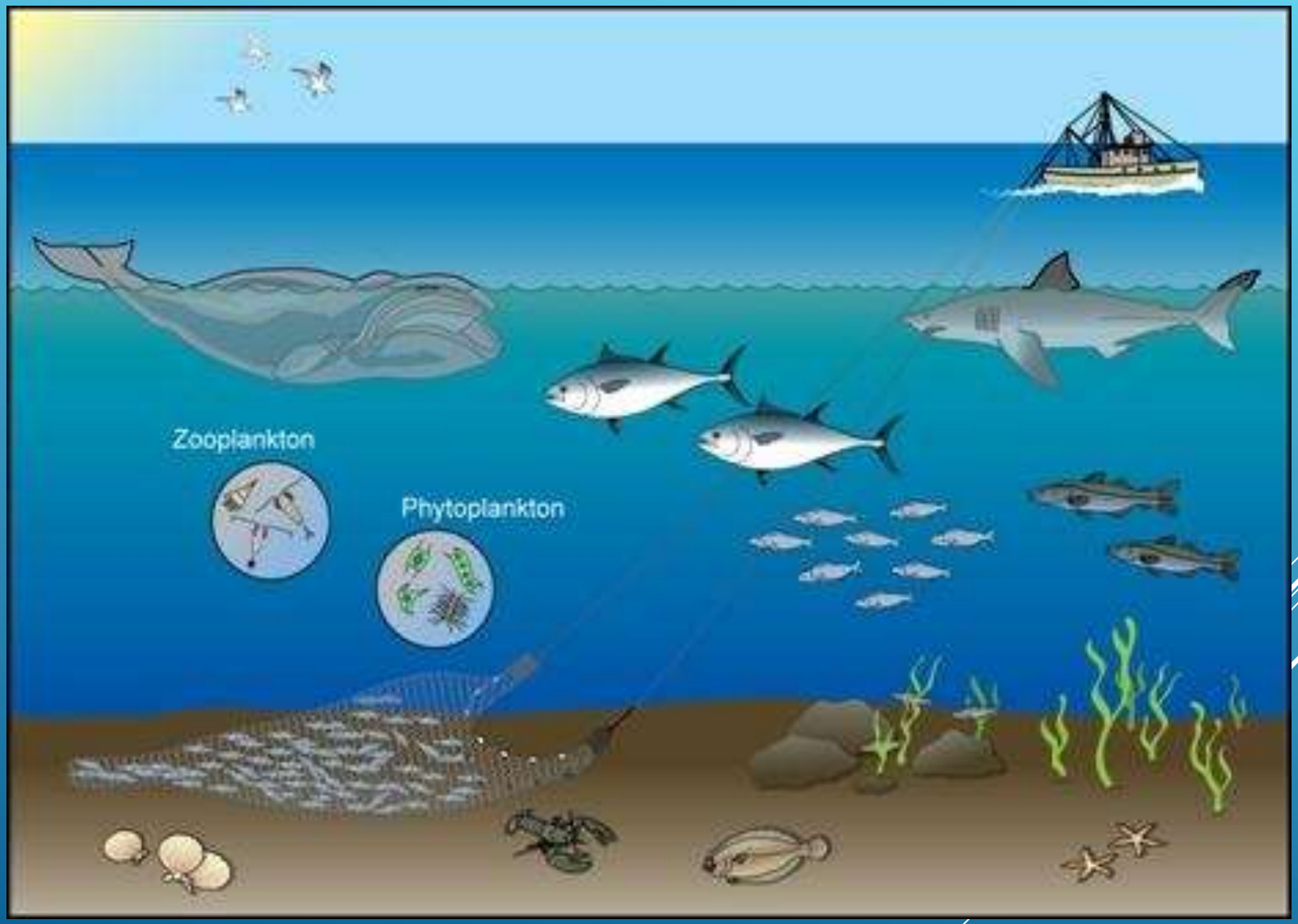
THE SOUTH ATLANTIC REGION ECOPATH MODEL

Forming a workgroup to facilitate SSC engagement

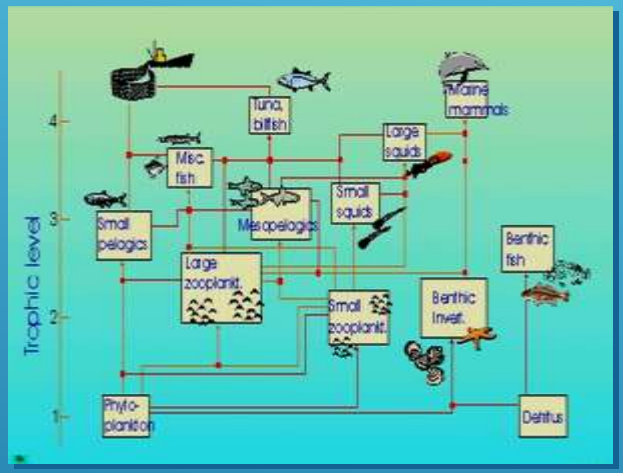
Tom Okey, Ocean Integrity Research and the University of Victoria
Roger Pugliese, South Atlantic Fishery Management Council
Howard Townsend, NOAA/NMFS/ST/Ecosystems

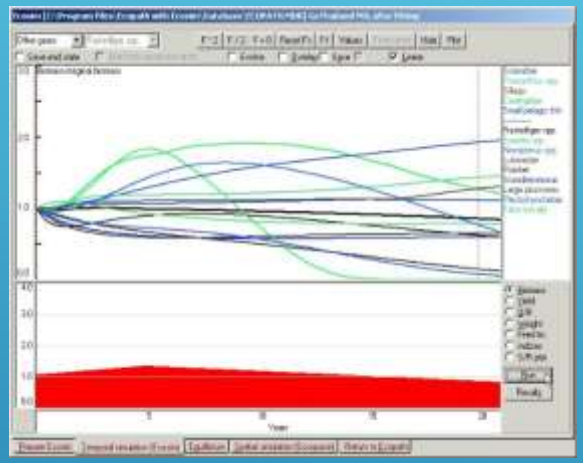
SAFMC Scientific and Statistical Committee Meeting
15-17 October 2018

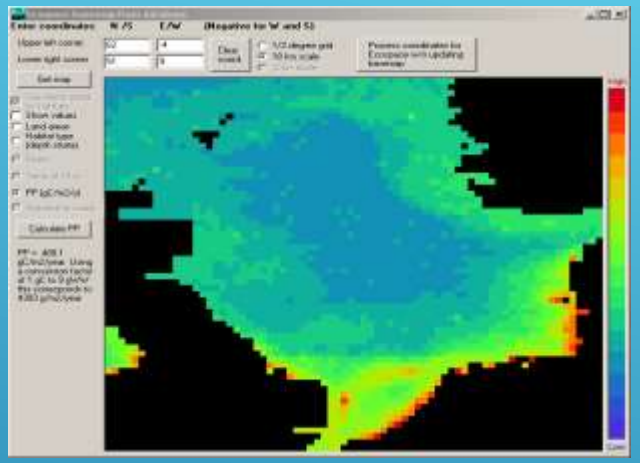
FISHERY-ECOSYSTEM MODEL

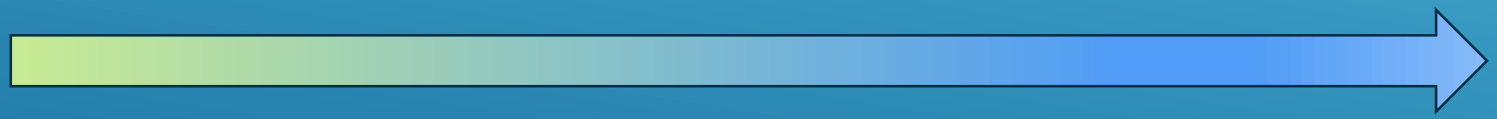


ECOPATH / ECOSIM / ECOSPACE

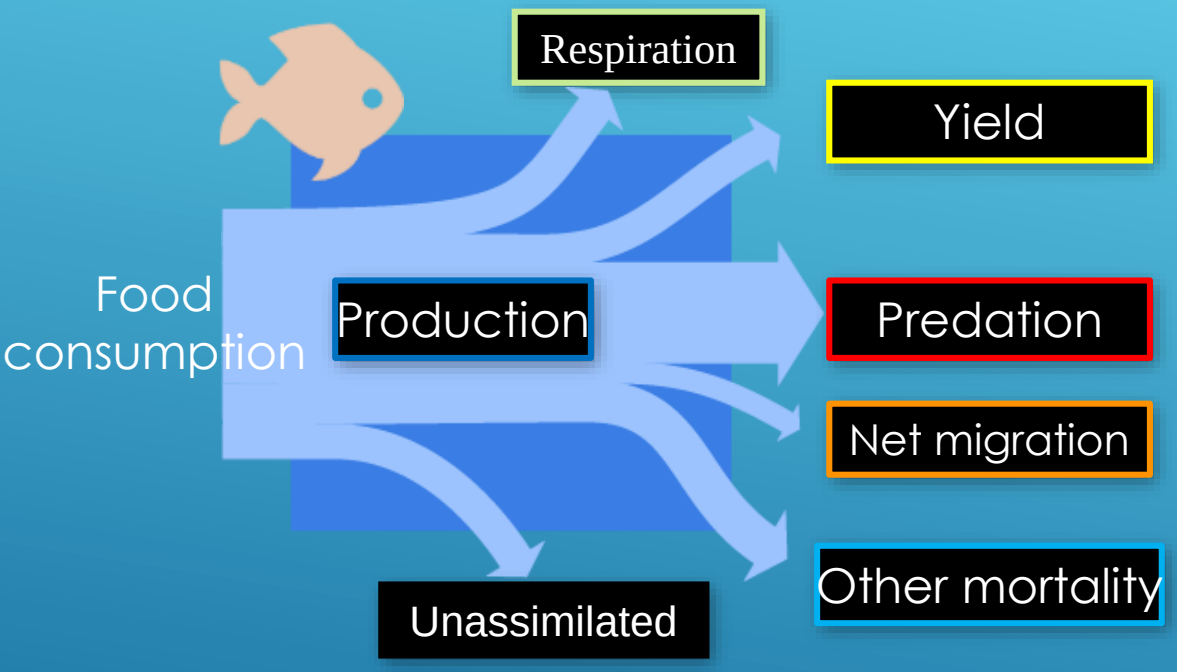








ECOPATH



B_i	Biomass
P_i/B_i	Production
Q_i/B_i	Specific consumption
DC_{ij}	Fraction of prey *i* in diet of predator *j*
B_iA_i	Biomass accumulation
EE_i	Production used in the system
$1\text{-}EE_i$	Unexplained mortality

