1.3.7 Data Gaps for the Benthos of the Deep-Sea Gulf of Mexico

P. Montagna

Harte Research Institute for Gulf of Mexico Studies, Texas A&M University-Corpus Christi

1.3.7.1 Abstract

Performing research on the deep-sea benthos is difficult and expensive, because it requires larger sea-going research vessels and heavy equipment to sample the bottom. Also, deep sea habitats are large, covering greater than 66% of the Earth's surface. The result is that only a tiny fraction of the deep sea has ever been sampled, and there are many data gaps. However, two gaps are critical because there is a lack of understanding of temporal dynamics, and taxonomy of deep-sea organisms. While past dogma suggested that the deep sea was stable, the influence of the Mississippi River on sediment and particulate flux, which can drive benthic dynamics, indicates there is likely temporal variability in the GOM. Two historical benthic data sets were combined to create a 13-year time series, and there was year-to-year variability in meiofauna and macrofauna abundances in the GOM deep sea. Community structure is the most fundamental piece of information about any ecosystem, yet there is a profound lack of knowledge about the species diversity of the GOM, particularly for small benthic infauna. Often, only 25% to 40% of taxa in a sample can be named. Ironically, research is racing ahead to identify environmental DNA in water and sediment samples using metagenomic and barcoding techniques, even though we don't know what is there. Thus, we are vastly underestimating the biodiversity of the Gulf and need increased effort in identifying and cataloging the species found.

1.3.7.2 Introduction

The deep sea benthic habitat is large, but the most efficient way to sample it is to drop a box core, grab, or multicore device from a ship. This sampling constraint confers two implications: the limitation of sampling devices means that we have sampled only a tiny fraction of the deep sea, and the high costs of ships means that it is expensive and difficult to obtain samples. Consequently, we know very little about deep-sea benthic habitats, even though they are the largest on Earth, because they are relatively inaccessible. The GOM deep sea benthic environment is especially interesting because it is a complex, heterogeneous environment where sediment transported by the Mississippi River dominates (Balsam and Beeson 2003). Soft-bottom sediments and communities are the dominant habitat on shelves and in the deep-sea, but there are some salt domes (or salt diapirs, which are emergent structures) that play a role in supporting hard-bottom communities (Love et al. 2013; Rezak et al. 1985). The hard substrate (including artificial reefs, oil and gas platforms, and natural reef or rock substrates) can act as fish habitat in the United States Exclusive Economic Zone of the GOM and accounts for about 4% of the total area of the bottom (Froeschke and Dale 2012), which implies that 96% of the Gulf is soft-bottom habitat. So, while it would be expected that there are many data gaps, the focus here is on two: temporal dynamics and taxonomy.

1.3.7.3 Temporal Change

The deep sea is uniformly dark and cold (4–5 °C) and relatively isolated from the surface water column. Thus, the dogma of deep-sea research is that the deep sea is a constant, invariant environment. This led Howard Sanders (1968) to propose the stability-time hypothesis to explain the high diversity found in deep-sea environments. Though the stability-time hypothesis does not adequately explain all deep-sea diversity patterns, the idea that the deep sea is generally more stable than shallow-water systems over time has persisted. The deep sea is thought to be a stable environment with less frequent changes in physical and chemical conditions compared to shallow, coastal habitats.

More recently, it has been discovered that pulsed events can drive deep-sea dynamics (Smith 1994). These kinds of events include biogenic mound building, benthic storms, phytodetritus pulses, and whale falls. In the GOM, the influence of the variability of the Mississippi River provides a plausible mechanism for both seasonal and year-to-year changes over time.

