Deep-Sea Research I 80 (2013) 66–77

Contents lists available at SciVerse ScienceDirect

Deep-Sea Research I

journal homepage: www.elsevier.com/locate/dsri

Complex depth-related patterns in taxonomic and functional diversity of polychaetes in the Gulf of Mexico

Russell Carvalho [a,*], Chih-Lin Wei [b], Gilbert Rowe [a,c], Anja Schulze [a,c]

[a] Department of Oceanography, Texas A&M University, College Station, TX 77843, USA
[b] Ocean Science Centre, Memorial University of Newfoundland, St. John's, Canada NL A1C 5S7
[c] Department of Marine Biology, Texas A&M University at Galveston, Galveston, TX 77553, USA

ARTICLE INFO

Article history:
Received 3 October 2012
Received in revised form
28 June 2013
Accepted 3 July 2013
Available online 10 July 2013

Keywords:
Gulf of Mexico
Deep-sea
Community structure
Functional diversity
Polychaete
Feeding guilds
Benthic communities

ABSTRACT

Patterns of taxonomic and functional diversity in polychaete assemblages were examined in the deep northern Gulf of Mexico, including the first analysis of polychaete feeding guild distribution. An analysis of samples from a total of 51 stations located along 7 transects plus additional nearby sites, indicated that density decreased exponentially with depth, with the central locations having higher densities than the eastern and western regions. Alpha diversity was also highest at the central stations associated with the Mississippi trough. The samples can be grouped into three significant clusters based on thirty percent similarity of species composition. BIO-ENV indicated depth, sediment particle size, and export POC were most important variables explaining distributions. The diversity of polychaete feeding guilds was high in the Mississippi trough, upper and mid-slope regions but declined to a few guilds on the Sigsbee abyssal plain. Combining feeding guild analysis with traditional analysis of species diversity contributes to a clearer understanding of trophic diversity in deep-sea benthic assemblages.

1. Introduction

Observing broad-scale patterns of macrobenthic biodiversity is an important aspect of many deep-sea studies. The 'classic' phenomenon of a parabolic curve with a mid-depth maximum (MDM) of species diversity has been reported in numerous deep-sea studies. Cosson-Sarradin et al. (1998) studied total macrofauna in the northeast Atlantic and observed a parabolic trend in the diversity of polychaetes, representatives of a dominant taxon in that region. Deep-sea species diversity typically peaks at mid-slope depths between 2000 m and 3000 m for regions of the western North Atlantic (Rex, 1983; Rex et al., 1993). Similar parabolic patterns of diversity were observed during a series of intense deep-sea sampling programs in the Atlantic (Paterson and Lambshead, 1995; Flach and de Bruin, 1999; Gage et al., 2000), as well as the Eastern Pacific and Indian Oceans (Levin and Gage, 1998). Pequegnat et al. (1990) focused on patterns of macrofaunal diversity in the Gulf of Mexico (GoM) and observed uniformly high polychaete species diversity (55 species per station) up to a depth of 1465 m, with a subsequent decrease (22 species per station) at 3000 m. Their results revealed a decrease in macrofaunal diversity from the east to the west, with the absence of a parabolic diversity trend. They concluded that diversity patterns are primarily the result of seasonal and regional variations. Pérez-Mendoza et al. (2003) sampled 10 stations along a bathymetric gradient (200–3760 m) in the Sigsbee basin and reported an atypical inverted parabolic curve for abyssal polychaetes in the GoM. These results suggest that the unique hydrodynamics and the geomorphology of the GoM play an important role in shaping the observed patterns in species diversity.

Riverine input into the GoM is extensive. It includes 20 major river systems (> 150 rivers) along the coast of the United States, Mexico and Cuba (Moody, 1967). The Mississippi discharges on an average 21,700 m^3 per second of fresh water into the Gulf, with an average nitrogen influx of 1,470,000 and total phosphorus influx of 140,000 metric tons (Aulenbach et al., 2007). This nutrient loading from the Mississippi has caused an increase of inorganic N and P for the past 50 years, resulting in high productivity (Rabalais et al., 2002) that may directly or indirectly influence the diversity and functioning of benthic communities, especially in the deep sea (Snelgrove et al., 1992).

Haedrich et al. (2008) mapped species richness for various taxa in the GoM using a generalized linear model (GLM). Polychaete richness was highly correlated to food, suggesting that the observed patterns were primarily due to levels of productivity in the GoM. The quality, quantity and the timing of organic input to the deep-sea benthos are key factors that influence the benthic

* Corresponding author. Tel.: +1 409 4546417.
E-mail addresses: russell_carvalho@yahoo.com, russell64@tamu.edu (R. Carvalho).

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http://dx.doi.org/10.1016/j.dsr.2013.07.002

polychaete community structure (Cosson et al., 1997; Shields and Hughes, 2009). Using sea-surface chlorophyll (SSC) data, Biggs et al. (2008) estimated export POC (particulate organic carbon) flux at 49 sampling sites of the Deep Gulf of Mexico Benthos program (DGoMB). They suggested that cross-margin flows generated by mesoscale eddies move low salinity high-chlorophyll Mississippi water offshore, ultimately leading to a higher POC input to the benthos in the Northeast GoM. Similarly, Wei et al. (2010a) reported food availability as a controlling factor for macrofaunal depth zonation in the GoM. Morse and Beazley (2008) highlighted strong correlations between organic carbon contents in the deep-water sediments and the abundance and biomass of macrofauna and meiofauna. These studies warrant a comprehensive examination of the role of food input in shaping the patterns of polychaete diversity in the GoM.

