FY10 Hypoxia Impacts on Fisheries Report

An Output from the *Workshop to Coordinate Gulf of Mexico Hypoxic Zone Research*
convened on 17-18 February 2010 in Bay St. Louis, Mississippi

Key findings and recommendations:

- Establish mechanism for including population level effects of hypoxia into stock assessment models for federally managed, vulnerable commercial and recreational fishery species;
- Hypoxic Zone Monitoring Implementation Plan requirements should also be coordinated with needs of researchers investigating impact of hypoxia on commercial and recreational fish populations so that monitoring plan also meets their research needs
- NMFS SEAMAP cruises collect a broad array of relevant data which are available for synthesis. Encourage researchers to use these data in development of models or analyses of the impacts of hypoxia along the coast.
- Researchers/modelers addressing hypoxia impacts issue and fishery scientists/managers should meet at least every 2 years to share scientific updates;

Workshop purpose

The *Workshop to Coordinate Gulf of Mexico Hypoxic Zone Research*, Bay St. Louis, Mississippi (17-18 Feb 2010), built on recent planning efforts to advance research in two areas central to managing the northern Gulf Hypoxic Zone (aka "the Dead Zone") - Day 1 addressed the impacts of the Hypoxic Zone on living resources with a focus on fisheries, and Day 2 addressed plans to improve Hypoxic Zone monitoring. This *Workshop*, sponsored by NOAA's National Centers for Coastal Ocean Science (NCCOS), National Coastal Data Development Center (NCDDC), and Gulf of Mexico Regional Collaboration Team, and the Northern Gulf Institute (NGI), brought together leading researchers and managers of the northern Gulf of Mexico region, and developed a plan to increase collaborations and coordinate hypoxia research activities. The Working Sessions from Day 1 of the *Workshop* aimed to make progress toward implementation of Action 5 from the *2008 Gulf Hypoxia Action Plan* (http://www.epa.gov/owow/msbasin/actionplan.htm):

Action 5: "Identify and, where possible, quantify the effects of the hypoxic zone on the economic, human and natural resources in the Mississippi/Atchafalaya River Basin and Northern Gulf of Mexico, including the benefits of actions to reduce nitrogen and phosphorus and the costs of alternative management strategies."

The primary objectives of the Hypoxia Impacts on Fisheries workshop portion were to:

1) present new results on hypoxia impacts and determine implications for follow-up research to advance understanding and management;
2) promote/establish collaborations among researchers and managers; and
3) develop strategies for application of findings and tools (models, bioindicators) to management. This *FY10 Hypoxia Impacts on Fisheries Report* summarizes the research findings and priority needs articulated at the workshop.

Introduction

One of the most critical issues facing coastal managers with responsibility for protecting and restoring Gulf of Mexico fisheries are the ecosystem impacts of the hypoxic zone. Some of the questions which are being explored include: 1) Are ecologically and commercially important fisheries threatened by an expanding hypoxic zone; 2) has increased hypoxia altered food web dynamics and has this led to reductions in fish health and/or populations; 3) has hypoxia induced a regime shift in benthic faunal abundance and diversity which is affecting fish composition; 4) has hypoxia-altered shrimp distribution and habitat loss resulted in compromised physiological health, and is this reflected in reductions in size and growth potential; 5) are there direct hypoxia effects on the development of fish reproductive systems and function, and consequently on population growth rates; and 6) how close is the ecosystem to reaching a regime change tipping point where the chances of recovery decline over time?

Most of the research addressing these issues for the Gulf of Mexico hypoxic zone (Dead Zone) comes from two groups – a) the NOAA National Marine Fisheries Service (NMFS) through their Southeast Area Monitoring and Assessment Program (SEAMAP) and b) the NOAA Northern Gulf of Mexico Ecosystems and Hypoxia Assessment Program (NGOMEX), a competitive program administered by the National Centers for Coastal Ocean Science (NCCOS).

