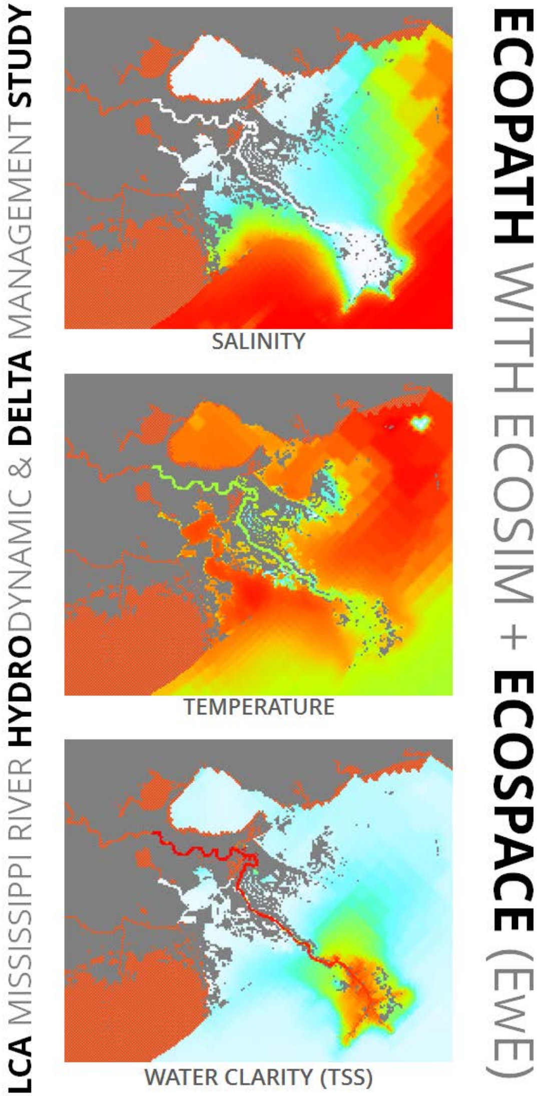


Louisiana Coastal Area Delta Management Ecosystem Modeling

Delta Management Fish and Shellfish Ecosystem Model

Kim de Mutsert, Kristy Lewis, Joe Buszowski, Jeroen Steenbeek, and Scott Milroy

US Army Corps of Engineers®
Engineer Research and Development Center

THE WATER INSTITUTE OF THE GULF

GEORGE MASON UNIVERSITY

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

COASTAL PROTECTION AND RESTORATION AUTHORITY
CPRA

Ecosystem modeling

Question: How do a select combination of river diversions affect fish and shellfish in the receiving basins?

Tool: Food web model that accounts for effects of environmental changes, fishing, and predator-prey interactions

- Simulates changes in biomass (tonnes km^{-2}) and catch (t km^{-2} yr^{-1}) of fish and shellfish species over 50 years
- Makes use of end-to-end model construction:

Output of the Delft3D hydrodynamic model drives

the fish and shellfish model

Ecopath with Ecosim and Ecospace

www.ecopath.org

Ecopath: Mass-balance "snapshot" of an ecosystem (initial conditions of the model)

Ecosim: Temporal dynamic simulations (used for model calibration)

Ecospace: Spatial-temporal modeling (framework of the model)

Model development: Ecopath

Key inputs:

- Average biomass of species representative of Louisiana estuaries
- Parameters quantifying turnover and growth: P/B, Q/B, EE, age at maturity, von Bertalanffy growth parameters
- Representative fishing fleets and annual landings
- Diet matrix

Groups in the 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

Model development: Ecospace

Key inputs:

- Ecopath model
- Basemap of model area with 1 km^2 grid
- Ecosim fishing effort (annual pattern kept constant for future)
- Spatial and temporal dynamic environmental drivers: values per grid cell, per month for each decadal simulation
- Habitat features (can be dynamic when habitat changes through time)

Key outputs:

- Monthly estimated biomass and catch projections for each km^2 grid cell for every 50-year simulation
- Used to determine if/where increases and/or decreases in biomass and catch can be expected under selected diversion operation scenarios relative to a future without action

Environmental driver and habitat input

- **Delft3D environmental drivers**
  - Monthly salinity, temperature, and Chl *a* per Ecospace grid cell (1 km^2) of target years between 1995-2020
  - Decadal percent wetland per Ecospace grid cell between 1995-2020
- **OECLs (oyster environmental capacity layers)**
  - Based on daily Delft3D output of sal, temp, and TSS
  - Creates capacity (suitability) per grid cell per month
- **Oyster cultch map**

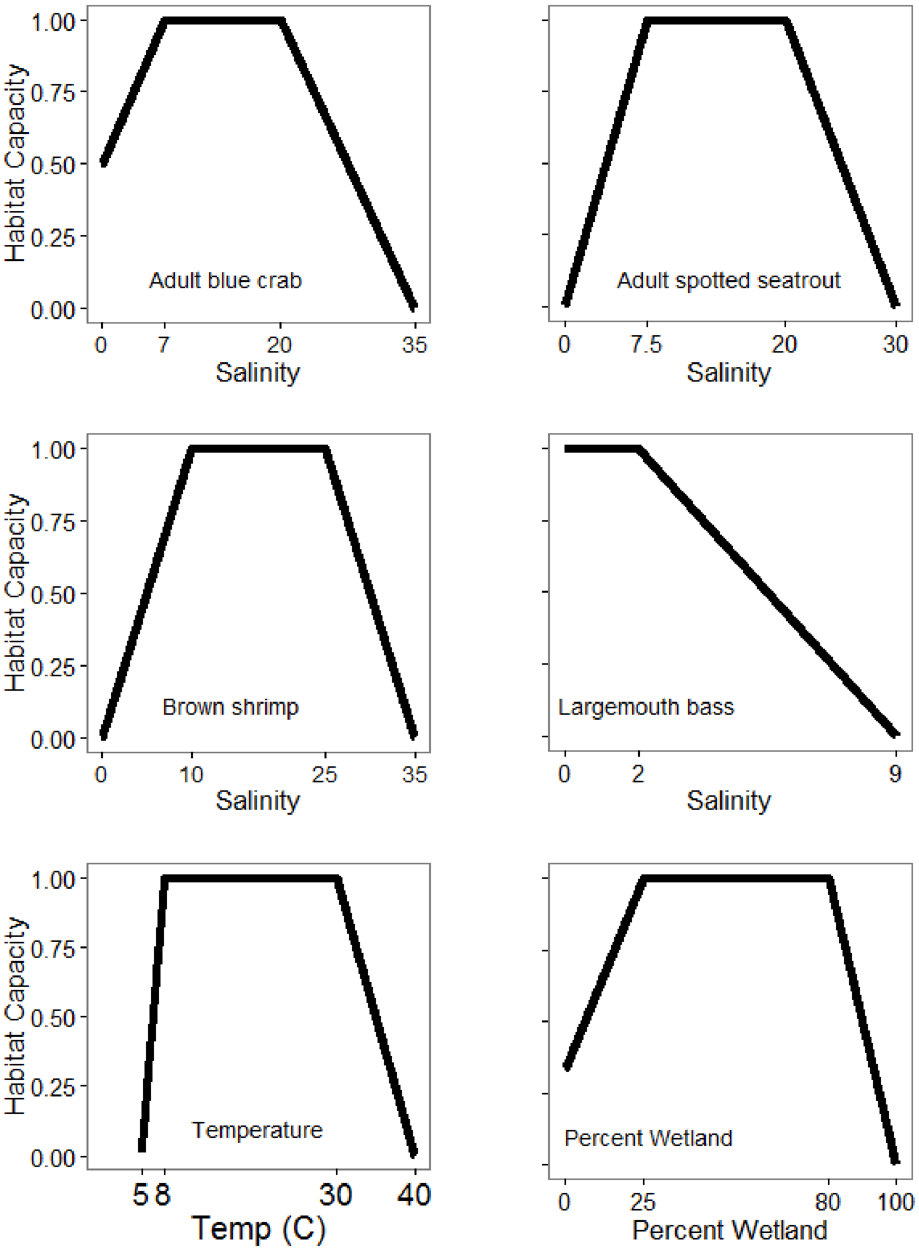
Response curves determine the effect of each of these drivers on individual species

