Hydroacoustic mapping system for quantitative identification of aquatic macrophytes, substrate composition, and shallow water bathymetric surveying

Eric Munday, Brian Moore, Janusz Burczynski
BioSonics, Inc.
Seattle, USA
ericmunday@gmail.com

***Abstract*— This paper reports a test in Puget Sound, Seattle WA, using a new aquatic habitat assessment system consisting of a single beam echosounder (BioSonics MX) and specialized post-processing analysis and mapping software (BioSonics Visual Habitat). Data were collected and processed to generate quantitative measurements of seagrass height and percent coverage, substrate type, and bathymetry. Results were favorable when compared to video data and visual observation and other ground truth measurements.**

Keywords—Hydroacoustic, echosounder, sonar, BioSonics, aquatic habitat, seagrass, substrate classification, bathymetry, submerged vegetation.

I. Introduction

Demand for fine-scale mapping tools to accurately assess the ocean floor has grown steadily as critical aquatic habitat areas and other natural resources have become increasingly scarce. Valuable seafloor mineral deposits can be located based on identification of specific substrate features, thus sonar-based substrate classification has become an area of intense focus by the burgeoning seafloor mining industry. Seagrasses and other macrophytes provide vital habitat areas and serve as a food supply for a range of aquatic organisms. The composition of seafloor substrate is also directly related to the viability and quantity of aquatic habitat. The viability of fish spawning beds, for example, may depend upon availability of specific sediment grain size. Such areas are highly sensitive to siltation due to anthropogenic impacts and any reduction or alteration of aquatic habitat areas can negatively impact the entire food web. Effective protection, resource management, and harvesting efforts require a baseline understanding of the existing quantity and location of areas with specific seafloor characteristics.

Hydroacoustic techniques are widely used and well proven in assessing seafloor habitat characteristics. The early 1980s also saw the development of techniques for acoustical classification of the seafloor. Over the past several decades a variety of sonar systems have proven effective for this application and several specialized software programs have been developed for acoustic classification of the seabed. Some of better known software brand names for substrate classification or bottom typing include; Quester Tangent QTC View, Sonavision RoxAnn [1], and BioSonics Visual Bottom Typer (VBT) [2]. As early as the 1980s, researchers realized the potential for hydroacoustics as a means to effectively assess submerged aquatic plants. In the 1990s, a methodology and processing software for hydroacoustic assessment of aquatic vegetation was pioneered by US Army Corps of Engineers scientist Bruce Sabol (SAVEWS) working with BioSonics and later commercially marketed by BioSonics under the brand name EcoSAV [3]. Another recently invented vegetation mapping system offers cloud-based processing services for data collected with low-cost recreational fish finders.

II. System Development

A. MX Echosounder

In 2012, a hardware/software system specifically for the assessment and mapping of aquatic habitat features including submerged macrophytes and substrate classification was developed by BioSonics, Inc. [4]. Development of the MX

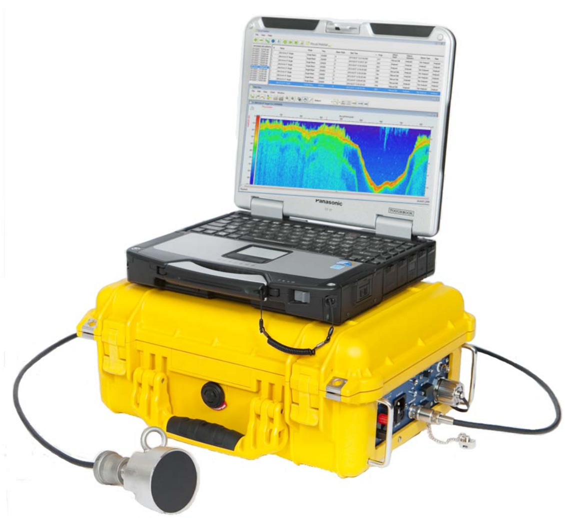

Fig. 1. MX Echosounder and laptop showing Visual Acquisition software

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echosounder (Fig. 1) was driven by interest from the scientific and environmental consulting communities in habitat assessment and demand for a scientific-grade instrument available at a lower cost than split beam fisheries echosounders. The MX utilizes a single beam 200 kHz transducer with nine degree beam angle. The echosounder ping rate (5.0 pps) and pulse duration (0.4 ms) are fixed.

B. Visual Habitat Software

Visual Habitat [5] was developed in tandem with the MX echosounder as a means to process hydroacoustic data quickly and generate output files that can be are readily interpreted and easily shared. Visual Habitat is designed with the intent that transects are collected as linear parallel lines with each data file representing a transect. Output file type options include comma-separated values (CSV) and Keyhole Markup Language (KML). Whereas CSV files are a typical format for import into GIS software for map making, KML files are viewable in Google Earth with separate files representing each data layer. Visual Habitat was built as an alternative to two previously existing BioSonics software programs (EcoSAV for plant processing, and Visual Bottom Typer for substrate classification). Visual Habitat utilizes new algorithms and offers fundamentally different functionality from prior software with a heavy emphasis on visual interpretation and ground truthing via map/transect and echogram synchronization.

