Evaluating Acoustic Technologies to Monitor Aquatic Organisms at Renewable Energy Sites

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LONG-TERM GOALS

The long-term goal of this program is to quantify and evaluate the the ability of three active acoustic technologies (echosounder, multibeam sonar, and acoustic camera) to characterize and monitor animal densities and distributions at a proposed hydrokinetic site. Data from stationary, bottom-mounted acoustic packages will be compared to that from a mobile, surface survey. Results from this study will inform the choice, deployment, and data analyses of acoustic instrumentation use at marine hydrokinetic (MHK) sites.

OBJECTIVES

Research objectives include evaluation of acoustic technologies through monitoring and characterization of animal densities and distributions at a proposed marine hydrokinetic site in Admiralty Inlet, Puget Sound, WA. More specifically, to describe spatio-temporal distributions of macro-invertebrate, fish, seabird, and marine mammal populations at the study site through a combination of efforts including: collecting temporally-indexed data from an upward-looking echosounder, multibeam sonar, and an acoustic camera, mobile active acoustic surveys, seabird/marine mammal counts, and midwater trawling surveys. Stationary instrument data will be compared to mobile acoustic survey data to evaluate technologies and to inform data acquisition at proposed or active marine hydrokinetic sites.

APPROACH AND WORK PLAN

Using active acoustics is common in fisheries science applications, particularly for mobile surveys. This study aims to develop a procedure for marine renewable energy applications by evaluating bottom-mounted acoustic packages to monitor biota in the water column at a proposed marine hydrokinetic site. These acoustic packages (a splitbeam echosounder, multibeam sonar, acoustic camera) will collect spatially- and temporally-indexed data to be compared to mobile acoustic data collected along surface transects. Acoustic targets were verified using catches from a midwater trawl.

A large team of individuals are contributing to this project: Dr. Jim Thomson (Applied Physics Laboratory, Univ. of WA) and Dr. Brian Polagye (Mechanical Engineering, Univ. of WA) (deployment/recovery of acoustic moorings and ADCP data collection), Drs. John Horne and Sandra Parker-Stetter (School of Aquatic and Fishery Sciences, Univ. of WA) (acoustic surface sampling, midwater trawling), Kurt Fresh and Dr. Brad Hanson (National Marine Fisheries Service, Northwest Fisheries Science Center) (fish and bird/marine mammal survey). Three vendor partners are responsible for autonomous bottom instrument package configuration and data acquisition: Bill Hanot (SoundMetrics) (acoustic camera), Jim Dawson (BioSonics) (splitbeam echosounder), and Paul Jublinski (RESON) (multibeam sonar). Dale Jacques (School of Aquatic and Fishery Sciences, Univ. of WA) is a graduate school student involved in analysis and processing of the surface survey and bottom-package acoustic data.

Data analysis and interpretation is the focus of the project at this time. Pre-processing of acoustic data is completed. Fish catch data and ADCP data have been compiled to support additional analyses of acoustic data. Spatial and temporal variability in distributions of pelagic fish and macrozooplankton densities are being quantified in the temporal and frequency domains. The potential to scale temporally-indexed data to a spatial range at the Admiralty Inlet marine hydrokinetic site is being investigated to enable a calculation of instrument density for monitoring programs.

WORK COMPLETED

During the reporting period, analytic effort focused on development and comparison of pre-processing methods for stationary acoustic data sets: the BioSonics' echosounder, the Soundmetrics' DIDSON acoustic camera, and the mobile survey Simrad echosounder. Pre-processing included removal of a second bottom echo that occurred in both stationary acoustic data sets, and exclusion of noise or bad data regions associated with the surface, water turbulence, vessel sonar, or bad weather in all data sets. Analytic decisions included determination of horizontal or temporal bin size to parse survey transect and stationary data; methods to characterize spatial and temporal variance in density distributions from mobile and stationary instruments; and choice of co-variates to partition the data including sample location, sample month, day and night sampling periods, and tidal state. Vertical depth distributions of biomass were calculated relative to the height of the OpenHydro turbines (13 m) proposed for the

Admiralty Inlet site, indexed using center of mass from acoustic backscatter its standard deviation. A suite of descriptive metrics were investigated for efficiency and efficacy to describe temporal and spatial vertical distributions of fish and macrozooplankton in the water column (cf. Urmy et al. 2012) and Table 1.