Response curves

The response curves describe the suitability of the parameter values to each species on a scale from 0-1 based on the species tolerance range

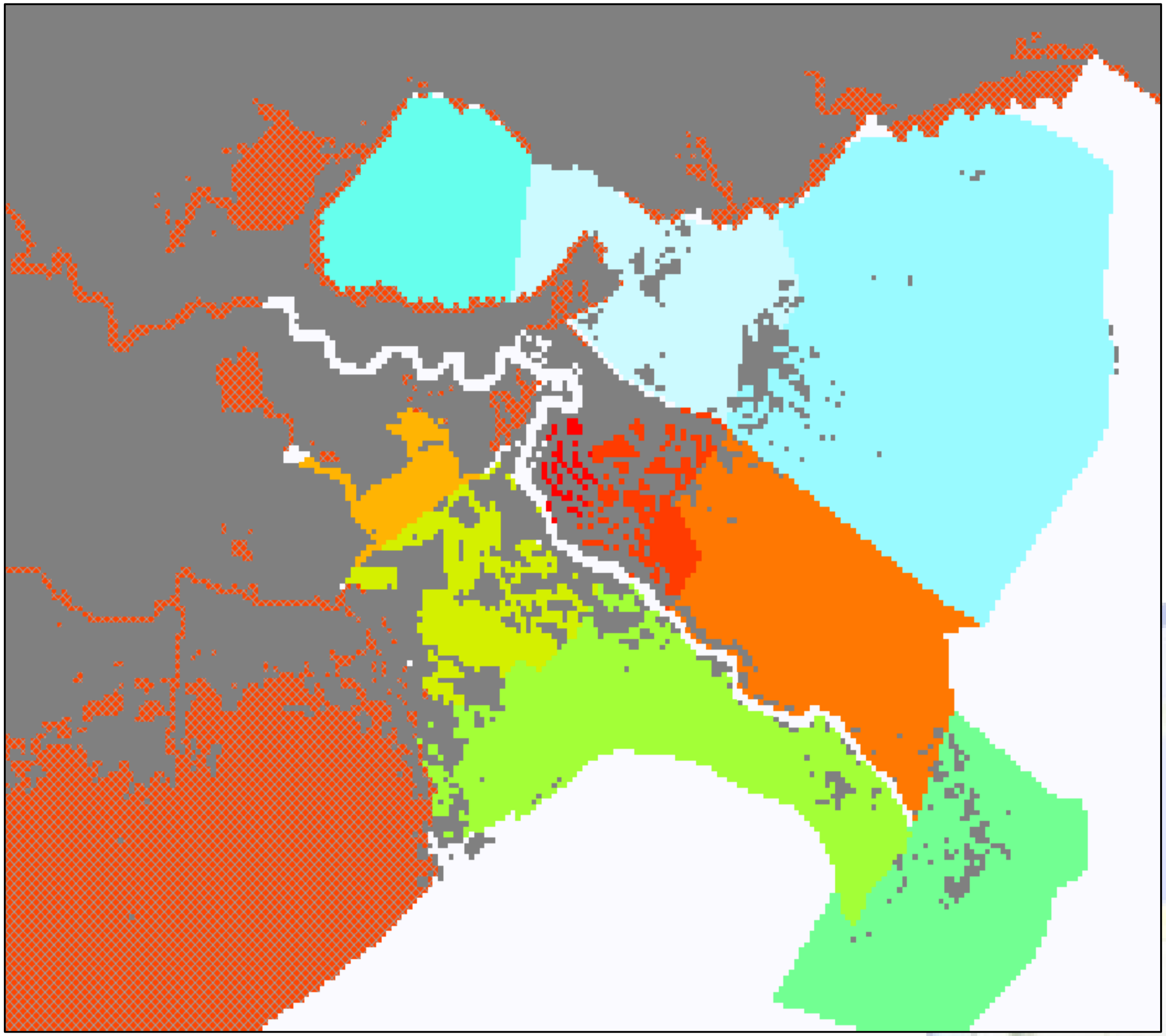
Movement to unsuitable cell reduced by multiplier based on all parameters affecting a species

Unsuitable cells will have reduced availability of prey



Test operation plan:

- Open 4 diversions for 50 years
- Compare against future without action



Test operation plan:

