Comments
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5-24-07 EPA SAB Hypoxia Advisory Panel Public Draft

Overall, the Public Draft captures the science, both the six CENR topical reports from 1999 as well as the more current science. There are places where I will offer additional information or critique. The overall conclusions that the current and historical science support of the existing Integrated Assessment and the existing Action Plan are correct. I recognize that the SAB HAP has had to incorporate many pieces of published materials and unpublished materials in this review, and should be commended for its thorough and diligent work.

These comments are made on the public draft copy, and follow those pages and line numbers.

P 7, Sec. 1.1, line 11, The process of nutrient flux, uptake and regeneration, and support of in situ production of phytoplankton is a continual process, occurring through the year. The in situ production of carbon is highest in the spring, and when the delivery of nutrients to the continental shelf are high, but continues through the summer after hypoxia has developed. Also, the in situ production reaches the bottom in the form of senescent algal bloom cells, fecal pellets generated by grazing zooplankton (a major component) and aggregates of cells, mucous, fecal pellets, detritus. Justić et al. 1993 show, based on monthly data from station C6 on transect C, a close cross correlation between river discharge, nitrate flux, development of hypoxia with time lags between the processes. While this is an introductory section, it can be more precise.

P 7, line 22, the Gulf of Mexico hypoxic area is the second largest zone of human-influenced hypoxia in the coastal ocean. There are larger areas where oxygen deficiency in upwelled systems impinges on continental shelves, but these are considered "normal" processes. The combined areas of the Baltic Sea represent the largest area of hypoxia. The northwestern shelf of the Black Sea adjacent to the Danube River discharge was second until reduction in nutrients (lack of USSR subsidies for fertilizer) was followed by a reduction in size of hypoxia to minimal or non-existent.

P 7, Figure 1, it would be better for our research group if the source attribution for the figure was given as Modified from Rabalais et al. 2002, 2006, or From Rabalais et al. submitted.

Rabalais, N. N., R. E. Turner and D. Scavia. 2002. Beyond science into policy: Gulf of Mexico hypoxia and the Mississippi River. BioScience 52: 129-142.

OR, Rabalais, N. N. and R. E. Turner. 2006. Oxygen depletion in the Gulf of Mexico adjacent to the Mississippi River. Pages 225-245 in L. N. Neretin, ed., *Past and Present Marine Water Column Anoxia*. NATO Science Series: IV-Earth and Environmental Sciences, Kluwer.

OR, Rabalais, N. N., R. E. Turner, B. K. Sen Gupta, D. F. Boesch, P. Chapman, and M. C. Murrell. Revision submitted May 2007**.** Characterization and Long-Term Trends of Hypoxia in the Northern Gulf of Mexico: Does the Science Support the Action Plan? *Estuaries and Coasts.*

P 8, line 10, suggest ….continental shelf, particularly during spring.

P 8, last paragraph. The results of Osterman et al. 2005 are well presented, with one exception. In line 18, it should say ….the intensity of low oxygen events…. instead of 'hypoxic events' since her proxy has not been tested against oxygen values.
If you want to cite other references that are more complete, suggest
Rabalais, N. N., R. E. Turner, B. K. Sen Gupta, E. Platon and M. L. Parsons. In press 2007. Sediments tell the history of eutrophication and hypoxia in the northern Gulf of Mexico. *Ecological Applications*, Special Issue, Nutrient Enrichment of Estuarine and Coastal Marine Environments.

P 9, line 1, suggest ….importance of increased nutrient inputs and eutrophication versus stratification…..
Works of Justić et al. and Donner et al., using different methods, show that the increase in the N load is 80% attributable to change in N concentration and 20% is attributable to increased discharge. However, comments following in the physical oceanography section about shifts in freshwater inflows might be relevant to this analysis. But, I have a few comments for that section as well.
From Rabalais et al. in review

"Using two different approaches, Donner et al. (2002) and Justić et al. (2003) both concluded that only 20 to 25 percent of the increased nitrate load between the mid-1960s to the mid-1990s was attributable to greater runoff and river discharge, with the rest due to increased nitrogen concentrations in the lower river. Nonetheless, with nitrate concentrations in the lower Mississippi River remaining near 100 μM since the early 1990s (Turner et al. 1998), climate-driven changes in discharge are likely to have a significant influence on the seasonal formation of and interannual variability in hypoxia in contrast to the period between 1970-1990 when nitrate concentrations were rapidly increasing. This is consistent with the results of Stow et al. (2005) who demonstrated a declining threshold for hypoxia formation as salinity stratification increased."