Table 1. Summary of stationary and mobile acoustic data metrics used to describe water column biomass with environmental and sampling covariates.

Attribute	Month	Photoperiod	Day of year	Tidal magnitude	Tidal flow	Location	Grid
Stationary							
Density	x	x	x	x	x		
Density variance	x	x	x	x	x		
Vertical distribution	x	x	x	x	x		
Vertical dist. variance	x	x	x	x	x		
Dispersion	x	x	x	x	x		
Dispersion variance	x	x	x	x	x		
Aggregation pattern	x	x	x	x	x		
Agg. pattern variance	x	x	x	x	x		
Mobile							
Density	x	x	x	x	x	x	x
Density variance	x	x	x	x	x	x	x
Vertical distribution	x	x	x	x	x	x	x
Vertical dist. variance	x	x	x	x	x	x	x
Dispersion	x	x	x	x	x	x	x
Dispersion variance	x	x	x	x	x	x	x
Aggregation pattern	x	x	x	x	x	x	x
Agg. pattern variance	x	x	x	x	x	x	x

RESULTS

Autocorrelation of integrated water column area backscattering coefficient (s_a, m^2/m^2) as a function of lag distance through the tidal cycle was shorter than expected in both temporally and spatially-indexed data series, ranging from < 0.5 m/s to > 1.5 m/s (Figure 1). These data were used to determine the horizontal bin size for the mobile (distance) and temporal (time) data series.

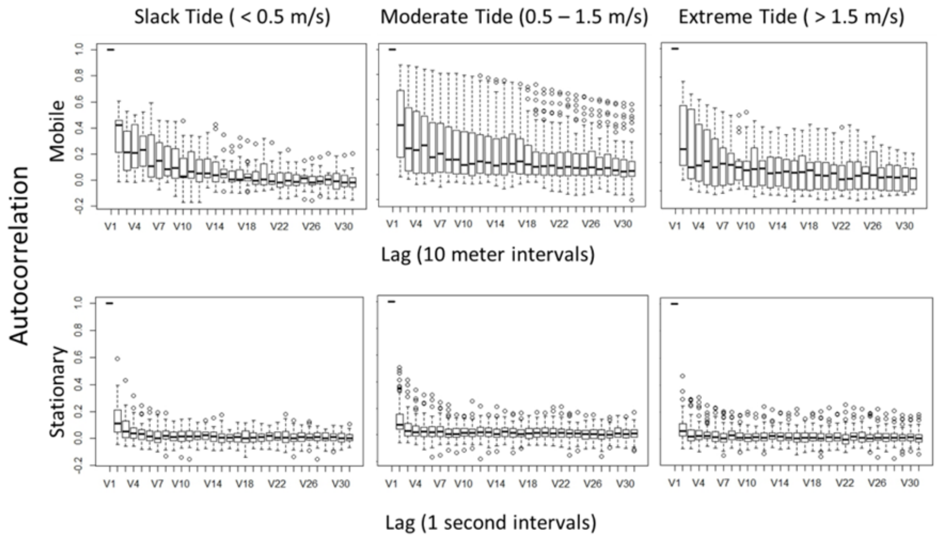

Figure 1. Box and whisker plots showing autocorrelation of integrated water column area backscattering coefficient (s_a) as a function of lag distance (10 m lags) in May 2011 for mobile (upper) and temporal (1 second lags) (lower) acoustic data sets from the north grid during slack (left), moderate (center), and extreme (right) tidal flows. The lag at which observations become independent (ACF approaches 0.0) is the bin size used to describe patterns of variability.