- Open 4 diversions for 50 years
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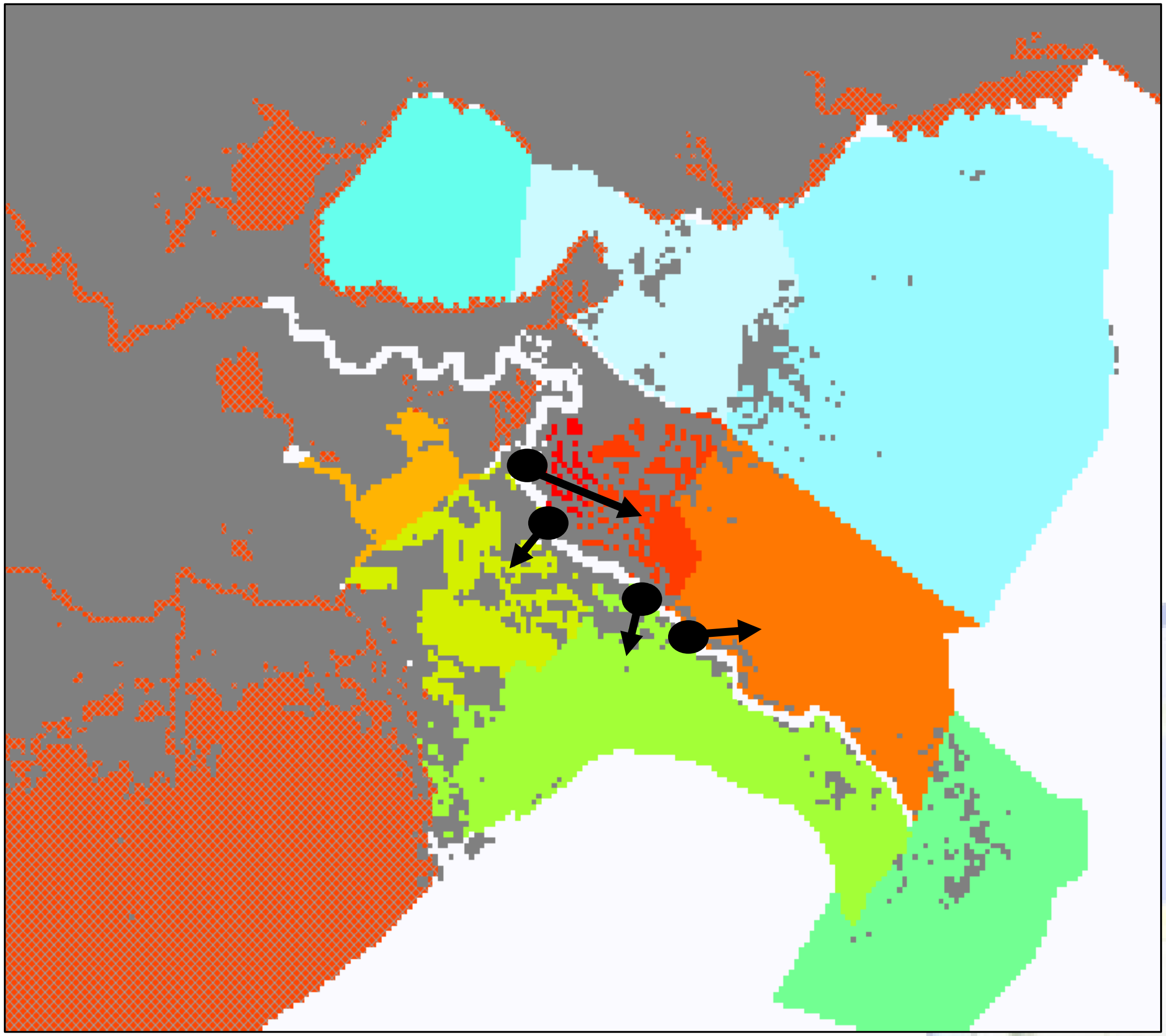
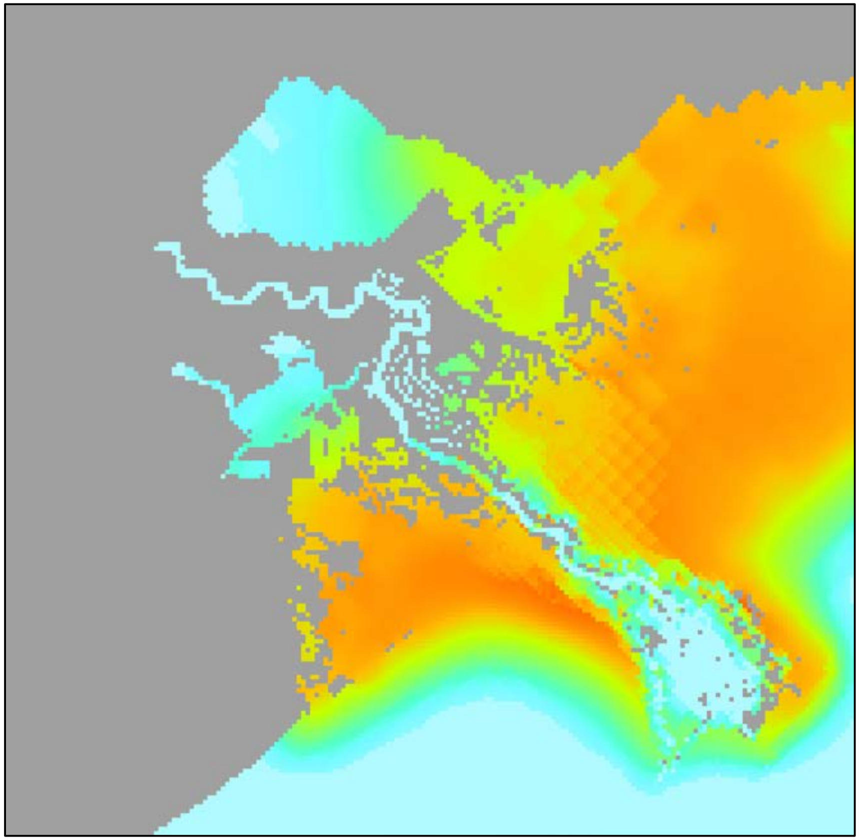
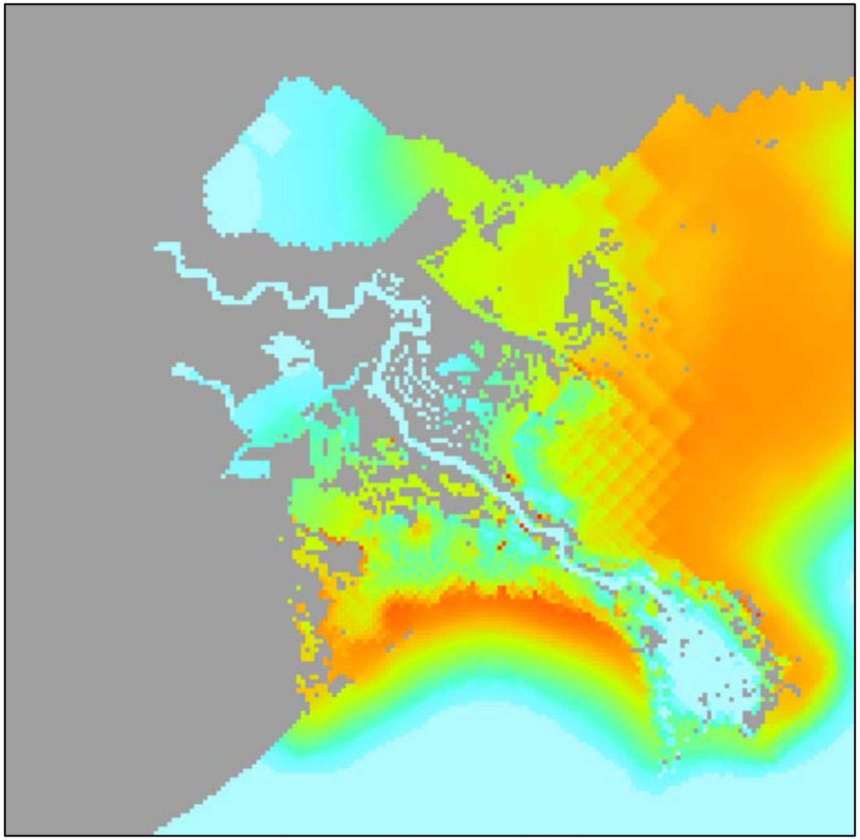


