



Deep-sea bio-physical variables as surrogates for biological assemblages, an example from the Lord Howe Rise

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ABSTRACT

Little is known about diversity patterns of biological assemblages in deep-sea environments, primarily because sampling deep-sea biota over vast areas is time consuming, difficult, and costly. In contrast, physical mapping capabilities are increasing rapidly, and are becoming more cost-effective. Consequently, the growing need to manage and conserve marine resources, particularly deep-sea areas that are sensitive to anthropogenic disturbance and change, is leading the promotion of physical data as surrogates to predict biological assemblages. However, few studies have directly examined the predictive ability of these surrogates. The physical environment and biological assemblages were surveyed for two adjacent areas – the western flank of Lord Howe Rise (LHR) and the Gifford Guyot – spanning combined water depths of 250–2200 m depth on the northern part of the LHR, in the Coral Sea. Multibeam acoustic surveys were used to generate large-scale geomorphic classification maps that were superimposed over the study area. Forty towed-video stations were deployed across the area capturing 32 h of seabed video, 6229 still photographs, that generated 3413 seabed characterisations of physical and biological variables. In addition, sediment and biological samples were collected from 36 stations across the area. The northern Lord Howe Rise was characterised by diverse but sparsely distributed faunas for both the vast soft-sediment environments as well as the discrete rock outcrops. Substratum type and depth were the main variables correlated with benthic assemblage composition. Soft-sediments were characterised by low to moderate levels of bioturbation, while rocky outcrops supported diverse but sparse assemblages of suspension feeding invertebrates, such as cold-water corals and sponges which in turn supported epifauna, dominated by ophiuroids and crinoids. While deep environments of the LHR flank and lower slopes of the Gifford Guyot were characterised by bioturbation with high occurrences of trails, burrows, and mounds, evidence for bioturbation was significantly less on the upper sections of Gifford Guyot, with mostly trails on the more sediment starved environments. The seamount summit also supported a variety of taxa, such as benthic ctenophores and rock-associated fishes that were not recorded in the deeper basin habitats. Physical characteristics of the seabed, particularly geomorphology, were good predictors of biological assemblage composition and percent cover of key taxa. Of the nine geomorphic classes assessed in this study, six predicted different physical habitats that supported distinct biological assemblages. However, other classes that were defined by spatial features (e.g., valleys, seamount dunes) where surficial physical variables were not unique, provided little predictive power of biological assemblages, but rather had characteristics that were shared with adjacent/surrounding geomorphic classes. Given the growing need to use surrogates in the management and conservation of marine environments, these results are promising. However, our findings suggest that there is a pressing need for careful testing and validation of surrogates, such as geomorphic classes, before classification schemes can be deemed effective and employed as a management tool to predict seabed habitats and their biological assemblages.

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1. Introduction

The physical structure and composition of the seabed plays a critical role in the distribution and abundance of benthic assemblages.

A wide range of physical variables are known to be important factors driving biological assemblage structure and species distributions (McArthur et al., 2010). For example, substrata type and complexity, topographic relief, sediment composition, and geomorphology of the seabed have all been identified as important descriptors of biological pattern (e.g., Jennings et al., 1996; Curley et al., 2002; Thrush et al., 2005; Anderson et al., 2009). Fine-scale bio-physical studies provide a critical understanding of these

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relationships, but the cost of biological sampling over large spatial extents is prohibitive, while direct extrapolation of fine-scale biological patterns over large management scales rarely captures the spatial complexity of these systems. Advances in acoustic technologies, such as multibeam and sidescan sonar, now mean that large areas of the deep seabed can be mapped quickly (on the order of $\sim 1000 \text{ km}^2$ per day at 1500 m depth) at high resolution ($\sim 30 \text{ m}$ pixel) providing seabed maps that capture much of the physical complexity of the seabed (Gardner et al., 2003; Brown and Blondel, 2009). Where strong and predictable relationships exist between the physical structure of the seabed and the organisms that occur there, broad-scale ($\sim 100 \text{ km}$ length scale) seabed maps or classifications may provide a valuable surrogacy tool for predicting large-scale occurrence, distribution, and abundance of marine organisms.

Classification of physical variables into seabed maps in the form of polygons, or surrogate classes (e.g., seascape, geomorphic, or habitat classes) is often used to infer biological patterns, and has been put forward as a potentially important management and conservation tool (e.g., Harris et al., 2005; Last et al., 2010; Anderson and Yoklavich, 2007). Given the increasing availability of habitat maps and the potential ability for habitat surrogates to be applied to management and conservation strategies, such as the designation of Marine Protected Areas (MPAs), it is necessary to examine and test the ability of surrogates to accurately predict biological pattern. An effective surrogate must be robust enough to take into account sources of mapping and biological uncertainty. For example, if a surrogate corresponds to the true habitat feature that the organism responds and orientates to (1:1 relationship), then it is likely to be a strong predictor in novel situations. Alternatively, a surrogate may implicitly, by virtue of its class definition, contain key finer scale habitat heterogeneity that, while unresolved at the map scale, still result in good predictive ability. Here, organisms may respond to finer-scale habitat heterogeneity and landscape features (e.g., edges), but these finer-scale habitat characteristics occur solely within a particular classification type. Regardless of the way in which a seabed class functions as a predictor, careful testing and validation are required before a classification scheme is deemed effective and employed as a management tool to predict seabed habitats and their biological assemblages.

