Gulf of Mexico Hypoxia Working Group
National Oceanic and Atmospheric Administration
National Centers for Coastal Ocean Science
Room 9127
1305, East-West Highway
Silver Spring, MD 20910.

Dear Members of the Hypoxia Working Group:

I am transmitting the attached as the State of Illinois' response to the Notice of Availability of an Integrated Assessment of the Causes and Consequences of Hypoxia in the Gulf of Mexico (FRL-6461-3).

I am concerned that the Draft Integrated Assessment produced by the Committee on Environment and Natural Resources (CENR) of the Executive Office of the President for the President and the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force appears to have been prepared with little or no consideration of the extensive comments I submitted on July 27, 1999 in response to the six technical assessments of hypoxia in the Gulf of Mexico. While the relationship between fertilizer use in the Midwest and Gulf hypoxia remains scientifically unproven, some of the recommended responses could have serious economic consequences for Midwestern farmers. I therefore encourage you to respond to the scientific concerns we have previously, and continue to express.

Sincerely,

George H. Ryan
Governor

Attachments (2)

GHR/IDNR/JDG/bda

Gulf of Mexico Hypoxia Working Group
National Oceanic and Atmospheric Administration
National Centers for Coastal Ocean Science
Room 9127
1305, East-West Highway
Silver Spring, MD 20910.

Dear Members of the Hypoxia Working Group:

Please allow this letter and attachments to serve as the State of Illinois' response to the Notice of Availability of an Integrated Assessment of the Causes and Consequences of Hypoxia in the Gulf of Mexico (FRL-6461-3).

Scientists in a number of state agencies have reviewed the Draft Integrated Assessment produced by the Committee on Environment and Natural Resources (CENR) of the Executive Office of the President for the President and the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. I submit their comments (Attachment 1) and request that this letter and the attached comments and diagrams be used in preparing the final Integrated Assessment and be made available on the Internet.

In general, state scientists find that the reports do not present a clear cause-effect relationship between fertilizer use and other nitrogen sources and hypoxia in the Gulf of Mexico, and the report does not adequately express scientific uncertainty. We are left with a great deal of confusion rather than clarity.

I am particularly disappointed that Governor Ryan and the State of Illinois have not received a response to the letter and 27 pages of comments on the six technical assessment reports that were submitted on July 27, 1999. It is very difficult to engage in a process that has multiple, sequential steps when the next step (i.e., Draft Integrated Assessment) is started before the previous step has been completed. The difficulty was even more so experienced by the Illinois scientists who had a hard time preparing a response to the Draft Integrated Assessment in the absence of a response to their many comments, suggestions, and concerns regarding the six technical assessment reports. Due to the absence of a response to our July 27, 1999, letter and comments, I resubmit our July 27 comments (Attachment 2) as part of this response to the Draft Integrated Assessment and I look forward to receiving responses to both sets of comments.

Once the CENR Hypoxia Working Group has finalized and approved the Integrated Assessment early next year, our scientists will review the report. In advance of finalizing the Integrated Assessment, I implore you to respond to the many issues and concerns we have raised regarding the science upon which the Integrated Assessment is based.

Sincerely,

Renee Cipriano
Senior Advisor to the Governor
Environmental and Natural Resources

Attachments (2)

GHR/IDNR/JDG/kac

cc: Brent Manning
Joe Hampton
Bruce Yurdin
Jim Garner
Brian Anderson
Derek Winstanley

ATTACHMENT 1

ILLINOIS REVIEW COMMENTS OF THE DRAFT INTEGRATED ASSESSMENT

Summary of comments

1. Concentration of total nitrogen in the Illinois River has decreased by about 50% since mid-century and is now about the same (+/- 40%) as it was at the start of the century.

2. Concentration of nitrate in the Illinois River increased from mid-century to about 1970 and then decreased. It is now about the same as in 1960.

3. Concentrations of organic nitrogen and ammonia in Illinois waters have decreased dramatically since mid-century.

4. There is no significant relationship (1978-1998) between annual nitrate+nitrite concentration in the Illinois River, or in rivers and streams state-wide, and annual use of nitrogen fertilizer in Illinois. This does not necessarily indicate that the application of fertilizer does not effect nitrogen concentrations, only that the effect coincides with rainfall events.

5. In major rivers of the Mississippi River Basin (Ohio, Middle Mississippi, and Lower Mississippi) there is also no consistent relationship (1954-1998) between concentration of nitrate and the use of nitrogen fertilizer in the Mississippi River Basin.

6. Measured concentration of total nitrogen in the Lower Mississippi River were lower in 1980-1996 than the calculated concentration at the start of the century, and much lower than mid-century.

7. There is no significant relationship (1985-1999) between the annual flux of nitrogen from the Mississippi/Atchafalaya River Basin (MARB) and the surface area of the mid-summer hypoxic zone on the continental shelf.

8. Data do not support the conclusion that the flux of nitrogen from the MARB has increased three fold in the last 30 years

9. The rate of primary productivity in the northern Gulf of Mexico adjacent to the discharge of the Mississippi River system has decreased since the 1950s.

10. Natural processes of hypoxia formation have not been adequately evaluated.

General Comments

On July 27, 1999, Governor Ryan submitted 27 pages of comments on the final 6 hypoxia assessment reports and has not received a response. The Draft Integrated Assessment (DIA) has been prepared by the Hypoxia Working Group of the Committee on Environment and Natural Resources (CENR), based on the 6 assessment reports and other considerations. The October 21, 1999, notice in the Federal Register announcing the release of the DIA for public review states that "*these reports, along with the comments on them, were* ***considered*** *in developing the Integrated Assessment" **[emphasis added].***

Our first comment on the DIA is that most of Illinois' comments on the 6 assessment reports appear to have been ignored or rejected without explanation.

As an introduction to our comments on the DIA, we summarize below key conclusions of the 6 reports and the DIA.

1. *"The northern Gulf of Mexico adjacent to the discharge of the Mississippi River system is an example of a coastal ocean that has undergone eutrophication (increased rate of primary production) as a result of increasing nutrients and that this has worsened hypoxic conditions on century-long and accelerating recent decadal time scales."* (Rabalais et al., 1999).

2. The annual flux of nitrogen from the MARB *"...is estimated to be 2.2 to 6.5 times higher than baseline "pristine" conditions for the North Atlantic Basin (Howarth, 1998)"* and has *" ...approximately tripled during the last 30 years..."* (Goolsby et al., 1999).

3. The prime cause of the increase in increase in nitrogen flux is agricultural activities throughout the MARB, with *"...fertilizer plus the inorganic nitrogen pool to be the largest source..."* (Goolsby et al., 1999).

4. The possibility that worsening hypoxia might be due in any significant way to natural processes is unduly discounted (Rabalais, et al., 1999; Diaz, et al., 1999).

Comment 1: Failure to adequately express scientific confidence/uncertainty.

The DIA states that "*Scientific understanding has been advanced significantly by the work on which this assessment is based. The conclusions provide a solid foundation on which to build an appropriate response strategy. There are, however, always uncertainties in scientific analyses.*" It goes on to find that priority research areas are in the areas of watershed nutrient dynamics and agricultural practices, nutrient cycling and carbon dynamics, long term changes in hydrology and climate as well as economic and social impacts.

There is a high degree of scientific uncertainty expressed throughout the 6 assessment reports (see July 27 comments) and reflected in some 15 pages of research *"needed to reduce uncertainties in important aspects of our understanding."* For brevity, we quote just 21 statements to this effect in our Comment 1 starting with the statement that, *"Results presented in this report are from an ongoing research program and should be considered preliminary and provisional in nature." "Some issues just cannot be resolved adequately without further data* *analyses, more data collection, or improved and different modeling efforts."* From the content of the 6 assessment reports, we conclude that the DIA fails to explicitly capture major scientific uncertainties surrounding the issue of hypoxia in the Northern Gulf of Mexico. Another way of expressing this shortcoming is that the DIA does not adequately express the level of confidence in the major scientific findings.

The Hypoxia Assessment's assertion that *"the conclusions provide a solid foundation on which to build an appropriate response strategy"* in the absence of substantiation of what constitutes *"a solid foundation"* is a statement of feeling not fact. There is a need in risk assessments to express levels of scientific confidence quantitatively and qualitatively along each step of the causal chain in order to provide decision analysts, decision makers, and non-technical experts involved in risk management and public policy formulation with a clear understanding of what is not known, and how well it is known with varying levels of confidence. It is most meaningful to express scientific confidence along each step of the causal chain from cause and effect through mitigation and control. In comparison, the National Acid Precipitation Assessment Program (NAPAP, 1989(a); NAPAP, 1989(b); NAPAP, 1991(a); NAPAP, 1991(b)) did do this.

We recognize that incorporating expressions of scientific confidence would have necessitated a more difficult and lengthy assessment process. At a minimum, the final IA should include a statement either that i) no attempt was made in planning and conducting the assessment to meaningfully express scientific confidence on the major findings, other than through identification of research needs, or ii) that the limited time set by Congress for conducting the assessment did not allow for meaningful expressions of uncertainty throughout the assessment reports. It should be stated in the IA that one key expression of scientific uncertainty is the identification in the 6 assessment reports of some 15 pages of research needs.

The following is a brief reiteration of some of the expression of scientific uncertainty expressed in the 6 assessment reports and other documents which belie the reported feeling of confidence:

i) "The hypoxia in the Gulf of Mexico is ***assumed [our emphasis]*** *to be a result of excessive nutrient loading from the Mississippi River."*

ii) *"We did find tantalizing bits and pieces of data pointing to differences and responses with hypoxia related effects but could not isolate confounding factors that could also produce similar responses."*

iii) *"Results presented in this report are from an ongoing research program and should be considered preliminary and provisional in nature." "Some issues just cannot be resolved adequately without further data analyses, more data collection, or improved and different modeling efforts."*

iv) "A total ecosystem approach to the problem will be the only successful one. Consideration of how hypoxia and other stressors interact with all aspects of the Gulf ecosystem is essential ***prior [our emphasis]*** *to planning any restoration efforts."*

v) *"Land-use characteristics are of secondary importance to climatic factors."*

vi) *"The economic assessment based on fisheries data, however, failed to detect effects attributable to hypoxia."*

vii) *"Overall, the above analysis indicates that rivers in the MRB generally meet ambient water quality standards for substances affected by nutrient loadings and concentrations (i.e., dissolved oxygen, pH, nitrate, and un-ionized ammonia). On this basis, it is reasonable to conclude that reductions in nutrient loadings to the rivers will not improve compliance with the* [existing ambient] *standards for these water quality variables."*

viii) *"There is not yet a complete understanding of the physical, chemical and biological processes that influence water quality responses in the northern Gulf of Mexico."*

ix) "Direct, quantitative information about the severity and extent of hypoxia is lacking."

x) *"The extent to which producers across the Mississippi River Basin are currently over-fertilizing is unknown."*

xi) *"The relative contribution of offshore sources of nutrients from upwelled waters of the continental slope is unknown."*

*xii) "... these early conclusions [*of an early version of a large-scale simulation model being developed] *should not be used as the basis for policy and management decisions."* [The model explains only an average of only 40 percent of spatial variability among individual model segments - which means that 60 percent is unexplained.]

xiii) *"The principal reason for this model limitation is that field measurements are not available to characterize temporal variability at the shelfwide spatial scale." "The results indicated that although the model represented the overall mean state of the system reasonably well, it explained an average of only 40% of the spatial variability among individual model segments."*

xiv) "Because of nutrient retention and loss mechanisms that vary in importance as a function of spatial and temporal scales, it is particularly difficult to predict downstream loads that will result from management changes in the upper part of the drainage basin." "The degree of nutrient limitation needed to affect substantial temporal and spatial diminishment in the hypoxic zone cannot yet be determined from the existing models."

xv) "A comprehensive research plan is needed as a focus for efforts at assessing both ecological and economic effects of hypoxia in the northern Gulf of Mexico."

xvi) "Most of the increase in oxygen stress (as indicated by the A-E index) occurred **prior to** the 1940s, and hence, cannot be attributed to the increased use of inorganic nitrogen fertilizer, which occurred after World War II.

xvii) Oxygen stress has decreased in some parts of the northern Gulf in the last 40-50 years.

xviii) The Proposed Draft Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico prepared by USEPA and discussed at the November 1999 meeting of the Task Force recognizes that, *"The relationship of the size and duration of the hypoxic zone to the nutrient loadings into the system are uncertain at this time."*

xix) One of the lead authors of the assessment reports recently gave a seminar at the University of Illinois that focused on scientific uncertainty in the assessment and discussed the role of economics in a situation of scientific uncertainty. Clearly, not all assessment authors share the feeling that the science is on a solid foundation.

xx) Goolsby et al. (1999) that *"A large body of additional nutrient concentrations is available from numerous State, local, and Federal agencies in the basin. However, these data were not used ......"*

In structuring our review comments on the DIA, we make some attempt to express levels of scientific confidence along the causal chain, both quantitatively and qualitatively, following the sequence of causal reasoning in the above assessment findings.

Comment 2. *"The northern Gulf of Mexico adjacent to the discharge of the Mississippi River system is an example of a coastal ocean that has undergone eutrophication (increased rate of primary production) as a result of increasing nutrients and that this has worsened hypoxic conditions on century-long and accelerating recent decadal time scales."* (Rabalais et al., 1999).

There are no known-to-us reported measurements of dissolved oxygen on the continental shelf of the Northern Gulf prior to the 1970s. Estimates of changes in oxygen stress and hypoxia have been made on the basis of surrogate measures from the analysis of sediment cores. Figure 1 shows time series of the A-E index, which is reported in Rabalais et al.(1999) to be an index of oxygen stress. It is apparent that there is only one site - G27 - with a long-term record going back to the 1700s. This record shows a large and sustained increase in hypoxia from the 1700s to the start of the 1900s. There is then some decadal variability, but the A-E index is no higher in 1980 than in 1920.

The A-E indices at two other sites - E30 and C10 - indicate increases in oxygen stress in recent decades, but there are no long-term records for these sites, and, therefore, no scientific basis for reconstructing a longer time series of the A-E index specifically at these sites. That changes in the sign of oxygen stress (increasing or decreasing oxygen) occur over such short distances is evident from a comparison of data from sites E30, C10, and G50. The A-E index at site G50 indicates a sharp decrease in oxygen stress in recent years, although the authors state that *"there is no trend"*. This site appears to be in an area occasionally experiencing hypoxia and, therefore, relevant to the study of hypoxia. The tantalizing evidence of decreasing oxygen stress (decreasing hypoxia) in some parts of the Northern Gulf raises the question as to whether there are other parts of the continental shelf experiencing a decrease in oxygen stress? Have scientists attempted to document decreases in oxygen stress as well as increases?

The ostracod time series in the DIA (Figure 2.2) also shows no change after 1955 with an earlier decrease from about 1930 to 1960.

In conclusion, these data from a small number of sites in the eastern part of the hypoxic zone do not provide a high degree of confidence to the broad conclusion that oxygen stress and related ecosystem changes throughout the hypoxic zone have been increasing since mid-century. They do indicate that at the only site with a long-term record oxygen stress increased substantially from the 1700s to about 1920, and that at another site oxygen stress has been decreasing in recent decades.

Data in Figure 1.2 in the DIA indicate that the surface, mid-summer area of the hypoxic zone has doubled since 1985 and that the area in 1999 is the largest in this time series. However, Boesch (1999)[1] states that *"I do not believe that one can conclude that nutrient loading or hypoxia have increased during the 1980s and 1990s."* The DIA notes that *"it is not clear why this large area has persisted in years following 1993."*

The National Hypoxia Assessment has used highly speculative and varying estimates of background primary productivity (1950s) for continental shelf waters of the Gulf receiving water from the MARB. The National Hypoxia Assessment has estimated that primary productivity off the Mississippi and Atchafalaya Rivers has increased 2- to 7-fold (background 20 to 60 g C/m^2 -yr primary productivity) to its current value of 122 g C/m^2-yr.

