South Atlantic Reef Fish Model (SARF) Ecospace Module

SAFMC SSC Model Team
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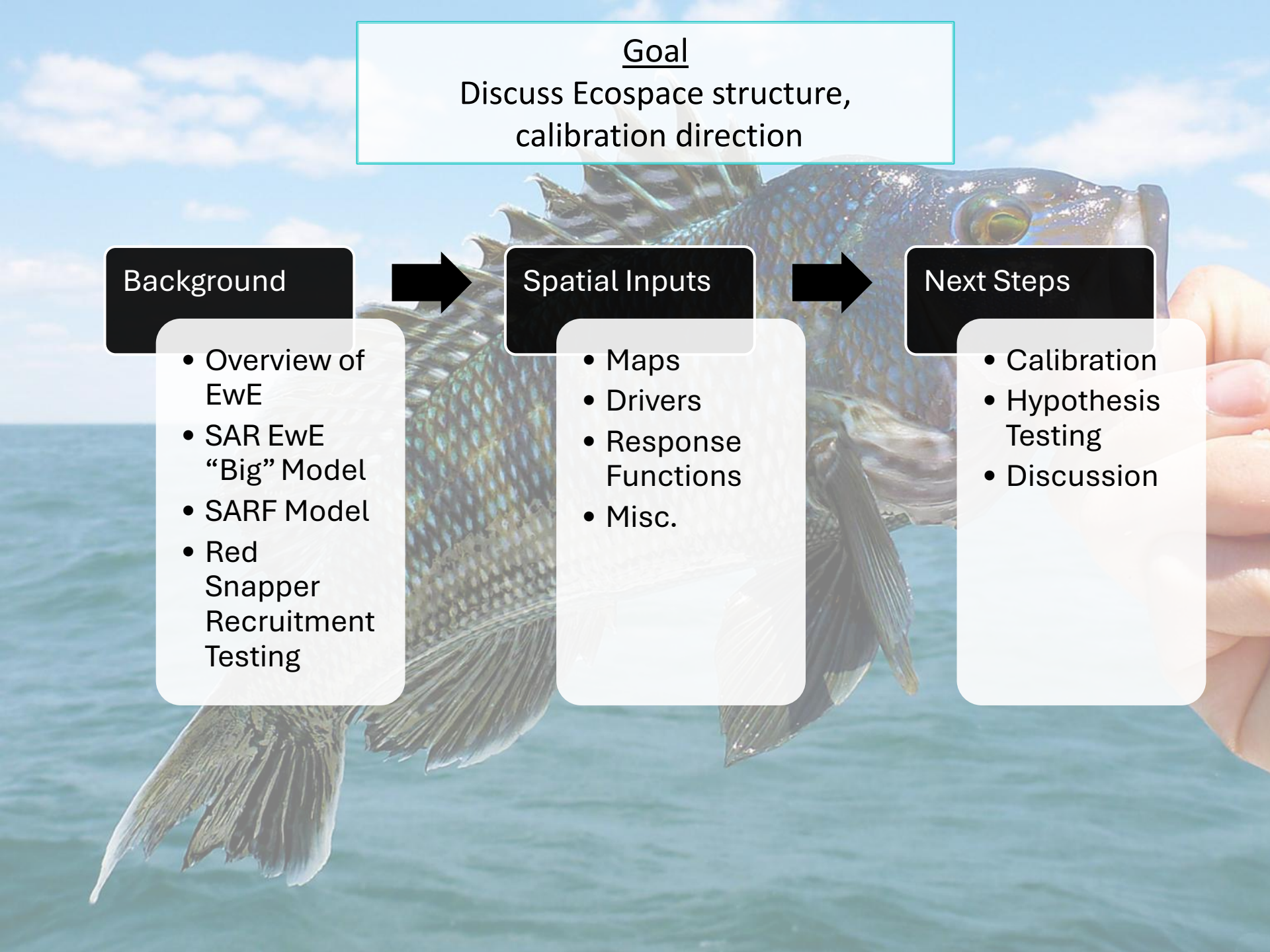
April 2025



Goal

Discuss Ecospace structure, calibration direction

Background

- Overview of EwE
- SAR EwE "Big" Model
- SARF Model
- Red Snapper Recruitment Testing

Spatial Inputs

- Maps
- Drivers
- Response Functions
- Misc.

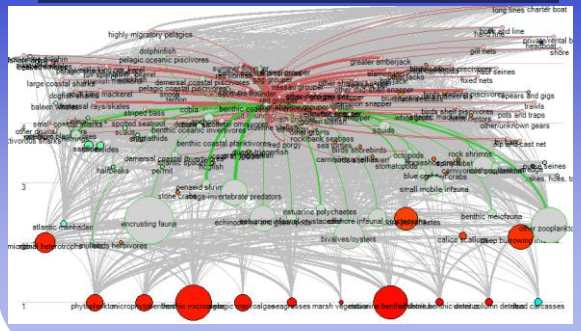
Next Steps

- Calibration
- Hypothesis Testing
- Discussion

Ecopath with Ecosim and Ecospace (EwE)

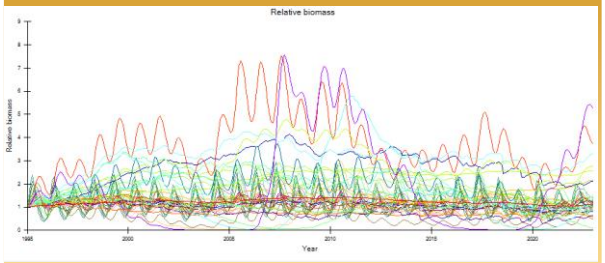
Ecopath

Snapshot of the ecosystem



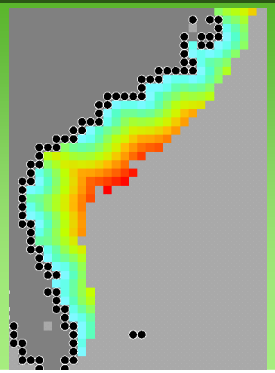
Ecosim

Time dynamics



Ecospace

Spatial-temporal simulations



<u>Inputs</u>
Species & Biomasses
Diets (links species)
Growth Parameters
Fishing Fleets
Landings

<u>Timeseries</u>
Chlorophyll *a*
Biomass
Effort
Catch
Indices of Abundance
Fishing Mortality
Mediated by Vulnerabilities
Monthly biomass dynamics

<u>Static Maps</u>
Habitat, Depth, Ports, MPAs
<u>Dynamic Maps</u>
Chl. *a*, Temp, Fishing Effort
<u>Habitat Preference Functions</u>
How each species responds to temp, depth, habitat, etc.

Model History – SAR EwE Model

First iterations

2001: 48 groups
2004: 98 groups
2014: 99 groups
2019: 143 groups

A PRELIMINARY ECOPATH MODEL OF THE ATLANTIC CONTINENTAL SHELF ADJACENT TO THE SOUTHEASTERN UNITED STATES

Thomas A. Okey[1] and Roger Pugliese[2]

Exploring the Trophodynamic Signatures of Forage Species in the U.S. South Atlantic Bight Ecosystem to Maximize System-Wide Values

Thomas A. Okey, Andrés M. Cisneros-Montemayor, Roger Pugliese, Ussif R. Sumaila

South Atlantic Region Ecosystem Model
"The Big Model"

2020: 140 groups
- 700+ species
- 250+ diets
- 153 timeseries
- More collaborators than we can count
- Reviewed by SAFMC SSC/Workgroup

2021: Used for Red Snapper Predation Analysis
Present: Prey analyses, Data Repository

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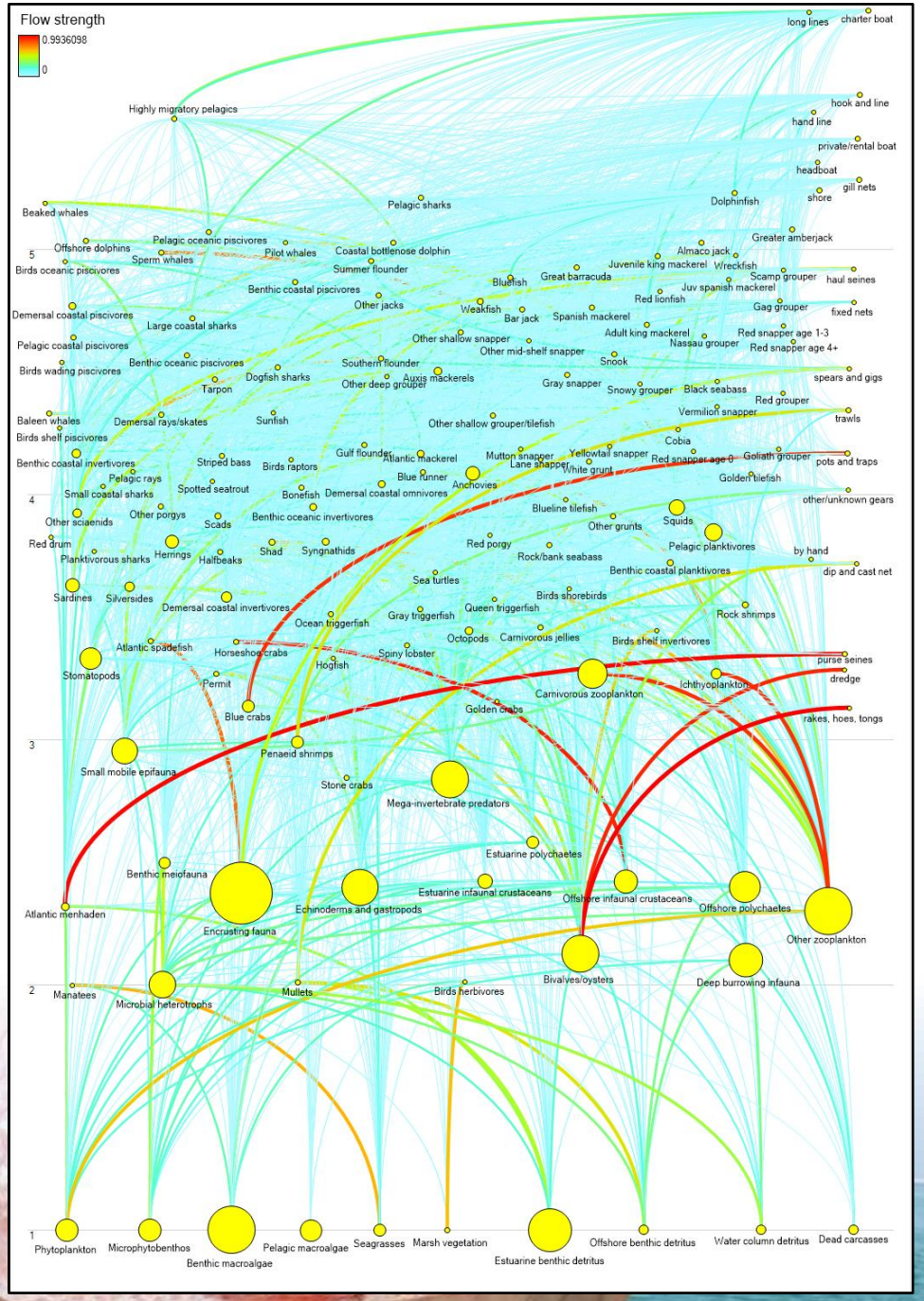


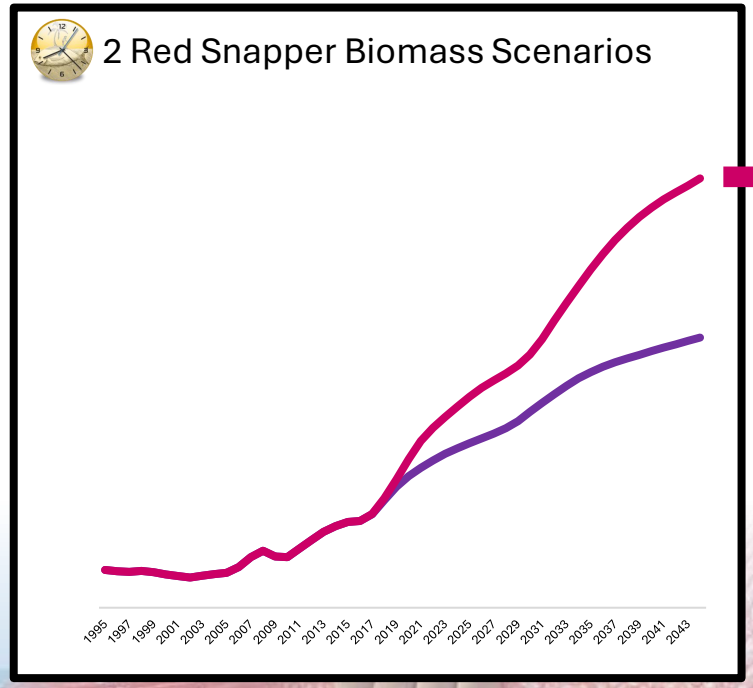
Red Snapper Predation Analysis

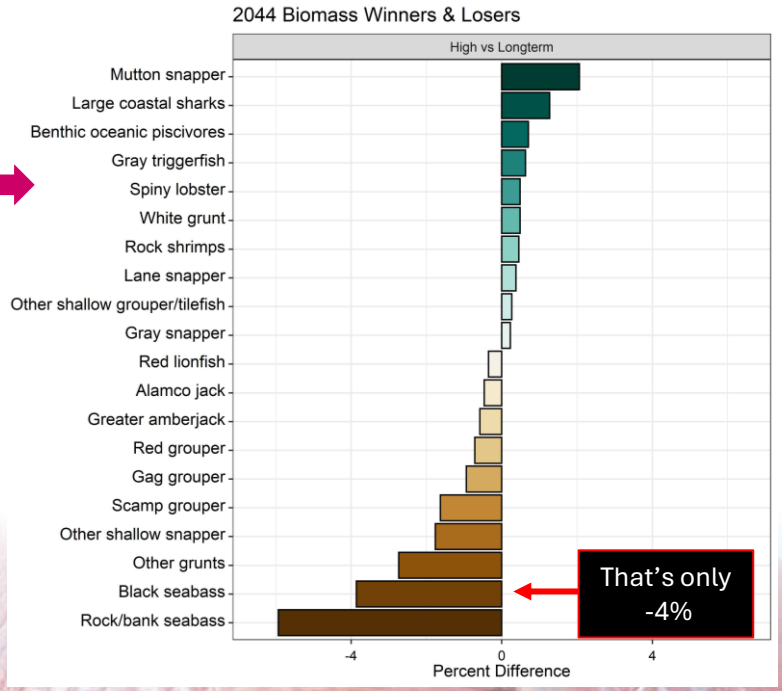
2 rebuilding scenarios driven by recruitment

- Longterm Average Recruitment/Rebuilding
- High Recent Recruitment/Rebuilding

Biggest Loser of High Recent Recruitment

4% decrease in black sea bass biomass



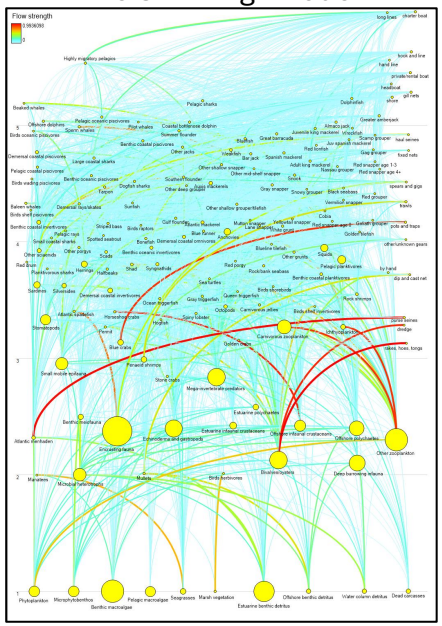


South Atlantic Reef Fish (SARF) Model

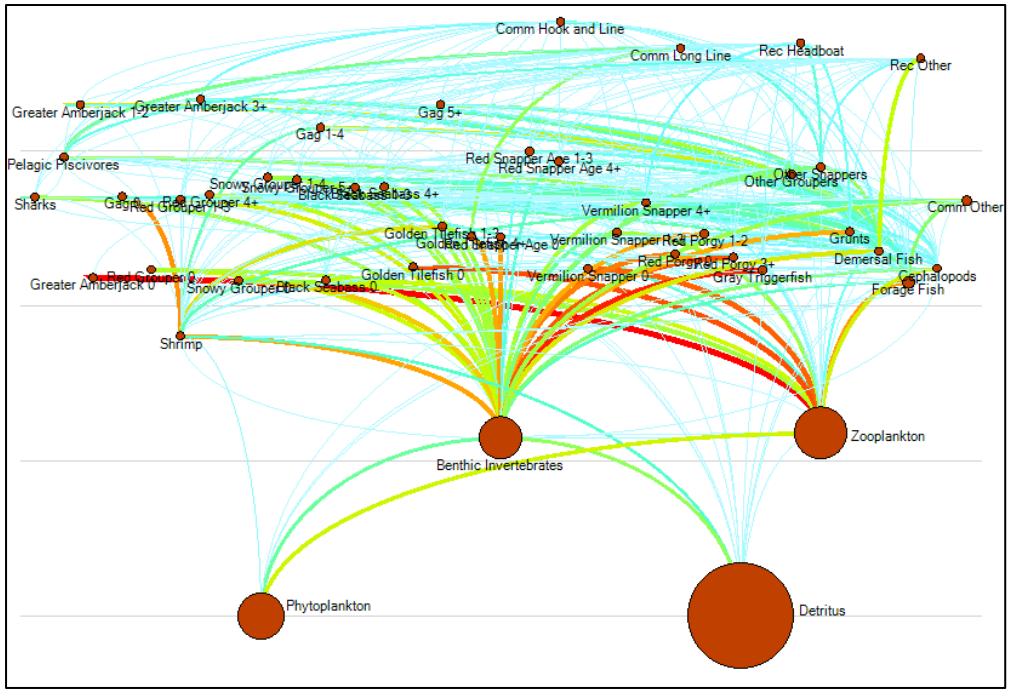
- Medium-sized version of full South Atlantic Ecosystem Model
- 41 groups focused on Snapper-Grouper Complex
  - Includes age structure (stanzas)

Sharks
Pelagic Piscivores
Greater Amberjack
Gag
Red Grouper
Snowy Grouper
Black Sea Bass
Golden Tilefish
Red Snapper
Vermilion
Red Porgy
Gray Triggerfish
Other Groupers
Other Snappers
Grunts
Demersal Fish
Forage Fish
Cephalopods
Shrimp
Benthic Invertebrates
Zooplankton
Phytoplankton
Detritus

The SAR "Big" Model



SARF Model



South Atlantic Reef Fish (SARF) Model

Medium-sized version of full South Atlantic Model

Ecopath

Fleets
- Currently adding select species-specific fleets to capture spatial dynamics

Diets
- Compressed from "Big" SAR EwE Model

Landings/Discards
- Stock Assessments, MRIP, ACCSP

SARF Fleets

1	Comm Hook and Line
2	Comm Long Line
3	Comm Other
4	Rec Headboat
5	Rec Other

Ecosim

Timeseries
- Catch
- Fishing Effort
- Fishing Mortality
- Absolute biomass
- Relative biomass
  - SERFS Indices of Abundance (trap and video)
  - Stock Assessment Indices of Abundance (HB, CL, CH, etc.)

