Linking Hypoxia to Fish Populations: Modeling Across Scales

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Does hypoxia have population level effects on coastal fish?

- Surprisingly little conclusive evidence for population level effects

- Multiple stressors and compensatory mechanisms make detecting the effects of hypoxia difficult

- Need for populations studies that quantify exposure and separate hypoxia effects from other stressors

What are the long-term effects of hypoxia on Atlantic croaker in the NWGOM?

- Croaker good test case

  – Well studied

  – Mobile, demersal

  – Tolerant to hypoxia

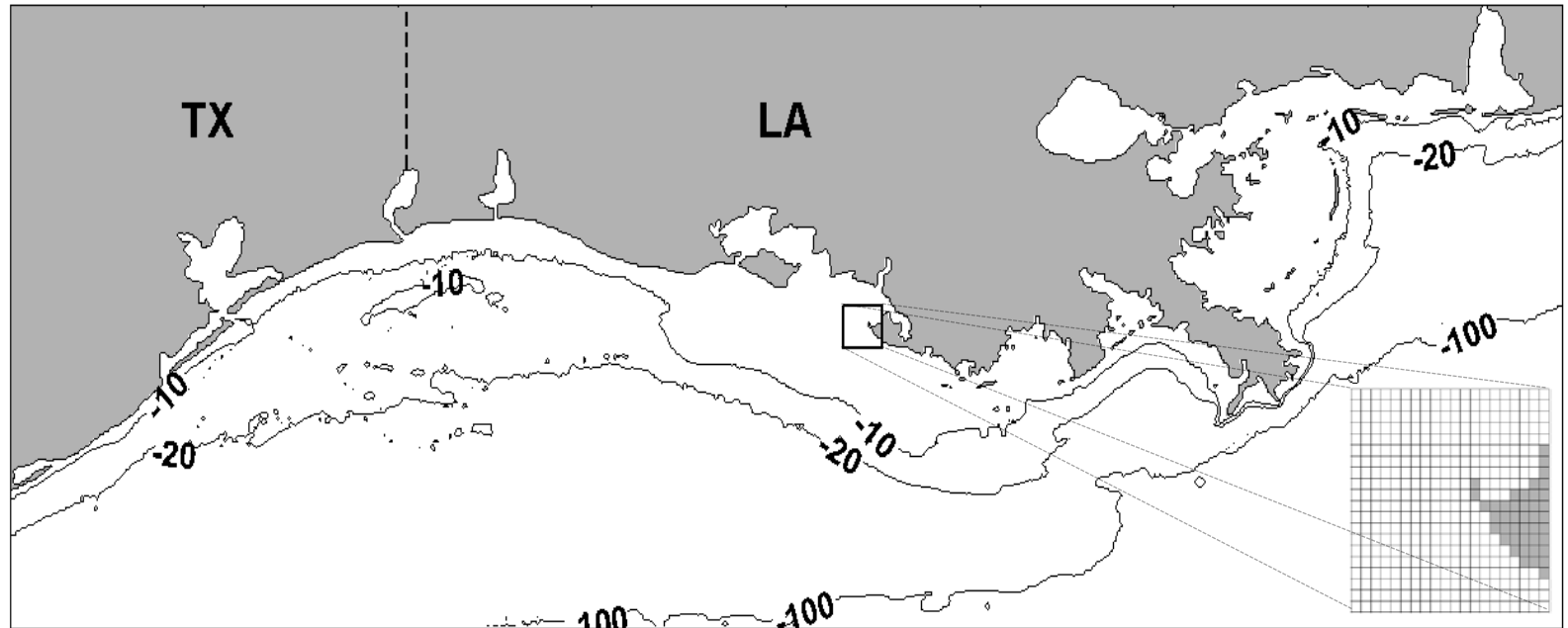 – Fecundity affected by

  hypoxia
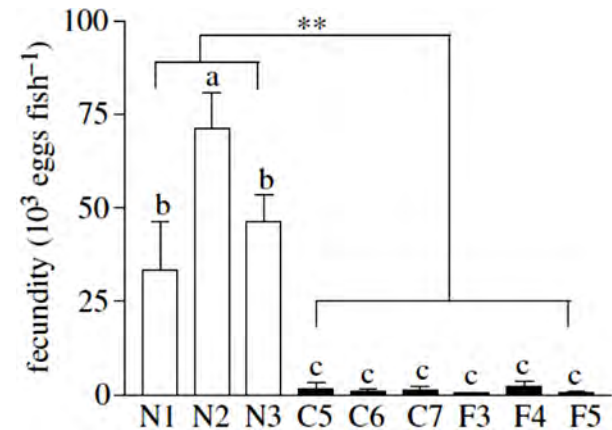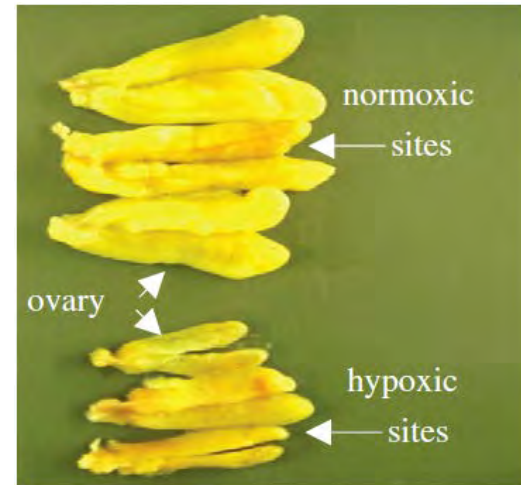
Craoker Model Overview

- Spatially-explicit IBM
  - Follow 7 stages
  - Max age is 8
  - Model year Sept. 1
  - Each year 365 days