III. Methods

A. Mobile Survey

A hydroacoustic survey was conducted to assess eelgrass and macrophyte coverage, bathymetry and substrate composition. The study site is a known seagrass bed adjacent to Golden Gardens Park, Seattle, USA. An MX single beam echosounder with a 200 kHz single beam transducer and an integrated DGPS for georeferencing were used for data collection. The echosounder was operated and configured using a Panasonic Toughbook CF-31 laptop computer running BioSonics Visual Acquisition software. A transect plan was designed using Fugawi Global Navigator software with 15 transects at 50 meter spacing. Transects were laid out running perpendicular to the shoreline. Depth range in the study site was from 30 meters to 1.5 meters. Data were collected at slack water to minimize effects from tidal flow and thereby obtain accurate seagrass height measurements. A SeaViewer Sea-Drop 950 underwater video system with a Sea-Trak GPS Overlay [6] was used to record geo-referenced video for ground truthing the presence absence of seagrass and substrate type. Video files from 13 waypoint locations were recorded to laptop computer using Microsoft Movie Maker software. Visual observations in shallow areas where water clarity allowed were noted and logged to the acoustic data files in real time using the Mark Event function in Visual Acquisition software.

B. Data Processing

All data files were processed using Visual Habitat software and an analysis procedure involving the organization and visual validation of each transect file using satellite imagery overlain with the transect map. During editing and analysis, Visual Habitat allows simultaneous viewing of each file in plan/map view and as a synchronized echogram (Fig. 2). Substrate classification is performed using a Principal Components Analysis (PCA) of each echo signal and clustering based on similarities of the components. This resulted in the delineation of areas with similar acoustic properties based on relative hardness and smoothness of the seafloor. Aquatic vegetation canopy height is determined via an algorithm that identifies the shift in signal strength of each echo as it passes through the water column and encounters vegetation. Plant density was calculated based on the presence or absence of vegetation in a sample (ping) contained in a report cycle. Bathymetry measurements were recorded with an accuracy of +- 1.7 cm. Processed data were exported to CSV and KML (Figure 2) file formats. Total processing time with Visual Habitat was approximately 45 minutes. Video data

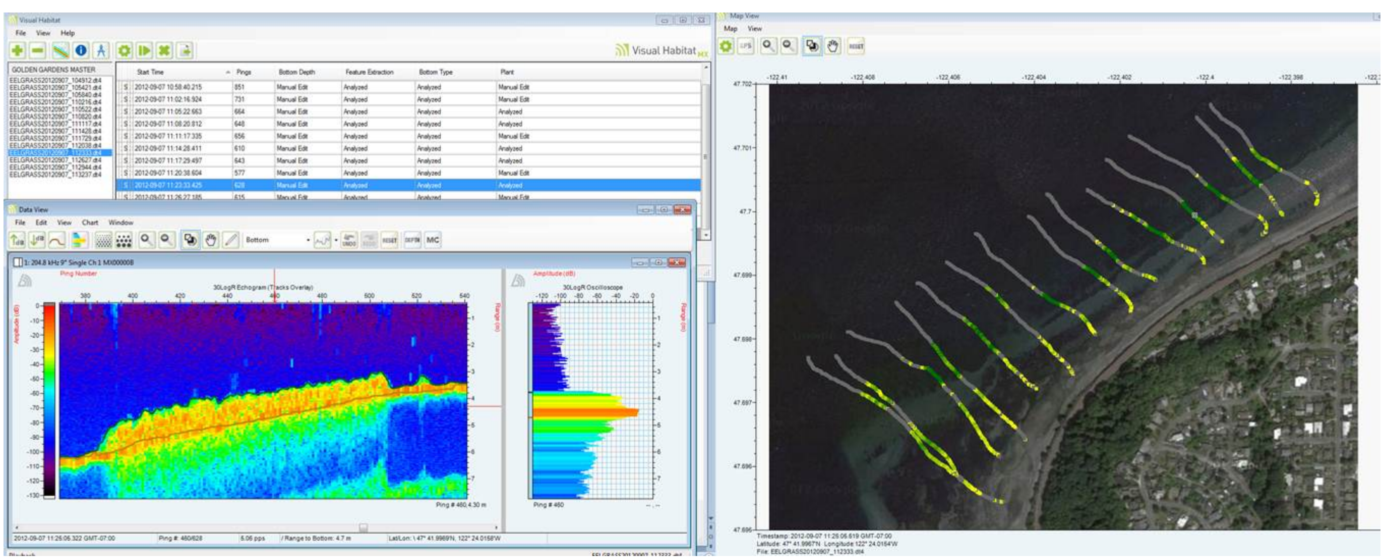

Fig. 2. Visual Habitat software showing synchronized echogram and map views

were reviewed and GPS coordinates were verified with sampling locations in Google Earth to generate site-specific video ground truth at the 13 predetermined locations (Fig. 3).