Brown shrimp Year 50

Future w/o Action June

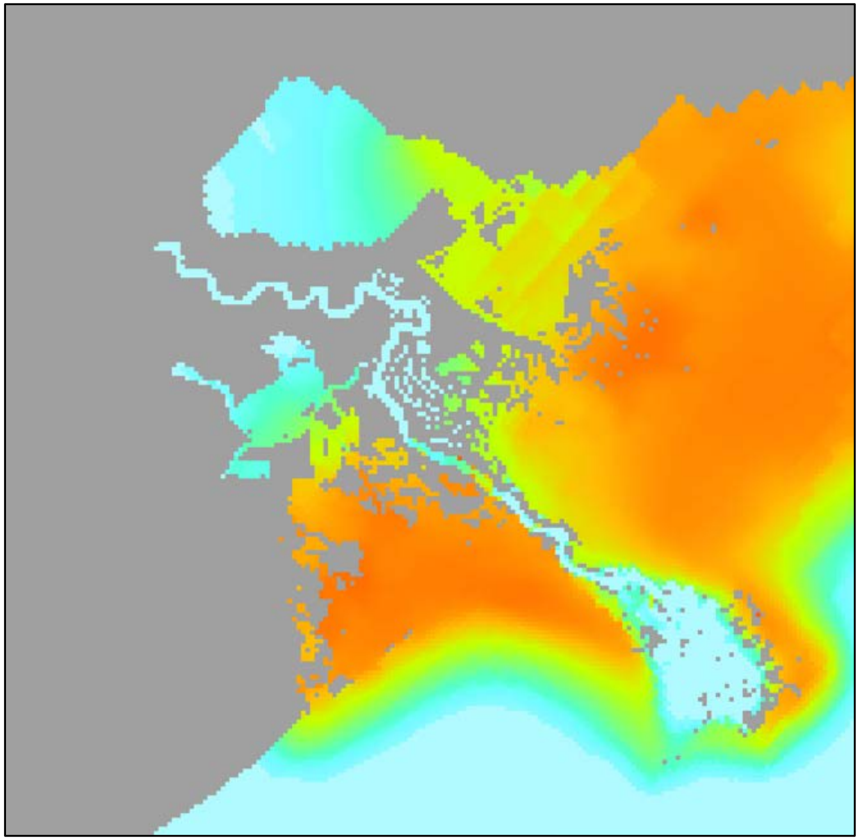


4 Diversions Open June

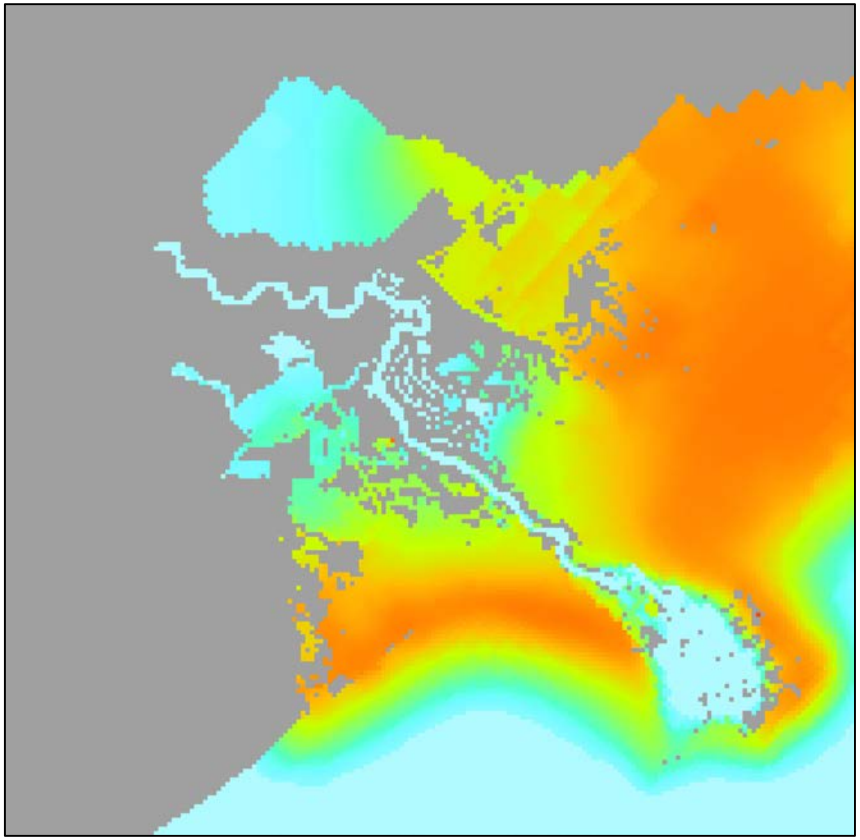


Brown shrimp Year 50

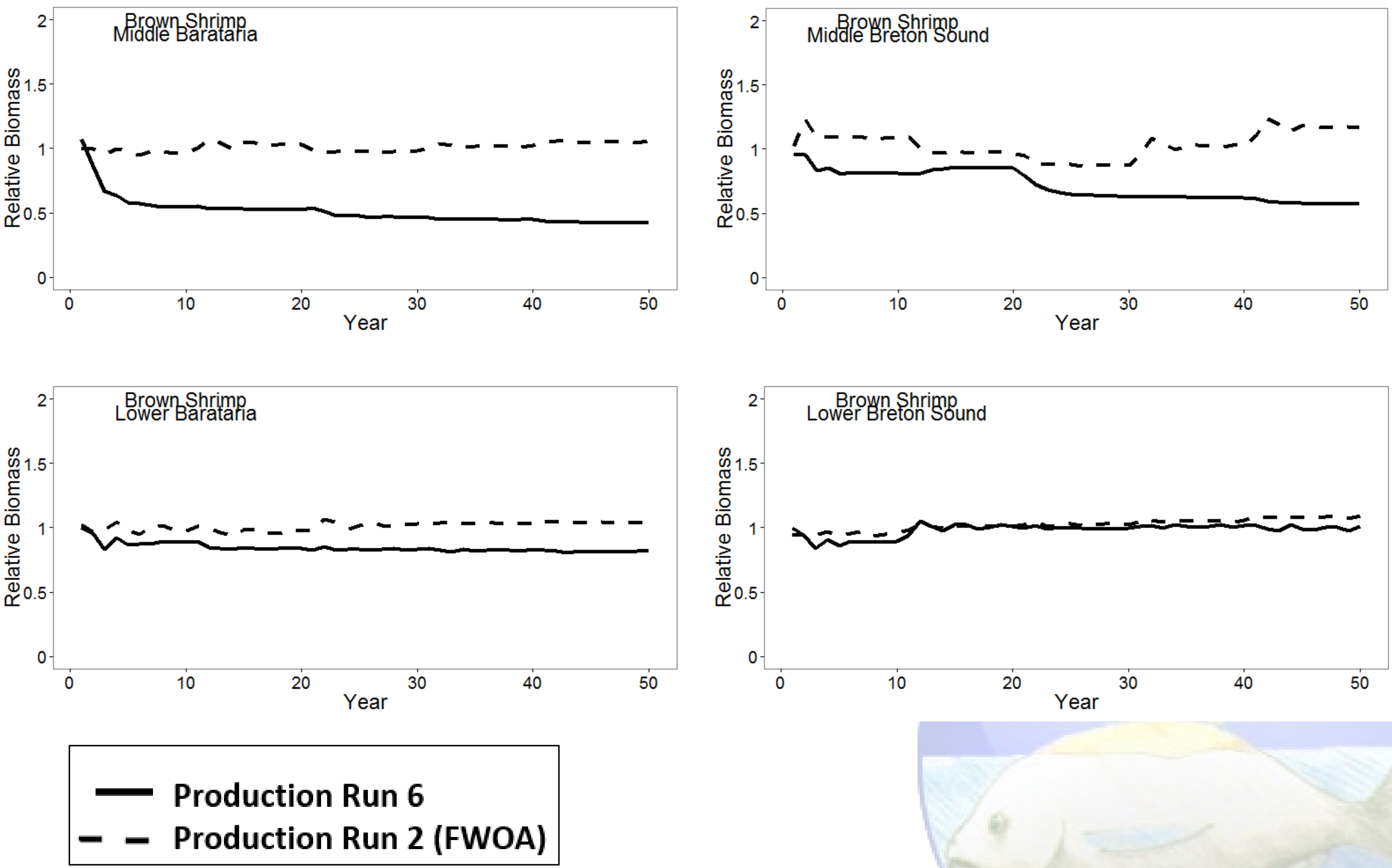
Future w/o Action October