- Hourly processes
  - Growth
  - Mortality
  - Reproduction
  - Movement

- Environmental conditions simulated on a 2-D spatial grid
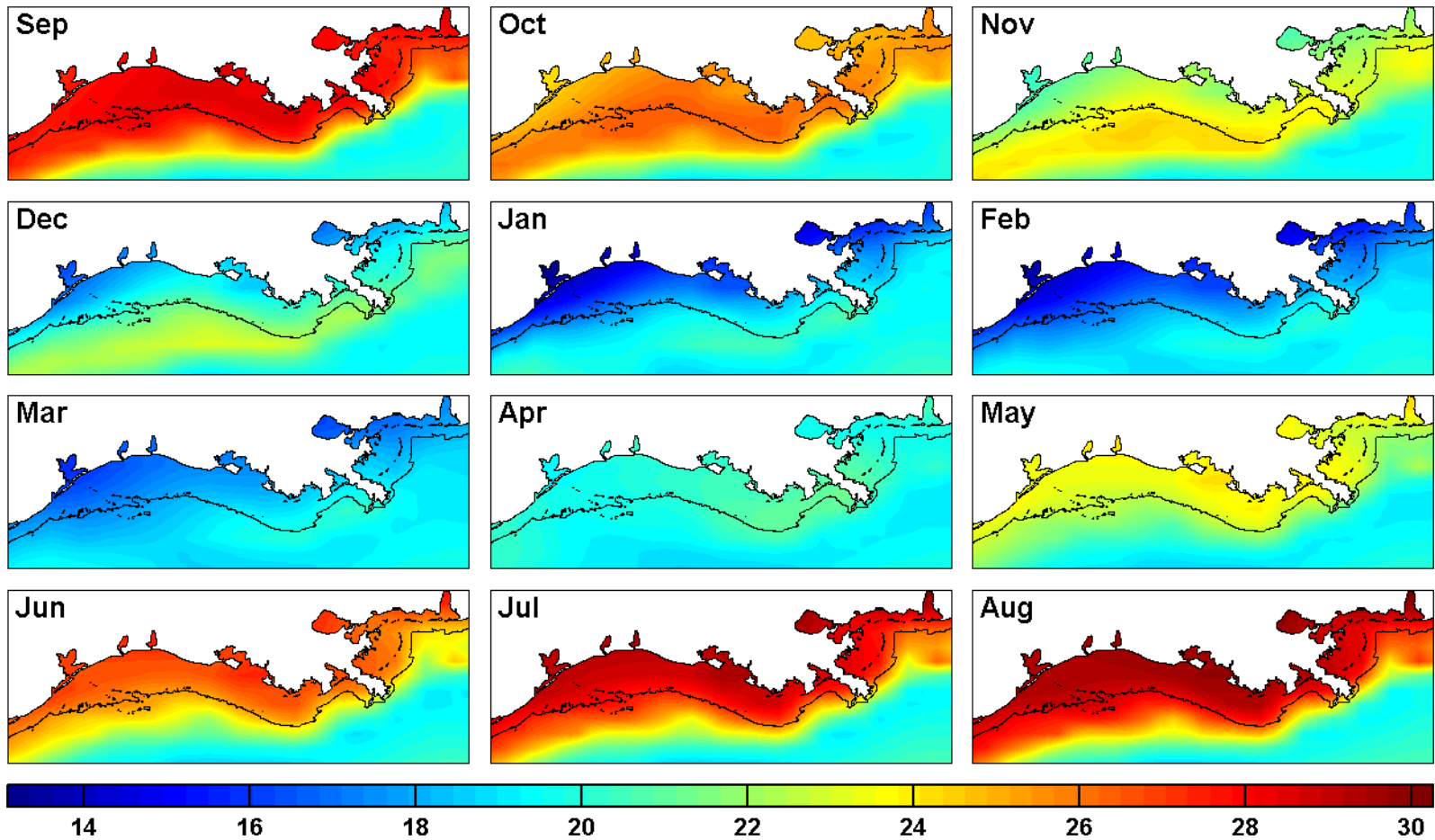 - Temperature, Chl-a, and dissolved oxygen
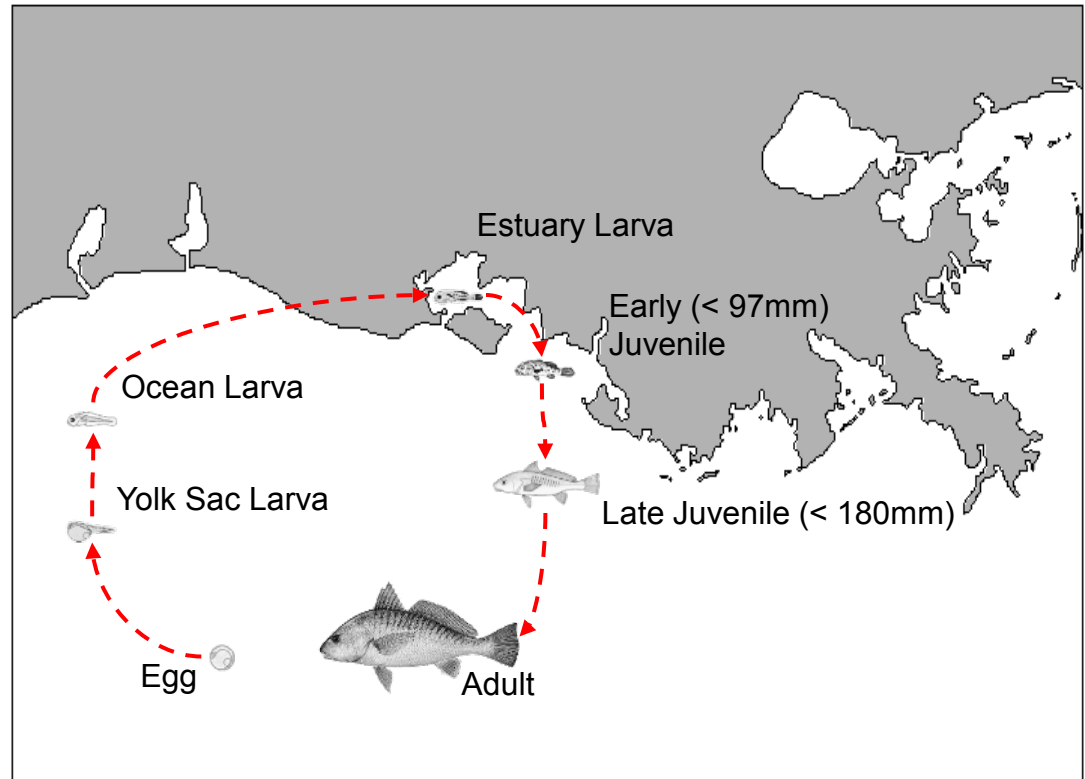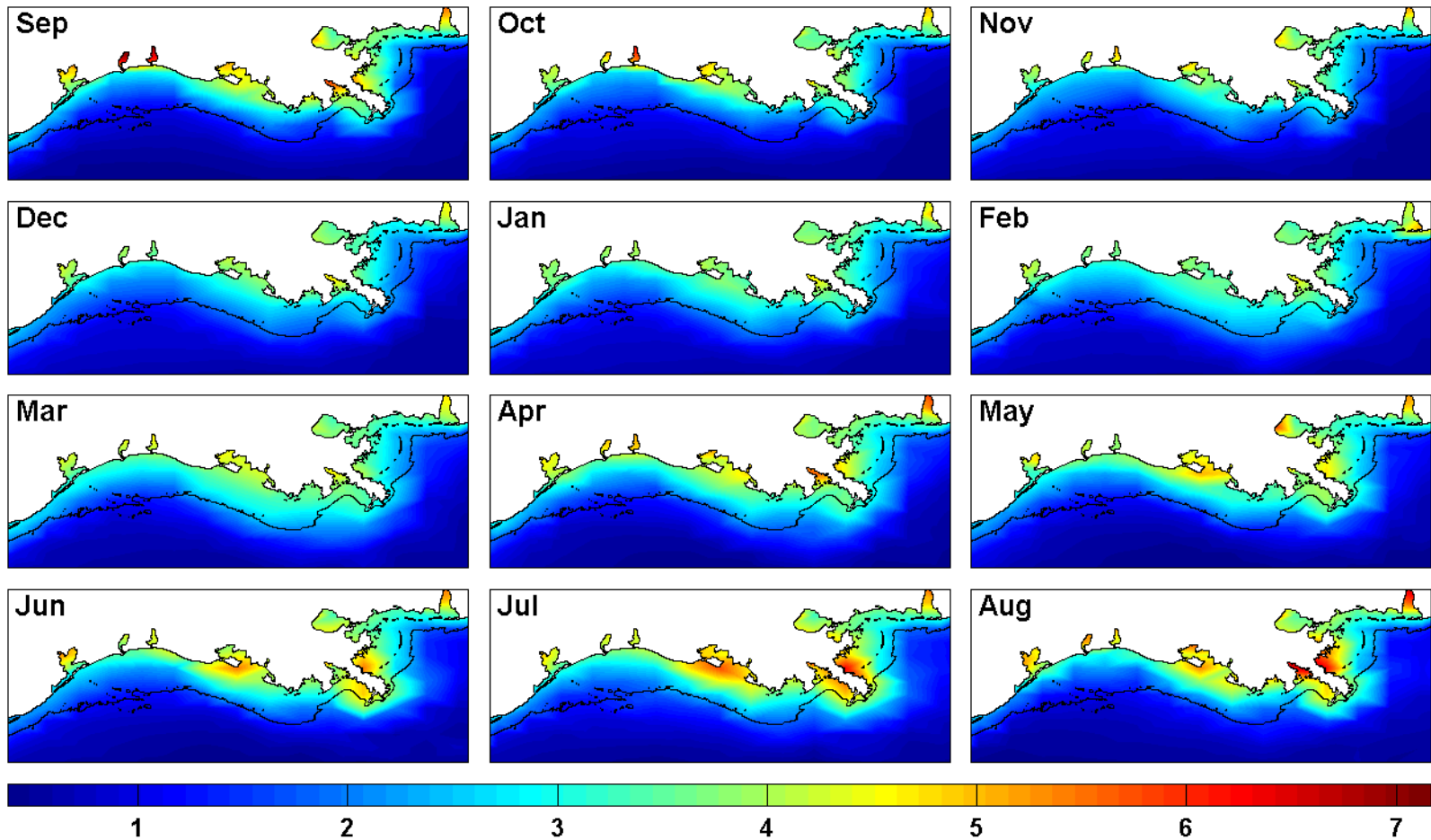
Croaker Model: Grid Configuration