DONNER S. D., M. T. COE, J. D. LENTERS, T. E. TWINE, AND J. A. FOLEY. 2002. Modeling the impact of hydrological changes on nitrate transport in the Mississippi River Basin from 1955 to 1994. *Global Biochemical Cycles* 16:10.1029/2001GB001396.

JUSTIĆ, D., N. N. RABALAIS, AND R. E. TURNER. 2003b. Simulated responses of the Gulf of Mexico hypoxia to variations in climate and anthropogenic nutrient loading. *Journal of Marine Systems* 42:115-126.

STOW, C. A., S. S. QIAN, AND J. K. CRAIG. 2005. Declining threshold for hypoxia in the Gulf of Mexico. *Environmental Science and Technology* 39:716-723

P 9, last paragraph. The Integrated Assessment discussed nutrients in general, not excluding P, but focused on N.

P 10, line 21, paragraph, The Task Force, per se, did not recognize the need…. The Action Plan (2001) calls for a 5-year reassessment of the Action Plan. This includes the assessment of the subsequent science results as called for by the Task Force, which led to the formation of the HAP.

P 13, line 36, ….a well-defined conceptual….
P 13, line 40, suggest ….management of water quality throughout the MARB and hypoxia in the northern Gulf of Mexico…. As written indicates that hypoxia occurs in the MARB.

P 14, line 17, I have heard from Piers Chapman, one of my co-authors in Rabalais et al. and a co-author in DiMarco et al. 2007, that the DiMarco et al. 2007 paper was rejected by *Estuaries and Coasts.* So, for citation of these materials, it would have to go back to the symposium synthesis on the Tetra-Tech site, or be dropped.

P 14, line 22, ….prior to 2000…. The 1999 CENR reports basically included data for the Miss R (Goolsby et al.) through 2006. The 1999 CENR report of Rabalais et al. included cruise data through 1998.

P 14, line 24, delete extra 'that'

P 41, bottom paragraph, While most of the cores are from the Louisiana bight where sediments accumulate and can be dated with 210-lead, there was an attempt by Turner et al. 2004 to get cores from along the continental shelf at 20 m depth contour. The only one that could be dated was I3. This core shows a later time period for the initiation of paleoindicator surrogates of eutrophication and hypoxia than the cores in the Louisiana bight (same methods applied to both areas)

Turner, R. E., C. S. Milan and N. N. Rabalais. 2004. A retrospective analysis of trace metals, C, N and diatom remnants in sediments from the Mississippi River delta shelf. Marine Pollution Bulletin 49:548-556.

Rabalais, N. N., N. Atilla, C. Normandeau and R. E. Turner. 2004. Ecosystem history of Mississippi River-influenced continental shelf revealed through preserved phytoplankton pigments. Marine Pollution Bulletin 49: 537-547.

Given the nature of the sedimentology along the Louisiana shelf, there may be limited opportunities to determine the temporal change in extent of hypoxia along the shelf.

P 15, bottom paragraph. There is also evidence from the foraminiferal data that *Quinqueloculina*, a low oxygen intolerant genera, has been missing from the foraminiferal community since 1900, indicating that there was at one time sufficient oxygen at the sediment-water interface, to support this organism (Rabalais et al. 2006, Rabalais et al. 2007 (these data are not in the Sen Gupta et al. 2006 *Geology* paper)).

Rabalais, N. N., R. E. Turner, B. K. Sen Gupta, E. Platon and M. L. Parsons. In press 2007. Sediments tell the history of eutrophication and hypoxia in the northern Gulf of Mexico. *Ecological Applications*, Special Issue, Nutrient Enrichment of Estuarine and Coastal Marine Environments.

Rabalais, N. N., R. E. Turner, D. Justić, Q. Dortch, W. J. Wiseman, Jr. and B. K. Sen Gupta. 1996. Nutrient changes in the Mississippi River and system responses on the adjacent continental shelf. Estuaries 19(2B): 386-407.

P 16, Key Findings, suggest a rewording based on the comments above about paleoindicators. The existing chronologies are reliable, as best as can be derived from running averages of Pb and Cs dated cores within a continental shelf with variable sedimentology. Extent will be more difficult given the lack of sediment accumulation along most of the continental shelf west of the Louisiana bight. There is a need to update paleoindicators given the changes in the Miss R loads of nutrients.

P 17-18, Physical Oceanography, the information here is more detailed than in other sections, but is okay. Two publications that are missing that shed some light on tidal effects and current regimes are Rabalais et al. 2004, which shows that tidally-forced currents may be responsible for advection of oxygenated water onto and off the shelf in the Louisiana Bight, but not along transect C off Terrebonne Bay, and Wiseman et al. 2004, which has a nice analysis of ADCP data at an observing station on transect C that is broken down into alongshore and offshore components, their relative contributions and strength, and multiple layer conditions through an extended period, spring through fall.