Mapping the physical structure and composition of the seabed in shallow coastal environments has considerably advanced our understanding and management of these environments (e.g., Yoklavich et al., 2002; Ratray et al., 2009). Similar habitat mapping in deep-sea environments has received considerably less effort, largely due to the prohibitive costs associated with working in these remote environments. Consequently, mapping deep-sea environments and their biological assemblages and assessing the utility of physical surrogates has rarely been undertaken. Deep-sea benthic environments were once thought to be comparatively stable, comprising mostly homogeneous soft-sediments. But more recently the deep-sea benthos has been found to support high biodiversity (Dayton and Hessler 1972; Levin et al., 2001) and to be more dynamic and patchy than previously thought (Ruhl, 2008). Some have suggested that the biodiversity of some abyssal habitats may be comparable to tropical coral reefs (Grassle and Maciolek, 1992), although these patterns might be a function of low sampling effort over much vaster areas in the deep sea (Gray et al., 1997; Roberts et al., 2006). Geophysical studies of deep-sea environments have catalogued an assortment of geomorphic features including both physically complex raised features such as seamounts, banks, ridges and hydrothermal vents, as well as more expansive subdued features such as basins, valleys and abyssal plains (Heap and Harris, 2008). Biological studies have focused on features of particular interest such as seamounts and hydrothermal vents, reporting these features as biodiversity hotspots (Clark et al., 2006; Samadi et al.,

2006; McClain, 2007). However, a lack of comparable studies on other deep-sea geomorphic features with similar/dissimilar substrata means there is inadequate information to provide a general view of the relationship between different geomorphic features and their biological assemblages (Przeslawski et al., 2011).

Cold water corals and sponges are important faunas of seamounts that are also found in other deep-sea systems, although information on the biology and distribution of deep-water sessile organisms is scarce (Stocks, 2004). Sessile suspension feeding faunas are often highly diverse in water depths of 200–1000 m, with some taxa occurring to depths of 4000 m (Freiwald et al., 2004). Many species of cold-water corals and sponges have emergent growth forms that provide food and shelter to other species (Beaulieu, 2001; Etnoyer and Morgan, 2005; Clark et al., 2006), and make them important habitat-formers that increase the habitat complexity of the benthos. Cold-water corals and sponges often have slow growth rates, fragile structures, and long lives compared to their shallow-water counterparts (e.g., bamboo coral in Andrews et al., 2009; Roark et al., 2009). As such, cold-water corals and sponges are particularly vulnerable to disturbance (Heifetz et al. 2009), with strong negative impacts of bottom trawling on cold-water-coral ecosystems found to last over a decade (Althaus et al., 2009). Changes in ocean circulation and acidification associated with climate change are also expected to affect growth and recruitment rates of cold-water-coral communities (Poloczanska et al., 2007). Consequently, there is strong management interest in the effects of human activities, such as coral harvesting, fishing and oil exploration, on these long-lived and fragile deep-sea organisms (e.g., Clark et al., 2006; Althaus et al., 2009).

Linking biological surveys with seabed maps provides a means to examine the feasibility of using physical habitat surrogates to predict biological assemblages. Video and camera surveys can traverse a broad range of deep topographic features over hard and soft substratum habitats to explicitly compare biological and physical patterns in the deep sea (Solan et al., 2003). Additionally, biological equipment, such as grabs, dredges and benthic trawls can also be deployed in a range of deep environments to provide fine-scale taxonomic resolution. Complementary video and camera surveys and *in situ* biological seabed sampling, when combined with physical data and maps, can provide comparative and detailed information on the distribution, abundance and spatial composition of benthic habitats and marine fauna and determine whether surrogates are effective predictors of biological pattern. In this study, we mapped the physical and biological environments of a 27,500 km^2 area in the northern section of the Lord Howe Rise (LHR) and examined the degree to which physical parameters of the seabed can be used to validate broad-scale geomorphic classifications and predict the composition of biological assemblages in these deep sea systems. Specifically, we measure the percent cover and presence of biological taxa from towed-video footage as a function of bathymetry, substratum hardness (backscatter), substratum type, habitat patchiness, and fine-scale geomorphology and relief. Biological epifauna and infauna were collected across the survey region to provide finer levels of taxonomic information and species-habitat associations. These data are then used to evaluate the viability of geomorphic surrogates in predicting biologically distinct assemblages in the deep sea.

2. Materials and methods

2.1. Study area

An area of $\sim 27,500 \text{ km}^2$ divided across two sections was surveyed on the northern part of the Lord Howe Rise plateau in

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