Polychaetes play a significant role in ecosystem function (Pagliosa, 2005; Bremner, 2008; Wagner and Barros, 2011). Dominant in terms of both abundance and species number, this taxon is widely used to assess community patterns and species richness estimates of macrofaunal benthic assemblages (Olsgard and Somerfield, 2000). Their diverse functional traits provide clues to ecological processes in deep-sea benthic environments and can be used for deciphering species diversity patterns (Pagliosa, 2005; Pacheco et al., 2011). The feeding guild concept of Fauchald and Jumars (1979) classified polychaetes into trophic groups based on morphology and their inferred feeding behavior. This pioneering effort was followed by a series of studies that utilized feeding guilds, most recently to investigate the reoxygenation and colonization potential of deep-burrowing polychaetes (Granberg et al., 2008), to interpret assemblage patterns (Domínguez-Castanedo et al., 2012; Wagner and Barros, 2011), to assess environmental conditions (Pagliosa, 2005), and to study the impacts of seafloor hydrodynamics on benthic fauna (Dolbeth et al., 2009). A traditional Linnean classification system may not always be adequate for describing the biodiversity, health and functioning of the deep marine realm (Warwick and Somerfield, 2008). Instead, taxon-specific functional traits are more useful in providing vital clues to ecosystem function (Woodin, 1987; Aarnio et al., 2011; Wagner and Barros, 2011) as well as modeling the flow of energy and matter through benthic systems (Christensen and Pauly, 1993; Pacheco et al., 2011).

Our aims in this study were (1) to re-assess large-scale trends in the composition and density of deep-sea benthic polychaete communities on the northern continental slope of the GoM, and (2) to test potential factors responsible for the observed patterns of distribution and their occurrence. We hypothesize that depth-related trends in feeding guild diversity are distinct from those in taxonomic diversity. Additionally, we predict that the magnitude of food input is the most important factor in shaping the taxonomic and functional diversity of deep-sea organisms.

2. Materials and methods

2.1. Study site

Extensive sampling of the sea floor in the deep waters of the Northern GoM was carried out between 2000 and 2002 during three cruises of the Deep Gulf of Mexico Benthos Program (DGoMB). Surveying a broad region of the northern Gulf, this study examined the community structure and function of the biota of the GoM. Stations sampled ranged from 22°–30°N latitude to 85°E–96°W longitude at a depth range of 200–3700 m (Fig. 1; Table S1).

2.2. Sampling methods

Samples were collected from 51 stations on the R/V *Gyre*. Macrofaunal specimens were collected using a 0.2-m^2 version GOMEX boxcore (Boland and Rowe, 1991). The boxcore collected at least 5 replicate cores per station. Sediment from the top 15 cm (covering an area of 1.725 m^2) was sieved at 300-μm mesh size, fixed in 10% seawater-buffered formalin and stored in 70% ethanol for permanent preservation. Polychaete feeding guilds were classified according to Fauchald and Jumars (1979). Only those samples that could be identified to species level (in some cases tentatively) were included in our analyses. The feeding guilds are a three-letter code, the first letter indicating the major feeding mode

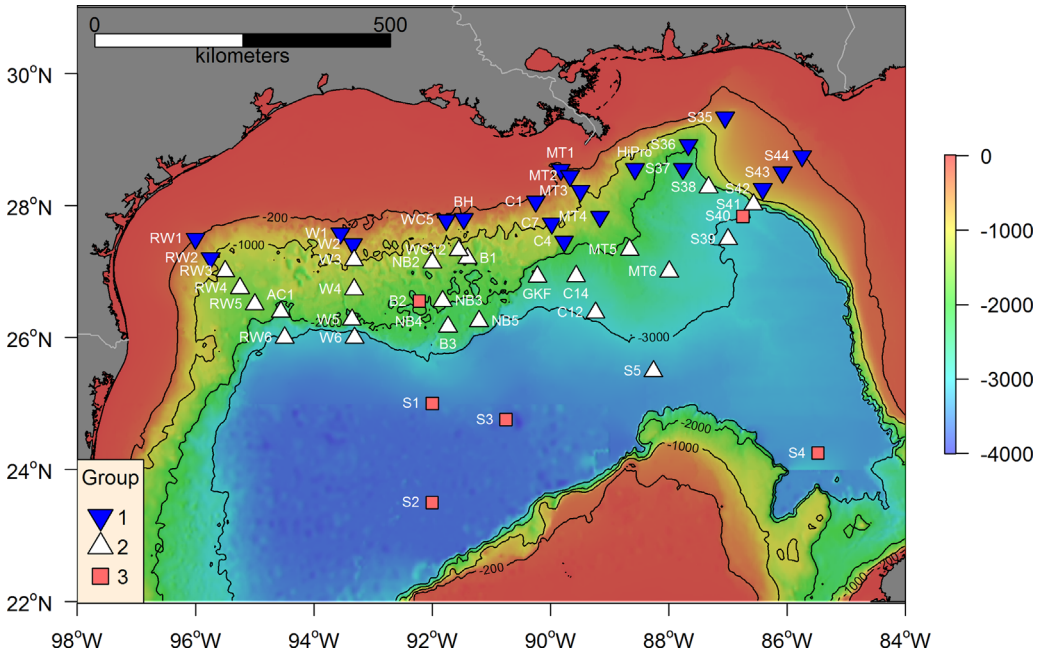

Fig. 1. Sampling stations for DGoMB cruises in the Gulf of Mexico. Symbols indicate significant faunal group ($p < 0.01$).