Rabalais, N. N., W. J. Wiseman, Jr. and R. E. Turner. 1994. Comparison of continuous records of near-bottom dissolved oxygen from the hypoxia zone along the Louisiana coast. Estuaries 17(4): 850-861.

Wiseman, Jr., W. J., N. N. Rabalais, R. E. Turner and D. Justić. 2004. Hypoxia and the Physics of the Louisiana Coastal Current. Pp 359-372 in J.C.J. Nihoul, P.O. Zavialov and P. P. Micklin (eds.), "Dying and Dead Seas," NATO Advanced Research Workshop, Liège, Belgium, NATO ASI Series, Kluwer Academic Publishers, Netherlands.

From the Wiseman et al.:
"From 14 March through 12 November 2002, we deployed an acoustic Doppler current profiler (ADCP) at a station in 20 meters of water midway between the Mississippi River birdfoot delta and the Atchafalaya River delta (29.5 N 91.25 W)……

The anticipated strong dominance of the alongshore currents is clear (Fig. 2). More surprising is the highly variable structure of the flow. Periods of strong vertical shear e.g. hours 3200-3500, are interspersed with long periods of very weakly sheared flow, e.g. hours 4800-5000. Long periods of flow contrary to the expected westward flow regime were also observed, e.g. hours 2700-3100. It is noteworthy that the vertical density difference between sensors at approximately 7 and 20 m depth showed reduced density difference associated with strong upper layer flow and, consequently, strong shear, even when the river was in flood and the flow was responsible for a strong lateral buoyancy flux (Fig. 3). The significant importance of shear-induced mixing is implied.

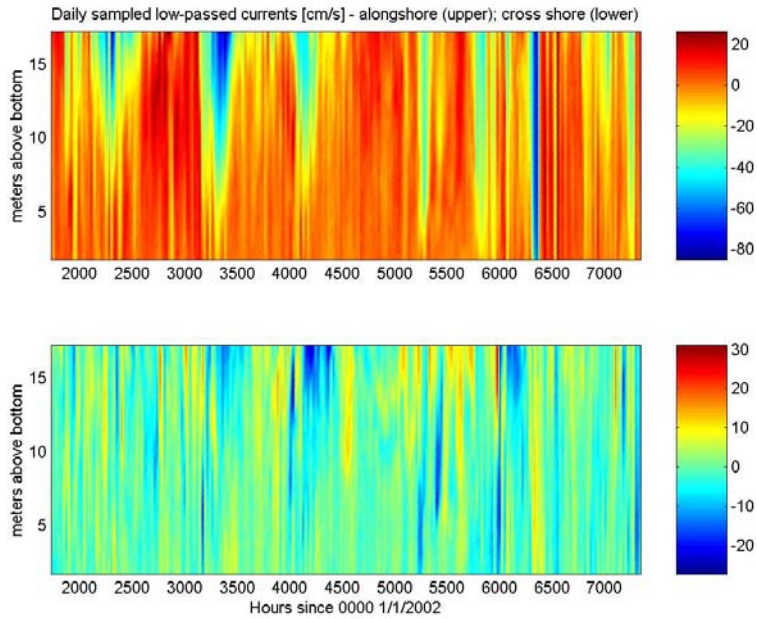


Figure ***Error! Style not defined.****-1.* Contoured daily samples of low-pass filtered currents (sm/s) after rotation into alongshore (top) and cross-shore (bottom) directions. Bins are 0.5 m thick and begin 1.71 m above bottom.

The mean flow is consistent with expectations. The flow is strongly sheared in the alongshore direction with weak lower layer flow and a weak indication of reversal (Fig. 4). The cross shore flow is consistent with a wind-driven downwelling regime as would be expected under the predominantly southeasterly winds affecting the region.

Two-layered flows or flow confined to the upper layer were anticipated from both theory and prior isolated observations, particularly during the highly stratified summer season. Yet, the complex EOF analysis (Kundu and Allen, 1976) indicates that 82% of the variance in the low-passed currents is accounted for by the first mode, which describes nearly unidirectional, vertically-sheared flow (Fig. 5). The second mode accounts for only 13% of the variance and describes a two-layered flow field. Yet, the vertical sigma-t gradient during the deployment was strong, generally greater than .075 m^{-1} and often 2 or 3 times this (Fig. 3)."

P 19, line 24, I have been corrected several times about saying 30% of the flow of the Mississippi River is diverted into the Atchafalaya since regulation in 1975. According to Charlie Demas of the USGS Water Resources the correct terminology is…. The amount of water diverted from the Mississippi River when combined with the flow of the Red and the Atachafalaya rivers is 30% of the total flow of the Mississippi River at the point of diversion. Much simpler at 30%, but thought you might want to know the details.

