figure 3**).

Figure 3. 0.5" to 0.75" reducer attached (panel A) and removed (panel B) to the sonar transducer.

2. Feed the sonar unit cable through the larger reducer with the 0.5" end towards the transducer and screw the reducer on to the threaded end of the Biosonics unit.

3. Feed the sonar unit cable through the 2" threaded aluminum pipe with the threaded end (if both ends are not threaded) of the pipe towards the transducer and screw the large, 2", end of the reducer on to the 2" aluminum pipe.

4. Carefully feed the aluminum pipe and sonar unit cable through the square bracket portion of the Kentucky 2 mount. Set the square part on the pipe mounted to the boat deck and tighten it so that the sonar unit is securely held in place, both vertically and horizontally. At this point, the transducer could be inside the boat as long as the transducer face is not touching anything (**Figure 4**).
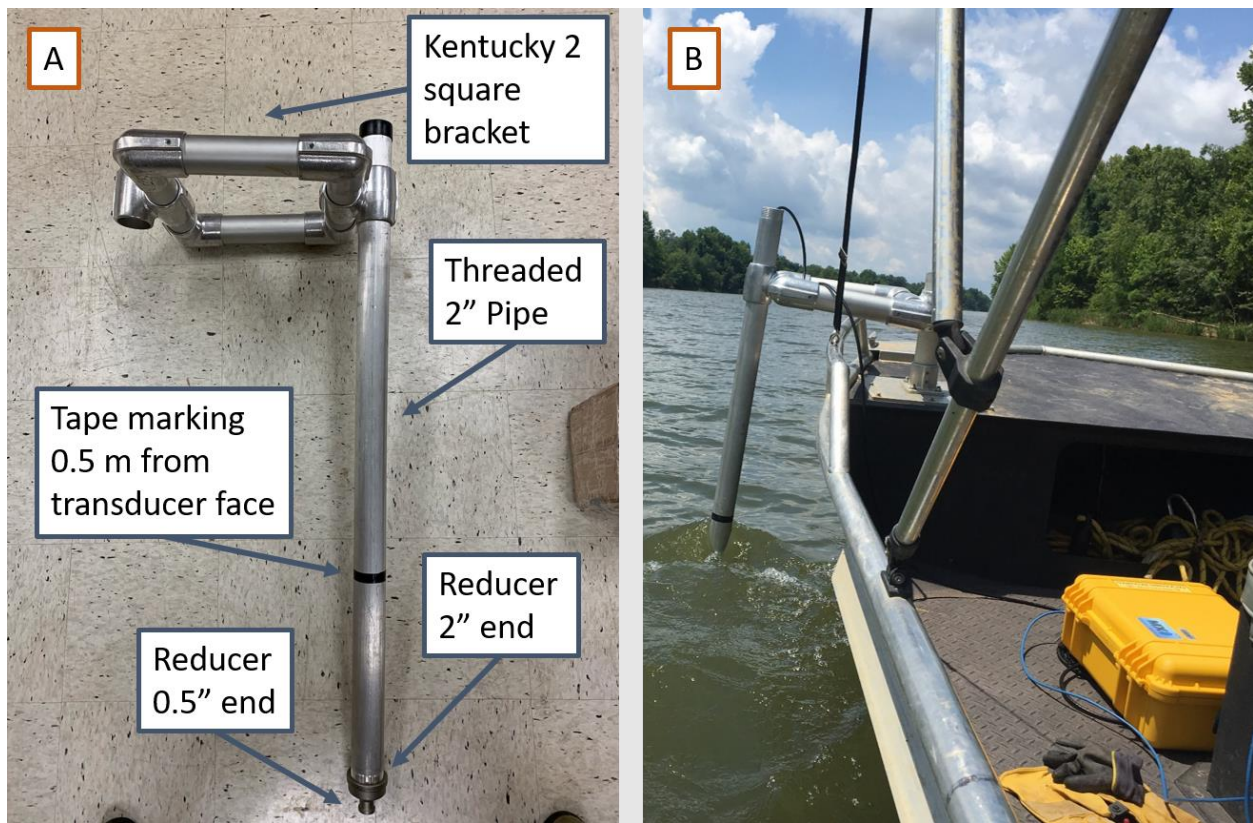
Figure 4. Example of Kentucky 2 mount out of the water (Panel A) and with transducer submerged and cables connected to the Biosonics case that contains the GPS receiver and power supply (Panel B).

While driving the boat quickly, e.g. while running from the dock to the permitted reach, the Kentucky 2 mount can be swiveled so that the sonar unit is inside the boat, if it is easier to install while on shore or while traveling to the site.

B.3   Transducer and Boat Setup – Lake

At Lake sites, the same trolling motor mount that was used for the Humminbird and 0.75" threaded pipe can be used to mount the Biosonics unit. If the threads of the pipe are rusted, a new piece of pipe may need to be used. The Biosonics ships with a 0.5" to 0.75" pipe reduced that should fit the galvanized pipe.

1. Install the 0.75" pipe into the trolling motor mount, if stored separately.

2. Feed the sonar unit cable through the 0.75" threaded pipe with the threaded end (if both ends aren't threaded) of the pipe towards the transducer and screw the larger end of the reducer on to the pipe.

3. Install the trolling motor mount on the side of the boat. Plastic or composite shims can be useful for getting the mount to be secure and steady (**Figure 5**, panel B).

Figure 5. Example of pipe and trolling motor mount with transducer submerged (panel A). Shims used to make the mount more stable can be seen in panel B. The cable is fed out through the top of the pipe to be connected to the Biosonics case that contains the GPS receiver and power supply.

B.4   Connecting Power and Communication on the Sonar System

1. Connect the twist lock connector at the end of the transducer cable to the 3-pin port labeled "transducer" on the Biosonics case after removing the protective metal cap from the port. Be sure to line-up the notch in the cable to the notch at the top of the receptacle on the case (**Figure 6**).

2. Connect the computer to the Biosonics case using the Ethernet cable after removing the protective metal cap from the port on the case (**Figure 7**).

3. Make sure that the power switch on the Biosonics is set to off. Connect the red and black connectors to the matching connectors labeled 12VDC on the case. Connect the alligator clips to the 12V battery (**Figure 7**). Leave the power switch set to off until you are ready to start collecting data (**Figure 7**).
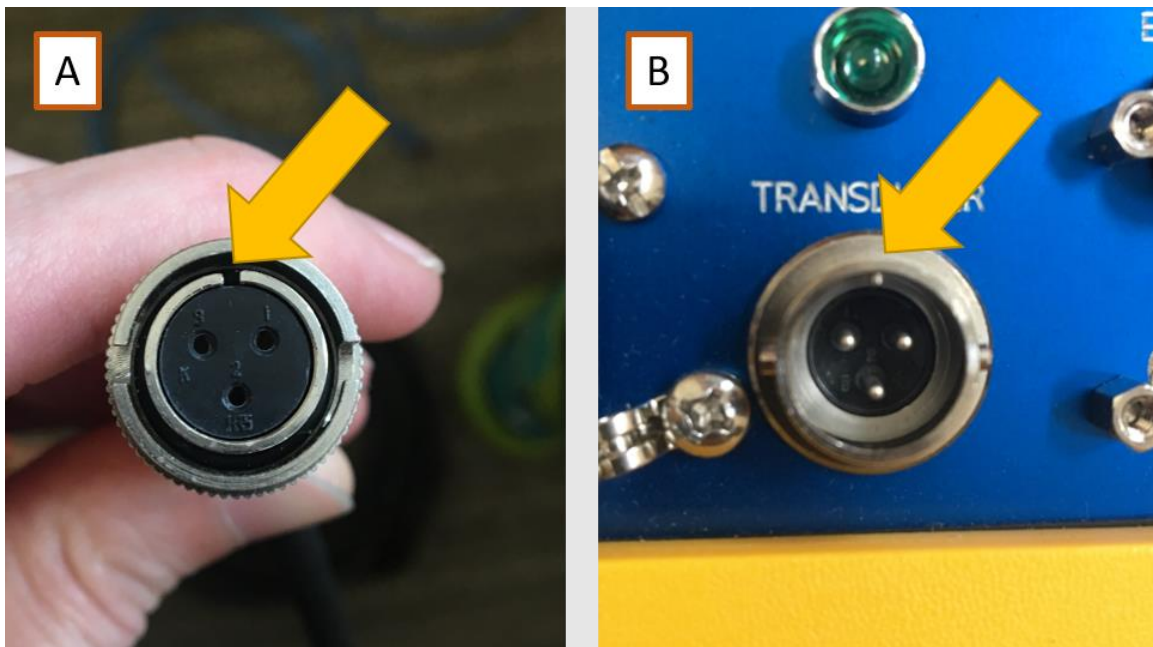
Figure 6. Transducer cable with arrow pointing at notch (panel A) and Biosonics case with arrow pointing at notch that needs to be aligned (panel B).

Figure 7. Example photo of all cables plugged into the case. Arrow points at the power switch that should be turned off until you're ready to collect data. Alligator clips should be connected to a 12V DC deep cycle battery. The sonar unit should be installed on the boat mount prior to connecting to the case.

