Using Ecosystem Models to Simulate Effects of Environmental Factors on Fish and Fisheries

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Ecopath with Ecosim

Widely used for construction of mass-balance trophic models of ecosystems

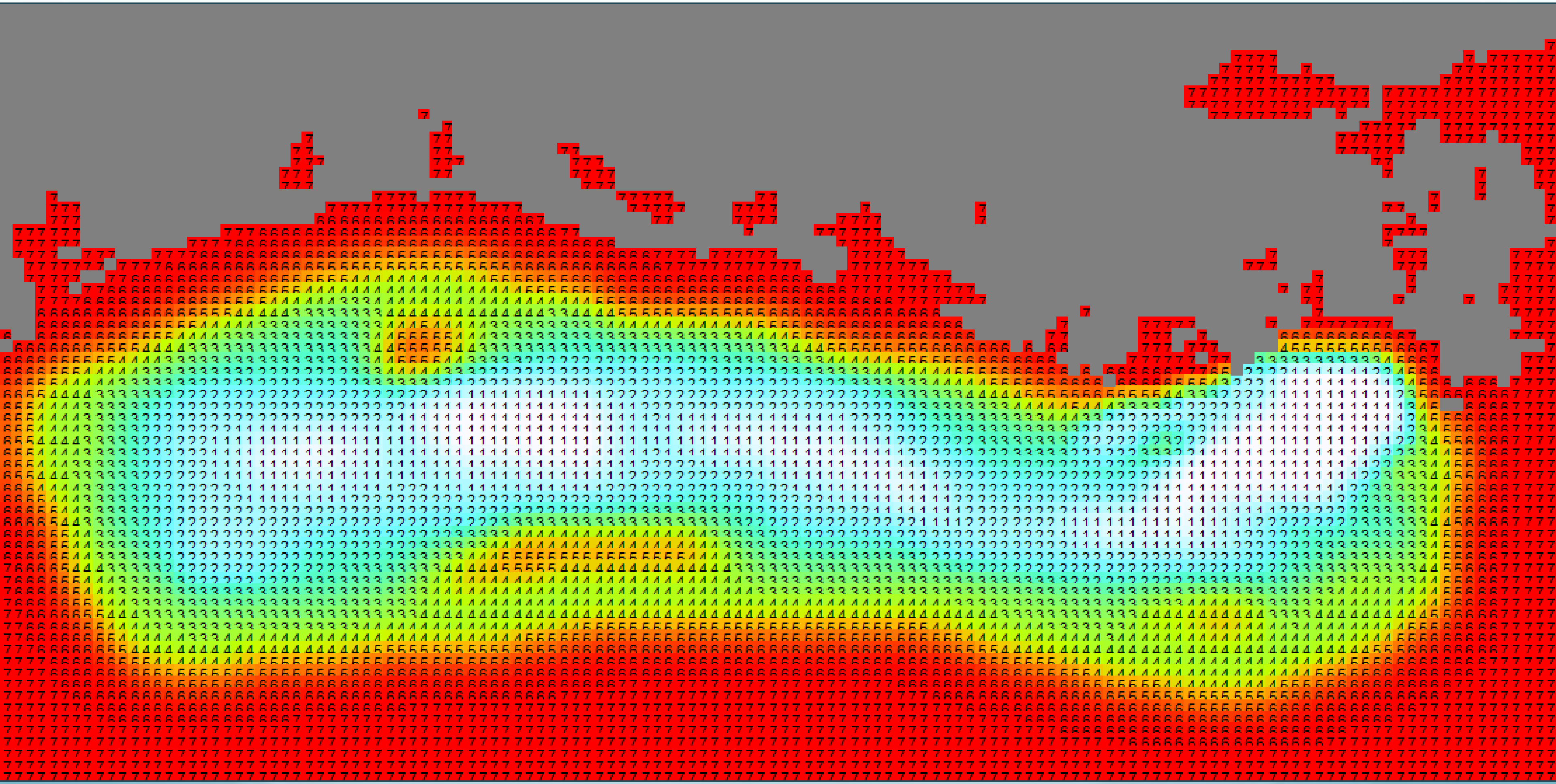
Simulates response of fish to fishing and environmental change; accounts for ecological interactions

Has three main components:

- <u>Ecopath</u> – a static snapshot of ecosystem trophic structure
- <u>Ecosim</u> – a time dynamic simulation module
- <u>Ecospace</u> – a spatial and temporal dynamic module

www.ecopath.org

Environmental driver: summer hypoxia



*Warmer (red) is higher DO; blue & white indicate hypoxia

A coupled physical-biological model of the Northern Gulf of Mexico shelf: model description, validation and analysis of phytoplankton variability

K. Fen

[1]Depa

[2]Depa

Receiv

Revise

Now spatial-temporal DO and Chl *a* output of a physical-biological model is used

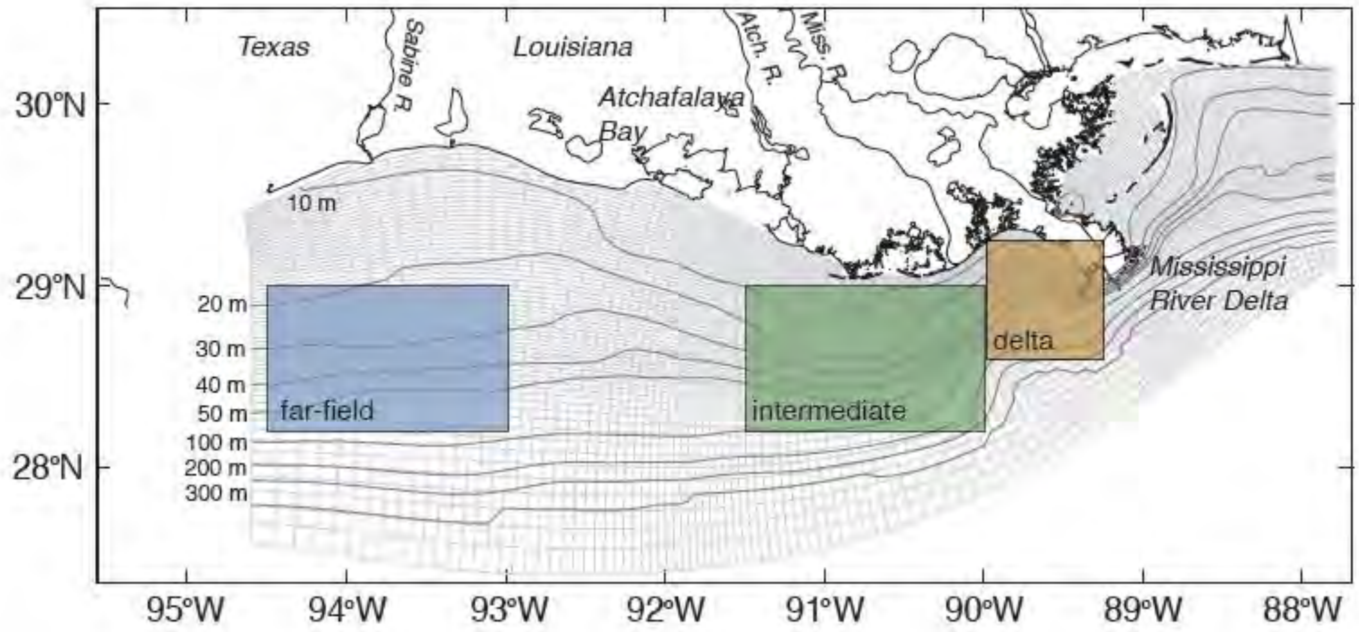
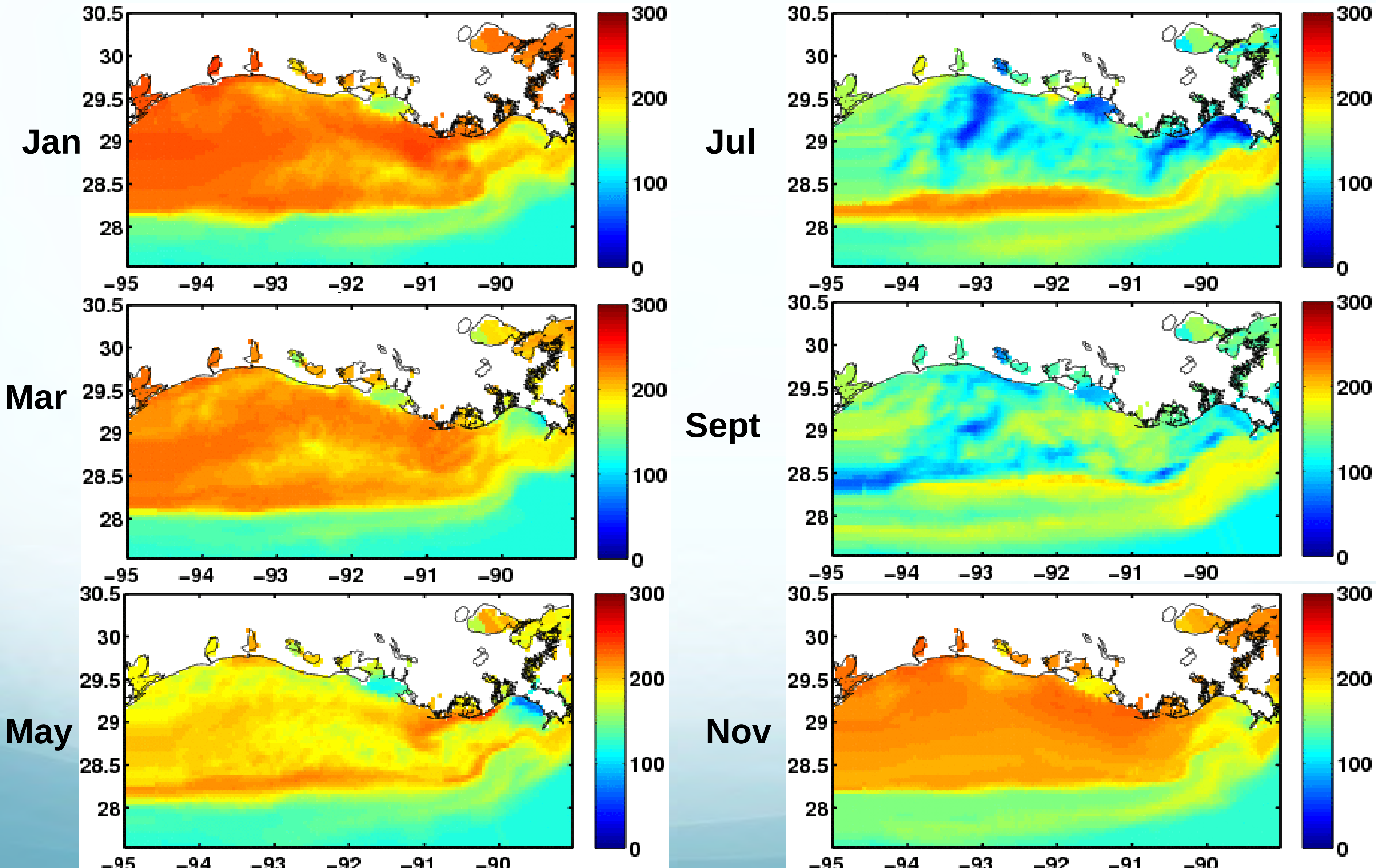
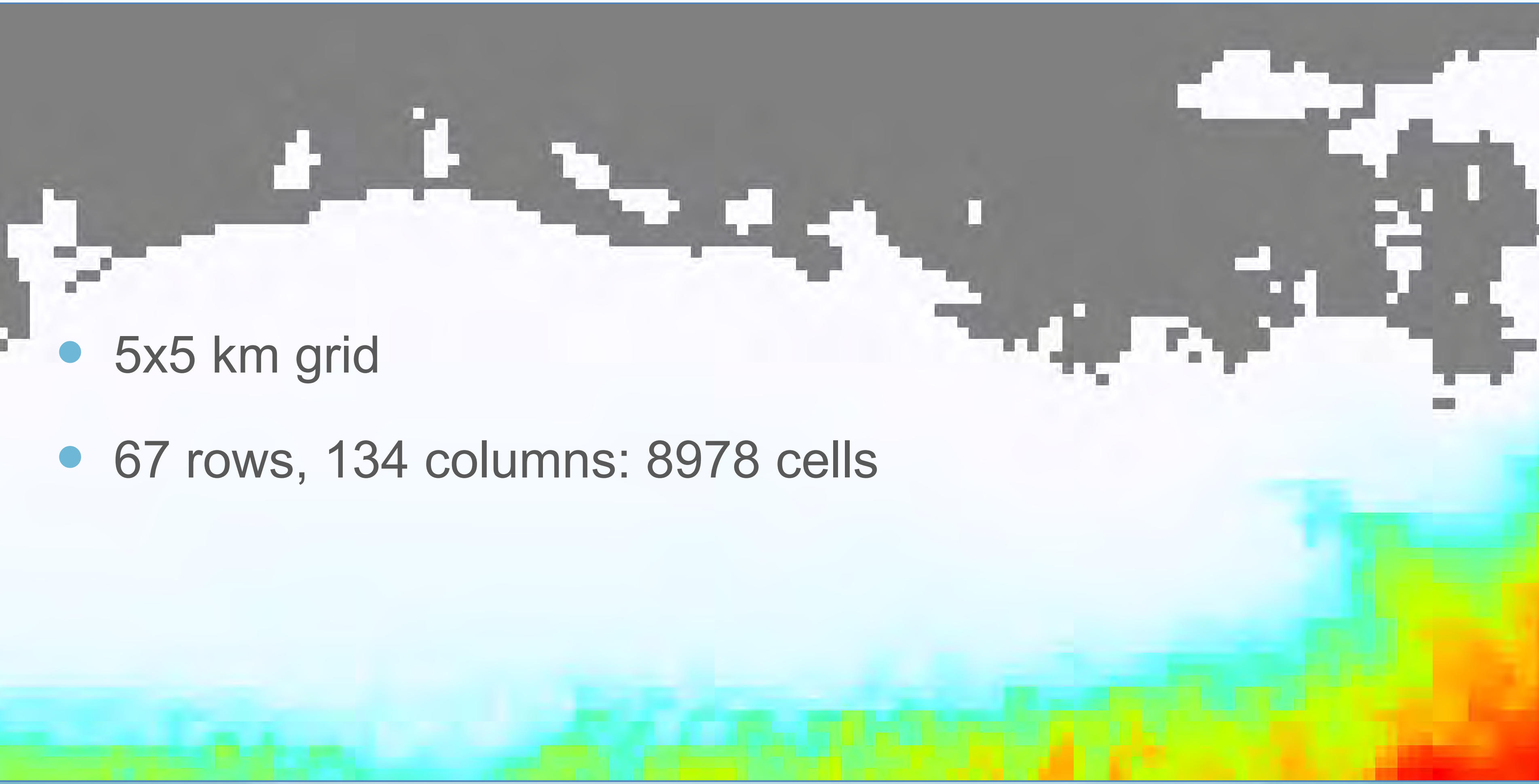