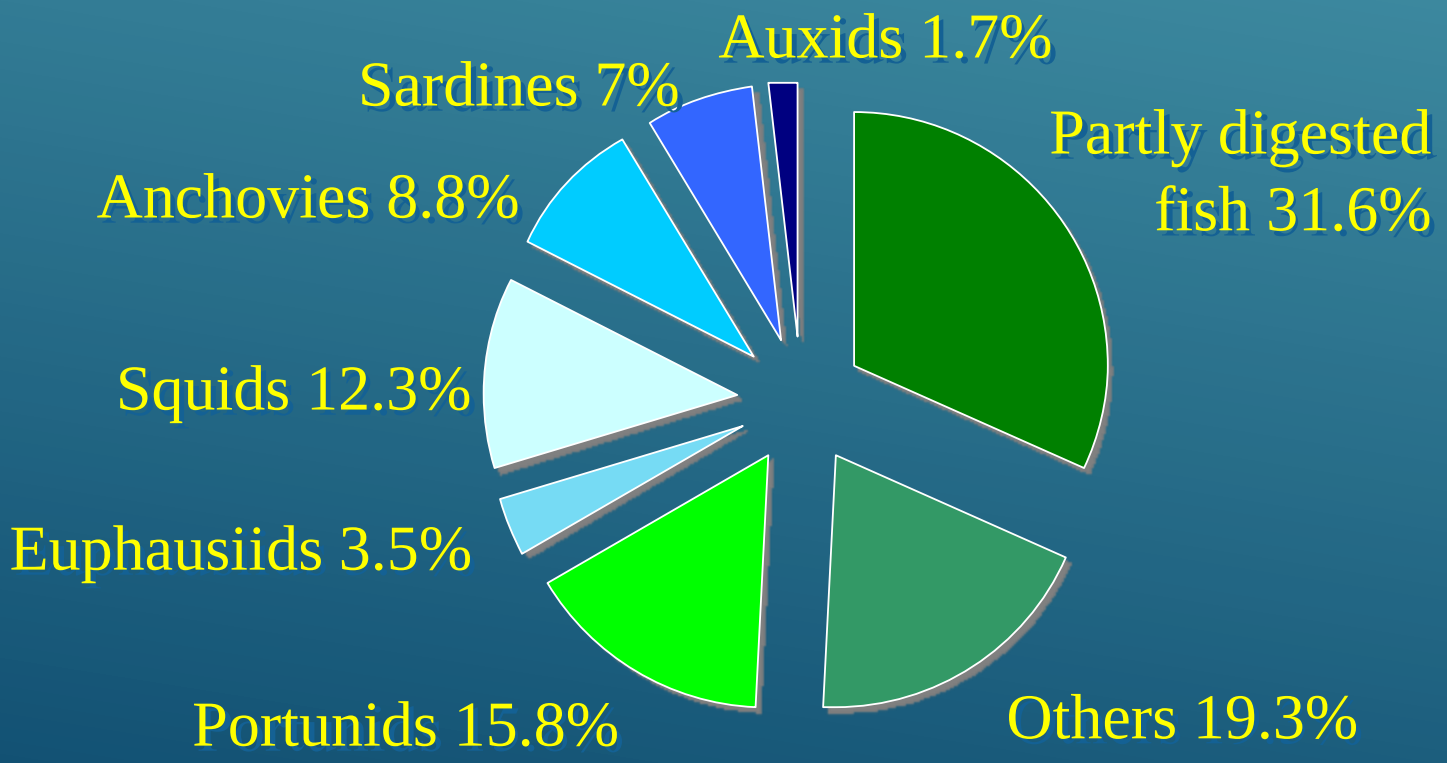
1. $$\left(\frac{Q}{B}\right)_i \cdot B_i = \left(\frac{P}{B}\right)_i \cdot B_i + R_i + UN_i$$

2. $$\left(\frac{P}{B}\right)_i \cdot B_i = \sum_{Pred\_j=1}^{n} \left(\frac{Q}{B}\right)_j \cdot B_j \cdot DC_{ij} + E_i + Y_i + BA_i + \left(\frac{P}{B}\right)_i \cdot B_i \cdot (1 - EE_i)$$

Polovina, J.J. 1984. Coral Reefs, 3:1-11; Pauly et al. 2000. ICES J. Mar. Sci., 57: 697-706; Christensen and Walters. 2004. Ecol. Model., 172(2-4): 109-139

Diet composition

e.g., for a tuna



Use volume or weight!

SOUTH ATLANTIC BIGHT FOOD WEB (99-BOX)

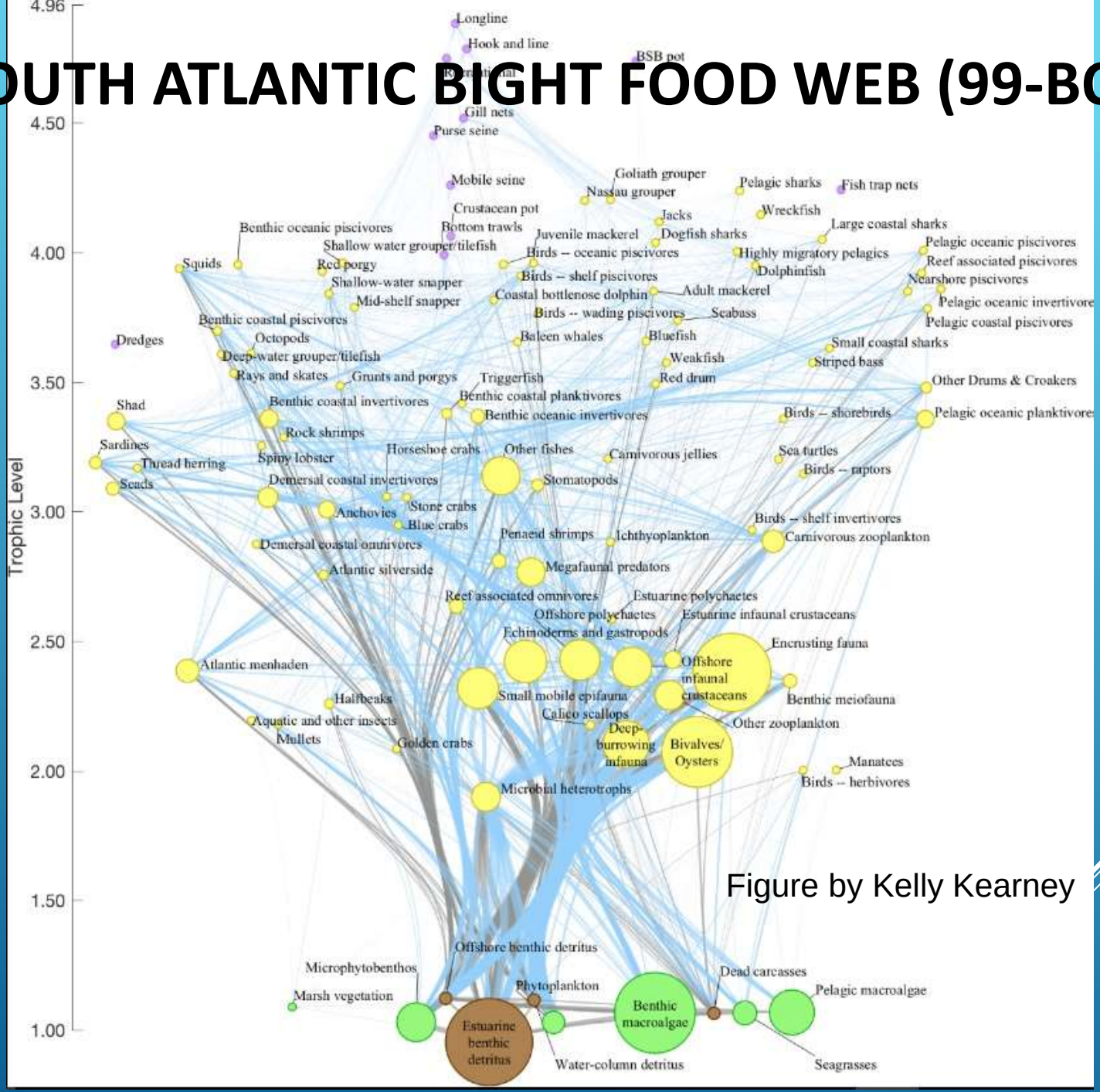


Figure by Kelly Kearney

HISTORY OF THE SAB MODEL

- 2001 - Strawman 48-group model constructed
- 2004 - Preliminary 98-group model developed
- 2014 - Model refined to address forage fish questions (99 groups)
- 2018 – Model refinement to articulate the managed species (137 boxes)

Preliminary SAS model

- Sponsored by SAFMC
- 42-box model
- 98-box model

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

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ABSTRACT

The biological communities of the Atlantic continental shelf adjacent to the southeastern United States are well known, but this knowledge is not integrated into a cohesive description of that region. We constructed a preliminary food web model of this area using Ecopath with Ecosim, as a way to initiate a long-term process of integrating this knowledge, learning more about the structure and resiliency of the system, and helping to guide research priorities in the future. The current model is considered to be a first iteration that can be used as a vehicle to stimulate a more rigorous refinement effort in the near future. The ecologically defined area covered by this model extends from Cape Hatteras, North Carolina to the easternmost extent of the Florida Keys, and from the intertidal zone (or the entrance of estuarine systems) to the 500 m isobath. The time period characterized by this preliminary model is the four years from 1995 to 1998.

the Gulf Stream advect the underlying nutrient rich slope waters onto the shelf (Mallin *et al.* 2000).. This region as a whole supports a diverse assemblage of marine organisms, as it is somewhat of an ecological interface, or gradient, between warm-water and cold-water species assemblages. We refer the reader to Mallin *et al.* (2000) for a general description of the ecological setting, processes, and related research. A brief overview of special habitats is presented below.

Human activities along the east coast of the southeastern United States have influenced the adjacent continental shelf ecosystem for thousands of years, as native Americans conducted some limited artisanal fisheries and modified fire regimes and the vegetation in upland watersheds (e.g., Cronon, 1983). Modifications to the ecology of the continental shelf ecosystem accelerated soon after the arrival of Europeans, who began fishing coastal waters (e.g., Mowat, 1984; Reeves *et al.*, 1999) in addition to introducing domesticated livestock, weed plants, disease, and new kinds of agriculture (e.g., Crosby, 1986).

Other profound anthropogenic modifications to this continental shelf occurred during the 20th century with the widespread use of powered fishing and whaling vessels, and coastal urbanization and industrialization. One particularly destructive type of fishing is bottom trawling, which destroys biogenic seafloor habitat in addition to simply removing fishes (Watling and Norse, 1998; Turner *et al.*, 1999).

Trawling activity is intense in this area, and little doubt remains that these activities have considerably modified the continental shelf. The

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Forage version 2014

- Sponsored by Pew Charitable Trusts
- Forage groups articulated
- 99-box model

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The University of British Columbia

Working Paper Series

Working Paper #2014 - 14

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

Year: 2014

Email: thomas.okey@gmail.com

This working paper is made available by the Fisheries Centre, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada.

Articulated forage groups in the 2014 99-box South Atlantic Bight *EwE* model

- Anchovies
- Atlantic menhaden
- Atlantic silverside
- Halfbeaks
- Mullets
- Sardines
- Scads
- Shad
- Thread herring
- Pelagic oceanic planktivores
- Squids
- Shrimps

Forage Groups in the 99-box South Atlantic Bight model

Group	Species included	B ($t \cdot km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)
Anchovies	Bay (Anchoa mitchilli), striped (A. hepsetus), silver (Engraulis eurystole)	3.75	1.45	17.50
Atlantic menhaden	Brevoortia tyrannus (not B. patronus)	7.05	1.70	7.84
Atlantic silverside	Menidia menidia	1.18	2.00	14.90
Halfbeaks	Ballyhoo (Hemiramphus brasiliensis), balao (H. balao), common or Atlantic silverstripe (Hyporhamphus unifasciatus)	1.22	2.60	11.70
Mullets	Striped (Mugil cephalus), other (Mugil spp.)	0.11	0.70	11.03
Sardines	Spanish (Sardinella aurita), scaled (Harengula jaguana)	1.93	1.11	11.82
Scads	Round (Decapterus punctatus), rough (Trachurus lathami), bigeye (Selar crumenophthalmus)	2.28	0.92	10.00
Shad	Alosa spp.	3.97	0.50	3.80
Thread herring	Atlantic thread herring (Ophistonema oglinum)	0.28	1.60	13.26
Pelagic oceanic planktivores	Chub mackerel (Scomber japonicus), lanternfish (Diaphus spp.), antenna codlet (Bregmaceros atlanticus), striated argentine (Argentina striata), flyingfish (Exocoetidae)	3.95	0.87	11.71
Squids	Shortfin (Illex illecebrosus), longfin (Loligo pealei)	0.45	2.67	36.50
Shrimps	Rock shrimps and penaeid shrimps	2.53	5.38	19.20