P 19, last paragraph, One additional component of the Bratkovitch et al. figure 4 is the overall Miss R flow; it might be useful along with the capture of flow by the Atchafalaya.

P 20, first paragraph, This is good information and supports and confirms earlier estimates of water to the west with greater precision.

P 20, line 40-44, the modeling that shows distinct plumes that both contribute to the hypoxia formation is verification of numerous field observations on the plumes and the distribution of hypoxia. Figure 1 of the HAP draft report, the frequency of occurrence of mid-summer hypoxia, qualitatively shows the influence of the plumes on the bottom-water hypoxia.

P 21, lines 9-13, There are no data in the Rowe and Chapman paper to support the statement that the bottom area of hypoxia has increased from the 1900s to the 1970s as more water was captured by the Atchafalaya. The total volume now is lower than in some historic times. This statement is inconsistent with earlier comments concerning paleorecords and the lack of evidence in the paleorecords for expansion of hypoxia over time.

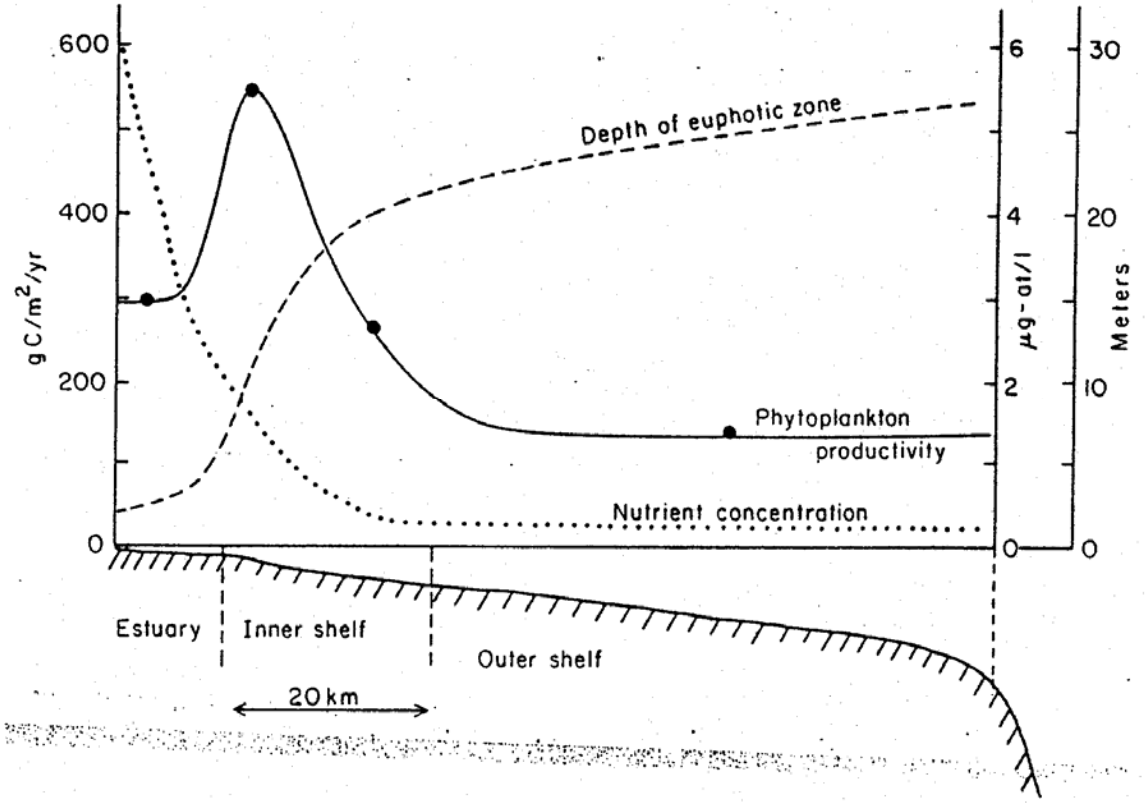
P 22, first paragraph, With regard to engineering the discharge in a period of energetic waves and currents, the highest discharge is now during the periods of higher wave and current energy.

P 22, line 8-9, suggest adding at the end of the sentence …..NGOM shelf without endangering other estuarine and coastal waters.