Fig. 1. Model domain and bathymetry. The colored boxes indicate areas used for averaging throughout the manuscript and are referred to as delta (brown), intermediate (green) and far-field (blue) region in the text.

2007 Bottom DO per month (mmol O_2 m^{-3})

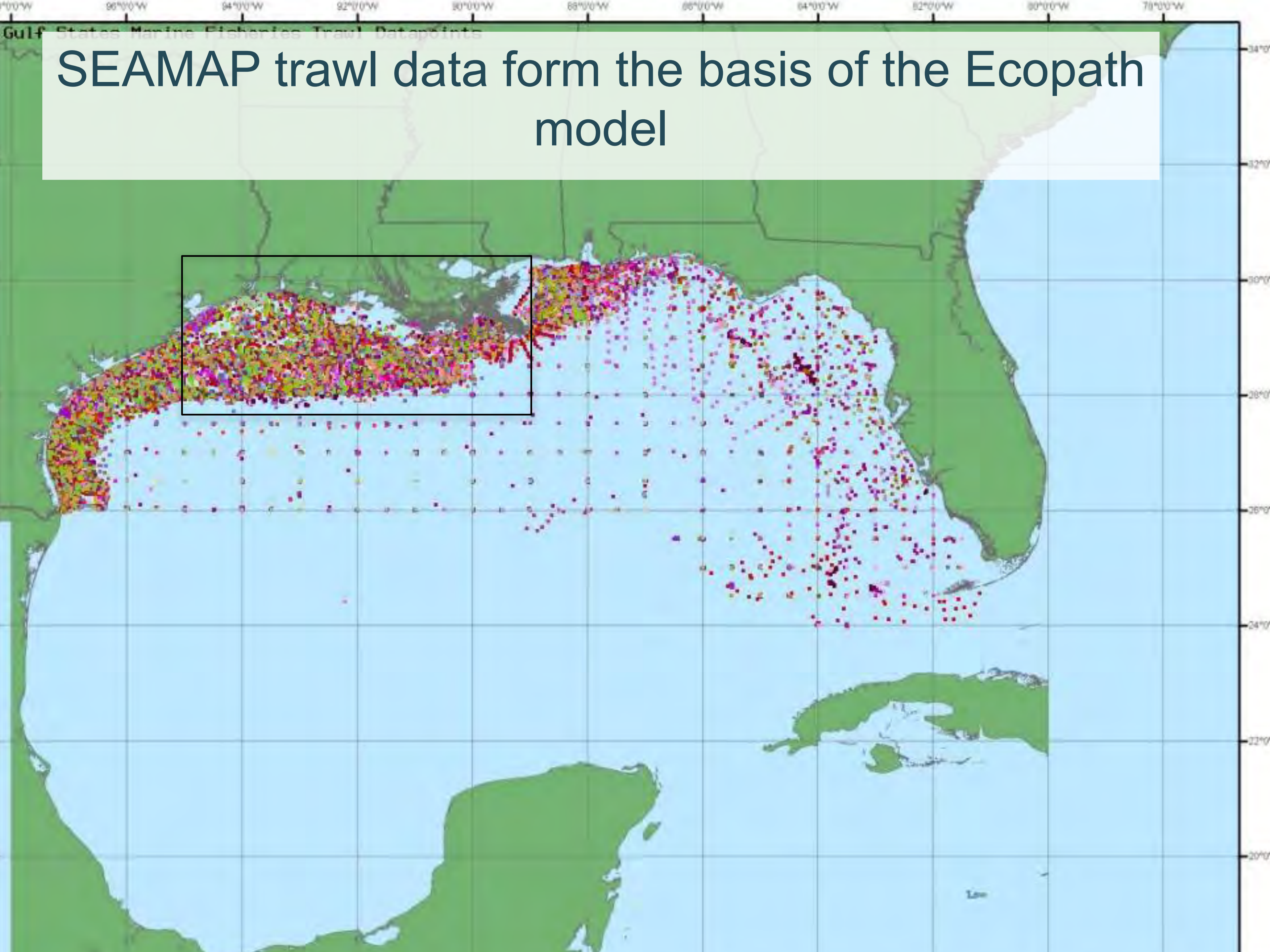


Ecospace base map



- 5x5 km grid
- 67 rows, 134 columns: 8978 cells

SEAMAP trawl data form the basis of the Ecopath model



Taxa/groups in the Ecopath model

Marine Mammals
Tunas
Birds
Atlantic Cutlassfish
Lizardfish
Sharks
Mackerel
Sea Trout
Red Snapper
Groupers
Other Snappers
Red Drum
Rays & Skates
Flounders
Pompano
Atlantic Bumper

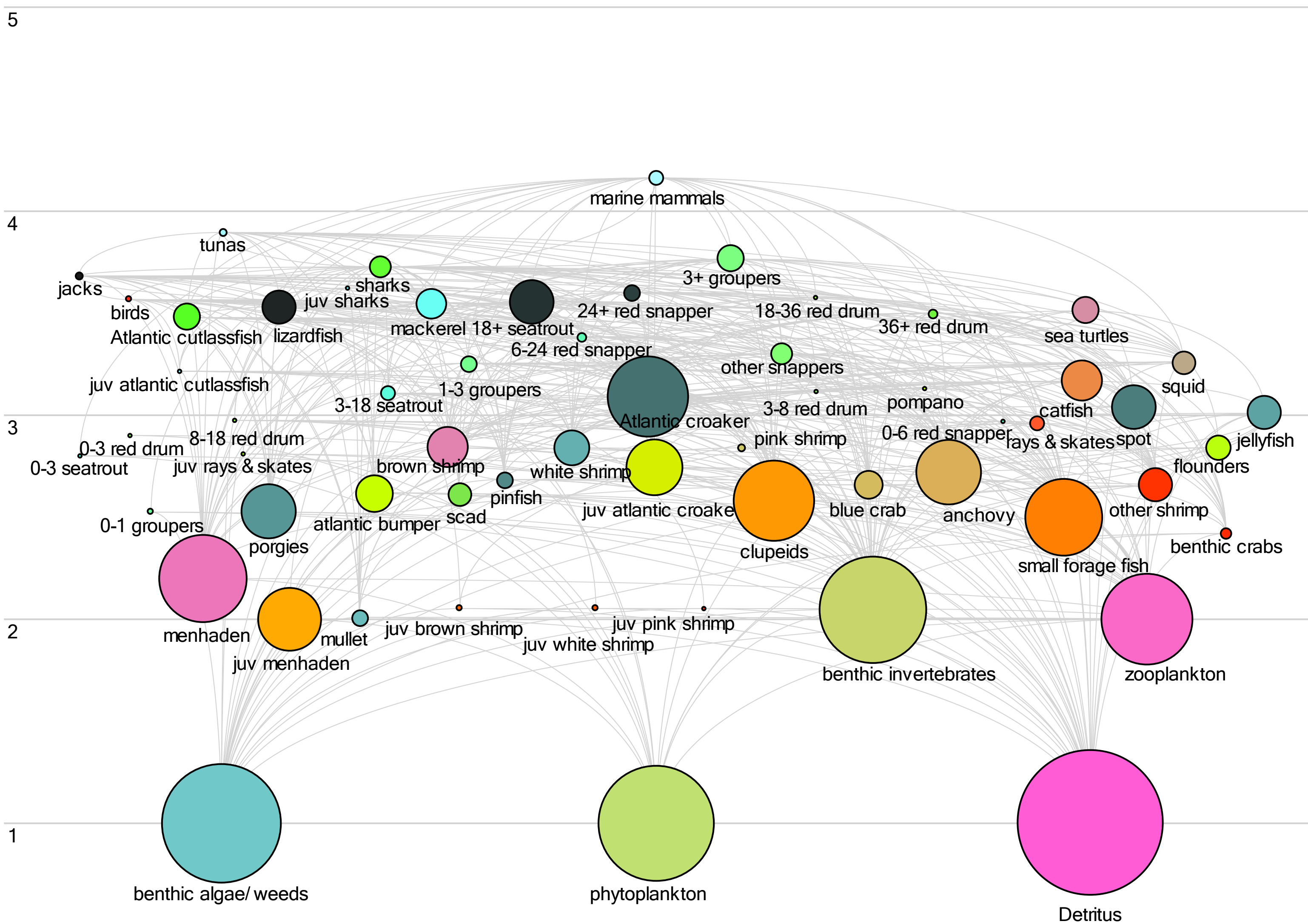
Scad
Atlantic Croaker
Catfish
Spot
Squid
Pinfish
Porgies
Anchovy
Menhaden
Other Clupeids
Mullet
Sea Turtles
Small Forage Fish

