Management needs related to living resource and habitat effects of large-scale Mississippi River diversions and Gulf hypoxia

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A White Paper to inform discussions to prioritize management needs (Breakout Session 1) at the 5th Annual NOAA/NGI Gulf Hypoxia Research Coordination Workshop, "Advancing Ecological Modeling for Diversions and Hypoxia in the Northern Gulf of Mexico", 14-16 July 2014 at the Mississippi State University Science and Technology Center at NASA's Stennis Space Center in Mississippi.

Because of the uncertainties surrounding Gulf of Mexico coastal ecosystem responses to: a) Mississippi River large-scale diversions, b) hypoxia mitigation, and c) the influence of diversions on hypoxia distribution and mitigation, management needs for sustainable living resources and habitats should use an adaptive management approach. As stated in Report #1 from the Expert Panel on Diversion Planning and Implementation (submitted to Coastal Protection and Restoration Authority, Feb. 2014):

> "Decisions about the design and construction of diversions must deal with significant challenges posed by a complex socioecological system that is dynamic and highly uncertain, as only limited knowledge exists on how the coupled system works. Adaptive management is well suited for dealing with these challenges. An adaptive management framework for diversions should be based on scenarios that project alternative future system conditions, flexible strategies for system-wide projects and individual diversion project design that account for a range of possible scenarios, and a monitoring program to track diversion project performance and required adaptive adjustments in project design and operation to deal with uncertainty and realistic expectations."

Adaptive management frameworks exist for both the diversion and hypoxia issues:

An Adaptive Management Framework for Coastal Louisiana was developed by The Water Institute of the Gulf (2013) "to identify the principles of adaptive management and provide recommendations for integrating adaptive management concepts and ideas into the current coastal [protection and restoration] program. The framework also serves as the foundation for developing an Adaptive Management Plan (AMP) that will create a formalized structure for implementing adaptive management."

Action 11 from Hypoxia Task Force 2008 Action Plan: "In five years (2013) reassess nitrogen and phosphorus load reductions, the response of the hypoxic zone, changes in water quality throughout the Mississippi/Atchafalaya River Basin, and the economic and social effects, including changes in land use and management, of the reductions in terms of the goals of this Action Plan. Evaluate how current policies and programs affect the management decisions made by industrial and agricultural producers, evaluate lessons learned, and determine appropriate actions to continue to implement or, if necessary, revise this strategy."

This white paper presents management needs that would inform the knowledge base and assessment components for the adaptive management processes, with a focus on the ecological modeling needs to ensure effective assessment of fisheries responses. The Water Institute of the Gulf (2013) Adaptive Management Framework (AMF) describes four key elements of the Knowledge Base to inform decisions:

- Research studies that explain system dynamics.
- Conceptual models that illustrate chains of cause-effect relationships and how they influence program objectives.
- Data derived from ongoing monitoring, periodic surveys, and research campaigns.
- Predictive models. Coastal responses to changes in system configuration or dynamics can be predicted using a combination of statistical and process models.

Ecosystem response through model predictions at the start of the adaptive management cycle are adjusted ("improved") at the end of the cycle based on knowledge gained through research, monitoring, and project implementation effects (Table 1, excerpted from The Water Institute of the Gulf 2013).

Table 1. Comparison of available information at different phases of an adaptive management cycle

Information	**Start of adaptive management cycle, e.g.,**	**End of adaptive management cycle, e.g., assessment**
System drivers including uncertainties (e.g., storm impacts) and boundary conditions (e.g., river discharge regime)	Assumed	Known
Knowledge utilization	Captured in models used for prediction	Improved models based on research/monitoring/projec t implementation
Action Implementation	Assumed	Known
Operation of existing projects	Assumed	Known
System state	Predicted using assumed	Measured using system monitoring Predictions using

The following table draws from several sources to list a suite of fisheries management and habitat conservation needs associated with ecosystem effects of Gulf of Mexico hypoxia and large-scale Mississippi River diversions. It will provide a foundation for Breakout Session 1 of the Hypoxia/Diversion Modeling Workshop, which will prioritize these needs based on their importance in informing adaptive management of diversions and hypoxia over two time frames:

- Shorter-term: over an adaptive management cycle (3-5 years)
- Longer-term: greater than one cycle (10-50 years)