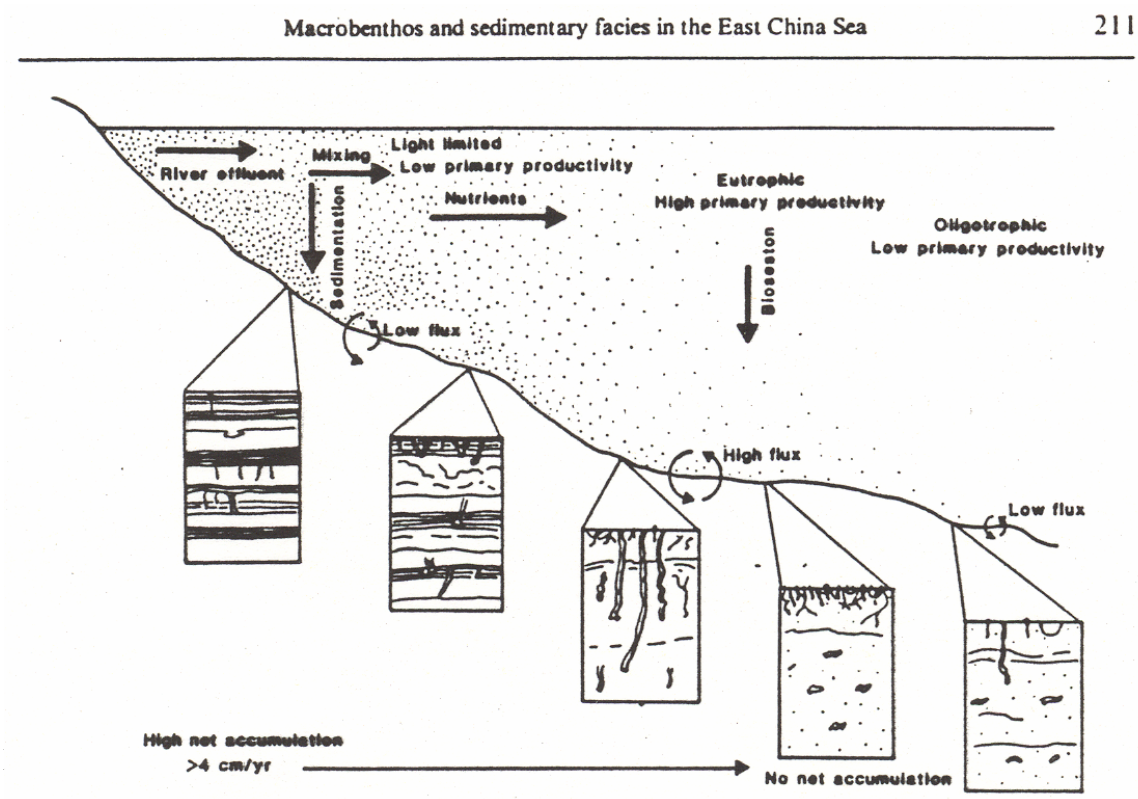
P 22, zones of hypoxia controls. Please consider a conceptual model of river plume nutrient, light, and primary production that is in the literature, with the added stratification and organic matter decomposition that leads to hypoxia. The gradients away from a river plume are near the delta, mid distance from the river, and far from the delta. The first area is high nutrient, high turbidity, light limited and low primary production and chlorophyll biomass accumulation. The second is an area of improved water clarity as sediments fall out, but sufficient nutrients to support high primary production. The cholorophyll biomass and primary production peaks on the LA shelf are in the 15 to 25 salinity range. The third area is low nutrients, low turbidity, clear water, and low primary production and chlorophyll biomass. The Rhoads et al. adaptation to this surface water river plume concept is the addition of flux of carbon and benthic processes. The conceptual model is linear, but can be distributed in multiple directions away from multiple sources. The complexity in the NGOM is driven by the dual deltas and the bidirectional flow of the discharges through winter and spring versus summer current regimes. The synthetic time-integrated information provides overall primary production, distribution of salinity and therefore stratification and subsequent hypoxia.

P 22, lines 28-29, will need to be changed to DiMarco et al. 2006 (unpubl) versus the 2007 paper.

P 23, figure 6. This is the summer period, but the spring is so important. Also, in summer the Atchafalaya River plume often moves to the east, not the west.



From some basic textbook.



Rhoads et al. 1976, I think, away from my office, It is in Continental Shelf Research.
P 23, Not sure if this is in relation to fluid muds which do not enter the hypoxic area, or the nepheloid layer, in which hypoxia is commonly present, both within the nepheloid layer and above it. I see this as not important in the formation of hypoxia.

P 23, lines 21-23. Would a change in shelf circulation or vertical mixing be expected during the 20th century, or are these processes of longer scale than any mid century or intra century change.

P 29, lines 28-end, There are ADCPs deployed in the hypoxic area, LSU WAVCIS and LUMCON BIO2 collaboration, and the Wiseman et al. 2004 paper discussed above shows some of those data, and one(?) with DiMarco et al. NGOMEX work.

