Gulf of Mexico Dead Zone – 1000 Year Record

The Hypoxia Problem

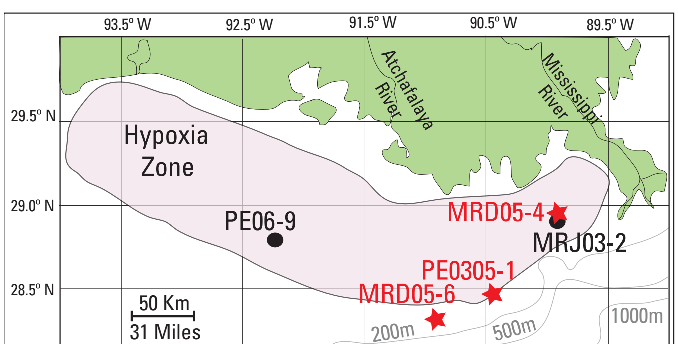
An area of oxygen-depleted bottom- and subsurface-water (hypoxia = dissolved oxygen < 2 mg per Liter) occurs seasonally on the Louisiana shelf near the Mississippi River (Fig. 1). The area of hypoxia, also known as the "dead zone," forms when spring and early summer freshwater flow from the Mississippi River supplies a large amount of nutrients to the shelf while creating a freshwater lens, or cap, above the shelf water. The excess nutrients cause phytoplankton blooms in the shallow shelf water. After the bloom ceases, the organic material sinks in the water column and uses up oxygen during decomposition. Thus, the subsurface waters become oxygen depleted. The seasonal dead zone exists until a reduction in freshwater flow, or overturning by storms, allows mixing of the water column to restore normal oxygen conditions.

Since systematic measurement of the extent of the dead zone was begun in 1985, the overall pattern indicates that the area of the dead zone is increasing (Turner et al., 2005). Several studies have concluded that the expansion of the Louisiana shelf dead zone is related to increased nutrients (primarily nitrogen, but possibly also phosphorous) in the Mississippi River drainage basin and is responsible for the degradation of Gulf of Mexico marine habitats (Goolsby et al., 2001). The goal of this research is to augment information on the recent expansion of Louisiana shelf hypoxia and to investigate the temporal and geographic extent of the low-oxygen bottom-water conditions prior to 1985 in sediment cores collected from the Louisiana shelf (Fig. 1).

We use a specific low-oxygen faunal proxy termed the PEB index based on the cumulative percentage of three foraminifers (= % Protononion atlanticum, + % Epistominella vitrea, + % Buliminella morgani) that has been shown statistically to represent the modern seasonal Louisiana hypoxia zone (Osterman, 2003). Our hypothesis is that the increased relative abundance of PEB species in dated sediment cores accurately tracks past seasonal low-oxygen conditions on the Louisiana shelf.

Anthropogenic Hypoxia

The network of PEB records (Figs. 1, 2) reveals a consistent pattern of increasing PEB from ~1960 to the present over a large portion of the modern dead zone, indicating that low-oxygen conditions developed more frequently from the mid-20th century to the present.



Base map and bathymetry modified from Rabalais et al., 1999

Figure 1. Location of the "dead zone" (Rabalais et al., 1999) and the three box- and gravity-core pairs (stars) and two other box cores (circles) collected on the Louisiana shelf.

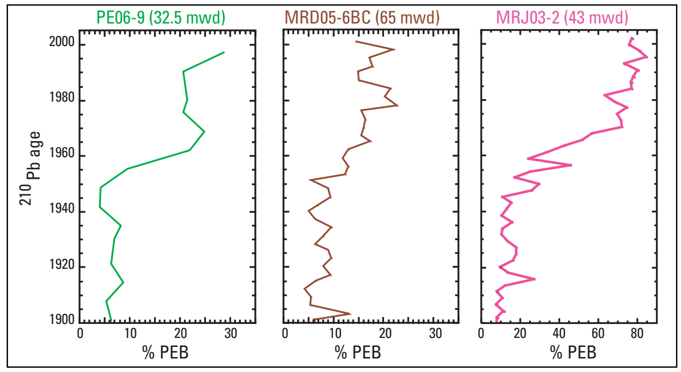


Figure 2. Plots of PEB percent in three ^{210}Pb-dated box cores (mwd = meters water depth). Higher PEB values indicate low-oxygen bottom-water conditions began around 1960 on the Louisiana shelf.

Our results are consistent with the interpretation that the modern increase in hypoxia is related to human activities and indicates that the anthropogenic signal extends back at least to 1960. In addition, our shelf cores provide a means to measure the geographic extent of hypoxia prior to the post-1985 systematic monitoring efforts. Our data indicate that by 1960 subsurface seasonal low-oxygen water was occurring over at least two-thirds of the area of the modern dead zone, as measured since 1985 by Rabalais et al. (1999) (Fig. 1).

Natural Low-Oxygen Bottom Water

Gravity cores MRD05-4, PE0305-1, and MRD05-6 (Figs. 1, 3) represent a three-core transect, from the center to just beyond the seaward edge of the modern dead zone, that can be used to monitor both the geographic extent and frequency of naturally occurring low-oxygen bottom water on the Louisiana shelf prior to 1985. Significant PEB excursions are found at depth in both MRD05-4GC and PE07-1GC. The lower absolute values and the number of data points associated with each PEB peak indicate pre-1900 low-oxygen bottom-water episodes were less frequent or less persistent than modern episodes recorded in the box core.