It is important and revealing to explore the evolution of estimates of primary productivity and their spatial variability.

Going back a few years, and referencing conditions in the 1950s, Rabalais[2], Turner[3], Wiseman, Jr., and Boesch (1991) acknowledge that, *"First, primary production in these waters is high (>300 g C/m2yr; Sklar and Turner 1981)."* [Note: "*these waters*" referred to waters *"across the Louisiana inner and middle continental shelf."*] In reality, these data were for sites just off Barataria Bay.

However, the National Hypoxia Assessment ignores the voluminous high quality primary productivity data actually measured, including data for inner- and outer-continental shelf waters during the 1950s. These data have been summarized and jointly published by the National Academy of Sciences, National Science Foundation, and the Scripps Institution of Oceanography (Figure 1; Table 1; Mishke et al. 1970).

These data are for rates of primary productivity in waters across the continental shelf to the west of the Mississippi delta for the 1950s "*background*" period. These data show waters of the northern Gulf of Mexico adjacent to the discharge of the Mississippi River system were highly productive (>500mgC/m2/day in the above table - high values found in only 3% of the world ocean), whose minimum value of primary productivity was greater than183 g C/m^2-yr, with a world mean value of 365 g C/m^2-yr (Table 1)..

Table 1. World Ocean Primary Production Values*.

Primary Production Level (mg C/m^2/day) Range	Mean	World Ocean (%)
< 100	70	41
100 - 150	140	23
150 - 250	200	24
250 - 500	340	10
> 500	1,000	3

* Modified from Table 1 of Mishke et al. (1970).

The scientific community has placed the highest confidence in these NAS/NSF/SCRIPPS data. These data are considered to be of the highest quality having been widely used by the scientific community at large, be it for assessing the impact of fossil fuel combustion on the global carbon cycle (e.g., SCOPE 13 -- Bolin et al., 1979) or estimating and assessing marine primary productivity in the geologic past (e.g., Demaison and Moore, 1980). Indeed, these are foundational data used by the scientific community as the oceanic component of the global carbon cycle from SCOPE 13 (Bolin et al., 1979) onward. Since the late 1950s, the global carbon cycle is so fine tuned that we can see seasonal changes, year-to-year changes of 100s millions tons and a growing unaccounted-for sink of 1-2 billion tons in an atmospheric global carbon cycle of some 200 billion tons CO^2-C/-yr.

The National Hypoxia Assessment has rejected these data, preferring their own speculations as to past primary productivity over those numerous high quality values actually measured.

These speculations have several implications. First, if the National Hypoxia Assessment is correct, then it means that the marine primary productivity component of the global carbon cycle is off by about an order-of-magnitude! This appears unreasonable.

Second, for America's "*Fertile Fisheries Crescent*" in the 1950s to naturally have a primary productivity value of only some 20-60 g C/m^2/yr would mean that waters around the Mississippi River delta would be extraordinarily unproductive for a coastal water -- more resembling the sterile, biological desert-like low fisheries areas of the open ocean. Nevertheless, these waters are historically known as America's "*Fertile Fisheries Crescent*" because of their fantastic biological productivity. For the "*Fertile Fisheries Crescent*" to have been a biological desert, as the National Hypoxia Assessment would have us believe, is unrealistic and unsupportable by historic observation.

Third, we should examine the estimates of background primary productivity being fervently advocated as science fact. We must assess these estimates to see if they are of such exceptionally high quality that we should place them over the universally consistent historic observations and measurements of these coastal waters being highly productive, rather than sterile, desert-like environments as the Gulf hypoxia enthusiasts would have us believe.

The original estimate of increase in primary productivity for the Louisiana Bight due to estimated increase in nitrogen loading from the MARB appears to have been done by Turner and Rabalais (1991). They assumed, erroneously, that a doubling in nitrate-N loading to be a doubling of total nitrogen loading from the MARB. And they assumed, erroneously, that this doubling in the assumed nitrogen loading would result in a doubling in primary productivity:

"*The mean annual concentration of nitrate in the lower Mississippi River was approximately the same in 1905-1906 and 1933-1934 as in the 1950s, but it has doubled in the last 35 years (Figure 2)... Nitrogen loading doubled from 1954-1959 to 1980-1985.*"

"*To calculate the potential increase in phytoplankton production rates for the continental shelf that might occur because of the increased nitrogen loading since the 1950s, we assumed that there has been a 100% increase in loading (Figure 6).*" (Turner and Rabalais, 1991).

Thus, from a reported current primary productivity of 290 g C/m^2-yr, Turner and Rabalais (1991) assumed the calculated background level of primary productivity to be acceptable at 145 g C/m^2-yr. Given that a "*total of only 39 g C/m^2-yr could be supported by this additional (since the 1950s) nitrogen loading from the river*" Turner and Rabalais (1991) calculated that nitrogen must be recycled 3.7 times per year to support the calculated 145 g C/m^2 -yr increase in primary productivity.

This nitrogen recycling rate is still reported to be supported by the Hypoxia Assessment, "*Evidence reviewed in CENR Report 1* [Rabalais et al., 1999] *suggests that an atom of nitrogen discharged by the river is used to produce organic carbon an average of four times before it is lost due to burial, denitrification or flushing off of the shelf.*" (Boesch, 1999).

However, six years after Turner and Rabalais (1991), Justic, Rabalais, and Turner (1997) came up with the now-accepted primary productivity value of just 122 g C/m^2-yr. While this new value is even less than the background value considered acceptable just a few years earlier, this new primary productivity value is now considered catastrophically too high for the environment.

While radically changing their reported value of contemporary primary productivity, Justic, Rabalais, and Turner (1997) still retained the previous conclusion that primary productivity has doubled due to a doubled nitrogen loading from the MARB -- putting background primary productivity at a biologically depauperate 60 g C/m^2-yr. Most recently, Rabalais et al. (1999) conclude, "*Consequently, the integrated annual net production was substantially lower than at present, and probably did not exceed 25 g C/m^2 /yr.*"

Not only is this new estimate of background primary productivity challenging to historic observations, it is also challenging to arithmetic -- the doubling of nitrogen load and the still retained nitrogen annual recycling rate of about 4 would put background primary productivity at 145 g C/m^2-yr, not 25 g C/m^2-yr.

The same nitrogen loading value grows from a two-fold increase in its initial 1991 telling up to a seven-fold increase with its final 1999 telling:

"*The mean annual concentration of nitrate in the lower Mississippi River was approximately the same in 1905-1906 and 1933-1934 as in the 1950s, but it has doubled in the last 35 years (Figure 2)...the percent nitrogen as nitrate...has leveled off this decade at 60%...From 1981 to 1987, annual nitrogen and phosphorus loading averaged 130.3 million kg atoms nitrogen* [1.824×10^9 kg N] *and 3.44 million kg atoms phosphorus* [1.07×10^8 kg P] *(Figure 6). Nitrogen loading doubled from 1954-1959 to 1980-1985.*" [Note: the most recent - 1995-1998 nitrogen loading is only about 1.33 million m tons, which indicates that the nitrogen loading has decreased by about 30% from its peak.]

"*To calculate the potential increase in phytoplankton production rates for the continental shelf that might occur because of the increased nitrogen loading since the 1950s, we assumed that there has been a 100% increase in loading (Figure 6).*" (Turner and Rabalais. 1991).

Later: "*The Mississippi River system encompasses 41% of the conterminous United States and delivers 580 km^3 of fresh water, 130.3 million kg atoms of nitrogen* [1.824×10^9 kg N], *and 210×10^6 tons of sediment to the Gulf yearly.*"

Executive Summary:

Nitrate concentrations in the Mississippi River and some of its tributaries in the upper Midwest are 2- to 5-fold higher than in the last century.

Nitrate flux from the Mississippi Basin to the Gulf of Mexico has averaged nearly 1 million metric tons per year since 1980 and is about three times larger than it was 30 years ago. " (Goolsby, et al.,1999).

And yet later:
"*Nitrogen (N) is the principal nutrient yielding excess organic matter sedimentation to the Gulf hypoxia zone. Nitrogen export from the Mississippi River Basin has increased 2- to 7-fold over the last century.*"

"*The majority of Mississippi River N originates from agricultural practice, while smaller fractions arise from human sewage, nonagricultural fertilizer use, and precipitation. The Mississippi River exports 1.8×10^9 kilograms (kg) (about 2 million short tons) of N each year.*" (Downing et al., 1999).

With the final - or at least, most recent - retelling, background primary productivity drops to as low as 17.4 g C/m^2-yr. With this, they have conducted a revisionist transformation of America's historic "*Fertile Fisheries Crescent*" into “America's Dead Sea”.

There are many reports documenting the productivity of the waters of the Northern Gulf.

Even Diaz et al. (1999) provide fleeting reference to the role of the major rivers in increasing fisheries productivity: *"The most productive fisheries zones around the world are always associated with significant inputs of either land(runoff) or deep oceanic (upwelling) derived nutrients (Hempel 1965)."* However, they make no attempt to estimate the magnitude of the increase in fish productivity due to nutrients from the land or upwelling. And yet, almost half a century ago, Gunter talked extensively about the fertility of the *"Fertile Fisheries Crescent"*:

"Russell and Howe (1935) have pointed out that the Mississippi may be termed the 'Father' of Gulf coast geology and geomorphology. It has a commensurate relation to the estuarine life in the region. The center of production of the white shrimp (Penaeus setiferus), of the South Atlantic and Gulf Coasts of the United States, is in Louisiana...the importance of the Mississippi River to the life of the adjacent sea is self-evident and there is no need to belabor the point."

"It is obvious that changes in the vast river system, even those which might be negligible or transient from the geological view, would have far-reaching effects upon the life of the valley and the marine areas at its mouth."

"The Atchafalaya River follows an old bed of the Mississippi...Eighty to ninety years ago there was a little footbridge across it...near the present town of Simmsport...Today at minimum stages the Atchafalaya is exceeded in flow only by the Ohio and the Mississippi rivers...In short the Atchafalaya has grown in a hundred years' time from a small stream or bayou to one of the major rivers of America. Obviously it has effected great changes in the marine area at its mouth...there is little wonder that Riley (1937) found that the Mississippi exerted a great influence on the fertility of the adjacent area of the Gulf. The Barataria-Terrebonne bay region has lost in these [nutrient] *materials and the Atchafalaya Bay region has gained...possibly the well-known shrimp productive capacity of the Morgan City area of the Louisiana Coast is a partial result of* ***increasing fertility of the region due to the increased flow of the Atchafalaya River.***" (Gunter, 1952) [emphasis added].

Boesch (1995) recognizes that *"The relationship of high fishery productivity to the enriching effects of the Mississippi River has long been known and led Gordon Gunter (19- -) to refer to the region as "the fertile fisheries crescent."* Boesch goes on to ask the important question, *"Is there a positive benefit of this enrichment and how does it compare with any negative effects?"* Due to its exclusive focus on the possible negative effects, the National Hypoxia Assessment has failed totally to even attempt to answer this question.

The National Hypoxia Assessment concludes that eutrophication and hypoxia in the Northern Gulf have increased coincidently with increases in nutrient loads from the MARB, especially from fertilizer use. The results of sediment analyses are stated to show these relationships. In particularly, the sediment coarse fraction and glauconite are considered to be indicators of oxygen stress and related closely to fertilizer use. Figures 2 and 3 show the data on sediment coarse fraction and glauconite with the linear trend removed [linear trends were included in the original article by Nelson et al., 1994]. Figures 2 and 3 show that there is no correlation between the sediment coarse fraction and glauconite and fertilizer use. The sediment coarse fraction values are the same in 1990 as they were at the start of the century, while fertilizer use in the USA has increased to over 50 million tons! Glauconite increased in the 1930s, when fertilizer use was still very low. Glauconite values in 1990 were the same as in the late 1930s! Again, loose relationships simply do not hold up under careful scrutiny.

In summary, the speculations of the National Hypoxia Assessment are so poor that they not only fail external reality checks, they are also internally inconsistent in that they literally do not add up. A comparison of measurements of the rate of primary productivity on the Louisiana continental shelf in the 1950s and in recent years demonstrate that the rate of primary productivity in these waters has decreased, not increased. The assumptions upon which the conclusion of an increase in the rate of primary productivity has been derived in the National Assessment are erroneous and lead to absurdly low estimates of the rate of primary productivity in earlier decades.

It is our conclusion that we should not abandon science, historic fact, and reason for a loose sea of erroneous speculations. It is a decrease in the rate of primary productivity that should be of major concern to ecosystem and fisheries productivity. Studies in other parts of the world (e.g., the Mediterranean Sea and Yellow Sea) have documented collapse of fisheries as riverine nutrient fluxes have diminished. As well as being concerned about hypoxia, commercial fisherman and environmentalists should also be concerned about declining productivity.

Comment 3. The annual flux of nitrogen from the MARB ***"...is estimated to be 2.2 to 6.5 times higher than baseline "pristine" conditions for the North Atlantic Basin (Howarth, 1998)"*** **and has** ***"...approximately tripled during the last 30 years..."*** **(Goolsby et al., 1999).**

The flux of nitrogen means the flux of inorganic+organic nitrogen, i.e., nitrate, nitrite, ammonia, and organic nitrogen. The DIA, like Goolsby et al., (1999), does not report any organic nitrogen or ammonia prior to the 1970s, although Goolsby et al. do acknowledge that hundreds of data points exist. In a presentation to the Task Force in Chicago on November 18, 1999, Don Pryor (NOAA), in attempting to refute our July 27 review, presented data on estimated total nitrogen concentrations at St.Francisville starting with 2.24 (2.80) mgN/l in 1905-06, increasing to 2.60 (3.25) mgN/l in 1955-65, and 5.80 mgN/l in 1980-96, and compared the estimated 5.80 mgN/l in1980-96 with the measured value of 2.26 mgN/l - presumably to demonstrate that assuming a constant 4-fold nitrate increase over time does not match the measured 1980-96 value. We agree that such calculations are not meaningful. This is not what we stated in our July 27 comments, which was as follows:

Organic nitrogen plus ammonia concentration was reported to be about 4-6 times higher than the nitrate plus nitrite concentration [note: data on all forms of nitrogen are included in, for example, the Leighton (1907) report cited by Report 3, but Report 3 chooses only to include the nitrate data]. Applying a 4:1 ratio of organic nitrogen plus ammonia to nitrate plus nitrite at St. Francisville for 1905-06 (nitrate = 0.56 mg/l - Report 3, Table 3-4), it can be concluded that the concentration of total nitrogen in the Lower Mississippi River almost one hundred years ago would have been about 2.8 mg/l. Applying this same ratio of organic nitrogen plus ammonia to nitrate plus nitrite ratio for St.Francisville for 1955-65 (nitrate = 0.65 mg/l - Report 3, Table

3-4), it can be demonstrated that the concentration of total nitrogen in the Lower Mississippi River some 40 years ago would have been about 3.25 mg/l. These figures compare with a mean concentration of total nitrogen at St. Francisville of 2.26 mg/l for the period 1980-1996 (Report 3, Table 3.1), and less than 2.0 mg/l in the most recent years.