The SEAMAP summer groundfish survey is conducted aboard the NOAA Research Vessel Oregon II. The survey follows a stratified random design to sample fishes and invertebrates with a bottom trawl, and ichthyoplankton with neuston and bongo nets, and acquire environmental profile data at stations east of the Mississippi River and in the area between the 10 m and 200 m isobaths in the western and north-central Gulf of Mexico. About 200 to 250 environmental profiles are acquired during three cruise legs conducted in June and July. The profiler is equipped with sensors to measure pressure, water temperature, conductivity, fluorescence, and transmittance. The environmental data are processed aboard the vessel to derive salinity, dissolved oxygen (DO), percent oxygen saturation, and water density. Since 2001, the bottom DO data have been available to researchers in near real time to support hypoxia research. The data are also used to generate bottom DO maps for the Gulf of Mexico Hypoxia Watch program (http://www.ncddc.noaa.gov/ecosystems/hypoxia) jointly operated by the NOAA National Coastal Data Development Center and NMFS.

Building on nearly 20 years of research, the NGOMEX program addresses the hypoxic zone in the Gulf of Mexico through the funding of multi-year, interdisciplinary research projects examining both the causes and the impacts of hypoxia. This NGOMEX research investment has led to an increased understanding of the impacts but many more questions remain. Some of the primary findings include:

- Significant hypoxia-associated reductions in benthic macrofaunal biomass, species richness, and abundance have been well documented (e.g. Rabalais et al. 2001).
- Brown shrimp are subjected to a significant amount of habitat loss due to hypoxia (Craig et al. 2005), congregating along suboptimal environments along the hypoxic zone edge, possibly causing a reduction in growth (Craig and Crowder 2005).

- Craig and Crowder (2005) also found that Atlantic croaker congregated in sub-optimal conditions along hypoxic zone edges, possibly resulting in a reduction of body mass.
- Movements of Atlantic croaker and shrimp in the Gulf of Mexico have produced a "halo effect" which describes the congregation of fish around the edge of the hypoxic zone (Craig and Crowder 2005, Craig et al. 2005).
- Chesney and Baltz (2001) hypothesize that finfish and mobile invertebrate populations have thus far been resilient to hypoxia effects, with other anthropogenic stressors (e.g. fishing) possibly having larger consequences.

Current NGOMEX studies (awarded in 2009) are documenting the dynamics of the hypoxic zone over the Louisiana continental shelf and helping to better define the biological, chemical, and physical processes that influence hypoxic zone development and determine its extent, and impacts on fisheries. These impact studies include an economic analysis of how the dead zone affects the shrimp fishery in the northern Gulf of Mexico (K. Craig et al.), the development of models to forecast how the populations of commercially important fish species will respond to changes in nutrient pollution and the dead zone (M. Roman et al.), and an in depth analysis of the reproductive effects on Atlantic Croaker fish populations (P. Thomas et al.). It is noteworthy that each of these projects has a strong link to NOAA's National Marine Fisheries Service (NMFS). For instance, two of the projects have NMFS Co-PIs. In addition, Peter Thomas' project involves in depth analysis of historical SEAMAP trawl data to inform exposure levels of Atlantic Croaker for development of models. Craig's project is using both shrimp and dissolved oxygen data from the SEAMAP cruises to guide their research into the impact of hypoxia on the Gulf shrimp fishery.

Major discussion areas to guide future coordination

Who needs the information about hypoxia?

The first step towards directing hypoxia impacts research for use in the sustainable management of commercial fisheries is to identify the relevant decision making bodies and then how research might be used to make those decisions. For fisheries management in state waters (out to 3 miles from coast), the Gulf State Marine Fisheries Commission makes recommendations to the five participating Gulf states, which then independently make decisions about regulating fisheries in their own respective state waters. The Gulf of Mexico Fishery Management Council is responsible for recommending fishery management plans for species in federal waters (from 3 to 200 miles from coast) as specified by the Magnuson-Stevenson Act (http://www.nmfs.noaa.gov/sfa/magact/). Both the Commission and the Council are comprised of appointed individuals representing a range of stakeholders. The Council consists of 17 voting members: the Southeast Regional Administrator of NMFS (or his designee), the directors of the five Gulf state marine resource management agencies (or their designees), and 11 members who are nominated by the state governors and appointed by the Secretary of Commerce. Appointments are three-year terms with a maximum of three consecutive terms. In addition, there are four nonvoting members representing the U.S. Coast Guard, U.S. Fish and Wildlife Service, Department of State, and the Gulf States Marine Fisheries Commission. The Commission is composed of three members from each of the five Gulf States: the head of the

marine resource agency of each state, a member of the legislature, and a citizen with knowledge of marine fisheries appointed by the governor.