P 24, should incorporate information from Wiseman et al. 2004.

P 25, Expect that the findings and recommendations might change post NO meeting and other comments.

P 25, line 9, There has to be both stratification and organic matter loading and decomposition to drive hypoxia. There can be organic matter respiration, but without stratification there will be no hypoxia. There can be stratification, but without organic matter loading, and hypoxia will not form (at least not as now). Historically, there were similar high freshwater inputs and similar currents, and hypoxia (as indicated by the AE index of Sen Gupta) was not present.

P 25, line 9, think this is not relevant

P 25, lines 10-11, statement above about this.

P 25, line 13, I find the sediment induced hypoxia unsupported by the literature.

P 25, bullet line 36, I agree, but I have had difficulty getting GCOOS interested. Most of the funding is from Minerals Management Service for LSU's WAVCIS and LUMCON's BIO2.

P 26, 2.1.3, I will defer to Gene Turner on these comments, because he has recently updated the flux estimates for post 1999 CENR reports for his synthesis paper for the Hypoxia Symposium, April 2006, and subsequently submitted *Estuaries and Coasts* submission.

P 26, line 21-22, While the Integrated Assessment focused on N, it did not preclude phosphorus as a nutrient that was important and needed attentions.

P 26, groundwater discharge, In Rabalais et al. (in review) from Hypoxia Symposium as submitted to *Estuaries and Coasts,* with regard to groundwater inflow, from Rabalais submitted for further review 2007

"The direct atmospheric deposition to the offshore surface waters is a small amount of the total nitrogen budget (1-2%, Goolsby et al. 1999). Upwelled flow of nitrate from deeper waters may be important at the shelf edge at depths of 100 m, but there are limited physical transport mechanisms for enhancing continental shelf processes (Wiseman et al. 2004) and no documented role for it in controlling the severity or size of the hypoxic zone. Groundwater discharges directly to the Gulf are unlikely to be important because of the lack of shallow aquifers along the Louisiana coast and the low potential for transfer in a cross-shelf direction (Wiseman et al. 2004). Saline groundwater seeps through bottom sediments on the inner to mid Louisiana shelf, but the source and composition of this groundwater is uncertain (Krest et al. 1999). Another study indicates that oil and gas formation water, geothermal convection, and seawater recirculation are the major sources of ground water on the Louisiana shelf, with a minimum input of terrestrially derived topography driven flow (McCoy et al. 2007)**.**

I.e., groundwater discharge is not important as a source to hypoxia in the NGOM.

McCoy, C., D. R. Corbett, B. A. McKee, and Z. Top. 2007. An evaluation of submarine groundwater discharge along the continental shelf of Louisiana using a multiple tracer approach. *Journal of Geophysical Research – Oceans* 112, C03013, doi:10.1029/2006JC003505.

P 27, first paragraph, see previous comments on zones, versus gradients of transition along a river plume that is variable on temporal and spatial scales.

P 27, l 15-21, new Turner et al. submitted, in review has the latest updates on TN and TP loads, and NO3-N loads, and TN:TP, etc.

P 27, l 25-27, the zones in Rowe and Chapman and as modified for this report are unrealistic.

P 28, lines 11-16, et seq. The information in Sylvan et al. 2006 needs to be written very carefully with regard to implications and summary statements. They have bioassays from 4 times in the year in the Mississippi River plume. One of these is in May for the year ???. This cannot be extrapolated to mean P limitation in the spring of all years. This is just one set of bioassays. The other bioassays indicate P or N-P co-limitation or N limitation. Si should also be considered with regard to Dortch and Whitledge, 1992 and Dortch et al. 2001.

You have Dortch and Whitledge 1992

Dortch, Q., N. N. Rabalais, R. E. Turner and N. A. Qureshi. 2001. Impacts of changing Si/N ratios and phytoplankton species composition. Pp 37-48 in N. N. Rabalais and R. E. Turner (eds.), Coastal Hypoxia: Consequences for Living Resources and

Ecosystems. Coastal and Estuarine Studies 58, American Geophysical Union, Washington, D.C.

P 29, line 1, re the strong P limitation during this period. From the Sylvan et al. 2006 publication it is evident that P limitation occurred in May of the 4 sample periods, and that this cannot be interpreted to represent 'spring' of this or other years in the long-term, it is one of four sampling periods in one year.

P 29, line 4, high TN:TP ratios, but see Turner et al. 2007 hypoxia symposium on the reduction of the TN:TP ratios.

P 29, line 41, springtime P limitation is supported by one sampling in the spring of one year.