Area backscattering strength (S_a, dB re 1(m^2/m^2), herein dB) values, a proxy for biomass, were compared and categorized by grid locations, sampling periods, tidal state, and diel period (Figure 2). An increase was observed from May to June with greater biomass in the north than in the south, higher at night than during the day (and with less variability), and approximately equal across tidal states.

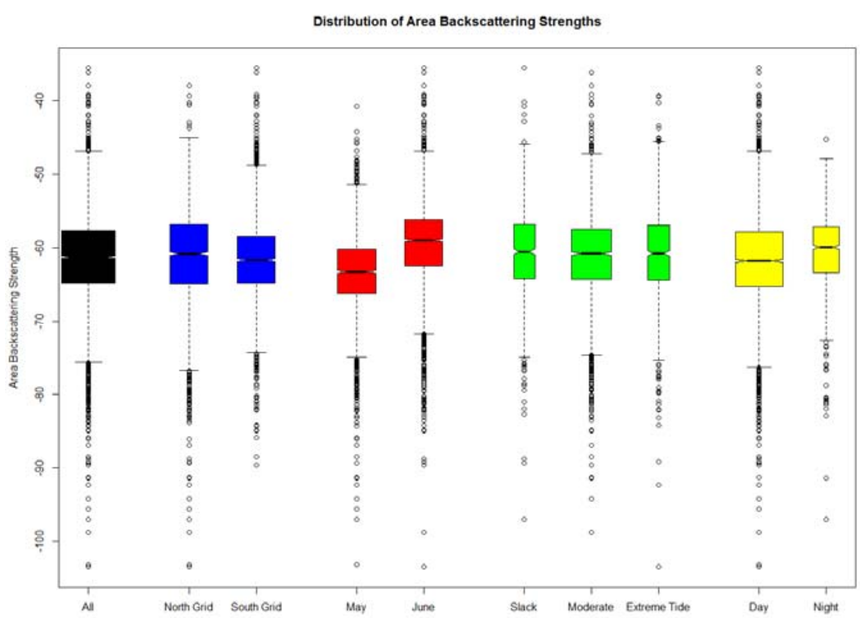

Figure 2. Mobile survey area backscattering strength (S_a, dB) box-and-whisker plots categorized by grid location (north, south), sampling period (May, June), tide state (slack, moderate, extreme), and diel period (day, night).

To characterize the vertical distribution of biomass relative to the 13 m height of the proposed OpenHydro turbines at Admiralty Inlet, cumulative distribution functions (CDF) of waster column acoustic backscatter were indexed using center of mass were tabulated as a function of distance from bottom (Figure 3). Across all samples, approximately 25% of the acoustic backscatter occurred at or below the height of the proposed tidal turbines. This value increased to 60% within one standard deviation, and to 95% within two standard deviations. CDF values did not differ between day and night samples (not shown). As expected, two standard deviation center of mass values were greater in night compared to day index values.

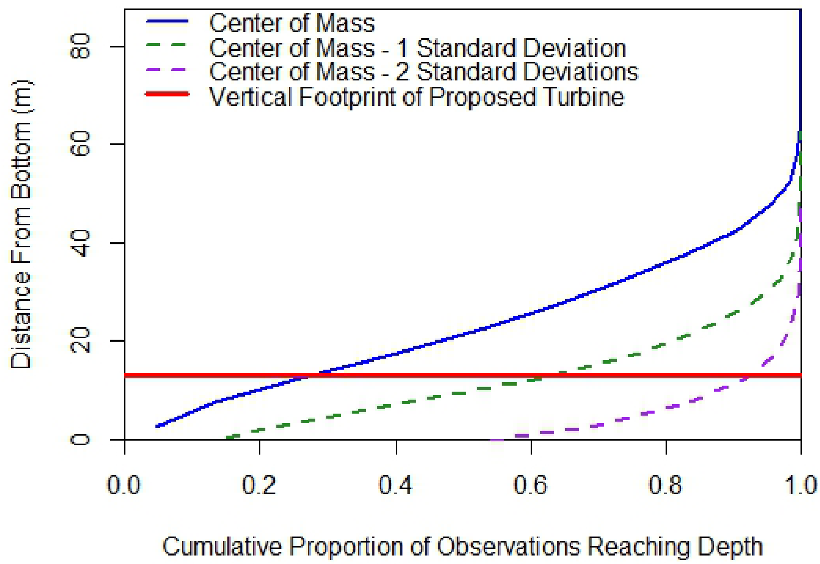

Figure 3. Acoustic area backscattering strength (S_a) center of mass from mobile surveys, minus one and two standard deviations, as a function of distance from bottom. The 13 m height of the OpenHydro turbines is shown for reference.

