

Panel Summaries

Gulf Science Symposium

Summary for Session 1 – Craig Stow

Session 1 was on the long-term evidence of hypoxia. Let me preface my comments by saying that I am here as the panel chair supposedly representing the panel and perhaps also the authors who presented this material. In just a couple of minutes I can't begin to do justice to the body of information that was presented. Also, the thoughts I have to offer have been affected by a lot of the material I have seen since then so I'd like to offer my comments and summary not so much as being representative of opinions and thoughts of all of the people involved but more as a springboard for discussion.

Again Session 1 was the session on long-term monitoring and information, and I'd like to offer the thought that a lot of big picture questions are well-addressed by taking this approach. Long-term data provides a wealth of information that helps us assess how a system is behaving. We were presented with a wealth of information representing multiple lines of evidence. These included evidence of some of the changes in forcing functions over time; this includes river flow as well as nutrient loadings. We saw evidence of changes in some of the responses over time, and that includes changes in dissolved oxygen and related sorts of parameters. We also saw the sediment paleo evidence of changes consistent with the long-term patterns that were presented. So we had multiple lines of evidence, some of them representing quite independent data sources and they were all very consistent with the big picture pattern of increased eutrophication as a result of long-term nutrient increases that result in excess production and ultimately bottom order hypoxia. And let me also say that the size of the hypoxic zone at the peak time which is in July has been pretty well characterized. That seems to be a pretty good indicator of the intensity of hypoxia in any given

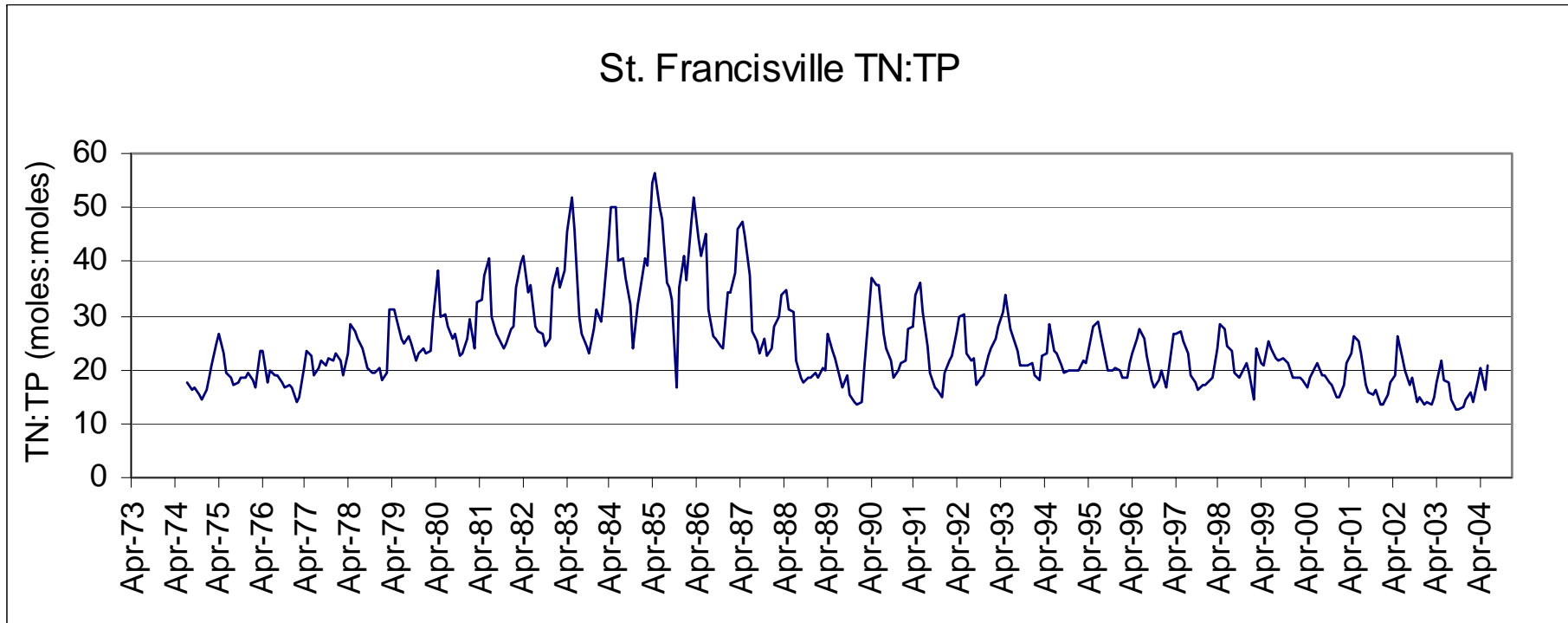
year. Where we're lacking some evidence is the year to year extent, duration, onset, and volume of hypoxia. And if it's decided that these are important things that we need to better assess the problem and how to address it, then that's one area that's ripe for additional monitoring and information gathering.