All timeseries updated with most recent stock assessments

Sharks
Pelagic Piscivores
Greater Amberjack
Gag
Red Grouper
Snowy Grouper
Black Sea Bass
Golden Tilefish
Red Snapper
Vermilion
Red Porgy
Gray Triggerfish
Other Groupers
Other Snappers
Grunts
Demersal Fish
Forage Fish
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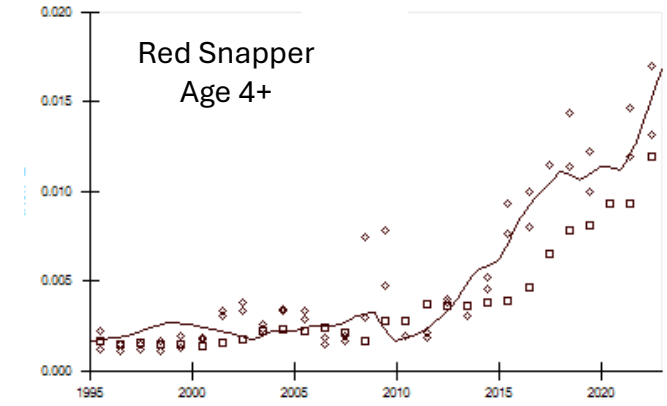
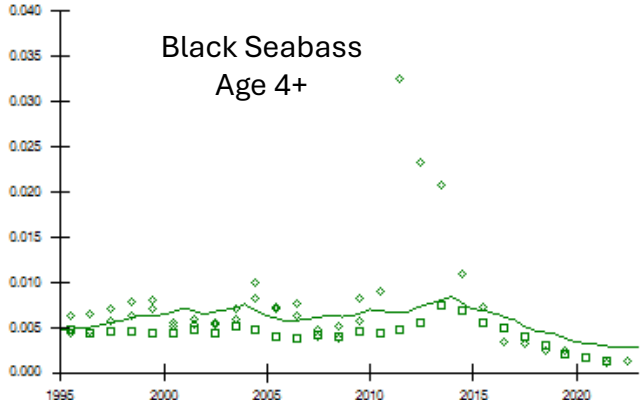
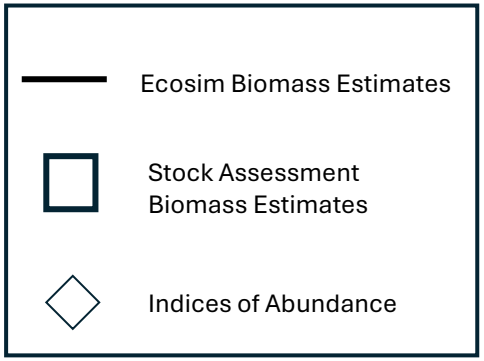
Shrimp
Benthic Invertebrates
Zooplankton
Phytoplankton
Detritus

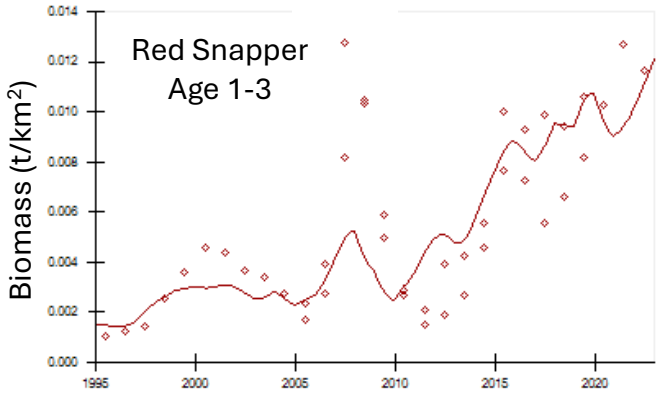
Ecosim fits

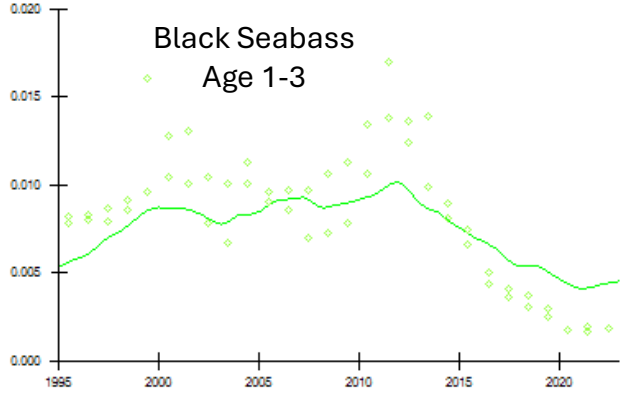
South Atlantic Reef Fish (SARF) Model

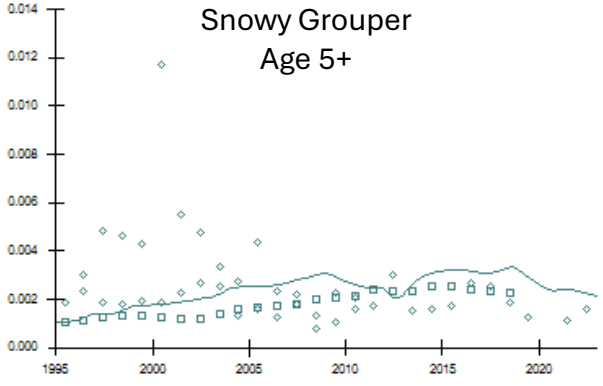


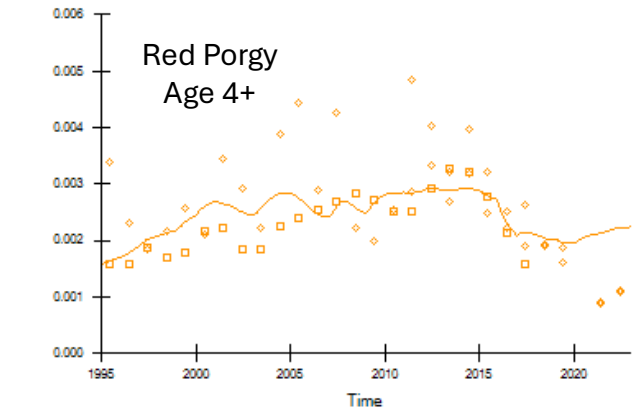


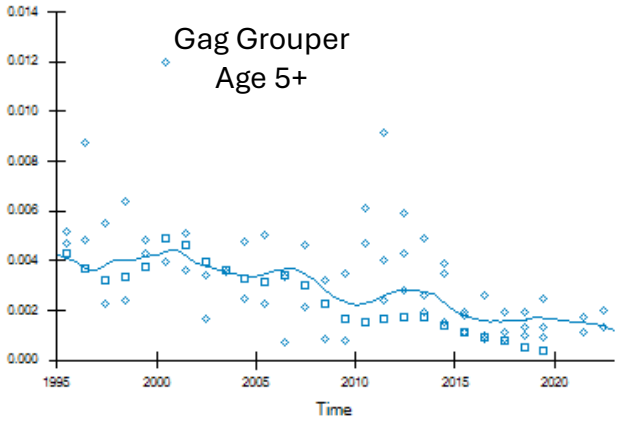


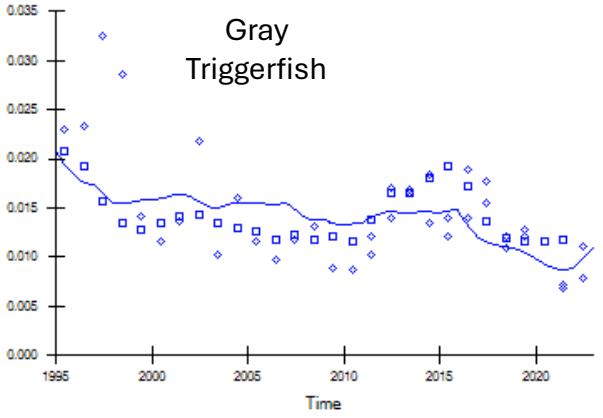






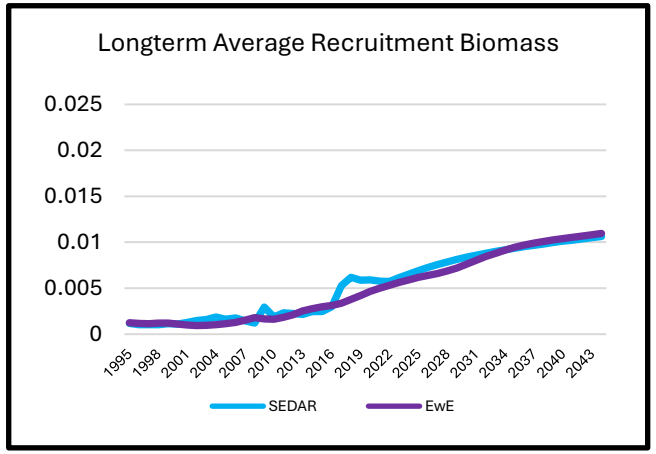


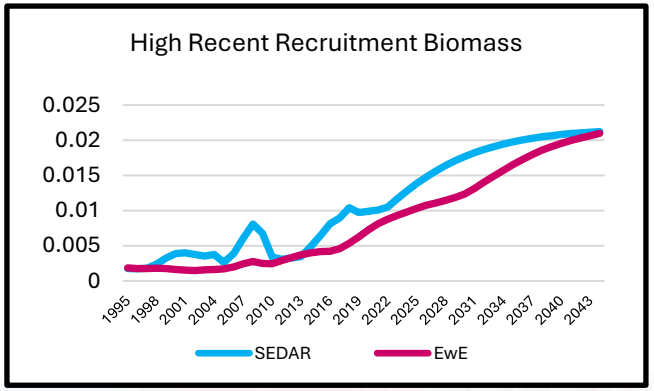




Red snapper predation testing 2.0

SAR EwE “Big” Model





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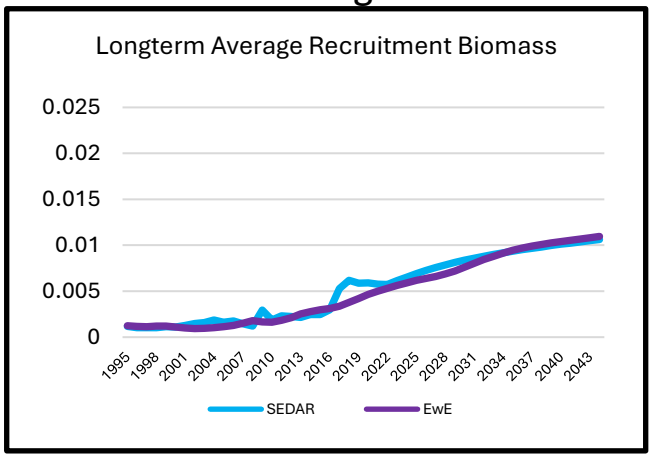
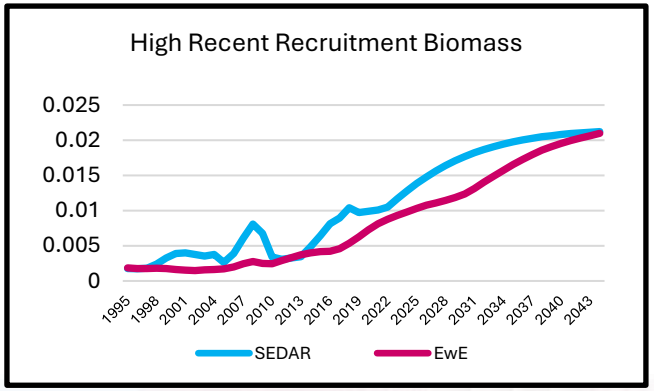
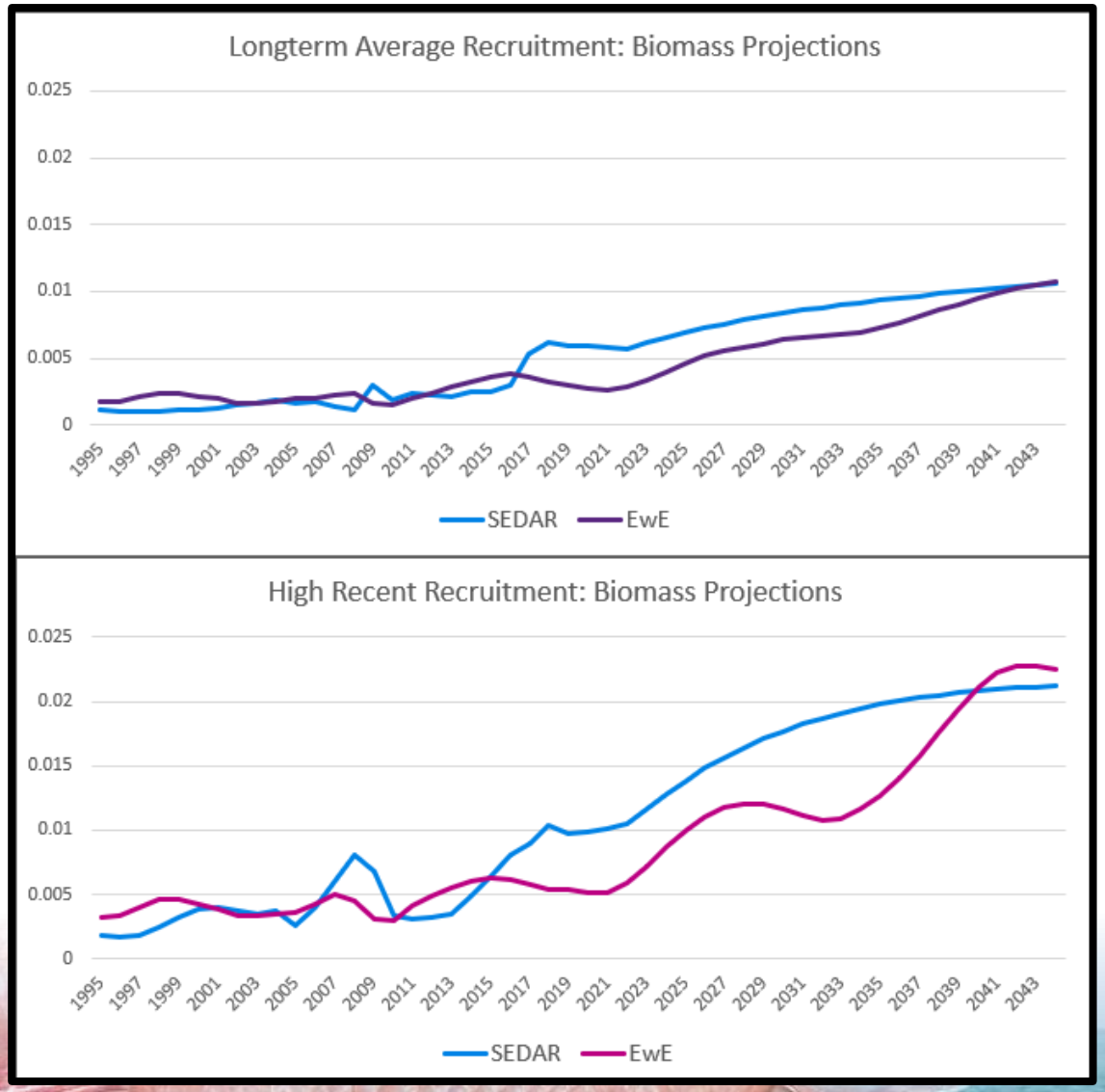


