Updates and data needs for an ecosystem approach to menhaden management

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Menhaden Advisory Committee Meeting
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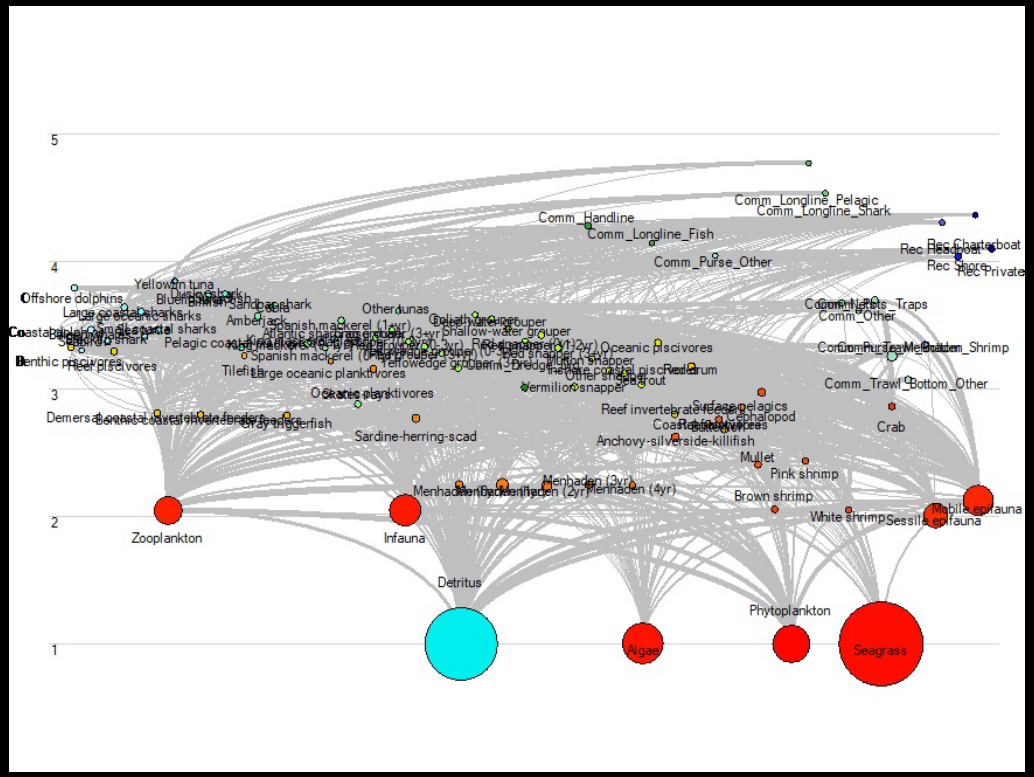
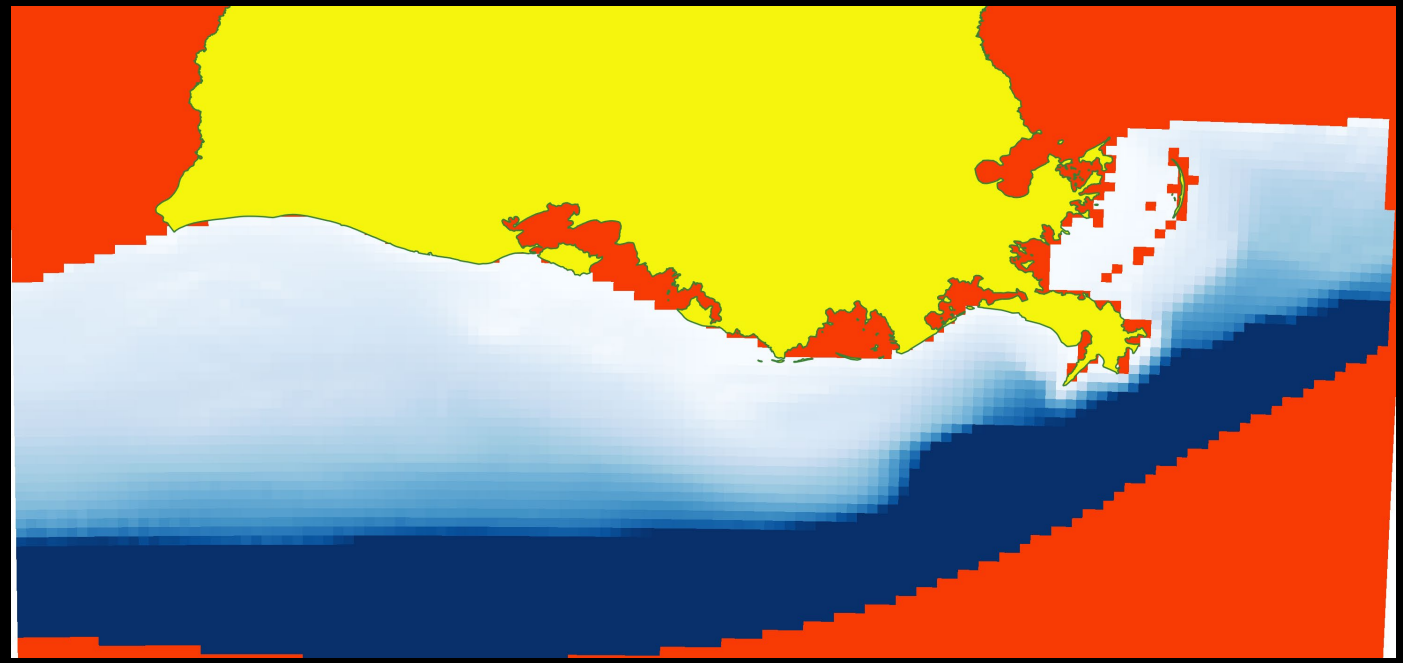
THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Two EwE models developed:

Gulf-Wide Ecopath Model



Northern Gulf of Mexico (NGOMEX) Ecospace Model

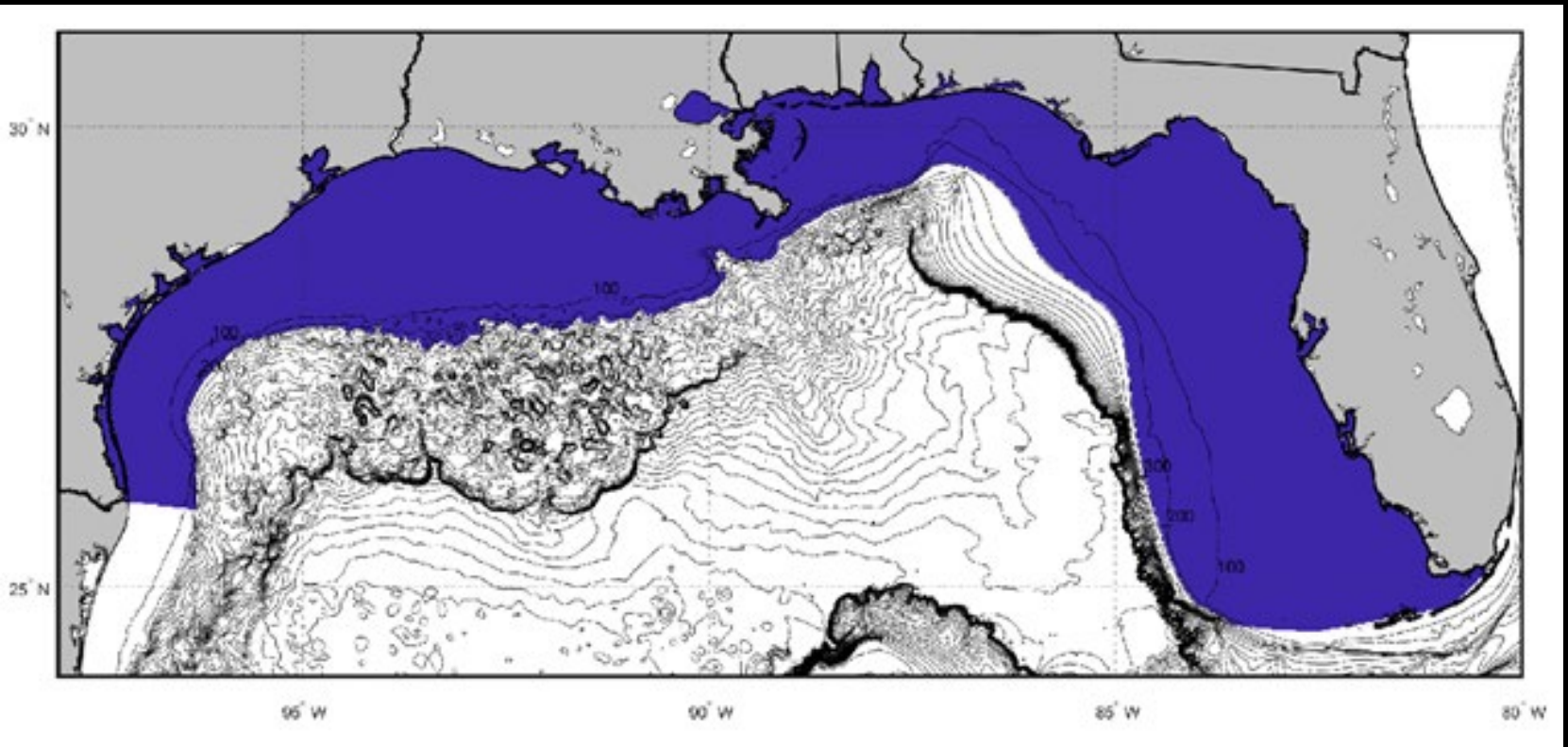


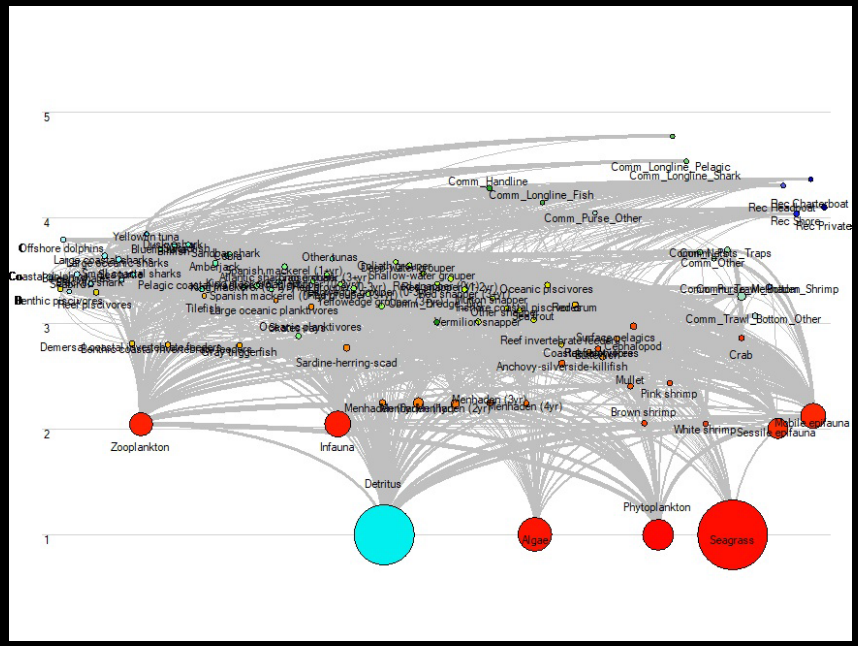
EwE modeling components

- Ecopath: Mass-balanced “snapshot” of an ecosystem
- Ecosim: Temporal dynamic simulations
- Ecospace: Spatial-temporal modeling