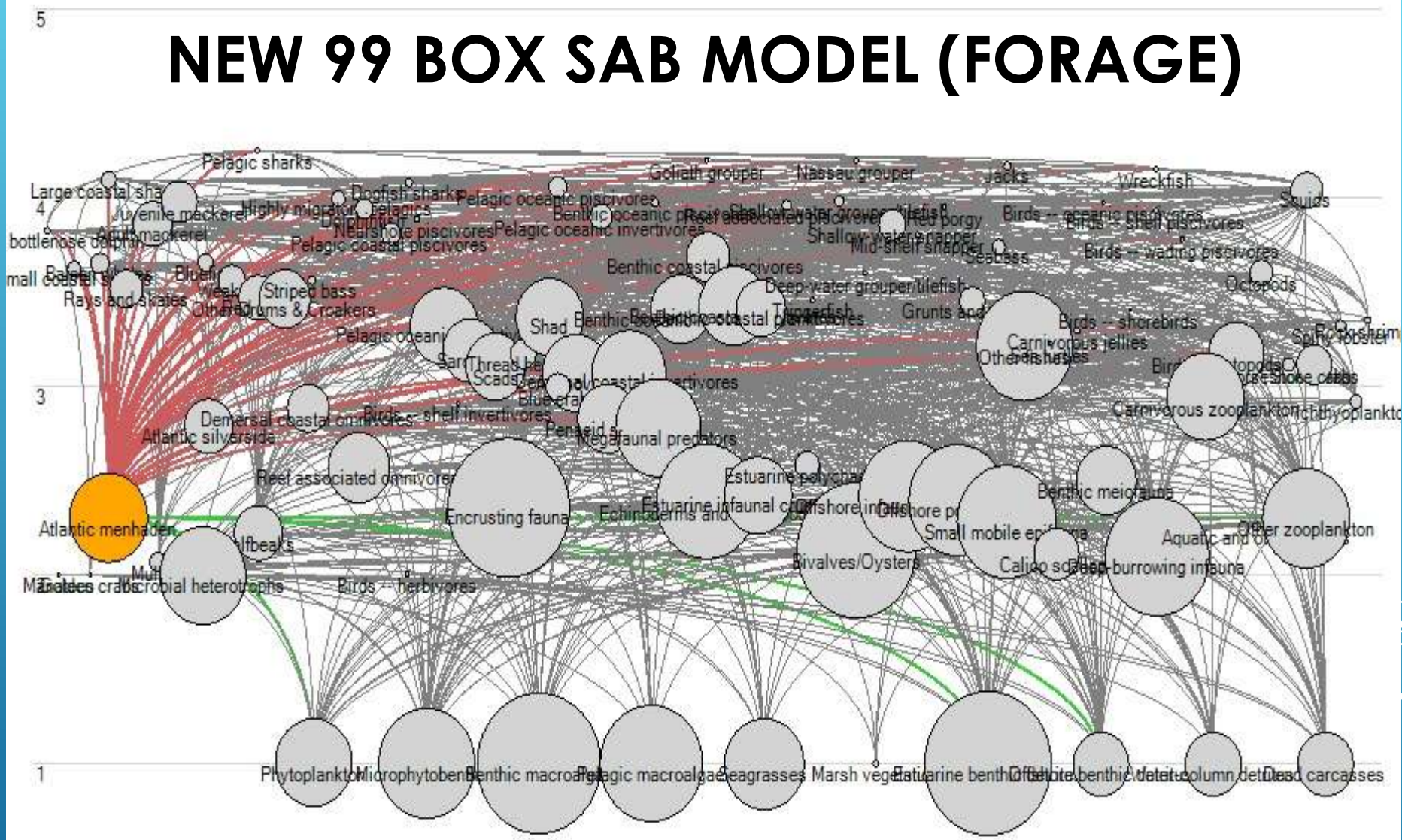
Focused on predatory fish of particular value in the 99-box SAB ecosystem model

Spanish/king mackerels
Vermillion snapper
Gag grouper
Dolphinfish
Black seabass
Greater amberjack
Cobia
Red snapper

Species / Groups in the 2014 SAB 99-box model

Coastal bottlenose dolphin	Thread herring	Seabass	Estuarine infaunal crustaceans
Manatees	Shad	Wreckfish	Estuarine polychaetes
Large coastal sharks	Anchovies	Other fishes	Bivalves/Oysters
Small coastal sharks	Atlantic silverside	Sea turtles	Offshore infaunal crustaceans
Baleen whales	Halfbeaks	Carnivorous jellies	Offshore polychaetes
Pelagic sharks	Pelagic oceanic invertivores	Birds -- oceanic piscivores	Small mobile epifauna
Rays and skates	Demersal coastal invertivores	Birds -- shorebirds	Calico scallops
Dogfish sharks	Demersal coastal omnivores	Birds -- shelf piscivores	Benthic meiofauna
Adult mackerel	Benthic oceanic piscivores	Birds -- herbivores	Deep-burrowing infauna
Juvenile mackerel	Benthic oceanic invertivores	Birds -- wading piscivores	Carnivorous zooplankton
Bluefish	Benthic coastal piscivores	Birds -- shelf invertivores	Aquatic and other insects
Weakfish	Benthic coastal invertivores	Birds -- raptors	Other zooplankton
Red drum	Benthic coastal planktivores	Encrusting fauna	Ichthyoplankton
Atlantic menhaden	Reef associated piscivores	Squids	Microbial heterotrophs
Mullets	Reef associated omnivores	Stomatopods	Phytoplankton
Other Drums & Croakers	Triggerfish	Octopods	Microphytobenthos
Striped bass	Shallow water grouper/tilefish	Blue crabs	Benthic macroalgae
Highly migratory pelagics	Goliath grouper	Horseshoe crabs	Pelagic macroalgae
Dolphinfish	Nassau grouper	Golden crabs	Seagrasses
Pelagic oceanic piscivores	Deep-water grouper/tilefish	Stone crabs	Marsh vegetation
Pelagic coastal piscivores	Shallow-water snapper	Spiny lobster	Estuarine benthic detritus
Nearshore piscivores	Mid-shelf snapper	Rock shrimps	Offshore benthic detritus
Pelagic oceanic planktivores	Jacks	Penaeid shrimps	Water-column detritus
Sardines	Red porgy	Megafaunal predators	Dead carcasses
Scads	Grunts and porgys	Echinoderms and gastropods	

NEW 99 BOX SAB MODEL (FORAGE)



Articulated Managed Species / Groups in the 2017 SAB 137-box model

Adult king mackerel	Red grouper	Vermilion snapper
Juvenile king mackerel	Black grouper	Silk snapper
Spanish Mackerel	Scamp grouper	Red snapper
Juvenile spanish mackerel	Other shallow grouper/tilefish	Other mid-shelf snapper
Spotted seatrout	Snowy grouper	Greater amberjack
Snook	Yellowedge grouper	Almaco jack
Tarpon	Other deep grouper	Bar Jack
Cobia	Blueline tilefish	Banded rudderfish
Bonefish	Golden tilefish	Blue runner
Permit	Yellowtail snapper	Other jacks
Atlantic Spadefish	Mutton snapper	Other porgys
Hogfish	Gray snapper	White grunt
Ocean triggerfish	Lane snapper	Other grunts
Gray triggerfish	Cubera snapper	Black Seabass
Gag grouper	Other shallow snapper	Bank/Rock seabass

Species / Groups in SAB 137-box model

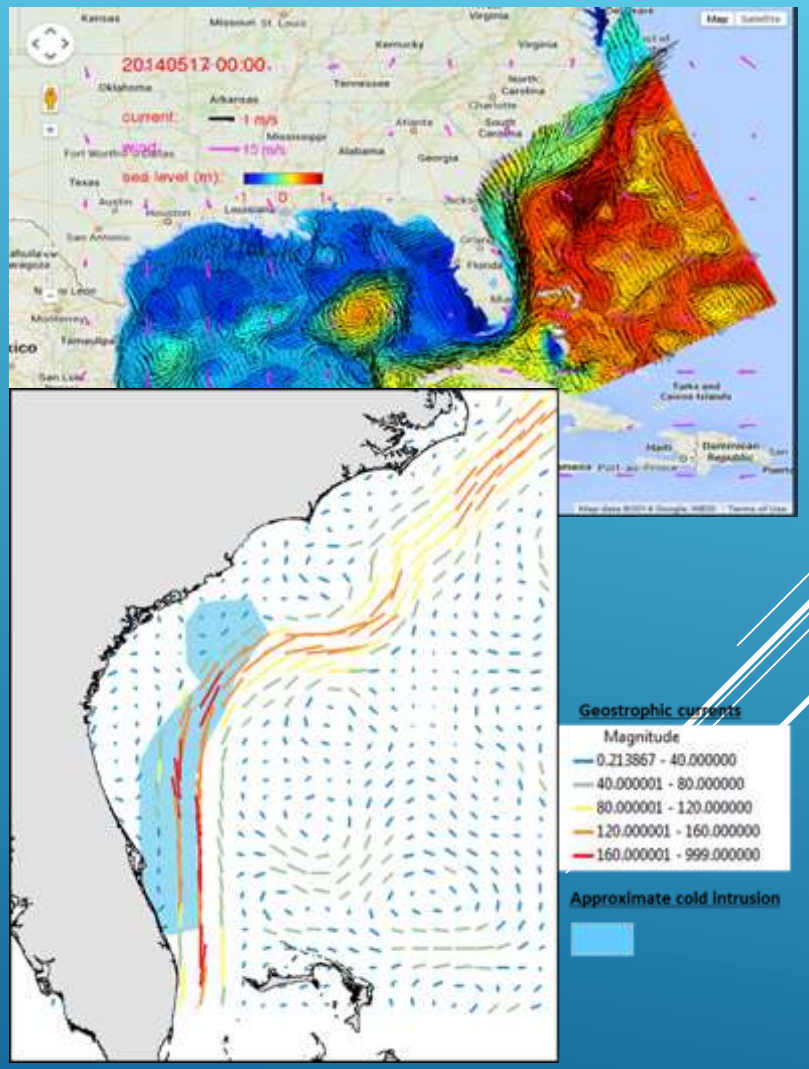
Coastal bottlenose dolphin	Nearshore piscivores	Gag grouper	Red porgy	Penaeid shrimps
Manatees	Pelagic oceanic planktivores	Red grouper	Other porgys	Megafaunal predators
Large coastal sharks	Sardines	Black grouper	White grunt	Echinoderms and gastropods
Small coastal sharks	Scads	Scamp grouper	Other grunts	Estuarine infaunal crustaceans
Baleen whales	Thread herring	Goliath grouper	Black seabass	Estuarine polychaetes
Pelagic sharks	Shad	Nassau grouper	Rock/Bank seabass	Bivalves/Oysters
Rays and skates	Anchovies	Other shallow grouper/tilefish	Wreckfish	Offshore infaunal crustaceans
Dogfish sharks	Atlantic silverside	Snowy grouper	Other fishes	Offshore polychaetes
Adult king mackerel	Halfbeaks	Yellowedge grouper	Sea turtles	Small mobile epifauna
Juvenile king mackerel	Pelagic oceanic invertivores	Other deep grouper	Carnivorous jellies	Calico scallops
Spanish mackerel	Permit	Blueline tilefish	Birds -- oceanic piscivores	Benthic meiofauna
Juv Spanish mackerel	Demersal coastal invertivores	Golden tilefish	Birds -- shorebirds	Deep-burrowing infauna
Bluefish	Demersal coastal omnivores	Yellowtail snapper	Birds -- shelf piscivores	Carnivorous zooplankton
Weakfish	Atlantic spadefish	Mutton snapper	Birds -- herbivores	Other zooplankton
Red drum	Benthic oceanic piscivores	Gray snapper	Birds -- wading piscivores	Ichthyoplankton
Atlantic menhaden	Benthic oceanic invertivores	Lane snapper	Birds -- shelf invertivores	Microbial heterotrophs
Spotted seatrout	Red Lionfish	Cubera snapper	Birds -- raptors	Phytoplankton
Mullets	Summer flounder	Other shallow snapper	Encrusting fauna	Microphytobenthos
Other Drums & Croakers	Southern flounder	Vermilion snapper	Squids	Benthic macroalgae
Striped bass	Gulf flounder	Silk snapper	Stomatopods	Pelagic macroalgae
Highly migratory pelagics	Benthic coastal piscivores	Red snapper	Octopods	Seagrasses
Dolphinfish	Benthic coastal invertivores	Other mid-shelf snapper	Blue crabs	Marsh vegetation
Pelagic oceanic piscivores	Hogfish	Greater amberjack	Horseshoe crabs	Estuarine benthic detritus
Snook	Benthic coastal planktivores	Almaco jack	Golden crabs	Offshore benthic detritus
Tarpon	Reef associated piscivores	Bar jack	Stone crabs	Water-column detritus
Pelagic coastal piscivores	Reef associated omnivores	Banded rudderfish	Spiny lobster	Dead carcasses
Cobia	Ocean triggerfish	Blue runner	Rock shrimps	
Bonefish	Gray triggerfish	Other jacks		