In addition, there are at least two datasets, with at least three years of data each, indicating that deep sea stability may not be true in the GOM. The Deep Gulf of Mexico Benthic Program (DGoMB) provides a case study (Rowe and Kennicutt 2008, 2009). A total of 43 stations were sampled during the first cruise (May–June 2000), seven stations were reoccupied during the second cruise (June 2001), and during the third cruise (June 2002), two stations were reoccupied, and five stations were sampled in the abyssal plain. Seven stations (C7, MT1, MT3, MT6, S36, S41, S42) were sampled twice (in 2000 and 2001), and one station (MT3) was sampled three times. Using just the two years where seven stations were sampled, provides a simple two-way analysis of variance (ANOVA). One important finding is that there are differences in meiofauna ($p = 0.0034$) and macrofauna ($p = 0.0085$) total abundance between the two years, but there is no significant "cruise-station" interaction, meaning that change across the area happened in similar ways at all stations. During the DWH Natural Resource Damage Assessment (NRDA), 34 stations were sampled during the fall 2010, spring 2011, and spring 2014 cruises (Reuscher et al. 2017). Differences in abundance were found for macrofauna ($p = 0.0042$), but not for meiofauna ($p = 0.5797$). One NRDA station (FFMT3) was the same as DGoMB station MT3 that was sampled twice. A plot of macrofauna and meiofauna abundance indicates change over time (Figure 42). These results indicate that there is year-to-year variability in the GOM deep sea.

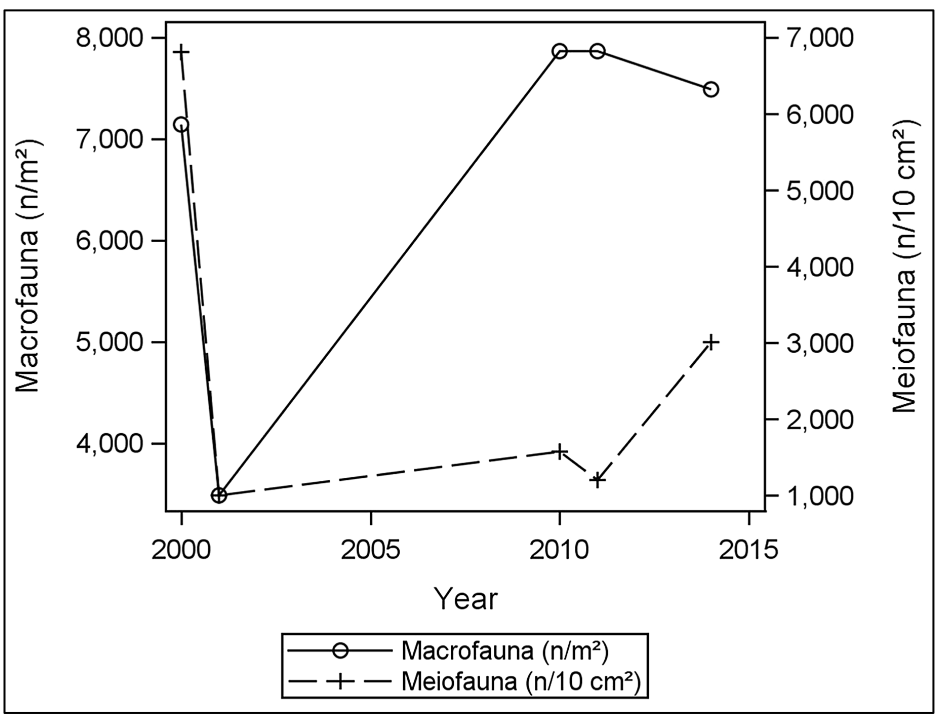

Figure 42. Macrofauna and meiofauna average abundance at station MT3 (same as FFMT3).
Location 28.218692 N, -89.491714 W, 1,002 m depth. Source: P. Montagna.

These time series studies illustrate an important point: the deep sea is not static, and any sampling program must be able to distinguish natural year-to-year variability from changes due to other events, such as oil spills. Temporal variability in benthic abundance also occurred over a nine-year period in the deep sea of the northeast Atlantic Ocean, and it is thought to be a result of interannual differences in food supply (Soto et al. 2010). In addition, the cruises in the NRDA study were deployed in fall and spring, so there is also the possibility that the NRDA study results are due to seasonal variability and not just year-to-year variability, because we really don't know if there is seasonality in benthic community composition in the GOM.