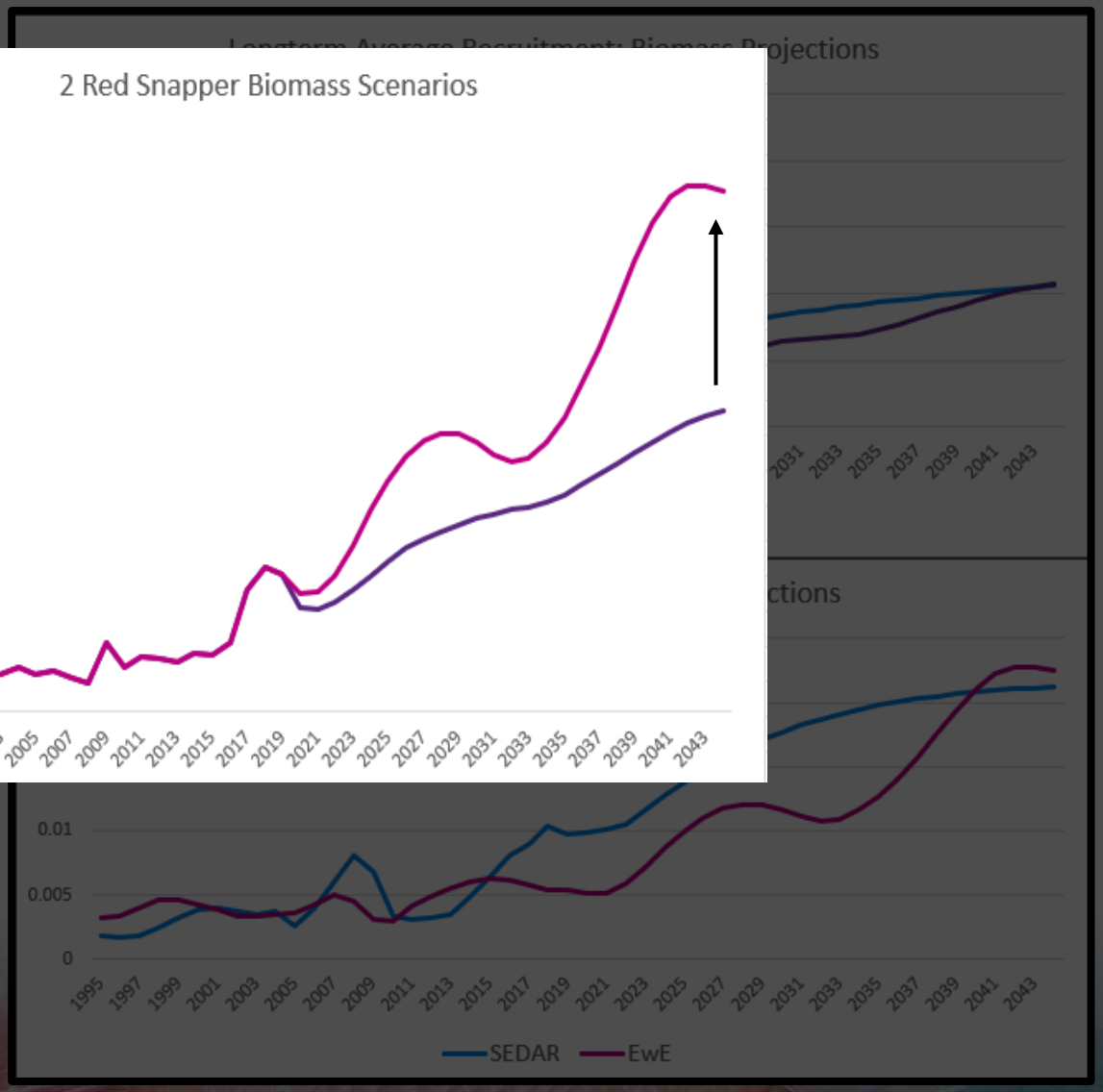


SARF Model

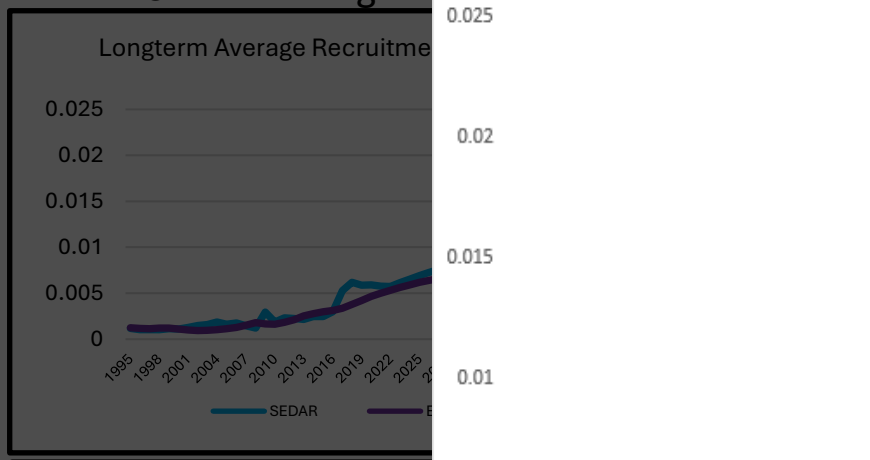


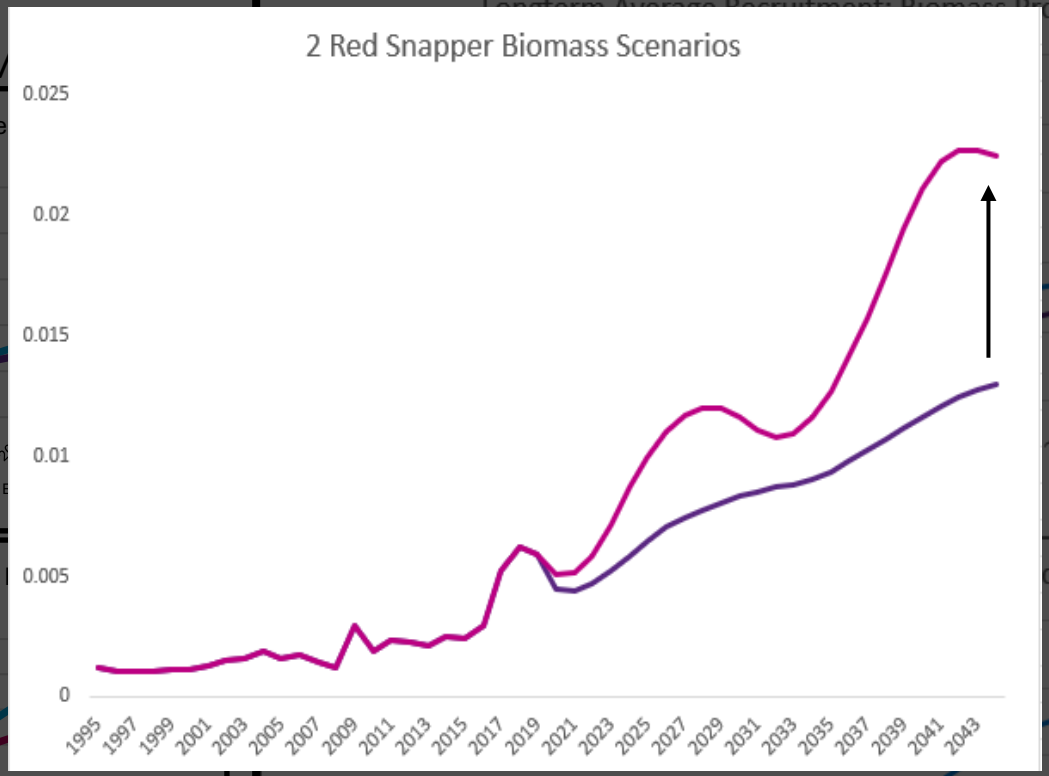
Red snapper predation testing 2.0

SARF Model



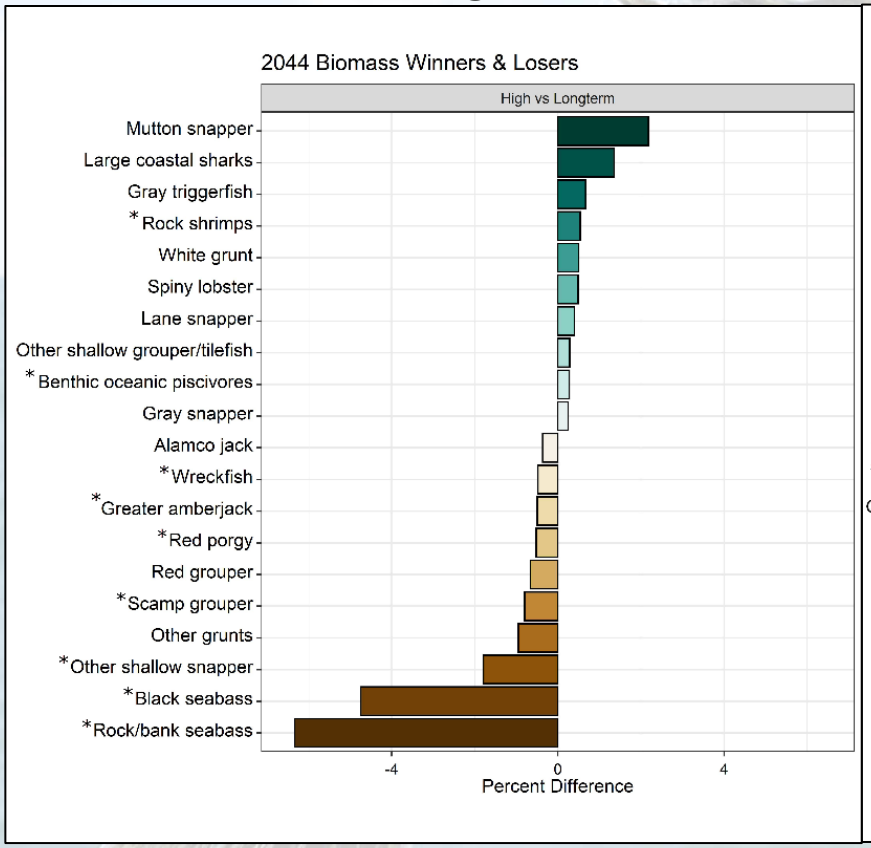
SAR EwE "Big" M



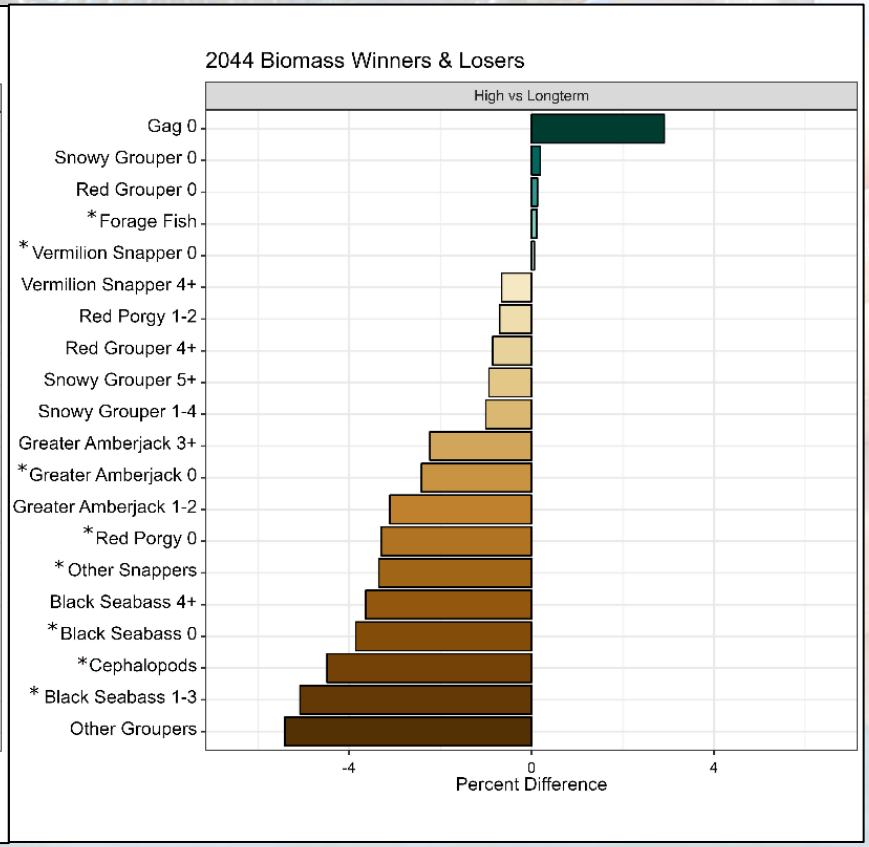


Red snapper predation testing 2.0
Winners and Losers

SAR EwE "Big" Model

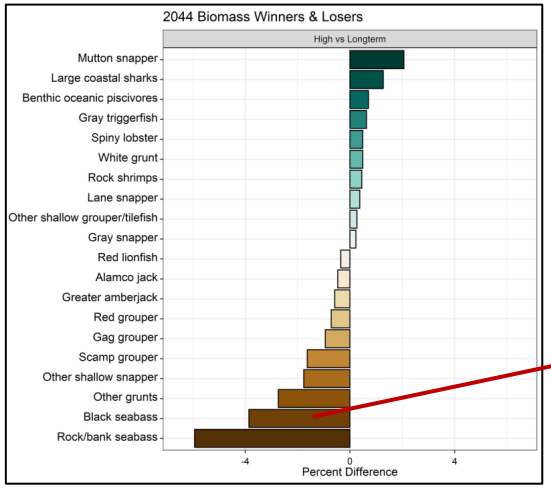


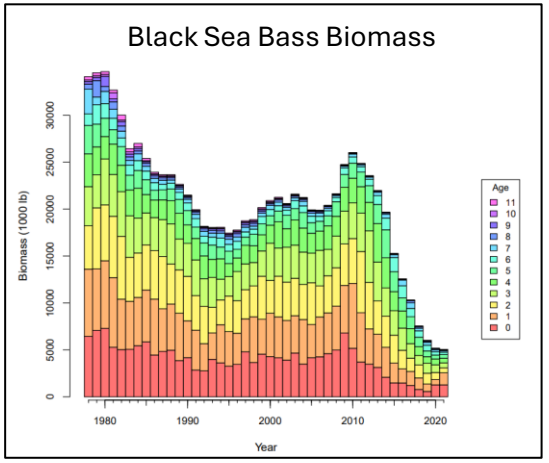
SARF Model



SARF Model

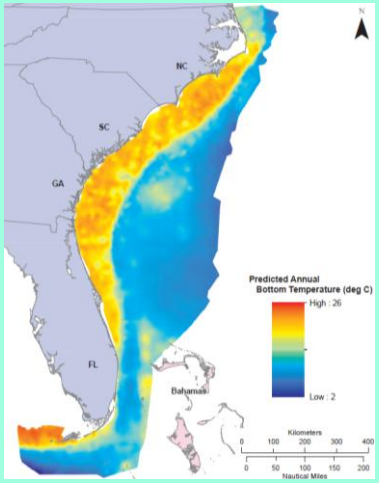
Ecospace/BSB Project





Hypotheses

Some like it hot – but not BSB?



Nearshore depletion

Low recruitment

Red snapper impacts

Ecospace Main Components

- Maps
  - Base Map
  - Habitats
  - Port Locations
  - Restricted Zones
  - Spatial-temporal Environmental Drivers
- Environmental Preference Functions
- Dispersal
- Fishing Effort
- Reference Data
- Economic Data
- Migrations

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Informs “habitat capacity” calculations per grid cell

- Dispersal
- Fishing Effort
- Reference Data
- Economic Data
- Migrations

Grid cell #1

Depth = 10 meters
Distance to shore = 2 NM
Proportion Reef = 1
Bottom Temp = 27°C

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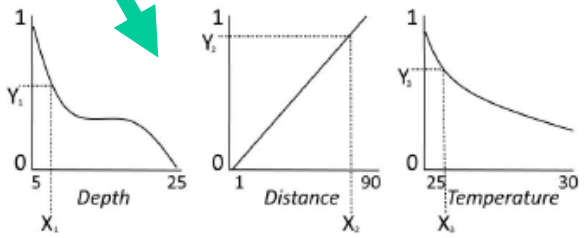

Figure 3-2. Conceptual diagram of habitat capacity values.

A habitat capacity value ($Y_1 \times Y_2 \times Y_3$) is a function of environmental preference values Y_i and environmental parameter values X_i (i.e., depth (m), distance to reef (m), and temperature (°C)) at a single raster cell (Christensen et al. 2014). The relationship between Y_i and X_i is defined by an environmental preference function represented as a solid black line.

Ecospace Main Components

Maps
- Base Map
- Habitats
- Port Locations
- Restricted Zones
- Spatial-temporal Environmental Drivers

Environmental Preference Functions

Dispersal

Fishing Effort

Reference Data

Economic Data

Migrations

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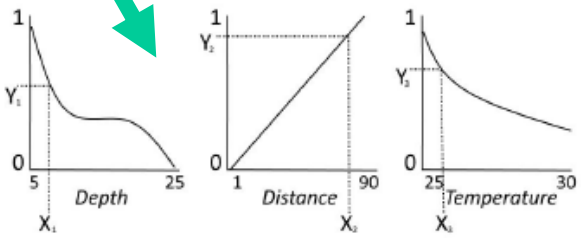

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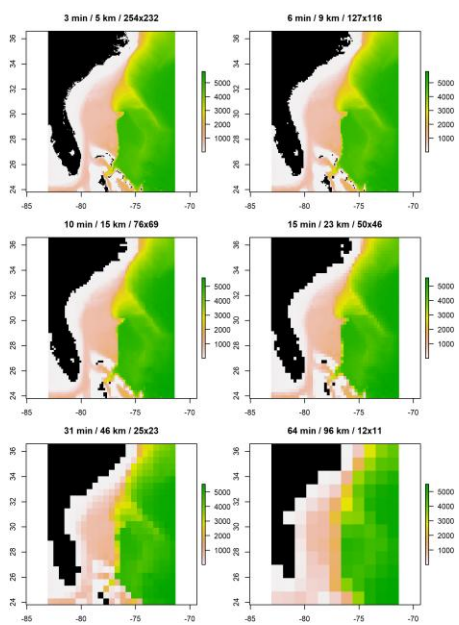
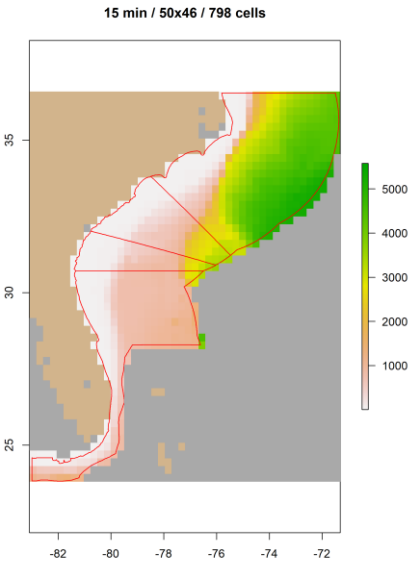
Grid cell #1

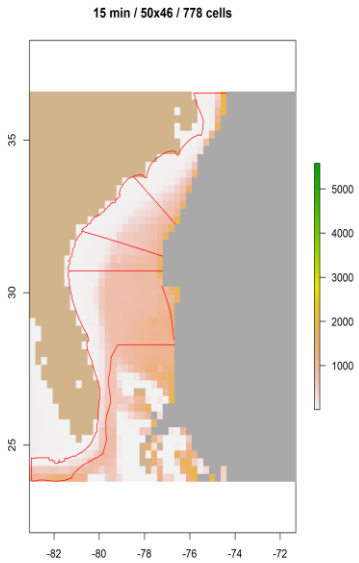
Habitat Capacity = some value from 0 to1

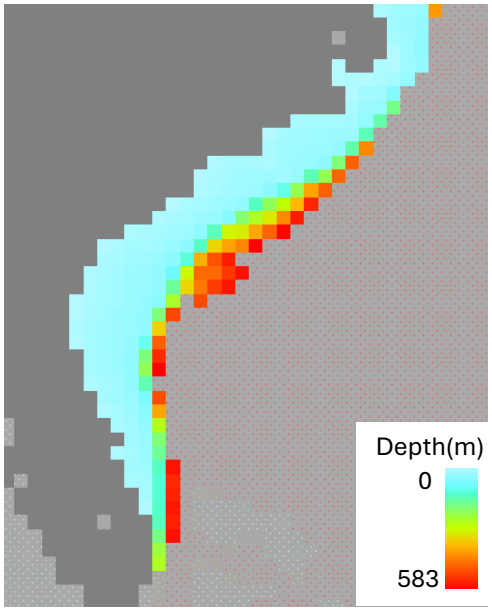
Decisions

- 15min (23km^2) resolution
- Boundaries at shelf (600m) and southern extent of SERFS sampling
- Depth: NOAA bathy database









SARF Model → Ecospace → Maps → **Habitats – Natural Reef**

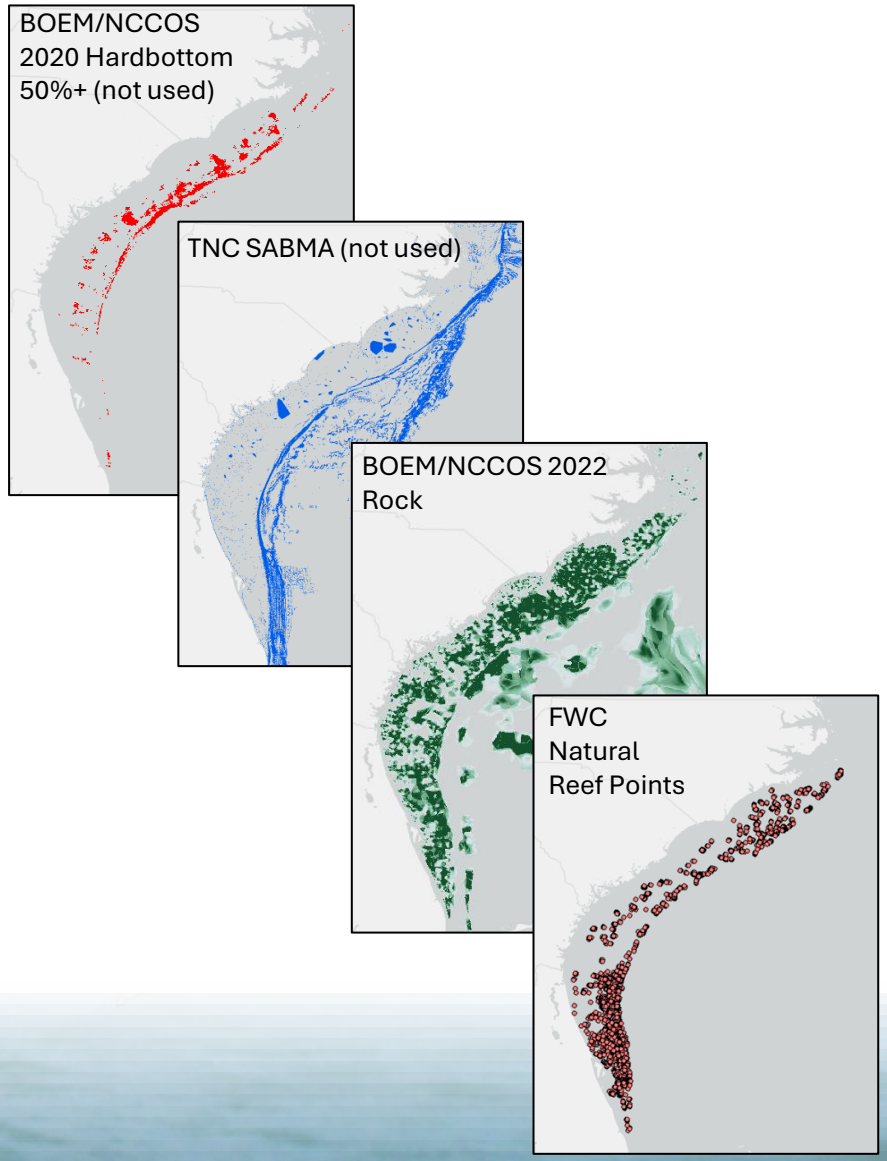
<u>Reviewed</u>

- BOEM 2020-002 NCCOS Predicted Hardbottom[1]
- TNC South Atl. Bight Marine Assess
- BOEM 2022-038 NCCOS Predicted Hardbottom[2]
  - Rock layer
- Natural Reef Points from FWC FIM/GAJ Count
  - SERFS sampling sites
  - FWC sites
  - USGS data
  - "Known Unknowns" from captain surveys

<u>Decision</u>

Using BOEM/NCCOS 2022 rock layer and FWC Natural Reef Points separately as habitat layers

Checked that rock layer covered SERFS sampling sites, TNC hardbottom data compilation, natural points map from FIM, and areas of highest hardbottom likelihood from BOEM2020



1) Pickens & Taylor 2020
2) Poti et al 2022

SARF Model | Ecospace | Maps | **Habitats – Artificial Reefs**

Reviewed

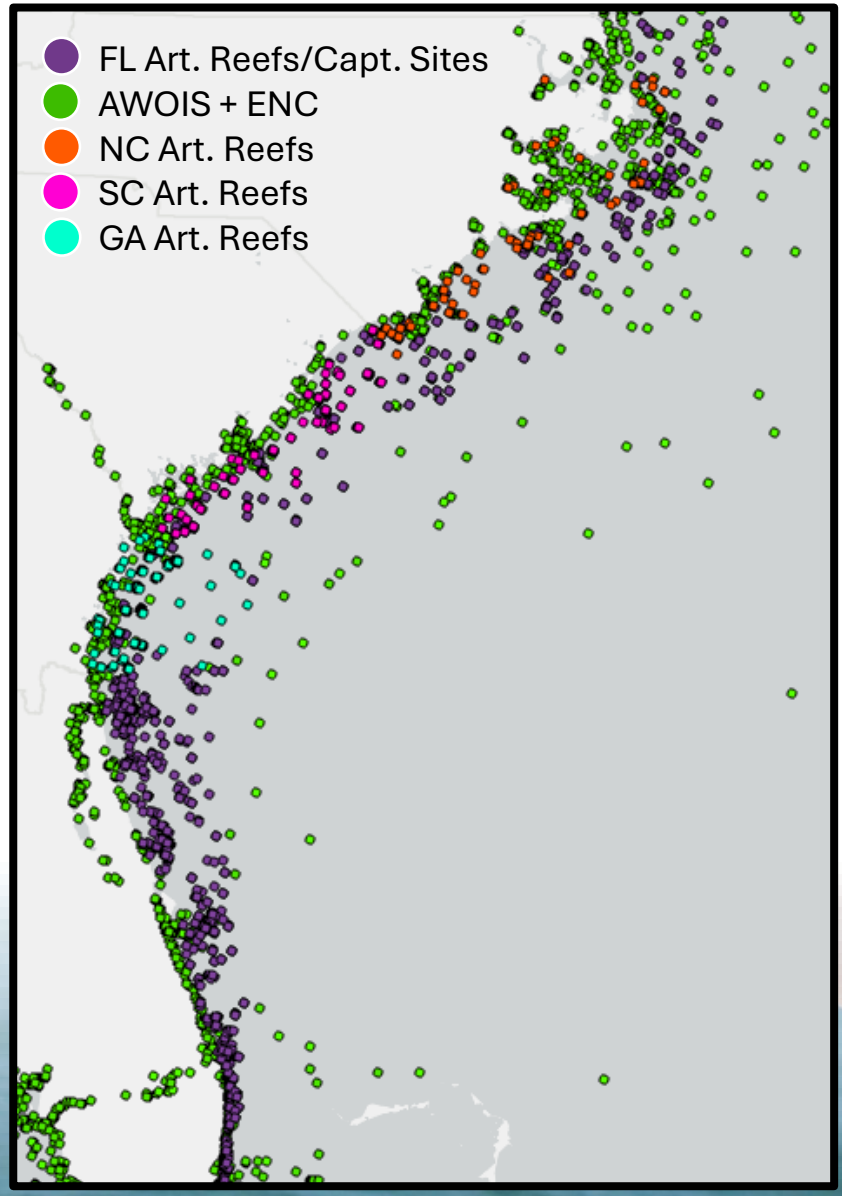
Artificial Reef layers from FWC FIM/GAJ Count

