Intertidal Habitat Characterization of Rocky Shores Using Terrestrial Laser Scans

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1. Introduction

Rocky shore research has been laying the fundamentals for ecological theories and ecosystem modelling for several decades. The rocky intertidal exhibit steep environmental gradients, variable physical conditions over short distances, and inhabits organisms that are mostly sessile or sedentary, reach high densities, and are small in size. These characteristics, combined with the relative ease of accessibility, make it one of the optimal study systems for ecological patterns and processes (Menge & Branch, 2001). Generally, coastal ecological-related research focuses on distribution patterns and dynamics of organisms and community assemblages and on understanding the physical, biotic factors, and processes that affect diversity, distribution and zonation. In recent years, climate change, biological invasions, and accelerated coastal development pose threat to the ecological stability of rocky shore habitats (Rilov & Treves, 2010). This raises additional research interest in this environment both as an indicator of overall ocean health and for conservation purposes.

Rocky shores are generally characterized by three distinctive habitats: subtidal, intertidal and coastal. Among them, the intertidal zones are characterized by diverse communities of marine organisms, many of which are limited to this habitat. These organisms are affected by the unique physical environment where rocky substrata are alternately exposed to air and submerged under water due to daily tidal cycles (Denny, 1999; Menge & Branch, 2001; O’Donnell & Denny, 2008). Other dominant factors that influence the distribution of intertidal organisms are wave exposure, induced hydrodynamic forces, and water coverage dynamics. All these factors strongly relate to the geomorphological features of the rocky substrata including elevation above sea level, the shoreline topographical complexity, and the rock’s micro topography, all of which can vary greatly from site to sites. The effect of these components on intertidal marine communities has been studied in the past, mostly on a metre-scale or higher, but in order to accurately represent their ecological patterns and forecast possible ecological changes due, for example to sea level rise, better observations are needed for the small scale topography. Along this line, Fraschetti et al. (2005) indicated that smaller scale spatial resolution would improve the interpretation of the intertidal zone and microhabitats.

Threats such as sea level rise are particularly relevant to regions where the tidal range is small but the intertidal area is large (i.e., large flat rock platforms at sea level). Such is the unique rocky shore habitat of vermetid reefs, a flat rocky formation located at mid sea level that is found in warm-temperate seas where the rocks are softs and easily abraded by waves and winds (Safriel 1974). This is a biogenic habitat, where sedentary gastropods (vermetids) create a crust on the rock flat as well as a rim at the waterline (formed specifically by the species *Dendropoma petraeum*), which stop or compensate the erosion of the rock. Such reefs are very abundant on the eastern parts of the Levant shore, and a recent finding indicates that the populations of the reef-building vermetids are almost extinct, raising the question, what would happen to the integrity of the habitat, especially in light of sea level rise. A detailed 3D characterization of the whole reef area allow to follow geomorphological changes over time, as well as model the effect of sea level rise on the available area for intertidal biota.

While classical surveying is still the commonly-used documentation and mapping technique of rocky shores, it falls short of describing the relevant topographical detail and the dynamic nature of the intertidal zone. Its outcome presents limited characterization of habitat structure and the complexity of reef environments (Marchand & Cazoulat, 2003; Bonnot-Courtois et al., 2005; Vierling et al., 2008). Use of airborne laser scans which has been proposed in recent years (e.g., Vierling et al., 2008; Chust et al., 2008; Brock & Purkis, 2009; Noernberg et al., 2010; Hamylton et al., 2014) provides only decimetre level accuracy and limited resolution. It is also incapable of characterizing the micro-topography and falls short of characterizing in detail coastal cliff edges and other near-vertical features. Moreover, it presents limited flexibility of repeated campaigns due to data acquisition costs.

To address these shortcomings and provide an insight into the effects of reef microhabitat, we apply terrestrial laser scanning technology, which offer centimetre resolution and even higher accuracy, and develop morphological characterizations of the coastal environment. We also sample the biodiversity, which links between rocky shores micro-habitats, biodiversity, and intertidal marine community structure. The proposed application creates a geomorphological and ecological representation of the rocky intertidal coastal system, including its topographical texture and complexity, rim form and completeness, species-habitat relationship, and potential ecological impacts of sea-level rise. Long-term monitoring of the reef would allow us a more accurate estimation of the marine biota changes as a result of the rim and micro-topography modifications.