OUR WORKING GROUP

- **Roger Pugliese –** South Atlantic Fishery Management Council
- **Dr. Rua Mordecai**, SALCC, **Dr. Simeon Yurek**, USGS
- **Dr. Marcel J. Reichert –** Marine Resources Research Institute, South Carolina Department of Natural Resources (**Tracey Smart, Wally Bubley**)
- **Dr. Howard Townsend –** NOAA/NMFS/ST/Ecosystems
- **Dr. Luiz Barbieri –** Florida Fish and Wildlife Conservation Commission, FWRI
- **Dr. Ruoying He –** Department of Marine, Earth and Atmospheric Sciences, North Carolina State University
- **Dr. Peter Sheng –** Professor and Director, Coastal and Oceanographic Engineering Program, University of Florida
- **Dr. Thomas Okey –** Ocean Integrity Research, Victoria, BC, Canada
- **Dr. Jerald S. Ault –** Rosenstiel School of Marine and Atmospheric Science, University of Miami
- **Dr. Jeroen Steenbeek –** Ecopath Research and Development Consortium
- **Dr. Patrick N. Halpin –** Director, Geospatial Analysis Program Duke University

THE UPDATED ECOPATH MODEL WILL:

- **Support the SA Fishery Management Council's move to ecosystem-based management**
- **Advance and refine the LCC conservation blueprint**
- Link to hydrodynamic oceanographic models and satellite data
- Provide more realistic predictions about spatial policy options
- Estimate impacts of episodic events that are limited in space (oil spills, red tides, upwelling)
- Meet the immediate needs of the SSC and the South Atlantic Council



FORMING AN SSC WORKGROUP

Analysis Type:	**Review, guidance for further development and evaluation of potential tool development associated with Ecosystem Model.**
Analyst:	Tom Okey, UVic and Roger Pugliese, SAFMC Staff. ➢ Possibilities of regional students and staff.
Workgroup Members:	Proposed -core SSC members and members of the Ecosystem Modeling Workgroup supporting SALCC funded model development.
Tasks and Timeline:	Development of the next generation Ecopath with Ecosim Model is nearing completion; therefore, this process will start with a review of data used, methods developed, decisions made, and analyses completed to date. More detailed timeline will be developed after initial meeting of workgroup.

START WITH A COUPLE OF EXAMPLES

A. Simulate use of MSY for all managed species to explore the broad ecosystem effects
B. Begin investigating red snapper and black sea bass interactions

B. Ecosystem Cascade - Red Snapper / Black Sea Bass

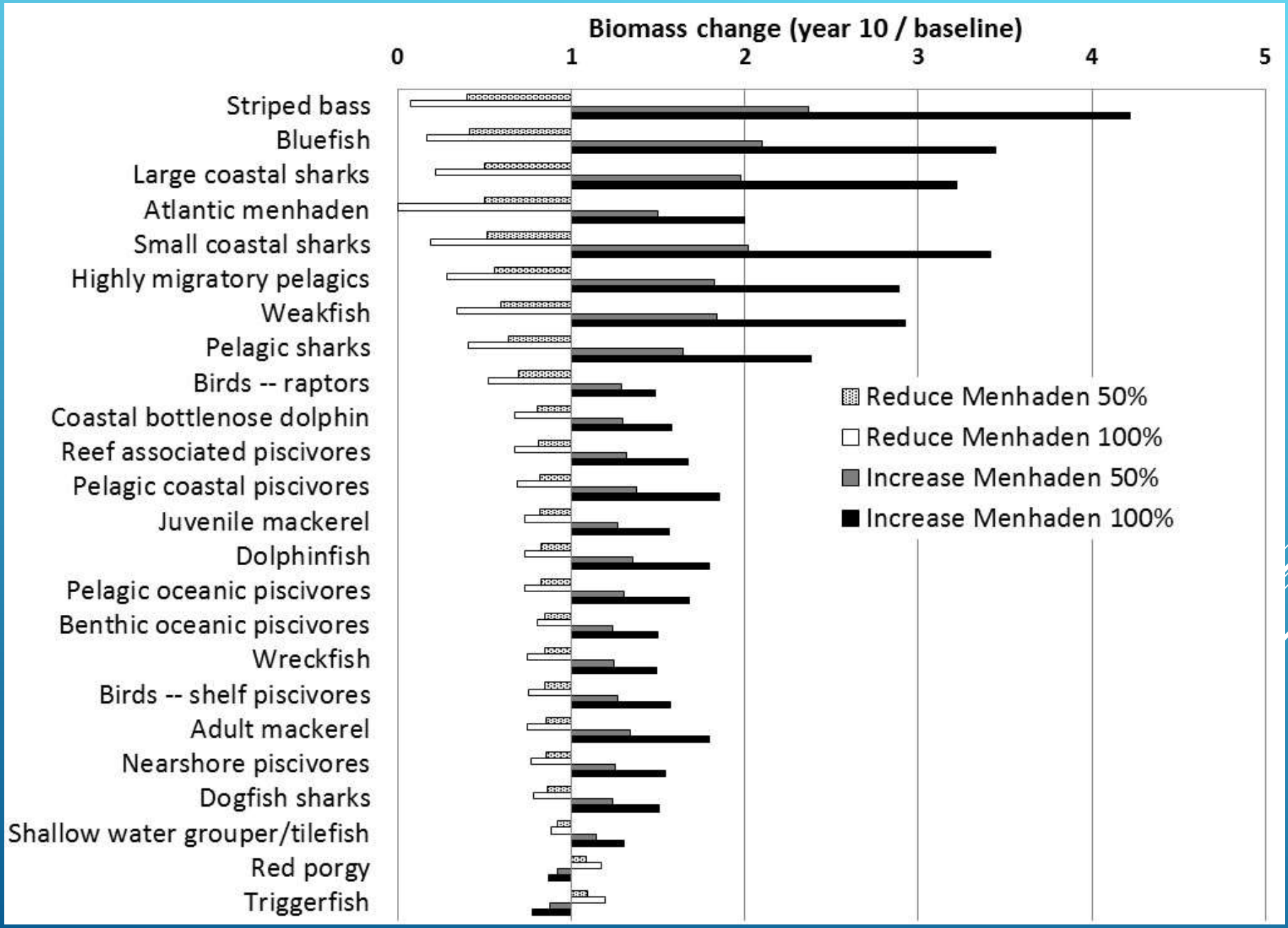
Hypothesis: South Atlantic Red Snapper extreme biomass shift is driven in part by environmental variation and prey fluctuations in the South Atlantic region, potentially affecting other competitors.

1. Black sea bass population is linked to red snapper as significant prey
2. Black sea bass are affected by environmental conditions (e.g., changing bottom temperature increased upwelling events off SE Florida) and availability of extensive nearshore and mid shelf live hard bottom habitat
3. Significant increase and recent shift south of black sea bass biomass into location of core (possibly spawning) distribution of red snapper off South East Florida.
4. Have currents shifted / eddies increased affecting settlement of black sea bass overall and onto South East Florida live hard bottom??
5. Does the increasing biomass of prey consumed by the growing red snapper population reduce availability to competitors possibly suppressing rebuilding/recovery (e.g., red grouper)?

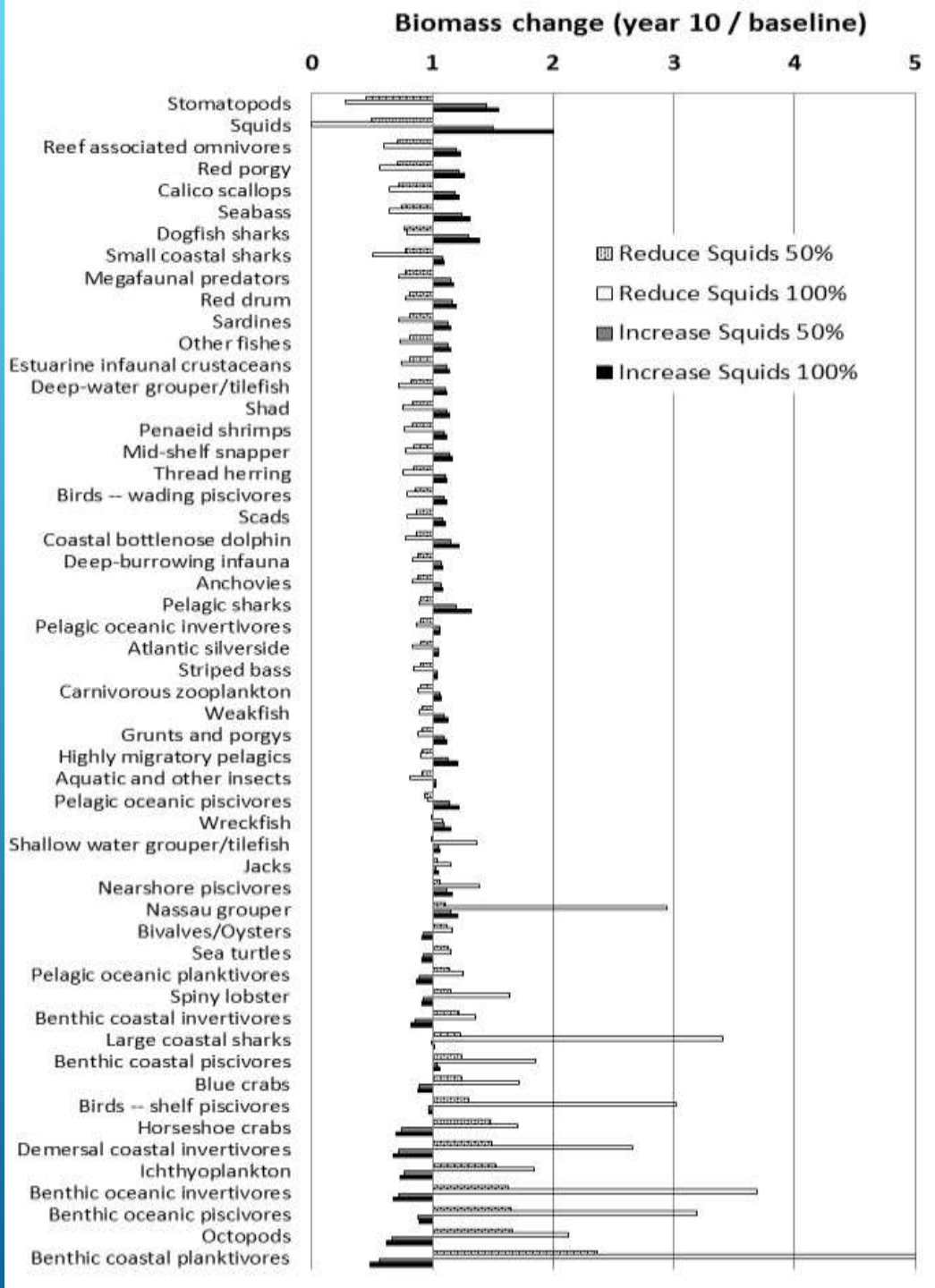
THIS COULD BE THE END OF THE PRESENTATION

I left in some additional slides in case there are any questions they can help with.