- Shipwrecks - AWOIS + ENC (both NOAA)
- Each state's artificial reefs layers
- "Known Unknowns" within 0.5 Nautical Miles of artificial reefs

Decision

Combine all point data into master map of artificial reef locations

-Expected large number of repeated sites from multiple data sources
-Summed points and proportioned to grid cells (0-1)
-Rescaled to reflect small area of artificial reefs in SA



SARF Model → Ecospace → Maps

Habitat Maps - Roughness

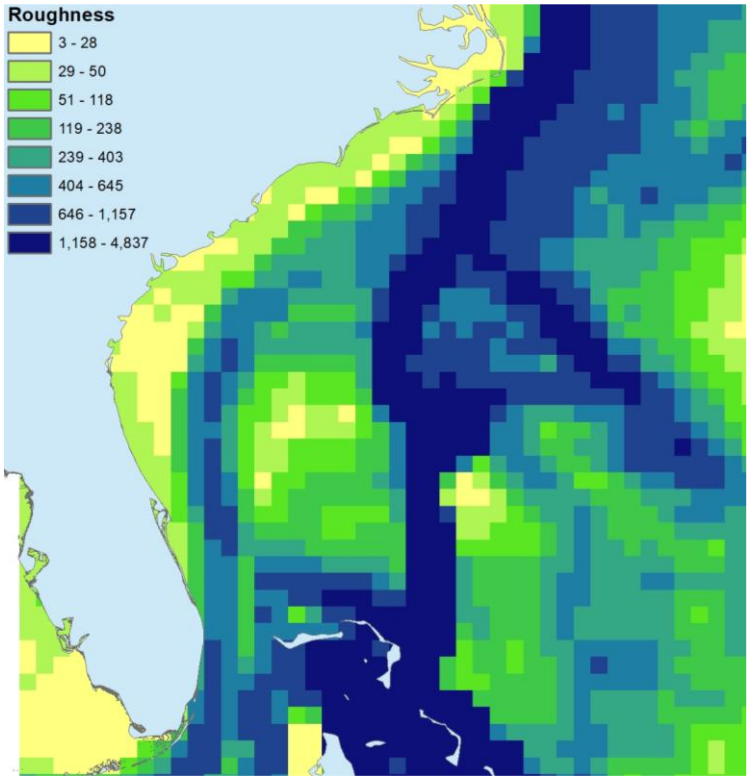
Serves as a coarse estimate of flat vs. rugose terrain relative to area's given resolution

<u>Reviewed</u>

- BOEM/NCCOS 2022 Roughness and Rugosity layers
  Incomplete over shelf
- NOAA Global Relief Model Topography (ETOPO 2022)
  Estimate terrain characteristics following Wilson et al. (2007)
  Initially considered:
  - Roughness (largest inter-cell difference between one pixel and its 8 neighbors)
  - Ruggedness (mean of the differences between pixel and 8 neighbors)
  - Topographic Position Index (difference between pixel and mean value of 8 neighbors)

<u>Decision</u>

Roughness from ETOPO 2022



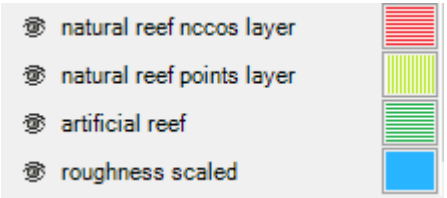
Wilson, M.F.J., O'Connell, B., Brown, C., Guinan, J.C., Grehan, A.J., 2007. Multiscale terrain analysis of multibeam bathymetry data for habitat mapping on the continental slope. Marine Geodesy 30: 3-35.

SARF Model

Ecospace

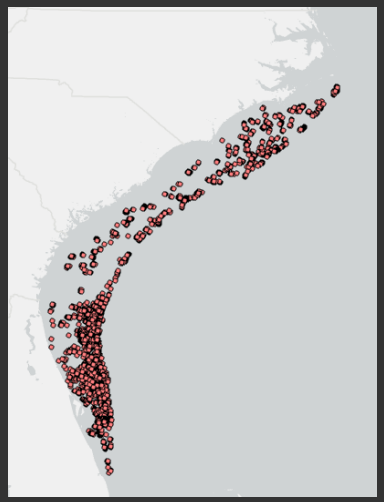
Maps

Habitat Maps -all

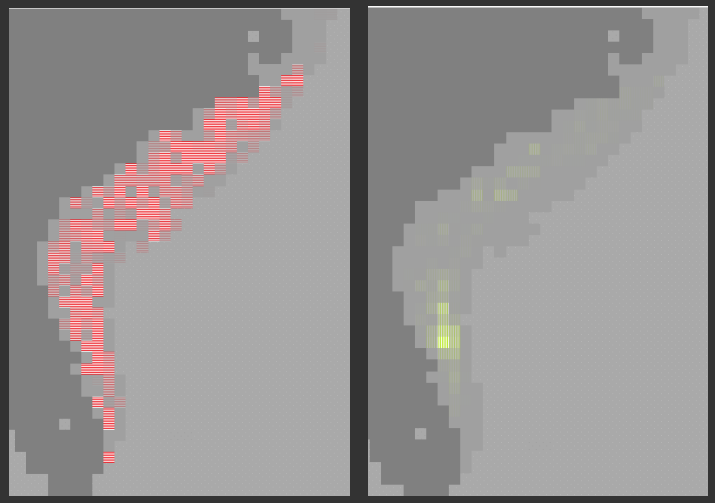


BOEM/NCCOS 2022 Rock

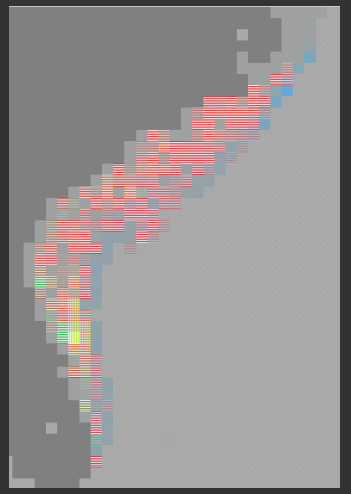
FWC Natural Reef Points



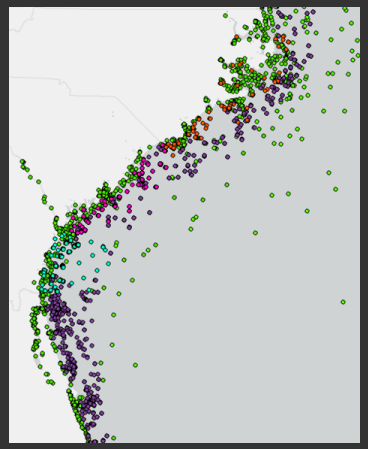
Ecospace Habitat Maps



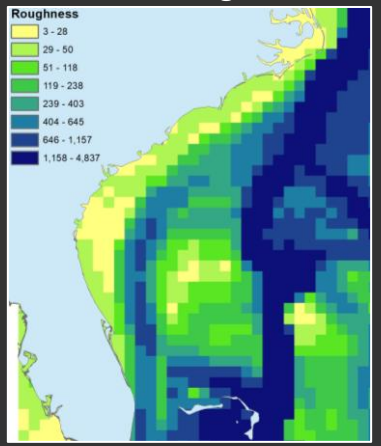
Ecospace Habitat Coverage

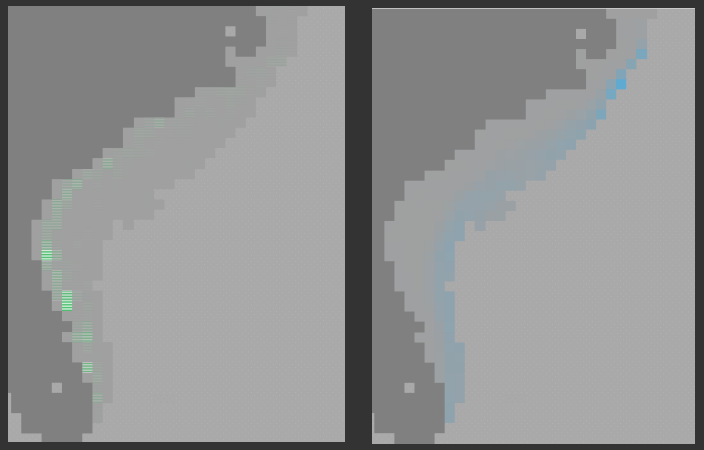


Combined Art. Reef Points



ETOPO 2022 Roughness



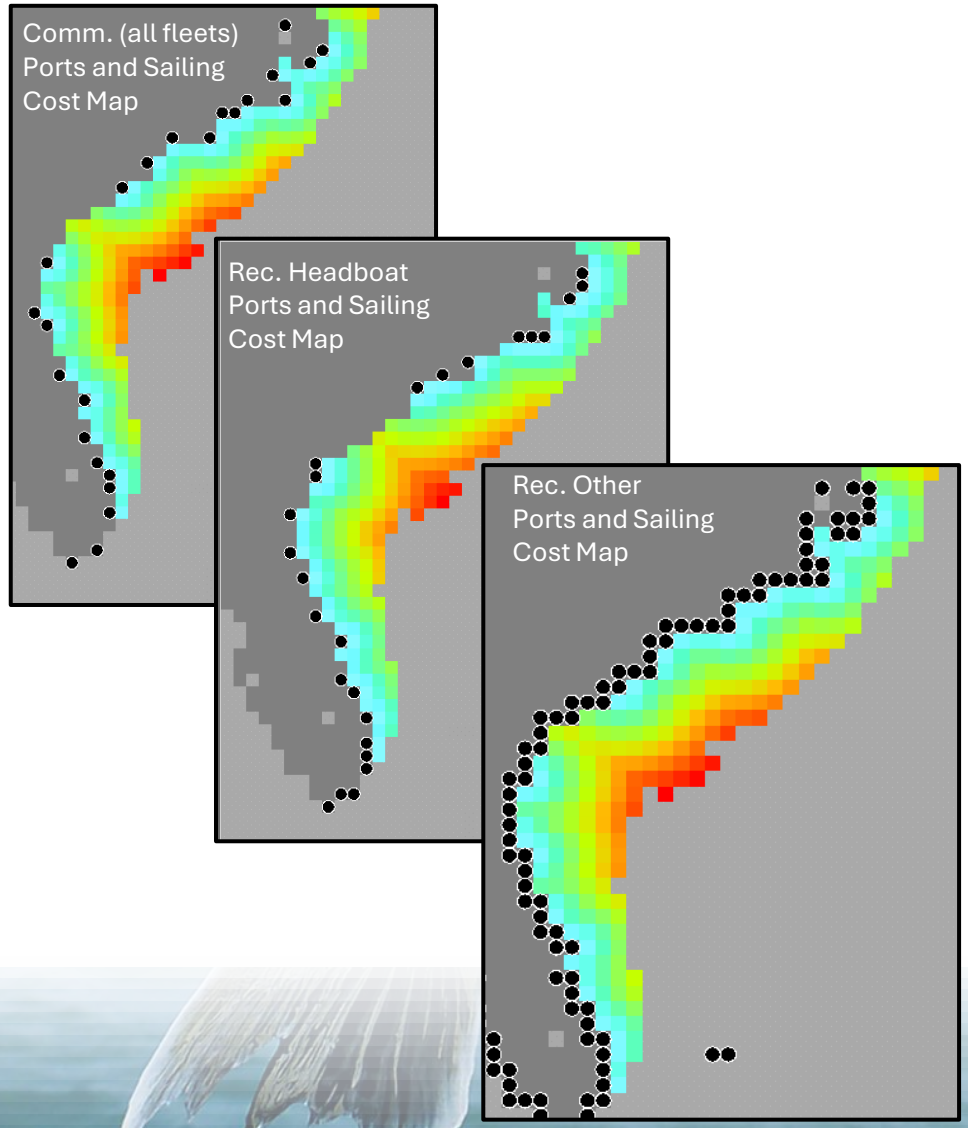


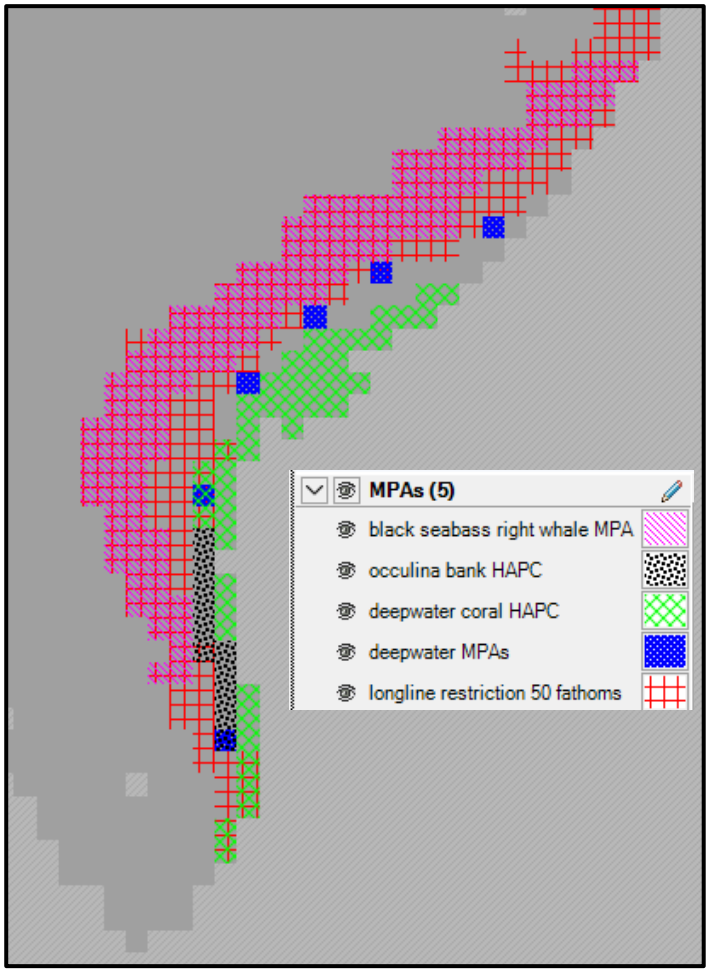
SARF Model

Ecospace

Maps

Ports & MPAs





Spatial-temporal environmental drivers

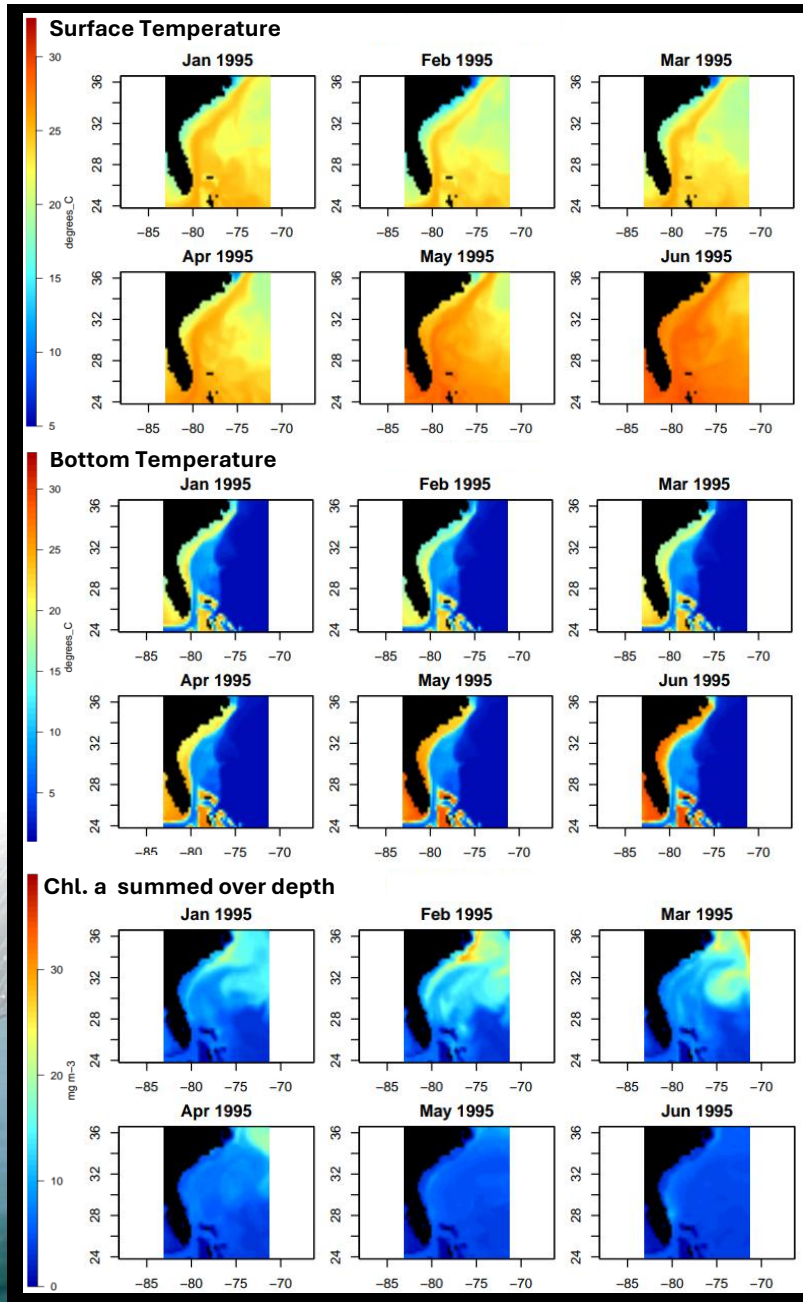
Purpose: EwE's habitat capacity model determines the area each species can use in each cell by functional responses to multiple environmental factors. ST drivers inform habitat capacity calculations for each functional group at each time step in each cell.