The points we have constantly made are that: i) a high percentage (60-80%) of total nitrogen in the Mississippi River at the turn of the century was as organic nitrogen+ammonia; ii) the organic nitrogen+ammonia load reached a maximum mid-century; iii) organic nitrogen+ammonia and total nitrogen have decreased since mid-century; and iv) nitrate+nitrite has increased since mid century. The figures of total nitrogen at St.Francisville of ~2.8 mgN/l at the start of the century, ~3.25 mgN/l mid-century, and 2.2 mgN/l in recent years reflect these changes. The data provided in Figure 2.4 of the DIA substantiate a decrease in the organic nitrogen+ammonia fraction of total nitrogen from 39% in 1980-1996 to ~26% in 1994-1998, continuing the decreasing trend..

Data at many points in the MARB in mid-century demonstrate high organic nitrogen+ammonia values in the MARB. The National Hypoxia Assessment has failed to identify and utilize these data, has failed to identify the high organic nitrogen+ammonia loadings mid- century (probably from a combination of many factors including newly-cultivated fields, large amounts of animal and human wastes, streambank erosion etc.), and failed to identify the massive clean-up that has occurred in the MARB in the past 4 decades. By the time we get into the 1970s and 1980s, much of the clean-up has already taken place. At Havana on the Lower Illinois River, mean annual ammonia concentration in 1967-1969 was 1.4 mgN/l (USGS) - 9-fold greater than at nearby Valley City in 1980-1996 (Goolsby et al., 1999). Mean nitrate concentration at Meredosia, near Havana, in the late 1960s was ~6.1 mgN/l, giving a mean concentration of total nitrogen >7.5 mgN/l. In the Upper Illinois River, mean TKN in 1973-1976 was 6.3 mgN/l and nitrate+nitrite 2.9 mgN/l, for a mean concentration of total nitrogen of 9.2 mgN/l. By 1991-1994, TKN had been reduced to 2.22 and nitrate+nitrite had increased to 3.61 mgN/l, for a mean concentration of total nitrogen of 5.83 mgN/l. Mean concentration of total nitrogen in the Illinois River at Peoria Lake in 1967 was >8.5 mgN/l. Mean concentration of total nitrogen at La Grange Lock and Dam in 1993-1998 had declined to 4.8 mgN/l (USGS). Had the concentration of total nitrogen in the Illinois River increased 3 fold since mid-century, it would today be 20-30 mgN/l!

Data since 1980 have a higher proportion of oxidized forms of nitrogen to reduced forms of nitrogen and lower values of total nitrogen relative to mid-century indicating the cleansing of the system that has occurred.

In Illinois, the cleansing of rivers and streams throughout the state is well documented by the Illinois Environmental Protection Agency (IEPA, 1984). In 1972 only 17.8% of the municipal wastewater treatment facilities were in compliance with discharge permit requirements. From 1972 to 1982 nearly 900 wastewater improvements were completed. Discharge from industrial and human waste in 1982 was a small fraction of the peak in 1922. However, 90% of the flowing water problems in 1982 were still attributed to municipal and industrial sources; non-point sources contributed only 10% of the problems.

Similar improvements were made throughout the MARB at this time. The severe nitrogen (and other) pollution earlier in the century and the clean up in recent decades is not restricted to the Illinois River.

Table 1 shows measured data on total nitrogen concentrations in various rivers in the MARB at the start of the century and in the 1990s. It should be noted that many changes have occurred over time in sampling frequency, methods, storage, analytical methods etc. Climate has also varied over time. Water diversions have taken place. The physical, biological, and chemical features of the rivers and watersheds have changed. All of these, and other factors may make accurate comparison of historical and recent data difficult.

A simple factor such as precipitation, for example, can influence the concentration of nutrients as well as their flux. In Illinois, there is a positive correlation in 1978-1998 between annual precipitation state-wide and the mean nitrate+nitrite concentration in rivers and streams (Figure 4); nitrate concentration in drought years is lower than in non-drought years. The1890s and early 1900s were characterized by drought in Illinois and the mean concentration of total nitrogen at Havana, and nitrogen flux calculations, should be adjusted upwards in order to meaningfully compare values at the start of the century with those in 1980-1996, the latter being a period of considerably higher rainfall. More appropriately, mean nitrogen concentration, and flux, in Illinois in 1899-1901 should be compared with mean nitrogen concentration, and flux, in 1987- 1989, as in both periods mean annual precipitation in Illinois was 32 ins, compared to the 1980- 1996 mean of just over 40 ins. As in all environmental analysis, great caution needs to be exerted in comparing samples from different time periods, especially when comparing data for 1-5 years with data from 17-19 years.

Similarly, streamflow in the Middle Mississippi River in1898-1902 was ~40% lower than in 1980-1996 (Goolsby, December 3, 1999, St. Louis) and the mean concentration of total nitrogen in 1898-1902 should be adjusted upwards in order to meaningfully compare values at the start of the century with those in1980-1996. More appropriately, mean nitrogen concentration, and flux, in 1898-1902 should be compared with mean nitrogen concentration, and flux, in 1987- 1989 - both drought periods. In the Lower Mississippi River, streamflow in 1897-1902 was about 23% lower than in 1980-1998, and the mean concentration of total nitrogen in 1898-1902 should be adjusted upwards in order to meaningfully compare values at the start of the century with those in1980-1998. More appropriately, mean nitrogen concentration, and flux, in 1897- 1902 should be compared with mean nitrogen concentration, and flux, in 1987-1989 - both drought periods. Also, at the start of the St. Francisville and Grand Chain records in the mid- 1950s precipitation was low: US average precipitation in 1952-1956 was 26ins and in 1979-1984 it had increased to 31 ins. In order to make meaningful comparisons, adjustments need to be made at other stations for precipitation and other factors. [Note: USGS/LTRM (1999) gives the discharge of the Illinois River in the 1990s as 650 m^3/sec.]

TABLE 2. MEASURED CONCENTRATION OF TOTAL NITROGEN (mgN/l)

Lower Illinois River

	total nitrogen
1894-1900, Havana	3.4
1896, Havana	4.3
1980-1996, Valley City	5.5
1993-1998, La Grange	4.8

Had total nitrogen increased 2.2 - 6.5 times, it would today be between 7.5 and 22.1 mgN/l.

Missouri River

1899-1900, Fort Bellfontaine	2.4
1980-1996, Hermann	2.2

Had total nitrogen increased 2.2 - 6.5 times, it would today be between 5.3 and 15.6 mgN/l.

Mississippi River (between St. Louis and Cairo)

1899-1900, Chain of Rocks	2.4
1980-1996, Thebes	3.6
1990s, Cape Girardeau	3.0

Had total nitrogen increased 2.2 - 6.5 times, it would today be between 5.3 and 19.5 mgN/l.

Given the data in Table 2 and the above uncertainties, we conclude that the concentration of total nitrogen in the Lower Illinois River, the Lower Missouri River, and the Middle Mississippi River (representing all the water from the Upper Mississippi and Missouri Rivers) is about the same (+/- ~40%) today as it was about a century ago. Concentrations of total nitrogen generally increased to mid-century and subsequently decreased. MARB waters have changed from being organic-rich to being inorganic-rich, which is what we would expect as inputs of total nitrogen have decreased, more dissolved oxygen is available to decompose organic nitrogen+ammonia, no-till and reduced-till practices have been implemented etc.

Similar decreases in total nitrogen and organic nitrogen and an increase in nitrate have been recorded in the River Rhine in Europe. The authors (Admiraal and Botermans, 1989) attribute these changes to the increased availability of dissolved oxygen and decreased toxicity.

In addition, Goolsby et al. (1999) show that the concentration of nitrate in the Lower

Ohio River has not increased since the 1950s; indeed it increased from the 1950s to about 1970 and then decreased. No data are presented for organic nitrogen+ammonia, or total nitrogen, prior to1980, except for the Lower Mississippi River back to 1973. Data in Table 2 indicate that the concentration of total nitrogen is slightly lower in recent years than at the start of the century.

The following is a summary of key findings by Goolsby et al. (1999), followed by an analysis to show that these findings can not be substantiated by the data presented.

1. *"Analysis of historical records shows that the concentration of nitrate in the Mississippi River and tributaries in the Upper Mississippi basin have increased by factors of 2 to 5 since 1900. The current average annual N flux from the MARB to the Gulf of Mexico is about 1.6 million [1,567,000] tons. The annual flux has approximately tripled during the last 30 years with most of the increase coming between 1970 and 1983. Expressed as a yield, the average total N flux for 1980-96 is 497 kg/km2/yr and it is estimated to be 2.2 to 6.5 times higher than baseline "pristine conditions for the North Atlantic Basin (Howarth, 1998)." "For the first 15 years of this period (1955-1970) the nitrate flux averaged 328,000 t/yr. However, for the last 17 years of the period (1980-96) the nitrate flux averaged 952,700 t/yr [933,500 m tons without the Red and Ouachita Rivers], almost a 3-fold increase." "Essentially all of this trend occurred between about 1970 and 1983."*

2. Total nitrogen flux for the Ohio River Basin (1980-1996) is 495,900 m tons, for the Missouri River Basin 239,100 m tons, for Mississippi River at Thebes (minus Missouri River) 600, 000 m tons, for the Arkansas River and the Lower Mississippi River Basin 170,000 m tons, and for the entire Mississippi River, including the Atchafalaya River diversion, 1,507,000 m tons.
3. The concentration of nitrate in the Lower Mississippi River decreased from 1954 to the late 1960s and then increased to about 1980. *"In contrast, nitrate concentrations appear to have changed very little in the lower Ohio River over the last four decades. These long-term data would indicate that the increase in nitrate concentrations at St. Francisville could not be attributed to water from the Ohio River basin. Instead, the increase must be caused primarily by increased nitrate concentrations in water entering the Mississippi River from other sources." "These samples* [for the Ohio River at Grand Chain] *do not show the trend in nitrate concentration shown in the St. Francisville data."*

4. *"It should be noted that the average annual streamflow has increased significantly over the 1955-1997 time period that is the focus of this report." "The combination of higher nitrate concentration and higher streamflow, and possibly decreased denitrification, in the 1980-96 period would produce significant increases in nitrate flux." "... and has led to a 3 fold increase in N flux to the Gulf of Mexico."*

5.*"Given the assumption that nitrogen is conservative in large rivers, ..." "... no significant denitrification losses occur between the outlets of the interior basins and the Gulf of Mexico."*

In addition, the CAST report (Downing et al., 1999) contains the following conclusion about river discharge: *"However, the Mississippi River's discharge has increased only slightly since the 1900s, while N flux has increased more." "Thus, long-term biological responses in the surfacewaters near the Louisiana coast probably are not due to changes in amount or* *distribution of freshwater runoff and resulting stratification, but rather due to changes in water quality." "Freshwater flux from the Mississippi River has remained relatively constant since the 1940s (Meade, 1995), ..., while N exports have increased substantially."*

Analysis

1. No data are presented on nitrogen concentrations and fluxes for any of the rivers prior to 1973.

2. Data in Figure 2.4 of the DIA show that mean annual nitrogen flux from the Mississippi River to the Gulf in 1973-75 was ~1,300,000 m tons, which is the same as for 1994-98. If it is claimed that nitrogen flux increased from the mid-1970s to about 1983, then it should also be stated that nitrogen flux since the 1980s and early 1990s has reversed to the levels of the mid-1970s. There has not been a sustained increase in nitrogen flux since the early 1970s and no data on nitrogen flux are presented prior to the 1970s.

3. If nitrogen flux from the Mississippi River to the Gulf has increased 3 fold over the last three decades, then nitrogen flux in the late 1960s must have been ~500,000 m tons.

4. SCENARIO 1: ANALYSIS OF NITROGEN FLUX TRENDS SINCE ~1970 ASSUMING CONSTANT PRECIPITATION AND STREAMFLOW, CONSTANT NITROGEN CONCENTRATION IN THE OHIO, MISSOURI, ARKANSAS, AND LOWER MISSISSIPPI RIVER BASINS, AND INCREASING NITROGEN CONCENTRATIONS IN THE UPPER AND MIDDLE MISSISSIPPI RIVERS.

o Assuming that nitrogen concentrations in the Ohio, Missouri, the Arkansas River and Lower Mississippi River Basin have not increased, the nitrogen fluxes for these rivers ~1970 must have been the same as in 1980-96, i.e. ~900,000 m tons, which is already ~ 400,000 m tons above the assumed baseline flux of ~500,000 m tons of nitrogen. Based on Goolsby et al. data showing that concentration of nitrate in the Ohio River has decreased since ~1970 and, on the continuing assumption that nitrogen concentrations in the Missouri, the Arkansas River and Lower Mississippi River Basin have not increased, the nitrogen fluxes for these rivers ~1970 must have been considerably higher than ~900,000 m tons, and much higher than the assumed baseline flux of ~500,000 m tons of nitrogen. Even if nitrate concentrations in the Upper and Middle Mississippi Rivers were zero, the ~500,00 m ton nitrogen background scenario is totally implausible.

6. SCENARIO 2: ANALYSIS OF NITROGEN FLUX TRENDS SINCE ~1970 ASSUMING INCREASED PRECIPITATION AND STREAMFLOW, CONSTANT NITROGEN CONCENTRATION IN THE OHIO, MISSOURI, ARKANSAS, AND LOWER MISSISSIPPI RIVER BASINS, AND INCREASING NITROGEN CONCENTRATIONS IN THE UPPER AND MIDDLE MISSISSIPPI RIVER BASINS.

o. Assuming that nitrogen concentrations in the Ohio, Missouri, the Arkansas Rivers and Lower Mississippi River Basin have not changed, but higher precipitation from 1970 to 1983 has resulted in increased nitrogen flux of, say, 30%, then the nitrogen fluxes for these rivers ~1970 must have been ~700,000 m tons, which is already ~200,000 m tons above the assumed baseline of ~500,000 m tons. Based on Goolsby et al. data showing that concentration of nitrate in the Ohio River has decreased since ~1970, and on the continuing assumption that nitrogen concentrations in the Missouri, the Arkansas River and Lower Mississippi River Basin have not increased, the nitrogen fluxes for these rivers ~1970 must have been considerably higher than ~700,000 m tons. Again, even if nitrate concentrations in the Upper and Middle Mississippi Rivers were zero, this ~500,00 m ton nitrogen background scenario is totally implausible.

Conclusion

- There is no foundation presented for the conclusion that nitrogen flux has increased 3 fold from ~1970. Nitrate concentration in the Lower Mississippi River can not be regarded simply as the "tail pipe" of everything happening in the Middle and Lower Mississippi River. Either the data are wrong or nitrogen biogeochemistry is highly complex.

Comment 4. The prime cause of the increase in nitrogen flux is agricultural activities throughout the MARB, with *"...fertilizer plus the inorganic nitrogen pool to be the largest source..."* (Goolsby et al., 1999).

Figures 5-9 show that throughout the MARB there is no statistically significant relationship between fertilizer use and the concentration of nitrate in the major rivers. The best data we have on the concentration of total nitrogen is that there is a negative correlation between total nitrogen and nitrogen fertilizer use. We conclude that the increase in nitrogen fertilizer is of lesser importance in accounting for changes in nitrogen concentration in the major rivers in the MARB than other factors. For example, Figure 4 shows a much stronger positive correlation between rainfall and nitrate+nitrite throughout Illinois than do Figures 6-9 for fertilizer use. The effect of fertilizer use and other nitrogen inputs may be reflected in rainfall events, but more detailed analysis is required to understand nitrogen concentrations and fluxes.

Figure 10 shows that the Illinois River was hypoxic earlier in the century, due to high biochemical demand, and that the concentration of dissolved oxygen has increased dramatically in recent decades, as has the proportion of oxidized forms (nitrate+nitrite) of nitrogen. Similar trends are observed on the Upper Mississippi River. As oxygen is essential in the production of nitrate, changes in oxygen availability and demand illustrate two factors that need to be considered in nitrogen cycling.