Management Needs	Diversions (D), Hypoxia (H), or Diversions and Hypoxia (D&H)
How do shifts in **environmental gradients** (e.g. salinity, temperature, sediments, nutrient composition and quantity) from the operation of diversions affect the assemblage, diversity, distribution/displacement, growth rate, survival rate, spawning success and production of **juvenile fishery species** and their prey? Can the above effects be assessed for particular species of interest (e.g., brown shrimp, blue crab, spotted seatrout, red drum, flounder, Atlantic croaker, etc).	D D&H
What effects will the response of **predator-prey interactions** to diversions have on fishery production? For example, if shrimp production is reduced, will that loss of potential prey affect the production of red drum, spotted seatrout or juvenile red snapper?	D
How will diversions affect fishery species in the **nearshore coastal zone**? Will estuarine-dependent fisheries be displaced into less than desirable habitats in the nearshore Gulf zone?	D D&H
How will shifts in environmental gradients from the operation of diversions affect **oyster** mortality, larval recruitment/spat dispersal?; e.g. - freshwater and temperature impacts to oysters in the lower part of the receiving basin; - fall, winter, and spring flows on gonad development to determine how remaining oysters responding	D

reproductively; - impacts to spat set for both spring and fall reproductive seasons; - rate and distribution of Dermo infections; - ability of oyster populations/beds within an estuary to adapt to changing environmental conditions. Would adequate hard-substrates be available for spat settlement if diversions pushed optimum environmental conditions towards the Gulf zone?	
How will **fishing pressure** change as a result of diversions, and how will that affect fishery assemblages? For example, if changes in fishery pressure occur as a result of changes in species distribution, how will this impact production?	D
How will **climate change** (including relative sea level rise, shifts in hydrology, etc.) influence diversion effects on fish abundance, production, and distribution? Are local estuarine nekton governed by large-scale climate forcing?	D
Will diversion effects on fish and shellfish result in changes in recreational and commercial **fleet effort**? Changes to dependent land-based business? Communities?	D
How will changes in **marsh** acreage and morphology affect abundance and habitat of key species? How will nutrient loading to the Gulf change as a result of diversion-induced changes in marsh habitat?	D D&H
How will **hydrologic restoration** affect habitat suitability and population sustainability? Does pulsed spring flow	D

affect nekton communities differently than continuous spring flow? Do effects on nekton communities vary by distance from the diversion (up-estuary vs. down-estuary) and over time (during diversion vs. 3 months post-diversion?	
What is the potential threat of **salt water intrusion** on fisheries, and how could diversions be operated to mitigate for this possibility?	D
Will frequent, rapid disturbances during diversion operations favor **invasive species**?	D
How do **alternative flow -management strategies** influence downstream nekton communities (abundance, diversity, assemblage)? Does restored riverine flood pulsing provide an exportable nekton subsidy? Does restored riverine flood pulsing affect short-term nekton growth? How will the timing and duration of flow affect: availability of optimal habitat, physiochemical attributes, flooded habitat, recruitment, growth?	D
Will the diversion of large quantities of nutrient laden waters into the system result in a higher potential for **eutrophication** (e.g. HABs, hypoxia) and consequent impacts on fisheries?	D D&H
What are the current effects of the **hypoxic zone on fishery resources** due to:	H

- direct mortality of managed species and their prey; - decreased fecundity (sublethal effects of exposure, reduced size); - loss of habitat and reduced habitat quality; - decreased growth; - increased susceptibility to predation; - altered migratory patterns; - bycatch.	
How will hypoxia effects on fisheries populations change over the long-term given scenarios of constant, decreased, and increased **annual hypoxic zone size**? What are the socioeconomic consequences?	H
What are the effects of hypoxia on **food web structure**, and what are the consequences on individual and reproductive fitness of important fish and shellfish species.	H
What is the **ecological resilience** of coastal systems to hypoxia, especially tributary nursery habitats, and their collapse threshold?	H
What are the diversion effects on hypoxic zone magnitude based on changes in **freshwater and nutrient loading**, and what are the consequences on fisheries production?	D&H
How will diversions affect the **timing, distribution, and duration of coastal hypoxia**? How will this affect	D&H

commercial and recreational fisheries (e.g. fishermen traverse the hypoxic zone in order to reach suitable fishing grounds and incur increased operating costs due to increased fuel expenditures and travel times)?	
Could freshwater diversions **"push"** estuarine and marine species into the dead zone?	D&H