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

60 groups

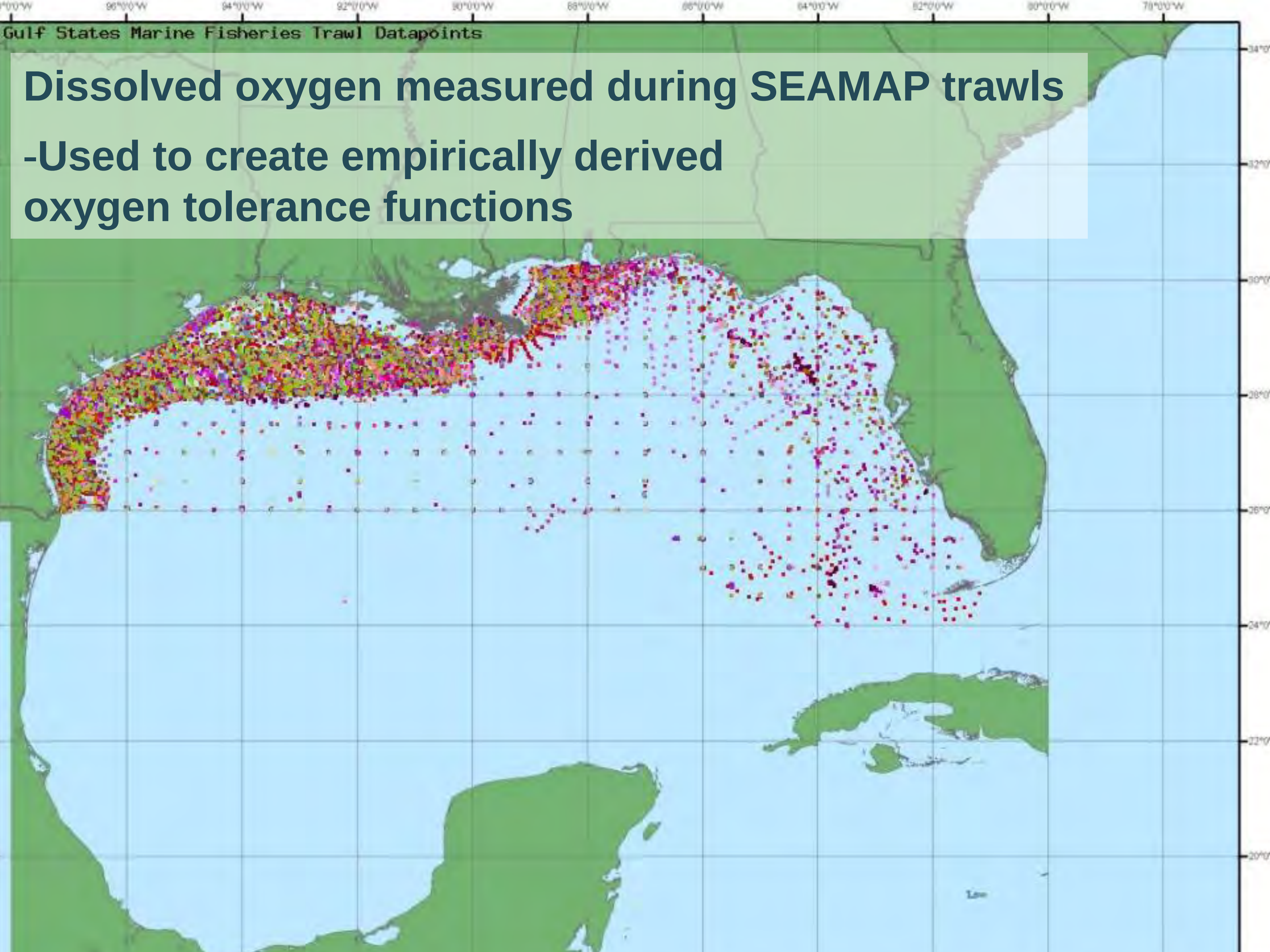
ontogenetic splits included

Coastal Northern Gulf of Mexico model

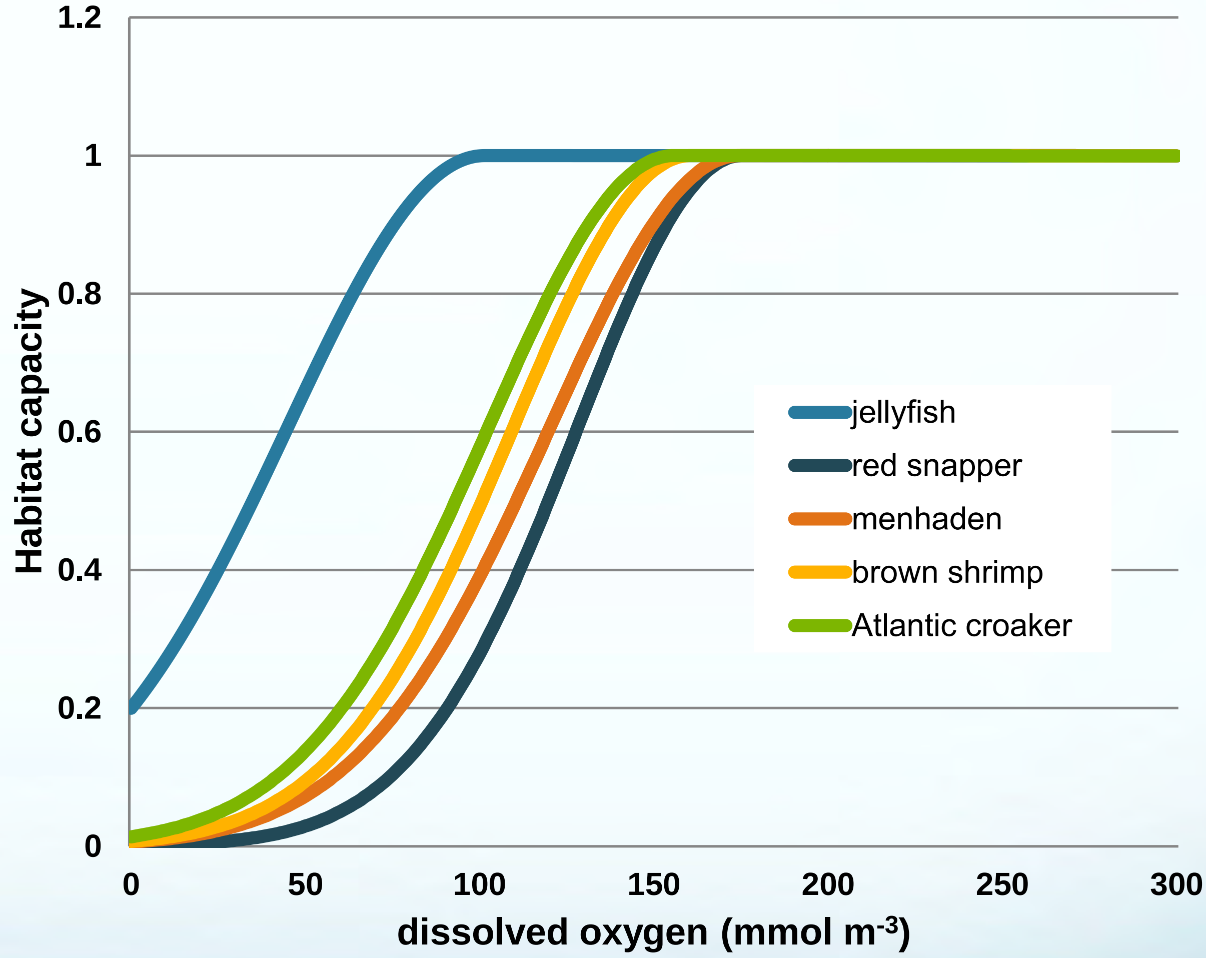


Dissolved oxygen measured during SEAMAP trawls

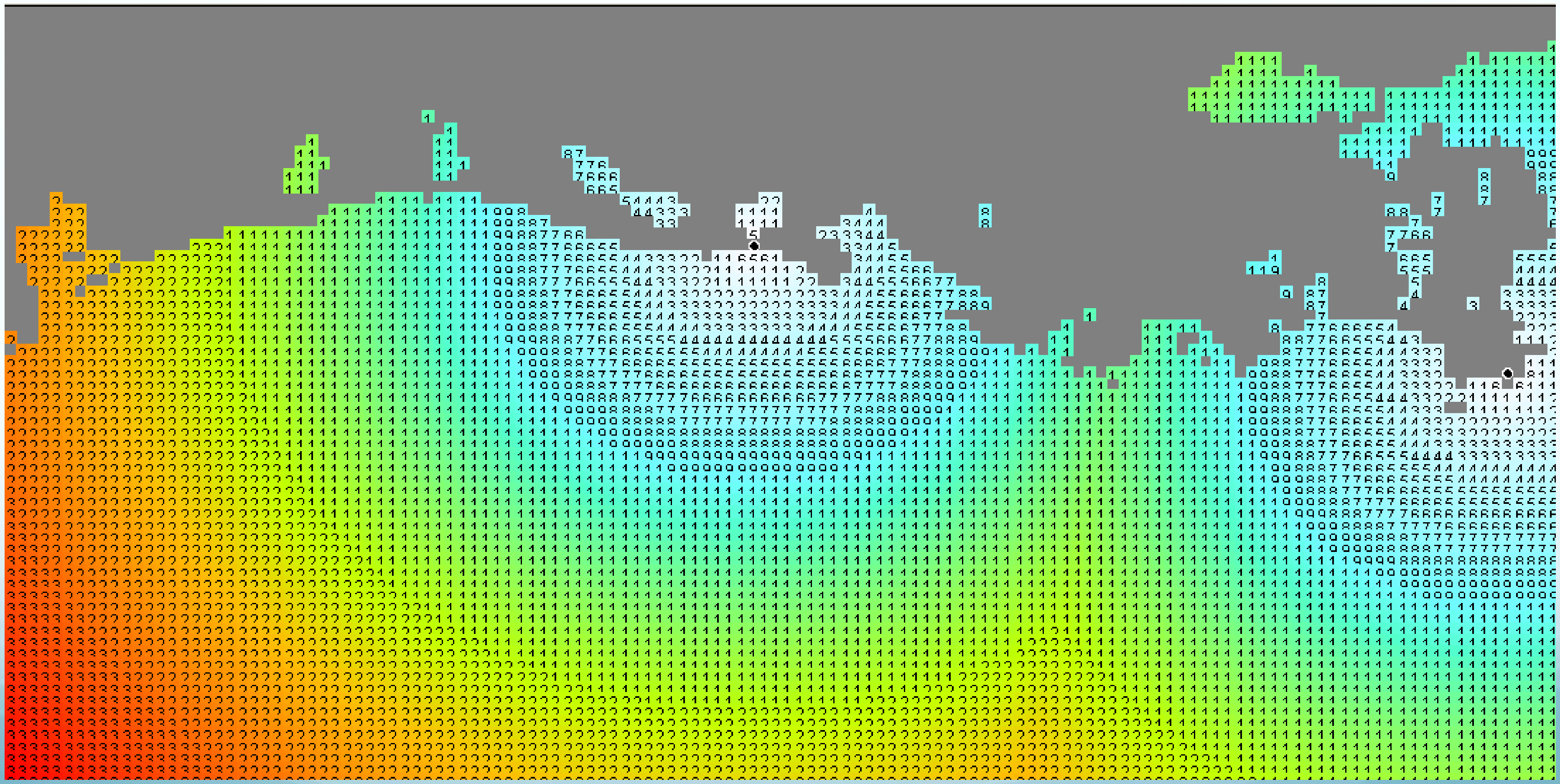
-Used to create empirically derived oxygen tolerance functions



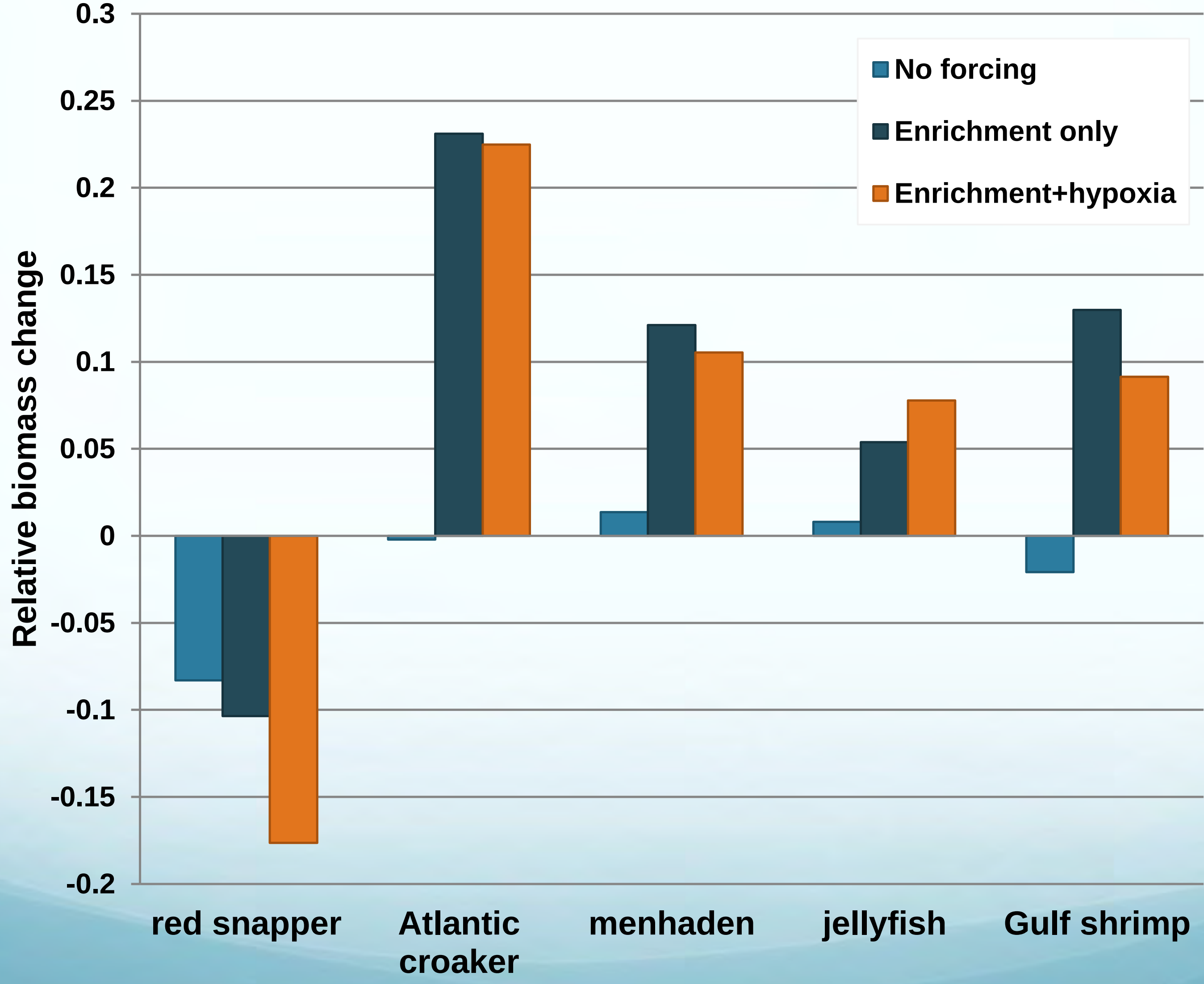
Transformed into oxygen response functions