B.5   Initialization and Configuration

1. Once on the water in a lake or at the end of the permitted reach in a river, power on the biosonics unit by turning the switch to "(DC) - on". The red power LED should light up at this point. If not, check the battery connection and verify the battery charge with a voltmeter, if needed. Ensure that the GPS switch on the Biosonics is turned to "INT" for the internal GPS to function.

2. Position the Biosonics yellow Pelican case in a convenient location for the whole day. The GPS receiver is located in the box and it's position should stay the same throughout the day relative to the sonar transducer. Record the horizontal distance (m) between the box and the transducer in the mobile application or in the remarks of the field data sheet. Measure from the transducer head to the GPS Selection switch on the blue panel of the pelican case (**Figure 7**).

3. Position the transducer between 0.3 and 0.5 m below the surface of the water. This can be accomplished by putting a piece of tape at a known distance above the transducer face and adjusting the mount to have the tape at the water surface. Make sure you know the depth within ± 3 cm since the value will need to be entered into the software prior to collecting data.

   a. In especially shallow areas the transducer can be mounted a 5-10 cm below the surface of the water but be sure to drive the boat slowly enough that surface waves do not

cause the transducer face to completely or intermittently come out of the water. Always be sure to record changes in transducer depth in the Visual Acquisition software.

4. Ensure that your computer's local area network (LAN) connection is set to 192.168.1.9.

5. Open the Visual Acquisition software. Make sure the MX radio button is selected and click OK.

NOTE: *If you are having trouble connecting to the sonar transducer, ensure that the "ecosounder Type" drop-down is set to "MX" in the Setup/Diagnostics/Configure wheel menu. The IP address in this menu will be "192.168.1.201" which is different than the computer settings (***Figure 8***).*

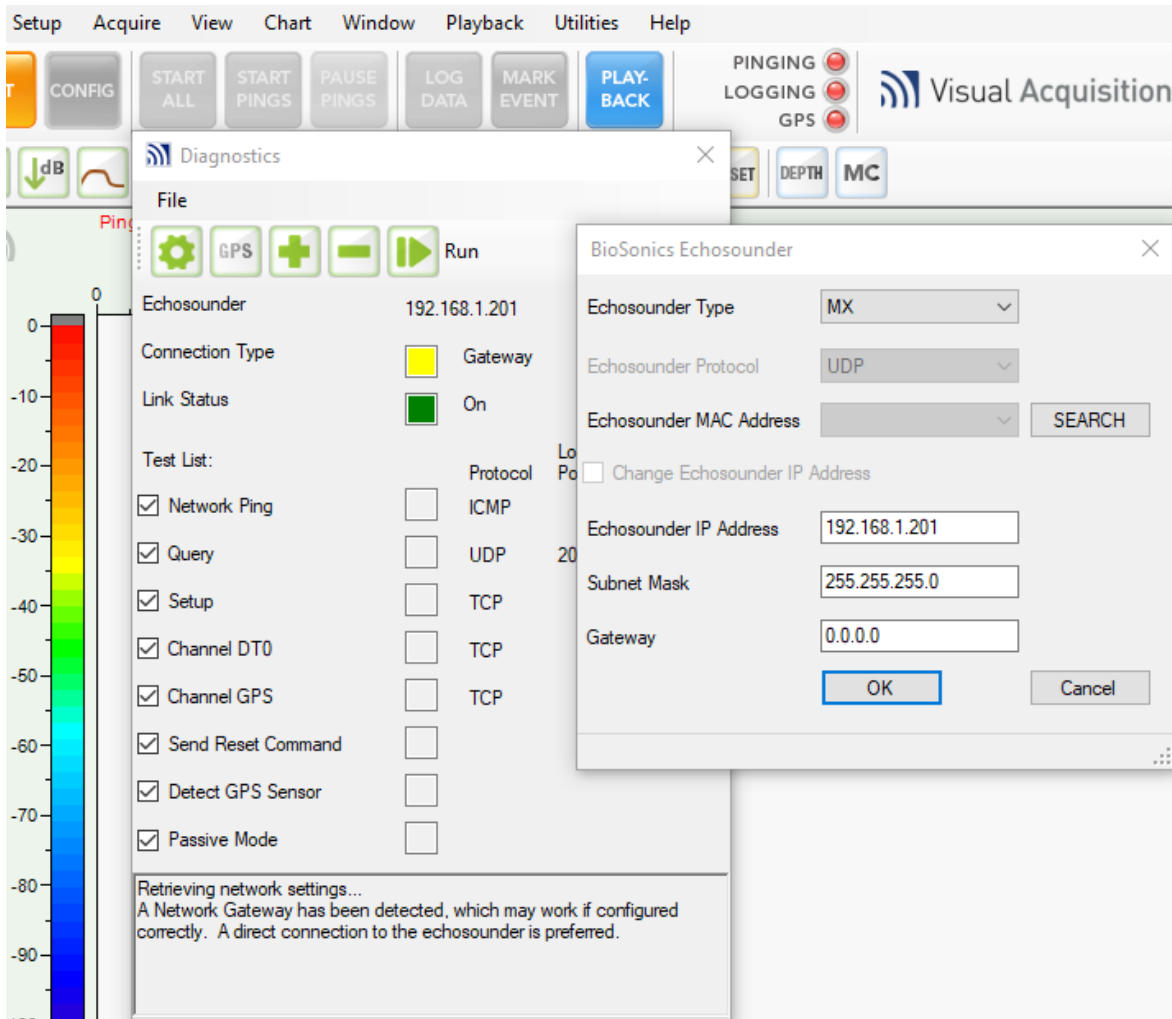**Figure 8**. Screenshot in Visual Acquisition showing that the "Ecosounder Type" is set to "MX" and "Ecosounder IP Address" is set to "192.168.201".

6. Click the orange INIT (initialize) button in the upper left-hand corner of the screen. A system information window will pop-up once the transducer is connected. Click ok and you should see several buttons change from grey to color in the top panel.

7. Click the purple CONFIG (configure) button next to the INIT button. In the pop-up, click Reset to Defaults and then:

   a. Click on "204.8 kHz 8.9° single" in the left panel and enter

      i. Set End Range (m) to the maximum depth you anticipate plus 1 m to be on the safe side. For example, if you expect the max depth to be 14 m, enter 15 in this field.

      ii. SITE_ as the file prefix

      iii. Check the Create DT4 files box, if not already checked

   b. Click on "Sensors/Mounting" in the left panel and enter:

      i. Transducer Depth (m), this is usually 0.3 to 0.5 m, but may be shallower if in an extremely shallow area. If the depth of the transducer below the water surface is changed throughout the day, it must be updated and recorded in the Visual Acquisition software.

NOTE: the depth that you enter here is not stored with the data. All data that is recorded is relative to the transducer face. So, be sure to also enter the transducer depth in the mobile application or field data sheets each day and any time it is adjusted throughout the day.

   c. Click on "Environment" and enter:

      i. Temperature (°C), collect a reading about 0.5 m below the water surface using the YSI handheld and enter the reading here to the nearest 0.1 degree.

      ii. Check the freshwater box as long as the conductivity is below 2,000 µS/cm. IF the conductivity is greater than 2000 µS/cm, check the salt-water box and enter the salinity in ppt of the water into the software. You can change the units of the YSI handheld sensor to ppt in order to get a reading in the correct units for entering into the Visual Acquisition software.

      iii. The software will automatically calculate the speed of sound and absorption coefficient.

NOTE: *If the depth of the transducer needs to be changed, a new file with the new depth and new YSI readings needs to be created since the software automatically applies the value during processing.*

   d. Click ok.

8. Ensure that any other sonar units are disabled, including navigational units (e.g. Humminbird). It is fine to leave GPS receivers on for navigation, but sonar units can interfere with bathymetry data collection.

SOP B

B.6 Beginning Bathymetry Transects

1. A bar check on the echosounder is performed at the beginning of each day of data collection by comparing the echosounder depth reading with that of a weighted measuring tape. Navigate the boat to one to two different areas and record the depths from the echosounder and the weighted line. Use the handheld depth finder if performing the bar check in deep or fast moving water. Adjust the offset (draft of transducer below the water surface) of the transducer in the on-board software until depth readings and the depth of the weighted line agree to within +/- 5 cm (Linhart and Lund, 2008). Refer to B.5.7.b.i if changing transducer depth.

2. Using a handheld anemometer, confirm wind speed is lower than 5 knots and that there are not surface waves on the water. If wind speed is higher than 5 knots and there are surface waves, suspend sampling. Wind speeds at some aquatic sites may often not go lower than 5 knots (e.g., D09 lakes). At these sites, it is recommended to initiate the bathymetry protocol when conditions are perceived to be the most ideal (e.g., early morning).