- Idealized 300 x 800 cell grid (1 km resolution)
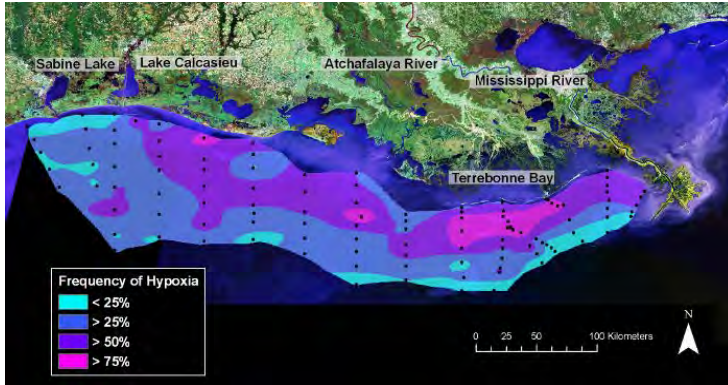
- 2 sub-regions: TX, and LA

Croaker Model: Temperature

Croaker Model: Chlorophyll-a
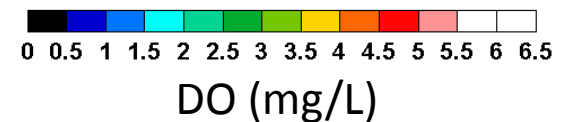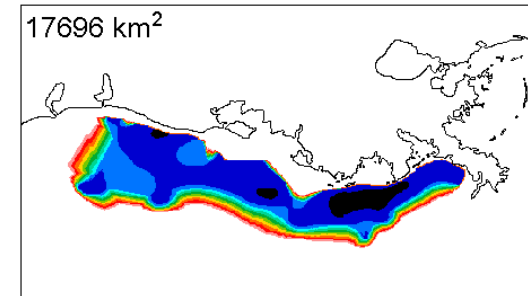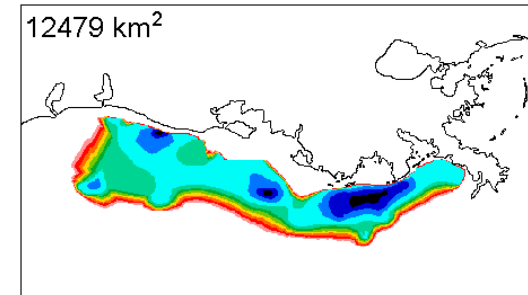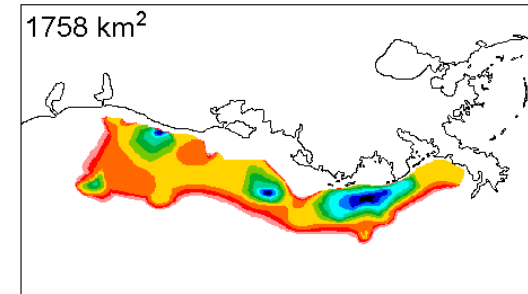
(mg/m³, sqr-transformed)

Croaker Model: Oxygen

www.gulfhypoxia.net

- Baseline: normoxic all year

- Hypoxia

  – June1-7, DO in hypoxic zone declines from 8 mg/L to specified local minimum

  – low DO from June to August

- Scenarios: mild, intermediate, & severe

DO (mg/L)

Croaker Model: Direct Effects of Low DO

- Exposure-effects sub-models (Neilan and Rose, in prep) are used to follow growth, reproductive, and survival vitalities

$$Vg, Vr, or\ Vs = \begin{cases} 1.0 - \alpha \dfrac{(DO - DO_{NE})^2}{(DO - DO_{NE})^2 + \beta^2} & \text{if } DO < DO_{NE} \\ 1.0 & \text{if } DO \geq DO_{NE} \end{cases}$$