It is reasonable to hypothesize that both seasonal and year-to-year variability exists in GOM benthic communities. Seasonality could be driven by discharge from the Mississippi River, which is higher in spring than at other times of the year. The surface waters have supplies of nutrients in spring that could lead to spring blooms and thus greater deposition of organic matter in spring, which would fuel increased benthic metabolism and could change benthic structure and function. The most obvious result of this process is the large hypoxic zone that forms off Louisiana every summer in shallow shelf waters (Rabalais et al. 2002), with interannual differences in the size of the hypoxic zone (Turner et al. 2012). Year-to-year variability could be driven by any one of three phenomena or a combination of all: inter-annual differences in weather that drives runoff and river discharge; interannual variability in the timing, location, and intensity of the Loop Current; and interannual variability in the number, frequency, and strength of tropical storms. We also know that interannual variability in weather is driven by teleconnections of the global climate system because the frequency of El Niño drives increased river flows to the coast in Texas (Tolan 2007), Louisiana (Piazza et al. 2010), and Florida (Beckage et al. 2003). The increases in flow rates likely increases export from the Mississippi River, which can drive oceanic processes in the deep sea. The El Niño and/or La Niña oscillations are known to drive benthic community structure in the northeast Pacific Ocean (Ruhl and Smith 2004).

Because we know little about temporal variability in the GOM deep sea, it is impossible to be certain that we can distinguish change due to natural variability from change due to anthropogenic effects. More study of this phenomenon is needed to complete our understanding of the drivers of living marine resources in the Gulf.

1.3.7.4 Taxonomy

Perhaps the most fundamental piece of knowledge about any ecosystem is: "What is there?" Yet, we have a profound lack of knowledge about the species diversity of the GOM. Of course, the lack of taxonomic information is less true for the large organisms, but the lack of knowledge for the smaller organisms is acute, especially for the deep-sea benthos. There is an important compendium of the biodiversity of the Gulf (Felder and Camp 2009), which spans 1,312 pages and covers all Gulf habitats and taxa. However, Felder and Camp note that taxonomy is a neglected scientific activity that requires renewed priority because of global climate change, declining diversity, exploitation of living marine resources, habitat destruction, and other nonsustainable practices by humans. It is estimated that as much as 80% of the species on earth remain unknown to science, and the problem, of course, is that much biodiversity could be lost before we even know it exists (Costello et al. 2010).

In general, the lack of taxonomic understanding in the GOM is a problem, because species diversity is a very sensitive indicator of change in the deep sea (Montagna et al. 2013; Montagna et al. 2017; Reuscher et al. 2017). Therefore, a lack of knowledge as to what is there impedes our ability to assess the state of the deep sea. This problem is not new and was pointed out previously (Carney 2001). Further, the GOM deep sea is recognized as one of the most threatened on earth because of the cumulative impacts of many variables (Costello et al. 2010).

The DGoMB study (Rowe and Kennicutt 2008, 2009) provides one of the very few large-scale spatial surveys of the GOM deep-sea benthos that are known to species level. A large effort was made to send samples or voucher specimens to taxonomists throughout the world for the many diverse taxa. However, only 40% (207 of 517) of polychaete species and 25% (31 of 124) of amphipod species found in the DGoMB study could be identified to species. Because of the lack of information at the species level, and the large expense to make these identifications, it is often the case that specimens are identified to the lowest taxonomic level possible. For the GOM, this was generally to the family level during the NRDA investigations (Montagna et al. 2013; Montagna et al. 2017; Reuscher et al. 2017). However, the lack of understanding of the diversity of these lesser known families is leading to a vastly underestimated biodiversity of the deep GOM (Reuscher and Shirley 2014).