1. U.S. Gulf-wide Ecopath model

- Ecopath snapshot year: 1980
- 78 functional groups
- 12 commercial fleets and 4 recreational fleets
- Representative of blue region below, but not a spatial model





The diet matrix is based on a statistically-derived method and on an extensive diet meta-analysis (>1900 diet observations)

(Sagarese et al. 2017) https://doi.org/10.1016/j.ecolmodel.2016.11.001

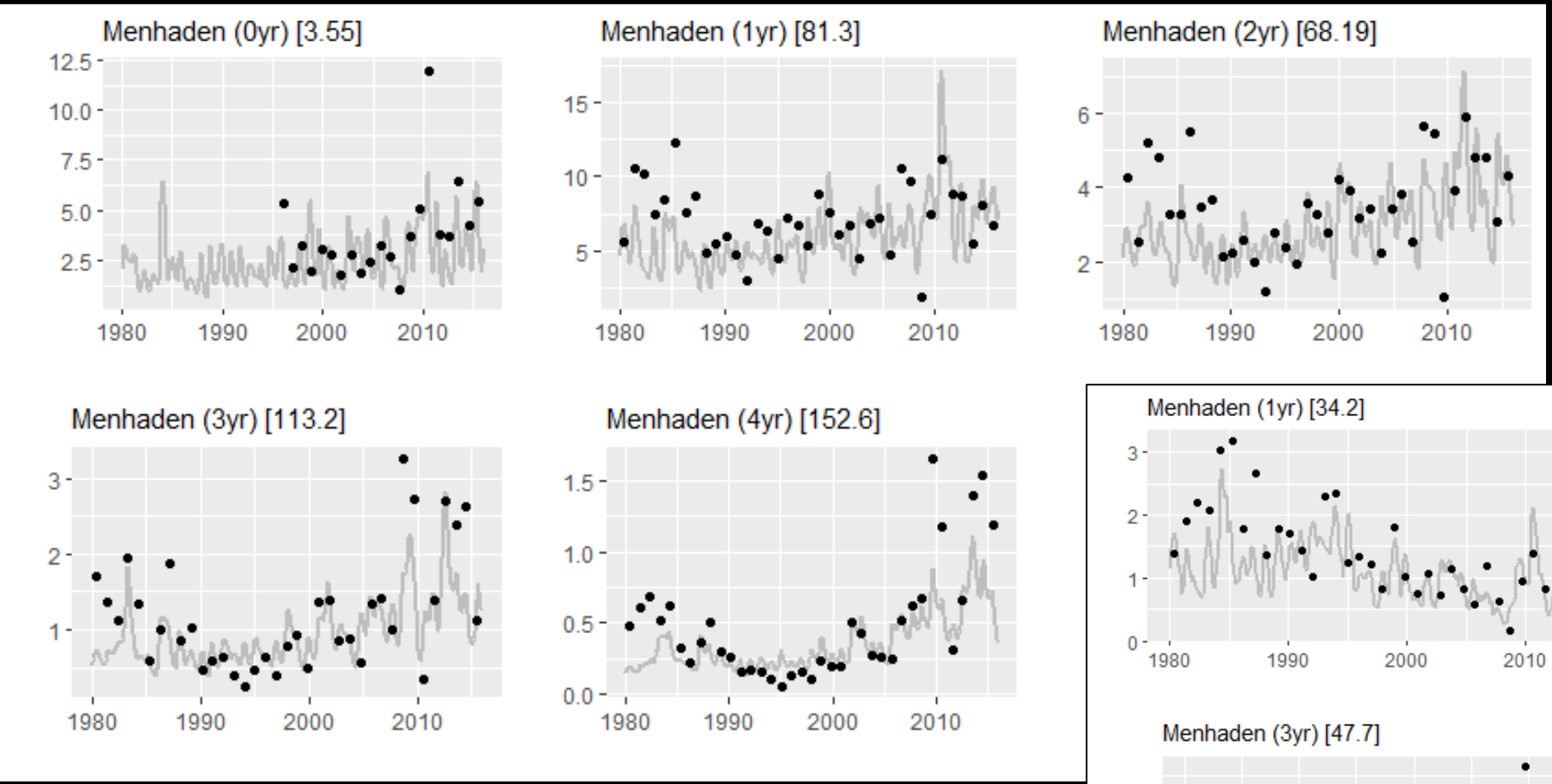
U.S. Gulf-wide Ecosim calibration runs

- Ecosim: 1980-2016
  - 160 input time series
  - Data sources:
    - Biomass, relative abundance (B): SEDAR, SEAMAP, ICAAT
    - Catch (C): NOAA landings,
    - Fishing mortality (F): F=C/B
    - Fishing effort (E): VOU database
  - Nutrient forcing: total Mississippi-Atchafalaya River Basin Loads
  - Fishing forcing: effort and mortality

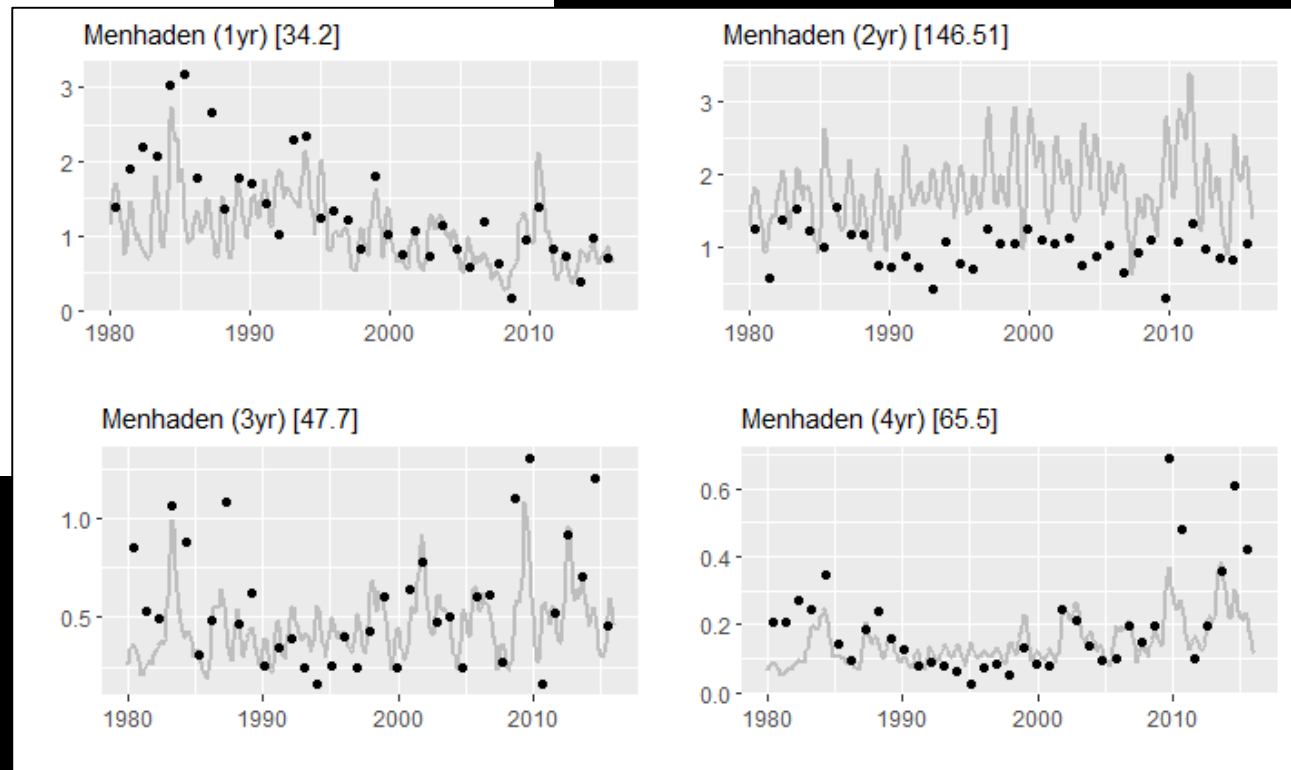
SEAMAP: SouthEast Area Monitoring and Assessment Program
SEDAR: SouthEast Data Assessment and Review
ICCAT: International Commission for the Conservation of Atlantic Tunas
MRIP: Marine Recreational Information Program
SRHS: Southeast Region Headboat Survey
VOU: Vessel Operating Units