Also, the question needs to be answered, "How can a decreasing trend in nitrate concentration from 1954 to the late 1960s the in the Lower Mississippi River be explained when nitrate concentration in the Ohio, Middle Mississippi and Illinois Rivers and fertilizer use were increasing? Similarly, how can one explain a decrease in nitrate concentration in the Ohio and Illinois Rivers from about 1970 to1980 and a leveling in the Middle Mississippi when fertilizer use was still increasing rapidly?

We need to document thoroughly the water-quality changes over time throughout the MARB, then seek to quantify nutrient flux changes, and finally identify and quantify all the major variables that can help explain the changes, ra•ther than continuing to force-fit a simple theory that does not explain the temporal and spatial variations in water quality. First, all the data need to be checked carefully for quality and consistency.

Also, trying to apply simple global relationships such as a constant nitrate:total nitrogen ratio, fluxes throughout the North Atlantic Basin, a world rivers approach etc. to the specific conditions in the MARB do not yield meaningful results for "pristine" conditions in the MARB. Maybeck's data, for example, *"are based mainly on major rivers from the subarctic and tropical zones which are still unpolluted and on smaller streams for the temperate zone. "* (Maybeck (1982). Maybeck insistently notes the poor scientific confidence level of the data, recognizes that *"it is very difficult to relate nitrate levels with environmental parameters", and* assumes that high levels of nitrate seen in temperate zone rivers are from pollution: *"In the temperate zone much higher levels are found in most major rivers probably as a result of pollution ... "* Maybeck does compellingly make the case for biogeochemical transformation of nitrogen between different forms in the aquatic system being quite robust.

If the National Hypoxia Assessment persists in comparing conditions in the MARB with other rivers of the words, it should include a more balanced perspective. For example, it should show that river export of nitrogen (in kg per km^2 per year) for the Mississippi River is 2 times less than the Hudson River, 3 times less than the Delaware River, 3 times less than the Yangtze River, 6 times less than the River Thames, and 9 times less than the River Rhine (Caraco and Cole, 1999). Caraco and Cole also conclude that *"Although the underlying factors for variable (or constant) N retention across systems are not fully understood, we know that at present retention of N on the regional scale is large. "*

In developing technical guidance for nitrogen criteria, USEPA recognizes the great diversity of ecoregions within the USA and the MARB. It is environmental conditions within these ecoregions that will be used to set background/reference conditions. The Illinois State Water Survey is currently engaged in a project to investigate the specific background conditions within ecoregions, taking into account landscape changes, animal populations, soils, etc., and using nutrient data from virgin plots. etc. As with Gulf primary productivity, real data for the MARB are much more relevant and meaningful.

Mayer et al. (1998) conclude that the modern Mississippi River delivers about 40-45% of its nitrogen via particulates and that the percentage of total river nitrogen loading (excluding DON) from particulate nitrogen has decreased from 58.2% in 1950-1952 to 39.9% in 1973-1982. The extent to which the increase in dissolved inorganic nitrogen has been compensated by a decrease in particulate-borne nutrient inputs needs to be calculated. In the Amazon River, on the other hand, percentage of total river nitrogen loading from particulate nitrogen has increased from 40.7 to 79.2%.

Also, changes in the flux of particulate organic material need to be incorporated in reconstructions of historical nutrient fluxes. In the Illinois River, for example, the flux of phytoplankton into the Mississippi River at the start of the century has been estimated at ~300,000 tons (Kofoid, 1904). Assuming a 6:1 carbon:nitrogen ration, then some 50,000 tons of nitrogen were exported from the Illinois River each year - equivalent to ~ one third of the mean annual flux of nitrogen in 1980-1996 estimated by Goolsby et al., (1999). This biological reservoir for nitrogen had largely disappeared by mid-century and probably contributed to the increase in the concentration of dissolved nitrogen in the Illinois River.

Comment 5. The possibility that hypoxia might be due in any significant way to natural processes is discounted (Rabalais, et al., 1999; Diaz, et al., 1999).

The Assessment Plan (http://www.cop.noaa.gov/HypoxiaPlan.html) acknowledges that " *Hypoxia occurs naturally in many parts of the world (e.g., Black Sea, Baltic Sea, Chesapeake Bay, New York Bight)* "and that "... *hypoxic and anoxic environments have existed throughout geologic time...* ". Rabalais, et al. (1999), acknowledges that *"Hypoxia occurs in many parts of the world's aquatic environments. Hypoxia and anoxic (no oxygen) waters have existed throughout geologic time ....*" *"The largest zone of oxygen-depleted coastal waters in the United States, and the entire western Atlantic ocean, is in the northern Gulf of Mexico on the Louisiana/Texas continental shelf.* " "Gulfwatch (1996) acknowledges that *"One of the difficulties of dealing with the hypoxia issue is that seasonally low dissolved oxygen in water bodies can be a natural phenomenon or a man-made disaster, according to the science presented at the December conference.* " The DIA acknowledges that *"Very low levels of dissolved oxygen occur naturally.....* ". However, the National Hypoxia Assessment fails to explore in any depth the hypothesis that hypoxia in the Northern Gulf might be due in significant part to natural processes. After cursorily mentioning natural hypoxia, contemporary hypoxia in the Northern Gulf of Mexico is simply defined as a man-made problem.

The National Hypoxia Assessment and Downing et al. (1999) leave the reader with the impression that natural hypoxia occurs in only a few parts of the ocean and no hypoxic area larger than that in the Northern Gulf exists off US shores. This is totally misleading. Diaz, lead author of Report 2, is the lead author of a scientifically peer-reviewed article on global hypoxia (Diaz and Rosenberg, 1995) which shows that millions of square miles of the world ocean are naturally hypoxic, including all the coast from the US/Canada border down to Chile. A similar map of natural hypoxia in the world ocean is shown in Figure 11. If hypoxia had been defined as <2 mg/l of dissolved oxygen, as in the National Hypoxia Assessment, then the extent of the world ocean that is naturally hypoxic would be even larger. Diaz and Rosenberg (1995) find that hypoxia on, for example, the continental shelf off Peru is found in waters only 20m deep, similar to the Northern Gulf of Mexico. Other scientific articles show natural hypoxia occurring on the continental shelf in many parts of the world. And, as many parts of the world ocean are not well studied, we do not know the true extent of coastal hypoxia.

Off the coast of France, hypoxia developed over a large area when a dam burst after heavy rainfall. In the New York Bight, hypoxia developed due to the upwelling of nutrients and anomalous currents.

The occurrence of severe oxygen depletion in continental-shelf waters is of great interest to geologists and oil companies, due to the fact that perhaps 80% of the world's petroleum has been generated from ancient organic-rich sediments created by oxygen depletion on continental shelves with river deltas being the classic oil-bearing formation (Tyson and Pearson, 1991). The reason there are some 3,000 rigs in the Northern Gulf is not because they are fishing for shrimp, but because they are drilling for petroleum. And why are they drilling there (and in places like Oklahoma and Texas)? Because in the past these were the locations of hypoxic and anoxic conditions in continental-shelf waters adjacent to the discharge of the paleo-Mississippi River. But then, we are forced to ask ourselves, how can hypoxia (and anoxia) have formed in continental-shelf waters adjacent to the discharge of the Mississippi River in the absence of input from nitrogen fertilizer and other human activities? The National Hypoxia Assessment needs to answer this question. Simply because hypoxic conditions in the Northern Gulf are dynamic in the present era and man-made hypoxia occurs in other parts of the world should not lead to an automatic definition of hypoxia in the Northern Gulf as a man-made problem.

The National Hypoxia Assessment would have benefitted greatly from the inclusion of some petroleum geologists on the teams.

The following are some examples of the findings in one of the most prestigious books on hypoxia and anoxia - Tyson and Pearson (1991).

- Oxygen depletion in modern shelf environments.

  "*However, on the shelves the supply of organic matter is probably a less critical variable, as there are often adequate amounts to result in some degree of oxygen depletion (at least 50%) provided that the downward mixing of oxygenated surface water is sufficiently restricted by vertical density gradients(pycnoclines) produced by surface warming (thermoclines), fresh-water run-off (haloclines), or a combination of the two.*" (Tyson and Pearson, 1991).

- "*Where the inclined thermocline extends over the upper slope and narrow shelves on the western coasts of the continents between latitudes 15 and 40 deg, wind-driven coastal upwelling can tap nutrient-rich water from below the pycnocline (100-200m) and result in very high productivity in the euphotic zone (Barber and Smith 1981; Barber and Chavez 1986). Bottom currents permitting, this leads to the deposition of very organic-rich shelf and upper slope sediments with very high oxygen demand.*" (Tyson and Pearson, 1999)

- In the New York Bight "*... the principal supply of nutrients to the Bight as a whole is from the advection of deeper slope waters onto the shelf (Falkowski et al. 1980).*" "*Many similarities of the New York Bight event occur regularly on the Louisiana shelf.*" "*As spring progresses and the Bermuda high pressure system intensifies, the winds along the Mexican and southern Texas coasts become southerly and favour upwelling. A convergence zone develops along the southern Texas coast. This region moves progressively northward and eastward during the summer season.*" (Boesch and Rabalais, 1991).

The DIA finds that "*occasional summer upwelling of oxygenated water from the deeper* *shelf waters* "occurs, but does not quantify the upwelling of nutrients. The DIA concludes that " *only increased nutrient loads from the Mississippi/Atchafalaya River system can account for the magnitude of the hypoxic zone and its increase over time in a non-contradictory manner.* " However, this itself is a contradictory statement, since the assessment reports also conclude that " *The relative contribution of offshore sources of nutrients from upwelled waters of the continental slope is unknown.* " Again, the question must be asked, what processes on shallow continental shelves, both today and throughout the geologic past, cause large areas of natural hypoxia in the absence of human-induced increases in nutrient loads? Perez et al., (1999) in studying upwelling in shallow waters off the Yucatan Peninsular conclude that: "*The high biomass observed at the front may be actively exported through the food web to adjacent or remote regions in the Gulf of Mexico.* " Maps of mean oceanic circulation in the Gulf demonstrate that nutrient-rich waters from the Yucatan move northward with the Loop Current and can be directed to the west of the Mississippi River delta (Leipper, 1954).

In the extensive hypoxic zone along the Pacific coast, "*The California Current System (CCS) is one of the best sampled ocean regions, yet it remains obscurely understood and inadequately sampled.* " "*Because of the resupply of nutrients by coastal upwelling, the CCS has high biological productivity.* " "*The CCS was once thought of as a sluggish eastern boundary current driven by coastal upwelling and characterized by broad, weak equatorward flow.* " Research is revealing many energetic, seasonally dependent flow regimes with diverse characteristics, including a rich eddy field (Miller et al., 1999).

Upwelling and other dynamic processes on the continental shelf, the continental slope, and other parts of the Gulf of Mexico and their significance as sources of nutrients in the hypoxic zone need to be evaluated rigorously. The National Hypoxia Assessment concludes that there is no physical connection between the hypoxia on the continental shelf and the oxygen minimum zone in deeper waters. However, the upwelling and transport of nutrients from deeper waters to the shelf has not been quantified, as is expressed in the conclusion that "*The relative contribution of offshore sources of nutrients from upwelled waters of the continental slope is unknown.* "This source of nutrients may have contributed to the high rate of primary productivity recorded in the 1950s by Sklar and Turner (1981) and Mishke et al. (1970).

That recovery from summer hypoxia in the Northern Gulf is rapid is also stated clearly in the book by Tyson and Pearson (1991): "*On the Louisiana-Texas shelf, large-scale hypoxia occurs virtually every year and recovery from the disturbance is rapid, because the community is kept in an early successional state by the annually recurring hypoxia.* "(Boesch and Rabalais, 1991)

A one year event that may be exemplary of the importance of long-term changes in sediment fluxes is described by Boesch and Rabalais (1991): "*From June through August of 1988, flow rates were about 4000m3/sec. It was not surprising, therefore, that there was less of an effect on the surface salinity field on the Louisiana continental shelf in summer of 1988 than in the three previous years.* " "*During this period of low river flow in mid-summer 1988, areas of bottom waters seriously depleted in oxygen were minimal.* " "*Reduced river flow, however, was accompanied by reduced sediment loads and increased water clarity across the continental* *shelf. Because of the exceptional water clarity in mid-summer 1988 primary production was occurring in bottom waters as deep as 30m, as shown by the high concentrations of chlorophyl a in bottom waters. The result was a high level of per cent oxygen saturation in bottom waters, or even conditions of supersaturation, compared to 1985-1987 when values were 20% saturation or less. Thus the weak stratification, which facilitated reaeration, was accompanied by photosynthetic production of oxygen in bottom waters, and the water column as well oxygenated from surface to bottom."*

The same logic needs to be applied to evaluate in detail the impact on stratification in the Northern Gulf of the long-term changes of the influx of fresh water from the Atchafalaya River and the impact of the ~50% decrease in sediment load from the MARB and its impact on photosynthesis and productivity. These changes are complex and may be either mutually reinforcing or offsetting.

The National Hypoxia Assessment has steadfastly failed to evaluate thoroughly the role of natural processes such as:

- the annual loss of 30-40 square miles of nitrogen- and carbon-rich Louisiana wetlands and marshes;
- the impact on coastal ecosystems of the capture of the Red River and part of the Mississippi River by the Atchafalaya River;
- the amount of nitrogen fixation in coastal waters, sediment, and vegetation;
- the amount of denitrification in estuaries, bays, and coastal waters;
- the impact of changes in coastline and sea-floor morphology (e.g., accelerating massive loss of barrier shoreline resulting in more intimate connection of the "dead zone" with hypertrophic coastal estuaries and wetlands; extrusion of nutrient-rich, 10-20 ft high mud lumps (mud diapirs), etc.);
- the magnitude and impact of fluxes of nutrients from deeper waters;
- the impact on light availability and primary productivity of a reduction in sediment transport of about 50%; [Report 4 finds that *"Dissolved oxygen concentrations were more sensitive to variations in light extinction coefficients and saturation light intensities than to variations in any other process parameters."*]
- the roles of the flux and resuspension of organic material brought down from the MARB and coastal zones;
- changes in meteorological and climatic factors.

Geomorphic and water-quality responses to change in flow are not instantaneous (as implicitly assumed). Atchafalaya mud stream, wetland decay, loss of barrier coastline, mud lumps, etc are not instantaneous responses to change in flow, but are decades time-delayed, time-accelerating responses to change in flow and geomorphic processes. It is inconceivable that the largest river capture in the modern world with a flux of water directly into the center of the hypoxic zone equivalent to four times the discharge of the River Nile, compared with a trickle down the Atchafalaya Bayou in the 19th century, has been *"inconsequential"* (Downing et al., 1999). It is inconceivable that the loss of 30-40 square miles of wetlands and marshes per year with a nitrogen content 4-5 times greater than the organic-rich soils in the Midwest and the ever-more intimate connection of these decaying wetlands with the "dead zone" has been inconsequential. It is inconceivable that the changes in the geomorphology of the continental shelf, the island barriers, and the bays and estuaries have been inconsequential.