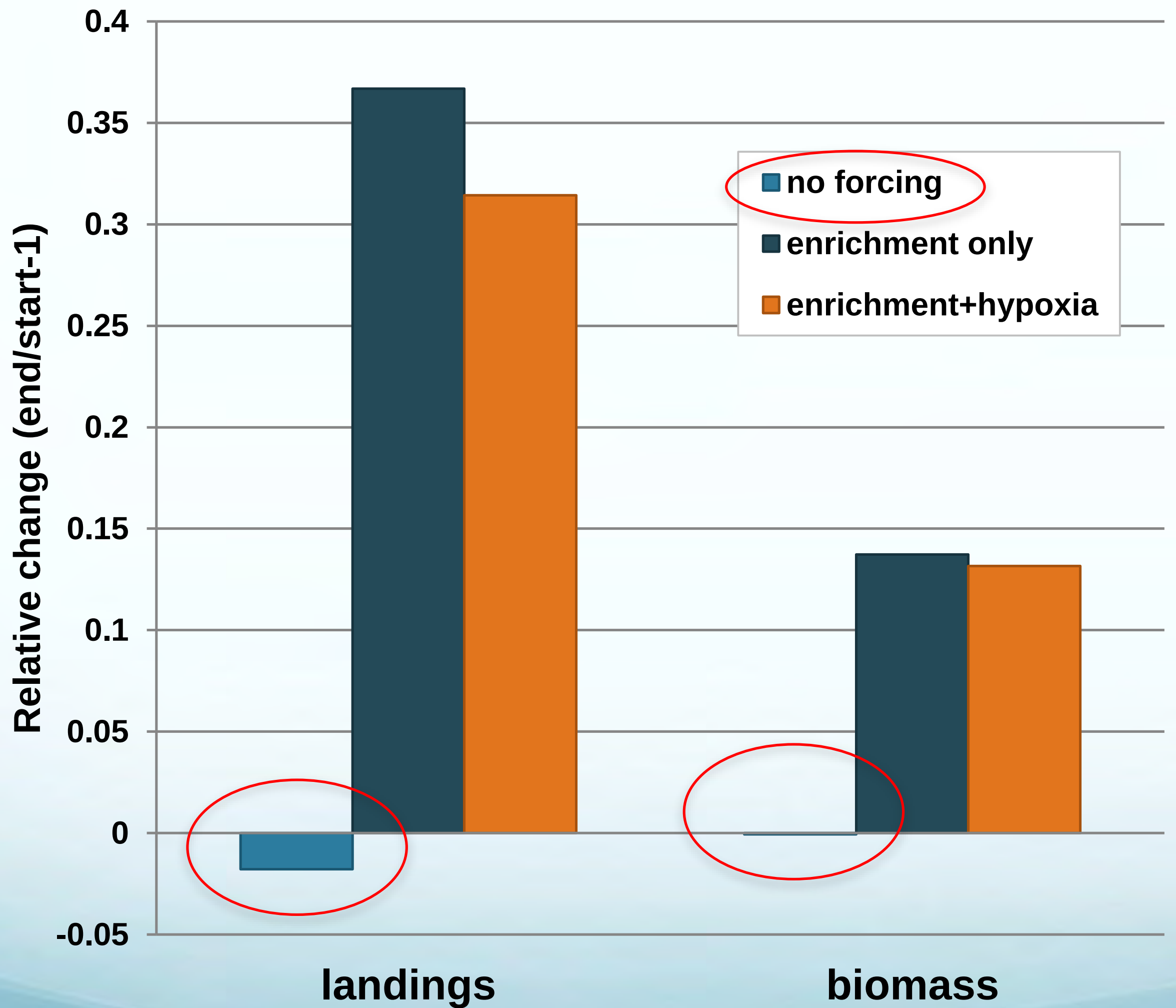
Ports and relative cost of fishing



Results: biomass



Results: totals



Discussion

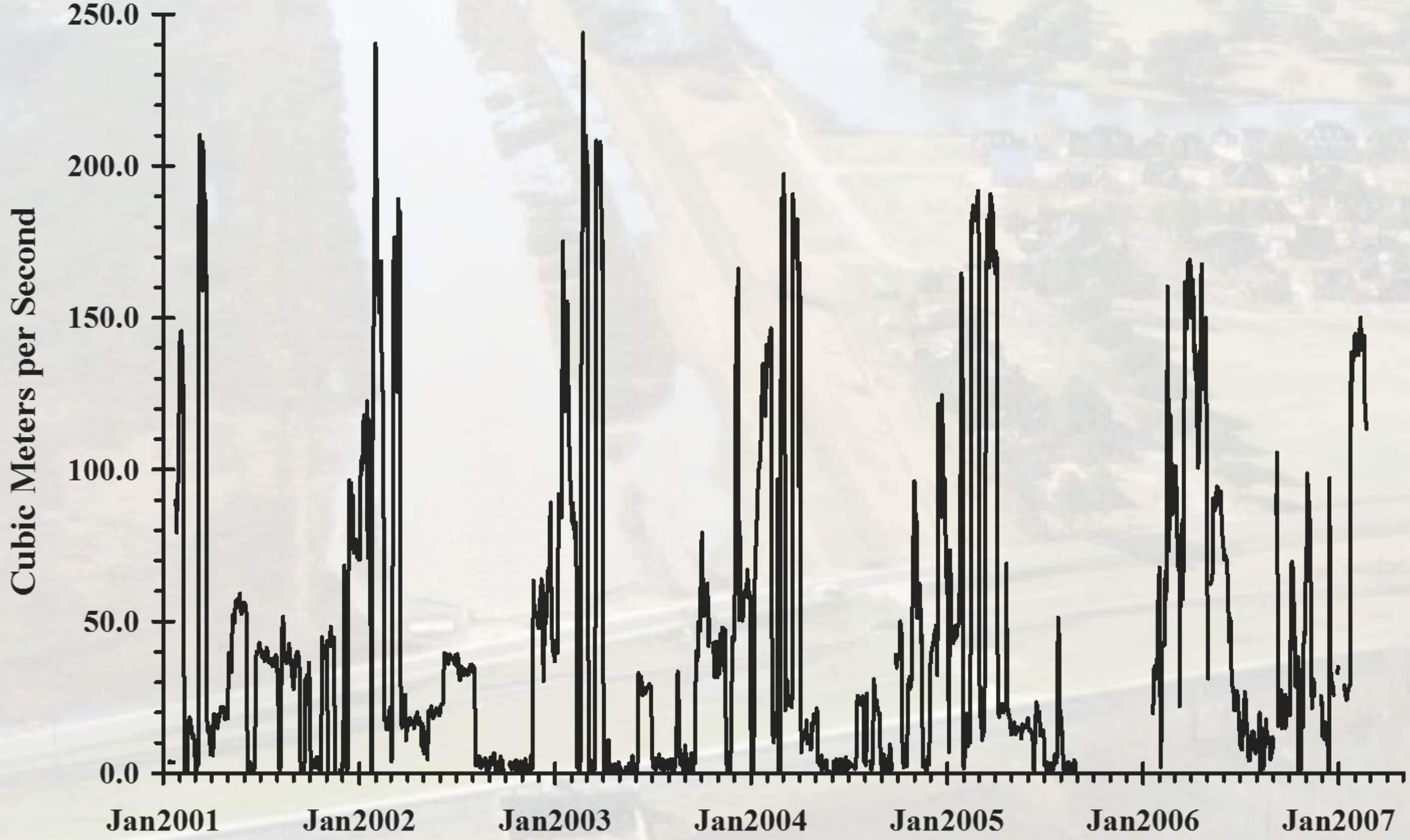
- The Mississippi River fuels the Gulf of Mexico coastal ecosystem
- Effects of hypoxia and nutrient enrichment are species-specific
- General trend: Mississippi River discharge increases GOM biomass and landings, hypoxia reduces what could optimally be achieved

Management advise?

- Are current nutrient loads negatively affecting living marine resources in the GOM?
- Net effect seems positive, but:
  - ‘No forcing’ scenario should be replaced with a reduced loading scenario
  - Cost-benefit analysis of nutrient reduction

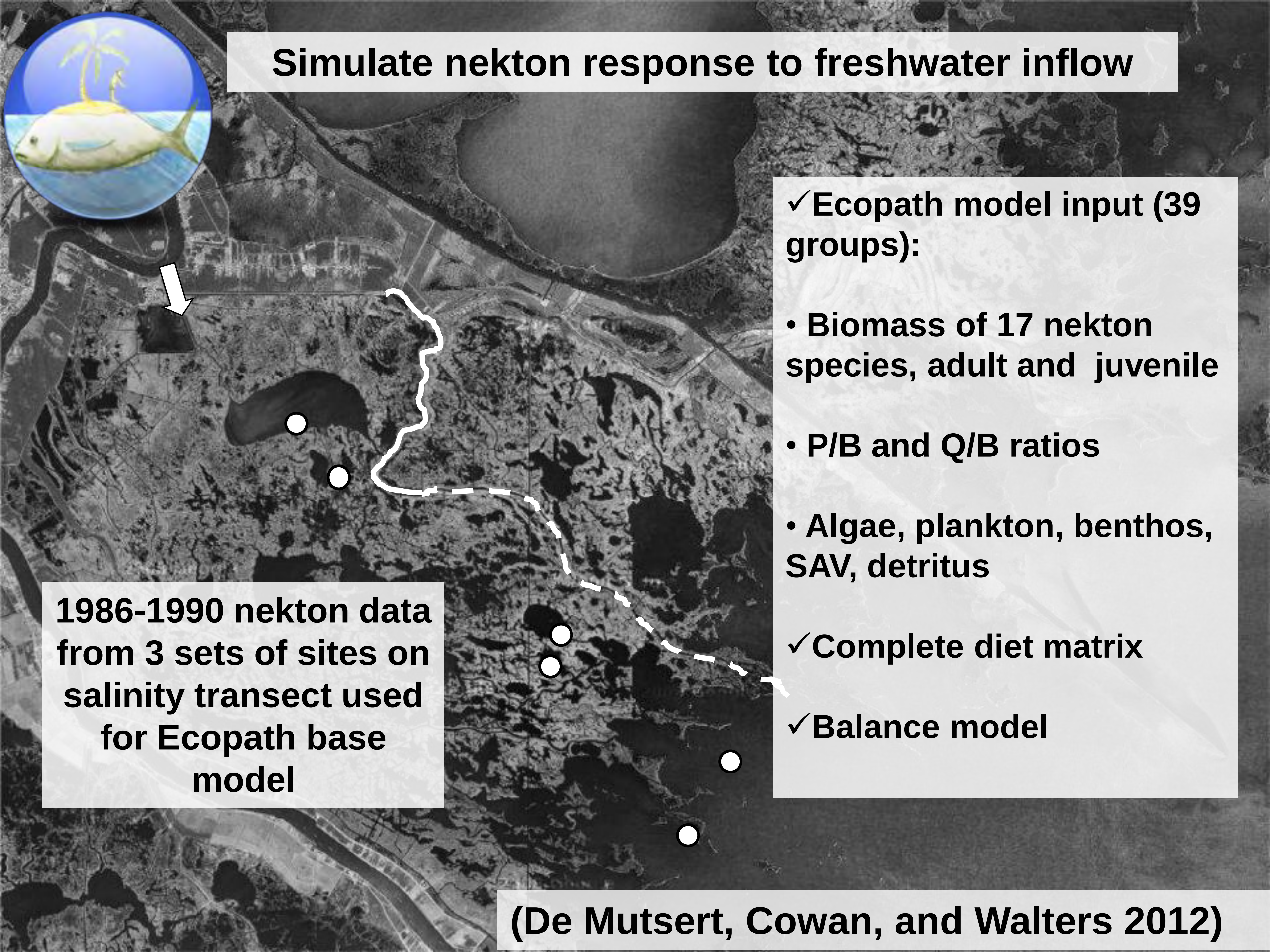
Effects of Diversions

Freshwater discharge through the Caernarvon Freshwater Diversion



sonris-www.dnr.state.la.us/www_root/sonris_portal_1.htm

Simulate nekton response to freshwater inflow



1986-1990 nekton data from 3 sets of sites on salinity transect used for Ecopath base model