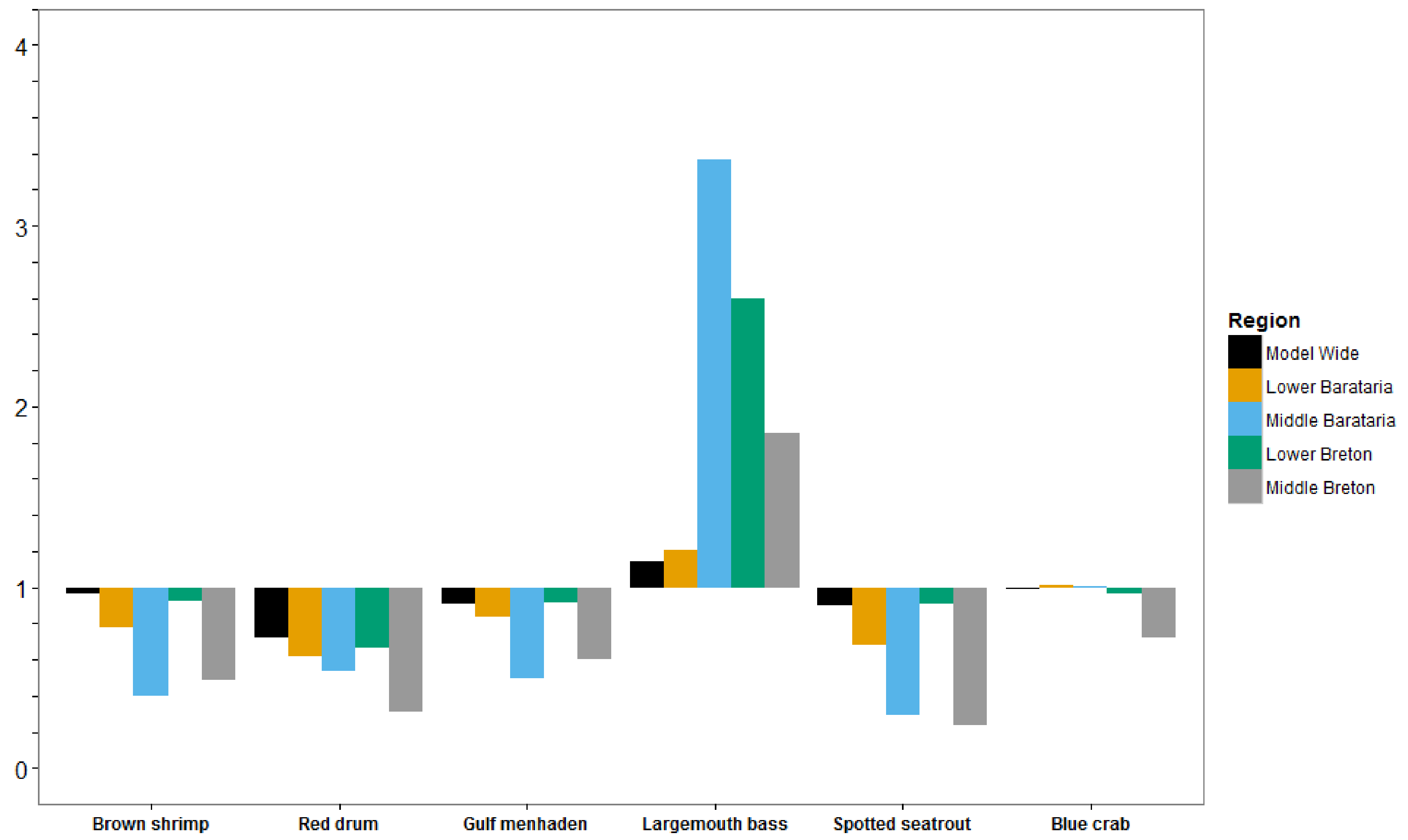
4 Diversions Open October



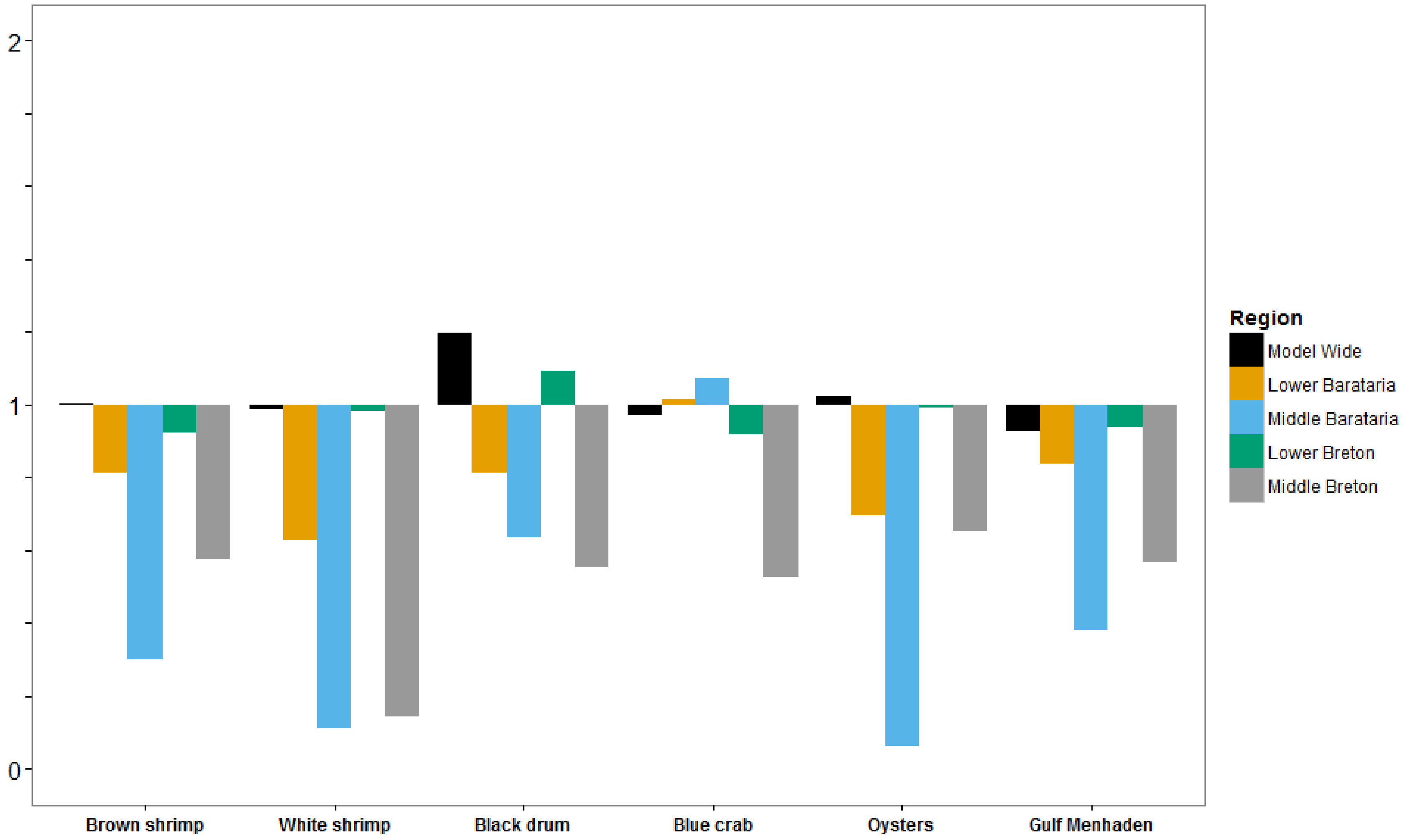
Biomass change from initial conditions



Biomass year 50 relative to FWOA



Catch year 50 relative to FWOA

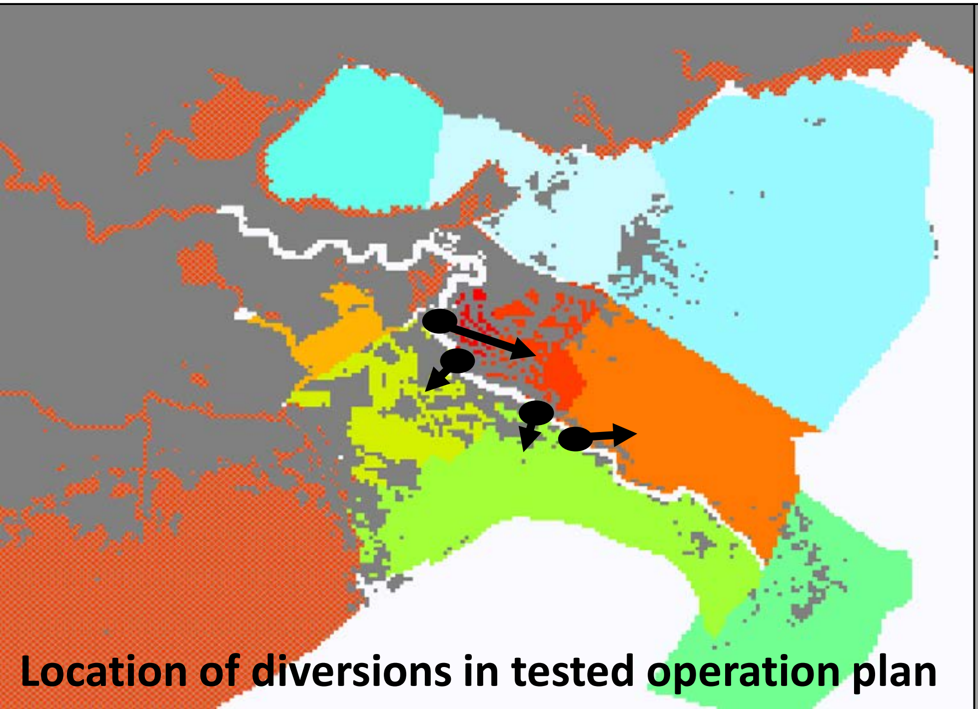


Operation plan summary