As the data volume prohibits naïve analyses, we develop methods to characterize the micro-morphology of the reef and its rim. The microstructure is described by its texture and complexity, and allows us to classify microhabitats and possibly explain zonation and patchiness patterns. The rim characterization, which is evaluated in terms of form and continuity, also allows estimation of seawater holding on the reef during low tide. Water held on the platform during low tide create special conditions for the organisms on the reef, thus erosion of the rim would change those conditions, as well as wave dynamics. Long-term rim characterization will provide information on the effect of the disappearance of the rim builder vermetid, *Dendropoma petraeum* on the reef structure. The dense spatial resolution provided by the laser scans allows also testing the effect of various sea level rise scenarios according to IPCC forecasts. The level of detail we achieve improves forecasting of the exact locations and microhabitats that would be flooded and become subtidal. Paired with the biodiversity analysis per habitat, a highly precise prediction of community changes and species loss would be made possible for the first time.

2. Study Sites

The application is demonstrated on two dissimilar sites along the Israeli Mediterranean coast, exhibiting different geomorphological characteristics and distinctive formation of vermetid reefs. The first, Achziv shore, at Northern Israel (Figure 1) is a continuous calcareous eolianite (kurkar) rocky shoreline of ca. 300 meters, extending seaward to create eight separate vermetid reefs (Figure 1b). At the back of the shore, a two metre high rocky cliff borders the shoreline from land.

The second is a tiny islet located at HaBonim shore (Figure 1), which features a well-developed elliptic continuous vermetid reef which surrounds a 4.5 meter high cliff. The platform at this site is approximately 10 cm lower than in Achziv.

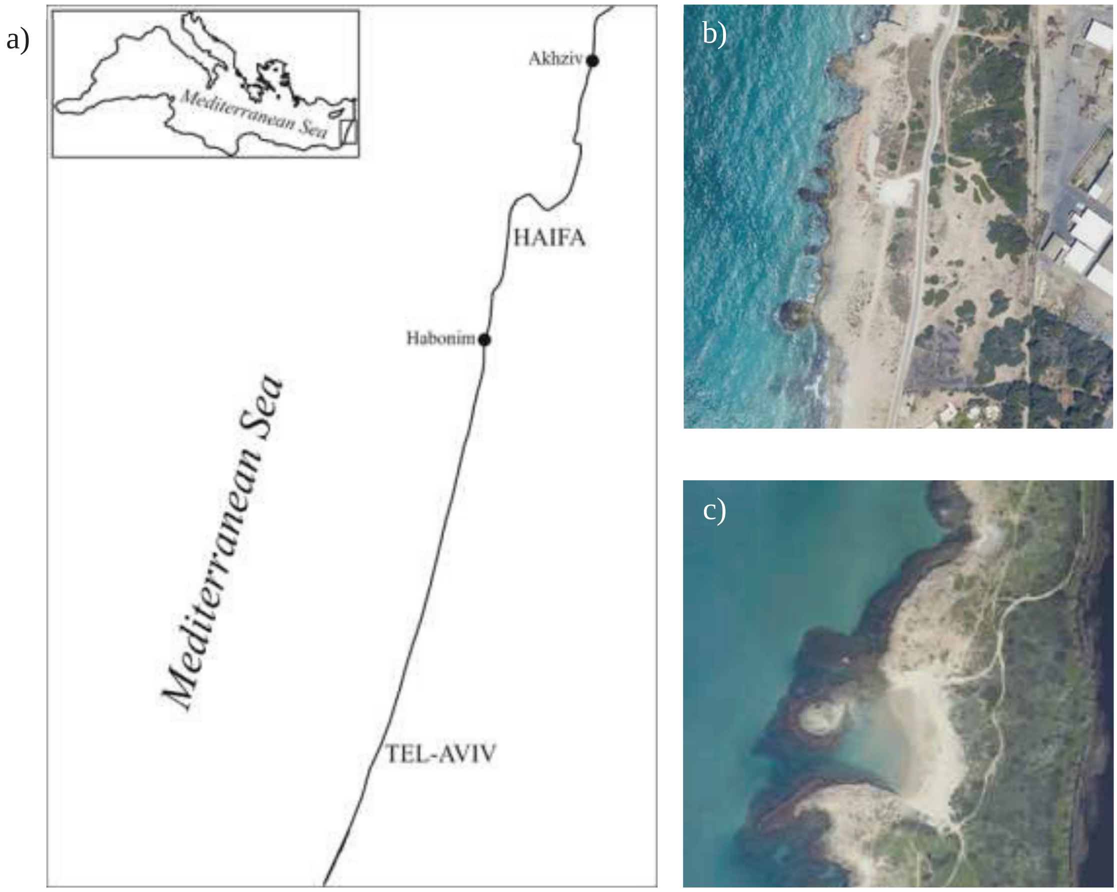

Figure 1: a) Israel coast and sites locations; b) Achziv aerial view; c) HaBonim aerial view

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