In 1982 Don Boesch edited the Proceedings of the Conference on Coastal Erosion and Wetland Modification in Louisiana: Causes, Consequences, and Options (Boesch, 1982). In his preface, Boesch recognized a geometric increase in the loss with time of Louisiana wetlands this century, culminating in a loss of 39.4 square miles of wetlands in 1980 alone. Articles in the Proceedings also documented the loss of coastal barriers, deltaic transgression, marine erosion, and the Atchafalaya mud plume (out to 63km). Turner et al. concluded that *"...canals are the causal agents for at least a majority (perhaps as much as 90%) of the present land loss, yet the Joint Committees of Natural resources of the Louisiana Legislature (1981) included no major programs for mitigation of canal effects ...."*

In particular, the National Hypoxia Assessment would have benefitted from using more the concepts of biogeochemical cycles, mass balances, and nutrient budgets to describe and explain complicated biogeochemistry in the MARB and the Gulf. For example, calculation of nitrogen mass balance in the MARB should quantify not only the components already identified in Goolsby et al. (1999), but also include the large historical changes in manure, human and industrial waste, flushing of N from virgin soils, changes in biomass in the rivers, changes in dissolved oxygen, light availability, changes in nutrient storage and release in the sediments, changes in precipitation etc. Analyses of historical water-quality records from Illinois and the Upper Mississippi River demonstrate the importance of including consideration of all these factors in reconstructing and attempting to explain changes in nitrogen concentrations and fluxes.

Calculation of a full mass balance in the Northern Gulf would include an open and transparent process for quantifying the inputs, storage, and fluxes of nitrogen in the hypoxic zone. This would include quantification of inputs of dissolved and particulate nitrogen from the Mississippi and Atchafalaya Rivers, from the coastal wetlands and marshes, from nitrogen fixation in the coastal waters, and from upwelling and resuspension - all under time-varying climatic, hydrological, biogeochemical, ecological hydrologic, and geomorphic conditions. Similarly, the outputs should quantify denitrification, movement of nutrients to the east and out of the hypoxic zone (Figure 12), movement of nutrients southward off the continental shelf, and movement of nutrients westward along the Gulf coast to Texas and Mexico. Figures 13 and 14 and Table 3 illustrate some of the dynamic processes that are occurring along the Louisiana coast that need to be more fully evaluated in the National Hypoxia Assessment. Full description and quantification of the oxygen and carbon cycles as they relate to hypoxia should also be developed.

Boesch (1999) takes a first cut at attempting such a mass balance for carbon and criticizes as "*simple minded*" calculations that do not take into account the geography, scale, and physical processes associated with shelf hypoxia. A similar criticism could be made of the failure to produce a comprehensive mass balance for nitrogen and oxygen in the Gulf and the failure to analyze more fully the available historical data on nitrogen, oxygen and carbon relating to concentrations and fluxes of nitrogen in the MARB.

Discussing carbon cycling, Boesch notes that *"the Mississippi is a long, nutrient-rich and well-oxygenated river that provides ample opportunity for mineralization of organic matter during transit. It is not clear how a significant portion of the labile carbon pool would travel down the river undegraded over weeks to months only to be rapidly degraded in the Gulf.... "*

Boesch notes correctly that organic nitrogen is also labile. USEPA also recognizes the importance of considering total nitrogen in setting nitrogen criteria and standards. It is also not clear, however, how a significant portion of the labile nitrogen pool (1980-1996 39% of total nitrogen in the Lower Mississippi River is organic nitrogen+ammonia (Goolsby et al., 1999) would travel down the river undegraded. Clearly, there is a lot we do not understand about nutrient dynamics in the MARB.

On the issue of the quantification of the labile amounts of allochthonous organic carbon in the hypoxic zone, Boesch concludes that *"In reality, far less than 11% of the river's organic carbon reaches hypoxic bottom waters on the shelf."* *"Several lines of evidence indicate that the fraction of the organic carbon loading that is labile or oxidizable is substantially less than 35%."* However, another line of evidence indicates that the fraction of the organic carbon loading that is labile or oxidizable is substantially greater than 35%. The organic carbon concentration of suspended sediment in the Mississippi River averages 2.28% (Malcolm and Durum, 1976), and the organic carbon concentration of the sediment in shelf waters is 0.6% (Sen Gupta, et al., 1996). What happens, then, to ~75% of the organic material, if it is not labile?

The final IA should include the results of a rigorous analysis of natural processes that can cause hypoxia in the Northern Gulf of Mexico.

6. Other comments and suggestions.

The DIA does not reflect key findings of the 6 National Hypoxia Assessment reports and other available data.

The following comments and suggestions focus on the Executive Summary. The same comments and suggestions apply to the body of the DIA and appropriate changes should be made throughout the IA.

i. Page 6. The strengths and limitations of models used in the analyses need to be incorporated. For example,

"*... these early conclusions* [of an early version of a large-scale simulation model being developed] *should not be used as the basis for policy and management decisions.*"

"*The principal reason for this model limitation is that field measurements are not available to characterize temporal variability at the shelfwide spatial scale.*" "*The results indicated that although the model represented the overall mean state of the system reasonably well, it explained an average of only 40% of the spatial variability among individual model segments.*"

ii. Page 4. Paragraph 1. It should be stated that there is no statistically significant correlation between the coarse fraction of continental shelf sediments, or glauconite, and nitrogen fertilizer use in the MARB. The coarse sediment fraction and glauconite are taken by the National Hypoxia Assessment to be indicators of changes in oxygen stress in the hypoxic zone. The per cent coarse fraction is no higher in the most recent measurement than at the start of the century. Glauconite shows a step-wise increase in the 1930s, but no trend since. Ostracods also show no trend since 1955. Nitrogen fertilizer use in the MARB only started increasing significantly after World War II.

The following major changes in the drainage basin should be added to the list in the first paragraph on page 7:

- Initial large increases in the concentrations and fluxes of carbon and nitrogen from agricultural practices, and industrial and human wastes, followed by large decreases in organic concentrations and fluxes.

- Initial decreases in the concentration of dissolved oxygen followed in the last few decades by a rapid increase in dissolved oxygen. Dissolved oxygen is the single most important indicator of water quality and is necessary for the transformation of organic nitrogen and ammonia into nitrate, followed by subsequent denitrification.

- A ~50% decrease in the flux of sediment down the Mississippi River since the 1930s. This change in sediment delivery is important to the fluxes of nitrogen, phosphorous, and carbon, and influences light availability, photosynthesis, dissolved oxygen, and primary productivity in coastal areas.

- An annual loss of wetlands and marshlands in Louisiana of 30-40 square miles per year. This, together with the loss of freshwater marshes and barrier shoreline, increases the fluxes of nitrogen and carbon into the coastal area.

- The decades-delayed breakthrough of the Atchafalaya River mudstream with subsequent increase and later breakthrough of the Atchafalaya River bedload resulting in the subsequent build-out of the Atchafalaya River delta across shallow continental-shelf waters, proceeding at a rate of ~400 yards per year, and increasing efficiency of ejecting mud directly into the geographic heart of the "dead zone".

- Increase in precipitation, especially of intense rainfall events. There is a positive correlation between precipitation and nitrate concentration. The increase in rainfall has resulted in an increase in nitrate concentration in the MARB. The National Hypoxia Assessment finds that *"Land-use characteristics are of secondary importance to climatic factors."*

- In addition, alterations in the landscape (deforestation along the rivers) have increased primary productivity in waters in states such as Illinois by decreasing the amount of shade and increasing the amount of light available for photosynthesis. In Illinois, light availability is a prime limiting factor on the rate of primary productivity.

iii. Page 7, paragraph 2. Modify the text to indicate that whereas loads of nitrate have increased in some rivers, total nitrogen in many rivers is about the same in the 1990s as it was around 1900. Organic nitrogen and ammonia contributed 60-80% of total nitrogen in MARB waters at the start of the century and in recent years (1995-1998) organic nitrogen and ammonia constitute only ~26% of total nitrogen in the Lower Mississippi. The flux of total nitrogen from the MARB has decreased since mid-century. USEPA recognizes the importance of all forms of nitrogen - total nitrogen - in setting nitrogen criteria and standards.

iv. Page 7, paragraph 2. Add the following: "Analysis of nitrate concentrations in the Lower Mississippi River, the Middle Mississippi River, the Illinois River, and the Ohio River show no consistent relationship with the use of nitrogen fertilizer in the MARB. The water and nitrogen in these rivers account for ~80% of all the water and nitrogen in the mainstem Mississippi River. Analysis of nitrate concentrations in Illinois Rivers and streams versus nitrogen fertilizer use in Illinois shows no statistically significant relationship over the last 50 years. Analysis of nitrate concentrations in Illinois rivers and streams versus the amount of precipitation shows a statistically significant relationship over the last 20 years."

v. Page 7. Add the following: "Measurements in the Northern Gulf indicate that the rate of primary productivity has decreased from the 1950s to the 1990s."

vi. Page 7. Add the following: "There is no statistically significant correlation between the annual flux of nitrogen from the MARB and year-to-year variations in the surface extent of the hypoxic zone in summer (Figure 15). This lack of correlation is further indication of the lack of a causal connection between sources and fluxes of nitrogen in the MARB and the extent of hypoxia in the Northern Gulf." The surface extent of the hypoxic zone in summer is recognized in the National Hypoxia Assessment as the benchmark for documenting year-to-year variations in the extent of hypoxia.

vii. Page 7. Add the following. "Fish productivity in the Northern Gulf is dependent to a large extent on the flux of nutrients from the MARB. A decrease in nutrient fluxes is likely to result in a decrease in fish productivity, as has been observed in other parts of the world."

viii. Page 7. Add the following key finding from Diaz et al. (1999): *"The economic assessment based on fisheries data, however, failed to detect effects attributable to hypoxia."*

ix. Page 7-8. Add the following key finding from Report 4: *"Overall, the above analysis indicates that rivers in the MRB generally meet ambient water quality standards for substances affected by nutrient loadings and concentrations (i.e., dissolved oxygen, pH, nitrate, and un-ionized ammonia). On this basis, it is reasonable to conclude that reductions in nutrient loadings to the rivers will not improve compliance with the* [existing ambient] *standards for these water quality variables."*

x. It states on page 8 that nitrogen loading appears to have reached a plateau at the level of about 1.6 million metric tons/yr, which is the mean loading over the period 1980-1996. In other parts of the DIA tables and figures from the 6 assessment reports have been updated to incorporate data through 1998. This should be done with the nitrogen flux data also. It should be stated that the flux of nitrogen from the MARB in recent years (1996-1998) has dropped to 1,330,000 tons (Boesch, 1999) - the same as in the early 1970s. It should also be pointed out that the major difference from the 1970s is that the fraction of total nitrogen that is organic nitrogen+ammonia has decreased from about 50% to ~ 26% - a continuation of the longer-term decrease in the organic nitrogen+ammonia fraction and total nitrogen since mid-century.

xi.. Pages 8-10. On page 8, 2nd paragraph, change the first sentence to: "Nitrogen loading appears to have decreased since mid century to 1.33 million tons in 1996-1998 (Boesch, 1999)." Change the second sentence to: "As we have failed to establish a statistical correlation or a causal connection between nutrient fluxes from the MARB and the severity of the hypoxic zone, we do not have a scientifically defensible basis for evaluating the impact on the hypoxic zone of changes in nutrient fluxes from the MARB." These findings should also be reflected throughout the rest of the text on pages 8-10.

xii. Page 11, 1st paragraph, add "No information is available on the extent of the hypoxic zone prior to 1985."

xiii. Page 11, 1st full paragraph should specifically address changes in the flux of total nitrogen.

xiv. Page11, add the following at the end of paragraph two: "The Integrated Assessment will be approved by the CENR Hypoxia Working Group."

xv. Page 11, paragraph 2. To provide better context, give as an example the percent of the land area in Iowa and Illinois that "should" be converted to wetlands and riparian areas. Goolsby et al., (1999) indicate that these 2 states contribute about 35% of the N flux which would convert to 1,750,000 acres of wetlands and nearly 7,000,000 acres of riparian areas. Combined, this would be about 20% of the corn and soybean acres in the 2 states.

xvi. Page 11, last paragraph, change the second sentence to the following: "The assessment plan was developed with little input from the Task Force and was approved by the CENR Hypoxia Working Group."

xv. Page 12, add that P.L.105-383 requires the President to submit an Action Plan to Congress.

xvi. Page 13, third and fourth line from bottom, modify the sentence to: "... the 1993 flood can nearly double the nitrate flux to the Gulf, but the August flood waters went east towards Florida and joined the Gulf Stream off the coast of the eastern United States."

xvii. Page 15 – Reference is made to the "overwhelming scientific evidence that indicates that inputs of nitrogen from the Mississippi River drainage basin is the primary factor driving hypoxia". References to technical reports and publications that support this statement should be included here.

xviii. Page 19 – Mention is made that peak river flows have increased over the past 150 years. It would help to know the impact of increased stormwater flows from cities, increased use of drain tiles on agricultural lands, diking of rivers and removal of floodplain pools and forests, etc.

xix. Page 21 – The impact of floods is significant and often quite long lasting. Chesapeake Bay was affected for years after hurricane Agnes in the early 1970s. The recent flood in North Carolina is already having a major impact on Pamlico Sound. We need to better understand the longer-term effects of major flood events and hurricanes, and the role that large amounts of organic contributions to these systems have over time.

xx. Page 25 – After the sentence: "In addition, in some basins sewage treatment plants and industrial sources add nitrogen directly to streams." add: "For example, in the Upper Illinois Basin about 37 percent of the total nitrogen load is from point source."

In the discussion at the bottom of the page on the impacts of hypoxia on the shrimp landings the habitat for the brown shrimp is not discussed. Is it more offshore than the white shrimp and was it an important component of the fisheries in the area now occupied by the hypoxic zone? It seems like a number of things are occurring simultaneously in this part of the Gulf. One is that increased nutrients from the Mississippi may be increasing productivity in parts of the Gulf. While inputs may be increasing here has anyone quantified the loss of nutrients coming from coastal wetlands, many of which have been destroyed over the last 100 years? The hypoxic zone may have decreased productivity in that portion of the Gulf at least during the warmer months. Changes in the distribution of fisheries during periods of hypoxia can sometimes lead to increased catches in areas unaffected by hypoxia.

xxi. Page 32 – Reference is made to the fact that reducing sources of nutrients from the

MARB can affect water quality conditions in the Basin itself. More discussion is needed on nutrient "problems" within the basin and expected improvements from nutrient reductions, citing the major findings from Report 4.

xxii. Page 32 – The last paragraph on this page discusses how reductions in nitrogen and phosphorus levels will increase underwater light and expand submerged aquatic macrophyte distribution. Unfortunately, turbidity is high in Illinois Rivers and is probably the primary factor in reduced light levels. Also, change "mix of source controls" to "mix of source reductions."

xxiii. Page 32. Changes in the Gulf of Mexico. The uncertainties in the model simulations should be described thoroughly.

xxiv. Page 36. It is unclear why a 10% reduction in nutrient loads wasn't also looked at. Because the impacts on Gulf fisheries are unclear it seems that we can afford to take a slower and less costly approach to reductions in nutrients (at least for the time being and until more detailed research studies have been conducted). In fact, the last sentence on Page 42 states that "the benefits of a program to reduce nitrogen loadings to the Gulf are difficult to calculate".

xxv. The discussion on methods of reducing agricultural inputs should emphasize that we are not able to determine the effectiveness of on-farm or edge-of-field reductions on loadings to the Gulf and that delivery rates vary between 0 and 100 percent depending on a number of site-specific variables.

ix Pages 39-41. The costs of the control and mitigation options should be stated clearly in billions of dollars per year, both here and in the Executive Summary.