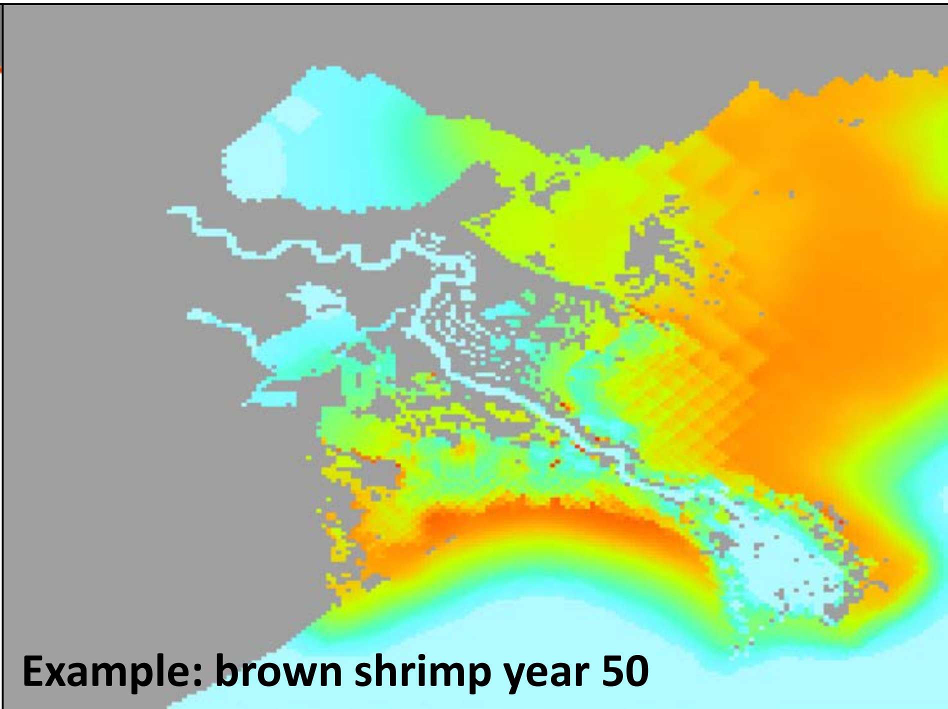
Decreases in species that prefer higher salinities on a sub-basin level, increases in (few) species that prefer lower salinities

Magnitude of change dampened on a larger spatial scale; redistribution of species