IV. Results

Processed data were exported to KML format and each data layer (bathymetry, plant height, plant coverage, and substrate type) was examined using Google Earth (Fig. 3). Results showed agreement with video ground truthing samples. Video recordings from showed direct correlation with hydroacoustic data for seagrass presence or absence and verified the presence and distribution of at least two distinct substrate types; sand and sandy clay, with a third substrate type of rock highly suggested by visual interpretation of echograms and PCA analysis. Bathymetry readings were consistent with ship's depth sounder (Garmin GPSMap 4010) readings

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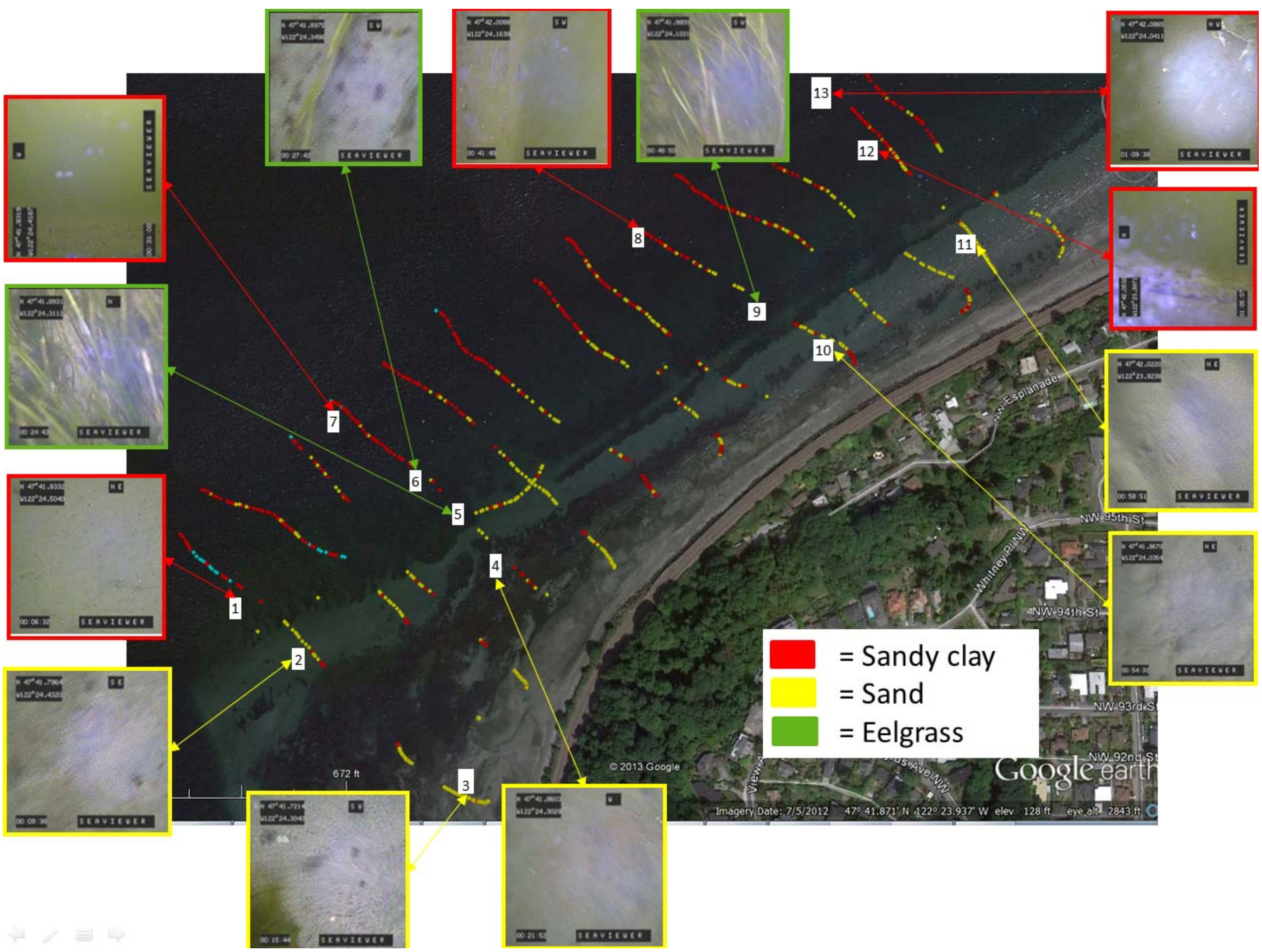

Fig. 3. Visual Habitat KML showing substrate type data layer with video sampling locations