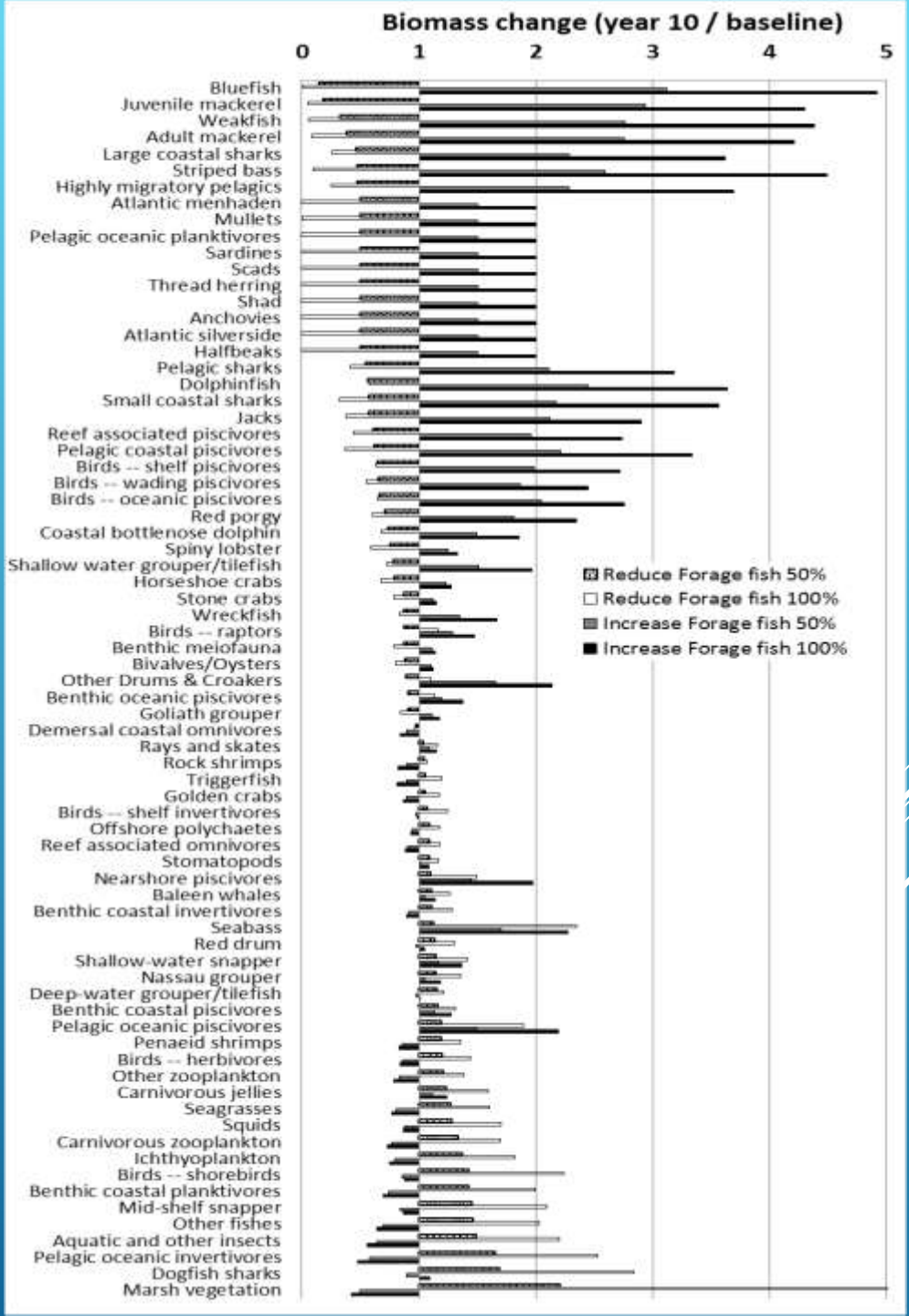
Effect of Menhaden on other groups



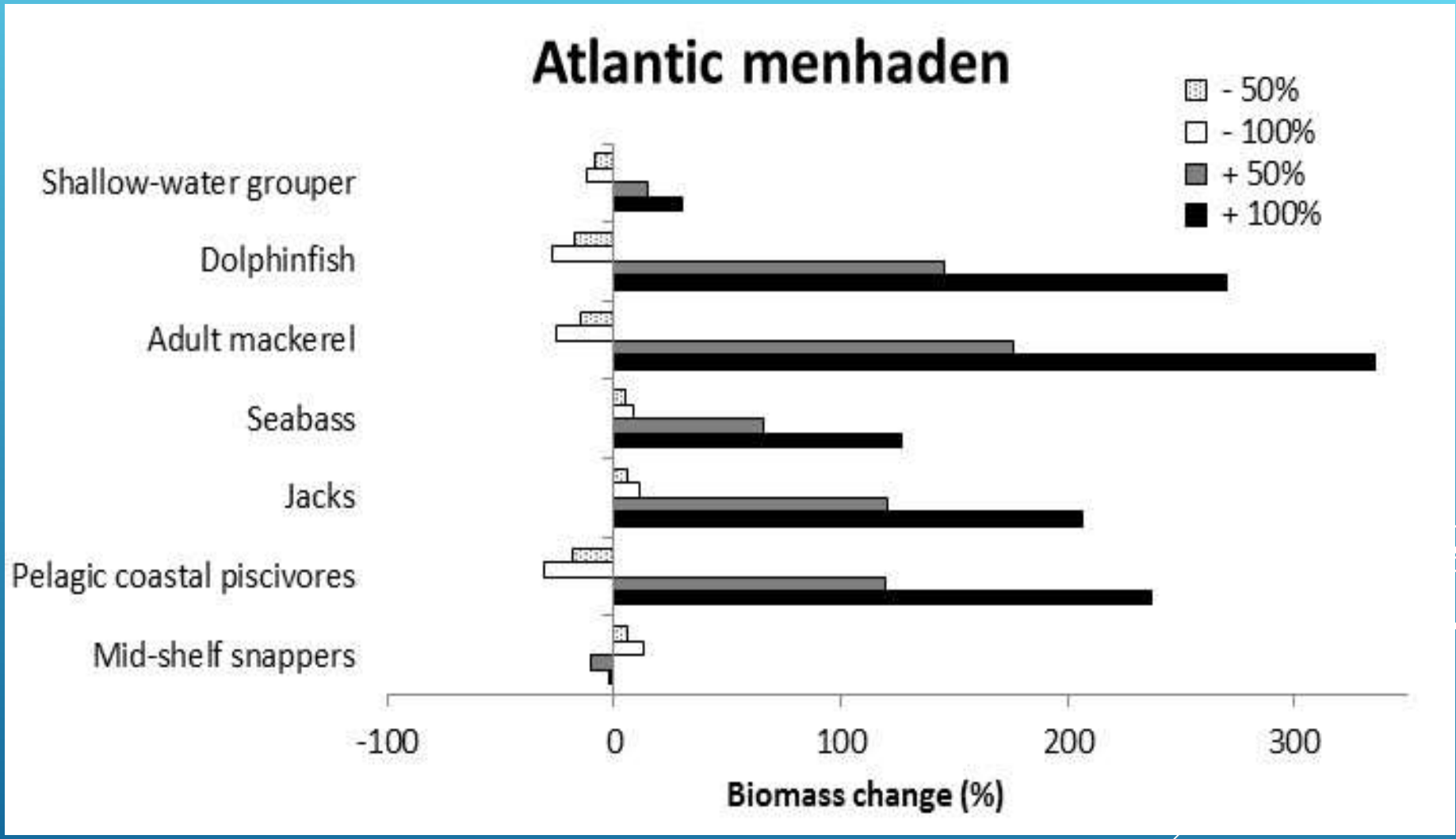
Effect of Squids on other groups



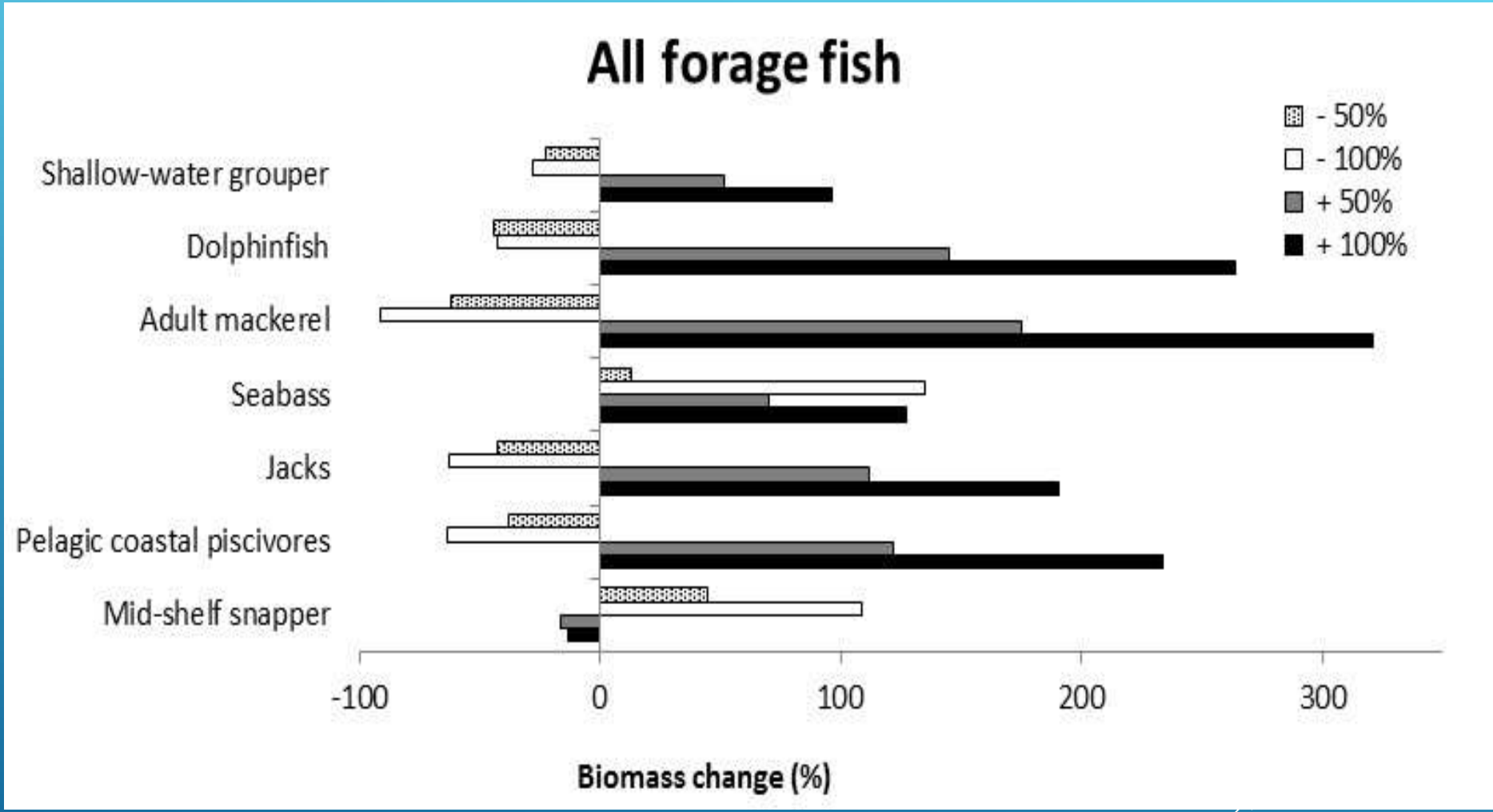
Effect of all forage fish groups on other groups