The in-load relationship to hypoxia in a given year was also alluded to. I don't remember that we saw specific figures that addressed that, maybe if we did, and again I don't want to mischaracterize anything that was presented, but that information was at least in some of the papers we were presented with before the session. And I think some of the apparent tensions that may occur between the relative strengths of some of the forcing functions could be properly resolved, or at least somewhat reconciled if we were careful about specifying the appropriate temporal and spatial scales on which these things are important. At some point in one of the presentations there was a suggestion that we need to make a diagram of these things and I think that might help to put some things in perspective. I'm thinking of the equivalent of a stamal diagram where you map out processes in log space and log time and I think if we were to do that we would begin to see that some of the processes (and I'm specifically alluding to hydrologic and physical forcing versus the biological and nutrient loading things) would begin to separate out and we'd see that they are both important precursors of hypoxia but in fact that they occur on some distinct spatial and temporal scales. They may overlap somewhat but they are important on scales in a way that we haven't elucidated very well yet.

And one of the thoughts I'm going to offer here is that we've seen this extended period of elevated nutrient loading and now an extended period of enhanced hypoxia. There may be some parallels to the problem of eutrophication in lakes that's been well documented over the last decade or so. We know very well that lakes become eutrophic as a result of extended nutrient loading. And we took a lot of steps to reduce that nutrient loading probably in the '70s, '80s, and early '90s and we know that at least a proportion of lakes have not responded well. And in part the literature has suggested recently that effectively what we've done is kicked these lakes into what's been called an alternate stable state. I'm suggesting that we may see some parallels here as a result of an extended period of nutrient loading. It's been alluded to that there's a memory in the system and what may

be occurring is that an extended period of nutrient loading has changed the temporal dynamic of some of the forcing functions so that the forcing functions that were dominant under previous conditions may not be as dominant currently. There's been a switch in some of the dominant processes. And the suggestion then if this is consistent with the analogy that I'm making, is that some of the response time may be pretty slow. Even if we were to effectively reduce nutrient loading very quickly, we may see an extended period of time for the system to adequately respond in the way that we would like it to and the hypoxic region to be effectively reduced. And I think we need to set our expectations and the expectations of the public and the various stakeholders appropriately in the instance that we're in that sort of analogous situation.

Session 2 Summary



1b. Is there a critical period or season during which nutrient or organic matter loading has a relatively greater impact on the size and persistence of the hypoxic zone than other seasons or periods within the year?

- There is consensus that the spring-time delivery of nutrients enhances primary production which subsequently fuels respiration and contributes to the onset of hypoxia.
- The importance of the timing of organic matter and organic nutrient delivery and their subsequent roles in the onset and maintenance of hypoxia is uncertain. Efficient delivery of organic matter to the bottom may be decoupled with development of stratification conditions responsible for development of hypoxia. Timing of these two factors may be different in different regions of the shelf.

2. What is the current understanding of the delivery pathways for nutrients, organic matter and freshwater discharge contributing to eutrophication and hypoxia in different regions of the hypoxic zone (i.e. east, central, west)?