3. Make sure that the transducer is submerged to a known depth and click the green START ALL button. The indicators for Pinging, logging, and GPS on the software toolbar to the left of the Visual Acquisition logo should turn green. It may take a minute or so for the GPS indicator to turn green. Check that the GPS is recording before continuing with the survey.

   a. The first indicator is the virtual GPS "light" in Visual Acquisition. It will be green if there is differential GPS detected, yellow for non-differential GPS, and red for no GPS.

   b. The next indicator would be down on the lower right margin underneath the echogram where the current latitude and longitude will be displayed while collecting data.

   c. The third is in the GPS Diagnostics (Visual Acquisition "Setup" drop-down menu). This is less of a real-time indicator and more where you can change the GPS baud rate or select which method of getting GPS into Visual Acquisition. It's very useful for troubleshooting GPS issues.

NOTE: *Pinging is when the transducer is pinging and data is visible on-screen but data is not being recorded. Logging is when the pings are also being recorded.*

4. Once all indicators are green, begin slowly (no more than 3.1 miles per hour or 2.7 knots) driving the boat around the lake or river in the suggested pattern (**Figure 10**).

   a. **At Lakes**:

      i. *Collect a shoreline survey track*. Be sure that the transducer face is at least 0.5 m above the bottom of the lake. So, if the transducer is mounted 0.3 m below the water surface the minimum depth for collecting good data is 0.8 m (0.3 m to the transducer face and 0.5 m of water between the face and the lake bottom, **Figure 9**). Also, be sure to avoid any rocks/boulders or large woody debris that may damage the face of the transducer.

ii. *Collect data for the rest of the lake in a back-and-forth pattern*. Transects should be spaced about 20 m apart. If there are habitat features, such as patchy plants, that are smaller than 20 m, the distance between transects may need to be narrowed. Contact HQ with any questions that arise. It is not necessary to collect a cross-hatched pattern with the Biosonics unit (**Figure 10**).

NOTE: *It is fine to collect each transect of data in a separate file.*

NOTE: *If the GPS or transducer stop working, just click "STOP ALL" and create a new file for the remaining data and potentially retrace your track if a large portion was missing due to the boat moving while rebooting the GPS and pings.*

b. **At Rivers:**

i. *Collect transects approximately parallel with the bank*. Six to eight transects should be collected. The width of the transducer beam is only about a meter with our settings and the maps benefit from more parallel transects. Be sure that the transducer face is at least 0.5 m above the bottom of the river. So, if the transducer is mounted 0.3 m below the water surface, the minimum water depth for collecting good data is 0.8 m (0.3 m to the transducer face and 0.5 m of water between the face and the river bottom, **Figure 9**). Also, be sure to avoid any rocks/boulders or large woody debris that may damage the face of the transducer.

ii. *Collect two zigzags along the river reach*. Two opposite zig-zags should be collected at about a 45° angle from bank to opposite bank. Aim for about 11 points to the zigzag that meet up with the edge of the channel transects. Make the second zigzag in an opposite pattern so that the 11 points line up with the opposite edge transect (**Figure 10**).
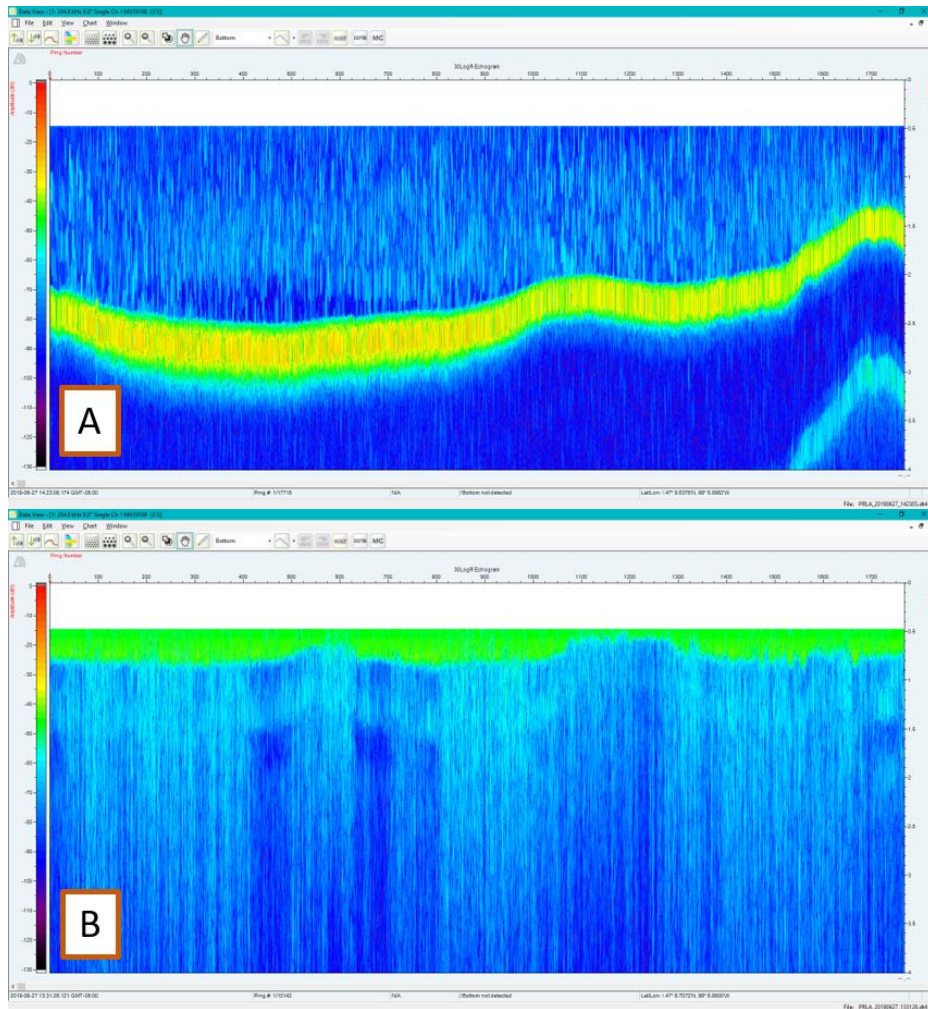
Figure 9. Example echograms. The top echogram, panel A, shows a good return where there is enough water between the transducer face and the bottom of the lake. The yellow/green band across the screen represents the bottom of the lake so you can see that the transducer is 1.5 to 2 feet above the bottom. The bottom echogram, panel B, shows a situation where the transducer is too close to the bottom of the lake, top of green stripe is not visible. Data from this echogram is invalid and cannot be used for bathymetry or habitat mapping. Move to a deeper part of the lake and/or move the transducer mount closer to the surface of the water.

5. If at any point during the day the depth of the transducer is moved, be sure to STOP PINGS or STOP ALL before removing the transducer from the water. The transducer will be damaged if it is still pinging when removed from the water. Also, be sure to record the change in depth on the mobile device or *Bathymetry Field Datasheet.*

6. Remember your point of departure and note the exact time of departure on the mobile device or on the *Bathymetry Field Datasheet* so that it can be used as a cut-off point for data processing.

7. Travel at no more than 5 kilometers (3.1 miles or 2.7 knots) per hour. Faster speeds will add errors to the readings by changing the rate of return of the sounder signal versus the GPS coordinate. Monitor your speed in the visual acquisition software.

8. Travel at a constant speed in a back-and-forth pattern. Be cautious of submerged vegetation, rocks, or other hazards that could come into contact with the transducer.

   a. It may be useful to use a GPS receiver with a screen to help with navigation. The visual acquisition software will not display a basemap with your location. The Humminbird GPS can be used while operating the Biosonics, but the sonar should be turned off completely or removed to avoid interference.

TIPS & TRICKS If a boat or barge passes leaving a wake, temporarily stop collecting data and wait until the waves subside. Then continue collecting sonar data.
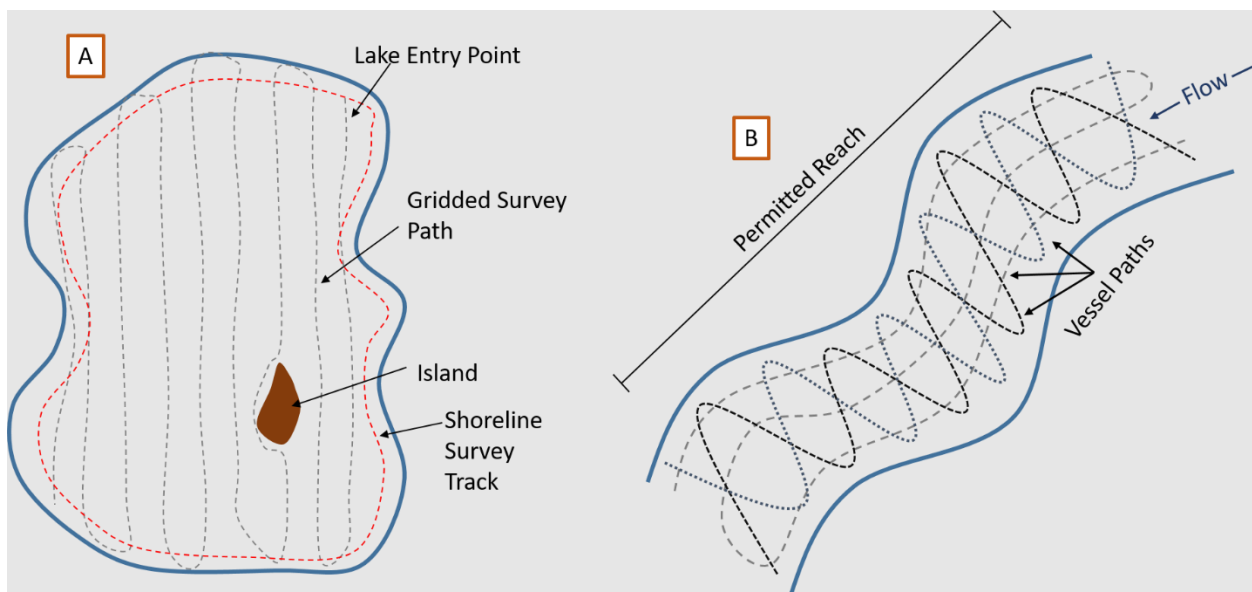
Figure 10. Schematic of survey pattern undertaken in the vessel for lake survey, including shoreline (panel A) and non-wadeable stream parallel to shoreline and zig-zag survey pattern (panel B). Note: lake lines should be approximately 20 m apart; figures are not to scale.

