SEABED SEDIMENT CLASSIFICATION AND SEAFLOOR BATHYMETRY USING SINGLE BEAM HYDRO-ACOUSTIC ECHO BACKSCATTER

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1. INTRODUCTION

Marine ecosystems are complex and dynamic; defined by currents, sedimentation, and climatic effects on biological recruitment and abundance. Our knowledge of these sub-tidal benthic systems is limited to anecdotal reference from industry fishers, although often lacking the spatial resolution necessary for stock assessment and management.

In the near-shore, hydro-graphic charts do not provide enough information for benthic biological assessments; therefore, hydro-acoustic surveys are an essential first stage for detailed spatial analysis of shallow sub-tidal marine environments, and single-beam acoustic survey technology is effective and accurate. Hydro-acoustic surveys are a source of supplementary physical habitat information, bathymetry and seabed sediment type, which are used to examine the spatial variability in stock density and biomass distribution.

The geoduck clam, *Panopea generosa*, is a large infaunal bivalve clam that has been harvested in a commercial fishery on the West Coast of Canada, since 1978. Geoducks are harvested by divers from unconsolidated sediments, primarily sand and pea gravel, using a pressurized water pipe to saturate the seabed sediments; so that the clam can be removed undamaged, and for a live export market.

Single-beam echo sounders, onboard fishing vessels, have been the most valuable asset for the exploitation of sub-tidal marine resources; they are used to locate soft bottom sediments for exploratory dives and ultimately charting commercially viable geoduck harvest areas. The geoduck stock assessment program has been collecting hydro-acoustic echo backscatter data, using QTC View and QTC Impact (Quester Tangent Corp., Sydney, BC, Canada) echo digitisation hardware and software, since 2001. To date, more than 10 000 ha of known geoduck harvest areas have been surveyed.

2. METHOD

Currently, a new single frequency shallow water system is being used to collect 50 kHz single-beam (Airmar 9° x 17° transducer) echo backscatter. This transducer frequency penetrates the seabed surface several centimetres, this is preferable in determining sediment consolidation; e.g. the distinction of light grain sand from hard packed sand to gravel or rock. For many past surveys, a 200 kHz frequency transducer that has a smaller beam width of seafloor insonification was also used, which detects more variability in the seabed texture, algal cover and surface sediments.

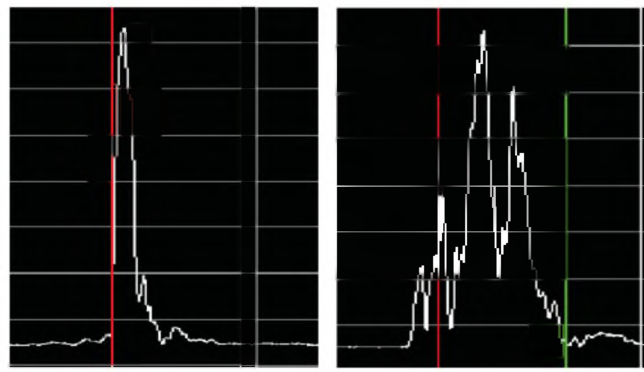

Figure. 1. Echo energy waveforms, less consolidated substrate (left) and more complex/consolidated substrate (right).

The variance in the amplitude and duration of the seabed echo backscatter is relative to the variance in the consolidation and complexity of the seabed surface sediments (Figure 1). The measured energy from single-beam backscatter is analysed to generate statistically descriptive features, which are then reduced to three principal components (Collins et al., 1996, Ellingsen et al., 2002, Murfitt and Hand, 2004). While there are limitations in acoustic technologies, water quality and sea floor slope, single-beam echo sounder systems are an invaluable technology for marine science (Anderson et al., 2008), particularly in refining harvest bed area estimates for geoduck stock assessment.