✓Ecopath model input (39 groups):

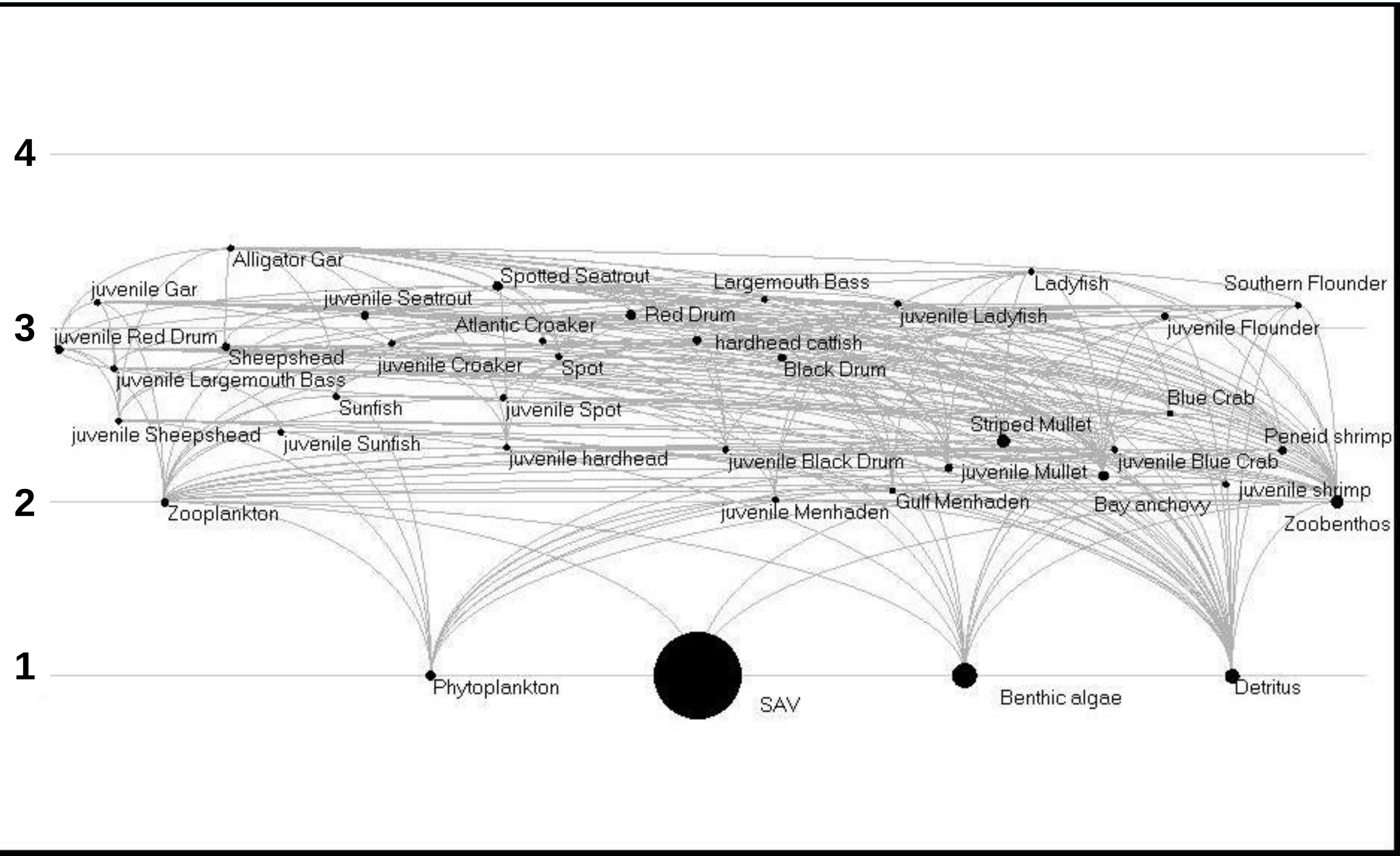
- Biomass of 17 nekton species, adult and juvenile
- P/B and Q/B ratios
- Algae, plankton, benthos, SAV, detritus

✓Complete diet matrix

✓Balance model

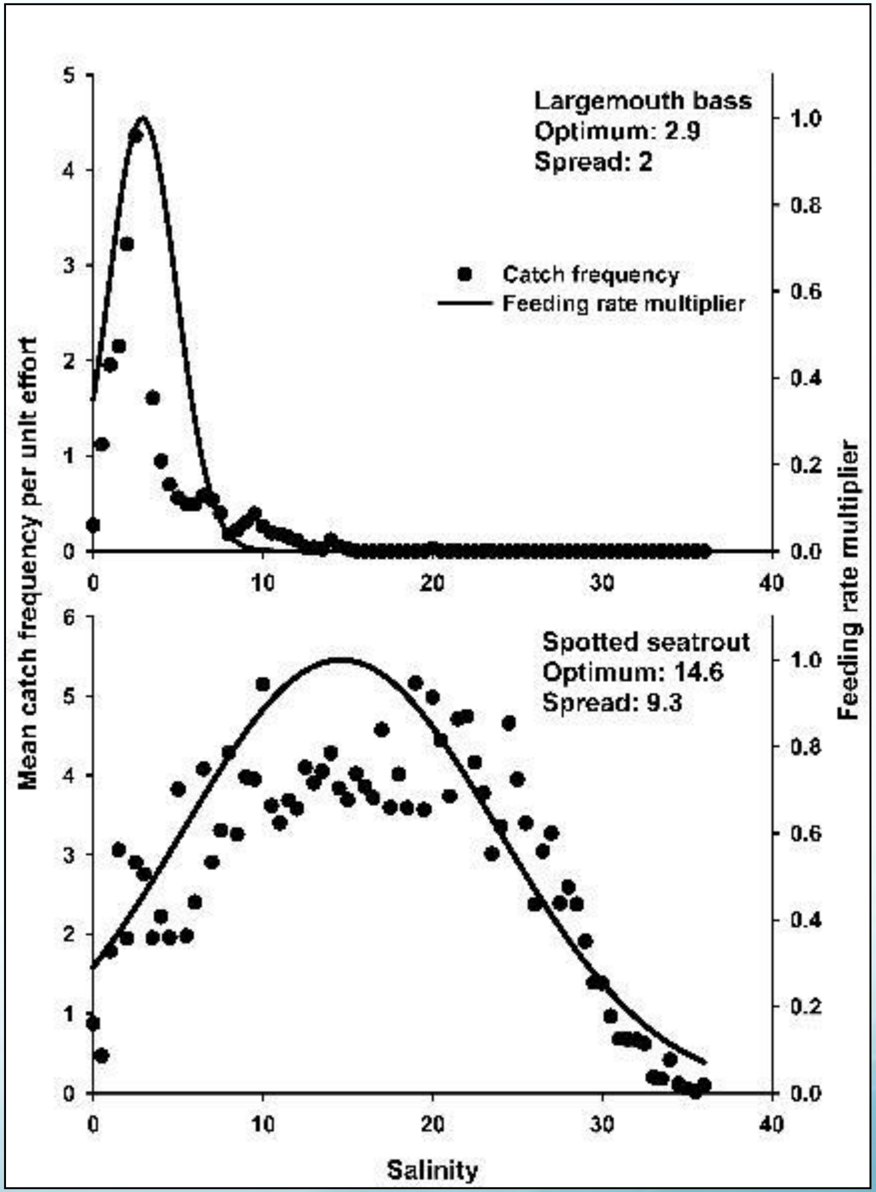
(De Mutsert, Cowan, and Walters 2012)

Breton Sound Ecopath model



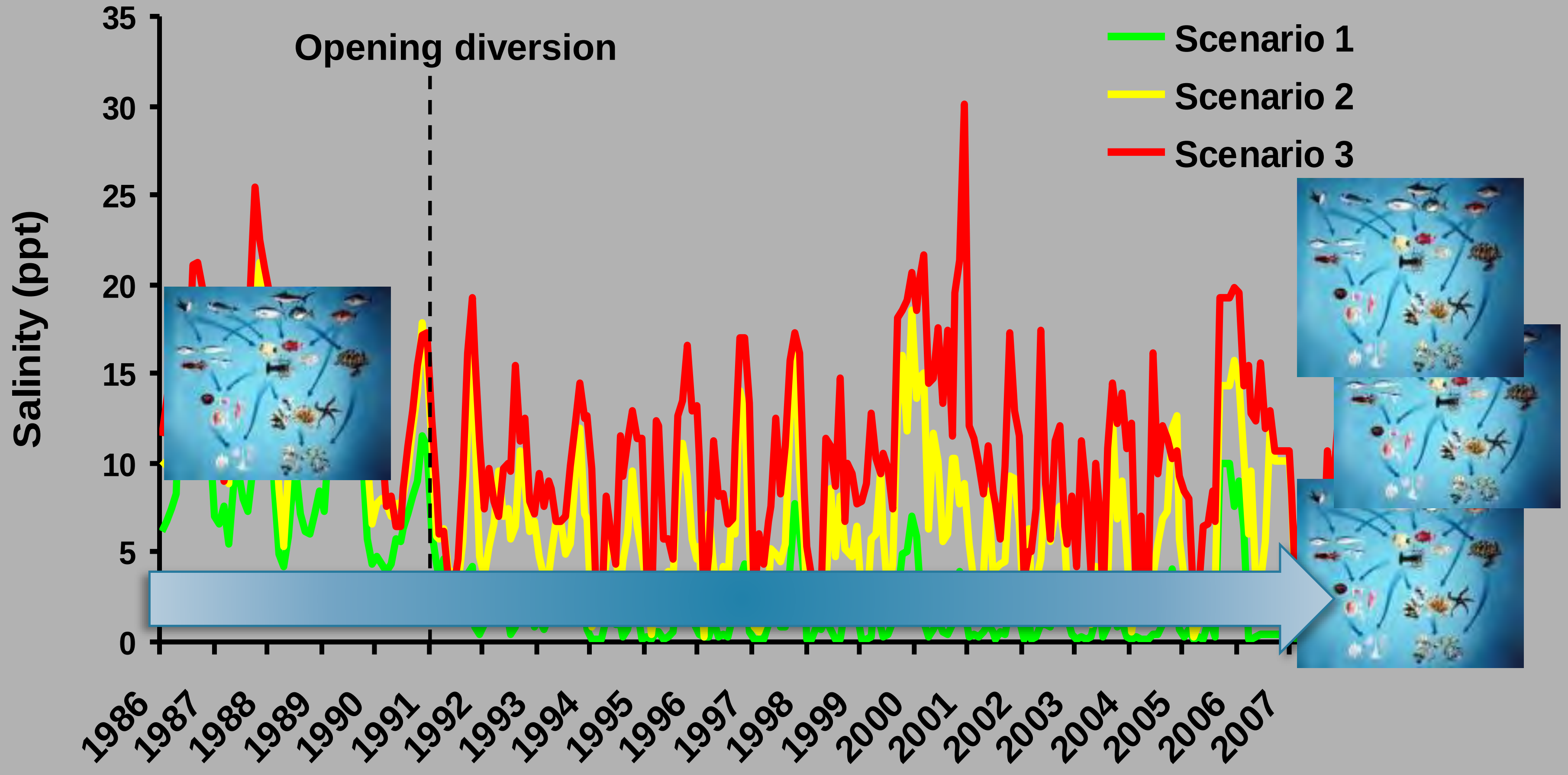
Environmental drivers

- Salinity only environmental forcing function
- Ecosim simulations at three distances from the diversion