Though it is well recognized that the gap in biodiversity knowledge is critical, there is no evidence of increased resources to identify and inventory marine biodiversity (Costello et al. 2006). There is a critical need for more taxonomists and species identification guides. These are the most basic requirement for studying biodiversity. In contrast, there is a large new field of genomics, and environmental DNA, such that standard phylogenetic markers are capable of recovering sequences from a broad diversity of eukaryotes and prokaryotes (Drummond et al. 2015). However, a major challenge for gene surveys is the accurate identification of biological taxa across multiple samples, and the ability to quantify the absolute abundance of individuals based on a sequence read (Bik et al. 2012). This leads to two difficult problems: (1) What good is it to know the DNA in two areas is different, but not know why?, and (2) How will we be able to calculate a true diversity index if we don't know the proportional representation of the species present?

1.3.7.5 Conclusions

In summary, there are many data gaps for the deep sea, especially for the deep-sea benthos, including (but not limited to) geographic coverage, understanding variability of sedimentation rates important for controlling food supplies, identifying ecosystem services and values supplied by the deep sea, and rates of geochemical and metabolic processes. While it would be important to examine all the data gaps that exist, here it is argued that the two most critical data gaps are understanding temporal dynamics and increasing the technical capacity to identify species diversity. Based on studies around the world and in the Gulf, it is likely that there is seasonal and interannual variability in the Gulf, which has important implications in an environment threatened by global change and increasing human uses. Thus, understanding the dynamic of temporal change is a key data gap. We also know that we are vastly underestimating the biodiversity of the Gulf and need increased effort in identifying and cataloging species. However, the trend over the last 30 years has been for decreased support for systematics and taxonomy, even though we still don't know what is there. It is important to reverse this trend before we lose things we didn't know we had.

1.3.7.6 References

Balsam WL, Beeson JP. 2003. Sea-floor sediment distribution in the Gulf of Mexico. Deep Sea Research. 50: 1421–1444. http://doi.org/10.1016/j.dsr.2003.06.001.

Beckage B, Platt WJ, Slocum MG, Panko B. 2003. Influence of the El Niño Southern Oscillation on fire regimes in the Florida Everglades. Ecology. 84: 3124–3130.

Bik HM, Porainska DL, Creer S, Caporaso JG, Knight R, Thomas WK. 2012. Sequencing our way towards understanding global eukaryotic biodiversity. Trends in Ecology and Evolution. 27: 233–243.

Carney RS. 2001. Management applicability of contemporary deep-sea ecology and reevaluation of Gulf of Mexico studies. Final Report. OCS Study MMS 2001-095. US Departmen of the Interior, Minerals

Management Service, Gulf of Mexico OCS Region Office, New Orleans, LA. Available at: https://www.boem.gov/ESPIS/3/3146.pdf.

Costello MJ, Bouchet P, Emblow CS, Legakis A. 2006. European marine biodiversity inventory and taxonomic resources: state of the art and gaps in knowledge. Marine Ecology Progress Series. 316: 257–268.

Costello MJ, Coll M, Danovaro R, Halpin P, Ojaveer H, Miloslavich P. 2010. A census of marine biodiversity knowledge, resources, and future challenges. PLoS ONE. 5(8): e12110. doi:10.1371/journal.pone.0012110.

Drummond AJ, Newcomb RD, Buckley TR, Xie D, Dopheide A, Potter BCM, Heled J, Ross HA, Tooman L, Grosser S. 2015. Evaluating a multigene environmental DNA approach for biodiversity assessment. GigaScience. 4(46). doi 10.1186/s13742-015-0086-1.

Felder DL Camp DK (editors). 2009. Gulf of Mexico origin, waters, and biota. Volume 1: biodiversity. College Station (TX): Texas A&M University Press.