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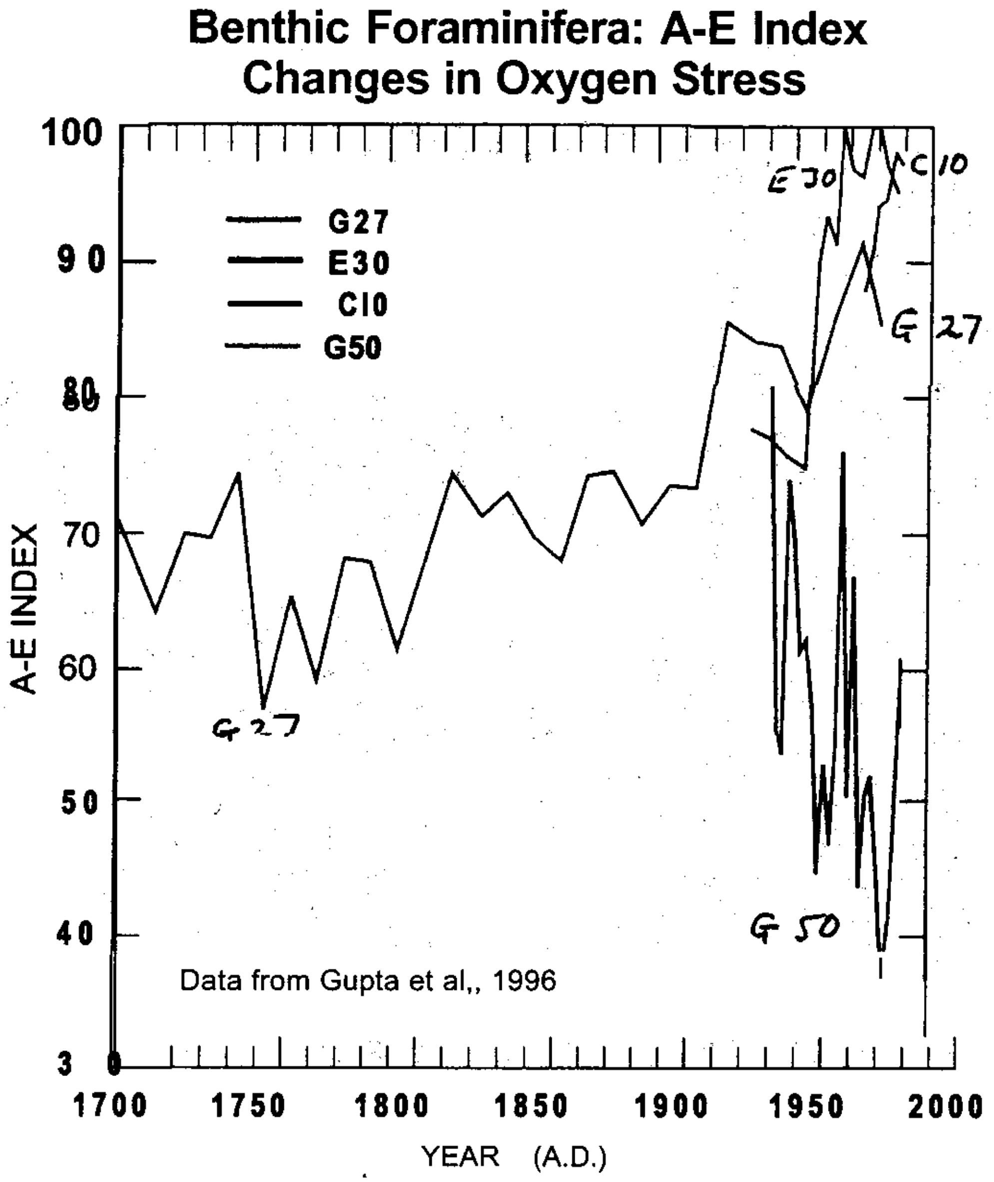
[2] Lead author of Report 1 of the National Hypoxia Assessment.

[3] Coauthor of Report 1 of the National Hypoxia Assessment.

Figure 1



Data from Gupta et al,, 1996

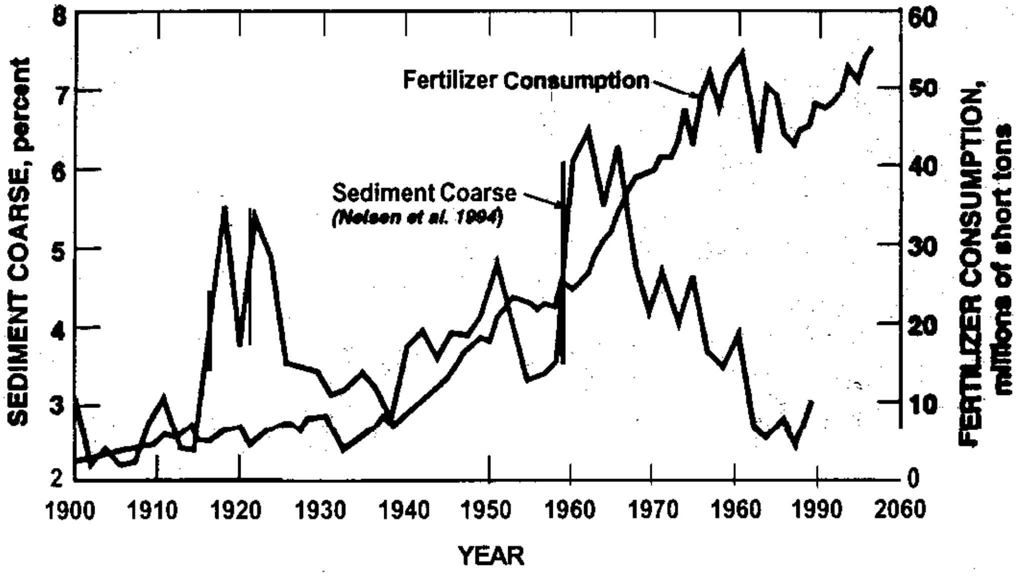
Explanation Only site G27 has a long record. This shows a large increase in the A-E index and oxygen stress since the 1700s, with no change from 1920 to 1980. G50 shows a decrease in the A-E index and oxygen stress, but the authors say there is "no trend" at this site

Figure 2

"The total coarse fraction displays an increasing upcore trend . ..".

"a linear trend analysis"

(Nelsen *et al. 1994)*

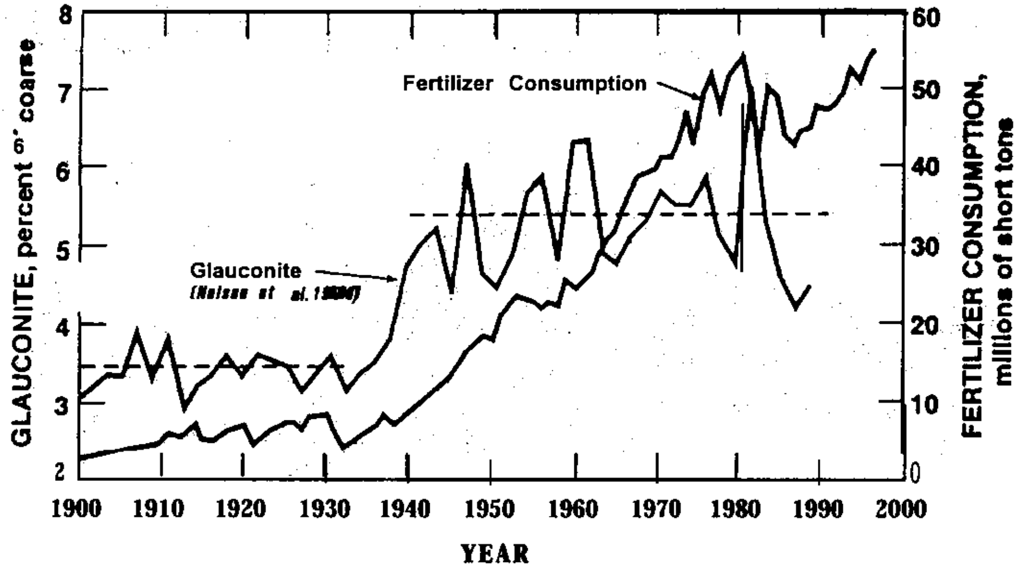


Explanation - There is no statistically significant correlation between sediment coarse fraction in the Northern Gulf of Mexico and N-fertilizer use. The original article by Nelson et al. (1994) puts a linear trend line through the sediment coarse fraction data, without conducting any statistical testing.

Figure 3

"A major increase in glauconite concentration coincident with the onset (-1940) of the increased use of commercial fertilizers in the United States."

"...post-1940's increase in glauconite..."
(Nelsen et al. 1994)



Explanation - The original article (Nelson et al. (1994) puts a linear trend line through the glauconite data and concludes a linear increase in glauconite, which is stated to be a measure of oxygen stress or hypoxia, is consistent with a linear trend in sediment coarse fraction and growth in fertilizer use provides "evidence for linkage between these diverse parameters". There was, in fact, a jump in glauconite in the 1930s when fertilizer use was low and there has been no increase in glauconite since the 1940s, although fertilizer use has increased to about 50 million tons.

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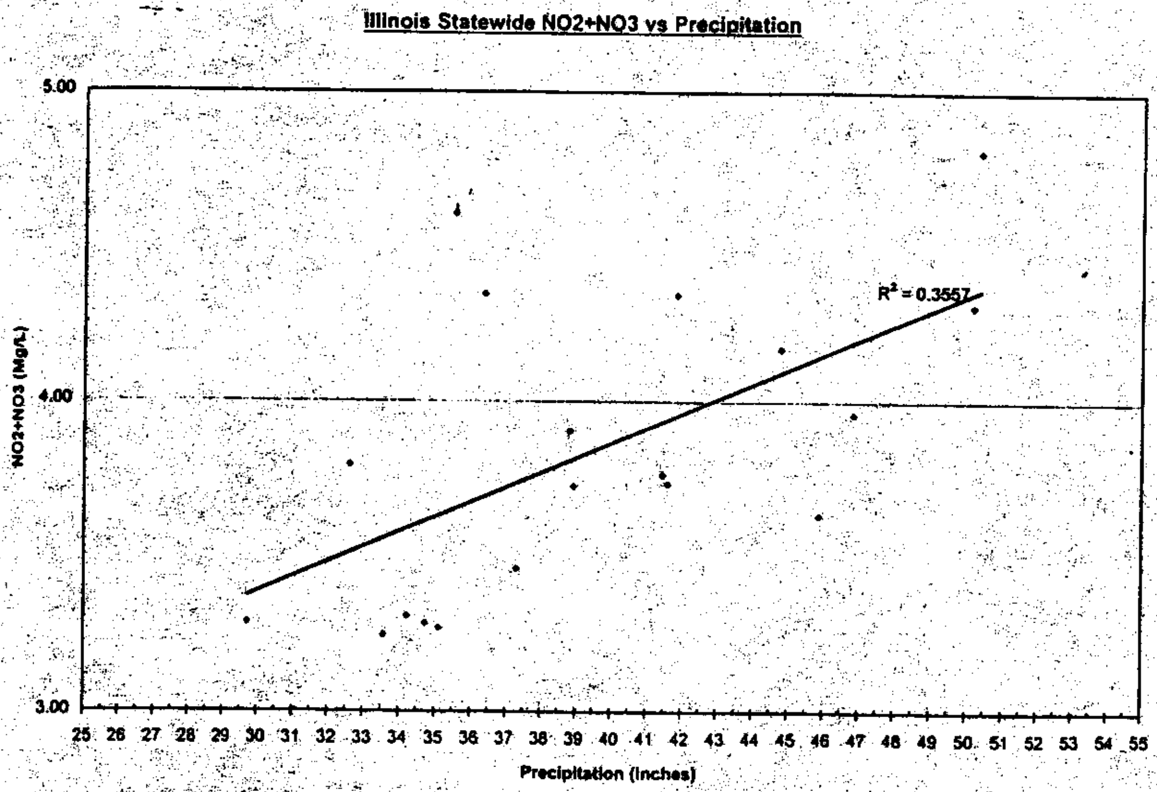

Figure 4. - Plot of the relationship between annual mean state-wide precipitation for Illinois, 1978-199, and annula mean state-wide $NO_3 + NO_2$ concentration in some 200 of Illinois rivers and streams, 1978-1998.

<u>Data Sources</u> - IEPA and ISWS

<u>Explanation</u> - Rainfall accounts for 36% of the variance in $NO_3 + NO_2$ concentrations.

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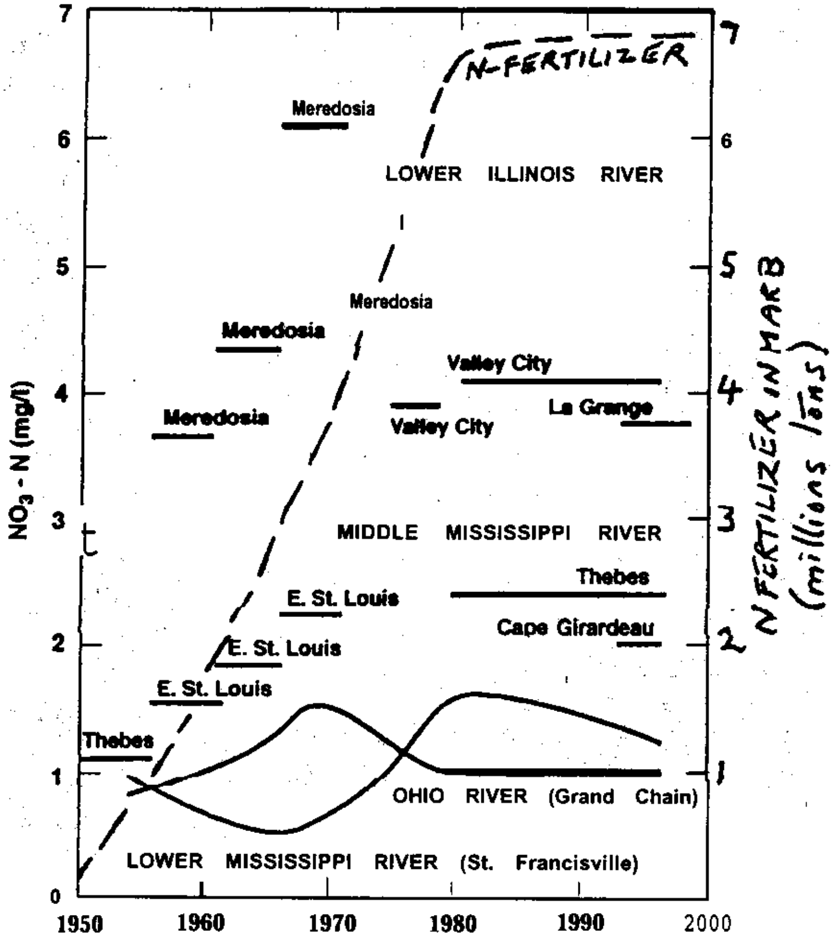
Figure 5

Nitrate Concentration in the Mississippi River Basin, 1950-1998



Data Soures - Goolsby et al. (1999); USGS; STORET; ISWS.

Explanation - Concentration of NC3 in the Lower Mississippi River at St. Francesville decreased from 1954 to the late 1960s and only ~1974 was as high as in 1954. Over this 20 year period, N-fertilizer use in the MARB increased from almost 0 to about 4.5 million tons. The concentrations of NO3 in the Ohio River, Middle Mississippi River and Illinois River increased rapidly from the 1950s to ~ 1970 and then either decreased or leveled off. N-fertilizer use in MARB peaked ~ 1980 and leveled off. There is no clear relationship between N-fertilizer use in MARB and the concentration of NO_3 in the major rivers.

