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Response of megabenthic assemblages to different scales of habitat heterogeneity on the Mauritanian slope

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ABSTRACT

The topographically complex deep seabed on the Mauritanian slope, from 990 to 1460 m water depth, was imaged with video in an extensive quantitative survey of 17,199 m^2 of seafloor using a Remote Operated Vehicle (ROV). This study investigated the influence of habitat heterogeneity at two scales on the megafaunal assemblages observed by ROV. Changes in megafaunal assemblages on the Mauritanian slope were assessed at a broad scale, within depth zones, and at a finer scale, in response to changes in local geomorphology associated with submarine landslides. Geomorphology was determined by classification of habitat parameters (slope, aspect, bathymetric position, curvature, fractal dimension and ruggedness) derived from an autonomous underwater vehicle-based multibeam bathymetry survey. Habitat parameters were classified by Iterative Self Organizing Clustering into six major geomorphological groups, four of which were assessed in the ROV video survey. A total of 29 megafaunal taxa were observed along the entire survey, with an overall average faunal density of 0.344 ind m^{-2}. Megafaunal assemblage density, species richness and evenness varied significantly across the depth range of the survey in the most common geomorphological zone (sedimentary plains of low slope and complexity). Characteristic species inhabited the shallow areas (asteroid, ophiuroid, anemone, small macrourid), intermediate areas (*Benthothuria funabris*, black ceríanthid, squat lobster) and deeper areas (the holothurians *Enypniastes eximia* and *Elipidia echinata*). Megafaunal density, species richness and evenness were not significantly different between geomorphogical groups within one depth zone (1300–1400 m). However, the steepest zone, on the edge of a major headwall feature, had four unique taxa (*Parapagurus pilosimanus*, a comatulid crinoid, a gorgonian and its associated ophiuroid).

1. Introduction

Habitat heterogeneity at local scales is a pervasive feature of bathyal continental margins and exerts a fundamental influence on the diversity and structure of benthic communities (Levin and Dayton, 2009). Broad-scale geological processes are important controlling mechanisms for benthic community structure (Carney, 2005), for example, creating fluid flow to the seafloor. Less is known about the role of large mass movements in creating habitat of high structural complexity in otherwise less complex soft-sediment regions. Many studies show habitat related controls on the distributions of benthic fauna, particularly in shallow waters (e.g., Kaiser et al., 2005). In the deep sea there is less information, although the association of megafauna with specific habitat types is revealed by very fine-scale patterns in sediment type (Auster et al., 1995), mid-scale associations with specific habitats (Dolan et al., 2008) to the broad-scale regional patterns (Bryan and Metaxas, 2006; Williams et al., 2010). At the broad scale, physical factors such as those associated with depth (Jones et al., 2007a) and water mass properties (Mortensen and Buhl-Mortensen, 2004; Williams et al., 2010) tend to become more important in describing patterns of benthic fauna (Levin et al., 2001).

Habitat heterogeneity on the West African continental margin has been increased by regional-scale submarine sliding (Wynn et al., 2000). Evidence of submarine slides off Mauritania is apparent along much of the slope, the most well known feature being the Mauritania Slide Complex which covers an area of 30,000 km^2 between 800 and 2000 m depth (Henrich et al., 2008; Krastel et al., 2006). This feature involved a multiphase submarine slide, which occurred ~10.5 ka ago and was followed by retrogressive failure that created a series of stepped headwalls upslope before being halted at around 700 m by a linear carbonate mound (Colman et al., 2005). The latest events are debris flow tongues dated at 10.5 ka (Förster et al., 2010). The Mauritanian Slide Complex has produced varied deep-water topography and exposed several stratigraphic units along the sliding

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planes (Fig. 3 in Henrich et al., 2008), breaking the deep-sea slope habitat into areas of low relief interspersed with high relief and differing geology. The changes in seabed topography brought about by the sliding processes may give rise to changes in benthic communities, as has been observed on breaks and escarpments elsewhere in the Atlantic (Mortensen et al., 2001). The effects of changes in habitat heterogeneity associated with major submarine landslides on deep-water biology are unknown, despite these features being ubiquitous along the world's continental margins (Masson et al., 2010) and particularly extensive in west Africa (Krastel et al., 2011).

Deep-sea megabenthic ecology has traditionally been reliant on semi-quantitative sampling with trawls and sledges (Thurston et al., 1994). More recent advances have used imaging methods to obtain quantitative data (Jones et al., 2007b). However, it has not been possible, in most cases, to obtain accurate spatial positional information of individual organisms or even communities on the seafloor (Dolan et al., 2008). Advances in detailed navigation technology and their application to deep-sea studies (Barry and Baxter, 1992), coupled with the increasing availability of high-resolution, spatially-accurate acoustic data on submarine topography and sediment properties, is now making it possible to link fine-scale patterns in biology to the broad-scale patterns in habitat type and subsea landscape. Given the sheer size and difficulties of accessing the deep-sea environment, accurate extrapolation of the fine-scale observations using information on the important physical controls for distribution is vital to describe the important broad-scale patterns in benthic biology.