Reviewed

- HYCOM
- MODIS
- Copernicus Marine Services (EU)
  Global Ocean Physics Reanalysis: **GLORYS**
  -Designed for compatibility with climate projections

Decision

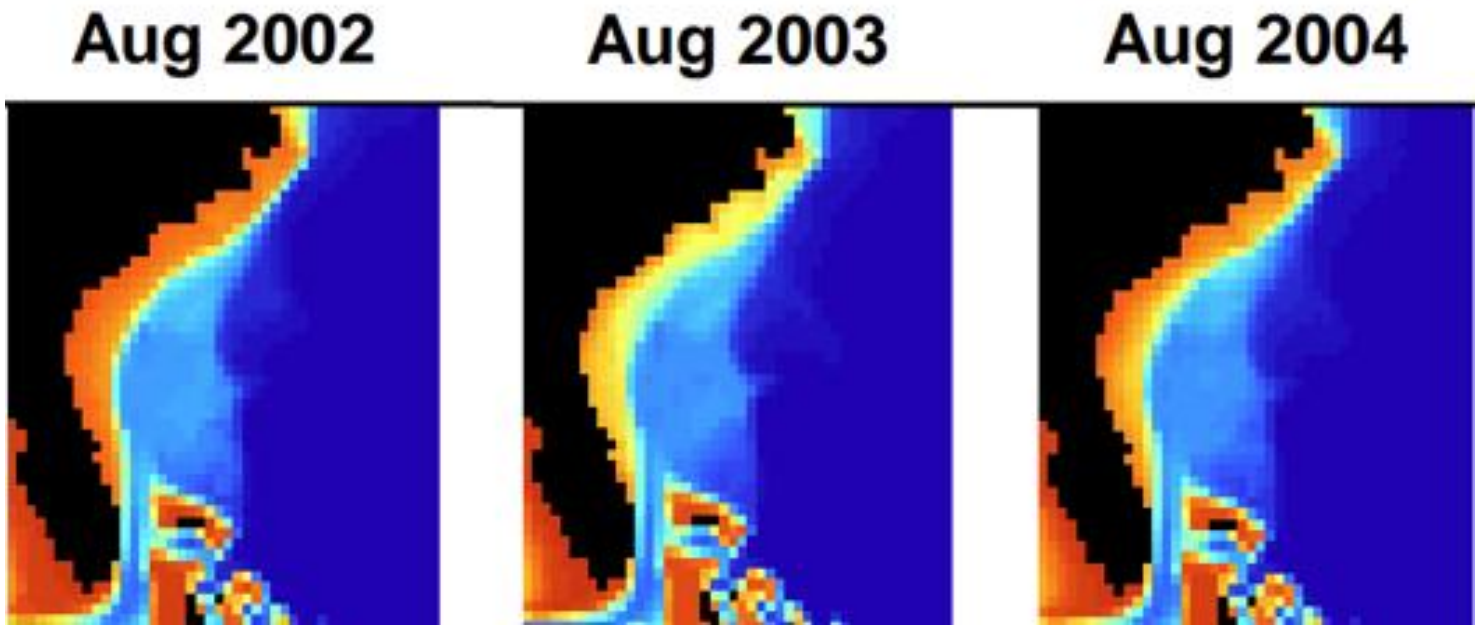
Using: SST, bottom temp, Chl. a
Monthly time steps 1995-2023



Workgroup request: temperature anomalies

- Check that local-level events are captured in GLORYS data
- WG and SAFMC provided a list of cold-water upwelling events during model period
- All but one were easily visible comparing year of event vs. before and after
  - Missing event lasted only 2-3 days

August 2003, coastwide upwelling:



Environmental Preference Functions

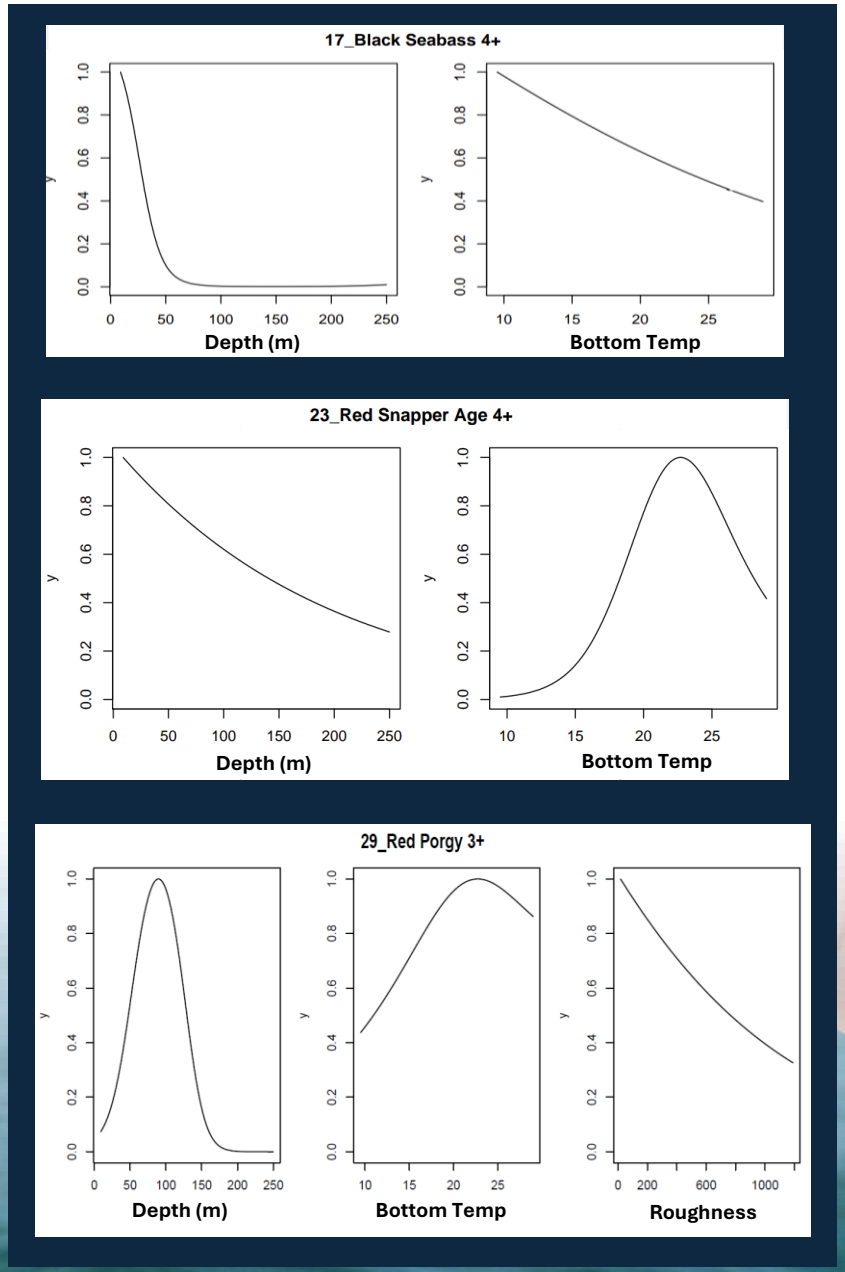
Purpose: Preference functions are used to calculate the habitat capacity in each grid cell, which drives movement, survival, and growth and generates spatial biomass distributions associated with environmental drivers.

Depth and Temperature

- SERFS Chevron Trap data
- SERFS Video data
- ROV Surveys from NOAA
- South Atlantic Deepwater Longline
- Aquamaps

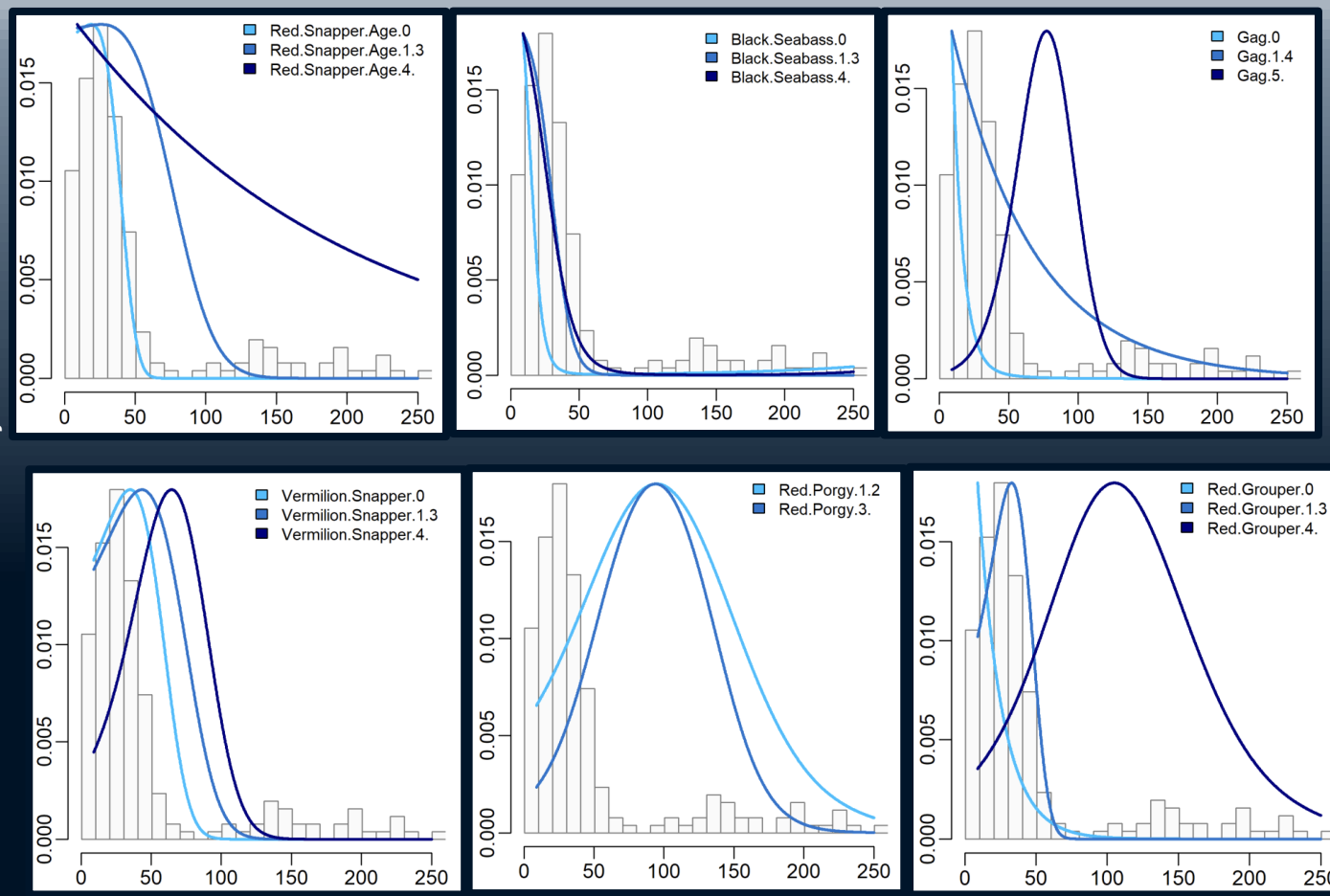
-Fitted binomial GAM model for each species/length stanza
-Predicted across the range of habitat values to create environmental preference functions
-Created another set with roughness as a covariate

Will select final versions as part of fitting process



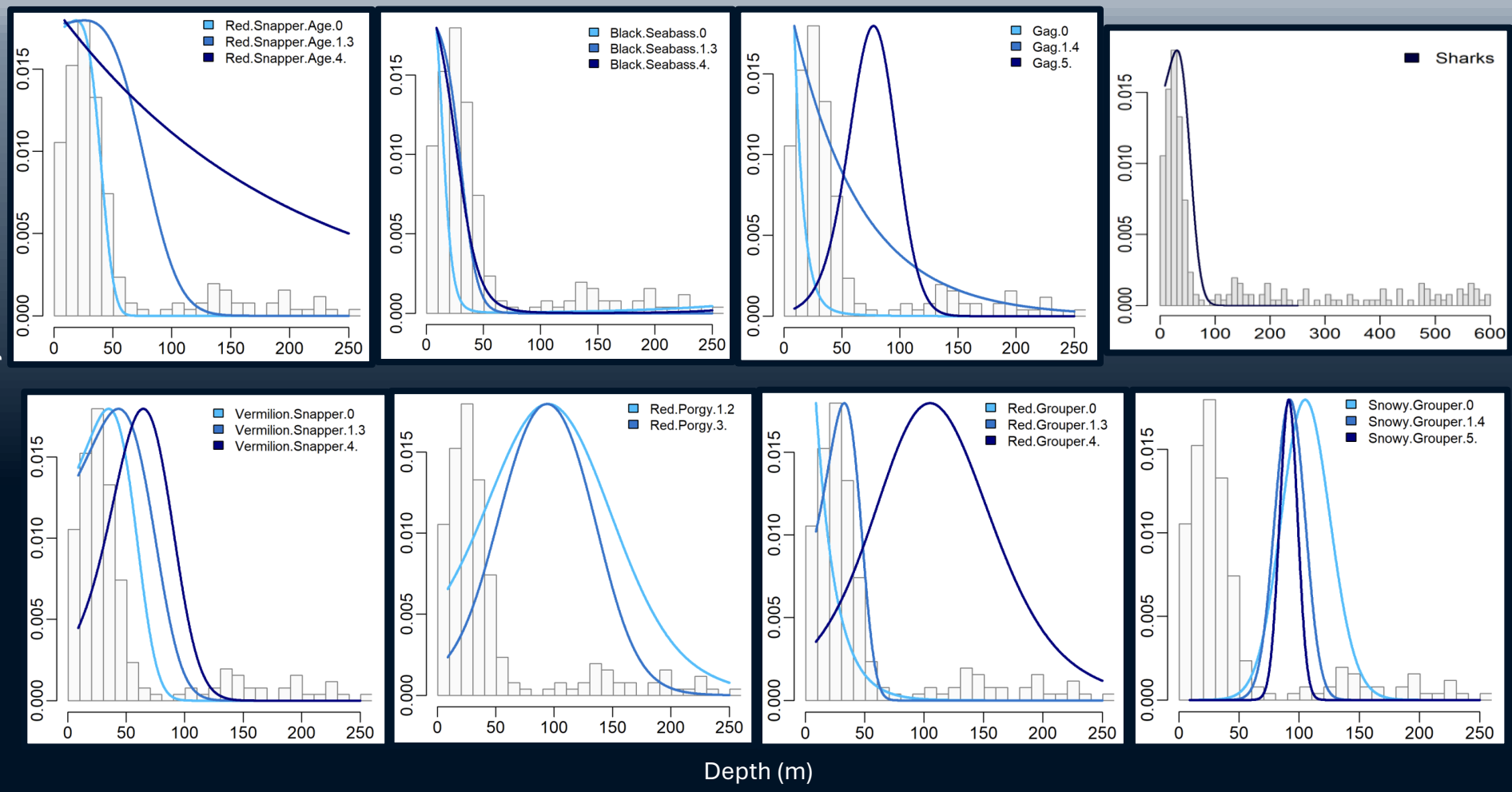
Environmental Preference Functions

WG Visualization: Depth values in basemap vs. depth preference functions



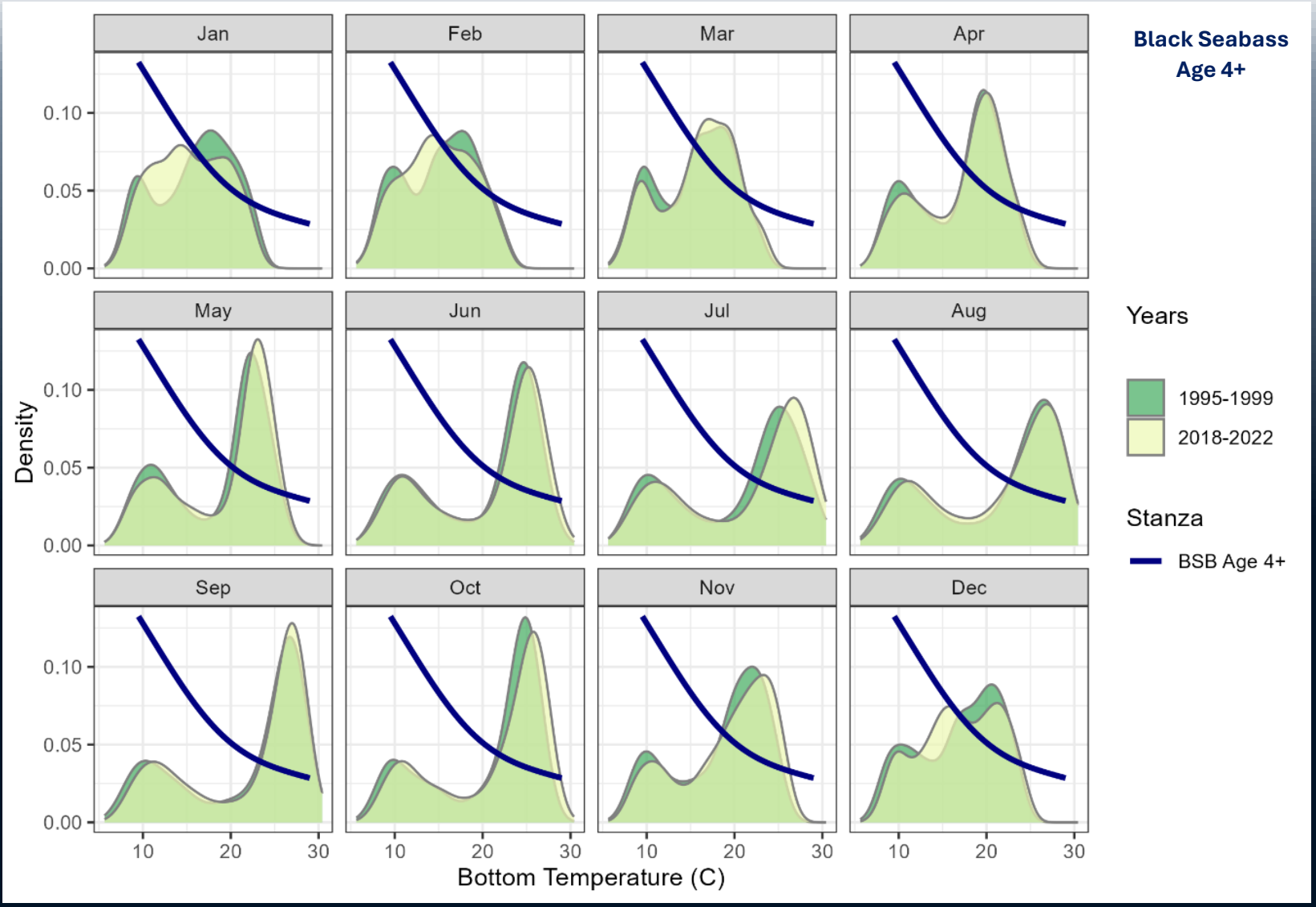
Environmental Preference Functions

WG Visualization: Depth values in basemap vs. depth preference functions



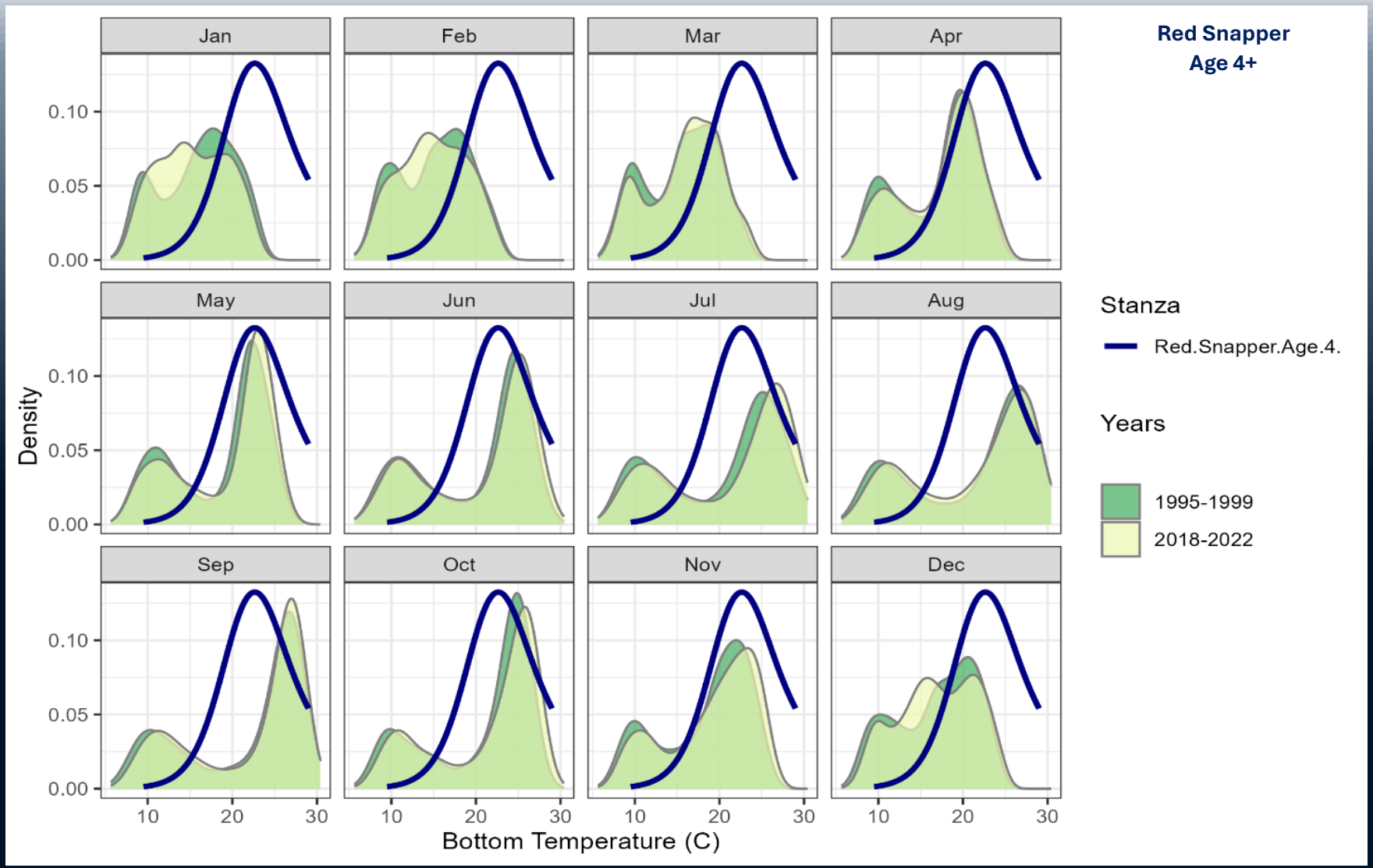
Environmental Preference Functions

WG Visualization: bottom temps in ST Drivers vs. bottom temp preference functions