From Rabalais et al. 2007 in review:

"An important management issue is the relative influence of nitrogen versus phosphorus concentrations and loads in controlling bottom-water dissolved oxygen on the Louisiana continental shelf. Model forecast results indicated a general tendency for responses to be somewhat greater for nitrogen load reductions than for phosphorus load reductions (Limno-Tech, Inc. 1995). Nitrogen is considered to be relatively more important than phosphorus in limiting primary productivity on the Louisiana inner shelf, but both phosphorus and silica may also be limiting at times and in certain locations, or combinations of nutrients may be limiting (Rabalais et al. 1999, 2002b, CENR 2000). A series of nutrient limitation or stress indicators [nutrient concentrations and ratios, alkaline phosphatase activity, phosphorus turnover times, and changes in chlorophyll *a* enrichment bioassays (four stations)] were examined in the Mississippi River plume in March, May, July and September of 2001 (Sylvan et al. 2006). The results indicated that phytoplankton growth at these locations was limited by phosphorus in May and July, phosphorus was weakly limiting in March, and nitrogen was limiting in September. The observed phosphorus limitation in May and July (Sylvan et al. 2006) is likely related to the excess nitrogen loading compared to phosphorus (see Turner et al. 2003), and thus, both nitrogen and phosphorus management have implications for reducing hypoxia."

Also,
From Rabalais et al. 2002 Hydrobiologia
"Ambient nutrient concentrations and ratios, bioassay experiments, and other indicators of nutrient limitation (Rabalais et al., 1999) all suggest that N, P or Si may be limiting at some times and places in the outflow of the Mississippi River. The details of when and where particular nutrients are limiting and the severity of limitation are not completely known. N limitation occurs most often at higher salinities and during low flow periods. In contrast, P limitation occurs mostly at intermediate salinities and during high freshwater input. Si limitation, which affects diatom growth, appears to be more spatially and temporally variable than P or N limitation but is more prevalent in spring than in summer. Phytoplankton species may be differentially susceptible to nutrient limitation, with an obvious example being the requirement of diatoms for Si, and there are species

differences among diatoms with regard to Si limitation. Although limitation by both Si and P does occur, N limitation is more frequent and extends over a larger area."

P 31, there is so much more than the N vs P vs N-P co-limitation. There are grazing communities that change through the year. In the Spring it is most likely copepods that eventually are able to respond to the spring phytoplankton bloom, and therefore the major component to the lower water column is fecal pellet carbon in spring. As the zooplankton grazing community changes from copepods to zooplankton such as larvaceans, the amount of carbon reaching the bottom changes.

P 35, line 38, ….to the small amount of lower oxygen conditions seen in …

P 36, lines 28-31, yes.

P 37-41 is a nice summary of recent work, the implications of which are not yet fully understood with regard to hypoxia, especially since the references were primarily focused on the source, transport and fate of OM.

P 41, bullet line 21, the wetlands carbon was earlier minimized as a source of OM related to the depletion of oxygen in offshore waters.

P 41, line 23, warranted.

P 41, line 31, …load or\f total nutrients….?

P 43, first paragraph, There is evidence of higher PO4 in bottom waters that are hypoxic, indicating a flux, however, there is no evidence of a gradient of this PO4 into the upper water column, especially when stratified. The mixing of bottom water nutrients occurs during mixing events that both reaerate the bottom and bring the nutrients to the surface. From Rabalais and Turner 2006

Rabalais, N. N. and R. E. Turner. 2006. Oxygen depletion in the Gulf of Mexico adjacent to the Mississippi River. Pages 225-245 in L. N. Neretin, ed., *Past and Present Marine Water Column Anoxia*. NATO Science Series: IV-Earth and Environmental Sciences, Kluwer.

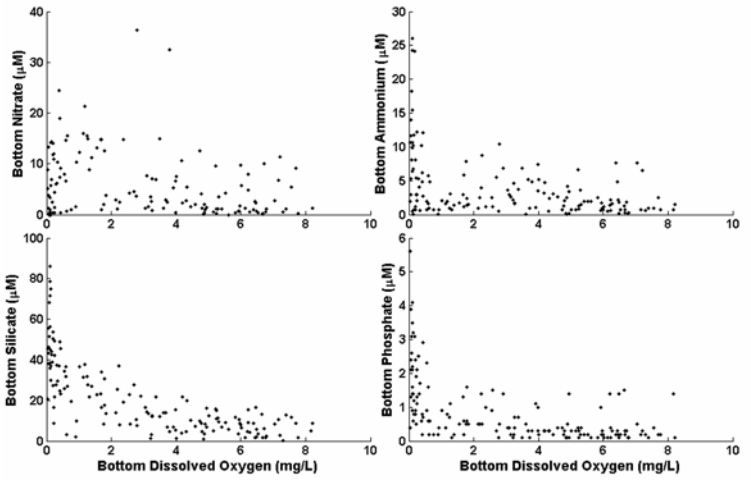


Figure 10. Comparisons of bottom water dissolved oxygen concentration and bottom water dissolved inorganic nutrient concentrations for all stations and all depths between 1985-1996 for the period May-September (modified from Rabalais et al. 1999). [[this is in Rabalais and Turner 2006]]