Most acoustic survey designs follow a 50 m parallel track-line grid in the perpendicular to shore direction, and an along shore 100 m parallel cross track-line. QTC Impact software is used for echo editing and principal component analysis (PCA) (Quester Tangent Corporation, 2004). Post-processing of the acoustical backscatter yields a file of track-line point data. Each file contains survey depth and three principal components, which maximise the variance of the acoustical backscatter. Principal components analysis of the statistical features generated by Quester Tangent echo analysis, and seabed classification as applied by the geoduck stock assessment program are further described in, Murfitt and Hand, 2004.

Depth is first corrected for tide height to chart datum, and then used to generate a continuous bathymetric surface and depth contours. Idrisi Geographic Information Systems software (Clark Labs, Worchester, MA, USA) is used for geo-statistical interpolation (Kriging method) of the depth and PCA point data into continuous surface images. Interpolated surface images are an additional step in seabed classification, but interpretation and distinction of transition between sediment-types is more obvious and objective than single point track-line data as generated by QTC Impact software. The bathymetric surface is used to calculate area in dive fishery working depth, and the visualization of the distribution of both current stock and stock removed.

The general principle in seabed classification is that the variability of the seabed echo impedance or reflectance can be discretely segmented to represent unique differences in the seabed by the strength and duration of the echo. K-means clustering is an iterative method that minimizes the distance between cluster centres and the data cluster members, grouping similar image cell values from the interpolated principal components (Eastman, 2006). All three PCA images are used to segment the data into a pre-determined number (k) of clusters[*] that represent distinct changes in seabed consolidation and/or seabed complexity, and are assigned to known seabed-types within the survey area. Acoustic survey data and seabed sediment classification is verified with geoduck harvest locations as reported on fishery dive logs.

3. RESULTS

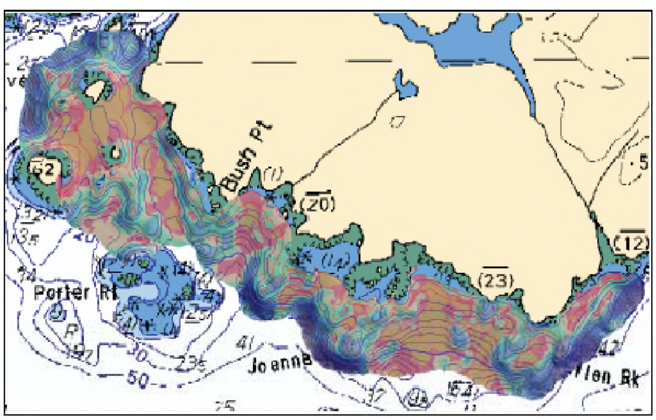

Figure. 2. K-means classification of seabed sediment consolidation, orange-red is a sand substrate.

Figure 2 shows the result of k-mean clustering of the acoustic data, the orange and red classes are the least consolidated sediments and the preferred areas for geoduck harvest effort. The depth range for this survey area is between 2 m and 40 m, the working depth range for divers is between 3 m (min. limit to protect eel grass beds) and 20 m (max. limit for diver safety). There are 3 invertebrate species commercially harvested at this survey area: red sea urchins (*Strongylocentrotus franciscanus*), sea cucumbers (*Parastichopus californicus*), and geoducks. While there is some overlap of species on seabed substrates, cucumbers and urchins are generally less abundant on preferred geoduck harvest sediments. With knowledge of depth and substrate extents, we can better estimate targeted populations and assess the impact of fishing on future stock recruitment.

The primary purpose for these acoustic surveys has been to calculate area of suitable substrate for the geoduck fishery quota calculation. The secondary purpose has been to determine the area in stratified working depths, relative to fishery harvest log depth and dive density survey depth.

4. DISCUSSION

Acoustic technologies have evolved substantially over the past ten years; however single beam is still an established dependable means of collecting seabed backscatter. There would be greater advantages in survey area coverage and resolution with more advanced transducers, particularly, combination lower resolution multi-beam and high resolution side-scan transducers, but with a higher capital expense.

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[*] Post processing, clusters are referred to as classes.