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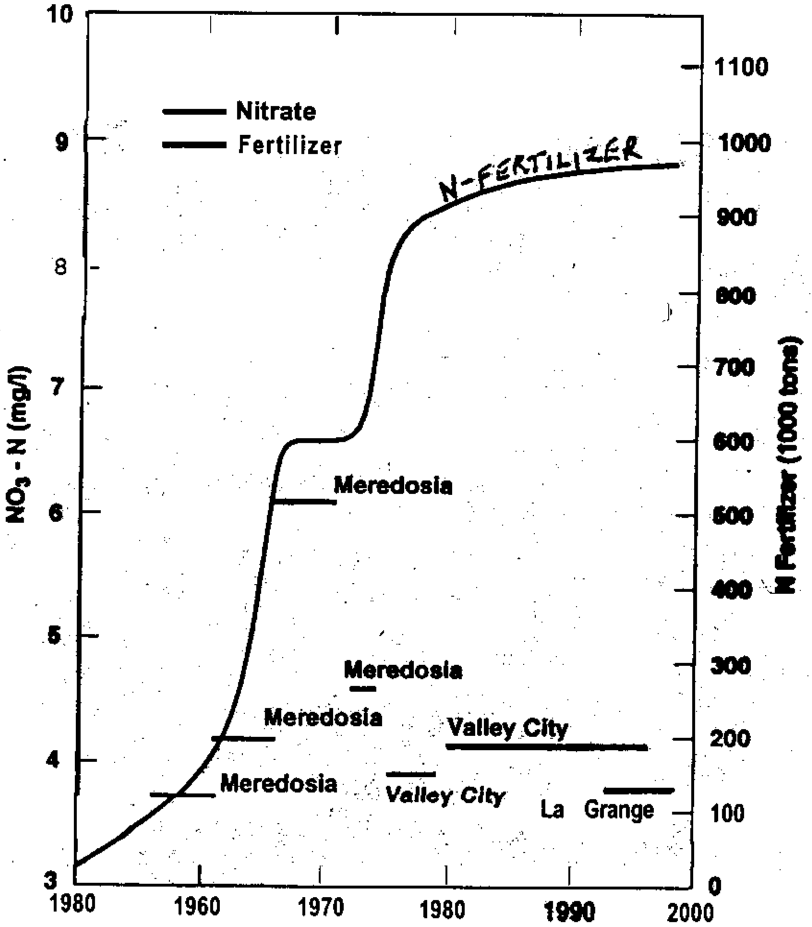
Figure 6

Time Series of N Fertilizer Use in Illinois and Nitrate Concentration in the Lower Illinois River, 1950-1998



Data Sources - USGS, STORET, ISWS

Explanation - Condentration of NO3-N in the Lower Illinois River increased rapidly from the 1950s to about 1970 and then decreased rapidly. Concentration of NO_3-N in the 1990s is about the same as around 1960. There is no statistically significant correlation between NO3 concentration in the Lower Illinois River and N-fertilizer use in Illinois, 1950-1998.

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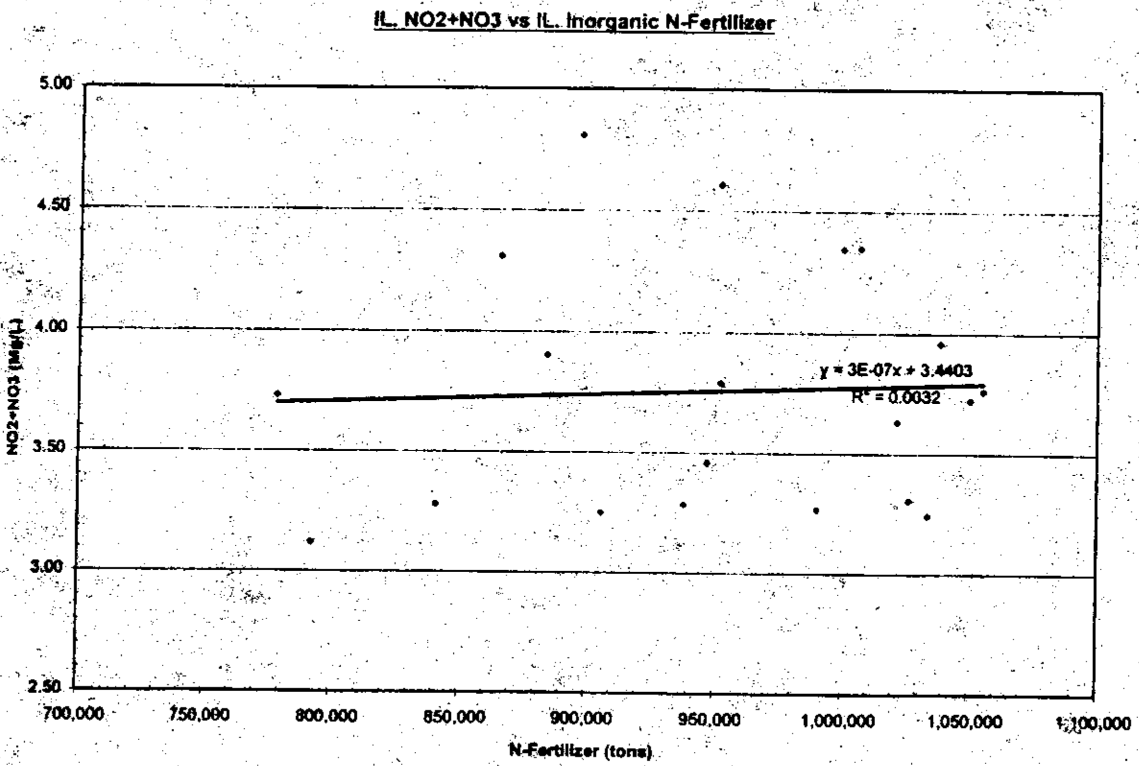

Figure 7. Plot of the relationship between annual mean state-wide N-fertilizer use for Illinois, 1978-1998, and annual mean state-wide $NO_3 + NO2$ concentration in some 200 of Illinois rivers and streams, 1978-1998.

<u>Data Sources</u> - IEPA and IDOA

<u>Explanation</u> - There is no statistically significant correlation between N-fertilizer use in Illinois and $NO_3 + NO_2$ concentration in 1978-1998.

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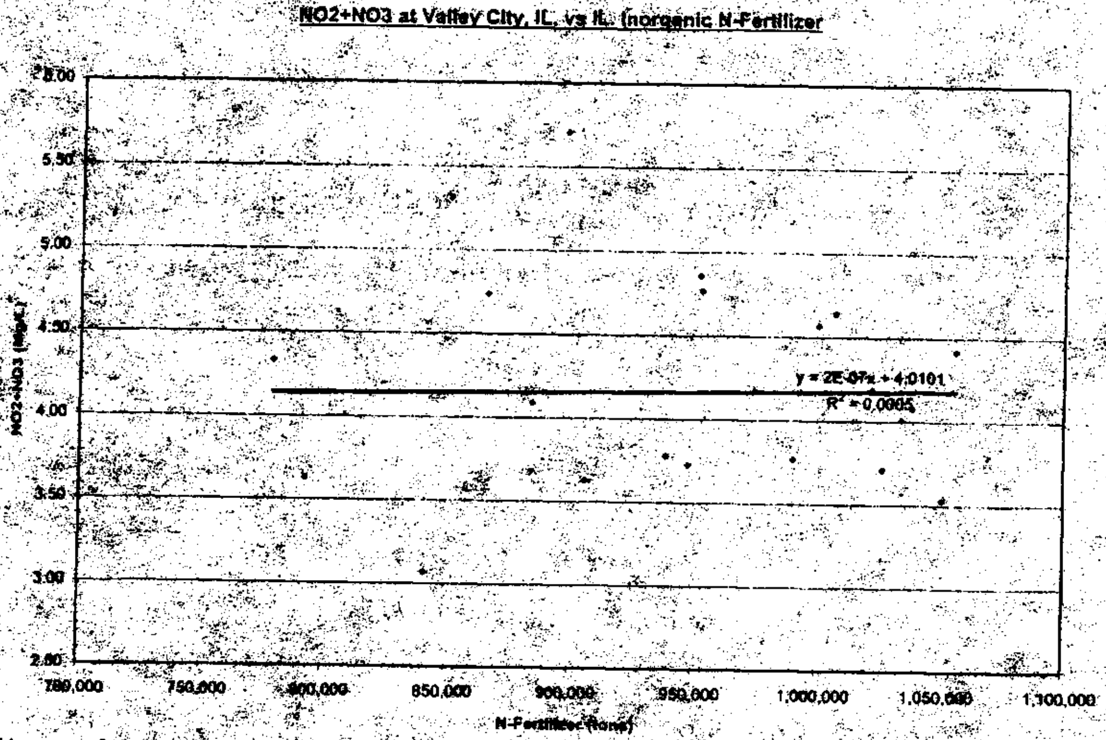
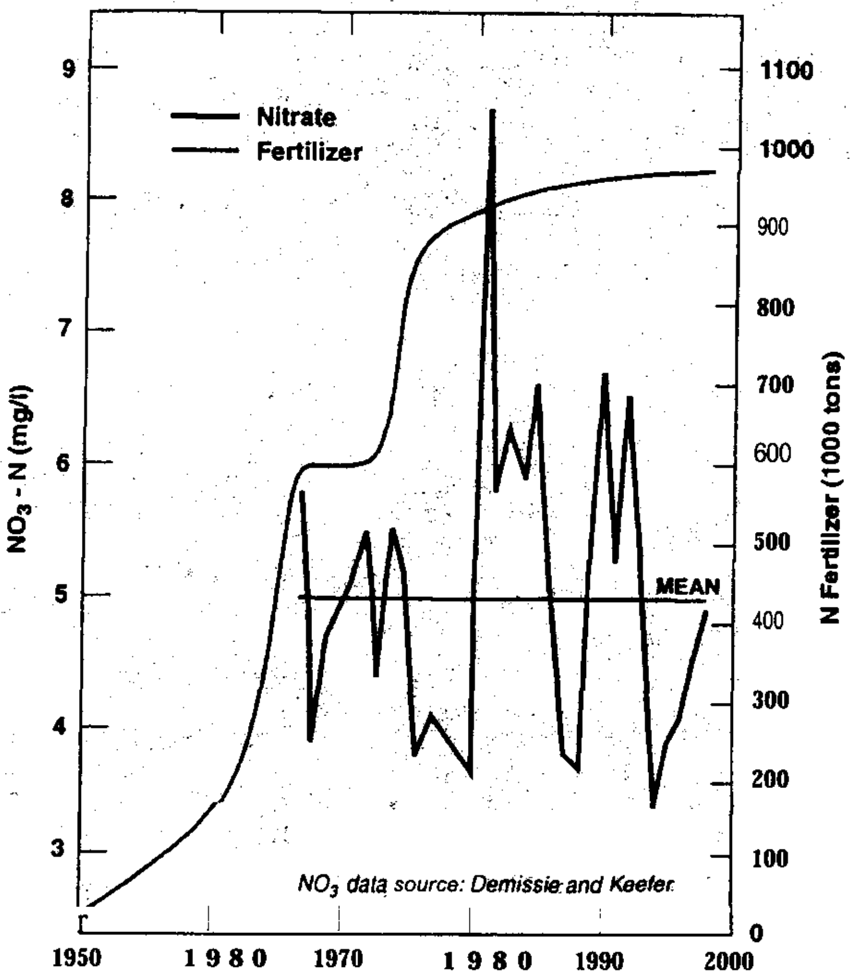


Figure 8. Plot of relationship between annual mean state-wide N-fertilizer use for Illinois, 1978-1979, and annual mean $NO_3 + NO_2$ concentration at Valley City on the Lower Illinois River, 1978-1979.

Data Sources - STORET and IDOA
Explanation - There is no statistically significant correlation between N-fertilizer use in Illinois and $NO_3 + NO_2$ concentration in the Lower Illinois River in 1978-1998.

Figure 9

Mean Annual NO3 - N Concentration
Lake Decatur, Illinois, 1967-1998
and N Fertilizer Use in Illinois, 1950-I 996

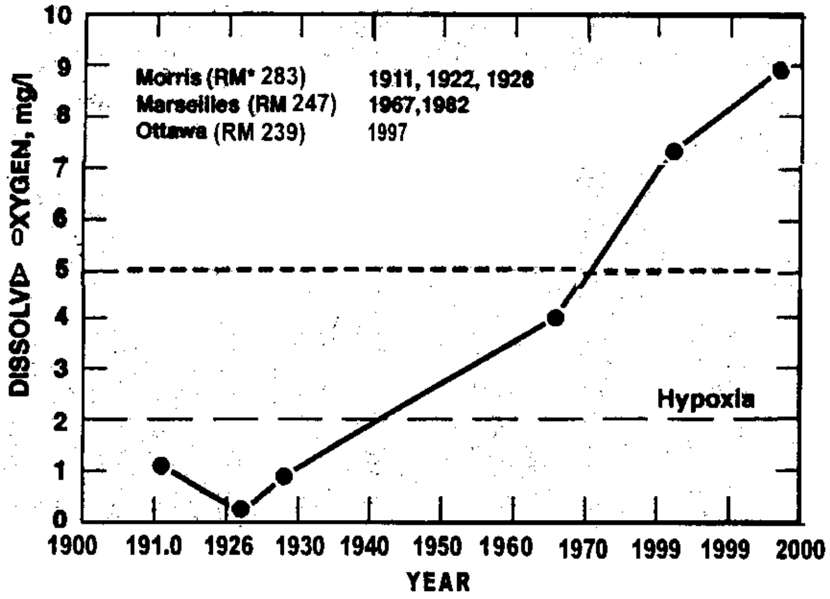


NO_3 data source: Demissie and Keefer

Explanation - Lake Decatur, IL, suffers from occasional NO3 drinking-water-quality exceedances. The continuous water-quality record since 1967 shows that the annual mean concentration of NO_3 **in Lake** Decatur has not changed since 1**967**, even though there has been a large increase in N-fertilizer use since 1967

Figure 10

Summer Values of Dissolved Oxygen in the Upper Illinois River



*RM= River mite above Mississippi River

Data Sources:
Talkington (1991)
USGS (1998)
Boruff and Buswell (1929)

Explanation - Concentration of dissvolved oxygen is the single most important water-quality indicator. Large parts of the Illinois River were hypoxic earlier in the century. Although the concentration of dissolved oxygen has increased dramatically in recent decades, water is still not fully oxygenated. Low values of dissolved oxygen earlier in the century reflect high biological and chemical oxygen demand. Large amounts of dissolved oxygen are needed to cleanse organic rich water and sediments,.

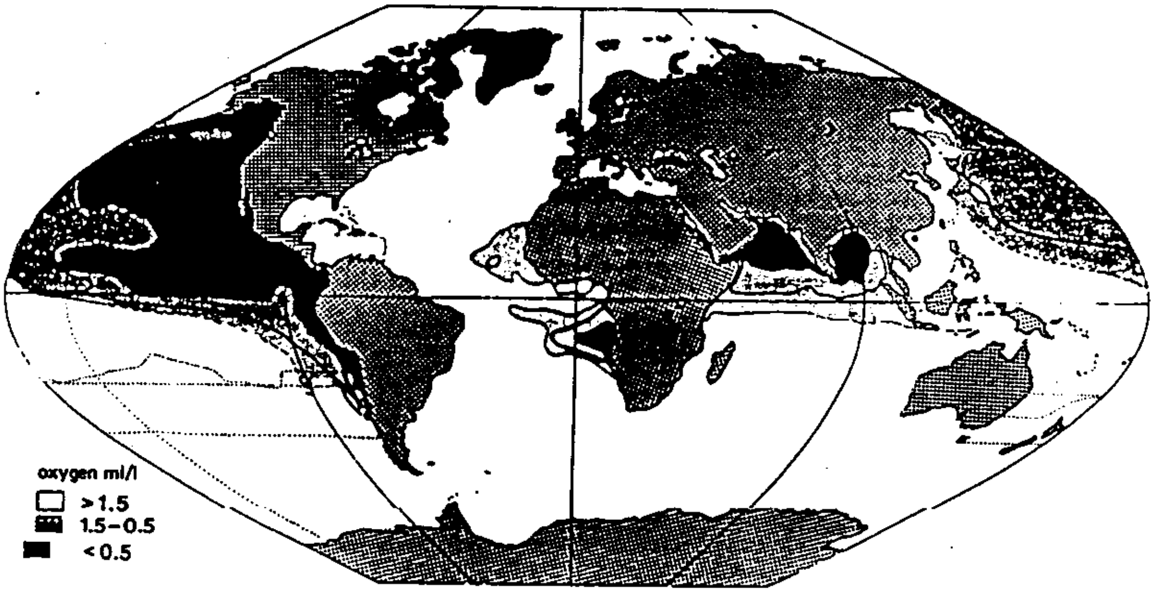


Figure 11. Maximum extension of oxygen-depleted layers in world ocean (from Demaison and Moore, 1980).