The Gulf of Mexico Hypoxia Task Force (http://water.epa.gov/type/watersheds/named/msbasin/msbasin_index.cfm) is also concerned about the impact of hypoxia on fisheries, as encompassed by Action 5 of the *2008 Gulf Hypoxia Action Plan* (above). The Task Force is focused on reducing the size of the dead zone through nutrient management upstream. Justification of nutrient management partly relies on determining how hypoxia negatively affects the population of commercially relevant species, the ability to fish and the overall ecosystem health. Therefore, this group and the general public both have a vested interest in knowing the extent of the damage being ultimately caused by excess nutrients.

NOAA has identified improved coastal and marine spatial planning (CMSP) as a priority issue in its Next Generation Strategic Plan (http://www.ppi.noaa.gov/NGSP3/plan.html). Hypoxia should be an element of this process as, for example, it would probably be a good idea not to locate a Marine Protected Area where hypoxia is occurring. Hypoxia may be redistributing fish – so should be considered when setting up MPAs.

Approaches for incorporating hypoxia impacts into fishery management decisions

The Gulf of Mexico Fishery Management Council convenes various advisory panels to provide advice related to fisheries management. These include a Scientific and Statistical Advisory panel (SSC), Stock Assessment panels for individual species (SAPs) and a Socioeconomic Panel. Membership in these panels is posted on the Council website: http://www.gulfcouncil.org/panels_committees/scientific_statistical_committees.php. NOAA Marine Fishery Service's Southeast Data, Assessment, and Review (SEDAR) is a process set up in 2002 to ensure the highest quality stock assessments (http://www.sefsc.noaa.gov/sedar/Index.jsp). SEDAR emphasizes stakeholder and constituent participation in species assessments and rigorous scientific analysis of completed stock assessments. SEDAR is the process now used by the stock assessment panels. According to the NMFS website (http://www.nmfs.noaa.gov/), "SEDAR is organized around 3 workshops. The first is a data workshop where datasets are documented, analyzed, and reviewed and data for conducting assessment analyses are compiled. The second is an assessment workshop where quantitative population analyses are developed and refined and population parameters are estimated. The third and final is a review workshop where a panel of independent experts reviews the data and assessment and recommends the most appropriate values of critical population and management quantities." Although the SEDAR process was not specifically discussed at the February workshop, it represents an important part of stock assessment development and one with which hypoxia researchers should be familiar.

Stock assessment scientists use population models to inform assessment recommendations. It is recommended that hypoxia be included in these models either as lost yield (take catch and effort data to back out what mortality would have been) or as an index parameter. The effect of red tide was included in the Red Grouper assessment which might be a guide for how hypoxia could be included in assessments for vulnerable species.

NOAA's Marine Fisheries Initiative Program (MARFIN) is described as "a competitive Federal assistance program that funds projects seeking to optimize research and development benefits from U.S. marine fishery resources through cooperative efforts involving the best research and management talents to accomplish priority activities." (http://sero.nmfs.noaa.gov/grants/marfin.htm). It was recommended that hypoxia in the Gulf be included as a research priority for this program. The Coastal Zone Management grants might also consider hypoxia for state water fisheries. The NGOMEX program already funds research developing models connecting hypoxia to population level impacts.

Data and Modeling Needs

A debate exists in fisheries management because the models used are simple in structure and are parameterized by data versus mechanistic models which can look at processes. It seems unlikely that mechanistic models can be used to determine allowable catch limits given the many sources of error. No model is helpful unless it can be related to population levels and setting catch allowances. Regardless, we need to figure out how to incorporate hypoxia into the models. For starters, the effects of hypoxia on fish behavior needs to be better understood and incorporated into models. Secondly, how does hypoxia affect recruitment? Some SEFSC modelers are considering the use of Ecopath and Ecosim in stock assessment modeling.

Species-specific guidance

Workshop participants discussed which species have been studied enough to be good candidates for understanding the impacts of hypoxia. Relatively well studied species include: Croaker, shrimp, Southern Flounder, Weakfish, and oysters. In addition, the SEAMAP database has long-term monitoring information on 170 species. Menhaden, amberjack, and snapper are probably not good candidates. 170 SEAMAP species, Menhaden populations are elevated probably due to eutrophication. Amberjack don't exist in the hypoxic zone, spawning beyond the hypoxic zone. Snappers spawn throughout the summer but the juveniles try to become demersal when hypoxia is compromising the bottom habitat. Adults don't inhabit the hypoxic zone.