9. Because the Biosonics sonar unit is a single beam, down looking unit, it cannot "see" anything that the boat does not drive over. So, important habitat features, such as floating vegetation mats or shallow, large, downed wood, that must be driven around are not captured using the sonar unit. Thus, collecting shoreline and in-water features that are added to the maps in post processing are critical to the scientific value of the bathymetry and habitat maps. Mark these types of features using the "Mark Event" button in the Visual Acquisition software. Enter a description of the habitat feature(s) in the pop-up window.

B.7   Ending Bathymetry Transects

1. Once the bathymetric mapping is finished, click the red STOP ALL button prior to taking the transducer out of the water at the end of the sampling day as the unit will be damaged if left in pinging mode out of the water.

2. Check the lake or stream elevation again by taking a reading from the staff gauge then record on the mobile device or the Field Metadata Sheet.

B.8   Collecting Staff Gauge Readings

1. Navigate to the location of the staff gauge. Take a reading of the water level at the beginning of the survey and at the end of the survey day; record on the mobile device or *Field Metadata Sheet* (**Figure 11**). Please make a note using the mobile device or the *Field Metadata* sheet if a staff gauge was not present at the time of the survey. If a change of over 15 cm (0.15 m) in stage occurs throughout the day, contact HQ science and re-sampling of sonar data may be required.

Figure 11. Example of a staff gauge. If conditions are wavy, note the mean height.

B.9   Collecting Shoreline and In-Water Features

<u>Shoreline Features</u>

The shoreline and other land-water interfaces (which could be an island within a body of water or plant mat that extends to the shoreline) should have spatial data collected with an alternative GPS since the sonar unit cannot drive over them. Plant patches do not need to be recorded if the boat can be driven over them. Even in shallow water, the sonar unit can return data sufficient to identify plant patches. The Mark Event button in the Visual Acquisition software should not be used for these land-water interface features that require a line or polygon to properly represent them (**Figure 12**).

Note: *If the shoreline cannot be walked or is shallow, collect a shoreline perimeter route using the biosonics unit (but not having transducer in water, just GPS recording) and mark the events of features*

that are in water less than 0.5m (e.g. patches of macrophytes) that would otherwise not be marked and associated distances (e.g. a vegetation patch or shallow water that extends from the recorded location xx meters to the shore). Reach out to HQ Science via a service now Incident explaining the situation and asking for input if this is not practical for your site conditions.

Bathymetry Matrix

		Shoreline Boundary	Large in-water features	Small in-water features	Random ground truthing	Field identified target	Targeted ground truthing
			LIWF	SIWF	RGT	FIT	TGT
WHAT	*Definition*	Land-water interface and plant patches that meet the water's edge	>1 m² woody debris, boulders/patches, objects, other features that need more than one point to accurately represent	<1 m². Can be represented by a point.	20 random points generated on ARCMap	Up to 10 points identified in the field, i.e. things that you can drive the boat over and appear unusual on the sonar data	HQ provided after data submitted
	Examples/Plan	Including the island if walkable?	Floating patches will be treated as LIWFs. LWD @ Reach 10. Fence line at reach 6, fence line at reach 10 etc. Island if not walkable.	Telephone poles, small boulder in plant bay if findable.	Points can be replaced by FITs. Ex: three FITs identified, now need only 17 RGTs	a field identified target would be an abrupt change in the sonar signal or bottom depth that need ground truthing	The Trimble will be used to navigate to these locations, but the information about those locations will be captured in fulcrum.
RECORD	*Visual Aqcuisition*	NO MARK EVENT IN VIS AC	MARK EVENT IN VIS AC (MULTIPLE POINTS)	MARK EVENT IN VIS AC	MARK EVENT IN VIS AC	MARK EVENT IN VIS AC	NO MARK EVENT IN VIS AC
	Trimble	Trimble Line or polygon site_YYYMMDD_ShorelineBoundary	NO TRIMBLE	NO TRIMBLE	NO TRIMBLE	NO TRIMBLE	NO TRIMBLE
	Fulcrum	Fulcrum grandchild- 'Shoreline boundary'	No Fulcrum	No Fulcrum	Fulcrum grandchild- 'Groundtruth random'	Fulcrum grandchild- 'Groundtruth field identified'	Fulcrum grandchild- 'Groundtruth targeted'
					Depth, Substrate type, Plants P/A, LWD P/A, Photo	Depth, Substrate type, Plants P/A, LWD P/A, Photo	Depth, Substrate type, Plants P/A, LWD P/A, Photo
	Notes	Different than the sonar shoreline tract- this is the walking one	If these just need the Mark Event and are not recorded in Fulcrum and not recorded on the Trimble, do it while Zig Zagging	If these just need the Mark Event and are not recorded in Fulcrum and not recorded on the Trimble, do it while Zig Zagging	Mark Event while doing zig zag transects. Come back with sonar, random list, random map, and Fulcrum device later	Mark Event while doing zig zag transects. Can collcet ground truthing information at a later time	Photos can be transmitted to HQ in a word or other document if that is easier than collecting them in the app

Figure 12. The Bathymetry Matrix defines shoreline boundaries, in-water features, and ground truth points and illustrates how each should be recorded on the appropriate device.

1. Map shoreline with a handheld GPS (Trimble) to create a shoreline/ bathymetry (0 meters depth) line file. This step must be done every time the bathymetric survey is conducted. If permitting or hazards prevent access to mapping the shoreline/in-water feature, contact Science.

2. To maximize the accuracy of the handheld GPS (Trimble) unit use the following settings in the Setup menu:

   a. Select Settings (wrench icon) from the upper left dropdown (**Figure 13**).

   b. Uncheck the box next to the Productivity/Precision scale.

   c. DOP Type – select PDOP

   d. Max PDOP – enter 6.0

   e. Min SNR – enter 12.0

   f. Min Elevation – enter 15°

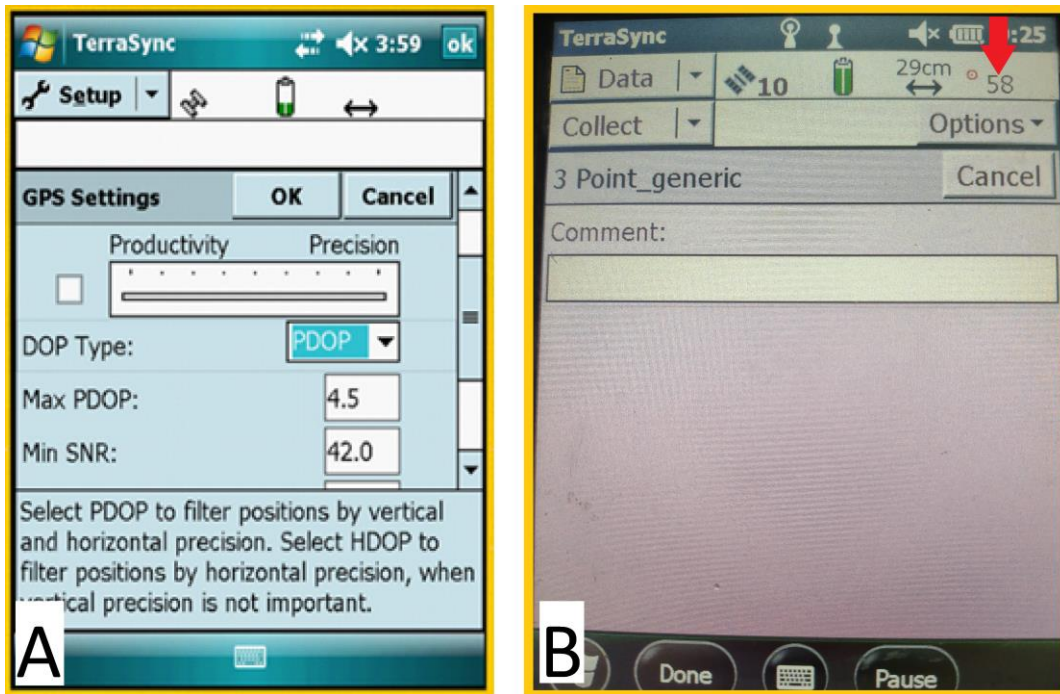   g. Select Done

Figure 13. A. Trimble Setup menu to adjust settings for optimal location accuracy. B. The red arrow indicates how many readings have taken place during a single "Point_generic" collection.

   h. Make sure four or more satellites are visible. Collect a single point with a minimum of 30 readings at each location where morphological or other in-water features are mapped with GPS.

    i. Click the "↔" icon in the upper right **Figure 13** and check that the minimum post-processing accuracy is ≤ 1.0 m.

    j. Some sites will not fit these "ideal" settings due to canopy cover, lack of satellite coverage, or other obstructions. Therefore, the settings may have to be adjusted or offset just to collect a reading. In this case, check the box next to the Productivity/Precision scale and slide pointer incrementally toward Productivity until data point collection can resume (sufficient satellite coverage).