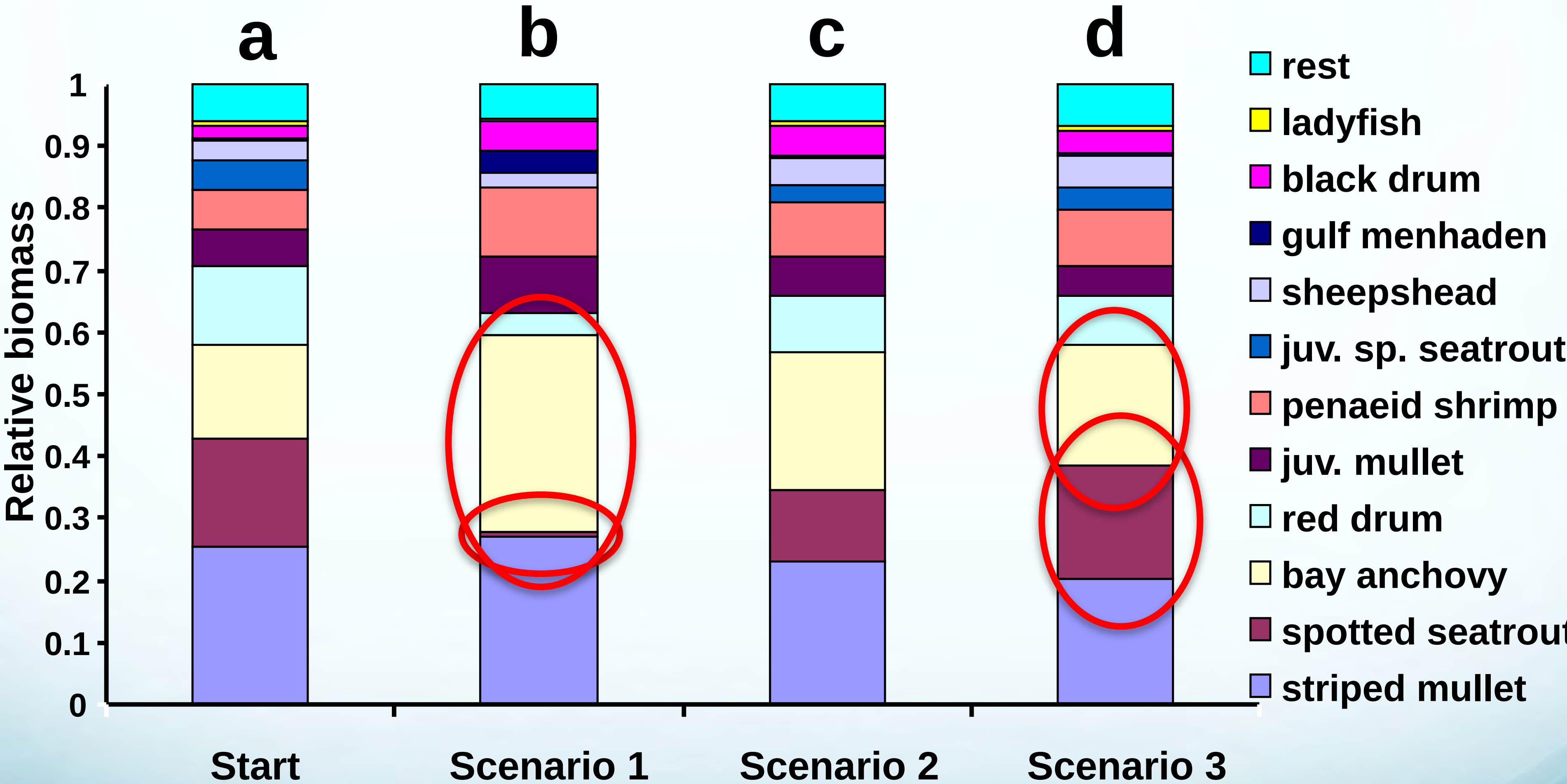


De Mutsert et al. 2012

Time dynamic Ecosim scenarios using salinity as forcing functions



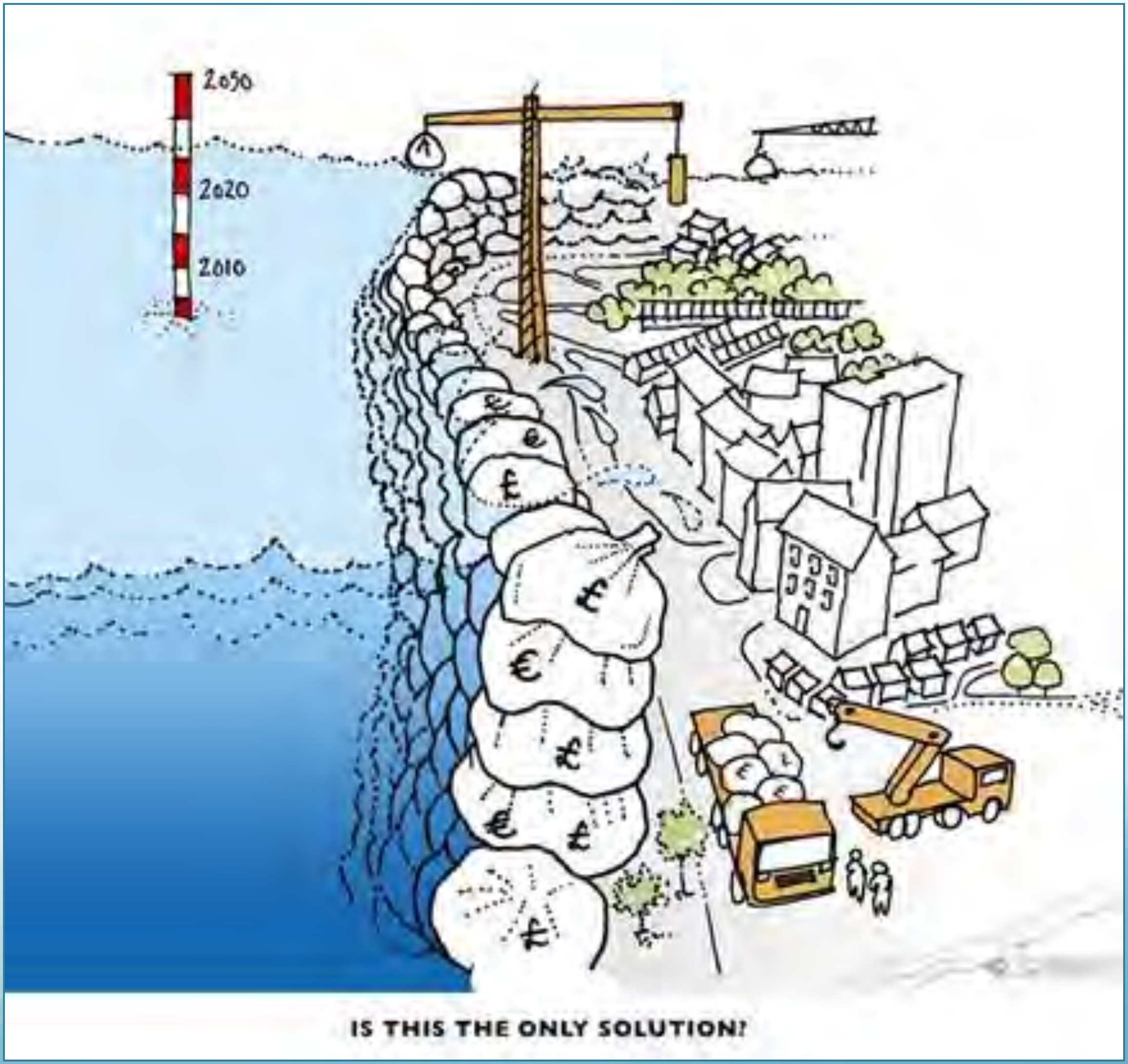
Ecosim results



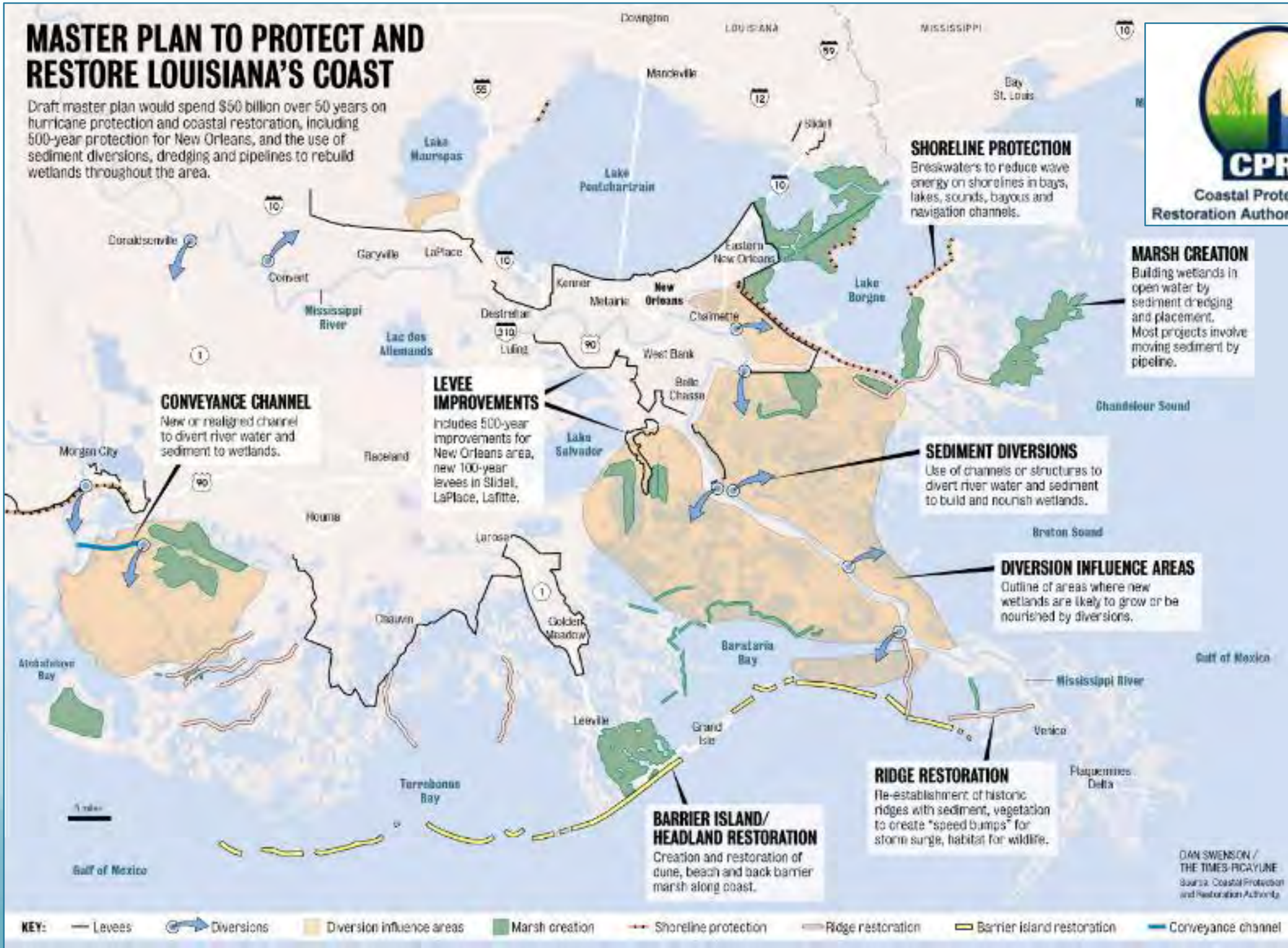
Before[a]	After[a]

Should river diversions be included in coastal restoration?