Blue crab, stone crab, grouper, bumper, butterfish and two species of sand sea trout are important fishery species which have not been well studied especially in respect to vulnerability to hypoxia. For instance, the sand sea trout species should be more abundant in and around the hypoxic zone than is currently found which may be a result of hypoxia.

In addition to specific species, life history processes which are vulnerable to hypoxia include reproduction, food sources, how food source populations change, and effects on other trophic levels which would have ramifications for the species of interest and its habitat.

Research and management needs and priorities

<u>Science Needs and Priorities</u>

- Quantification of the interactive effect of hypoxia with other anthropogenic stressors, especially fishing, but also climate change, wetland loss, and contaminants;

- Improved understanding of spatial and temporal movements of fauna, including zooplankton, in relation to the hypoxic zone; Some predominant species spawn out past the zone but grow up in the estuary so they must pass through hypoxic areas;

- Tipping point for how hypoxia affects fish?

- Species-specific fish responses to different DO levels (e.g. hypoxia thresholds). Some research has been done with freshwater species.

- Influence of hypoxia on bycatch. There is an indication that it increases which causes unwanted mortality in non-target species. There is serious bycatch in shrimp trawls.

- Effects of hypoxia on the winter habitat value of dead zone geographic area;

- The effect of hypoxia-induced habitat loss on populations.For instance, 25 – 50% of ideal shrimp habitat has been lost due to hypoxia;

- Impacts of moderate DO on ecosystems (above 2 but below about 5 mg/l);

- Quantification of hypoxia-induced food web alterations, and the consequences on individual and reproductive fitness of important fish and shellfish species;

- Expansion in the suite of species used for laboratory bioenergetic analyses coupled with *in situ* field-based examinations;

- Translation of laboratory based physiological effects and exposure studies into field-based studies.

<u>Management Needs and Priorities</u>

- Improved monitoring and quantification of the extent and duration of hypoxia with a transition to the quantification of volume, in addition to area;

- Coordination and standardization of faunal monitoring surveys allowing for quantifiable fishery-independent population trends;

- Integration and development of physical and biological models with improved commonality between systems, quantified levels of uncertainty, and explicitly defined forecasting goals;

- Development of bioeconomic models to assess the socioeconomic impacts of quantified effects;

- Improved development of bio-indicators to document exposure and physiological effects with improved translation to the individual and population level;

- Determine the ecological resilience of coastal systems to hypoxia, especially tributary nursery habitats, and quantify the collapse threshold of these systems through modeling.

How to evaluate the cost of hypoxia?

Some discussion centered around the need to better understand the costs of hypoxia to the fisheries versus the cost of reducing nutrients upstream. It is exactly this relative cost analysis which is needed to build the case for nutrient reductions – however few researchers are evaluating. Kevin Craig was recently funded by NGOMEX to evaluate the economic impact of the hypoxic zone on the shrimp fishery using complex economic analysis and field data.

It is recommended that this evaluation include the broader evaluation of loss of ecosystem functions that result from hypoxia – not just the direct effect on fishery species populations. In addition, how do you measure the loss of recreational fishery activity resulting from fisherman who, unknowingly, go out several times to the hypoxic area, don't catch fish and stop fishing?

Is the forecast relevant for fisheries management?

There was general agreement that seasonal and synoptic forecasts of the hypoxic zone which included both size and location would be useful for:

1) highlighting existence and size of the zone,
2) letting fishermen know where and where not to fish,
3) informing shellfish harvesting decisions (e.g. closures) in the case of closer to shore hypoxia forecasts,
4) testing the accuracy of predictive models, and
5) improving efficiency of fishery closures.

On the last point, it might make sense to open a shrimp fishery early if a bad hypoxia season is forecasted – so fishermen can catch shrimp before they migrate offshore through hypoxic zone eroding their growth and increasing mortality. As far as the specifics of a forecast, it is strongly recommended that the uncertainty and validation of the forecasts be better communicated.