  - Vr only affected by the *last 10 weeks* of exposure when DO < **4.0 mg/L**

  - Vg affected only when growth (G) is positive and DO < **3.0 mg/L**

  - Vs affected when DO < **1.25 mg/L**

  - Vg and Vs are reset to 1.0 on September 1; Vr not reset until Jun 1

- Only imposed on late juveniles, age-1 adults, and age-2 adults

Croaker Model: Design of Simulations

- 20,000 super individuals (Scheffer et al. 1995) per age-class

- 60% of incoming estuary larvae allocated to LA

- 100 years simulated in each run, first 20 years ignored
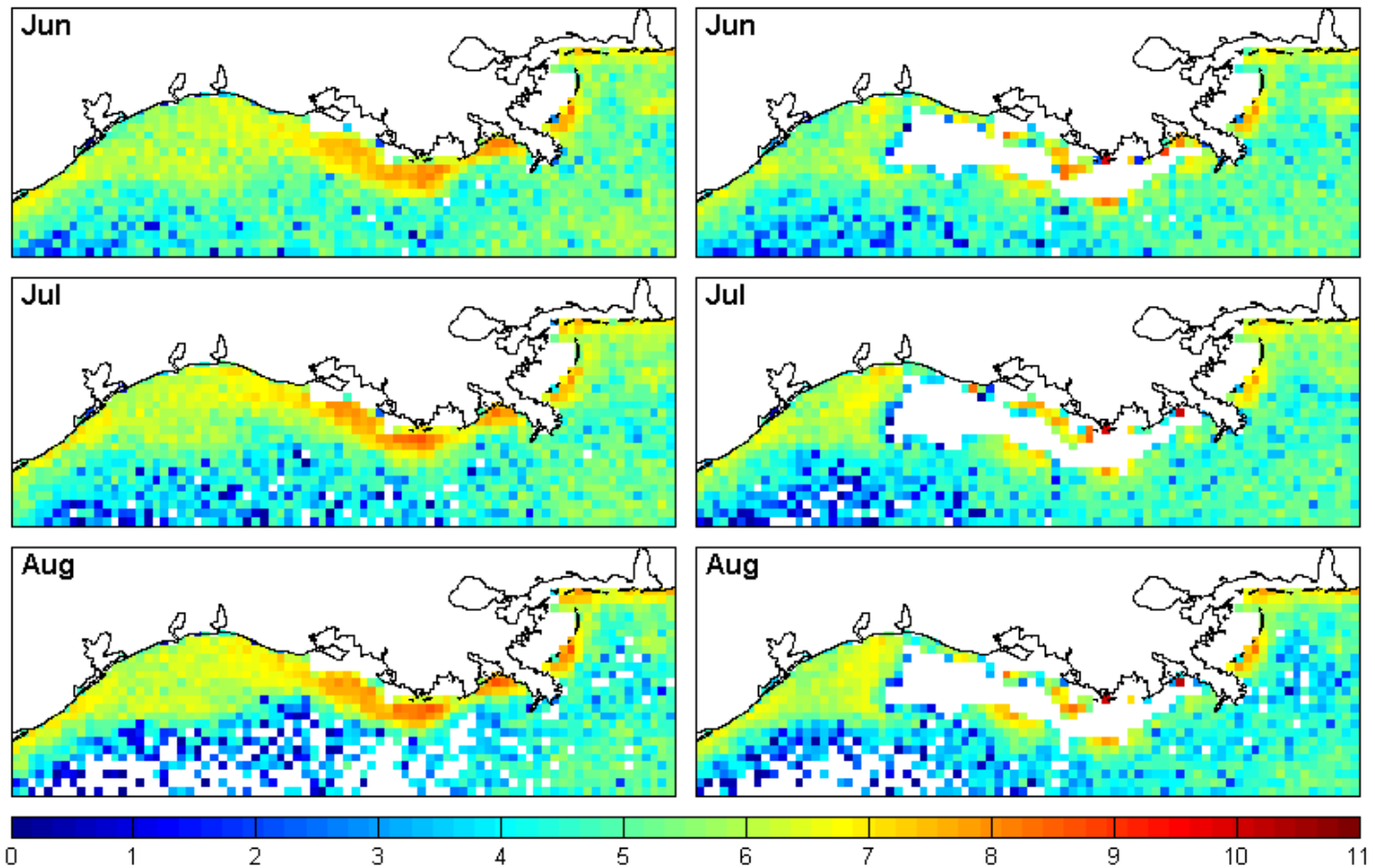
- Calibration of baseline (not shown)

Croaker Model: Baseline Age-1 Adult Distribution
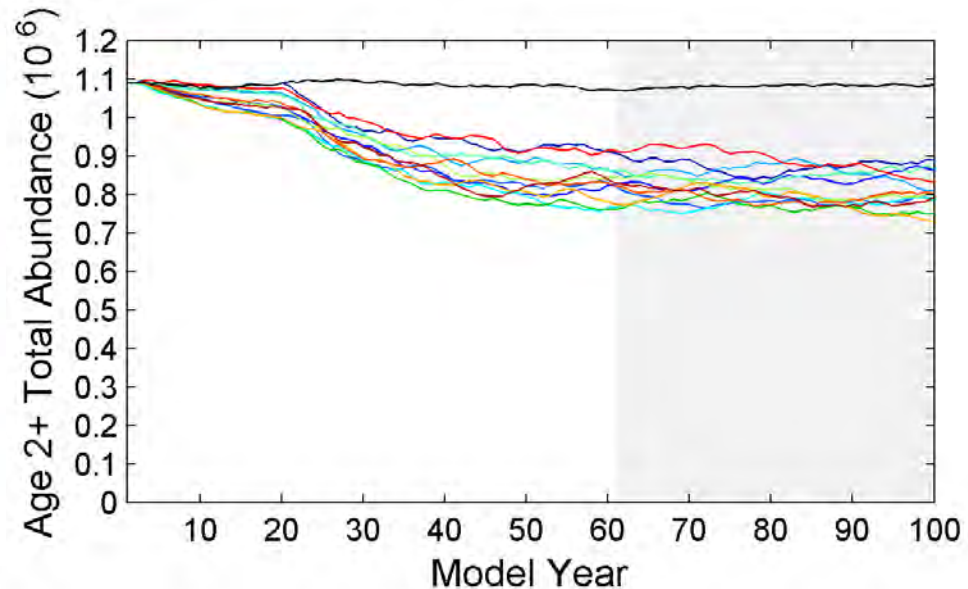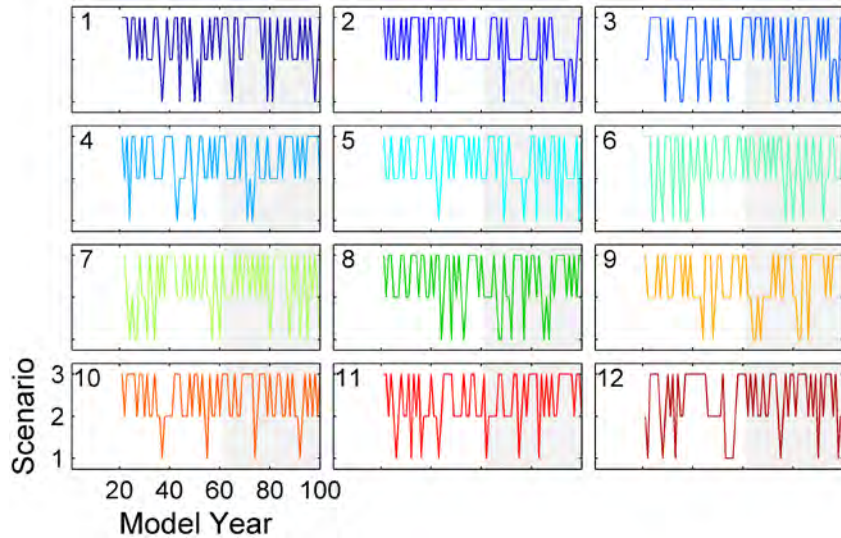### (fish / 10 km², ln-transformed)
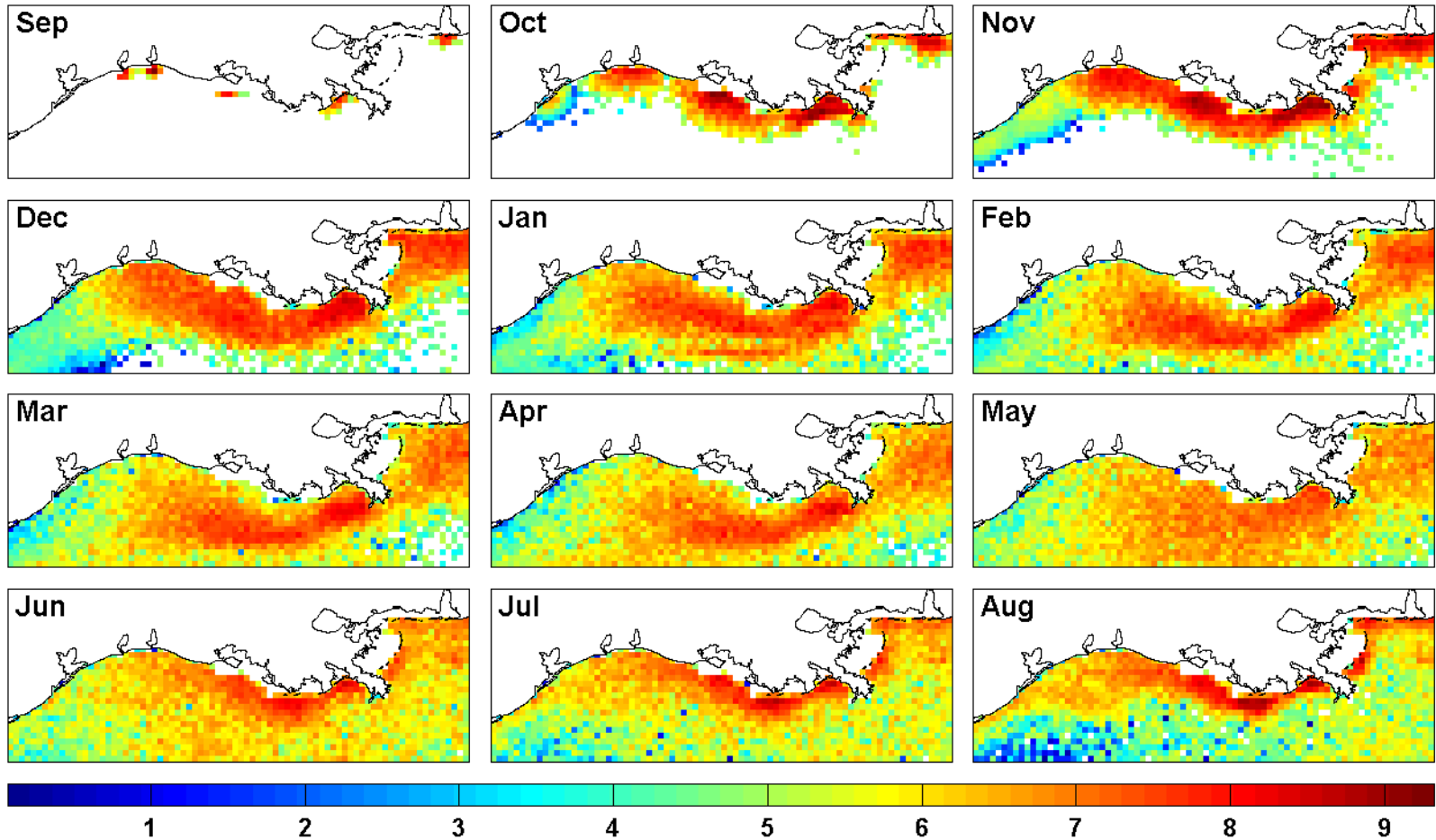
Croaker Model: Severe Hypoxia Effects
(fish / 10 km², ln-transformed)