Explanation - Hypoxia occurs naturally over millions of square miles of the world ocean.

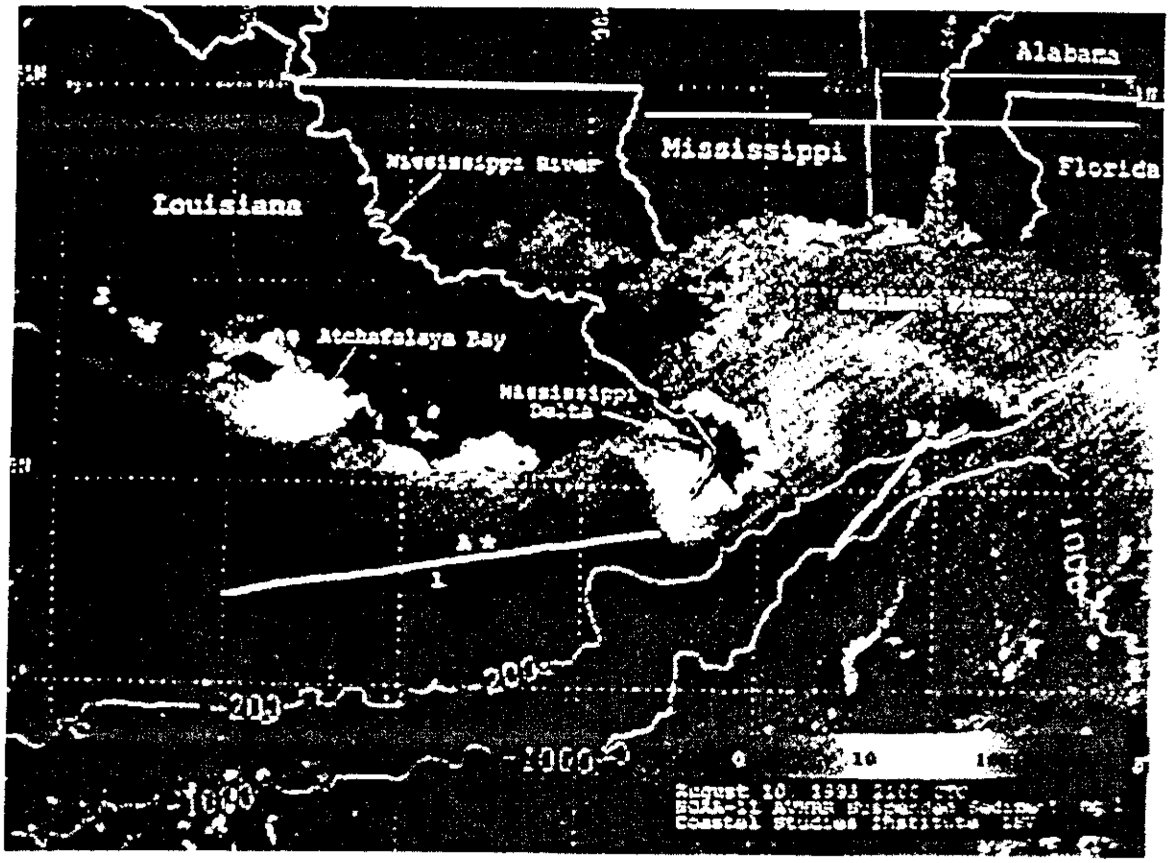


Figure 12.

From - Walker, 1994

Explanation - The satellite photograph on August 10, 1993, was taken at the time the peak Mississippi River flood was discharging into the Gulf of Mexico. It shows that the plume from the Mssissippi River flowed eastwards, away from the hypoxic zone to the west. It also shows discharge of materials into the hypoxic zone from the Atchafalaya River and the coastal bayous, estuaries and wetlands.

Figure 13

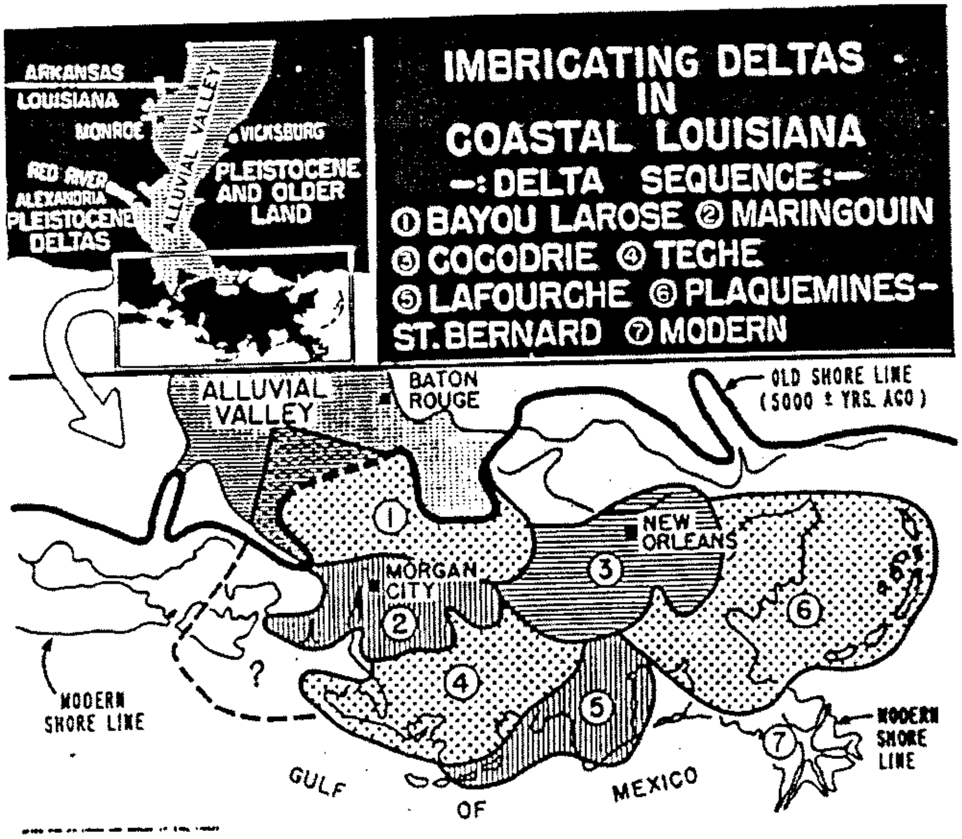


Fig. 15. - The alluvial plain in coastal Louisiana consists of imbricating Mississippi delatas, and was developed step by step

<u>Explanation</u> - Coastal Louisiana is a highly dynamic area. Changes in hydrology, geomorphology, and coastline are always occuring. These changes effect water quality and ecosystems in the coastal water.

Figure 14

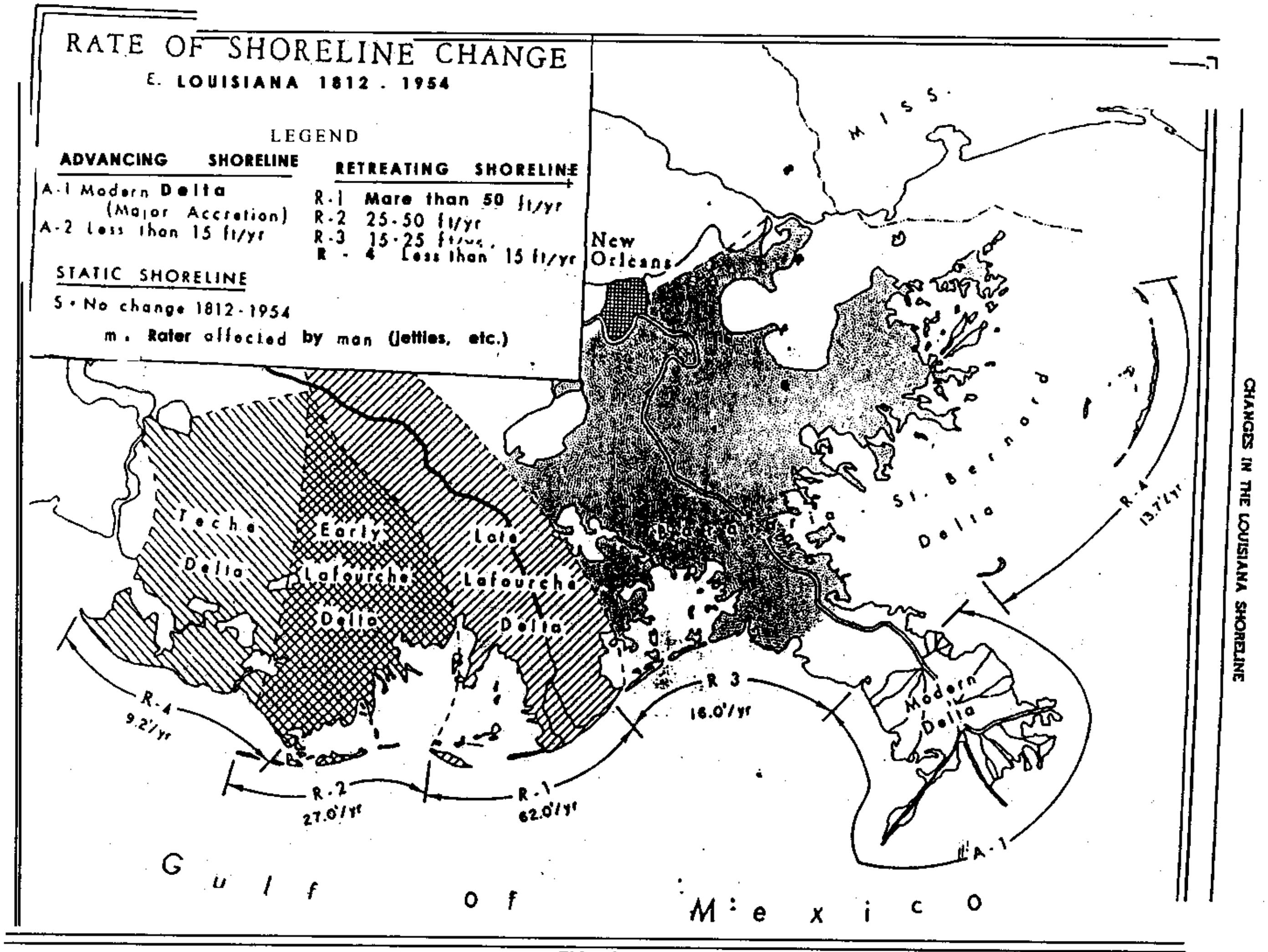
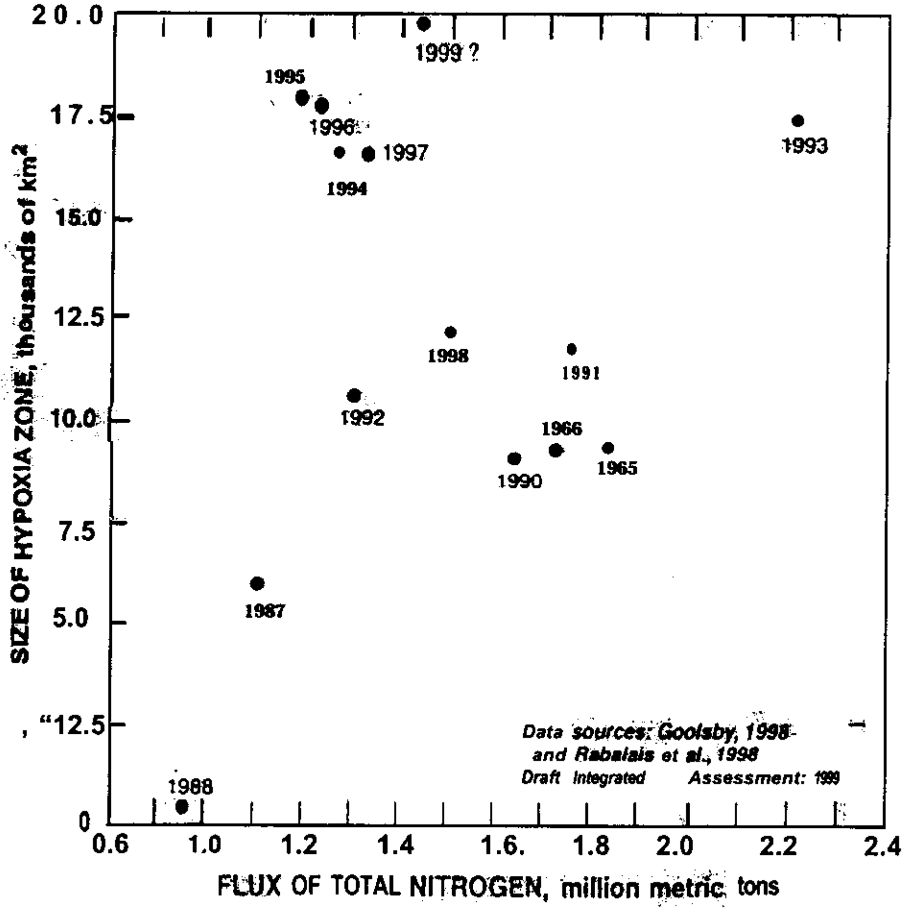


FIG. 4

Explanation - This map shows retreat of the Louisiana coast from 1812 to 1954 of up to 62 feet per year. The loss of wetlands, marshes and other coastal features continues today. A new delta and wetlands are building further west at the mouth of the Atchafalaya River.

Figure 15

Relationship between the annual flux of total nitrogen by the Mississippi River and the estimated areal extent of bottom water hypoxia (<= 2 mg/l) in the Gulf of Mexico for midsummer cruises, 1985-1988 and 1990-1996



Data sources: Goolsby, 1998 and Rabalais et al., 1998
Draft Integrated Assessment: 1999

__Explanation__ - This diagramshows that there is no statistically significant" **relationship** between the Annual **flux** of nitrogen from the **Mississippi** River and the surface **areal** extent of bottom-water hypoxia in the Gulf of Mexico. The surface extent of bottom **water hypoxia** is the- **"benchmark for year-to-year comparisons"** of mid-summer hypoxia.,,

Table 3

Diverted freshwater and sediment cause massive wetland loss downstream of the Atchafalaya due to chemical and physical erosion.

Percent Organic Matter and Nitrogen Content of Hississippi Delta Marsh Soils by Vegetation Type.'

	Salt Marsh	Brackish Marsh	**Freshwater Marsh**
Organic **Matter**	13.18	30.84	40.16
Nitrogen	0.44	1.07	1.41

* **Calculated from soils dry weight data of Chabreck** (1972).

Opening up of naturally-leveed is bleeding 1,000s of years of stored nutrients and organic matter into the surrounding waters of the "*dead zone*"

Barataria Bay alone (10% of estuarine area) is bleeding an organic load into the surrounding waters of the "dead zone" ~ 2/3rds total "*dead zone*" primary production.