It should not be discouraged because of presumed negative impacts on fish and shrimp

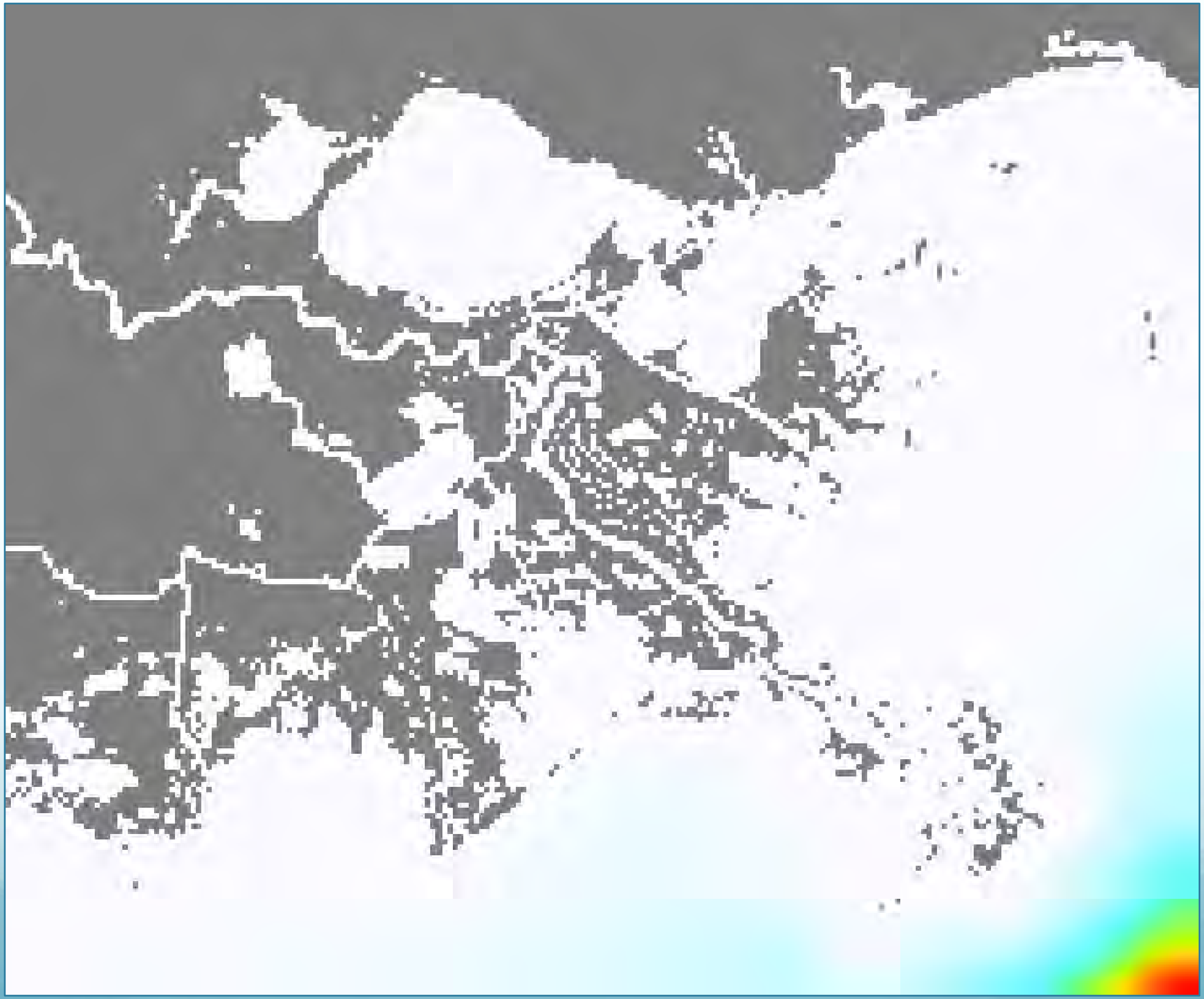


Future directions: what are the ecological effects of planned restoration projects?



CPRA
Coastal Protection and Restoration Authority of Louisiana

2017 Coastal Master Plan Ecospace Model



Questions?

Acknowledgements:

Input or data received from Katja Fennel, Arnaud Laurent, Jim Cowan, Carl Walters, Jeroen Steenbeek, Joe Buszowski, Rex Herron, and Aaron Adamack

Data used from SEAMAP and other NOAA NMFS data sources, LDWF, USGS, Fishbase, and LUMCON

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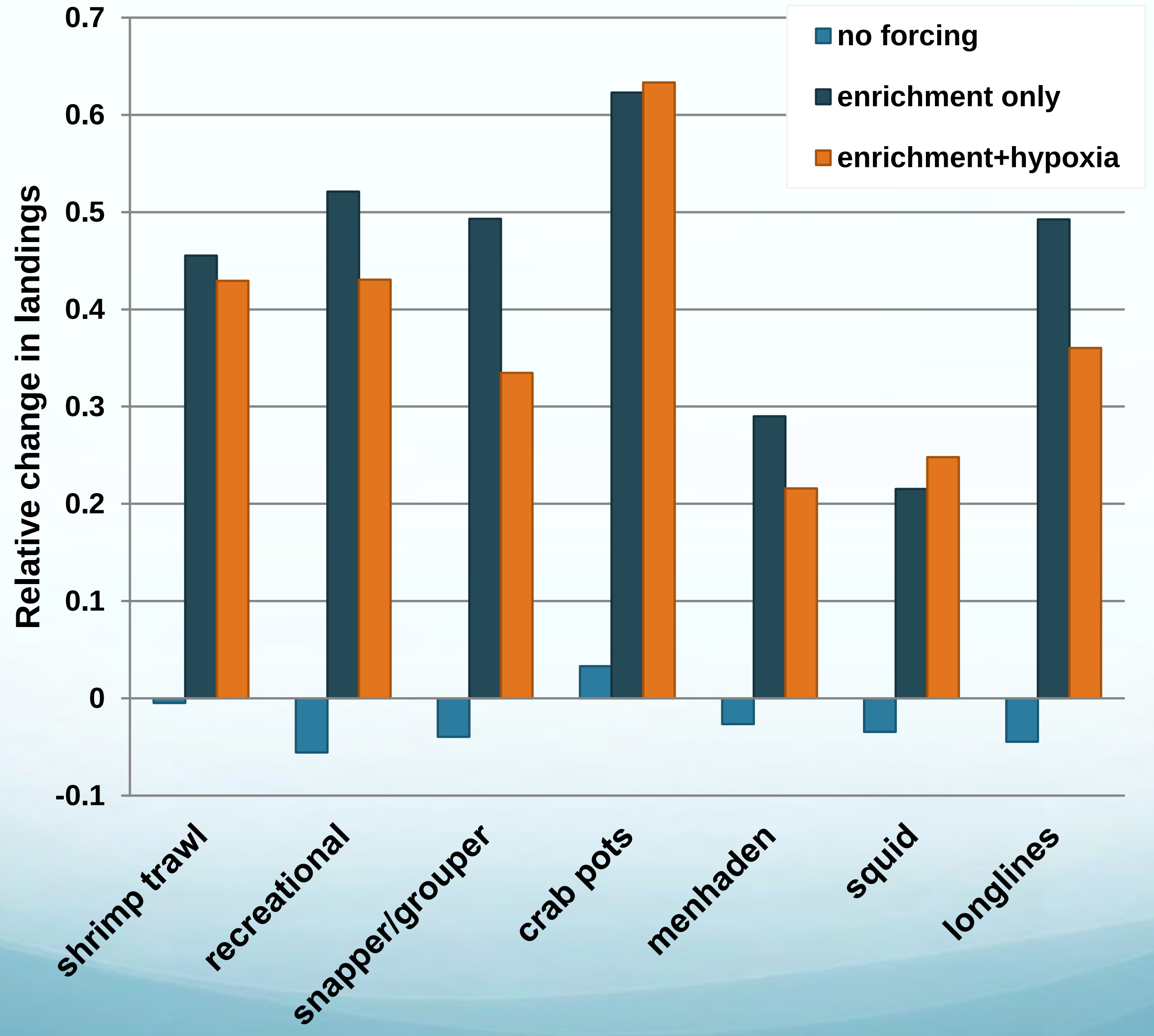
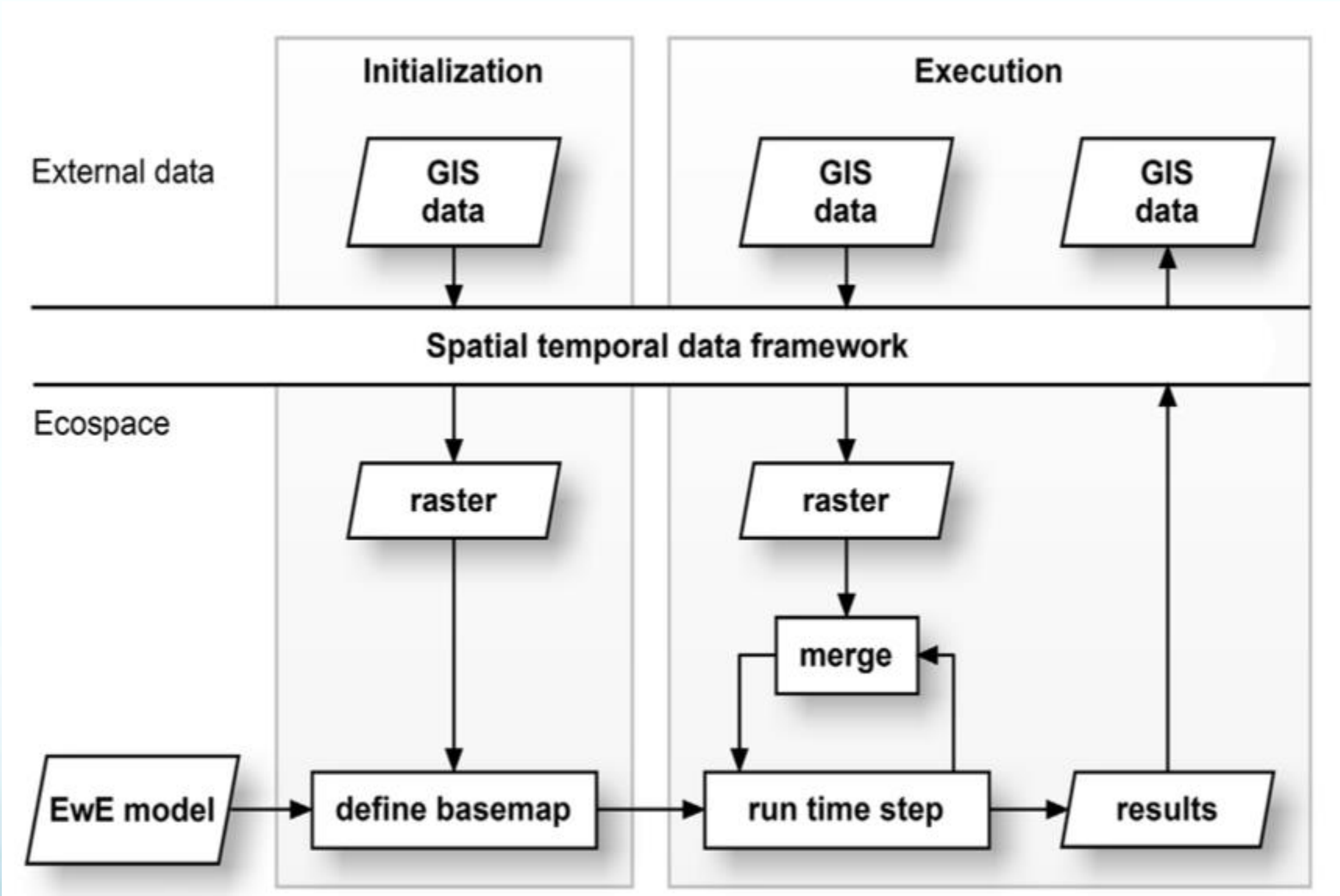
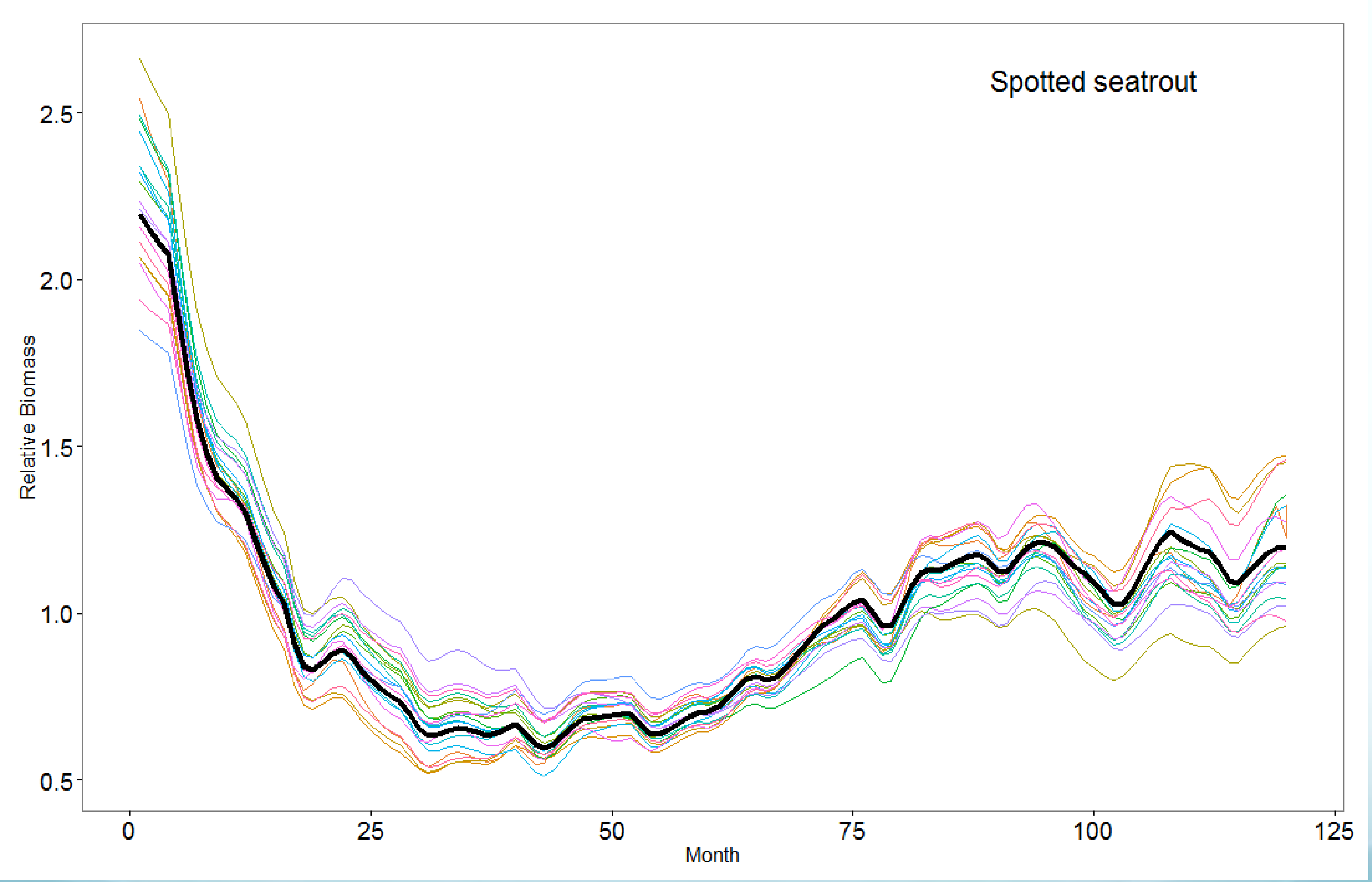
Results: landings