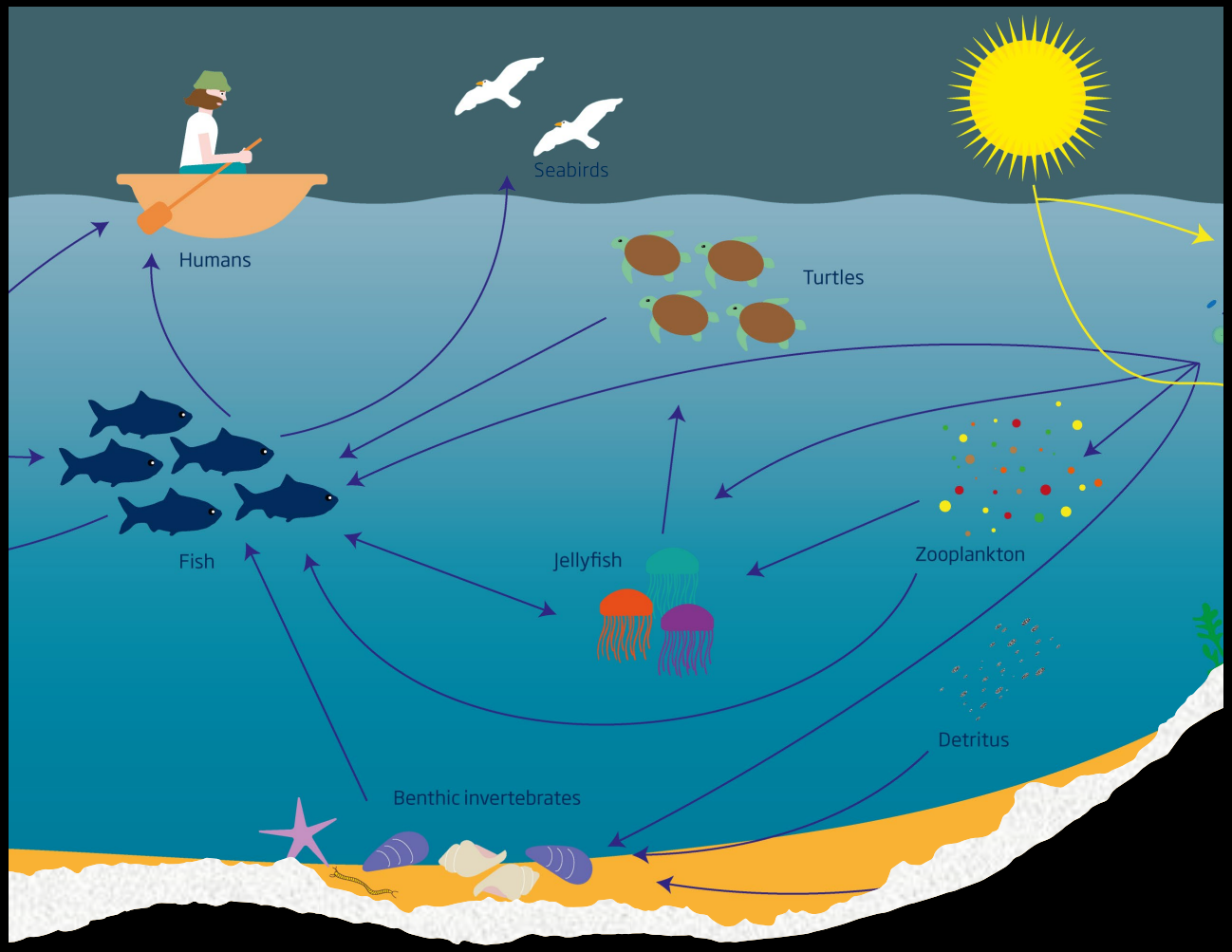
U.S. Gulf-wide Ecosim calibration – time series fits

Biomass



Catch

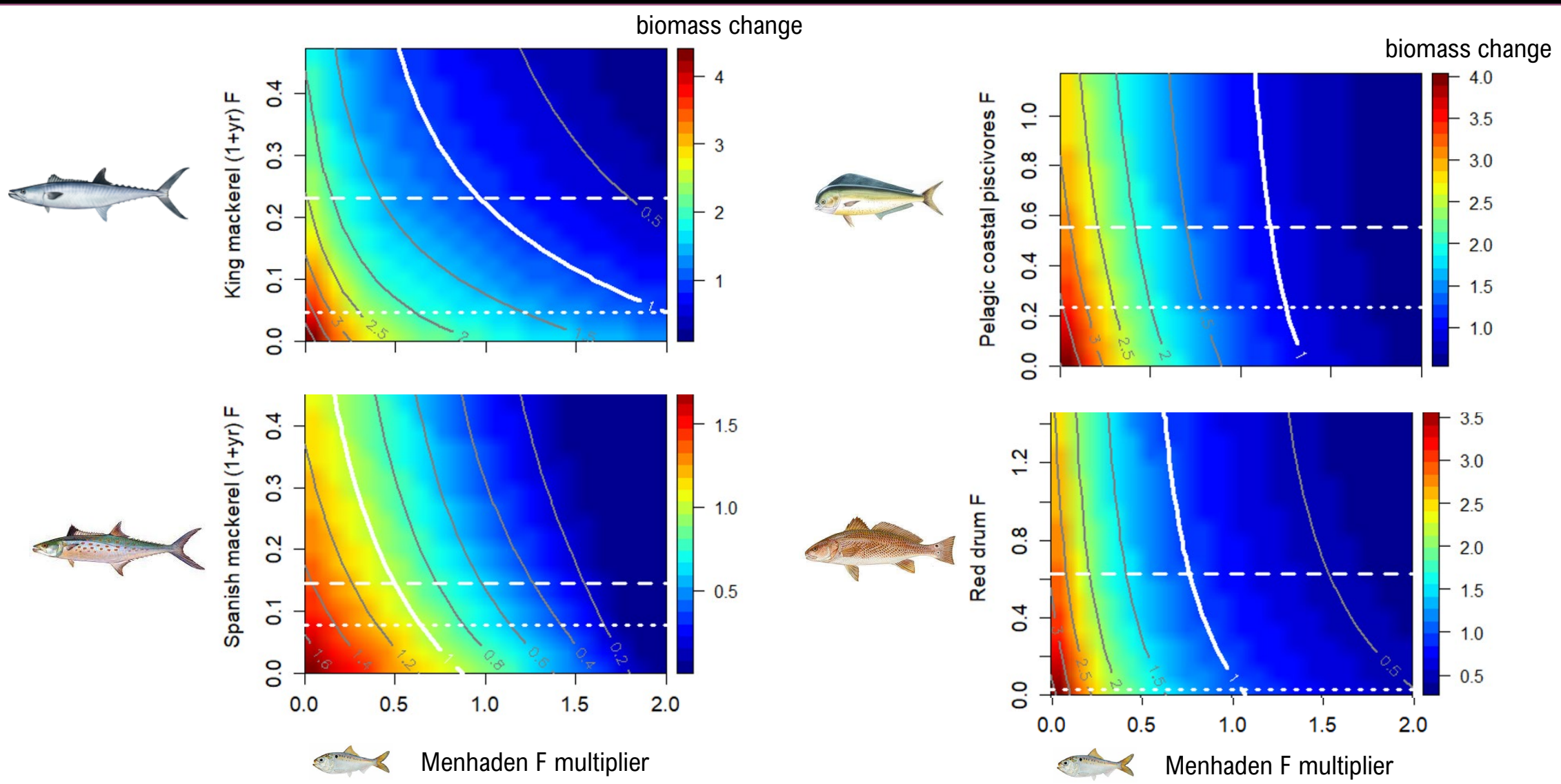




Model strengths and use to management

- Trophic interactions linking predator and prey biomass
- Ecosystem effects of bycatch and bycatch reductions

Gulf menhaden– the effect of F on predators



Model needs and limitations

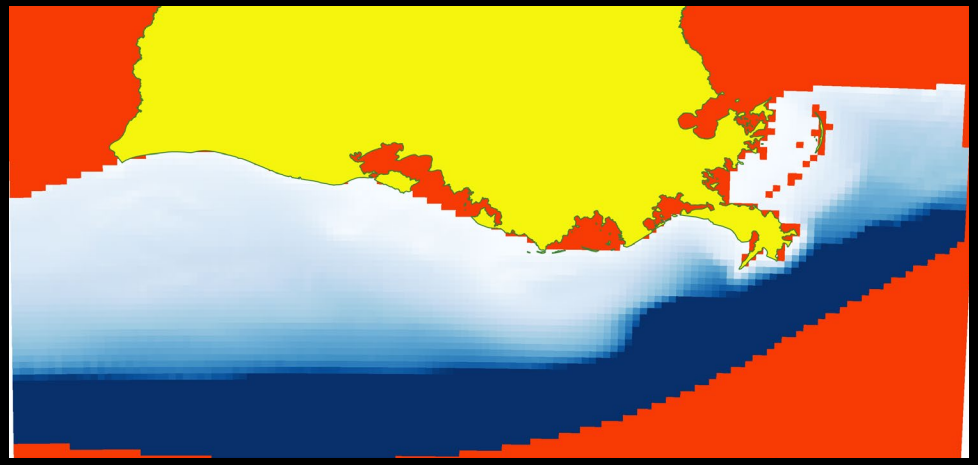
- Low ecotrophic efficiency estimates for menhaden (range 0.03-0.456)
  - Consumption of menhaden was limited by relatively low abundance of predators
  - Unknown sources of mortality, e.g., hypoxia
  - Under-representation of menhaden consumption in the diet matrix
  - Overestimate of menhaden biomass
- Diet data needs
  - Age-specific predation and consumption
  - Comprehensive stomach sampling in a single year throughout all seasons
  - Complementary methods: e.g., DNA barcoding and stable isotopes
- Uncertainty associated with Age-0
- Uncertainty associated with the vulnerability parameters
- Uncertainty associated with Bycatch estimates
- Uncertainty due to spatial dynamics not captured with the model

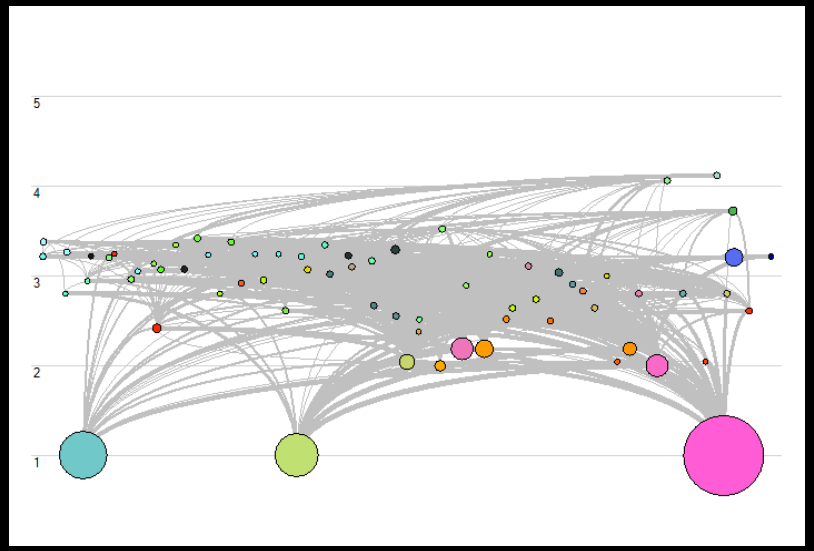
Data needs and future work

- Spatial application of Ecopath -> Ecospace
- Bycatch studies
- Long-term monitoring of diets and ontogenetic patterns
- Comparison to other modeling frameworks (e.g., Atlantis, OSMOSE)
- Gain better understanding of predation on age-0 menhaden
- Updating reference time series for recently conducted stock assessments
- Incorporating the effect of additional environmental drivers (e.g., temperature and hypoxia)