Croaker Model: Time Series

*scenario: 1 = mild, 2 = intermediate, and 3 = severe

- Age 2+ abundance ranged from 71-82% of baseline abundance

- The percent of baseline abundance over years 61-100 was uncorrelated to the proportion of mild (r^2 = -0.5609) or severe (r^2 = -0.0301) years

Coupling to Hydrodynamics

- Fennel et al.
  - DO, temperature, chl-a for 2004-2009
  - DO only for long-term

- Justic et al.
  - DO for 2002
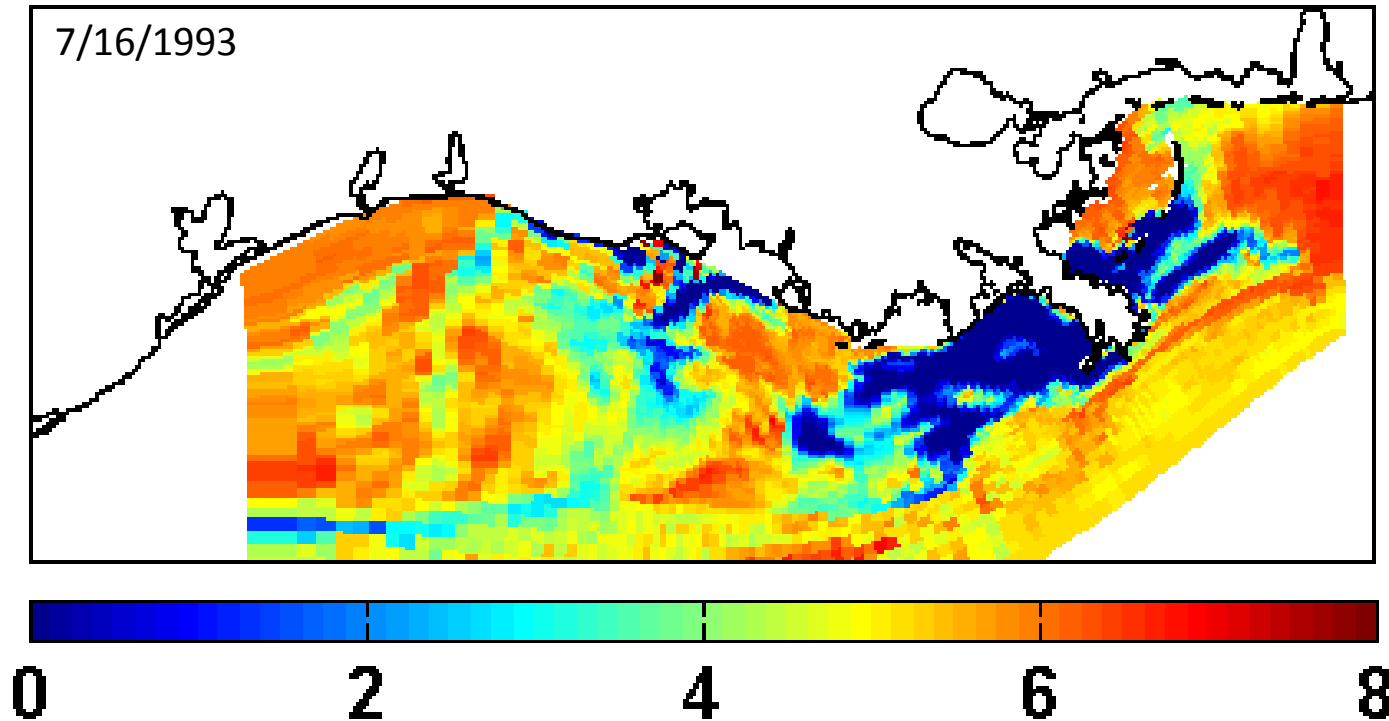 - Avoidance behavior (with Haosheng Huang)

Fennel et al.