Spatial pattern suggests two lower diversions mostly responsible for the changes



Location of diversions in tested operation plan



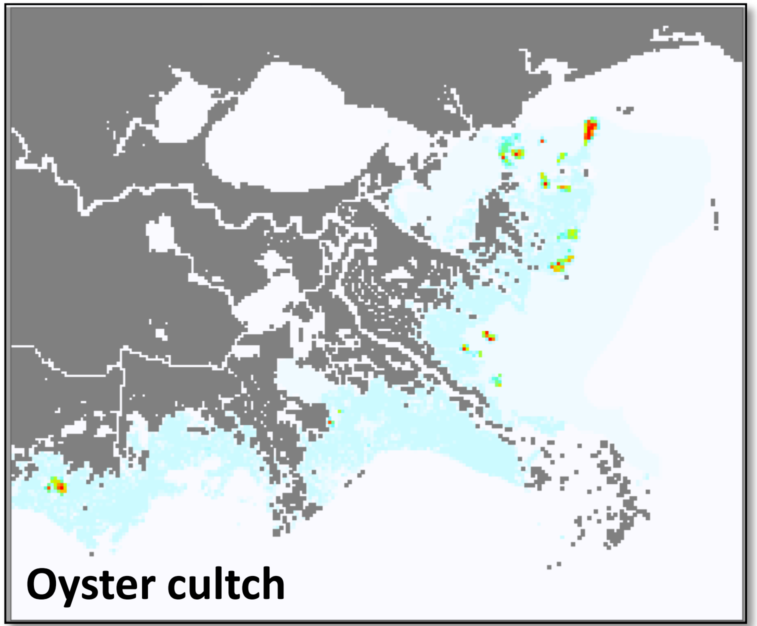
Example: brown shrimp year 50

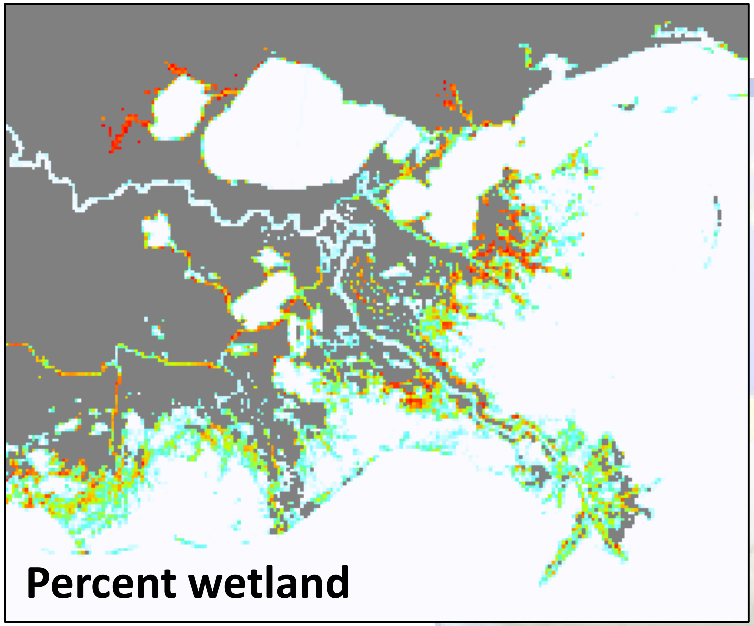
Questions?

Approach

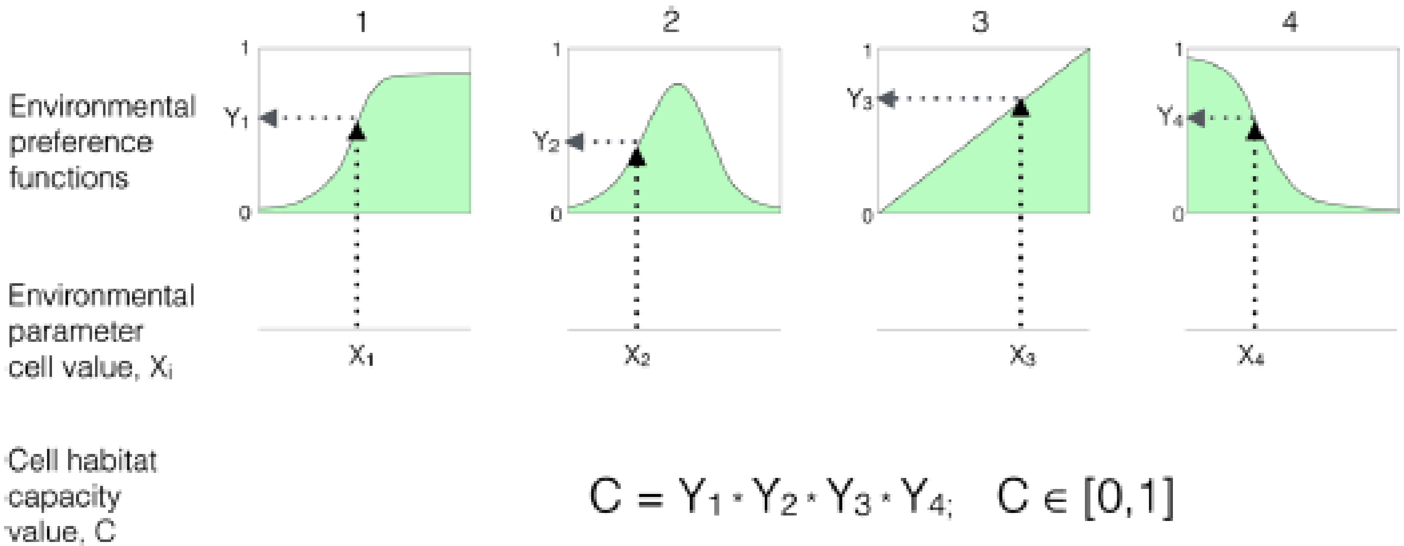
Ecospace

- **Basemap**: grey cells inactive, all other cells active
- **Grid cell size**: 1-km^2
- **Ecosim in every cell, monthly time step**
- **Movement:** does not represent species-specific swimming speed or seasonal migration, but prevents entrapment of nektonic species in unsuitable habitat using a generic rate of 300 km yr^{-1}. Movement is also needed to not have a spatial disconnect between juvenile and adult groups that may have different habitat preferences.
- **What determines if habitat is suitable?**
  - **Habitat: cultch, percent wetland, depth**
  - **Environmental drivers: Chl *a*, salinity, temperature, TSS**





Approach
Ecospace: Habitat capacity model



Capacity C affects the size of the foraging arena area in a grid cell; low capacity reduces consumption

The habitat capacity of a cell affects movement as well, such that movement towards unsuitable habitat is slowed as a function of the habitat capacity (C) of that neighboring cell