- Clear differences between the Atchafalaya and Mississippi margins appear evident. The passes of the MR deliver constituents to a relatively deep, in comparison to the AR distributary, coastal ocean environment. The AR distributary system discharges to a shallow broad shelf.
- Detailed understanding of all of the delivery pathways, timing and controlling processes for nutrients, organic matter and freshwater, **and also sediment** – a key component of the organic matter burial term – appear to be insufficient at this time to provide mechanistic predictions.

3. What are the relevant magnitudes of different chemical forms of nutrients and organic matter delivered to the Gulf from riverine sources?

- Characterizations of nutrient concentrations/compositions from the river are available at several USGS sites, primarily St. Francisville, but often at low temporal resolution. Characterization of organic matter delivered by the MR and AR as dissolved, suspended, and mobile muds to the Gulf are less understood in terms of composition, source and reactivity.

4. Aside from the Mississippi and Atchafalaya Rivers, are there other important sources of nutrients, organic matter and freshwater discharge that influence hypoxia?

- The role of groundwater seems to have been settled as being relatively unimportant.
- Non-point discharges of nutrients/organic matter, such as coastal erosion/marsh degradation have not been quantified.
- Upwelling of nutrients by wind-induced shallow upwelling is believed to be important but is unquantified.
- The seabed as a large reservoir of mobilizable organic matter/nutrients is also thought to be important but is currently unconstrained.

5. Is the current monitoring of freshwater discharge, sediment loading, riverine nutrient adequate to characterize the riverine inputs that contribute to hypoxia on the shelf?

- The general consensus is that the temporal frequency, character (surface individual samples vs. depth-, cross-channel integrated sampling) and spatial resolution of the riverine nutrient, organic matter and sediment loading is insufficient. The current monitoring activities are poorly fitted to help constrain the inputs at the appropriate temporal and spatial scales needed.

6. What are the long-term trends in freshwater discharge, riverine nutrient loading, riverine nutrient concentrations in the lower river, and Gulf surface water nutrient concentrations? How are these related to long-term trends in the areal extent of hypoxia?

- Over the last 30-40 years discharge has increased by up to 30% by some estimates.
- Coincident with the increased flow there was an increase in N concentration in the river and thus greater N loading.
- Trends in phosphorus concentrations are not apparent. Though the recent decline in TN:TP suggests that either P has increased or N has decreased.
- We are not aware of any analyses of trends in Gulf surface water nutrient concentrations.
- Positive trends in freshwater discharge and nutrient loads are coincident with an increase in the areal extent of hypoxia.
- The accelerated land-loss in coastal Louisiana also is coincident with the increase in the areal extent of hypoxia.

Session 3 Summary

- Basic description and understanding of the physical system and processes relating to hypoxia:

River discharge – stratification isolates lower water column and circulation that distributes constituents cross-shelf and along-shelf

Wind forcing – vertical mixing that injects oxygen to lower water column and modifies plume (stratification) structure (width, thickness, and alongshelf extent)

- Mississippi and Atchafalaya contributions to westward plume(s) similar but dynamics are different because of discharge characteristics
- “Shelf waves” or meanders may play an important role in cross-shelf and vertical exchange that will impact oxygen distribution

Issues:

- Stratification - Spatial-temporal distribution, relationship to river discharge and wind forcing including hypoxia disruption events
Are there long-term trends in stratification - plume structure, wind forcing, thermal stratification (surface heat flux and absorption)
- Connections and interactions between the Mississippi and Atchafalaya plumes
- Importance of cross-shelf exchange processes – upwelling, meanders

Needs:

- Synthesis of existing data sets to quantify stratification trends, distributions
- Few long-term mooring sites to quantify trends in stratification, hypoxia (Need to know duration as well as area or volume?)
- Process studies combining observations and modeling to address Mississippi and Atchafalaya interaction, importance of stationary meanders

Session 4 Summary – Causes of Hypoxia III: Influence of water column processes

- High N loading has led to P-limitation in the near-field at certain times of the year (including the spring bloom period). If feasible the management plan should include both nutrients, but N management should be maintained.
- Reductions in nitrate loading are expected to result in <1:1 ratio in the reduction of vertical flux of organic matter to sediments and thus <1:1 reduction in hypoxic area.
- Terrestrial dissolved organic carbon plays a minor direct role in causing hypoxia.
- Terrestrial dissolved organic N accounts for ~20% of the total dissolved N load, and the remineralization of this N plays an important role in fueling primary production.