- ## ROMS
  1-20 km
  20 layers

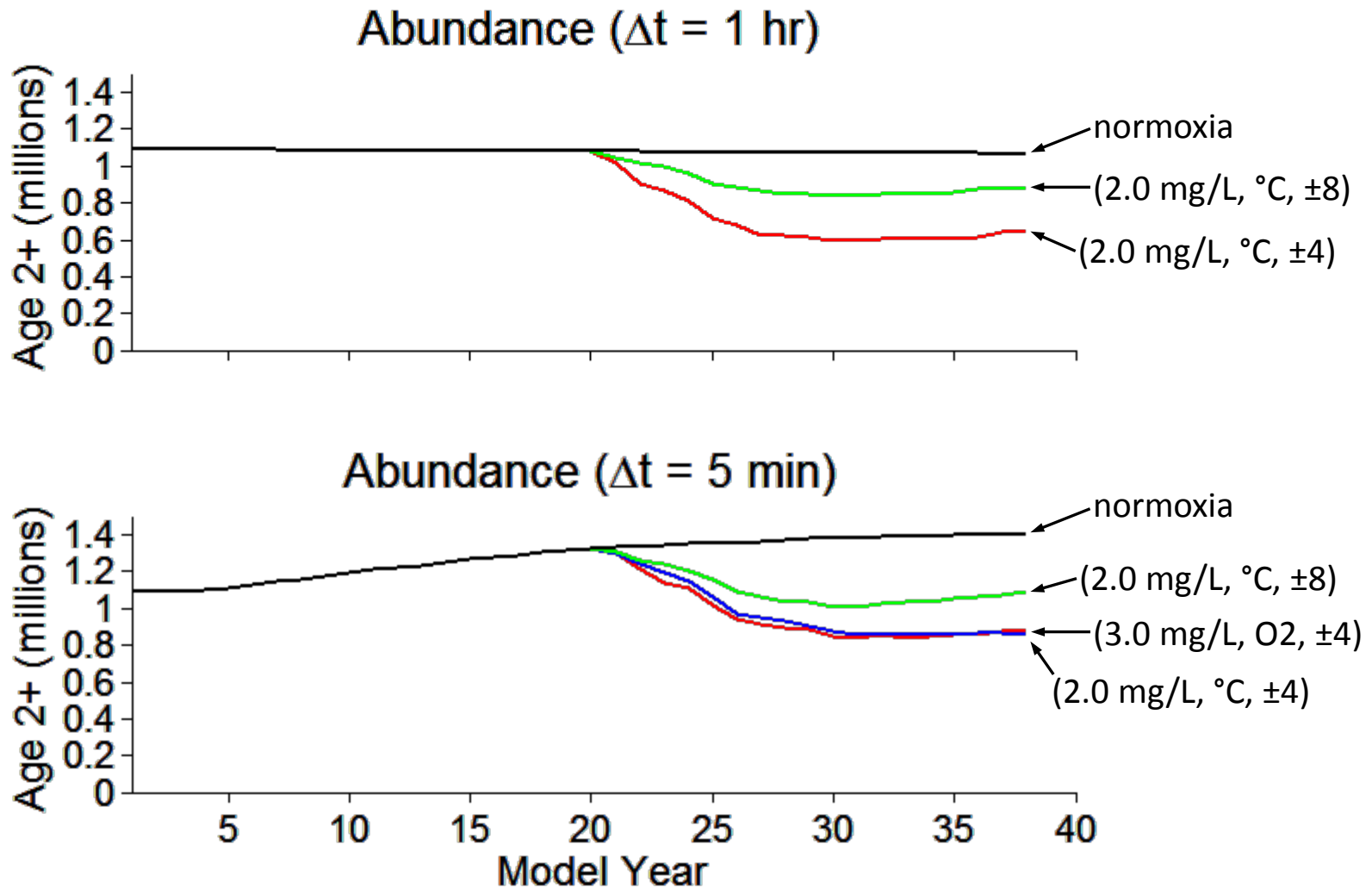- ## Nitrogen cycle

- ## 1990-2007 Daily DO
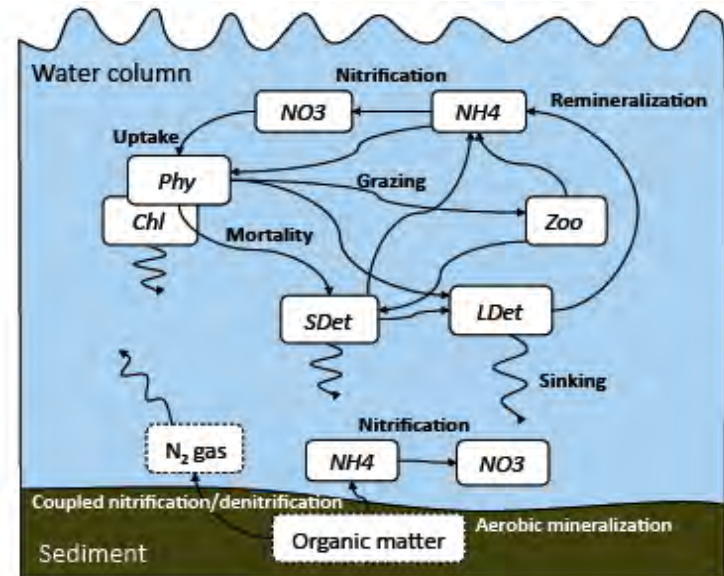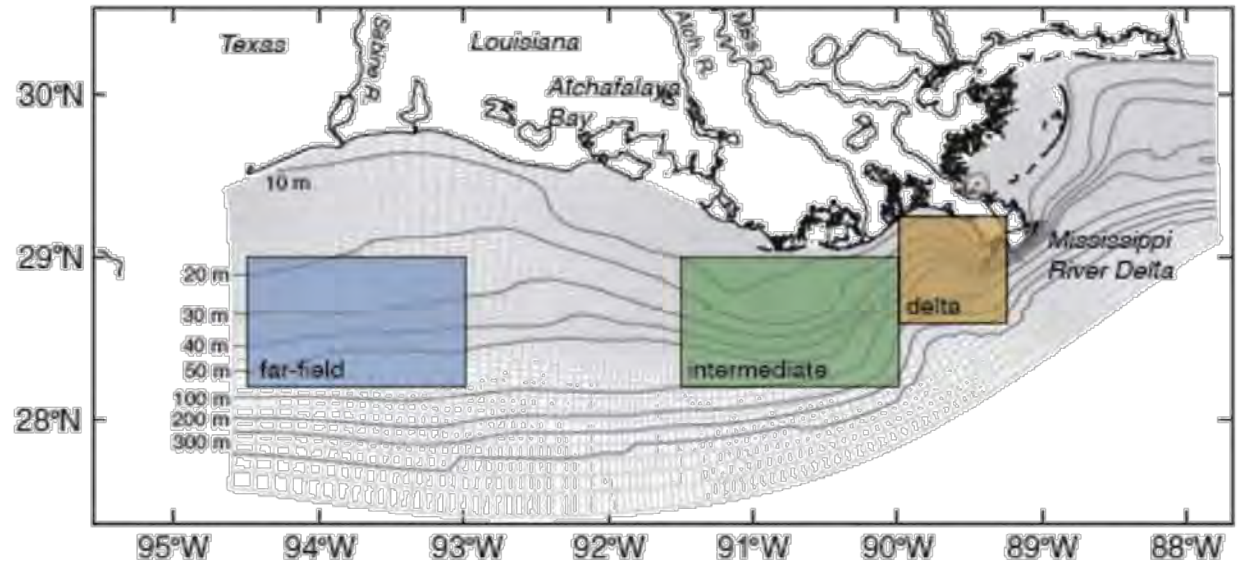
Fennel, Hetland, Feng & DiMarco (2011) A coupled physical-biological model of the Northern Gulf of Mexico shelf: model description, validation and analysis of phytoplankton variability *Biogeosci.* 8:1881-99

