Occurrence of Low Dissolved Oxygen (Hypoxia) in Nearshore Coastal Waters of the Grand Strand

A brief review of the phenomenon, research conducted, and current understanding & uncertainties

A multi-investigator, multi-institution collaboration

Dr. Erik Smith, Research Coordinator, NI-WB NERR
November 15, 2012- Withers Swash Watershed Tour
First reports of hypoxia in Long Bay in July 2004:
→ Unusually high flounder catches in the surf zone of fishing piers

Franz von Holshouser
GRAND STRAND OUTDOORS

Harry Ross of Myrtle Beach holds a 15-inch flounder caught off Springmaid Pier on Wednesday. The high number of flounder caught this week are an anomaly.

Photos by Randall Hill The Sun News

I haven’t seen anything like this,” said Kris Reynolds, a natural resources technician with the South Carolina Department of Natural Resources Office of Fisheries Management. “I’ve talked to at least 75 old-timers who’ve fished on the piers for 10 to 40 years and they’ve all never seen anything like it either.”

“I’m sure it’s a result of the hypoxia issue,” said John Smith, a local fisherman who has been fishing in the area for over 30 years. “I’ve never seen so many dead fish in one place.”

If a fish is in a stressful situation, they tend not to eat well,” Reynolds said. “These fish are eating like there’s no bait left.”

Cain added, “It’s coincidental we’re finding dead fish to so many flounder being caught.”

Watch those limits
First reports of hypoxia in Long Bay in July 2004:

→ Unusually high flounder catches in the surf zone of fishing piers

→ Fortuitous sampling at fishing piers by CCU researchers

Approximate Dissolved Oxygen Criteria For Normal Activity and Behavior
(milligrams of dissolved oxygen per liter of water [mg/L])

- Red drum: 5 – 6
- Flounder: 5
- Hard clam: 5
- Blue crab: 3
- Spot: 2
- Worms: 1

Source: Susan Libes, CCU
The Grand Strand is not alone in this problem:

World Hypoxic and Eutrophic Coastal Areas

Eutrophic and Hypoxic Areas
- **Areas of Concern**
- **Documented Hypoxic Areas**
- **Systems in Recovery**

Data compiled from various sources by R. Diaz, M. Selman and Z. Sugg.
The Grand Strand is not alone in this problem:

World Hypoxic and Eutrophic Coastal Areas

- Observations
- Doubling per decade

Number of coastal areas experiencing hypoxia

Data compiled from various sources by R. Diaz, M. Selman and Z. Sugg.
How does hypoxia happen?

Hypoxia = rate of oxygen demand > rate of oxygen resupply

Oxygen demand ≈ microbial decomposition of organic matter
Oxygen resupply ≈ photosynthesis by plants (algae) & atmospheric oxygen diffusion

Conventional model of hypoxia formation

Terrestrial Loadings

- N&P = Nitrogen & Phosphorus
- Phyto = Phytoplankton (algae)
- OM = Organic Matter
- Micro = Microbes, primarily bacteria

Air – Sea Exchange

Photosynthesis

Surface water

Bottom water

Respiration

Diffusion & Mixing

Physical Forces
“Constrained Enrichment” Hypothesis for Hypoxia Formation along the Grand Strand

“Normal” conditions: terrestrial inputs widely dispersed & diluted throughout coastal region

1) Moderate SW winds cause upwelling of bottom water
2) Bottom water intrusion acts as a physical barrier preventing dispersion of inputs
3) Inputs concentrate inshore
4) Elevated concentrations greatly stimulate DO consumption rates leading to localized hypoxia

Hypoxia formation driven primarily by a combination of:
1) Regional-scale physical conditions (upwelling process)
2) Local-scale terrestrial inputs of nutrients & organic matter

Figure: Erik Smith, NI-WB NERR
“Constrained Enrichment” Hypothesis for Hypoxia Formation along the Grand Strand

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Figure: Erik Smith, NI-WB NERR
Oxygen consumption rates (respiration) in Long Bay:

High variability in rates:
- **Spatial variability**
  - Inshore rates > offshore rates
- **Temporal variability**
  - Summer rates >> winter rates

Rates span range observed in other SE nearshore coastal environments.

Nearshore waters off Georgia in summer:
13.3 – 27.3 µg O₂ L⁻¹ h⁻¹ (mean = 17.9)

Data from Jiang et al. 2010

Source: Erik Smith, NI-WB NERR
What drives variability in respiration rates?

Nonparametric Correlation Matrix:
Spearman’s ρ value and probability

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Perfect correlation = 1.00 =

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: $p<0.0001$  
: $p<0.001$  
: $p>0.05$

Source: Erik Smith, NI-WB NERR
August 2009 Low DO Events:

Sources: Susan Libes, CCU (top); Erik Smith, NI-WB NERR (bottom)
Radon-222 activity at Apache Pier during August events

Rn-222 is a ‘tracer’ of terrestrial groundwater input

Rn-222 activity is a function of input rate and dispersion rate

→ High activities imply high substrate concentrations (prev. slide) are a result of inhibited dispersion in the nearshore zone.

Source: Richard Peterson, Clay McCoy, CCU
Research conducted to date in Long Bay:

- **2006 – 2008 SC Sea Grant Consortium funded research**
  - Identification of Coastal Hypoxia Mechanisms and Hypoxia Monitoring in Inner Shelf Waters of Long Bay, South Carolina – E. Koepfler, S. Libes, E. Smith
  - Numerical Study of the Physical Conditions that Lead to Hypoxia Events in Long Bay, South Carolina – G. Voulgaris, R. Sanay
  - Electrical Characterization Of Submarine Groundwater Seeps On The South Carolina Continental Shelf – R. Viso, P. Gayes, C. McCoy

- **2009 ad-hoc hypoxia sampling**
  - CCU, NI-WB NERR, DNR, SCSGC sampling of August hypoxia – anoxia events

- **2010 – 2011 SCDEC/OCRM funding**
  - Time-series analyses of existing physical, meteorological & water quality data – G. Voulgaris; USC
  - Continued water quality and Rn-222 data collection at Apache Pier S. Libes, E. Koepfler, R. Peterson, R. Viso; CCU
  - Biogeochemical studies on factors controlling oxygen consumption rates E. Smith, NI-WB NERR
**Major Conclusions and Management Implications:**

- Hypoxia appears to be restricted to immediate nearshore waters of Long Bay.

- Hypoxia is driven by an interaction between:
  - Regional-scale physical conditions (wind-induced upwelling process)
    - *Nothing we can do about this.*
  - Local-scale terrestrial inputs of nutrients & organic matter
    - *This is potentially amenable to local management actions.*
    - *Increasing nutrient/organic loading to coastal waters will decrease the physical threshold necessary for hypoxia formation.*
Many Remaining Questions (Known Unknowns):

1) True temporal & spatial extent of low DO conditions in Long Bay?
2) What are the physical thresholds necessary for hypoxia formation in Long Bay?
3) Role of water column versus sediments in DO production & consumption?
4) Role of upwelling in resuspension of sediment particulate organic matter?
5) Where exactly are nutrients & organic matter coming from?
   i. Relative roles of swashes & outfalls relative and “natural” inputs?
   ii. Relative roles of surface runoff and groundwater inputs?
6) What is the relative balance between terrestrial and offshore organic matter production?