2. NGOMEX Ecospace model

- Ecopath snapshot year: 2000
- 66 functional groups
- 4 commercial fleets and 1 recreational fleets
- A 2D spatial model with 5 km^2 grid cells and 10318 cells

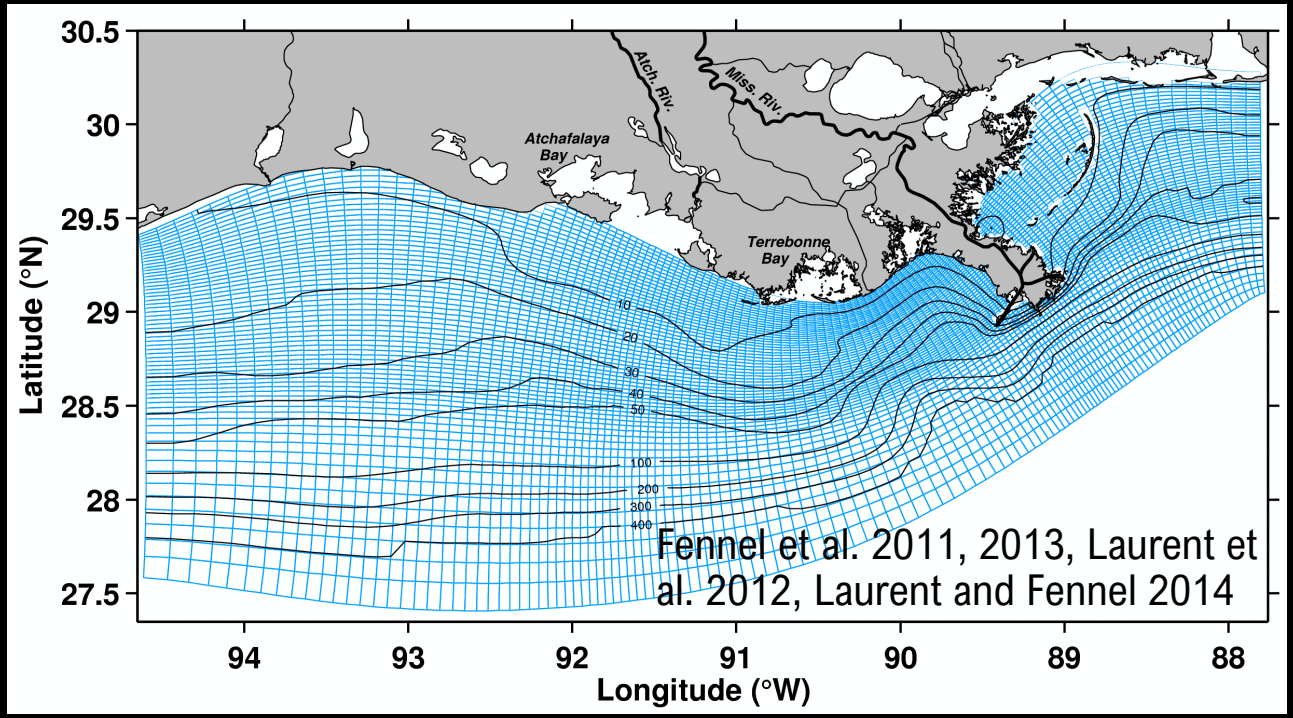


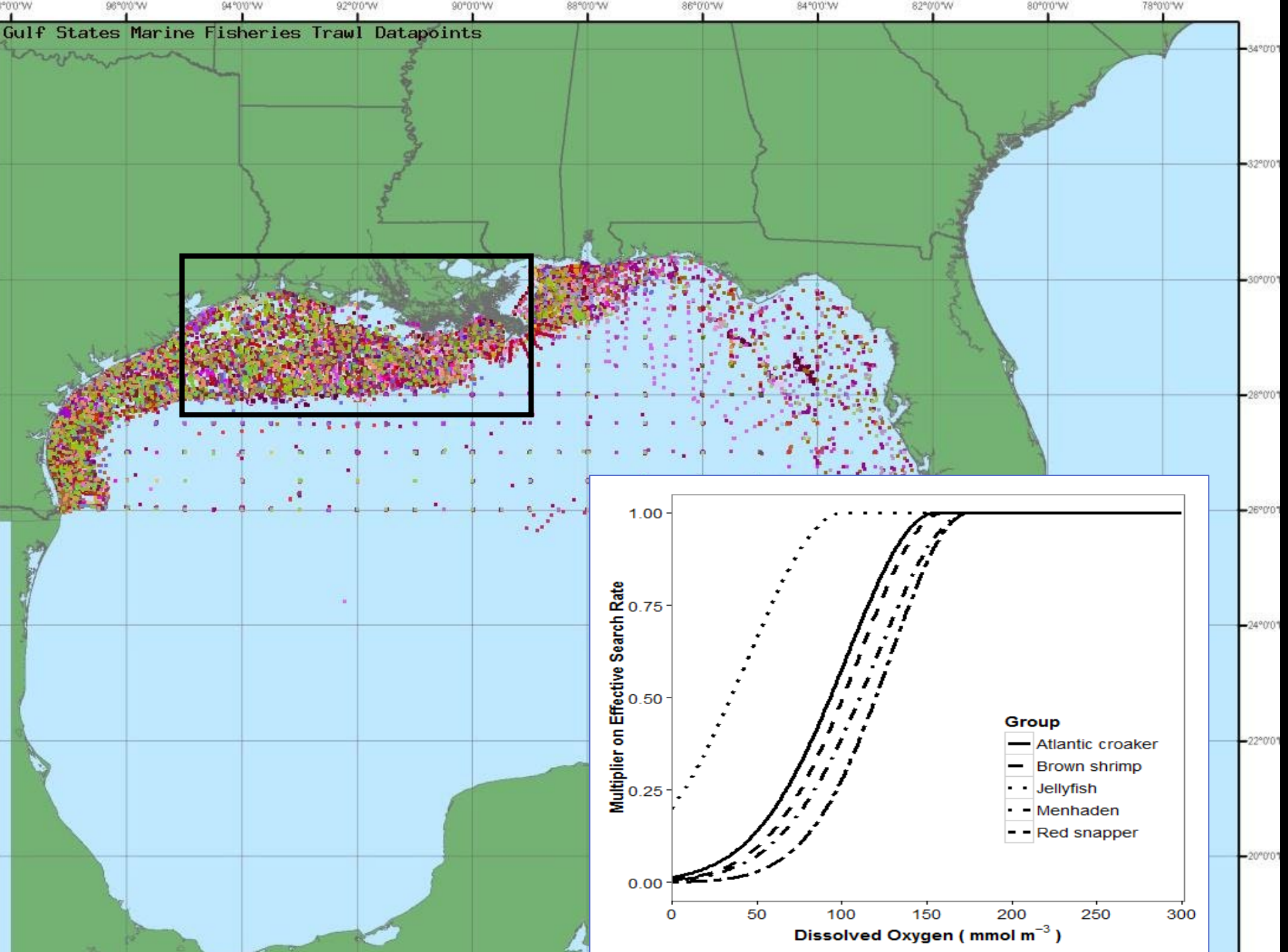


Environmental Drivers

2000-2016 model hindcast output used of ROMS-based physical-biological model:

- Dissolved Oxygen
- Temperature
- Salinity
- Phytoplankton





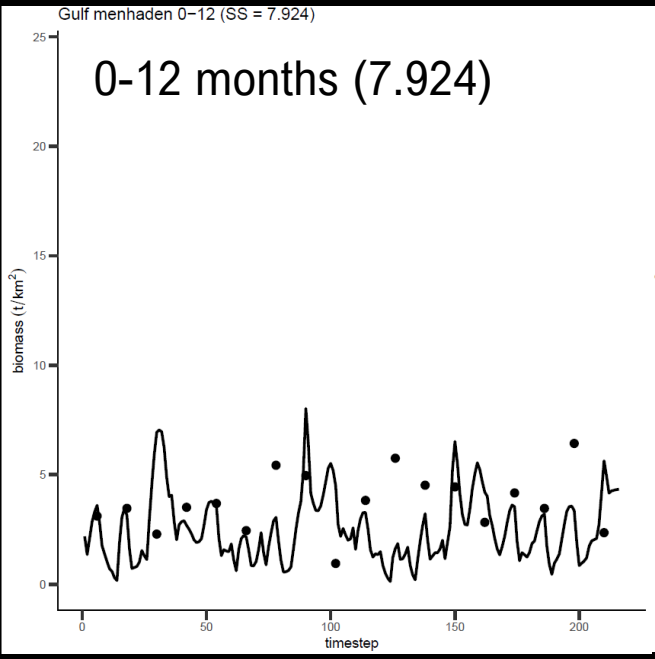
Response Curves

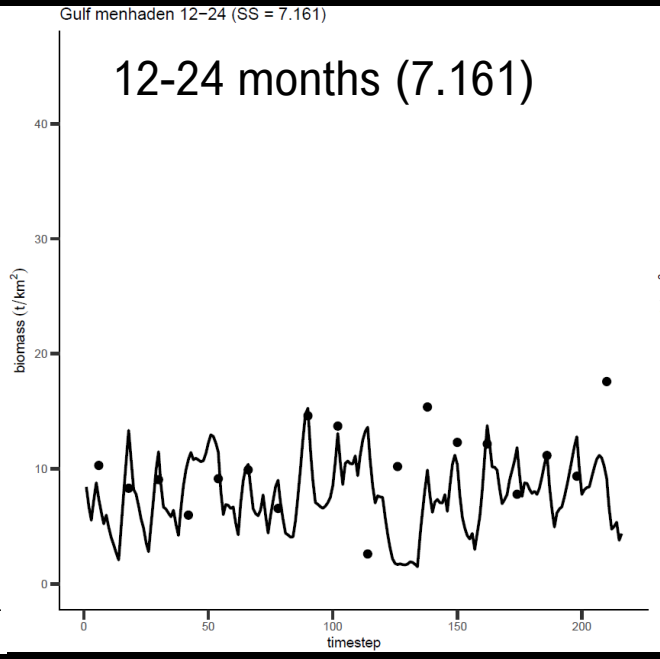
- Species-specific
- SEAMAP surveys measure water quality when collecting fish