Results from the stationary echosounder (120 kHz) data series will be used to illustrate vertical changes in biomass using distribution metrics, and environmental or sampling covariates. Similar analyses will be conducted for other acoustic data series. Enhanced box and whisker plots (McGill et al. 1978; Chambers et al. 1983) are used to characterize changes in index values through the instrument deployment period. Median area backscattering strengths (S_a, dB), a proxy for biomass, measured by the stationary 120 kHz echosounder increased by as much as 3 dB through the deployment (Figure 4a). A 3 dB increase in area backscattering strength represents a doubling in reflected energy and a proportional increase in animal biomass. The increase in acoustic backscatter observed between May and June is attributed to animal growth and changes in both species composition and density. As backscatter increased during the deployment, the center of mass, the weighted mean location in the water column, shifted higher in the water column (Figure 4b) and became more dispersed (Figure 4c). The aggregation (i.e. patchiness) of acoustic backscatter did not significantly change through the deployment (Figure 4d). It is interesting to note that observed peaks in the aggregation index at the start and middle of the deployment (approximately centered on day 129 and day 144) coincided with peaks in maximum tidal magnitude during the deployment.

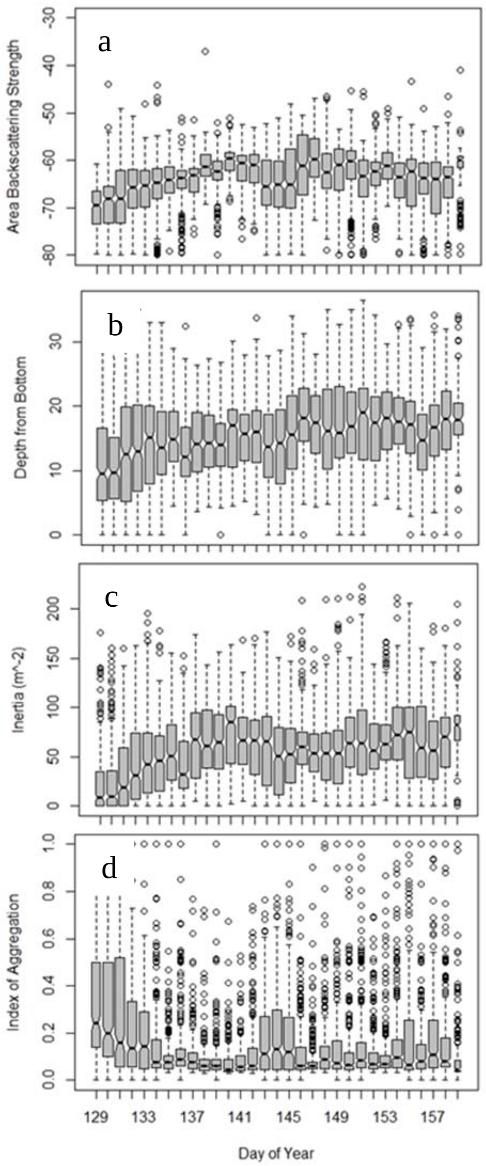

Figure 4a. Box-and-whisker plots showing daily acoustic area backscattering strength (S_a) from the stationary 120 kHz echosounder in May – June 2011.

Figure 4b. Box-and-whisker plots showing acoustic area backscattering strength (S_a) center of mass from the stationary 120 kHz echosounder in May – June 2011.