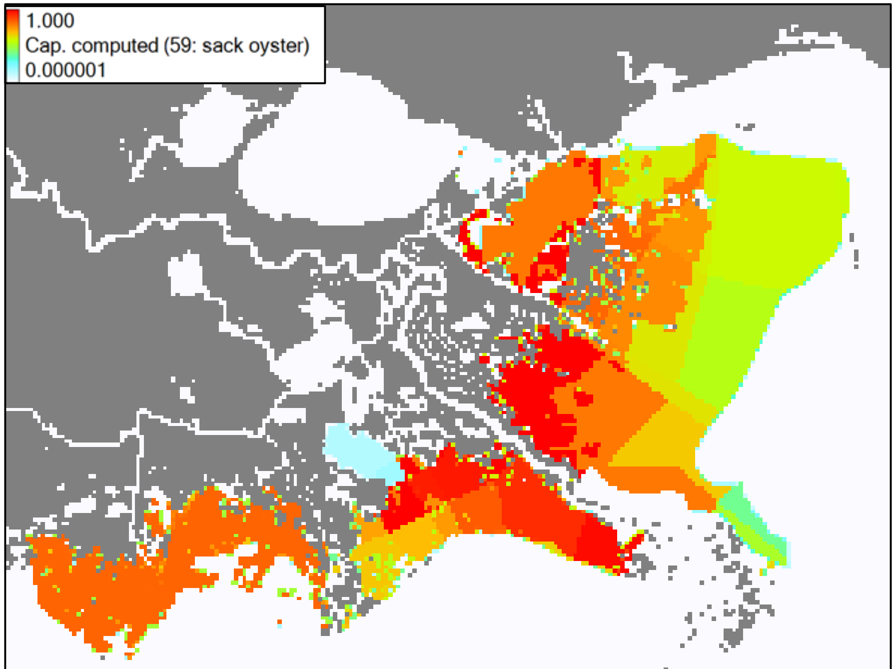
Christensen et al. 2014

Approach
Ecospace: Habitat capacity model

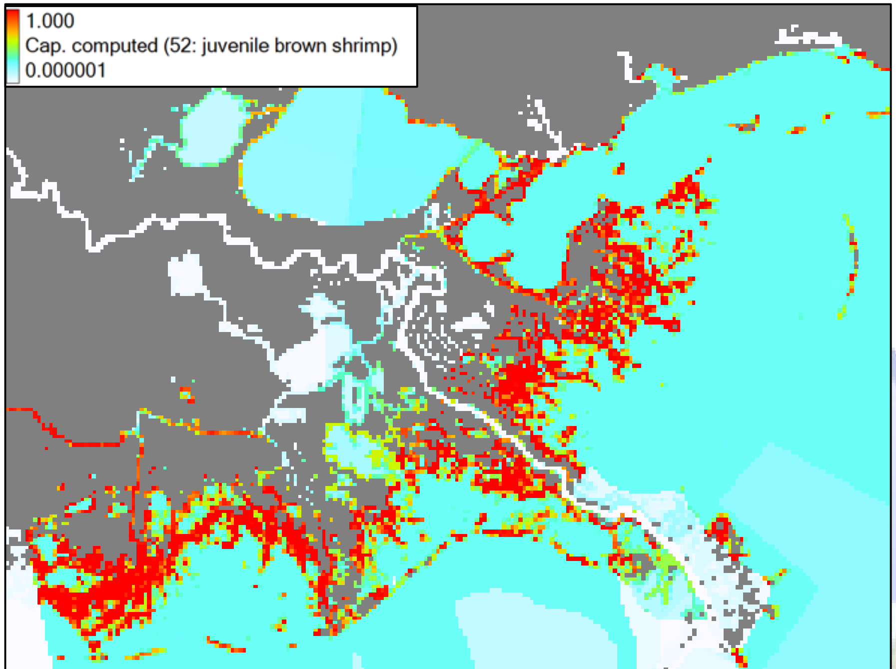
For each group capacity maps are created

These are comparable to HSIs

Fishing, trophic interactions, and changes in capacity over time will determine group biomass during simulation runs



Example capacity map sack oysters



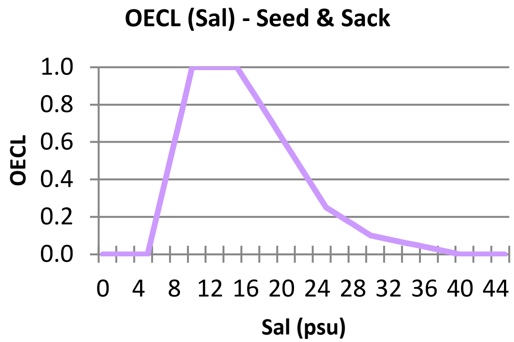
Example capacity map juv. brown shrimp

Approach

Special handling: oysters

Oysters may be affected by specific sal, temp, and TSS values that persist for shorter periods than a month, which may be masked by monthly averages of those values

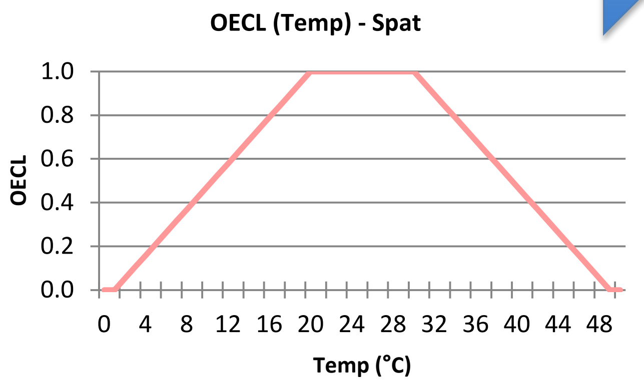
TroSim Oyster Environmental Capacity Layers (OECLs)



Input: daily sal, temp, TSS

Daily sal*temp*TSS OEC averaged by month (0-1)

Output: monthly ascii files with OEC per Ecospace model grid cell



The layer is loaded into Ecospace as an environmental driver with a linear response curve

How habitat capacity changes the foraging arena equation:

$$V_{ij} = \frac{v_{ij} \cdot B_i}{2 \cdot v_{ij} + a_{ij} \cdot B_j} \longrightarrow V_{ij} = \frac{v_{ij} \cdot B_i}{2 \cdot v_{ij} + a_{ij} \cdot B_j / C_{rcj}}$$

V_{ij} = vulnerable portion of the prey
v_{ij} = vulnerability exchange rate
B_i = prey biomass
a_{ij} = effective search rate
B_j = predator biomass
C_{rcj} = relative habitat size or habitat capacity of the cell

In effect, low habitat capacity for a predator in a grid cell cell reduces the foraging arena area, and the vulnerable portion of the prey (so the predator is not eating less, but running out of available food)

Christensen et al. 2014

How habitat capacity affects movement:

For each border between cells, for example between cell (r,c) and cell (r,c+1) to its right, Ecospace assumes instantaneous mixing rates $m_{1j}B_{rcj}$ to the right and $m_{2j}B_{rcj}$ to the left. This movement is affected by the habitat capacity of the neighboring cell

$$\frac{m_{1j}}{m_{2j}} = \frac{C_{rc+1j}}{C_{rcj}}$$

Ecospace sets the exit rate to m_j (user supplied dispersal rate; 300 km yr^{-1}) for whichever cell has lower capacity C_{rcj}, then adjusts the exit rate for the cell with higher C_{rcj} to M_j times the capacity ratio.

Christensen et al. 2014