Environmental Preference Functions

WG Visualization: bottom temps in ST Drivers vs. bottom temp preference functions



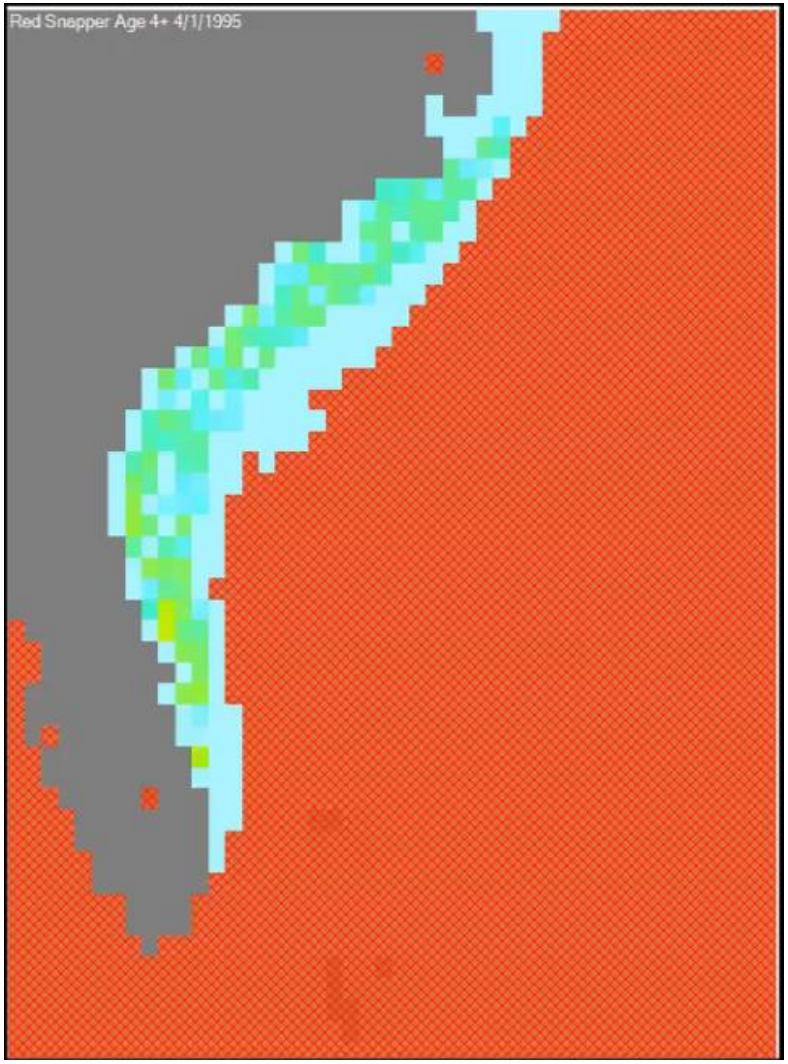
SARF Model

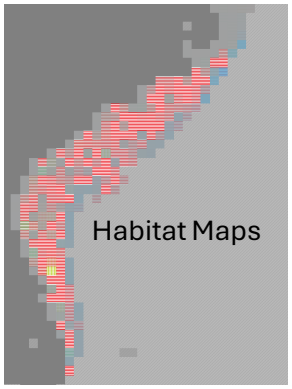
Ecospace

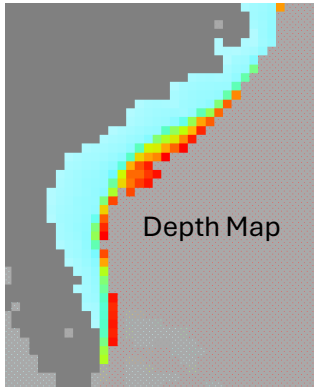
Maps

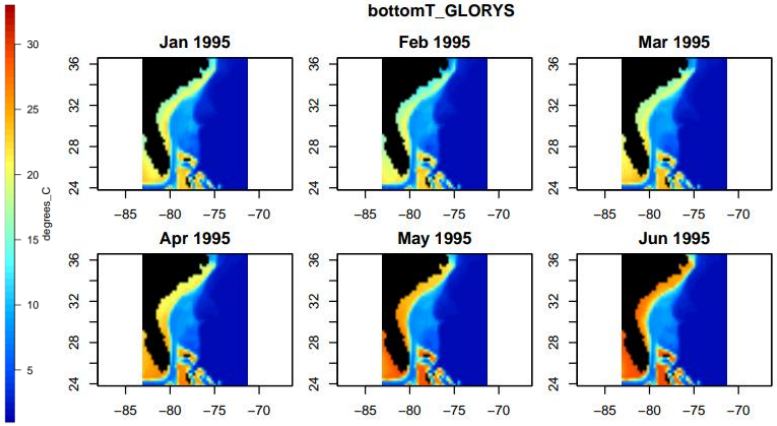
Habitat Capacity – Prelim Run

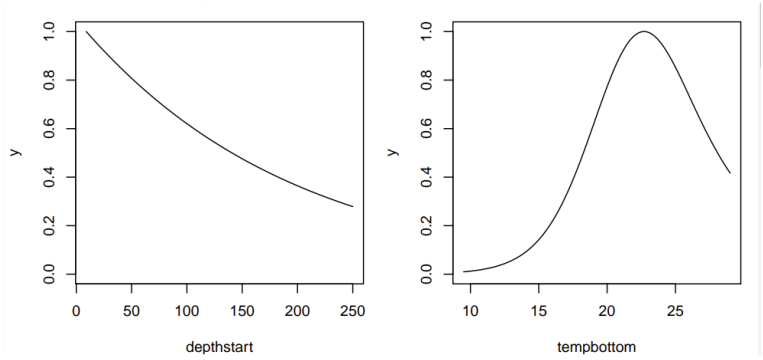
Computed Habitat Capacity - Video



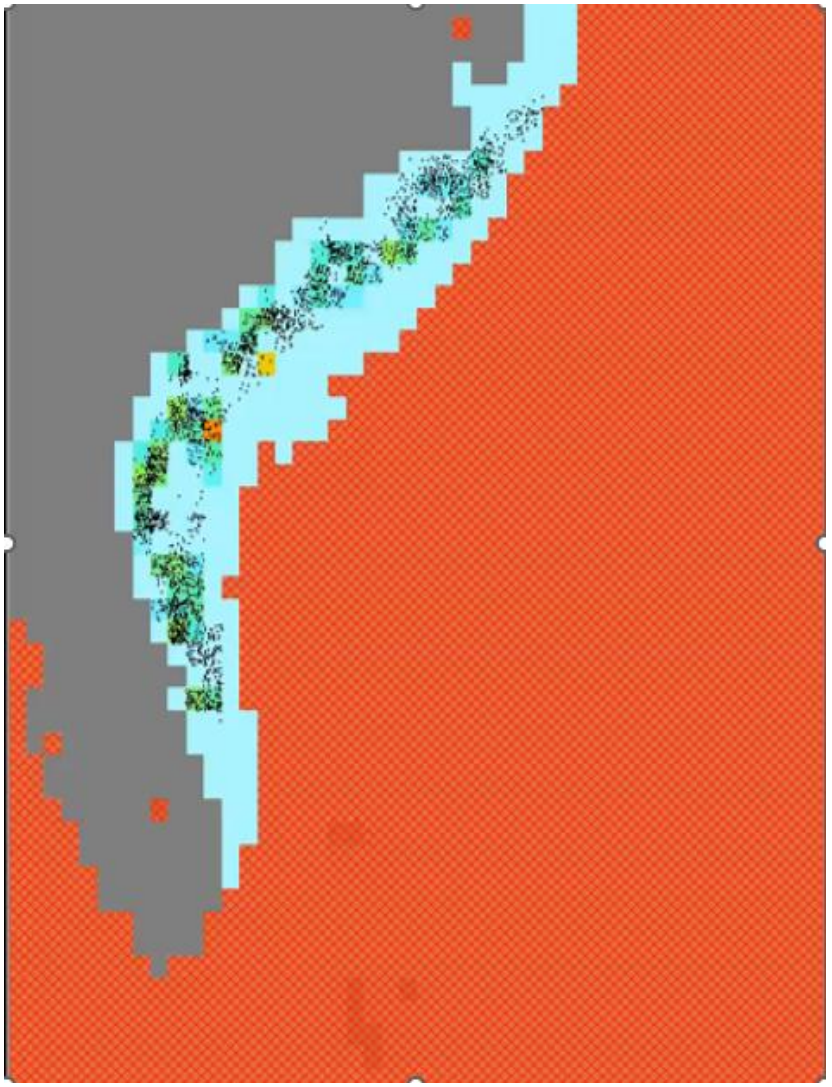








Example Run – Biomass - video

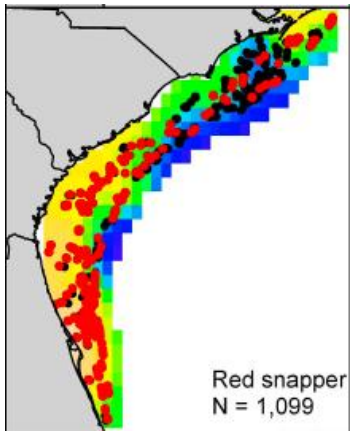


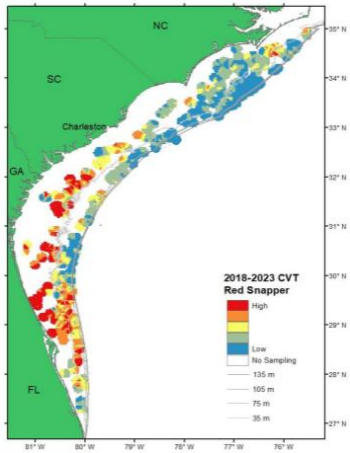
SARF Model | Ecospace | Misc. | **Reference Data**

<u>Purpose</u>
Compare model outputs vs. maps/trends in R
Potentially use directly in model if needed

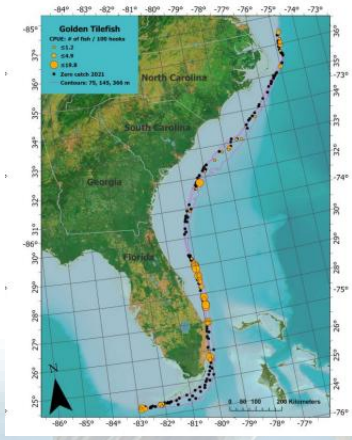
<u>Reviewed</u>
SERFS Video Predicted Probably of Presence Maps[1]
SERFS Chevron Trap heat maps
South Atlantic Deepwater Longline distribution maps

SERFS Video indices of abundance
SERFS Chevron Trap indices of abundance
Short Bottom Longline abundance trends
Long Bottom Longline: insufficient data for trends
ROV inside/outside MPA abundances

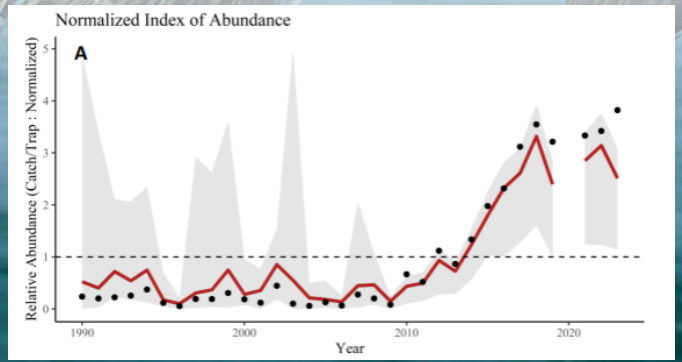


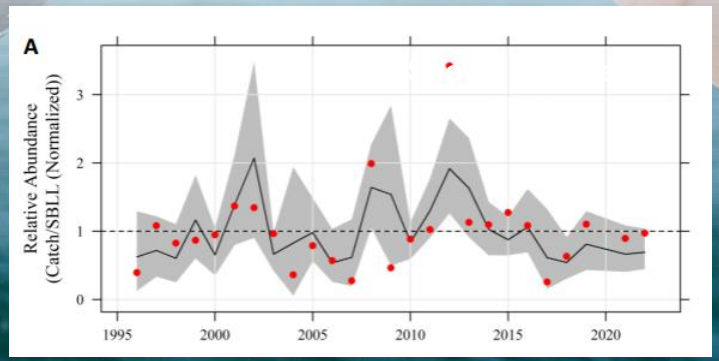


Golden Tilefish



Snowy Grouper

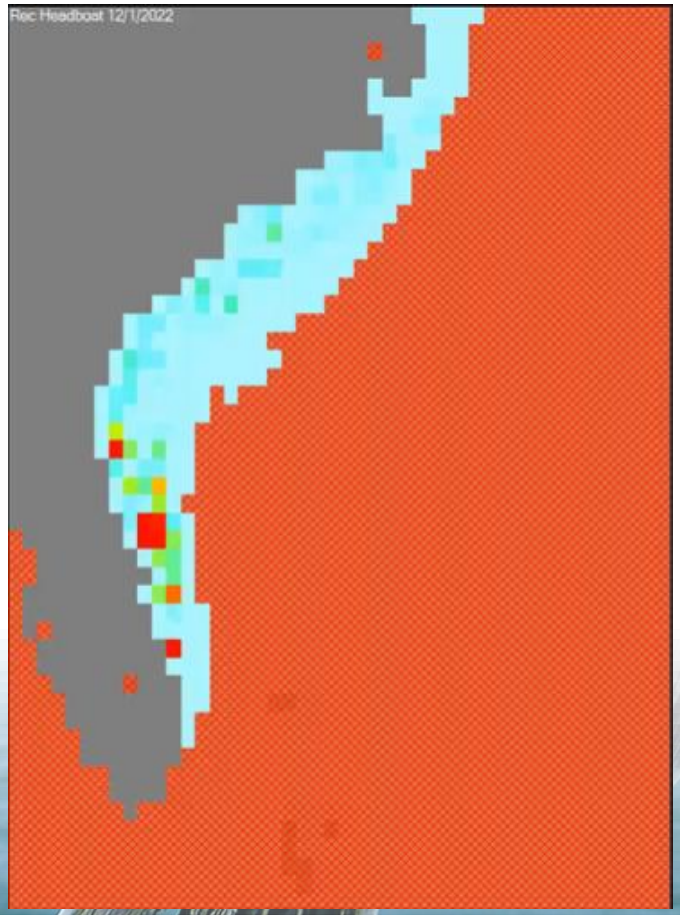




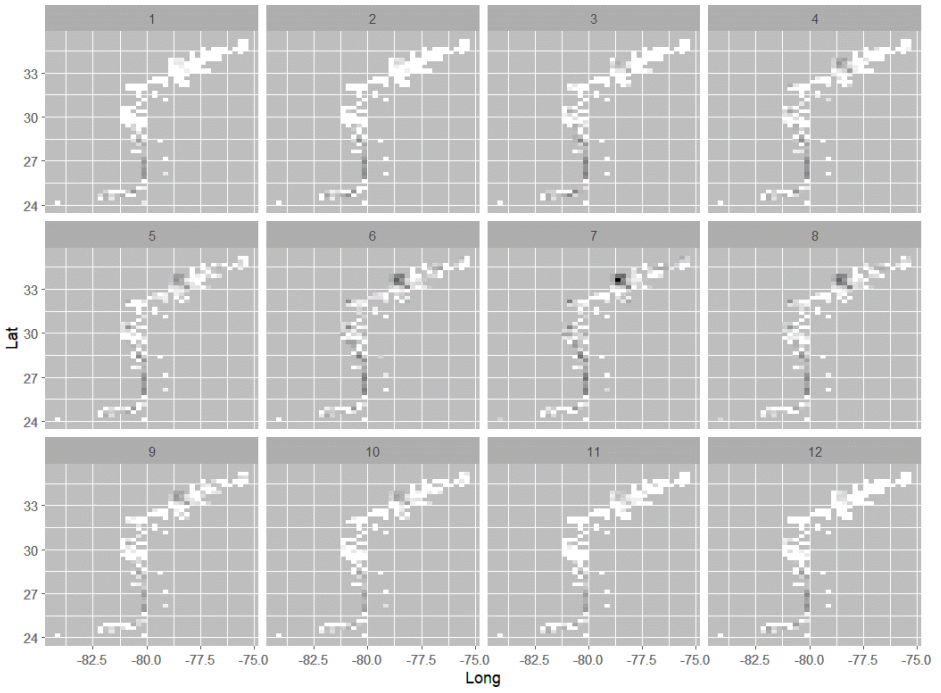
[1]Bacheler NM, Schobernd ZH, Berrane DJ, Schobernd CM, Mitchell WA, Teer BZ, et al. (2016) Spatial Distribution of Reef Fish Species along the Southeast US Atlantic Coast Inferred from Underwater Video Survey Data. PLoS ONE 11(9):e0162653

Reference Data – Fishing Effort - video

Headboat Effort Estimates – Preliminary Run



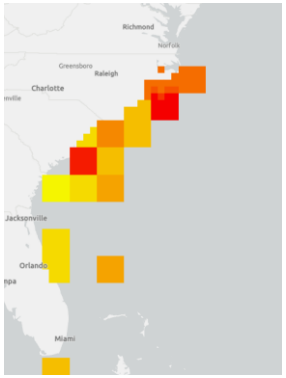
Headboat vessel + angler data, monthly, average 2013-2023

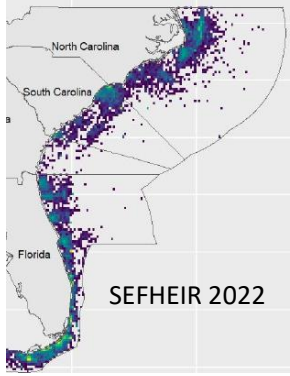


SARF Model | Ecospace | Misc.