The distal site, MRD05-6, outside of the modern hypoxic zone did not experience any natural low-oxygen bottom-water conditions during the last ~1000 14C years but does show increased PEB values in the last ~ 50 years. This indicates an anthropogenically caused expansion of low-oxygen conditions to this area of the Louisiana shelf (Osterman et al., 2007)

Conclusions

The elevated PEB values in gravity cores MRD05-4 and PE0305-1 document that bottom water with low dissolved-oxygen content has occurred periodically on the Louisiana continental shelf for at least the last 1000 years. These naturally occurring low-oxygen bottom-water conditions are believed to result from climatically driven

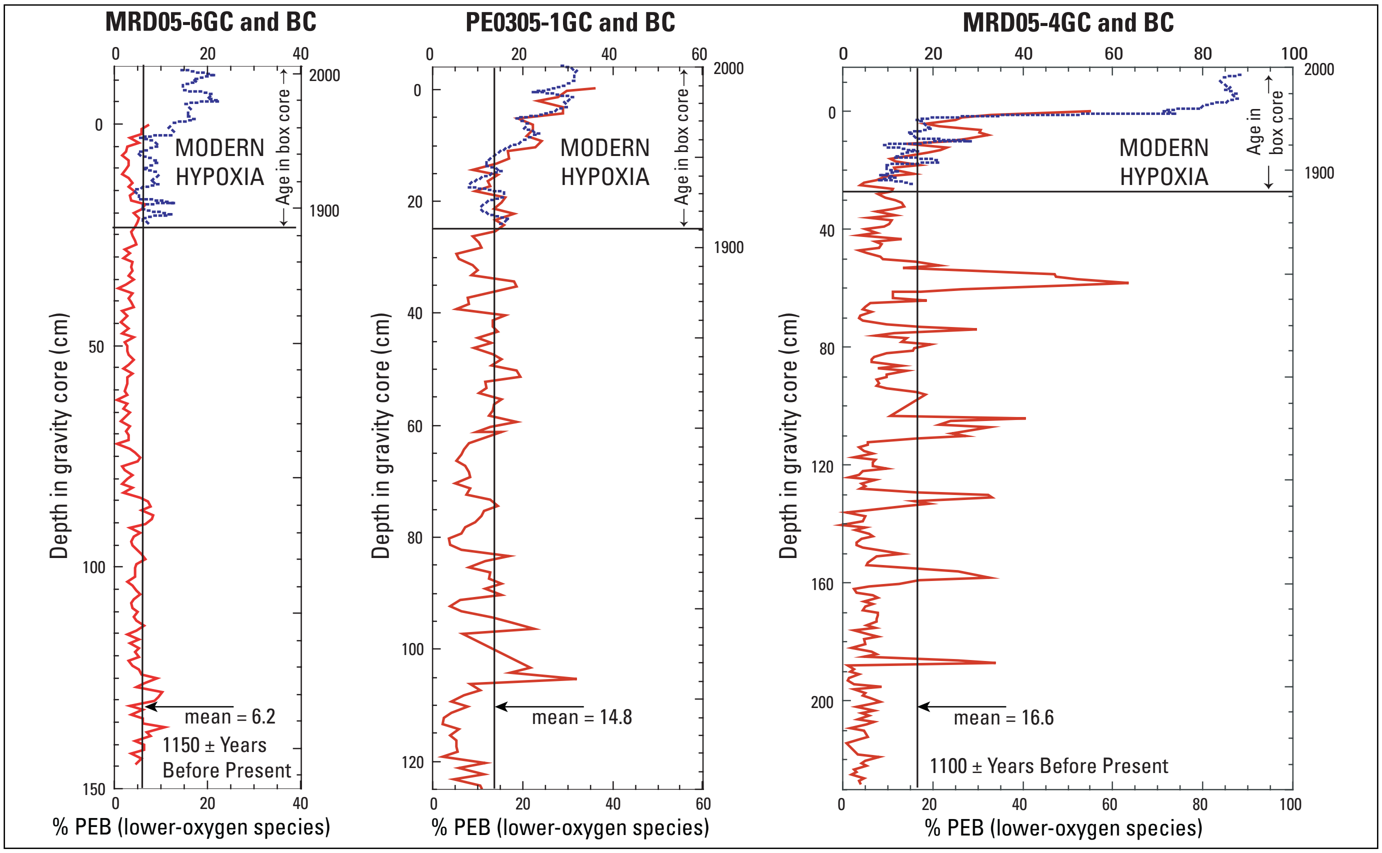


Figure 3. Plots of the PEB percent in three pairs of gravity (in red by depth) and box cores (in blue by age provided by excess ^{210}Pb) (see Figure 1 for location). Both the proximal and intermediate cores record significant PEB excursions at depth within the cores. The distal core only records elevated PEB values in the last 50 years, Basal ^{14}C dates (on foraminifers) are also shown.

decade-long wetter intervals with increased fluvial transport of nutrients and/or organic material. Recently, the geographic extent and frequency of these low-oxygen bottom-water episodes began to change. By 1960, lower-oxygen conditions were experienced along the Louisiana shelf out to the location of PE06-9BC and impacted areas where low-oxygen bottom-water conditions had not occurred during the last 1000 14C years (MRD05-6GC). Recent expansion of the hypoxia zone has been linked to anthropogenic activities and has been systematically measured since 1985 (Turner et al., 2005). Our results allow a better under-standing of the timing and spread of the recent rise in anthropogenic hypoxia before 1985. Low-oxygen bottom water is a natural phenomenon that has been negatively impacted by human activity during the last ~50 years.

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Figure 4. USGS scientists collect faunal samples in a sediment core recovered from the Louisiana shelf. Photograph by Tim Ourbak, University of South Florida.

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