2017 Master Plan	NOAA NMFS	Scientific Name	Life Stage	Priority
Coastal sharks	.	*Carcharhinus leucas**	juvenile and adult	High
	Blacknose shark	*Carcharhinus acronotus*		Low
.	Bonnethead shark	*Sphyrna tiburo*		Low
.	Atlantic sharpnose shark	*Rhizoprionodon terraenovae*		Low
Bottlenose dolphin	Bottlenose dolphin	*Tursiops truncatus*		High
.	Kemp's Ridley sea turtles			High
.	Alligator gar	*Atractosteus spatula*	adult	Low
Seabirds	.	*Pelecanus occidentalis**		High
Spotted seatrout	Spotted seatrout	*Cynoscion nebulosus*	juvenile and adult	High
Red drum	Red drum	*Sciaenops ocellatus*	juvenile and adult	High
Black drum	Black drum	*Pogonias cromis*	juvenile and adult	High
Largemouth bass	Largemouth bass	*Micropterus salmoides*	juvenile and adult	High
Gulf sturgeon	.	*Acipenser oxyrinchus desotoi*	juvenile and adult	Low
Blue catfish	Blue catfish	*Ictalurus furcatus*	juvenile and adult	High
Sea catfish	.	*Ariopsis felis* and *Bagre marinus*	juvenile and adult	High
.	Florida pompano	*Trachinotus carolinus*	adult	Low
Southern flounder	Southern flounder	*Paralichthys lethostigma*	juvenile and adult	High
Sheepshead	Sheepshead	*Archosargus probatocephalus*	juvenile and adult	High
Atlantic croaker	Atlantic croaker	*Micropogonias undulatus*	juvenile and adult	High
.	Threadfin shad	*Dorosoma petenense*	adult	High
.	Gizzard shad	*Dorosoma cepedianum*	adult	High
.	Grey snapper	*Lutjanus gresius*		Medium
.	Cobia	*Rachycentron canadum*		Low
.	Lane snapper	*Lutjanus synagris*		Low
.	Dog snapper	*Lutjanus jocu*		Low
.	Spanish mackerel	*Scomberomorus maculatus*		Low
Spot	Spot	*Leiostomus xanthurus*	juvenile and adult	High
.	Pinfish	*Lagodon rhomboides*		High
.	Silver perch	*Bairdielle chrysoura*		Medium
Sunfishes	Sunfishes	*Lepomis sp.*	juvenile and adult	High
Striped mullet	Striped mullet	*Mugil cephalus*	juvenile and adult	High
Bay anchovy	Bay anchovy	*Anchoa mitchilli*	juvenile and adult	High
Killifishes	Gulf killifish	*Fundulus grandis**		High
Silversides	.	*Menidia beryllina* and *Membras martinica**		Medium
Blue crab	Blue crab	*Callinectes sapidus*	juvenile and adult	High
White shrimp	White shrimp	*Litopenaeus setiferus*	juvenile and adult	High
Brown shrimp	Brown shrimp	*Farfantepenaeus aztecus*	juvenile and adult	High
Gulf menhaden	Gulf menhaden	*Brevoortia patronus*	juvenile and adult	High
Grass shrimp	Grass shrimp	*Palaemonetes spp.*		High
.	Crawfish	*Procambarus sp.*		Low
.	Bay squid			Low
Oyster drill	.			High
Eastern oyster	American oyster	*Crassostrea virginica*	spat, adult, market size	High
Benthic crabs	.			Medium
Mollusks	.			Medium
Zooplankton	.			High
Zoobenthos	.			High
Phytoplankton	.			High
SAV	.			High
Benthic algae	.			High
Detritus	.		NA	High

2017 Master Plan	Scientific Name	Gillnet	Seine	Trawl	Square-Meter	Data Source
Coastal sharks	*Carcharhinus leucas*	131	2	7		**Geers et al. 2014**
Spotted seatrout	*Cynoscion nebulosus*	**25043**	3395	2869		LDWF FIMP Gillnet
Red drum	*Sciaenops ocellatus*	**3752**	1729	330		LDWF FIMP Gillnet
Black drum	*Pogonias cromis*	**4096**	293	475		LDWF FIMP Gillnet
Largemouth bass	*Micropterus salmoides*	**915**	965	28		LDWF FIMP Gillnet
Blue catfish	*Ictalurus furcatus*	500	101	**2314**		LDWF FIMP Trawl
Sea catfish	*Ariopsis felis/Bagre marinus*	28066	10973	**42764**		LDWF FIMP Trawl
Southern flounder	*Paralichthys lethostigma*	214	468	**2115**		LDWF FIMP Trawl
Sheepshead	*Archosargus probatocephalus*	**2880**	476	784		LDWF FIMP Trawl
Atlantic croaker	*Micropogonias undulatus*	11087	59387	**588756**		LDWF FIMP Trawl
Spot	*Leiostomus xanthurus*	22463	15098	**134158**		LDWF FIMP Trawl
Sunfish	*Lepomis macrochirus/microlophus*	305	**4802**	194		LDWF FIMP Seine
Striped mullet	*Mugil cephalus*	8892	**20833**	2039		LDWF FIMP Seine
Bay anchovy	*Anchoa mitchilli*	7	520700	**2304746**		LDWF FIMP Trawl
Killifishes	*Fundulus grandis/similis/spp.*	0	**10649**	48		LDWF FIMP Seine
Silversides	*Menidia beryllina/Membras martinica*	0	**120616**	3242		LDWF FIMP Seine
Blue crab	*Callinectes sapidus/similis*	5763	21315	**65473**		LDWF FIMP Trawl
White shrimp	*Litopenaeus setiferus*	6446	18855	**232264**		LDWF FIMP Trawl
Brown shrimp	*Farfantepenaeus aztecus*	59	26958	**514162**		LDWF FIMP Trawl
Gulf menhaden	*Brevoortia patronus*	90412	**178740**	69534		LDWF FIMP Seine
Grass shrimp	*Palaemonetes spp.*	0	**258434**	32615		LDWF FIMP Seine
Oysters					**28522**	LDWF FIMP Square-Meter

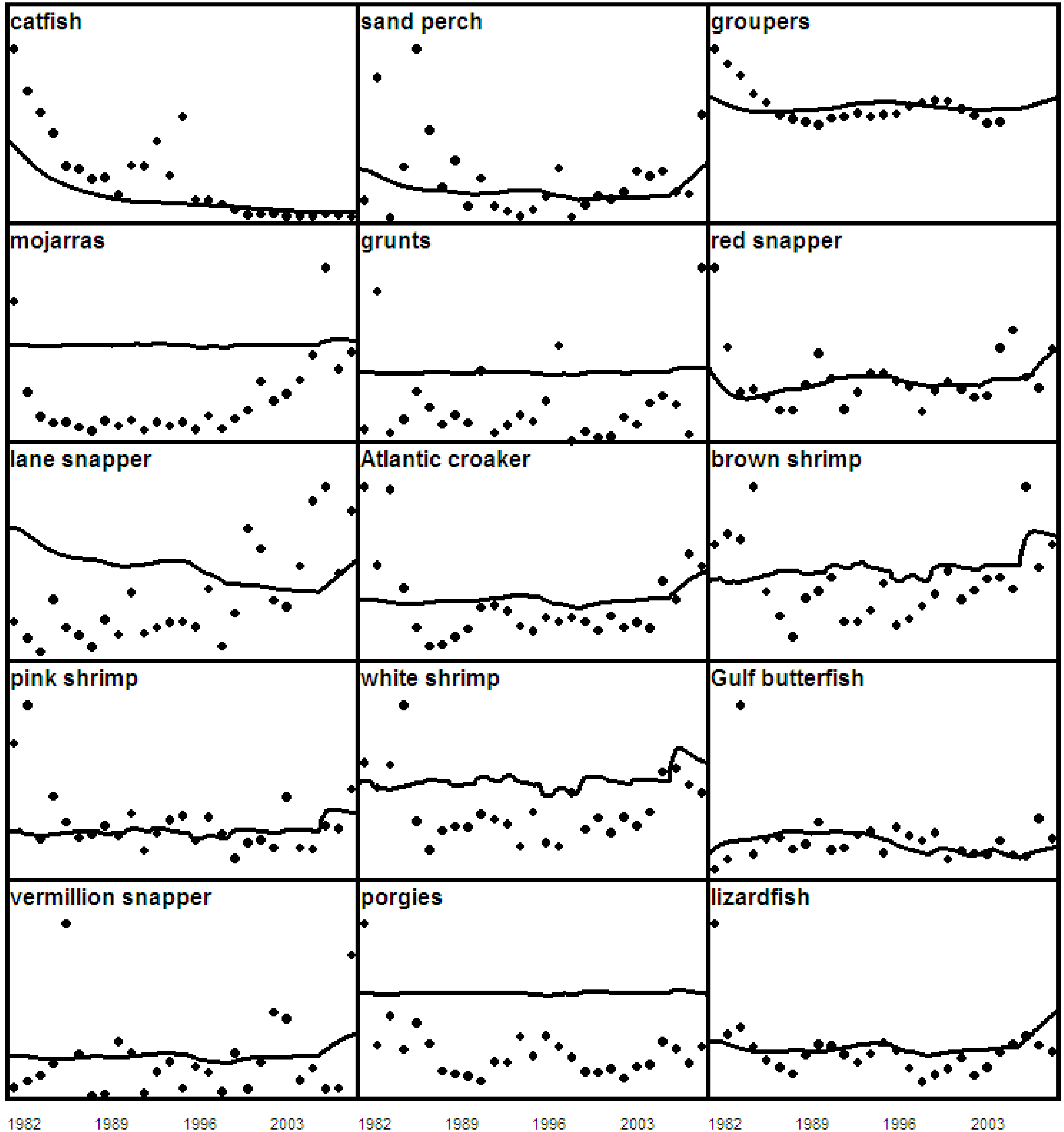

Initialization
Execution
External data
GIS data
GIS data
GIS data
Spatial temporal data framework
Ecospace
raster
raster
merge
EwE model
define basemap
run time step
results



Spotted seatrout
Relative Biomass
2.5
2.0
1.5
1.0
0.5
0
25
50
75
100
125
Month

Ecosim model runs versus absolute biomass time series

No DO forcing
SS = 780



Ecosim model runs versus absolute biomass time series

With DO forcing SS = 670