- There is a temporal disconnect between chlorophyll biomass and productivity with highest biomass in spring and high productivity through the summer.
- Vertical particle fluxes are not well constrained, but there is evidence that small as well as large phytoplankton contribute to overall fluxes. Zooplankton grazer composition (microzooplankton, copepods, larvaceans) plays an important role in mediating particle fluxes.
- The food web off the delta supports ~25% of hypoxia development.
- N and P loadings contribute to sinking particulates and hypoxia once per field season until mixing returns nutrients to the euphotic zone.
- N, P and Si can be limiting on varying temporal and spatial scales, and the ratio of these nutrients affects species composition. Data exist to explore this more thoroughly.

- **Priorities for future studies**
- Upwelling and cross pycnocline mixing
- Measurements of oxygen production and consumption in waters below the pycnocline
- Role of Atchafalya discharge in driving hypoxia
- Role of wetland erosion in oxygen consumption and N and P regeneration in coastal waters (<15 m)
- Effects of seasonal nutrient (N & P) reductions on new and regenerated production and vertical C flux
- Volumes of hypoxic water need to be determined for assessment of C demand to maintain hypoxia.

Session 5 Summary

Overview Comments

(1) Unique features of N GOM shelf

- Large iron pool
- Mobile muds
- Multiple vertical density discontinuities in WC
- Shallow clear water & benthic PS

(2) Surprisingly limited benthic process data

- Sediment-water solute fluxes
- Vertical solute profiles in PW and OW
- POM sinking rates

(3) Need for understanding?

- Compelling arguments?
- Detailed models

Assigned Workshop Questions

Role of benthic processes in hypoxia?

- Aerobic vs. anaerobic respiration?
- Chemoautotrophy and other processes?
- Benthic vs. planktonic metabolism?

Sources of carbon and nutrients?

- POM sinking
- Lateral transport
- Benthic primary productivity

Role of benthic primary productivity?

- Intersection of 1% light with sediment surface
- Seasonal variations
- Spatial variations along gradients

Role of benthic recycling of N and P?

- Limited data (fluxes, PW or OW gradients)
- Substantial fluxes of NH_4 , little PO_4
- Episodic fluxes (especially with hypoxia)?

Residual sediment O₂ demand and nutrient source

- Short-term to seasonal lags are likely
- Little evidence for longer term labile storage
- Unique features of GOM?

Role of benthic denitrification

- Limited data with direct measurements
- What about stoichiometry of fluxes or profiles?
- Favorable conditions

Spatial, temporal variations in benthic processes?

Other Issues Raised

- Does anoxia ever occur? Why?
- How does hypoxia affect N and P recycling?
- Role of macrofauna in benthic biogeochemistry?
- Alternative modeling approaches?
- Height of hypoxic layer
 - Regulating physics
 - Biogeochemical factors
 - Variability in time and space

Session 6 Summary

- Modeling activities should continue indefinitely and with more sustained funding.
- Shortcomings and limitations of existing models have been detailed by co-authors in publications, etc.
- A consensus modeling approach is preferred over one “best” model. (C. Cerco insists that there should ONE model for management.)
- Models should continue to be developed with a range of approaches, assumptions, and degrees of complexity.
- Models should be built with specific “target processes” in mind.

Modeling Panel Bullets (continued)

- The models that are built should include a shelf-wide physically-coupled, spatially- and temporally-resolved (seasonal) model.
- Existing models still offer a valid, but qualified, scientific rationale for setting an N reduction goal of at least 30% to achieve the target 5,000 km² average hypoxic area.
- Further modeling to provide additional information about relative importance of N, P, (and potentially Si) is warranted and should be conducted to evaluate dual (N and P) nutrient reduction strategies.
- Improved representation of benthic-pelagic coupling and sediment processes (e.g., SOD) is important.
- Improved treatment of the open boundary is an important area for improvement of existing models.