P 44-46, Possible Regime Shift

While interesting, further expansion of this topic, other than to include NGOM biology, not just changes in the water flow and examples from other areas, does not add much more to the report with regard to new science available to review the concepts of the Integrated Assessment and Action Plan

There are indications from several sources that there are shifts in abundance of members of the NGOM ecosystem that follow similar changes in eutrophied coastal ecosystems, for example the northwestern shelf of the Black Sea, until the early 1900s. The transition was long and the recovery is not complete (Tolmazin 1985, Zaitsev 1992, Mee et al. 2001, Mee 2001, 2006, Mee et al. 2005). Several chapters in the Rabalais and Turner 2001 book and other papers (e.g., Turner et al. 1998) indicate shifts in communities.

Dortch et al. discuss shifts in diatoms as a result of Si limitation.

Purcell et al. discuss the increases in certain gelatinous zooplankton, *Aurelia* in the surface waters and *Chrysaora* in bottom waters from SEAMAP trawls (data of Monty Graham, Dauphin Island Sea Lab)

Chesney and Baltz show that two demersal species that were common in trawl bycatch in the 1950s are not currently, and that two pelagic species that were not common in trawl bycatch in the 1950s are now more common. This is similar to other eutrophied areas where there are shifts from demersal to pelagic fishes.

Turner discusses food web changes in relation to eutrophication.

Chesney, Edward J. and Donald M. Baltz, 2001, The Effects of Hypoxia on the Northern Gulf of Mexico Coastal Ecosystem: A Fisheries Perspective, 321-354 in Nancy N. Rabalais and R. Eugene Turner (eds.), *Coastal Hypoxia: Consequences for Living Resources and Ecosystems.* Coastal and Estuarine Studies 58, American Geophysical Union, Washington, D.C.

Dortch, Quay, Nancy N. Rabalais, R. Eugene Turner and Naureen A. Qureshi, 2001, Impacts of Changing Si/N Ratios and Phytoplankton Species Composition, 37-48 in Nancy N. Rabalais and R. Eugene Turner (eds.), *Coastal Hypoxia: Consequences for*

Living Resources and Ecosystems. Coastal and Estuarine Studies 58, American Geophysical Union, Washington, D.C.
Mee, L. D. 2001. Eutrophication in the Black Sea and a basin-wide approach to its control. Pp. 71-91 in *Science and Integrated Coastal Management.* Edited by B. von Bodungen and R. K. Turner. Berlin: Dahlem University Press.
Mee, L. D., J. Friedrich and M. T. Gooier. 2005. Restoring the Black Sea in Times of Uncertainty. *Oceanography* 18: 32–43.
Mee, L. D. 2006. Reviving dead zones. *Scientific American* November 2006:79-85.
Purcell, Jennifer E., Denise L. Breitburg, Mary Beth Decker, William M. Graham, Marsh J. Youngbluth and Kevin A. Raskoff, 2001, Pelagic Cnidarians and Ctenophores in Low Dissolved Oxygen Environments: A Review, 77-100 in Nancy N. Rabalais and R. Eugene Turner (eds.), *Coastal Hypoxia: Consequences for Living Resources and Ecosystems.* Coastal and Estuarine Studies 58, American Geophysical Union, Washington, D.C.
Rabalais, N. N. and R. E. Turner (eds.). 2001. Coastal Hypoxia: Consequences for Living Resources and Ecosystems. Coastal and Estuarine Studies 58, American Geophysical Union, Washington, D.C., 454 p.
Tolmazin, R. 1985. Changing coastal oceanography of the Black Sea. I. Northwestern shelf. *Progress in Oceanography* 15: 217-276.
Turner, R. Eugene, 2001, The Effects of Eutrophication on Pelagic and Demersal Marine Food Webs, 371-398 in N. N. Rabalais and R. E. Turner (eds.), *Coastal Hypoxia: Consequences for Living Resources and Ecosystems.* Coastal and Estuarine Studies 58, American Geophysical Union, Washington, D.C.
Zaitsev, Y. P. 1992. Recent changes in the trophic structure of the Black Sea. *Fisheries Oceanography* 1:180-189.

P 46, line 8, ….changes in frequency of hypoxia…. Not sure the meaning or the data that support this statement.

P 50, Donner and Scavia is now published. L&O, 2007, 52(2):856-861.