This paper is the first study that investigates the variation in benthic megafaunal assemblages across a major submarine landslide. Quantitative remotely operated vehicle (ROV) imaging is used to assess the changes in megabenthic assemblages in response to changes in habitat at two scales. First, we assess broad-scale patterns in megafaunal assemblages within depth bands. We then explore patterns within a depth band at a fine-scale by assessing the response of megafaunal assemblages to surficial geomorphology, classified from a range of habitat variables. Megafaunal assemblages will be linked to specific geological units exposed by multiphase sliding events off Mauritania. As these huge slide events affected large sections of the Mauritanian slope, with similar units exposed at similar depths, this may enable extrapolation of the information on local benthic megafaunal assemblages collected here to a larger proportion of the Mauritanian slope.

2. Methods

2.1. Study site

This work was conducted as part of an environmental survey of the TIOF field, Mauritania (17°55′ N 16°53′ W). It covers an area of around 54 km^2 of seabed at a depth of 900–1500 m. One exploration well had been drilled in the area (location 17° 56′ 17.677″ N 16° 52′ 3.078″ W). The ROV passed this site during this survey, but all video data from within 500 m of the previously drilled site were excluded from analysis. This was done to ensure that any effects of seabed disturbance did not confound the analysis.

The Mauritanian margin has high primary productivity, caused by continuous trade-wind-driven oceanic upwelling. The high productivity is concentrated in surface waters above the outer shelf and shelf edge (van Camp et al., 1991) but offshore advection means that much of the biogenic detritus is deposited on the upper- and mid-slope at water depths of ~1000–1500 m (Fütterer, 1983; Henrich et al., 2010). The high productivity off north-west Africa leads to substantially denser and more diverse deep-water benthic communities (Thurston et al., 1998). This is consistent with the high diversity of fish caught in trawl samples off Mauritania (Merrett and Marshall, 1981).

The Mauritania Slide Complex was discovered by Seibold and Hinz (1974) and subsequently mapped and described by Jacobi (1976), who estimated the area of seafloor affected by the mass movement to be in the order of 34,300 km^2, and the total volume of excavated material to be about 400 km^3. Recent data confirm these early estimates, indicating that the total area affected by the slide is about 30,000 ± 4000 km^2 (Henrich et al., 2008). Seismic profiles of the Mauritania Slide Complex, taken ~70 km south of the study site, reveal the headwall area is characterised by three distinct morphological steps each up to 75 m high between 800 and 1300 m water depth (Henrich et al., 2008). The headwalls cut well-stratified slope sediments. Relatively thin (< 30 m) blocky deposits dominate the area immediately downslope of the headwall area to ~2000 m water depth. Here, a reduction in slope angle to ~1° corresponds to a major change in depositional pattern, with stacked tongue-shaped acoustically transparent debris flow deposits occurring below the break in slope (Henrich et al., 2008). The morphology to the north-east of the sidewall is highly complex with several canyons and large distinct blocks (Henrich et al., 2008).

Several biological studies focus on the deep-water demersal and benthic megafaunal assemblages off the north-west African continental slope and abyss, including off Mauritania (Duineveld et al., 1993a; Duineveld et al., 1993b; Galeron et al., 2000; Henriques et al., 2002; Keller and Pasternak, 2002; Merrett and Domanski, 1985; Merrett and Marshall, 1981; Pfannkuche et al., 1983; Sibuet et al., 1993), the Canaries (Uiblein et al., 1996), the Meteor Seamounts (Fock et al., 2002; Piepenburg and Muller, 2004; Uiblein et al., 1999) and Mid-Atlantic Ridge and Azores (Bergstad et al., 2008a; Bergstad et al., 2008b; Gebruk et al., 2010; Moss, 1992). These studies show a generally diverse and abundant deep-water fauna, but with high variability between sites and depths studied.

2.2. Broad-scale habitat classification

Bathymetric data were obtained from a commercial survey of the area (Woodside Petroleum) using the World Geodetic System '84 reference datum. The 200 kHz multibeam bathymetry data were collected using a Kongsberg Maritime *Hugin* 3000 Autonomous Underwater Vehicle (AUV) operated by C & C Technologies, Inc. AUV positioning was achieved by Kongsberg "High Precision Acoustic Positioning System" ultra-short baseline navigation system, an inertial navigation system and Doppler velocity log integrated in a Kalman filter. Data were provided for this study by Woodside Petroleum, post-processed and gridded to 90 m spacing. The Mauritanian slope was divided by depth into polygons representing 100 m depth bands using ArcGIS.

2.3. Fine-scale geomorphological classification

Fine-scale classification of geomorphology was based on six primary derivatives of the bathymetry dataset (slope, aspect, bathymetric position, curvature, fractal dimension and ruggedness). These were then combined using Iterative Self Organizing (ISO) clustering into a single geomorphological classification.

2.3.1. Bathymetry derivatives

Slope, or the measure of steepness (a first-order derivative), was derived using the ArcGIS Spatial analyst extension's surface analysis. Aspect, or orientation of benthic habitat, is relevant to