NOTE: *The position dilution of precision (PDOP) is indicative of the geometry of the satellite's location relative to others in the constellation and the receiver. Low PDOP indicates an even distribution of satellites throughout the sky and therefore indicates a higher probability of accuracy. The signal-to-noise ratio (SNR) is a measure of the signal strength of the satellite relative to the signal noise. As the ratio between the signal and the noise decreases, data is distorted by the noise therefor, a higher SNR value represents a stronger signal and less noise distortion. The elevation mask restricts the receiver to using satellites that are above 15° elevation. This ensures that both the hand held unit and a nearby base station (used in post-processing) can see the same satellites.*

NOTE: *Maximizing GPS accuracy is important for relating the bathymetry data to the edge (zero meter depth) of the lake or non-wadeable stream.*

3. Select "Data" from the Main Menu.

4. Set File Type to "Rover" and Location to "Default."

5. Enter a unique file name. Example *D03_SUGG_Shore_20170616.* Record the GPS file name on the mobile device or the *Bathymetry Field Datasheet*. Also, include the waypoint name, feature type (e.g. shoreline), accuracy, accuracy units (meters or feet), start time, and description.

6. If applicable, select the data dictionary previously created.

7. Select "Create" on the upper right side of the page.

8. Select "Line_generic" to create a path around the lake edge.

9. Walk around the lake or stream edge or current water line at a normal pace and hit "OK" to terminate data collection.

Note: *If the shoreline cannot be walked or is shallow, collect a shoreline perimeter route using the biosonics unit (but not having transducer in water, just GPS recording) and mark the events of features that are in water less than 0.5m (e.g. patches of macrophytes) that would otherwise not be marked and associated distances (e.g. a vegetation patch or shallow water that extends from the recorded location xx meters to the shore). Reach out to HQ Science via a service now Incident explaining the situation and asking for input if this is not practical for your site conditions.*

10. Additionally, while undertaking the bathymetric survey, record any main morphologic features (such as an island, large submerged woody debris, objects on sediment floor, vegetation, or other; if other describe in the comments) seen on the SI images (**Figure 12**). Map the perimeter

of the in-water feature with the handheld (Trimble) GPS (**Figure 14**). Record the file name(s) on the mobile device or *Bathymetry Field Datasheet*. Include the waypoint name, feature type, accuracy, start time, and description.

11. Please create one Trimble file with a unique name, e.g. site_YYMMDD_inWaterFeatures, that contains the lines/polygons for each feature along with a descriptive comment and a line/polygon ID that corresponds to data entered in the mobile app (e.g. Line1, Line2 etc.).
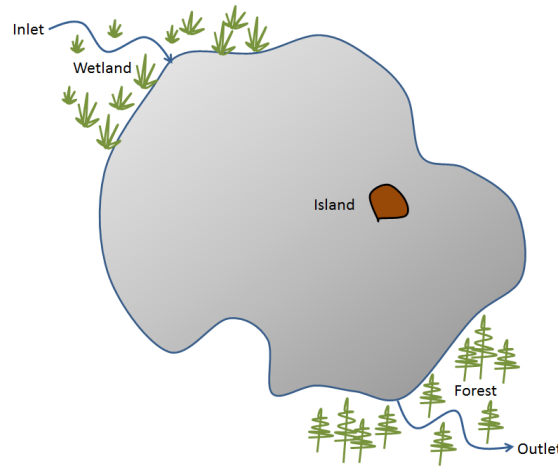

Figure 14. Detailing of morphometric features identified in the field.

In-Water Features

Small habitat features (<= 1m2) can accurately be represented as a point and the Mark Event button in the Visual Acquisition software should be used to collect geospatial coordinates for these types of data (marking with the Trimble GPS is not needed for ground-truth data collected alongside sonar data). Data for small habitat features, such as a single boulder, a small pile of woody debris, or a buoy only need to have an event marked in the Visual Acquisition software while collecting the sonar survey data (**Figure 12**).

For larger in-water features, multiple events will need to be marked in the Visual Acquisition software. Select a short descriptive phrase for each feature and add a number for each point. For example, a large patch of woody debris could be noted by "LWD patch by boat ramp" with "Point 1", "Point 2", etc. added for each point associated with the feature (**Figure 12**).

It is not possible to view the marked events in the Visual Aquatic software. However, a table of marked events can be exported from the Visual Acquisition software (**Figure 15**).

1. Click Utilities>File Utilities

2. Check Export Data to CSV Files

3. Clicking the button with ellipsis "…" next to it

4. Check the box next to "Mark Event" in the pop-up window

5. Click "ok"

6. Click the "Process Files…"

7. Select the files that you would like to export the marked events for. They will be exported to either a user specified folder or the input folder (upper righthand menu pane).
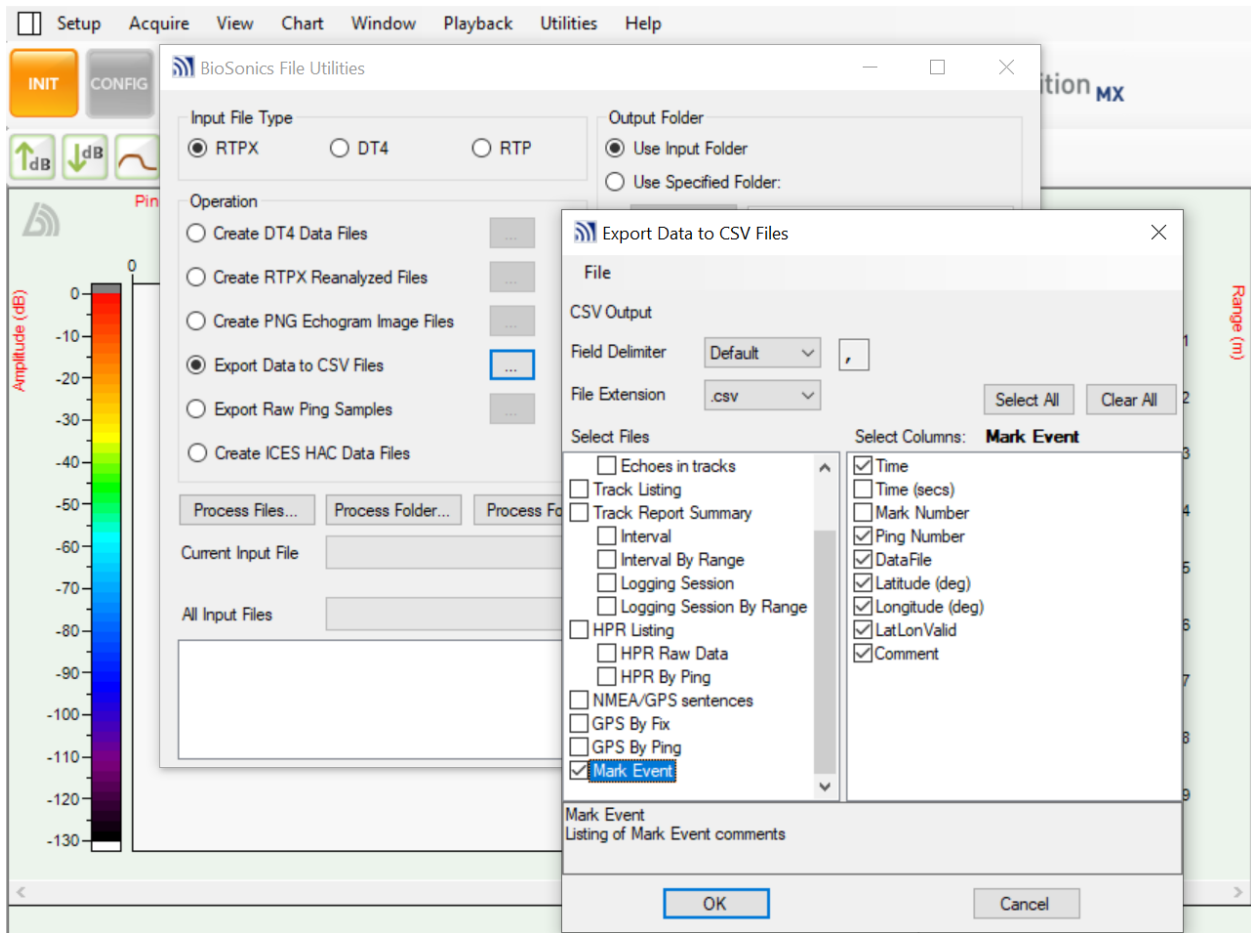
Figure 15. Screenshot of exporting Mark Event from Visual Acquisition software.