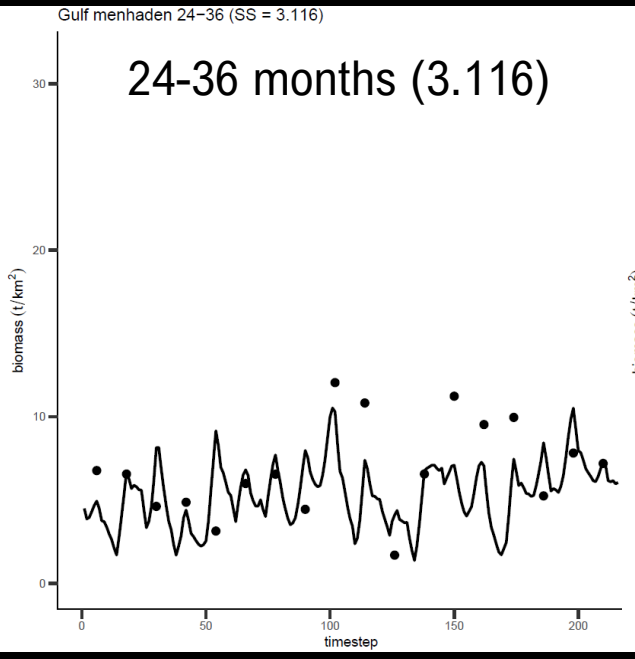
(De Mutsert et al. 2016)

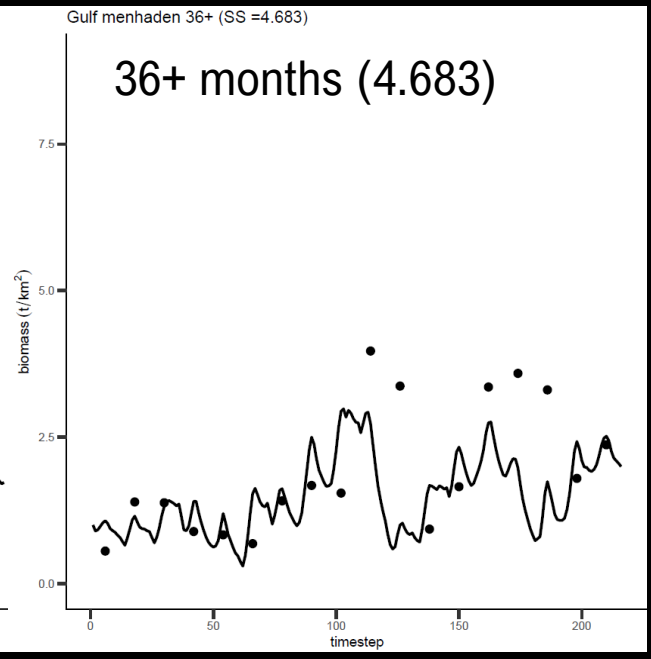
NGOMEX Ecosim calibration – time series fits