Figure 4c. Box-and-whisker plots showing inertia (i.e. dispersion) of acoustic area backscattering strength (S_a) from the stationary 120 kHz echosounder in May – June 2011.

Figure 4d. Box-and-whisker plots showing aggregation index for acoustic area backscattering strength (S_a) from the stationary 120 kHz echosounder in May – June 2011

IMPACT AND APPLICATIONS

National Security

If marine renewable energy installations reach commercial scale or are used to supply power to strategic assets, then the ability to monitor biologics and to distinguish biologics from anthropogenics will increase the ability to determine threat risk to marine hydrokinetic infrastructure and coastal infrastructure.

Economic Development

Two of the three vendor partners that developed products for use in this project are now commercially marketing the products. BioSonics combined a new system controller with a pressure housing and is now marketing an autonomous echosounder package. RESON developed a bottom platform and power supply system that can be used as a mount for any instruments in their product line, and now offers this platform as a commercial autonomous system. Software programming by SoundMetrics for the instrument used in this project has been used in the development of a new operating system for the second generation acoustic camera, now commercially available.

Quality of Life

An additional objective of this project is to recommend general equipment choice, deployment, and biological monitoring strategies for marine renewable energy sites. These recommendations should improve accuracy and help standardize environmental monitoring in an emerging ‘green’ energy industry and be applicable to other ocean monitoring applications (e.g. ocean observing).

Science Education and Communication

A graduate student is being trained in the use of active acoustics, survey design, and environmental monitoring during this project. Results of this project have been reported by print, radio, and television media to the public, and presented at scientific conferences. Additional discussions have been held with representatives from the Department of Energy, the Bureau of Ocean Energy Management, and the National Science Foundation to identify needs for biological monitoring at marine renewable sites, and the necessary graduate student training to provide private industry and government with a pool of people capable of measuring and evaluating biological data used in the siting, development, and monitoring operations of marine hydrokinetic sites.

TRANSITIONS

Economic Development

Two vendors (BioSonics and RESON) are now commercially marketing equipment that was designed for use in this project. The third vendor (SoundMetrics) incorporated software used in this project into the development of new operating software. In all three cases, economic development has resulted directly from this project.

Science Education and Communication

Results of this project are being communicated to the marine hydrokinetic science community and may be used to compare results with at least two other projects located in Maine and Nova Scotia, Canada with the aim of deriving best scientific practices for environmental monitoring. Additional international projects are being sought to evaluate metrics and scaling procedures developed in this project.

RELATED PROJECTS

Four projects are relevant to work included in this project: development of echosounder controller for autonomous deployment, Admiralty Inlet monitoring, monitoring for strike of turbine blades, and development of a program to aid scaling pilot to commercial scale projects. First, the Northwest National Marine Renewable Energy Center (NNMREC), a DOE-funded research center, partnered with BioSonics Inc. in 2009 to develop the first-generation controller for autonomous echosounder deployments. This development was leveraged by BioSonics for use in this project. Second, NNMREC has been working with Snohomish PUD to characterize the biological and physical environment in northern Admiralty Inlet ahead of a proposed hydrokinetic turbine deployment in 2014. Sea Spider instrumentation packages have been deployed at this location since 2009. These deployments have allowed NNMREC to demonstrate the mechanics of instrumentation deployment and retrieval in high-flow environments, and then were applied to similar deployments in this project; and improved the understanding of tidal currents at this location, which was used to provide more accurate tidal predictions for trawls than possible using NOAA tide and current tables. All data collected is posted at http://depts.washington.edu/nnmrec. NNMREC has developed a stereo imaging system to monitor potential interactions between operating tidal turbines and pelagic nekton. This system will be deployed with Snohomish PUD's hydrokinetic turbines in 2014. Data collected from this project will help define the species composition likely to be observed in the vicinity of the turbines. A recently funded NSF sponsored project, "Tidal Energy Scalability: Moving sustainability to large-scale utilization" aims to ensure sustainable development of technical, environmental, and social aspects of tidal energy projects. At present, the tools that could enable large-scale, sustainable utilization of tidal energy are underdeveloped.

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