The use of the SHOALS waveforms to assess habitat complexity within the benthoscape

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Abstract

Water-land interfaces develop such heterogeneous ecological niches that the natural capital, deeply correlated with biodiversity, of these biotopes embodies one of the most important on earth. In these systems, widely dispersed field or ship-based observations and lack of broad scale data have historically precluded quantification of large-scale patterns and processes and hindered management efforts, necessary within a context of unprecedented temporal changes. However, relatively recent advances in Airborne LiDAR Bathymetric (ALB) have begun to address these issues and are now permitting assessments of pattern in shallow water [1]. Such a LiDAR system is able to survey synoptically and simultaneously shore and shoreface, and furthermore, to map and classify benthic habitat patterns [2]. The purpose of this study is to set up the statistical relationships between the SHOALS-3000 (Scanning Hydrographic Operational Airborne LiDAR Survey) benthic waveforms with benthic measurements of habitat complexity.

The survey covered 82 km² in 12 hours and represented 80 million individual depth and elevation measurements. They were collected by SHOALS between July 1st and 3rd 2006 over the Baie des Chaleurs, southern Gulf of St. Lawrence, Quebec, Canada. The maximum depth penetration reached was 16.7 m over sandy zones and 8 m over macroalgae.

Through its infrared (1064 nm) and blue-green (564 nm) laser beams, it currently embodies the only airborne LiDAR which can measure topographic (20 kHz) and bathymetric (3 kHz) range during the same flight. Moreover, the strength of returned signal is digitalized as a function of time over 4 channels’ responses, namely shallow and deep blue-green, infrared and Raman. Small-footprint SHOALS-3000 has the unique capability to detect the fine grain (<2 m) while broad-extent coverage is acquired. In topographic context (density mode: 1.2x1 m²) this return signal corresponds to target reflectance at the laser wavelength. In bathymetric domain (density mode: 2x2 m² over intertidal areas) this measure integers both bottom reflectance and water
column properties. Meaningful ground-truth measurements and their ad hoc processing (seafloor photographs, inherent species richness and ecological properties) came to support the basis of characterizing variability of ALB return signals with the mosaic of littoral patches.

In bathymetric domain, the “benthic” curve was retrieved from the deep-green waveform and was decomposed into 12 quantitative variables, which were added up to the bathymetry, the turbidity and the rugosity, allowing to constitute an array of explanatory variables (ALB table). In the same way, another matrix (Ground-Truth table) was carried out by geo-referenced benthic measurements, encompassing bio-sediment coverage, height heterogeneity and α-diversity (i.e., species richness), standing for dependent variables. Accordingly, computations linear simple regression models highlight that the designed habitat complexity index was deeply correlated with (1) the benthic volume indices and (2) the local bathymetric heterogeneity (i.e., rugosity). Afterwards, in order to avoid the redundancy of the indices, due to their underlying covariance, the ALB and GT tables, representing two sets of variables measured on the same statistical units, were submitted to a Canonical Correlation Analysis (CANCOR), a method that finds out the linear combinations of one set of variables that are maximally correlated with the linear combinations of another set of variables [3]. There were 5 statistically pairs of canonical variables from the dataset of ALB estimates and the corresponding dataset of GT structure. Then, correlations between the 5 canonical variables and, on the one hand, the ALB variables, and on the other hand, the GT variables revealed that LiDAR-derived benthic volume indices reliably point out the patterns of habitat heterogeneity.

A multivariate statistical methodology applied on SHOALS-3000 waveform-derived indices shows evidence for consistently quantifying benthic (sedimentological facies and biological association) measurements. Within the second phase, we will correlate ALB indices with GT clues from intertidal areas in designing a vegetation index based on green and infra-red channels to seamless monitor the patterns of coastal benthic communities from the upper marsh to the shallow water areas.

References