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On the use of high-frequency broadband sonar to classify biological scattering layers from a cabled observatory in Saanich Inlet, British Columbia

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ABSTRACT

This paper explores the use of broadband acoustics to differentiate between biological scattering layers using observatory-based acoustic observations with minimal supporting biological observations. Targets and layer assemblages were classified based on 85–155 kHz acoustic data collected on the VENUS observatory in Saanich Inlet, B.C. between March 2008 and February 2010 using a clustering algorithm and different broadband acoustic data descriptors. First, a 6-h segment of data, for which there were coincident depth-resolved net-tow data, was analyzed. Clustering based on the calibrated spectrum of volume scattering strength for each target resulted in clusters that were distributed just as those resulting from clustering based on 120 kHz narrowband data because the clustering was dominated by the scattering level, rather than the spectral shape. When the target spectra were normalized, the clustering results were consistent with the different taxa found in the net samples, but often could not distinguish taxonomic groups. However, layers with distinct species assemblages had different distributions of target classifications, suggesting the assemblages could be distinguished using frequency-dependent scattering information. Ensemble-averaging the scattering observations and converting the spectral data to a 3-descriptor acoustic color representation prior to clustering was (1) more effective

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at distinguishing the dominant scattering layers based on their assemblages and (2) much more efficient in terms of computational cost. Clustering two years of acoustic-color data identified 4 main groups (diel migrating euphausiids and chaetognaths, fish, and a mix of pteropods and bottom-to-oxycline migrating amphipods) that were consistent with contemporaneous and historical observations of zooplankton in the inlet. A wider frequency band might be effective in better distinguishing individual zooplankton targets.

1. Introduction

High-frequency acoustic observations, each ping rich in information on the whole water column, are ideally suited to long-term deployment on cabled ocean observatories. High-frequency acoustics can provide high-resolution, long-term records of fine-scale vertical distribution and abundance of zooplankton and other marine organisms in the ocean. On cabled observatories, long-term acoustic records are no longer limited by data storage or power (Dewey et al., 2009), leading to unprecedented ability to perform longitudinal studies (e.g. inter-annual variability in zooplankton populations). However, work remains to be done to develop reliable target and layer discrimination and classification algorithms (Horne, 2000). Accurately discriminating and classifying targets and layers composed of a mixture of targets is critical for ecological (e.g interaction within or between different trophic levels) and fisheries (e.g. stock assessment) studies (Trenkel et al., 2011).

The information in acoustic scattering signals that allows target discrimination is largely frequency dependent. This has led to studies using multi-frequency (e.g. Horne, 2000; Warren et al., 2003) and broadband (e.g. Lavery et al., 2010; Stanton et al., 2010) acoustic data, along with other environmental data, to infer species composition. Broadband data have the added benefit of improved spatial resolution, allowing better target isolation and noise suppression through the use of pulse compression techniques (Chu and Stanton, 1998). Broadband measurements and theoretical physics-based approaches for classifying zooplankton have been combined successfully (Stanton et al., 1998; Roberts and Jaffe, 2007, 2008) in the laboratory. Field-applicable broadband target discrimination and classification techniques, however, are still in the early stages of development (e.g. Stanton et al., 2010). Ground-truth information remains critical for accurately estimating the abundance and composition of acoustically-observed animal aggregations (Holliday, 1977; Greenlaw, 1979; Lawson et al., 2008).

Acoustic datasets, and particularly broadband datasets, collected during ship-based surveys or from a moored instrument can be enormous. Automated or semi-automated classification techniques can be very useful in managing and interpreting this acoustic information. Cluster analysis has been used effectively to classify fish, based on both school properties (e.g. Burgos and Horne, 2008) and frequency dependence (e.g. Anderson et al., 2007), as well as krill swarms (e.g. Cox et al., 2011; Tarling et al., 2009) and seabed type (e.g. Preston, 2009). Clustering, or another blind classification scheme (i.e. one that is not trained based on some supporting dataset), is well suited to datasets where the supporting biological observations are sparse and likely not representative of all the species present throughout the observation period. This limitation due to insufficient supporting data is certainly present in the 'typical' observatory-based acoustic dataset. Combining this with the fact that no hierarchical relationships are expected between the zooplankton groups, it is likely that simple non-hierarchical, blind classification techniques are likely to be the most useful in the automation of the identification of zooplankton layer in mooring-based acoustic observations.

One of the biggest difficulties in applying clustering techniques to acoustic data is choosing what variables or descriptors of each data point to include as dimensions in the multidimensional space in which the clustering algorithm operates. Broadband acoustic data offers a means of distinguishing between different types of scatterers based on their scattering spectra (e.g. Lavery et al., 2010; Stanton