Biomass 2000-2016



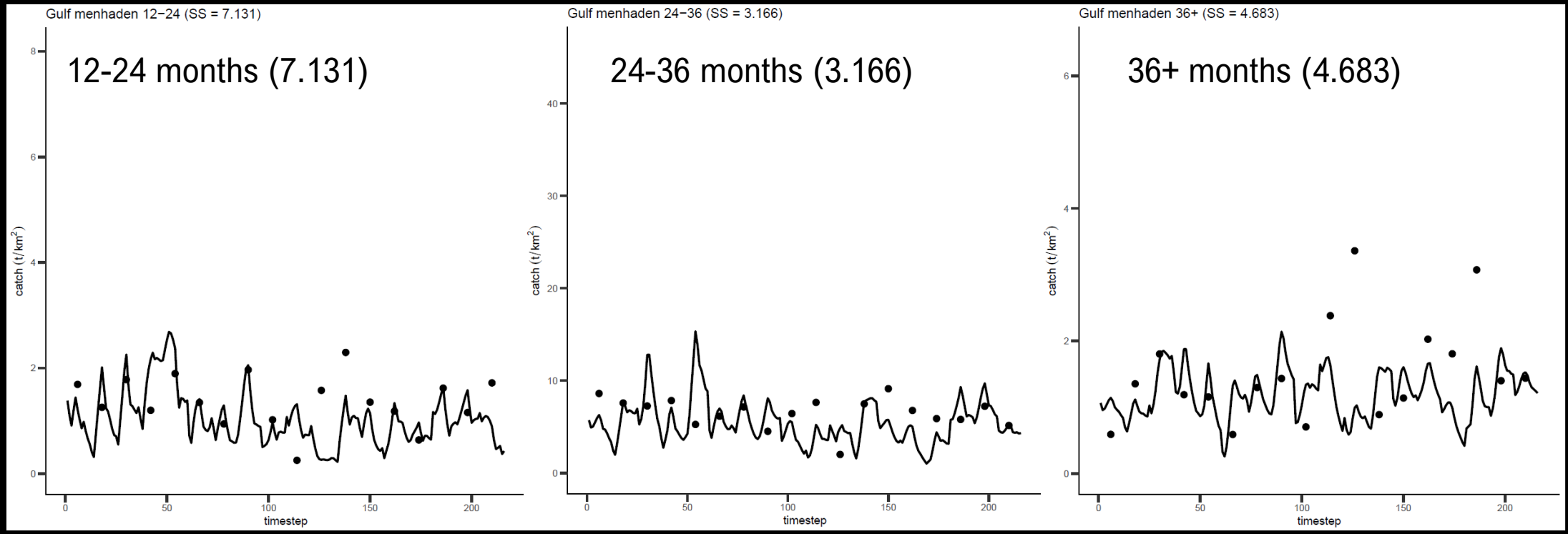


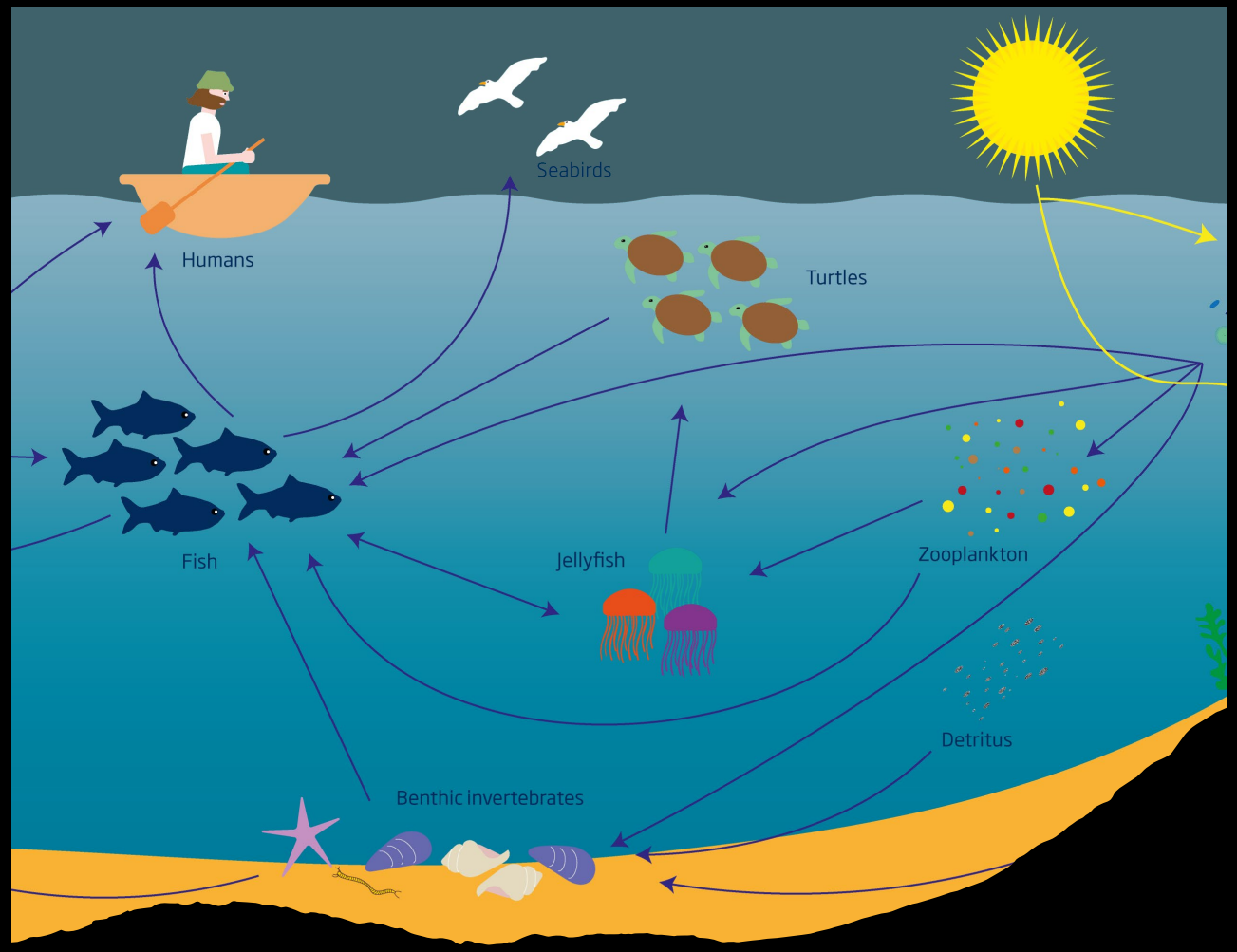




NGOMEX Ecosim calibration – time series fits

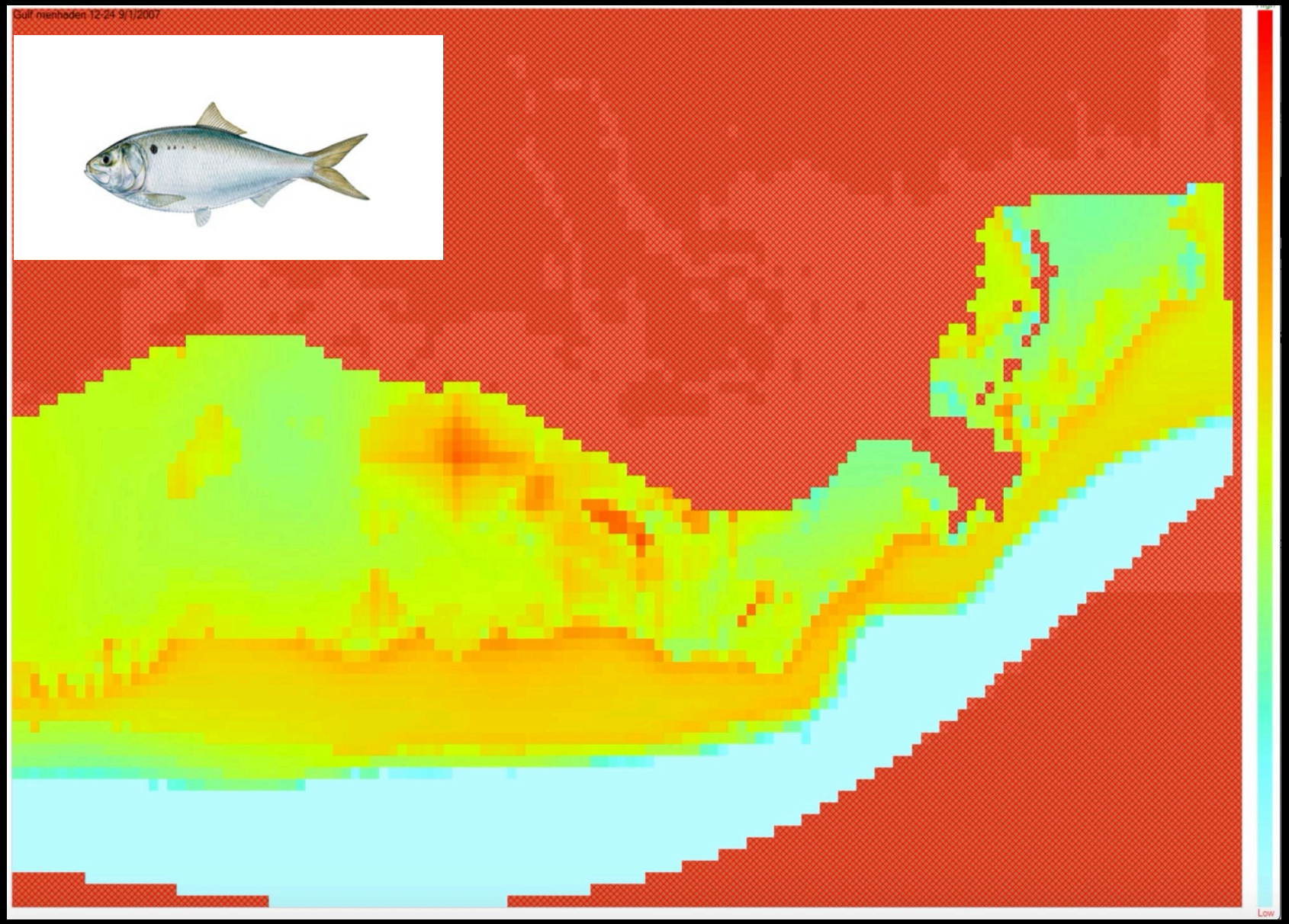
Catch 2000-2016



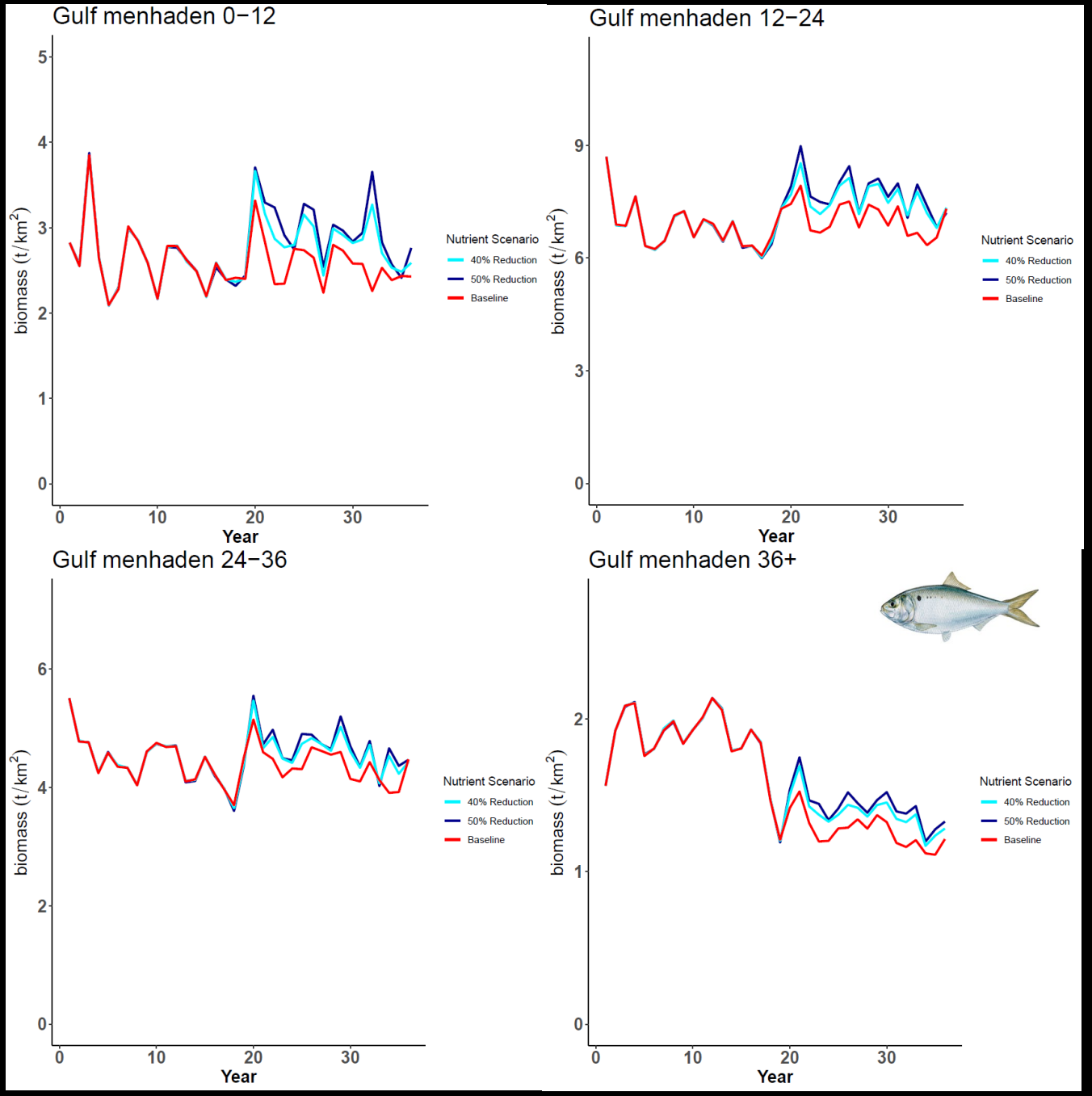


Model strengths and use to management

- Effects of environmental variables on biomass and distribution
- Indirect effects due to trophic interactions
- Spatial dynamics of fishing and environmental factors

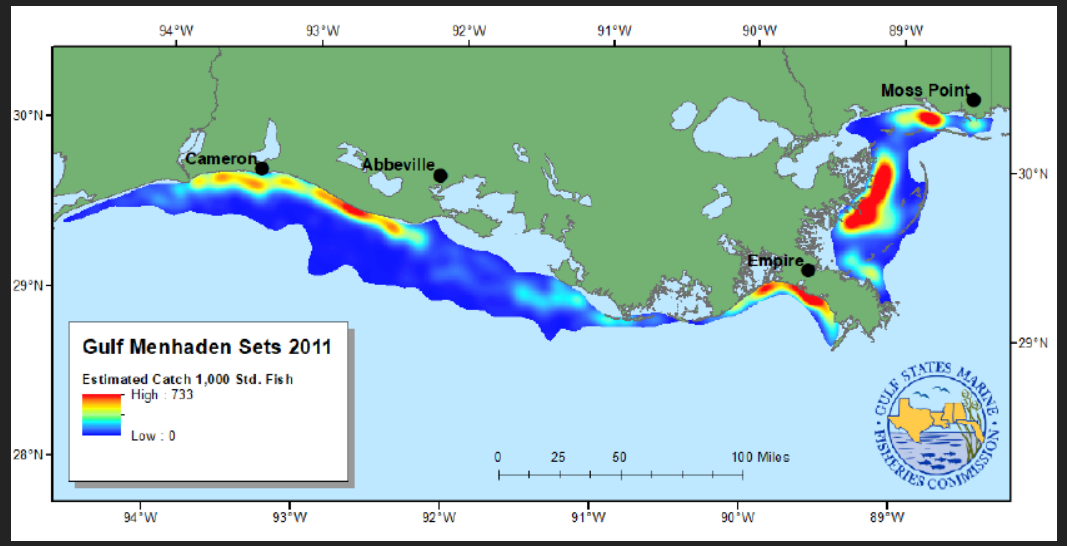


Menhaden biomass: Response to hypoxia 2000-2016



Effects of nutrient reductions on Gulf Menhaden biomass

- Both nitrogen and phosphorus from MS River outflow are reduced by 40 and 50% (blue lines)
- This encapsulates the nutrient reductions necessary to reduce to hypoxic zone to 5000 km^2
- New IBM simulations reveal the increased localized mortality due to hypoxia does result in small benefits of nutrient and hypoxia reductions
- Decision support tool shows the effects of nutrient reductions on different species in time and space



Menhaden fishing in the model

- Fleets are included in Ecopath
- Spatial effort included in the Ecospace model using years with available data
- Three plants included as ports in Ecospace: Abbeville, Empire and Moss Point
- Fleets gravitate to cells with highest revenue

Model needs and limitations

- Diet data needs:
  - Age-specific predation and consumption
  - Complementary methods: e.g., DNA barcoding or stable isotope
- Uncertainty associated with the vulnerability parameters
- Environmental variables at the resolution needed usually means using model output
  - Need for physical-biological model that covers both inshore (estuarine) and offshore areas

Data needs and future work

- Bycatch data
  - Small percentages of bycatch based on menhaden biomass could constitute high removal rates for small predator populations
- Long-term monitoring of diets and ontogenetic patterns
- Comparison to other modeling frameworks (e.g., Atlantis, OSMOSE)
- Updating reference time series for recently conducted stock assessments
- Annual high resolution spatial effort distribution data
- Evaluate potential for simulating effects of coastal spatial effort restrictions in Louisiana
  - Higher resolution estuarine model may be more suitable
  - Different physical-chemical model needed if including environmental variables

Model Domain Delta Management Model

- Developed to evaluate effects of large sediment diversions
- Finer resolution Ecospace model with 1 km^2 grid cells
- Coupled to a Delft3D model that simulates land gain but also outputs water quality parameters (inside yellow lines)
- May be better equipped to evaluate coastal spatial effort restrictions