Froeschke J, Dale D. 2012. Fixed petroleum platforms and artificial reefs as essential fish habitat. Generic Amendment 4 to the Fishery Management Plans in the Gulf of Mexico. Including Environmental Impact Statement, Fishery Impact Statement, Regulatory Impact Review, and Regulatory Flexibility Act analysis. Publication of the Gulf of Mexico Fishery Management Council, Award No. NA10NMF4410011. National Oceanic and Atmospheric Administration, US Department of Commerce.

Love M, Baldera A, Yeung C, Robbins C. 2013. The Gulf of Mexico ecosystem: a coastal and marine atlas. New Orleans (LA): Ocean Conservancy, Gulf Restoration Center.

Montagna PA, Baguley JG, Cooksey C, Hartwell I, Hyde LJ, Hyland JL, Kalke RD, Kracker LM, Reuscher M, Rhodes ACE. 2013. Deep-sea benthic footprint of the Deepwater Horizon blowout. PLoS ONE. 8(8): e70540. doi:10.1371/journal.pone.0070540.

Montagna PA, Baguley JG, Cooksey C, Hyland JL. 2017. Persistent impacts to the deep soft-bottom benthos one year after the Deepwater Horizon event. Integrated Environmental Assessment and Management. 13:342-351. doi: 10.1002/ieam.1791.

Piazza B, La Peyre M, Keim B. 2010. Relating large-scale climate variability to local species abundance: ENSO forcing and shrimp in Breton Sound, Louisiana, USA. Climate Research. 42(3): 195–207.

Rabalais NN, Turner RE, Wiseman WJ. 2002. Gulf of Mexico hypoxia, aka “The dead zone.” Annual Reviews of Ecology and Systematics. 33: 235–263.

Rezak R, Bright TJ, McGrail DW. 1985. Reefs and banks of the northwestern Gulf of Mexico: their geological, biological and physical dynamics. New York (NY): John Wiley & Sons.

Reuscher MG, Baguley JG, Conrad-Forrest N, Cooksey C, Hyland JL, Lewis C, Montagna PA, Ricker RW, Rohal M, Washburn T. 2017. Temporal patterns of the Deepwater Horizon impacts on the benthic infauna of the northern Gulf of Mexico continental slope. PlosOne. 12(6): e0179923. https://doi.org/10.1371/journal.pone.0179923.

Reucsher MG, Shirley TC. 2014. Diversity, distribution, and zoogeography of benthic polychaetes in the Gulf of Mexico. Marine Biodiversity. 44: 519–532.

Ruhl HA, Smith KL Jr. 2004. Shifts in deep-sea community structure linked to climate and food supply. Science. 305: 513–515.

Rowe GT, Kennicutt II MC (editors). 2008. The Deep Gulf of Mexico Benthos Program. Deep-Sea Research Part II. 55: 24–26.

Rowe GT, Kennicutt II MC, editors. 2009. Northern Gulf of Mexico continental slope habitats and benthic ecology study: Final report. US Deptartment of the Interior, Minerals Management.Service, Gulf of Mexico OCS Region, OCS Study MMS 2009-039. New Orleans, LA. Available at: https://www.boem.gov/ESPIS/4/4842.pdf.

Sanders HL. 1968. Marine benthic diversity: a comparative study. American Naturalist. 102: 243–282.

Smith CR. 1994. Tempo and mode in deep-sea benthic ecology: punctuated equilibrium revisited. Palaios. 9: 3–13.

Soto EH, Paterson GLJ, Billett DSM, Hawkins LE, Galeron J, Sibuet M. 2010. Temporal variability in polychaete assemblages of the abyssal NE Atlantic Ocean. Deep-Sea Research II. 57: 1396–1405.

Tolan JM. 2007. El Niño-Southern Oscillation impacts translated to the watershed scale: estuarine salinity patterns along the Texas Gulf Coast, 1982 to 2004. Estuarine Coastal Shelf Science. 72: 247–260.

Turner RE, Rabalais NN, Justić D. 2012. Predicting summer hypoxia in the northern Gulf of Mexico: redux. Marine Pollution Bulletin. 64: 319–324.