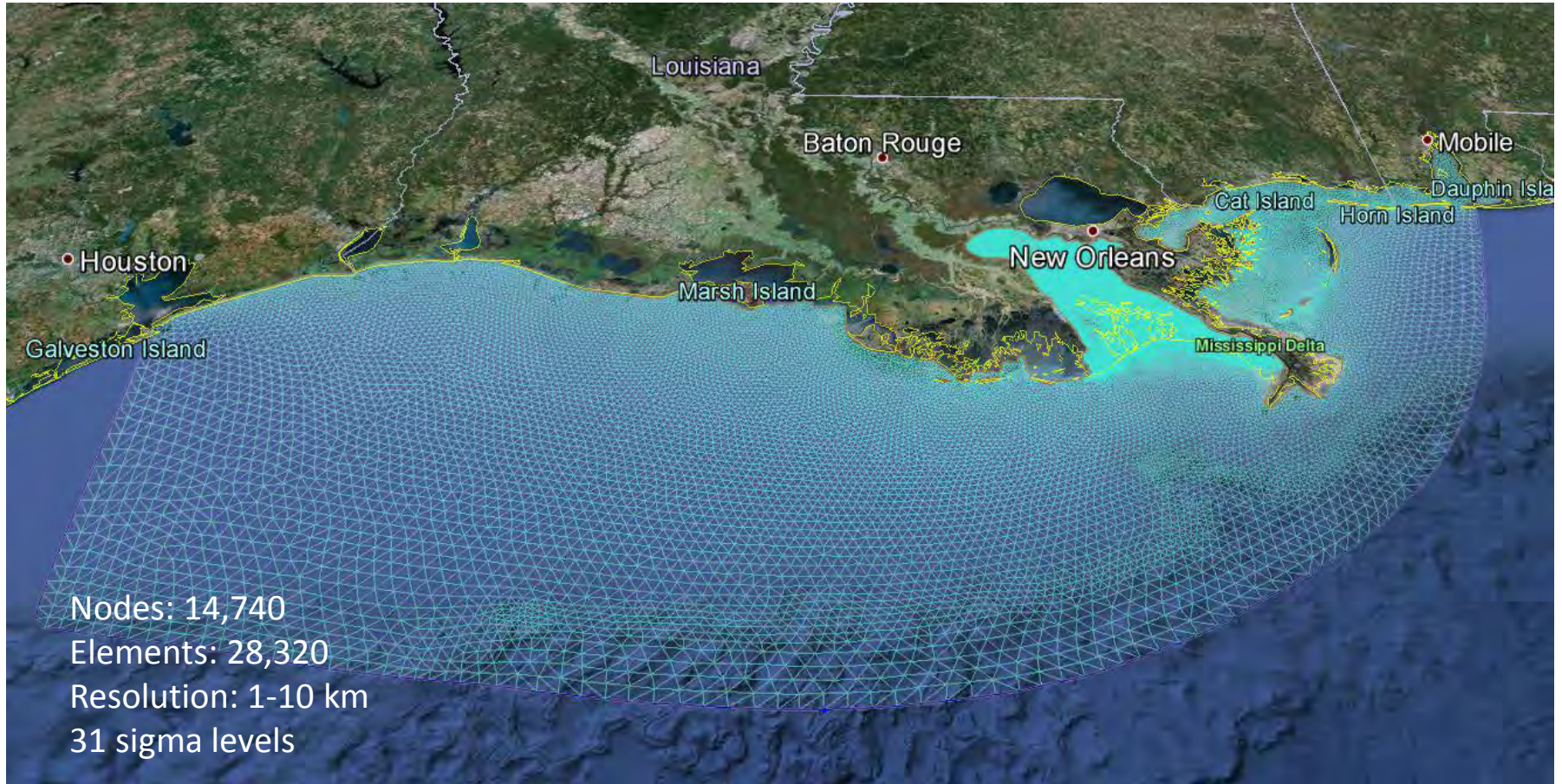# Fennel et al. : New Hypoxia Scenarios

7/16/1993

Fennel et al. : IBM Results

Abundance (Δt = 1 hr)

normoxia
(2.0 mg/L, °C, ±8)
(2.0 mg/L, °C, ±4)

Abundance (Δt = 5 min)

normoxia
(2.0 mg/L, °C, ±8)
(3.0 mg/L, O2, ±4)
(2.0 mg/L, °C, ±4)

Justic et al.: FVCOM-LaTex Model
Computational Domain and Grid

Nodes: 14,740
Elements: 28,320
Resolution: 1-10 km
31 sigma levels

Wang and Justic (2009), Justic and Wang (2009)

Justic et al.: FVCOM LaTex Water Quality Model

Justic and Wang (in preparation)
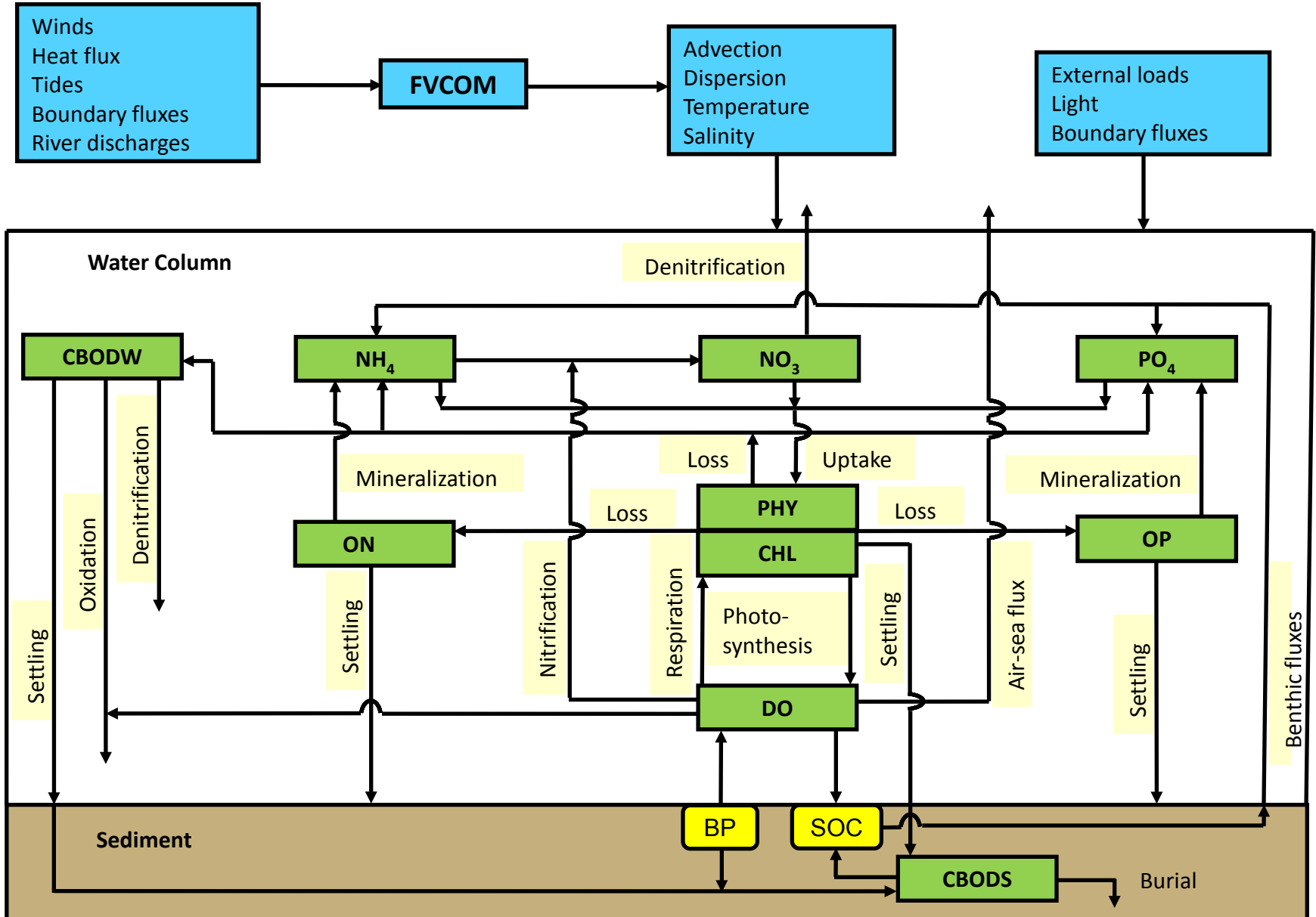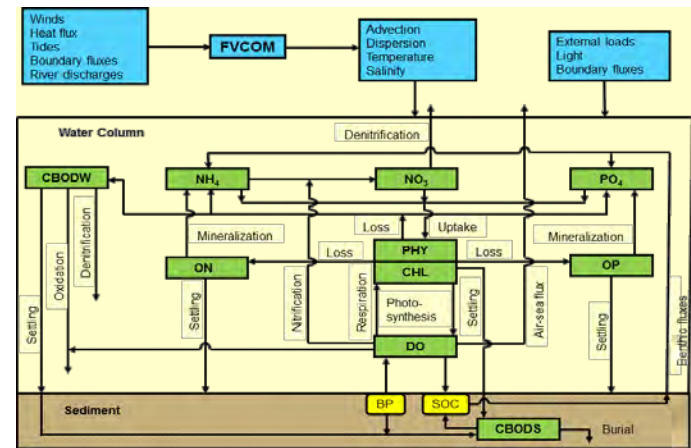
Justic et al.: FVCOM-LaTex