B.10 Collecting Ground-truth Data

The purpose of ground-truthing in conjunction with the bathymetric surveys is to collect visual (e.g. viewing bucket with a Plexiglas bottom) and/or sampled (e.g. ponar; rake) information about the benthic substrate and presence of aquatic vegetation at lake and non-wadeable stream sites. Ground-truthing measurements of lake and non-wadeable stream bottom types (e.g. plant, rock, silt) allow accurate classification and description of the benthos. In order to produce habitat maps, which are a component of Bathymetric and Morphological Maps data product (NEON.DP4.00132), ground-truthing will be required. This information will be collected during the bathymetric survey and following post

processing to identify habitat patches derived from sonar data. These data will be used by NEON Science to classify habitat along with mapping software when creating maps. While surveying, collect waypoints of substrate, habitat, and vegetation features such as sand fields, boulders, cobbles, large woody debris, or human structures (roads, fences, boats, etc.). Also, collect waypoints where patches of plants occur (**Figure 12**). Press the teal **MARK EVENT** button on the Visual Acquisition software and enter a description of the location in the box that pops up.

NOTE: *Ground-truth data needs to have an event marked in Visual Acquisition and in the mobile application so that the geolocation information lines up with the sonar survey and so that the additional ground truth information can be collected and ingested (***Figure 12***).*

NOTE: *Field identified targets are related to ground-truthing. These would be things you can drive the boat over and appear unusual on the sonar data. Ground-truthing is done to figure out what the item is.*

Once the survey is complete, return to the ground-truthing locations and follow the procedures described below.

Each ground-truthing technique requires the collection of field observations from random and targeted points. Equipment will be selected to optimize data collection for the substratum, depth, and visibility of the sampling location, similar to other AOS collection procedures (e.g., aquatic plant or sediment chemistry sampling). Equipment includes:

- Petite ponar
- Rake
- Viewing bucket
- GPS
- Handheld depth finder
- Tablet with the bathymetry Fulcrum application
- Field Datasheets in the event that the tablet or application are not working

Only a single ground truthing data collection tool is required provided that the field scientists are confident in their assessment even if the lake is turbid or deep.

Low-impact observational ground-truthing techniques using a viewing bucket are preferred over the more invasive collection methods such as using the petite ponar or rake where possible. At lake or non-wadeable stream sites where plants occur, use the rake to collect and confirm the presence of aquatic vegetation. At deep lakes or where the water column is too turbid to view the bottom, the ponar is the best option for ground-truthing. General substrate descriptions and sub-aquatic vegetation presence/absences observations from each ground-truthing point are recorded.

Two ground-truthing techniques, random and targeted observations, will provide essential information to aid in the classification of subaquatic features (habitat and substrate) during the post-processing activities.

1. Random Observations

A proportional number of randomly selected ground-truthing points are generated prior to conducting the bathymetric survey. They should be generated using a shapefile on ArcGIS similar to the plant protocol. However, the random bathymetry points should not overlap directly with random points used for the plant protocol. When creating the random ground-truthing points, use a shapefile of the entire lake in order to cover areas that may not be colonizable to plants, but might contain a variety of bottom types.

NOTE: *ArcGIS step by step instructions are available in the "Determining Sampling Locations" presentation in the Training Center.*

At the end of the survey day or during a suitable breaking point in the survey, navigate to the random survey points and follow the sampling steps below. Non-wadeable stream sites will have between 10-20 random points to collect ground-truthing information. Lake sites will survey 20-30 random ground-truthing points. TOOK which has an area of roughly 1,500,000 m^2 will survey 40-50 random ground-truthing points.

2. Targeted Observations

Targeted observation locations are collected from the previous bathymetric survey. There are two types of targeted ground-truthing procedures.

3. Field Identified Targets

The first includes 5-10 sampling locations identified by FOPS while conducting the bathymetric survey (see SOP C.3 Identify Ground-Truthing Locations, above). These observations may include unique features that appear on the sonar display or are visually observed that are different from the expected benthos (e.g. unusual habitat patches, large woody debris, or unique substrate features). Up to half or 10, whichever is lower, of the random points can be replaced by field identified targets, if needed. An example of a scenario that would merit a field identified target would be an abrupt change in the sonar signal or bottom depth (**Figure 16**).
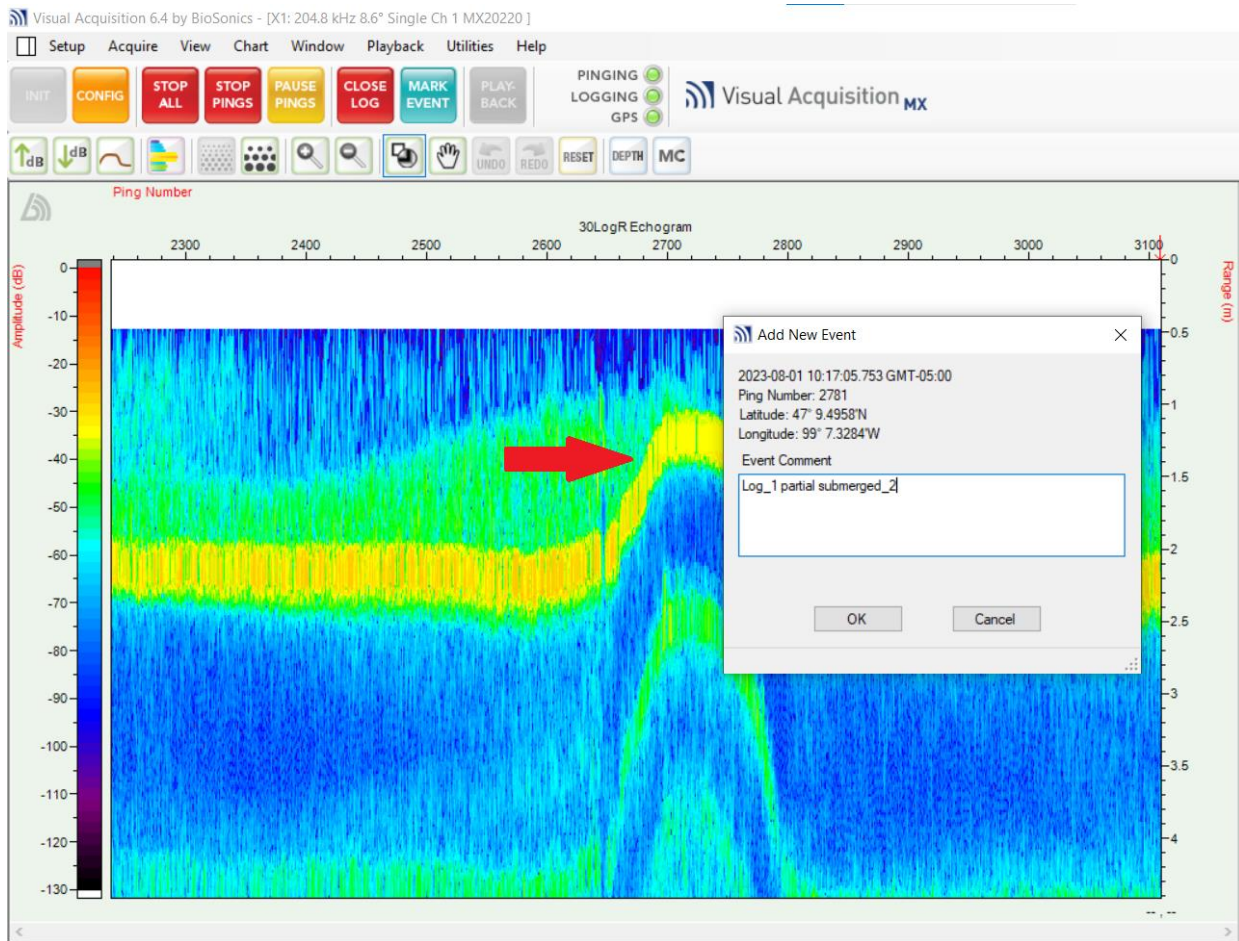
Figure 16. The red arrow indicates an abrupt change in the bottom depth from the sonar data that could be marked as an event and used as a field identified target.

4. Post-Processing Identified Targets

The second targeted ground-truthing procedure includes 5-10 sampling locations identified by HQ Science from the post-processed bathymetric survey data. These will be communicated using a request in the ticketing system. The targeted sampling effort is expected to take one day (up to three days) depending on the size of the non-wadeable stream or lake.