(De Mutsert et al. 2017)

Thank You

Diversion work publication (aim phone camera)
(De Mutsert et al. 2017)

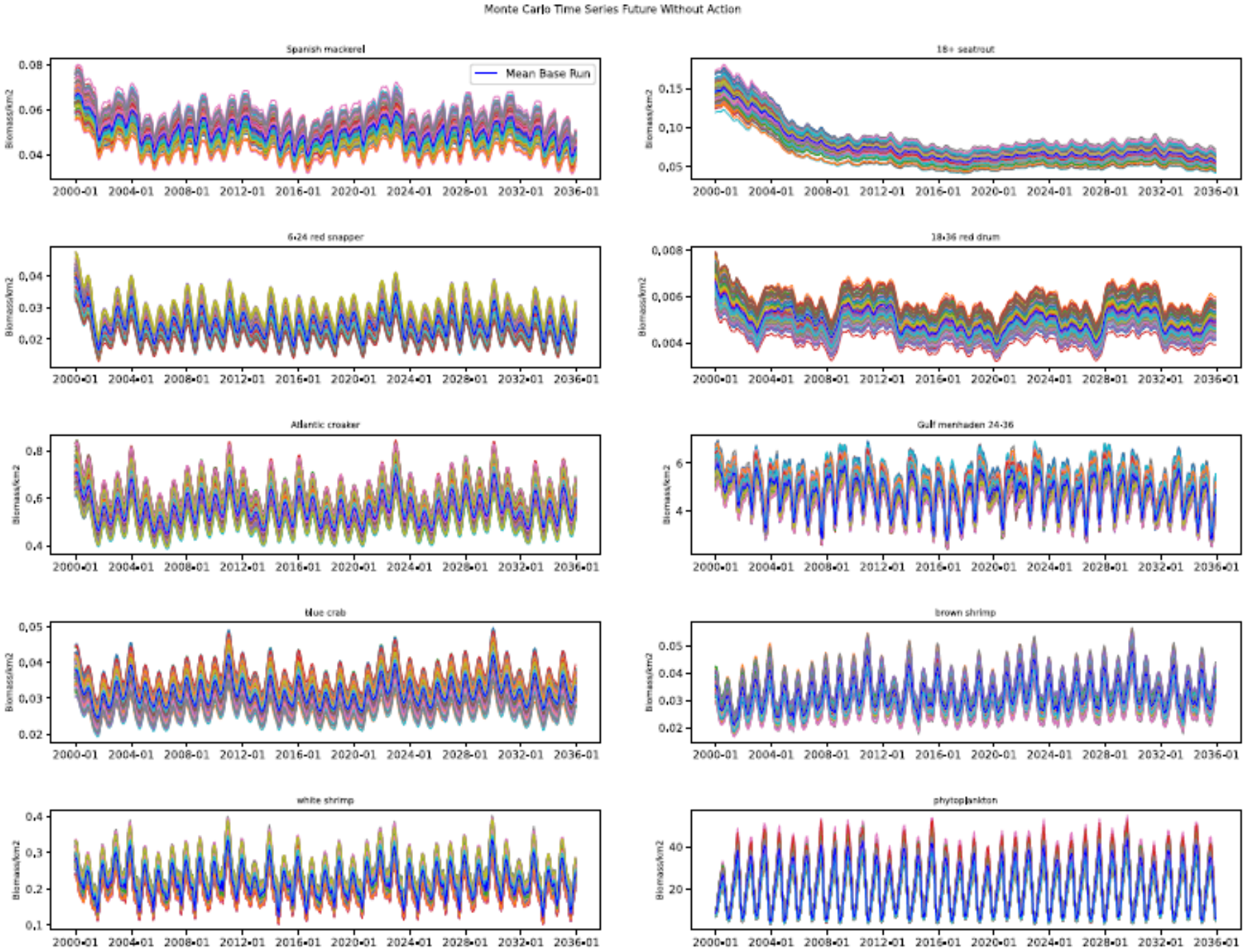
I would like to acknowledge the following sponsors and collaborators:

- Sponsors: NOAA National Centers for Coastal Ocean Science (Northern Gulf of Mexico Ecosystems and Hypoxia Assessment Program and the NOAA RESTORE Science Program)
- Collaborators: Arnaud Laurent, Joe Buszowski, Sara Marriott, Kristy Lewis, Michelle Shaffer, Jeroen Steenbeek, Steve Brandt, Matt Campbell, Cynthia Sellinger, Cassie Glaspie, Alex Van Plantinga

Diet data meta-analysis
(Sagarese et al. 2017)

Hypoxia work publication
(De Mutsert et al. 2016)

Spatial Monte Carlo Analyses



Taxa in the NGOMEX ecosystem model

Marine Mammals
Tunas
Carangidae
Birds
Atlantic Cutlassfish
Lizardfish
Sharks
King Mackerel
Spanish Mackerel
Sea Trout
Red Snapper
Serranidae
Other Snappers
Red Drum
Rays & Skates
Flounders
Atlantic Bumper

Scad
Atlantic Croaker
Catfish
Gulf Butterfish
Spot
Squid
Pinfish
Porgies
Anchovy
Gulf Menhaden
Other Clupeids
Mullet
Sea Turtles
Small Forage Fish

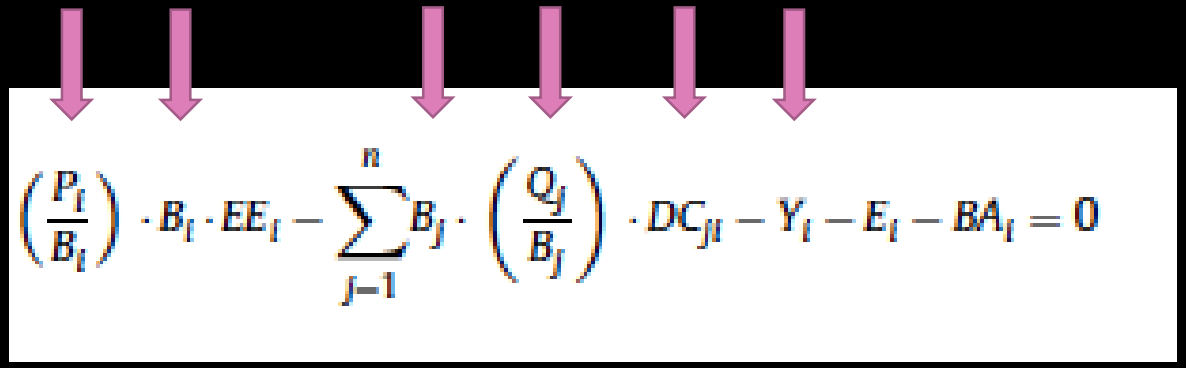
Jellyfish
Blue Crab
Brown Shrimp
White Shrimp
Pink Shrimp
Other Shrimp
Benthic Crabs
Benthic Invertebrates
Zooplankton
Benthic Algae
Phytoplankton
Detritus

66 groups

Life stages included

Model balancing

- Solving:



$$\left(\frac{P_i}{B_i}\right) \cdot B_i \cdot EE_i - \sum_{j=1}^{n} B_j \cdot \left(\frac{Q_j}{B_j}\right) \cdot DC_{ji} - Y_i - E_i - BA_i = 0$$

- This is a mass balance assumption at the base of Ecopath
- We've provided everything but EE – Ecotrophic Efficiency
- EE of species *i* describes what proportion of this species is used in the system, and cannot exceed 1
- In cases where biomass is uncertain EE is provided:
  - (other) clupeids and 'small forage fish': 0.8
  - Benthic crabs and benthic invertebrates: 0.85

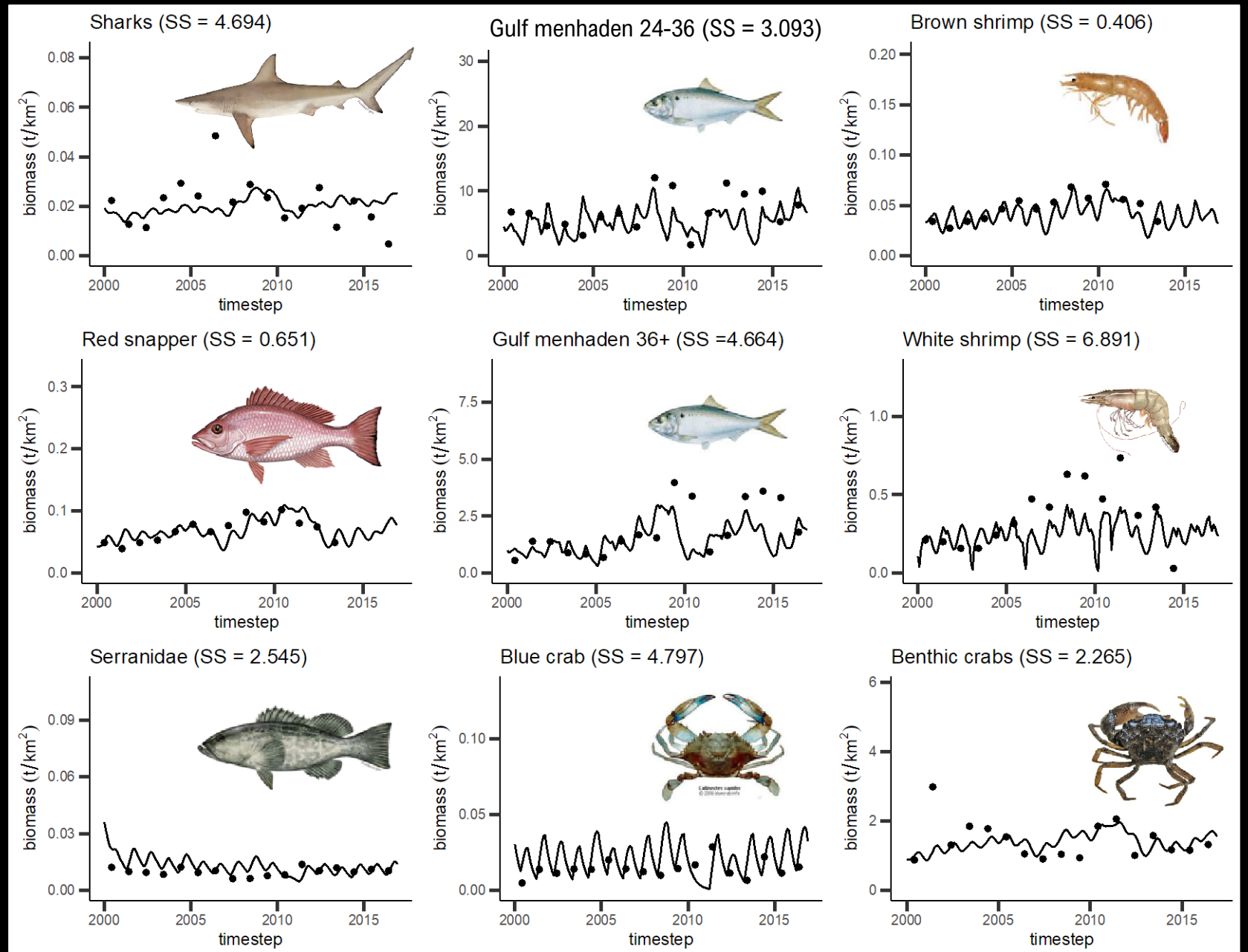
Fishery

- ‘Fleets’ included in the model:
  - Shrimp trawl
  - Menhaden
  - Recreational
  - Snapper/grouper (commercial)
  - Other commercial finfish
- Landings – NOAA’s landings query, MRIP, stock assessment
- Discards – stock assessment