- Year 2002
  - largest hypoxic zone on record (22,000 km^2)

- Using bottom layer as daily input to the croaker IBM

- Coupling to IBM
  - Spin-up and then simulate population response
  - Use to test avoidance movement algorithms
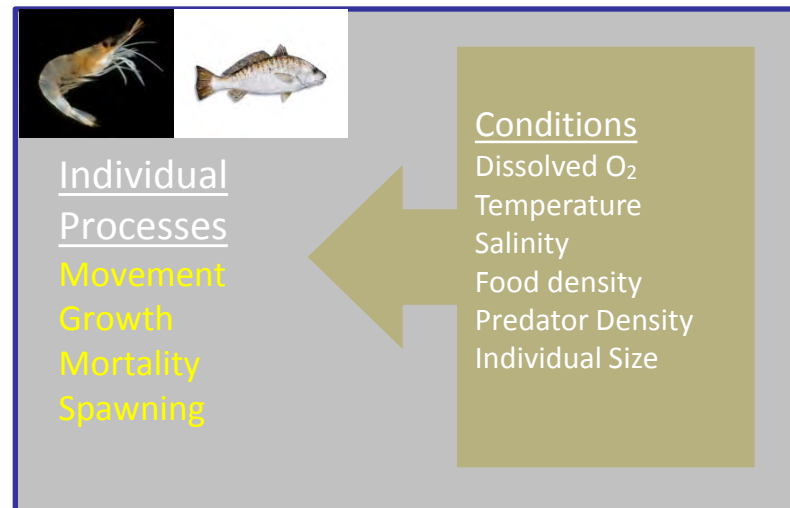
Justic et al.: FVCOM LaTex Model

FVCOM

WASP

IBM

Individual Processes
- Movement
- Growth
- Mortality
- Spawning

Conditions
- Dissolved O_2
- Temperature
- Salinity
- Food density
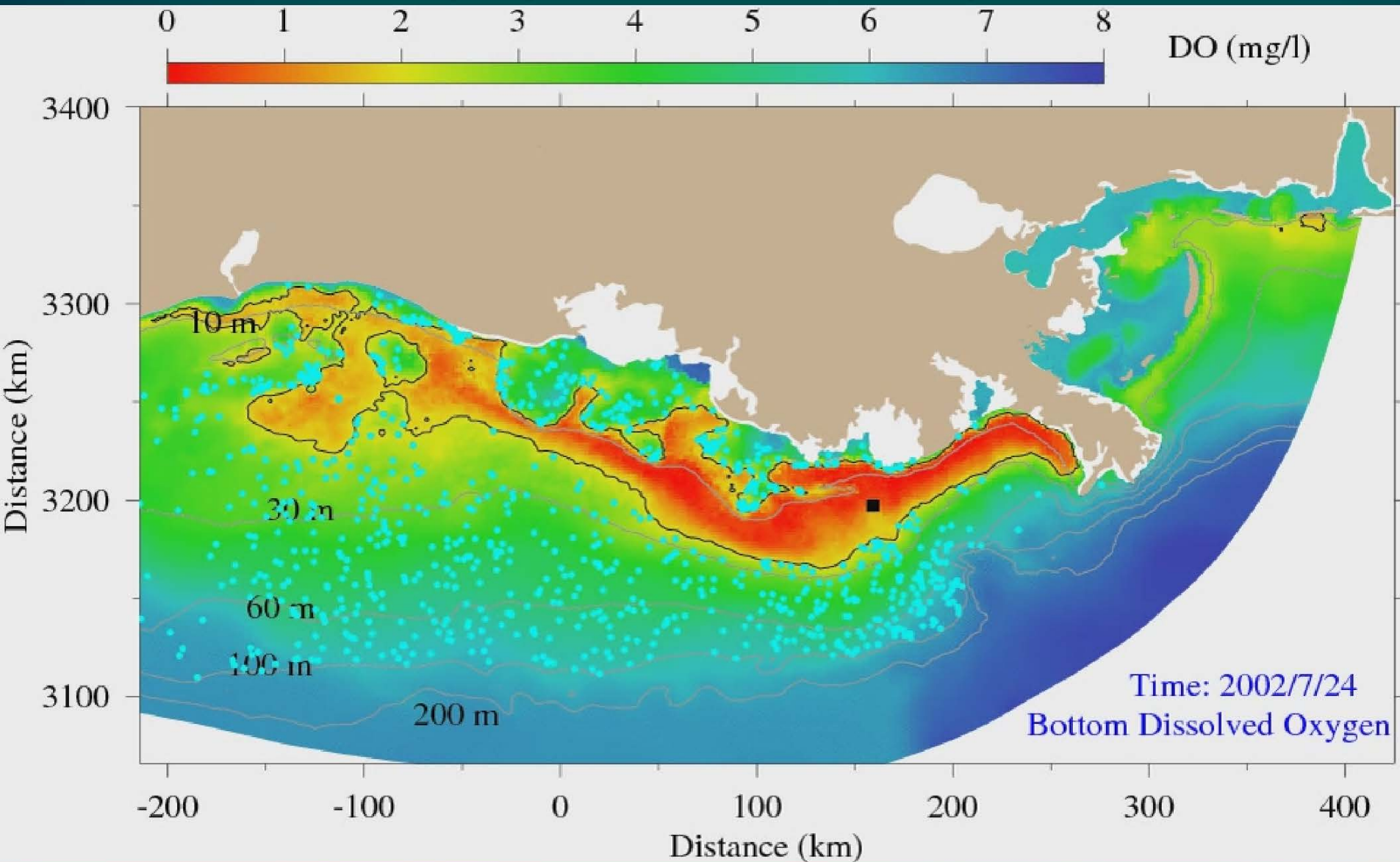- Predator Density
- Individual Size

Justic and Wang (2009, in preparation); Wang and Justic (2009); Rose et al. (in preparation)

FVCOM LaTex Bottom DO + Fish
(May 1- October 1, 2012)

Justic et al. (in preparation)

Challenges to Coupling

- Snapshots

- Temporal and spatial variability
  - Further confused by a horizontal slice
  - Pseudo 3-D

- Km-scale variation

- Nearshore

- Accuracy:
  - Grid compatibility
  - Overlay interpolations