5. Collecting and Recording Ground-Truthing Data

The following ground-truthing survey procedures are applied to both Random and Targeted surveys. Therefore, there are two phases to the bathymetry survey, 1) the initial survey with random ground-truthing and 2) follow-up ground-truthing with targeted locations identified by field science and targeted locations based on post-processed data. These steps need to be conducted within one month from the time of the initial bathymetric survey in order to minimize seasonal changes to the benthic features being classified in the habitat map. The bathymetric survey as well as the random and targeted ground-truthing efforts need to occur within the one-month period. FOPS and the lead aquatics scientist

will coordinate the timing of these activities to ensure that sufficient time is available to provide targeted ground-truthing locations.

    a. Navigate to the first ground-truthing location. Set the boat anchor if needed to stay in place. Select the appropriate observation tool according to the following:

        i. In shallow, less turbid water, use the Plexiglas viewing bucket to observe and record observations of the bottom.

        ii. In deeper and/or turbid water where the viewing bucket is not effective, use the aquatic plant survey rake to collect plant material and the petite ponar to collect soft sediments (silt or sand).

    b. Record the header information and observations on the mobile device or on the *Bathymetry Ground-Truthing* field datasheet.

        i. Header information includes:

            1) Domain

            2) Site ID

            3) Protocol Number and Revision Number

            4) Sonar System Model

            5) Distance between Transducer and Box (m)

            6) File prefix

            7) Measured By

            8) Recorded by

            9) Targeted Ground Truth Complete?

            10) Remarks

        ii. Daily Information Entries

            1) Metadata

                a) Date

                b) Time

                c) Enter or Select Field Metadata and Gauge Height Record

            2) Spatial Data Collection

                a) GPS Unit Model

                b) GPS File Name

                c) GPS Accuracy Units

        d) Antenna Height (m)

   iii. Enter Point Information

      1) Metadata

        a) Bathymetry Feature Type

        b) Time

      2) Location Information

        a) Waypoint

        b) Description

      3) Groundtruthing

        a) Depth (m)

        b) Sample Type

        c) Substrate Type

        d) Plants Present?

        e) Large Woody Debris Present?

        f) Photo

        g) Remarks

c. **NOTE:** *Taking a photo is not necessary but can be done if you are unsure and feel it will help Science classify the substrate type. Photos must be taken using the mobile device and uploaded to the Fulcrum record on a laptop in the online app. Name the photo using the format: Site.date.waypoint number (ex:BLWA.20230825.007).* Discard any collected ground-truthing material once the information has been recorded.

d. Discard any collected ground-truthing material once the information has been recorded.

e. Take and record a depth measurement using the handheld depth finder (Vexilar).

f. Record the ground-truth location using the handheld (Trimble) GPS.

g. Navigate to the next ground-truth location and repeat the steps described above.

SOP C   Post-Field Sampling Tasks

C.1   Activities at the End of a Sampling Day

1. Download survey data following the bathymetric survey and save to the appropriate location at the Domain Support Facility. By default, files are saved in the following directory on your computer: C:\BioSonics\VisualAcquisition6\data. Files are saved with the same name, but 3 different file extensions that include .dt4, .rtpx, and .dtb. The only file types needed are those with .dt4 and .rtpx extensions. The other file types are not needed by Science.

2. Review the collected data using the Visual Aquatic program by selecting file > Add Files, and selecting all of the .dt4 files that were created over the bathymetry survey. It will take a few moments for the files to load, especially if they are big or there are a lot of them.

3. To view the tracks on top of a basemap, click View > Show Map View. Once a new window pops up, click Map > Base Map and then the Select… button next to Map Image (orange box, **Figure 17**).

4. Once the completed survey tracks are projected in Visual Habitat, confirm that the survey was complete (i.e., no excessive gaps or missing sections). If the survey is not complete, reschedule a time to complete the survey as soon as possible.

5. If the survey is complete, save files for all bathymetry survey days to the CI Dropbox on the N: Drive (N:\DSF\CI Dropbox\Domain##\your path). Create and submit a generic service now science request assigned to GIS support assignment group to alert HQ that the sonar data for targeted ground-truthing is ready for analysis. Be sure to include the path to the files on the CI dropbox in the description. Save files locally until HQ science confirms the integrity of the files that were transferred using the CI dropbox. Files include:

   a. Save the .dt4 and .rtpx files associated with the sonar data

   b. Shoreline shape file (example PRLA_SHORLINE_20160728.SSF)

   c. In-water features shape files (example PRLA_ISLAND_20160728.SSF)

   d. Waypoints .CSV file (example PRLA_WAYPOINTS_20160728.CSV)

6. Following transmission and processing of data at HQ, a set of targeted points will be sent that should be collected by re-visiting the site. During this second visit for targeted ground-truthing, the MX sonar unit does not need to be used. It is most helpful to use a viewing bucket, rake/ponar, or other information to confirm substrate type rather than spatial information. Photos are not required unless FSCI finds them helpful. When collecting information about targeted ground-truthing specified by HQ, the Trimble GPS must be used. The Biosonics software will not be used. Photos are not required unless FSCI finds them helpful.
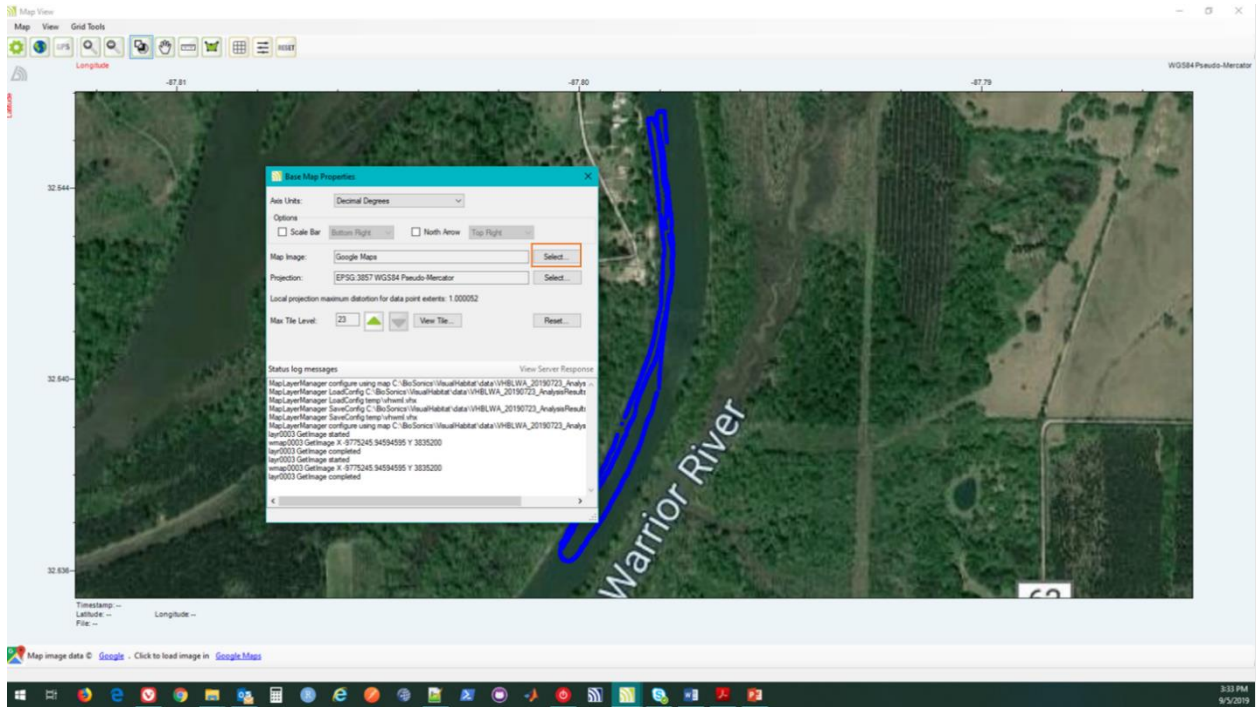
Figure 17. Screenshot of the Map View in the Visual Aquatic Software. Orange box indicates the button to click in order to load a base map for overlaying GPS tracks.

7. Equipment Maintenance, Cleaning, and Storage

    a. Ensure all equipment is properly decontaminated and dry prior to storage as per NEON Aquatic Decontamination Protocol (RD[07]).

    b. Refer to the Visual Acquisition MX User Guide for specific maintenance procedures and equipment troubleshooting.

SOP D   Data Entry and Verification

Mobile applications are the preferred mechanism for data entry. Data should be entered into the protocol-specific application as they are being collected, whenever possible, to minimize data transcription and improve data quality. Mobile devices should be synced at the end of each field day, where possible. Alternatively, devices should be synced immediately upon return to the Domain Support Facility.

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should be carried along with the mobile devices to sampling locations at all times. Data collected on paper data sheets must be transcribed within 14 days of collection or the end of a sampling bout (where applicable). See RD[04] for complete instructions regarding manual data transcription.

SOP E   Sample Shipment

Not applicable to the Bathymetry and Morphology of Lakes and Non-Wadeable Streams protocol.

8   REFERENCES

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U.S. Army Corps of Engineers. 2002. Engineering and Design-Hydrographic Surveying Manual No. 1110-2-1003: Washington, D.C., 510 p.

APPENDIX A   QUICK REFERENCES

Step 1 – Check that batteries are charged and packed along with any other needed supplies.