Reference Data – Fishing Effort

Grunts
Hook and Line
Catch (Proportion)
Avg. 1995-2023





Purpose

Reference data to compare to Ecospace effort predictions
Assess seasonal trends in effort
Can use to constrain or direct effort if needed

Recreational

MRIP directed effort by month
- Seasonality

Headboat logbook trip data
- 2013 onward due to changes in reporting
- Vessel and angler data combined
- By year or by month (avg. '13-'23)

SEFHEIR data: 2021 onward

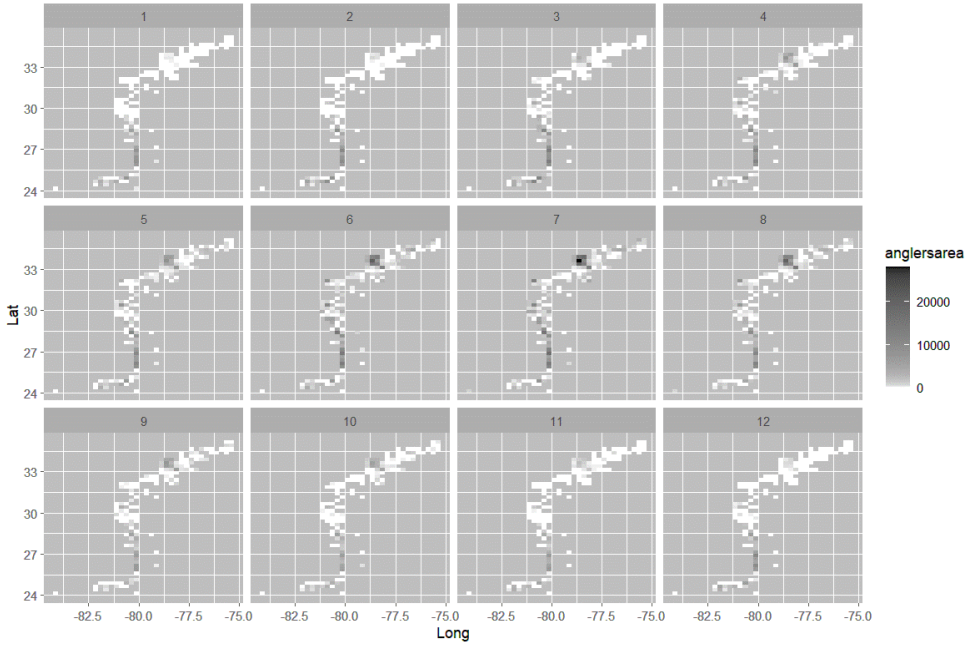
Commercial

ACCSP Catch data by FAO fishing area (total lbs)
- Relative trend
- Gear-specific annual catch maps for BSB/RS
- Gear-specific average maps for other groups

In progress

Coastal Fisheries Logbook data for trip by gear by month for SG fishery

Headboat vessel + angler data, monthly, average 2013-2023

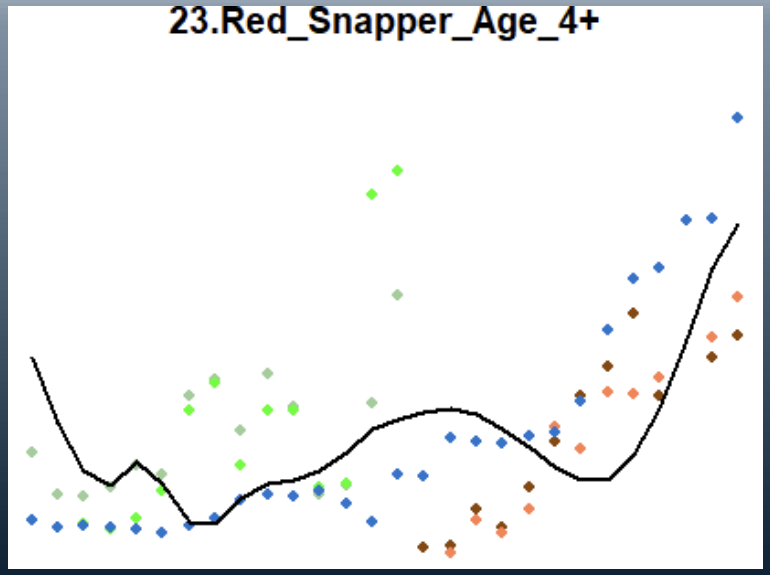


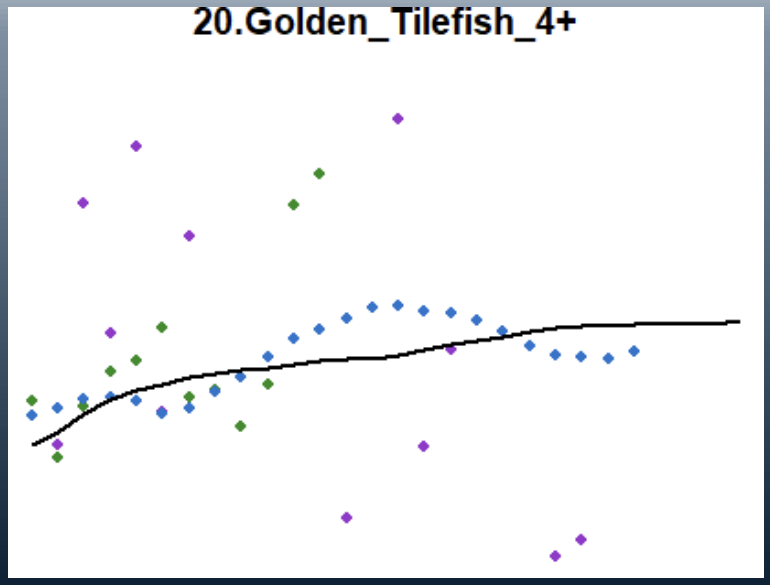
SARF Model

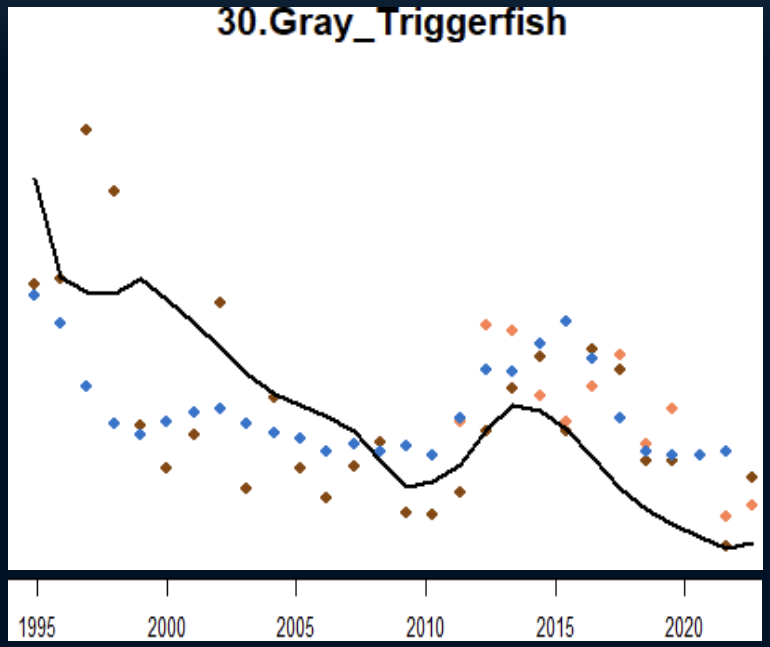
Ecospace

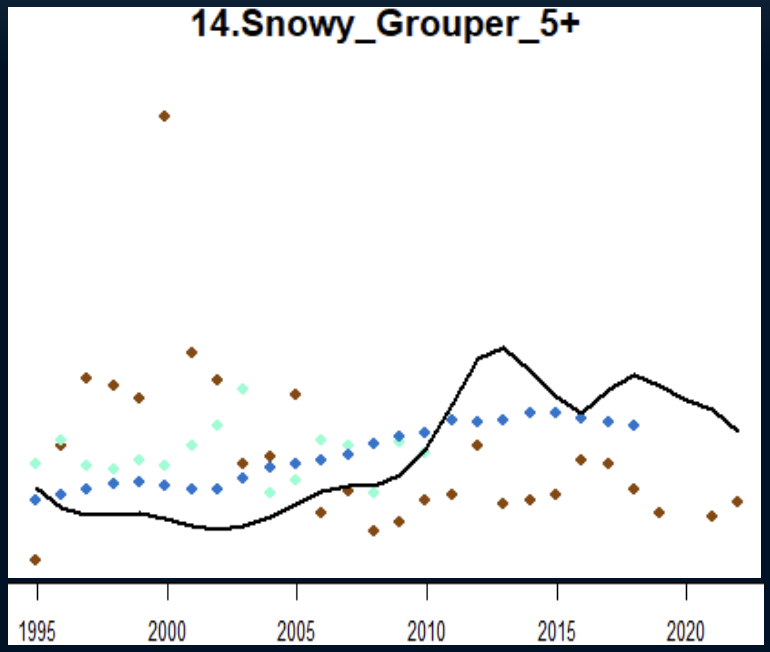
Ecospace prelim run – fits to timeseries

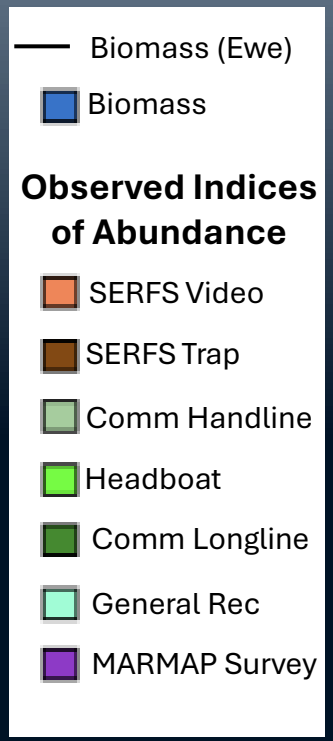
The Good...





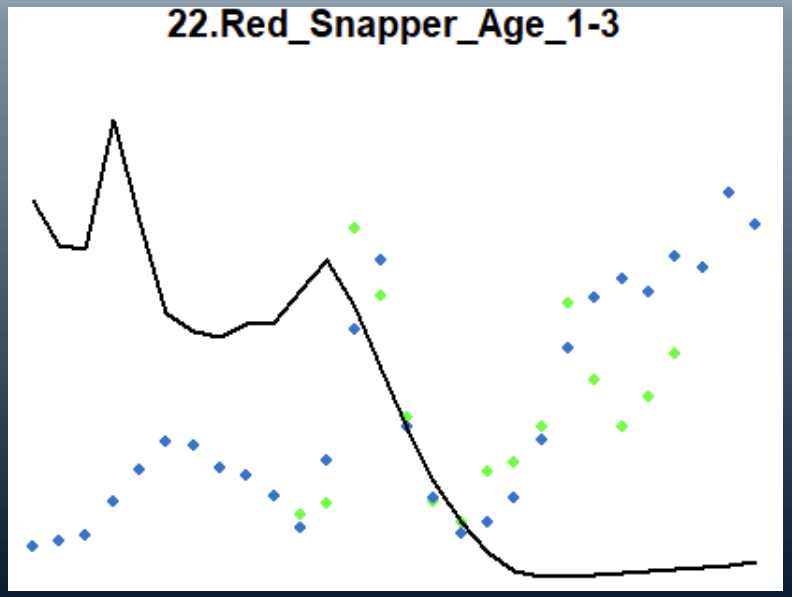


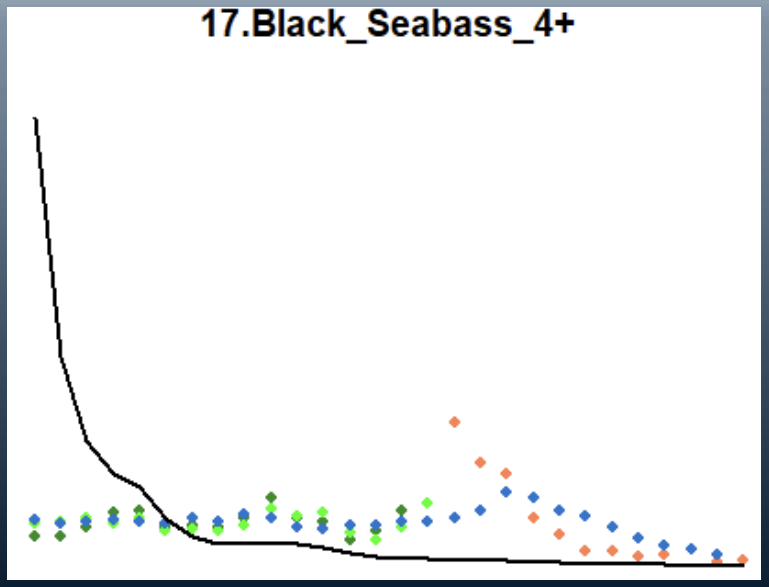


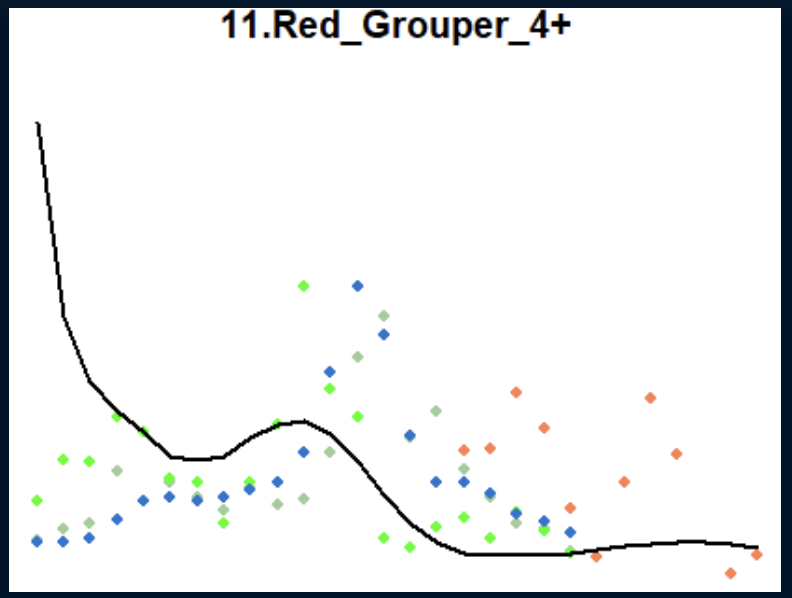


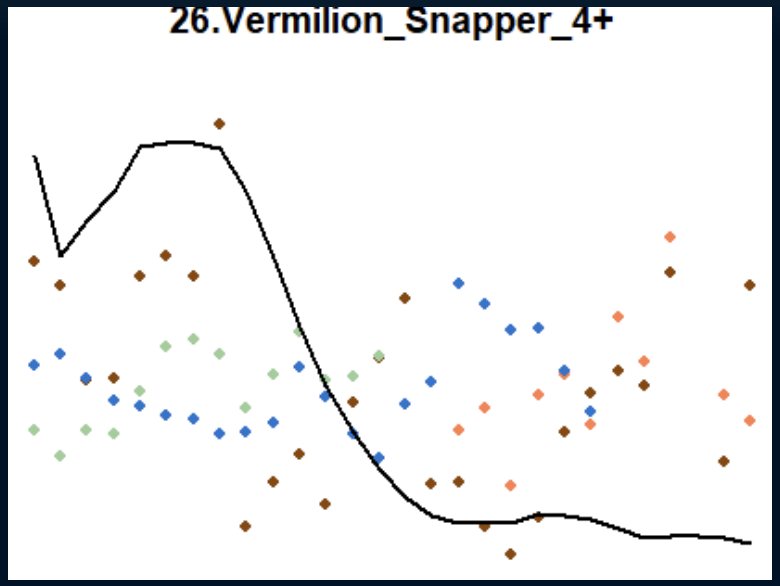
Ecospace prelim run – fits to timeseries

The Bad...









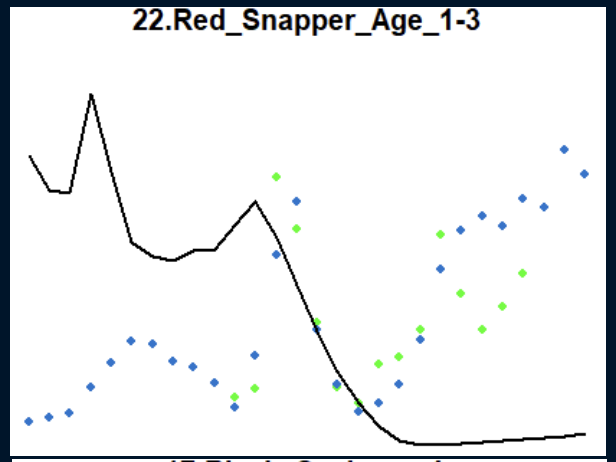
Biomass (Ewe)

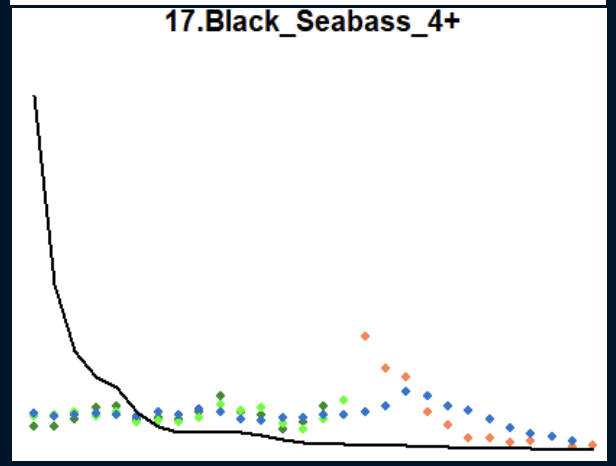
Biomass

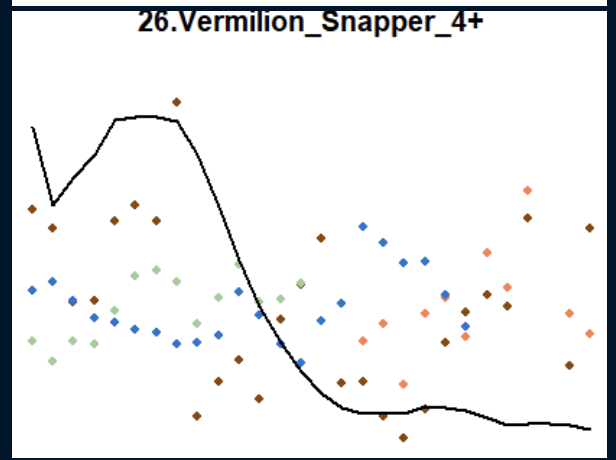
Observed Indices of Abundance

- SERFS Video
- SERFS Trap
- Comm Handline
- Headboat
- Comm Longline
- General Rec
- MARMAP Survey

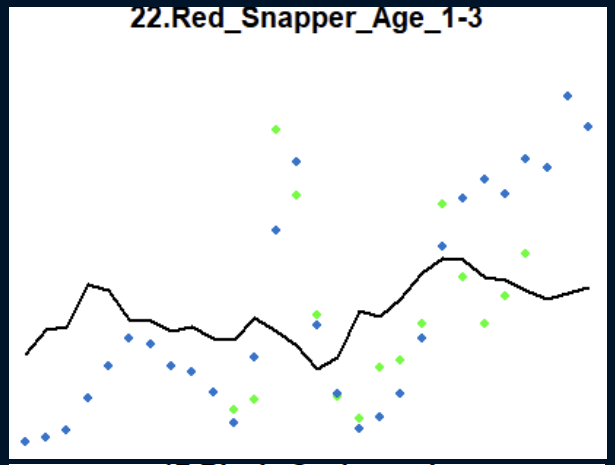
Base Model

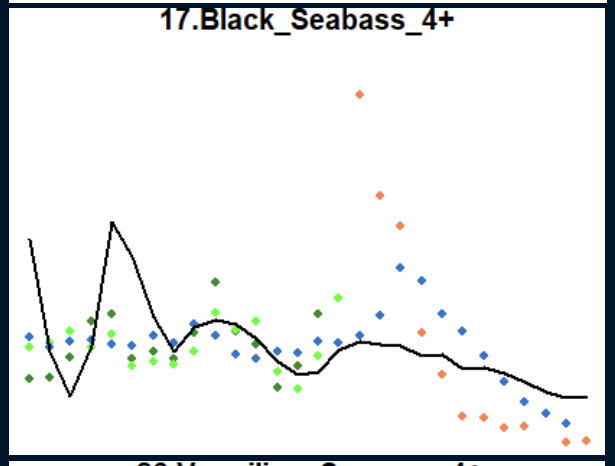


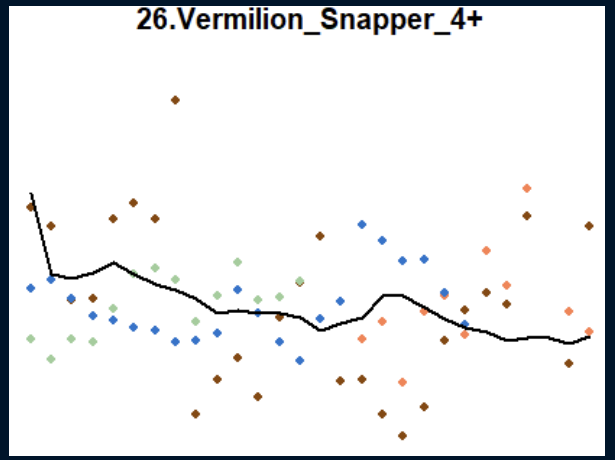




Base Model with Red Snapper Fleet







...and the Getting Better

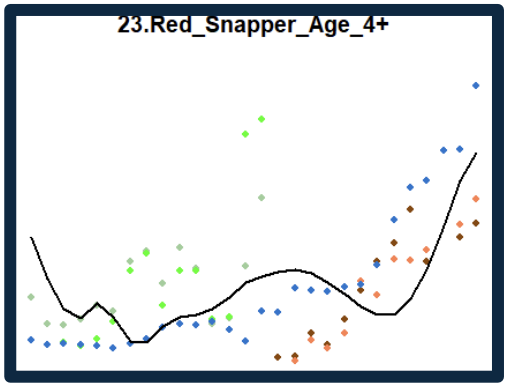
Biomass (Ewe)