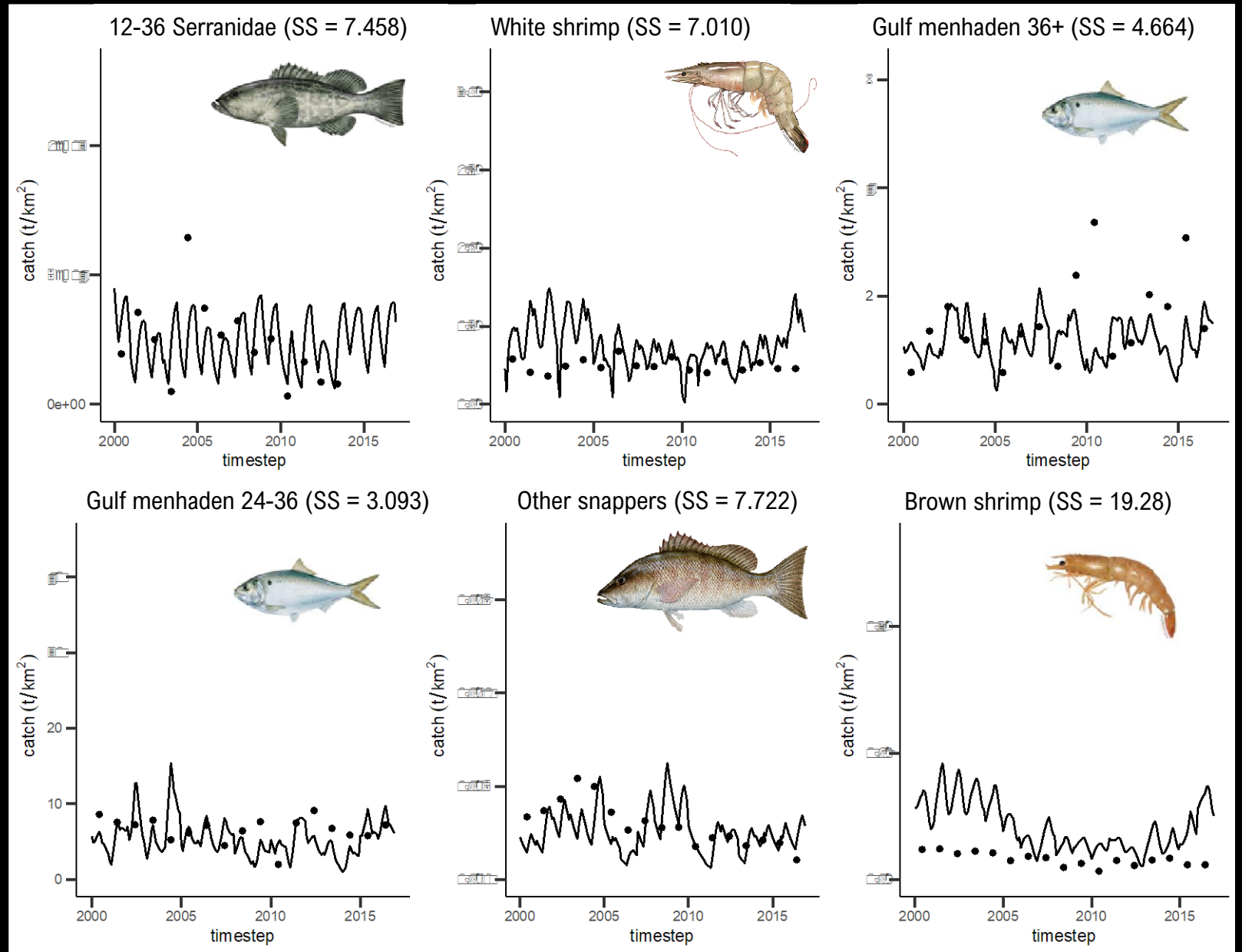
Time series

- Sixty-one time series with observations loaded to calibrate the model
- Calibration period: 2000-2016 (time period for which coupled model output is available)
- Catches – stock assessment, NOAA landings query, MRIP (for recreational-only available until 2013)
- Biomass – stock assessment, SEAMAP
- Fishing mortality – stock assessment (driver that determines fishing effort per species)

Calibration - Biomass



Calibration - Catch



Groups in the Delta Management model

Fish

Atlantic Croaker[1]
Bay Anchovy[1]
Black Drum[1]
Blue Catfish[1]
Coastal sharks[1]
Gizzard Shad[1]
Grey Snapper[1]
Gulf Menhaden[1]
Gulf Sturgeon[1]
Killifishes
Largemouth Bass[1]
Pinfish[1]
Red Drum[1]
Sand Seatrout[1]
sea catfishes[1]
Sheepshead[1]

Fish

Silver Perch[1]
silversides
Southern Flounder[1]
Spot[1]
Spotted Seatrout[1]
Striped Mullet[1]
Sunfishes[1]
Threadfin Shad[1]

Invertebrates

Benthic crustaceans
Blue Crab[1]
Brown Shrimp[1]
Eastern Oyster[2]
Grass Shrimp
Mollusks

Invertebrates

Mud crabs
Other shrimp
Oyster Drill
White Shrimp[1]
Zoobenthos
Zooplankton

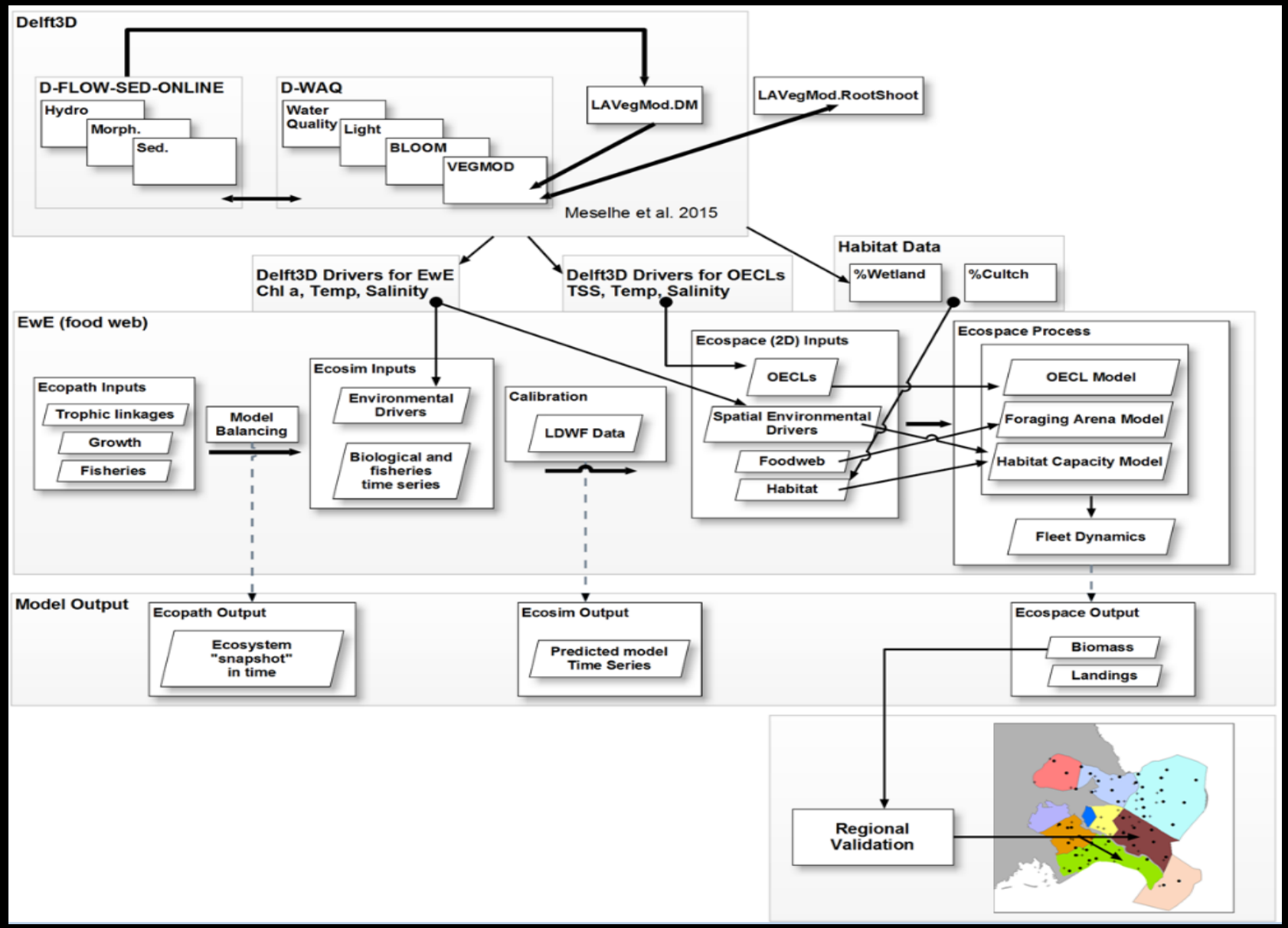
Primary producers

Phytoplankton
SAV[3]
Benthic algae

Other

Kemp Ridley sea turtle
Dolphins
Detritus
Seabirds

[1]Juvenile and adult, [2]spat, seed, and sack, [3]submerged aquatic vegetation



Delta Management Model Coupling

De Mutsert et al. 2017