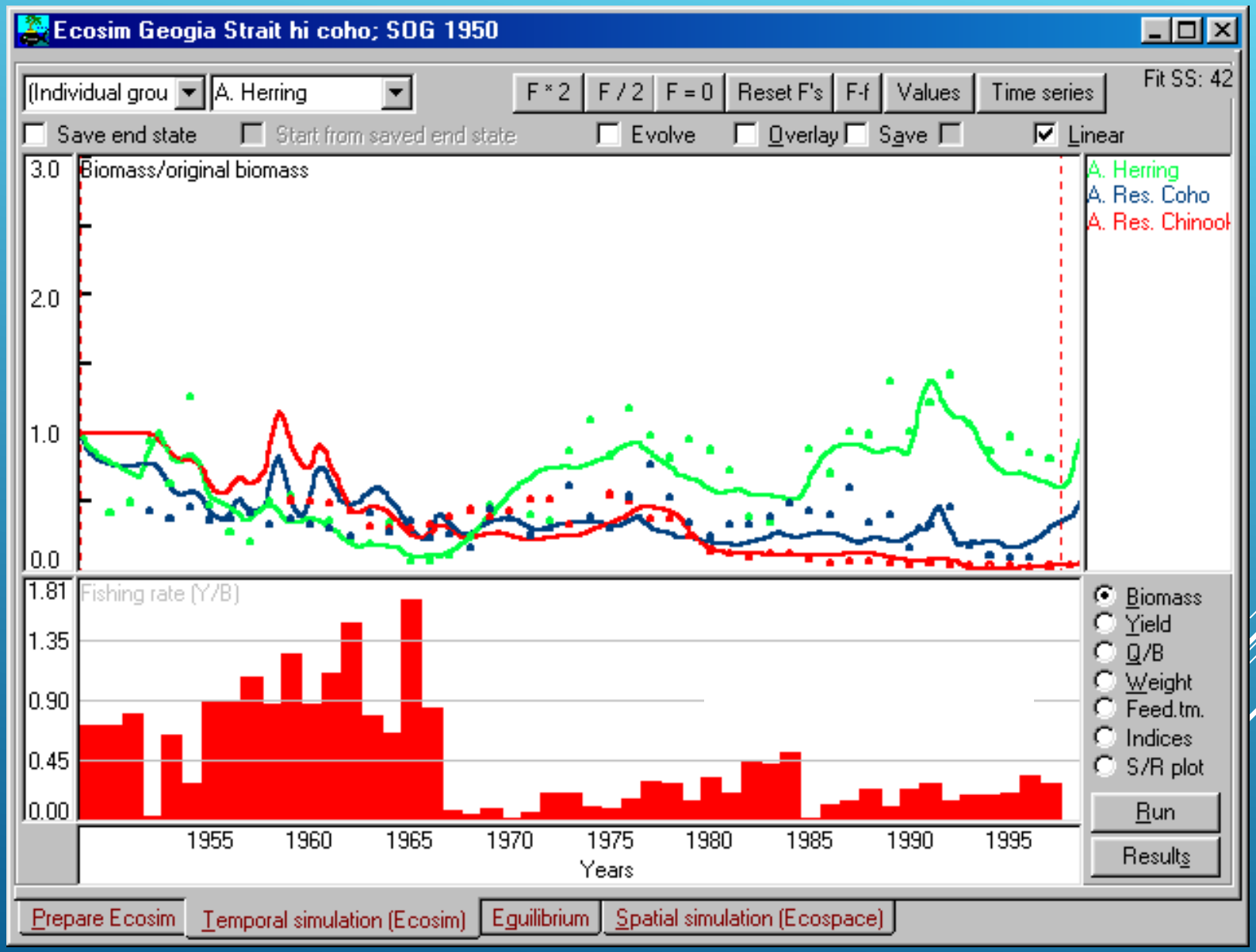
Effects of menhaden on valued predatory fish



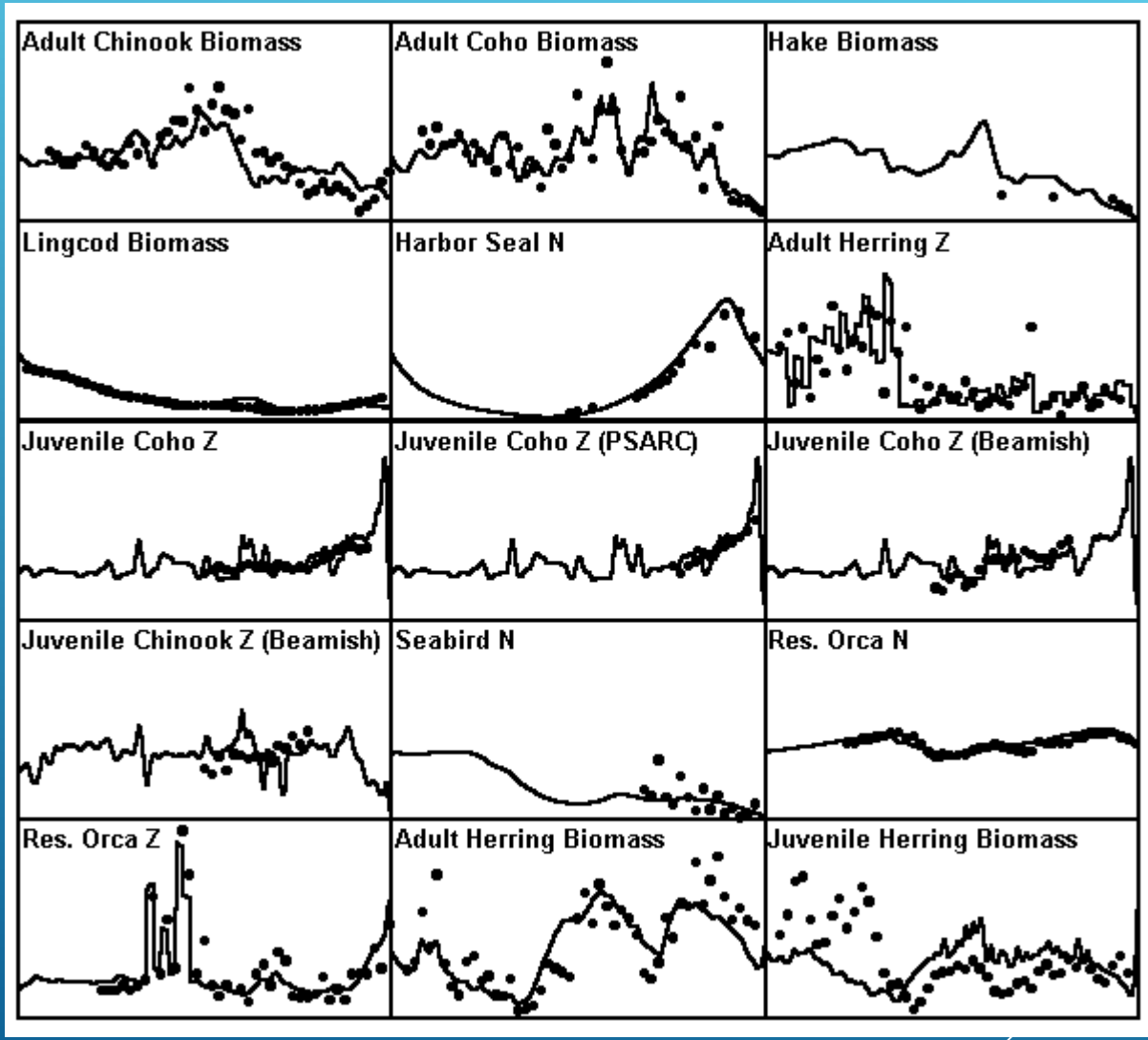
Effects of all forage fish on valued predatory fish