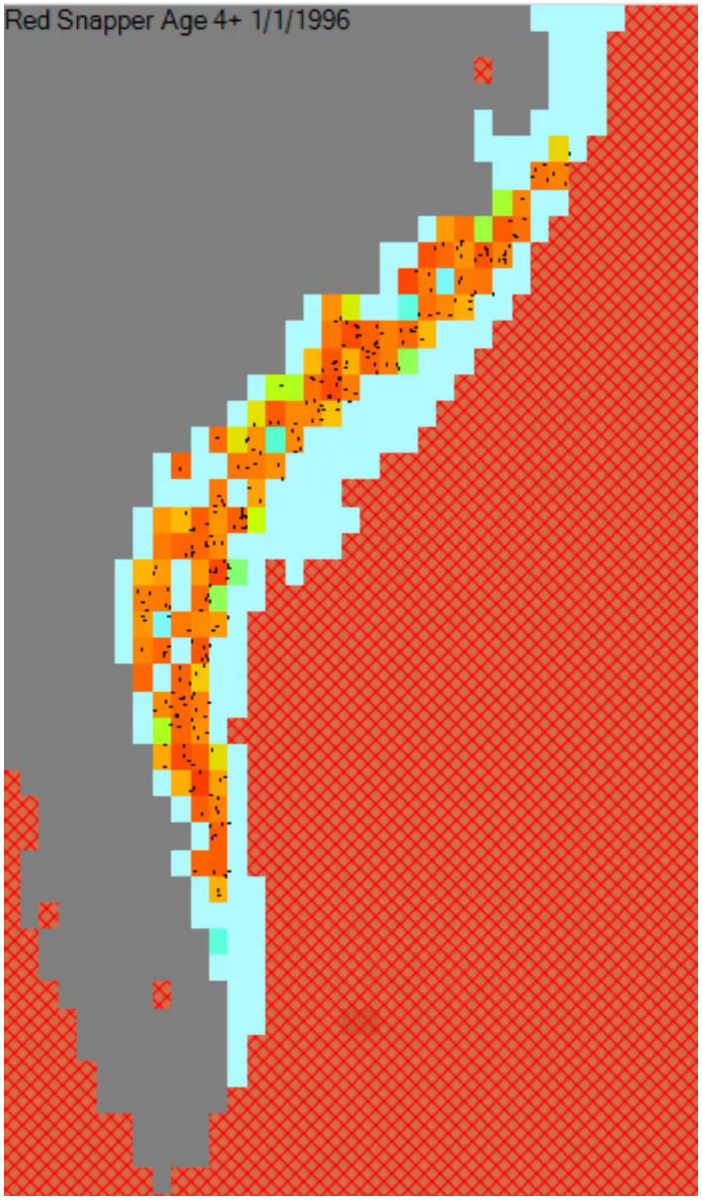
Biomass (SEDAR)

Observed Indices of Abundance

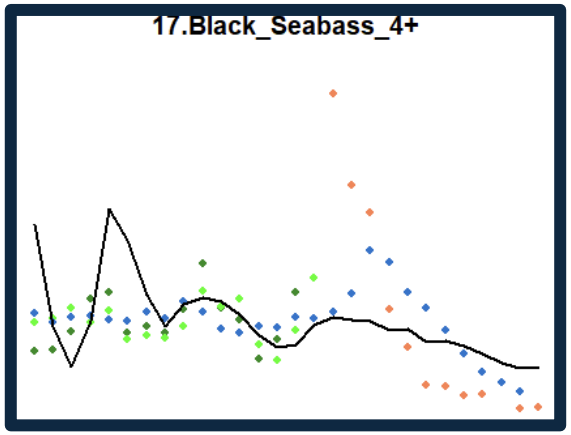
- SERFS Video
- SERFS Trap
- Comm Handline
- Headboat
- Comm Longline
- General Rec
- MARMAP Survey

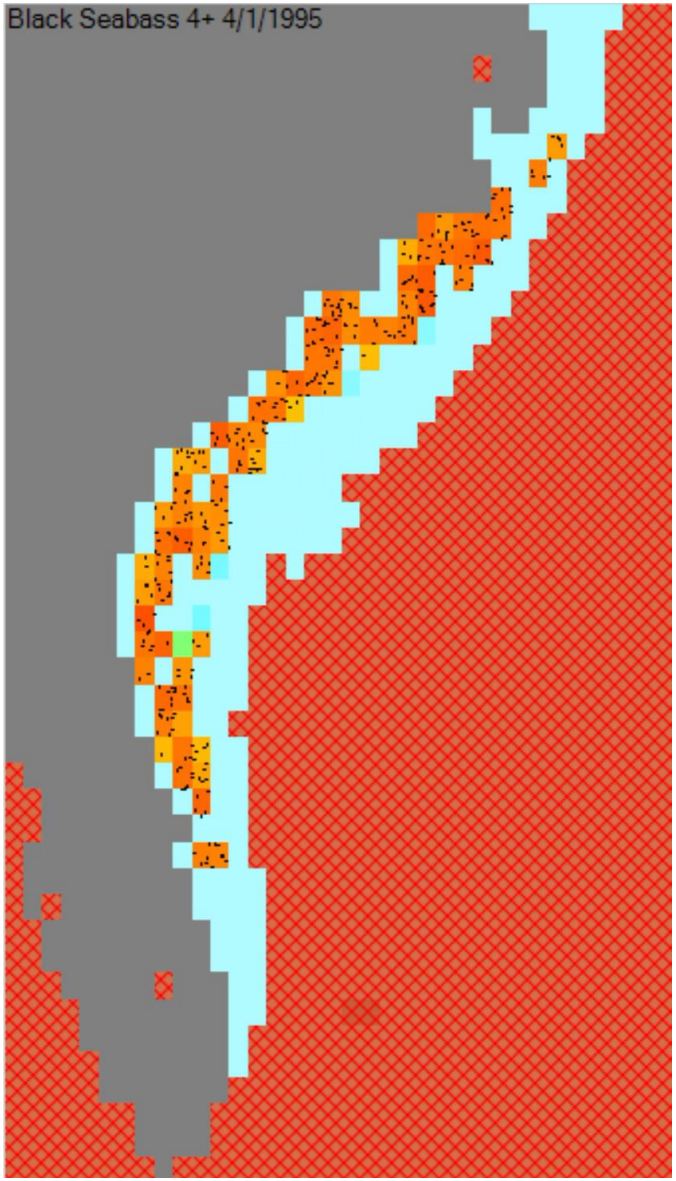
Ecospace prelim run - biomass





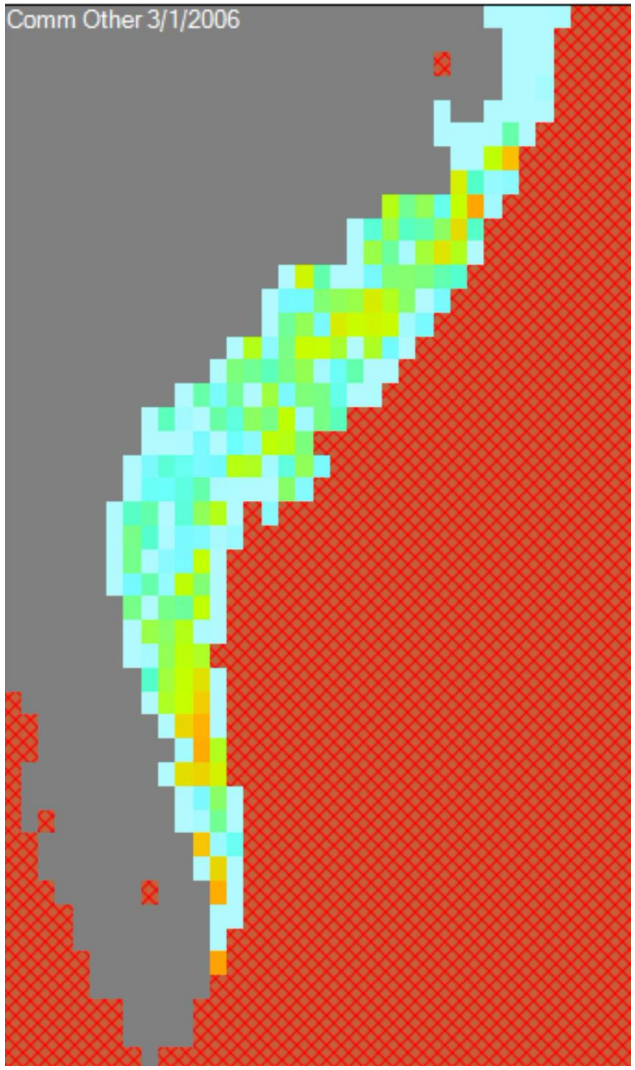
Ecospace prelim run - biomass



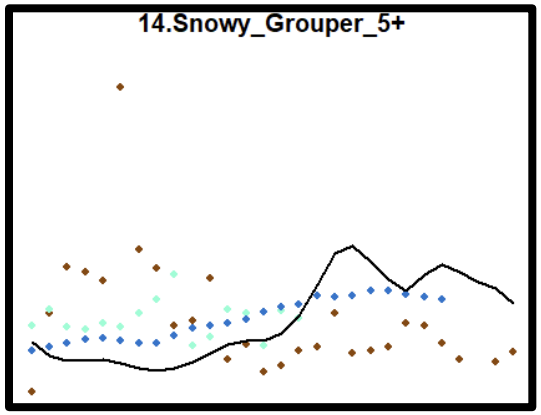


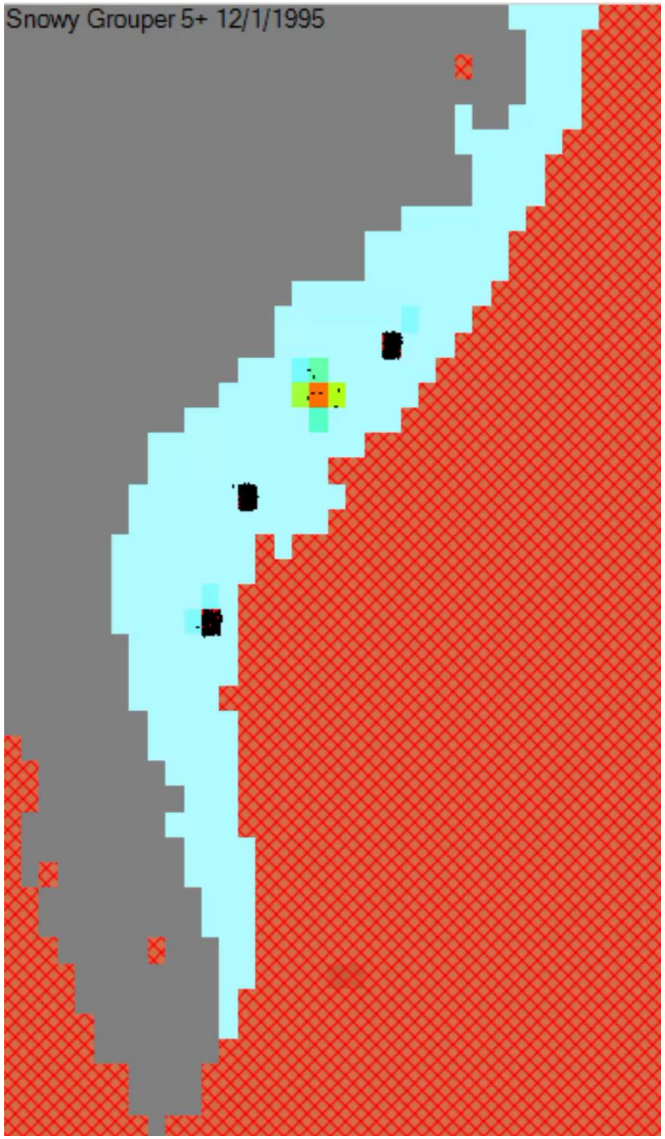
Ecospace prelim run

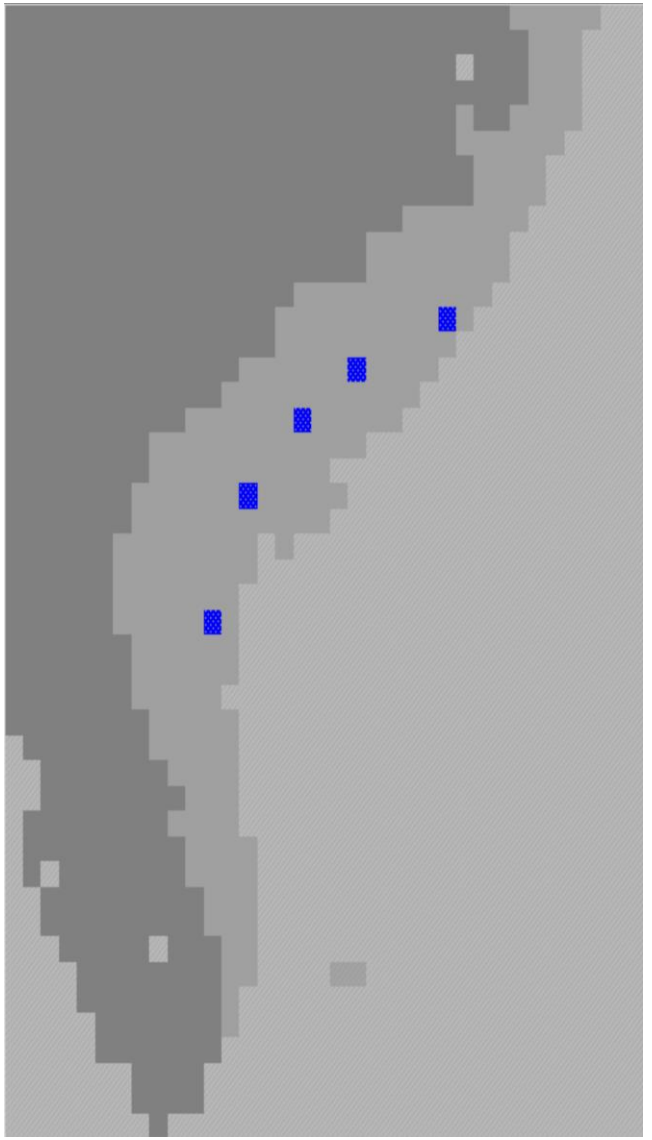
Fishing Effort: Commercial Other



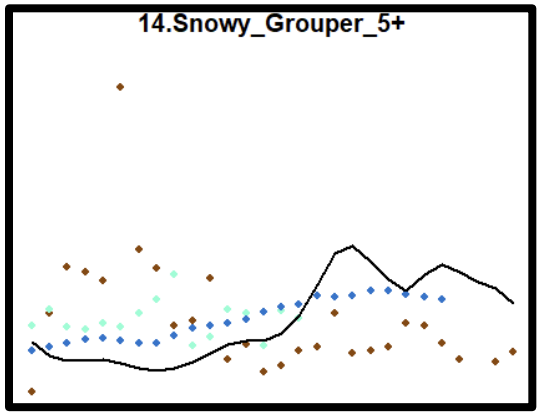
Ecospace prelim run - biomass

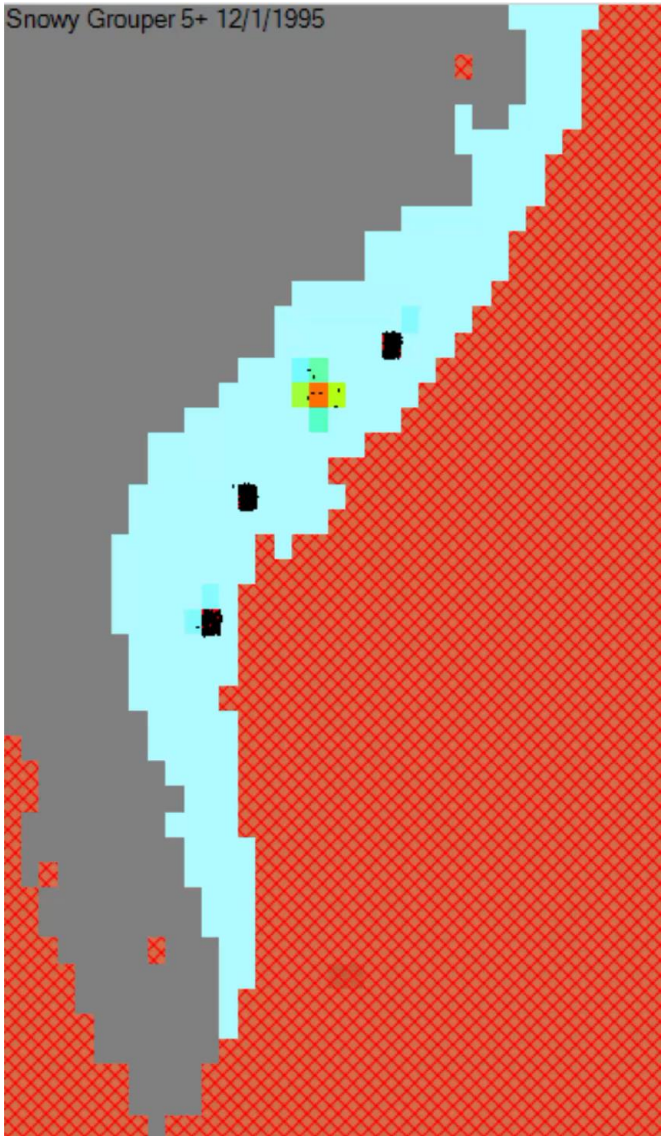






Ecospace prelim run - biomass



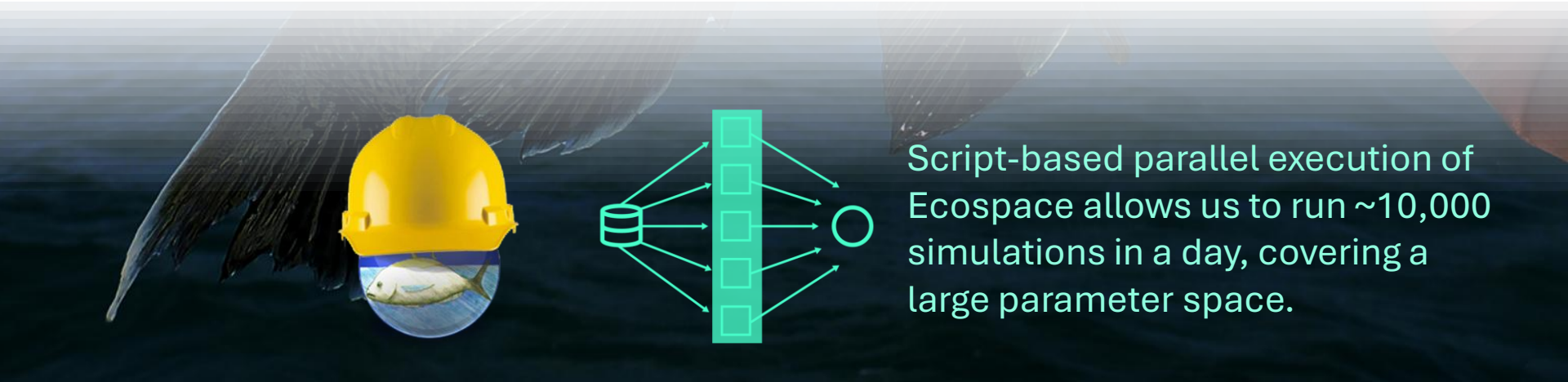


Formal calibration:

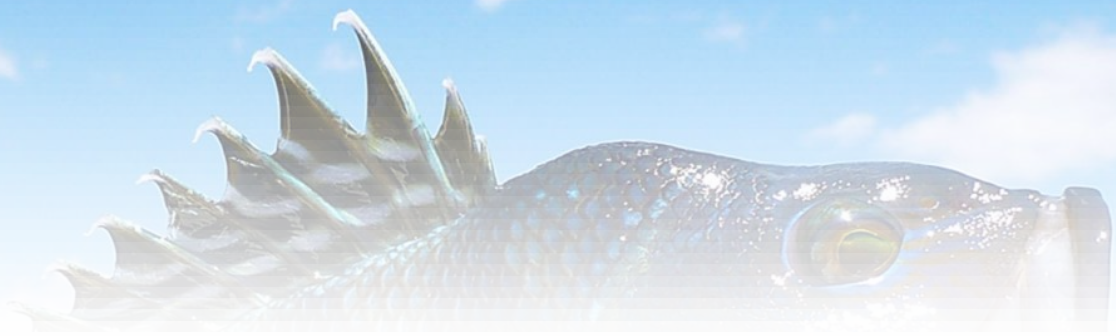
1. Develop cost function to statistically assess model fit to time series and spatial reference data
   - SERFS Video & Trap maps (occurrence, density) and abundance indices
   - South Atlantic Deepwater Longline maps
   - Fishing effort maps where available
   - Other derived maps and metrics (Cao et al. 2024)
   - Others?

2. Conduct sensitivity analysis around key parameters for predatory-prey interactions, environmental preferences, movement, and fishing power
   - Change each parameter, run the model, and record the cost function

3. Estimate most sensitive parameters
   - Challenging due to long model run-time and *unknown* parameter correlations



Script-based parallel execution of Ecospace allows us to run ~10,000 simulations in a day, covering a large parameter space.



SSC Discussion

1) Ecospace structure: Habitat maps, ST drivers
    - Thoughts? Any additions?
2) What data we're calibrating to
    - SERFS Video & Trap maps (occurrence, density) and abundance indices
    - South Atlantic Deepwater Longline maps
    - Fishing effort maps where available
    - Other derived maps and metrics (Cao et al. 2024)
    - Others?

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