Step 2 – Set-up and secure the sounder on the mounting rod.

Step 3 – Take a reading of gauge height and record on the mobile device or *Bathymetry Field Datasheet*.

Step 4 – Verify that the Biosonics and handheld GPS units have a good signal and that the transducer and computer are functioning.

Step 5 – Record any depth changes made to the transducer throughout the day.

Step 6 – Start recording on the Visual Acquisition software and create a back-and-forth or zig-zag pattern around the lake or non-wadeable stream.
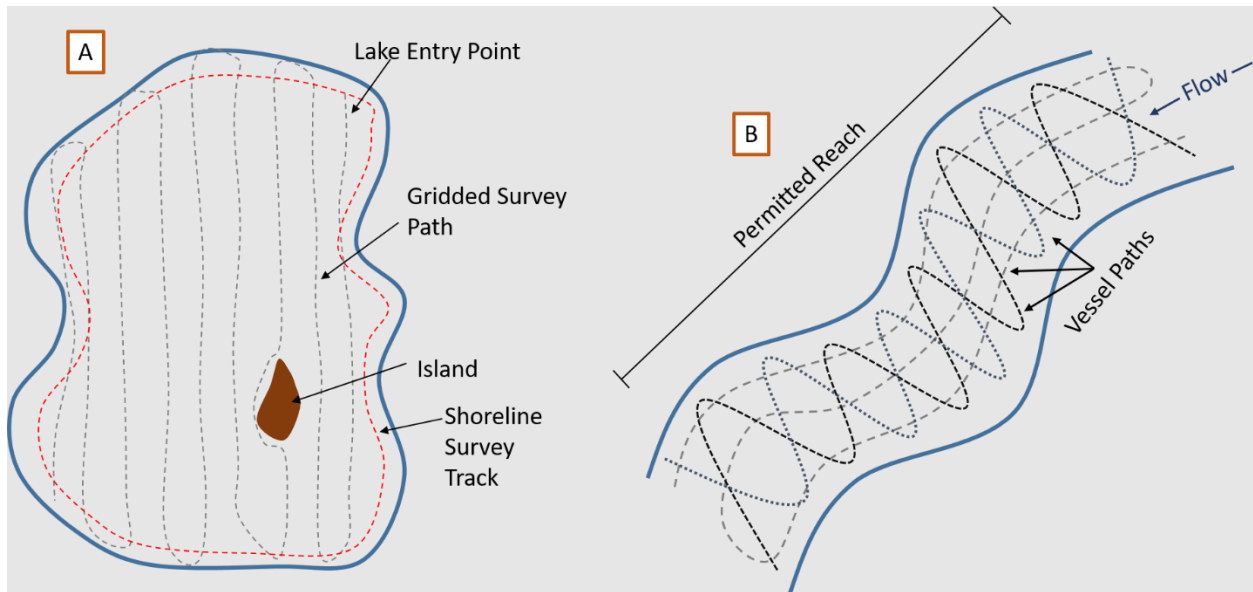
Step 7 – Record the shoreline and all morphological features encountered both within the lake or stream (i.e., islands, lake bottom biological and physical features) with the handheld (Trimble) GPS.

Step 8 – Record the location of unique substrate, habitat features, or vegetation with the Visual Acquisition software for ground-truthing.

Step 9 – Once the transects are completed, stop recording on the Biosonics unit.

APPENDIX B   REMINDERS

Before heading into the field: Make sure you…

- ❑ Collect and prepare all equipment.
- ❑ Fully charge all batteries and electronic equipment the night before.
- ❑ DO NOT assume that batteries are functional or fully charged even if new.

Bathymetric mapping: Be sure to…

- ❑ Do not operate any other sonar unit, e.g. navigational Humminbird. Using the Humminbird GPS feature is ok, though!
- ❑ Do not start pings until the transducer is in the water
- ❑ Travel at no more than 5 kilometers (3.1 miles) per hour. Faster speeds will add errors to the readings by changing the rate of return of the sounder signal versus the GPS coordinate.
- ❑ Travel at a constant speed in a back-and-forth pattern.
- ❑ Given the beam angle for the instrumentation, the grids should be spaced approximately 20 meters apart.
- ❑ Stop and clear vegetation from transducer/rod after passing through aquatic vegetation.
- ❑ Monitor your speed on the Biosonics unit.
- ❑ Use the same handheld GPS (Trimble) receiver for all data collection throughout the day.

If wind speed is higher than 5 knots and surface waves are present, suspend sampling.

APPENDIX C   ESTIMATED DATES FOR ONSET AND CESSATION OF SAMPLING

Each domain has site-specific guidelines for timing of sample collection, which can be found in Domain Specific Sampling Designs (**Table 4**). The dates in the Sampling Design documents are estimated from historical hydrologic and meteorological data. Peak-greenness cannot be assessed until the end of the season. However, if it seems like the conditions for a particular year do not align well with the predictions in the Sampling Designs, please reach out to HQ science using the trouble ticketing system with details.

Table 4. Site-specific bout number, start dates, end dates and additional site-specific sampling guidance.

Domain Number	Document Number	Document Name
01	NEON.DOC.003600	Aquatic Site Sampling Design – NEON Domain 01
02	NEON.DOC.003601	Aquatic Site Sampling Design – NEON Domain 02
03	NEON.DOC.003602	Aquatic Site Sampling Design – NEON Domain 03
04	NEON.DOC.003603	Aquatic Site Sampling Design – NEON Domain 04
05	NEON.DOC.003604	Aquatic Site Sampling Design – NEON Domain 05
06	NEON.DOC.003605	Aquatic Site Sampling Design – NEON Domain 06
07	NEON.DOC.003606	Aquatic Site Sampling Design – NEON Domain 07
08	NEON.DOC.003607	Aquatic Site Sampling Design – NEON Domain 08
09	NEON.DOC.003608	Aquatic Site Sampling Design – NEON Domain 09
10	NEON.DOC.003609	Aquatic Site Sampling Design – NEON Domain 10
11	NEON.DOC.003610	Aquatic Site Sampling Design – NEON Domain 11
12	NEON.DOC.003611	Aquatic Site Sampling Design – NEON Domain 12
13	NEON.DOC.003612	Aquatic Site Sampling Design – NEON Domain 13
14	NEON.DOC.003613	Aquatic Site Sampling Design – NEON Domain 14
15	NEON.DOC.003614	Aquatic Site Sampling Design – NEON Domain 15
16	NEON.DOC.003615	Aquatic Site Sampling Design – NEON Domain 16
17	NEON.DOC.003616	Aquatic Site Sampling Design – NEON Domain 17
18	NEON.DOC.003617	Aquatic Site Sampling Design – NEON Domain 18
19	NEON.DOC.003618	Aquatic Site Sampling Design – NEON Domain 19

APPENDIX D   EQUIPMENT

The following equipment is needed to implement the procedures in this document. Equipment lists are organized by task. They do not include standard field and laboratory supplies such as charging stations, first aid kits, drying ovens, ultra-low refrigerators, etc.

Table 5. Equipment list – Collecting sonar data.

Supplier/ Item No.	Exact Brand	Description	Purpose	Quan-tity
	N	Mobile field data recording device (Tablet)	Recording data	1
	Y	Biosonics MX Habitat Echosounder	Creating bathymetric imagery, marking locations, and monitoring speed	1
	N	Laptop computer with Visual Acquisition software installed	Recording data	1
	N	12V DC deep cycle marine battery	Power Biosonics sonar unit	1
	N	Camera	Photographing site locations	1
	N	Handheld depth meter	Measuring water depth for transducer calibration	1
	N	Weighted line with depth increments (m)	Measuring water depth for transducer calibration	1
Forestry Suppliers; 89183	N	Handheld wind meter	Measuring wind speed before operating boat	1
YSI; Pro2030	N	Handheld water quality multimeter	Measuring water temperature for sonar software configuration	1
	N	Volt meter	Checking battery charge level when troubleshooting	1

Table 6. Equipment list – Mounting sonar unit to small boat using a trolling motor mount (lakes).

Supplier/ Item No.	Exact Brand	Description	Purpose	Quan-tity
	N	Mounting pole, ¾" EMT conduit	Vertically mount Biosonics to trolling motor mount	1

Supplier/ Item No.	Exact Brand	Description	Purpose	Quan- tity
5038K49	N	Mounting Bracket (trolling motor mount)	Affix the threaded pipe to the side of the boat	1-2
	N	Composite/plastic shims	Useful for fine tuning the orientation of the mount so that the pipe can be vertical in the water column	4 - 6

Table 7. Equipment list – Collecting shoreline GPS coordinates.

Supplier/ Item No.	Exact Brand	Description	Purpose	Quan- tity
	N	Mobile field data recording device (Tablet)	Recording data	1
88180-04 57972-10 58129	Y	GPS receiver, decimeter accuracy (Trimble GEO XH 6000 or 7000), MGIS Tornado Antenna, and Range Pole	Mapping the shoreline and in-water features	6
	N	Hip Waders (when necessary)/boots/	Safe wading	1/person wading