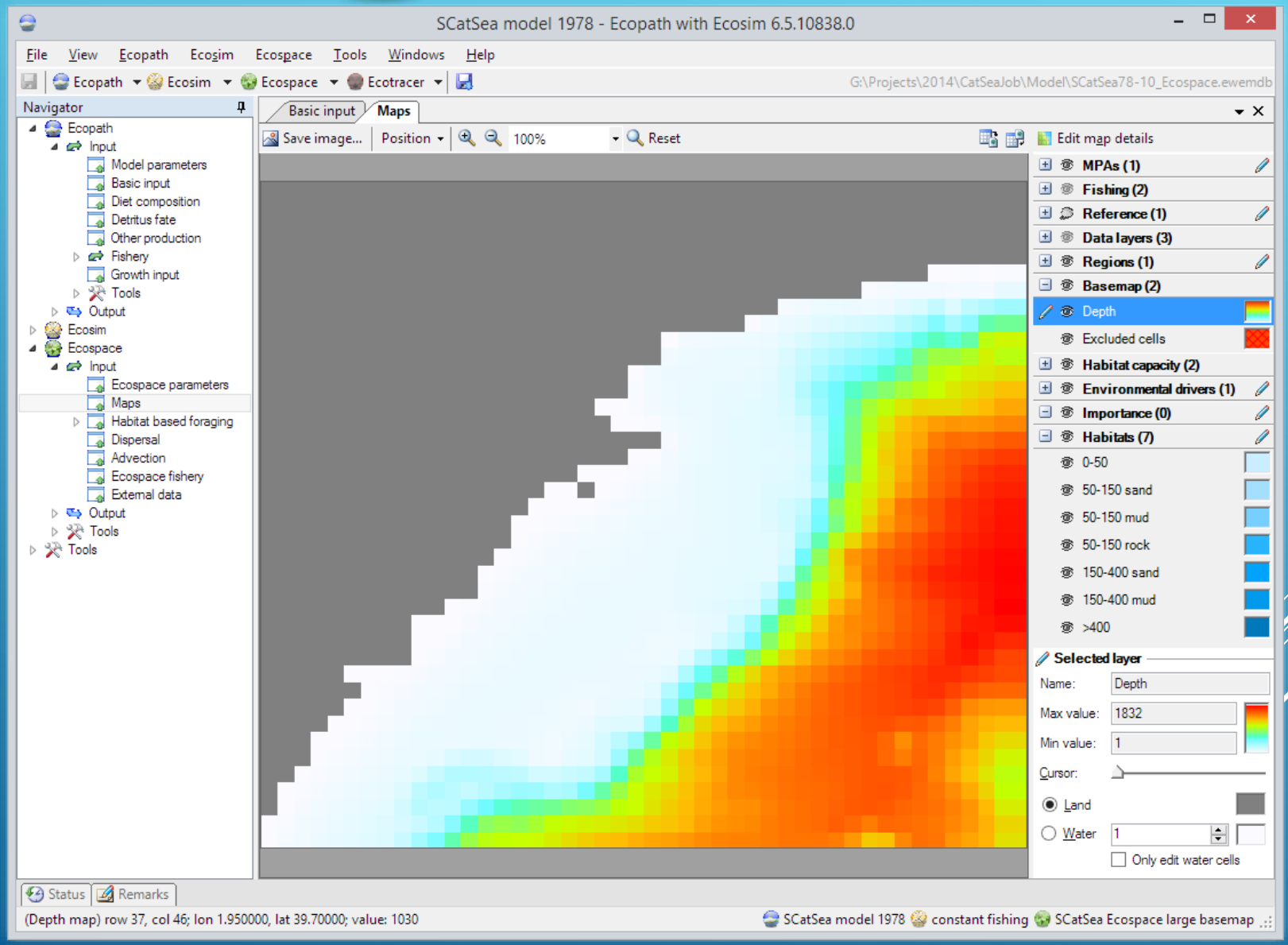
CALIBRATING THE MODEL



TIME PREDICTIONS FROM THE STRAIT OF GEORGIA MODEL, 1950-2000



ECOSPACE


SCatSea model 1978 - Ecopath with Ecosim 6.5.10838.0
File View Ecopath Ecosim Ecospace Tools Windows Help
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Ecopath
Input
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Basic input
Diet composition
Detritus fate
Other production
Fishery
Growth input
Tools
Output
Ecosim
Ecospace
Input
Ecospace parameters
Maps
Habitat based foraging
Dispersal
Advection
Ecospace fishery
External data
Output
Tools
Tools
Basic input
Maps
Save image...
Position
100%
Reset
Edit map details
MPAs (1)
Fishing (2)
Reference (1)
Data layers (3)
Regions (1)
Basemap (2)
Depth
Excluded cells
Habitat capacity (2)
Environmental drivers (1)
Importance (0)
Habitats (7)
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50-150 sand
50-150 mud
50-150 rock
150-400 sand
150-400 mud
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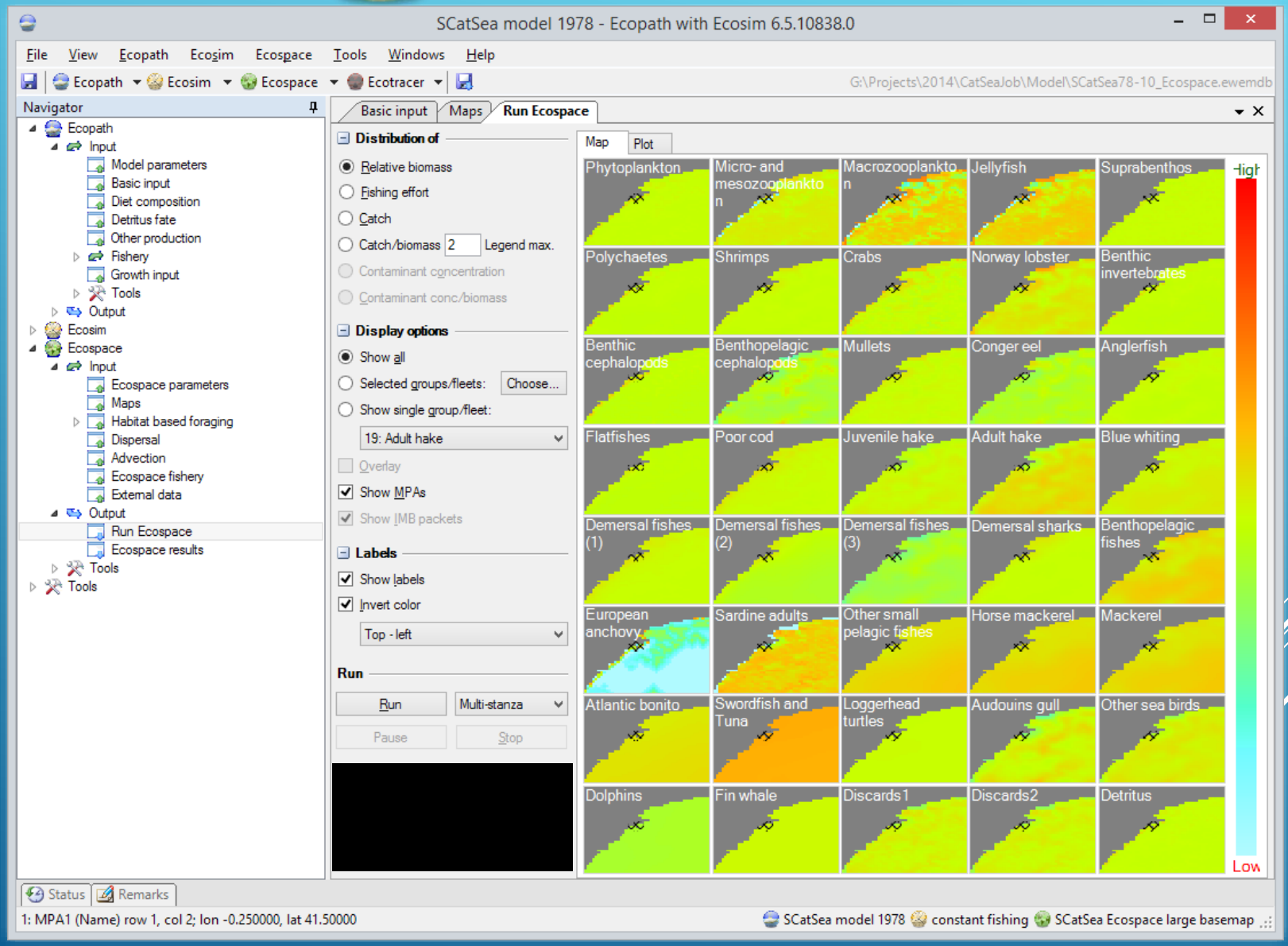
Cursor:
Land
Water 1
Only edit water cells
Status
Remarks
(Depth map) row 37, col 46; lon 1.950000, lat 39.70000; value: 1030
SCatSea model 1978
constant fishing
SCatSea Ecospace large basemap

ECOSPACE


SCatSea model 1978 - Ecopath with Ecosim 6.5.10838.0
File View Ecopath Ecosim Ecospace Tools Windows Help
Ecopath Ecosim Ecospace Ecotracer
G:\Projects\2014\CatSeaJob\Model\SCatSea78-10_Ecospace.ewemdb
Navigator
Ecopath
Input
Model parameters
Basic input
Diet composition
Detritus fate
Other production
Fishery
Growth input
Tools
Output
Ecosim
Ecospace
Input
Ecospace parameters
Maps
Habitat based foraging
Dispersal
Advection
Ecospace fishery
External data
Output
Run Ecospace
Ecospace results
Tools
Tools
Basic input
Maps
Run Ecospace
Distribution of
Relative biomass
Fishing effort
Catch
Catch/biomass
2
Legend max.
Contaminant concentration
Contaminant conc/biomass
Display options
Show all
Selected groups/fleets:
Choose...
Show single group/fleet:
19: Adult hake
Overlay
Show MPAs
Show IMB packets
Labels
Show labels
Invert color
Top - left
Run
Run
Multi-stanza
Pause
Stop
Map
Plot
Phytoplankton
Micro- and mesozooplankton
Macrozooplankton
Jellyfish
Suprabenthos
Polychaetes
Shrimps
Crabs
Norway lobster
Benthic invertebrates
Benthic cephalopods
Benthopelagic cephalopods
Mullets
Conger eel
Anglerfish
Flatfishes
Poor cod
Juvenile hake
Adult hake
Blue whiting
Demersal fishes (1)
Demersal fishes (2)
Demersal fishes (3)
Demersal sharks
Benthopelagic fishes
European anchovy
Sardine adults
Other small pelagic fishes
Horse mackerel
Mackerel
Atlantic bonito
Swordfish and Tuna
Loggerhead turtles
Audouins gull
Other sea birds
Dolphins
Fin whale
Discards1
Discards2
Detritus
High
Low
Status
Remarks
1: MPA1 (Name) row 1, col 2; lon -0.250000, lat 41.50000
SCatSea model 1978
constant fishing
SCatSea Ecospace large basemap

HAB. CAP. CASE STUDY

1. Define environmental drivers

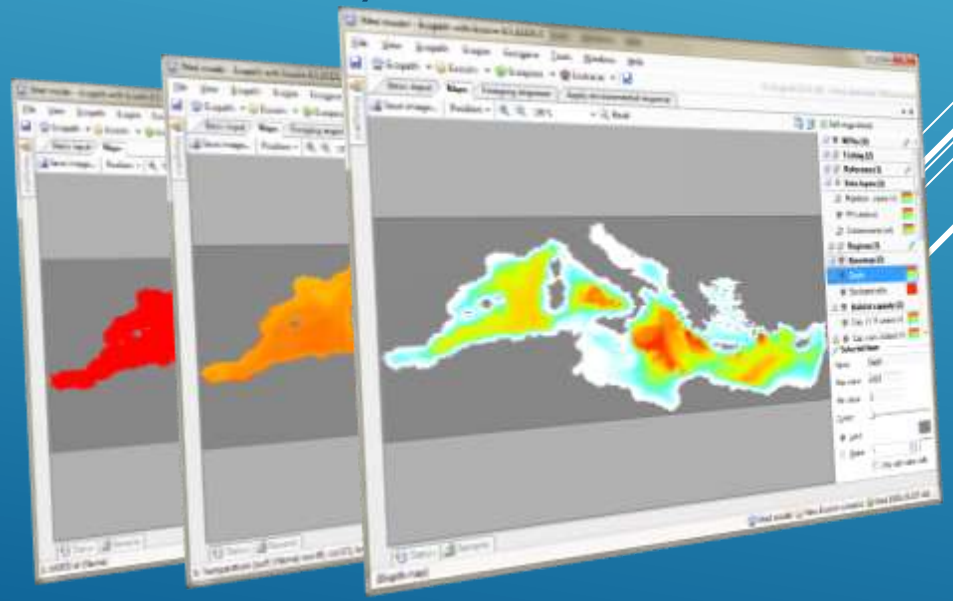
Primary production

Salinity (surface and bottom)

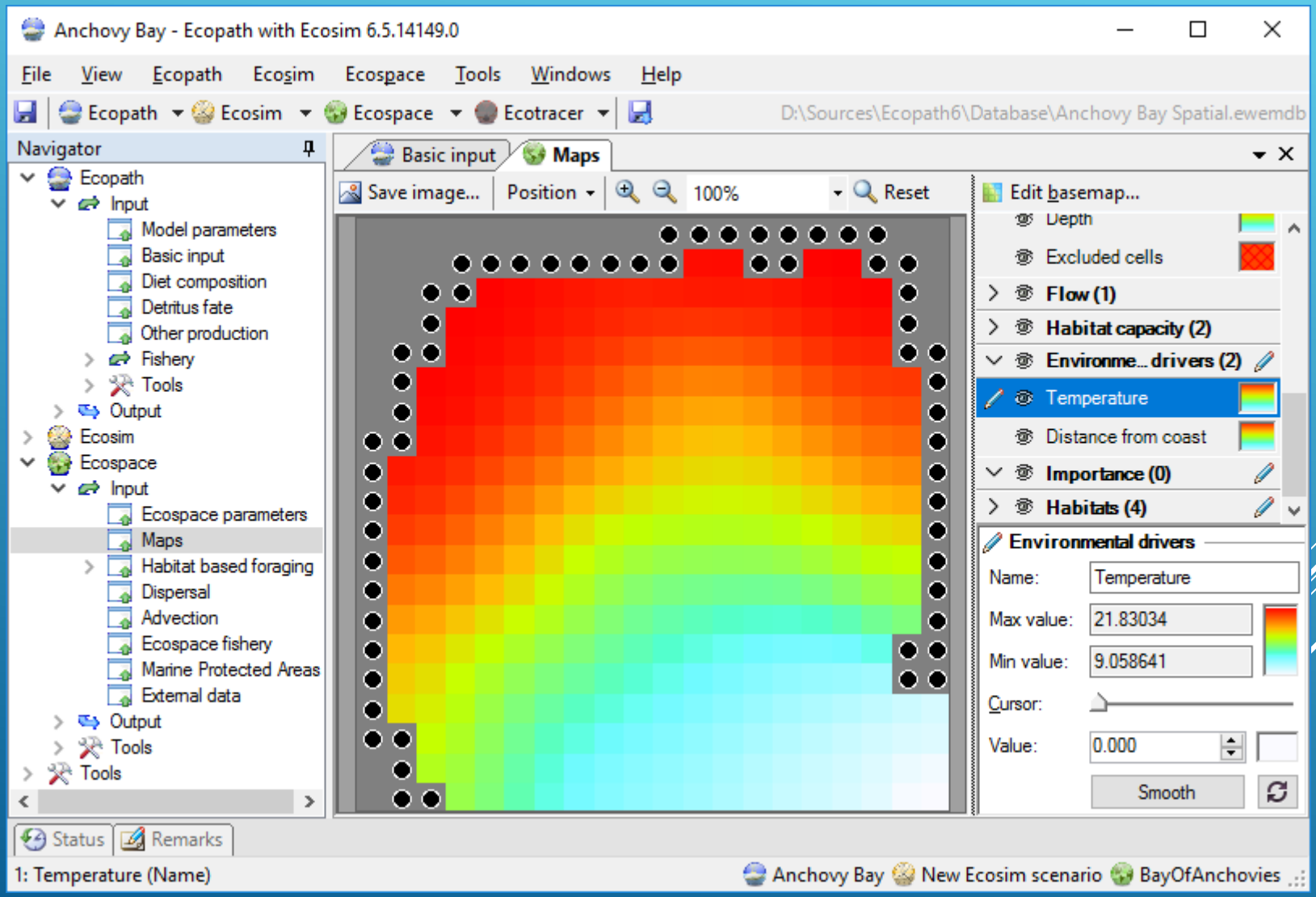
Temperature (surface and bottom)

Depth

MSFD area restrictions

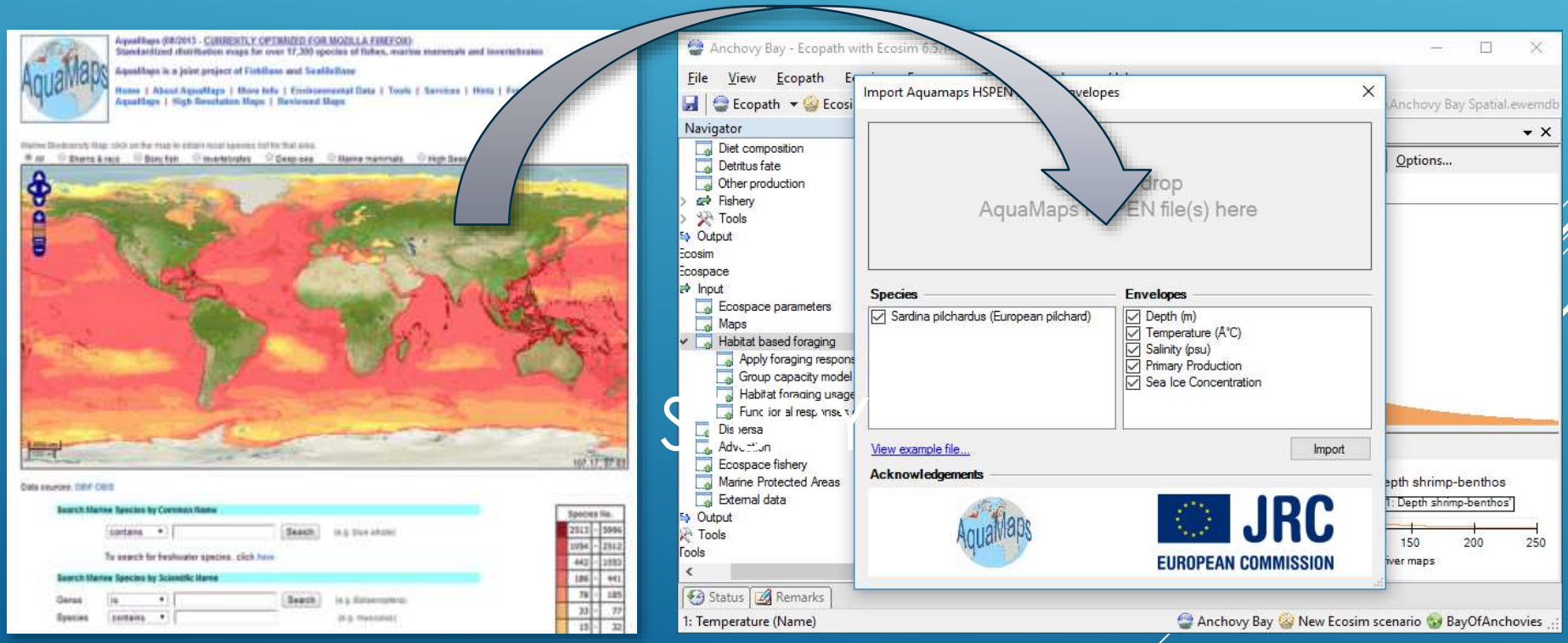


3. POPULATE ENV. DRIVER MAPS



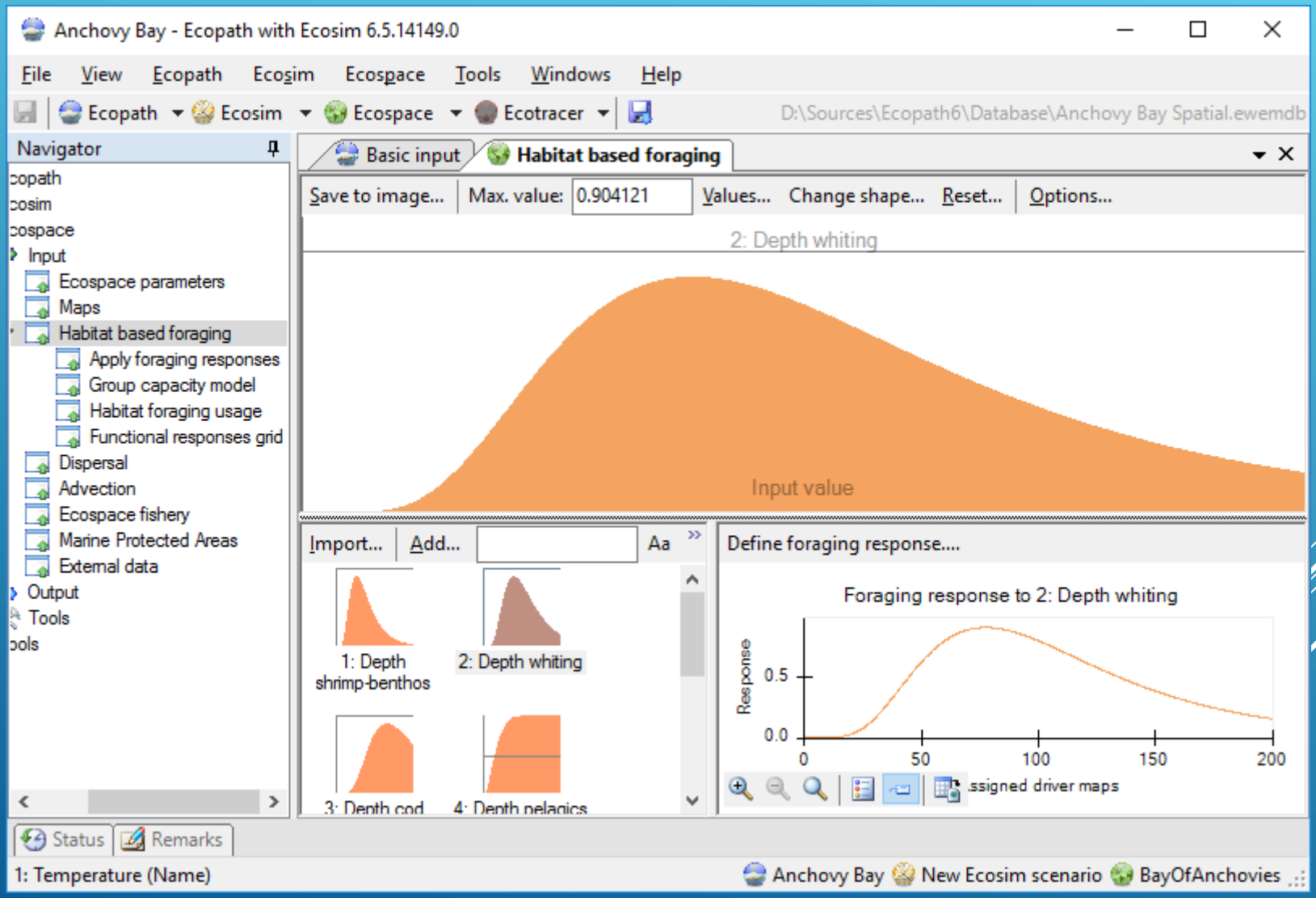
2. Define environmental responses

Here we are using a plug-in to import environmental responses from AquaMaps species envelopes



Piroddi et al (in progress)

4. DEFINE ENV. RESPONSE CURVES



HAB. CAP. CASE STUDY

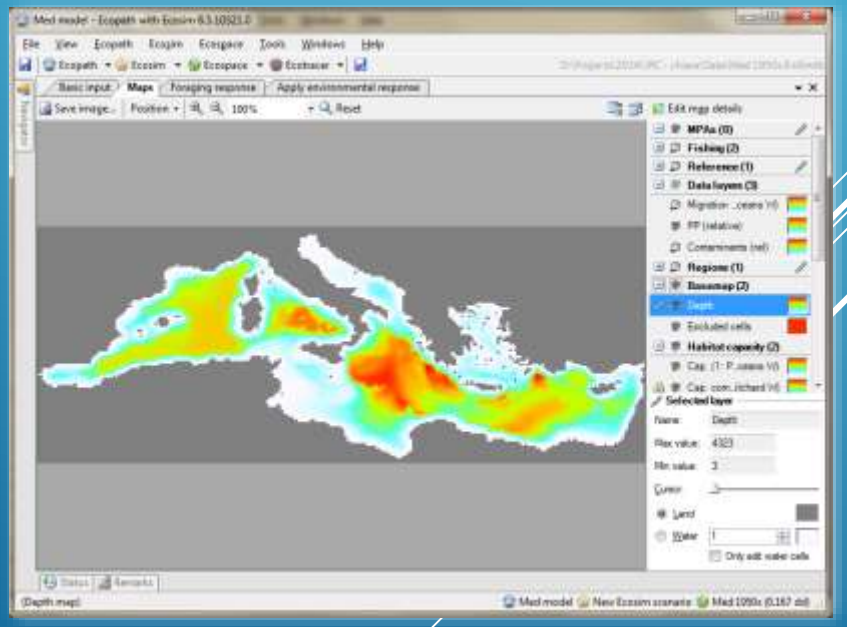
Foraging habitat capacity model case study

Full Mediterranean EwE model

90+ functional groups, assigned to 4 MSFD zones

Time frame 1950 – 2010

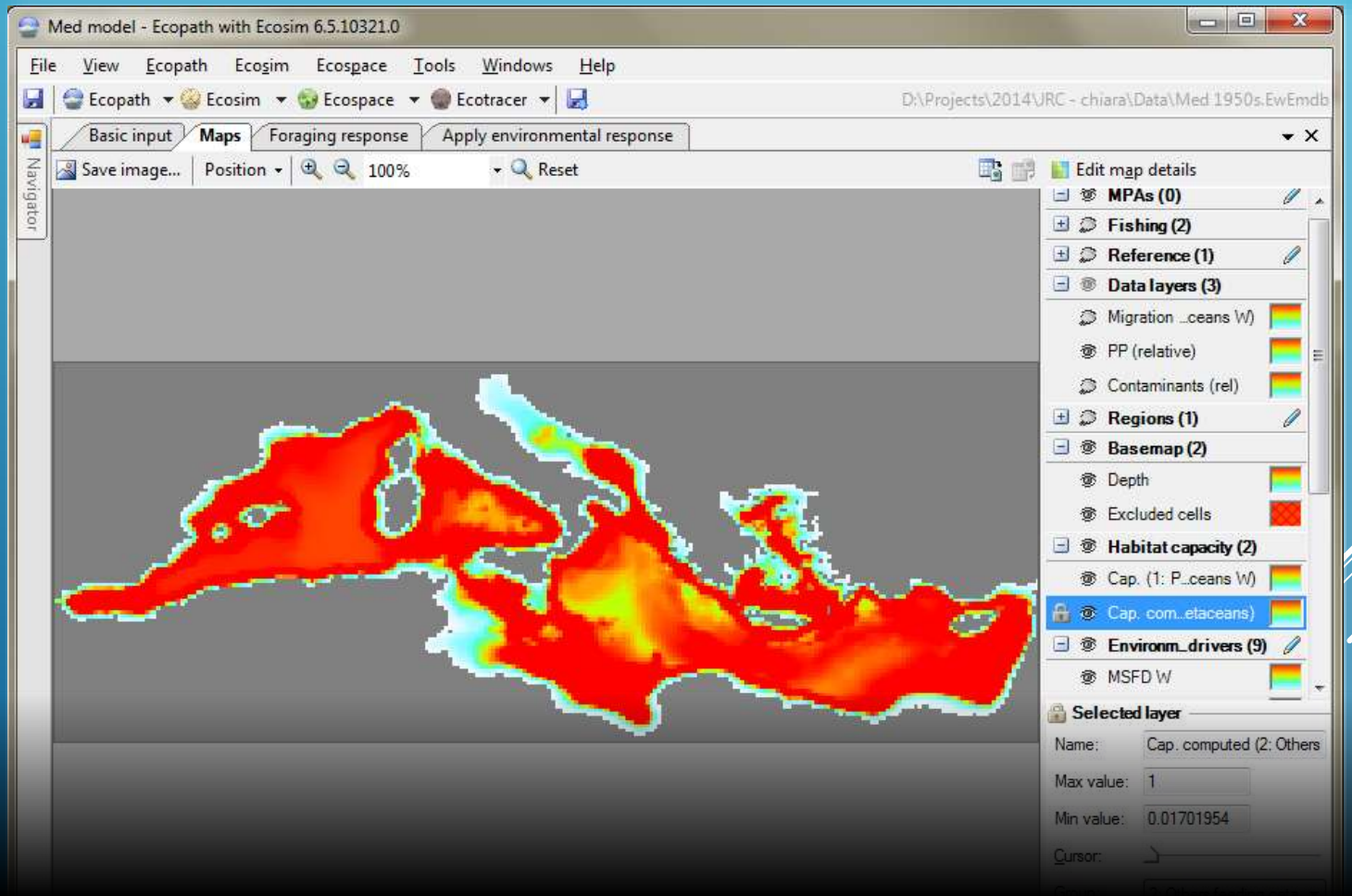
Entire basin at 0.167 dd grid



Piroddi et al (in progress)

HAB. CAP. CASE STUDY

4. Ecospace computes capacity (cetaceans - depth)



HAB. CAP. CASE STUDY

4. More capacity (Western sardine - depth, MSFD W)