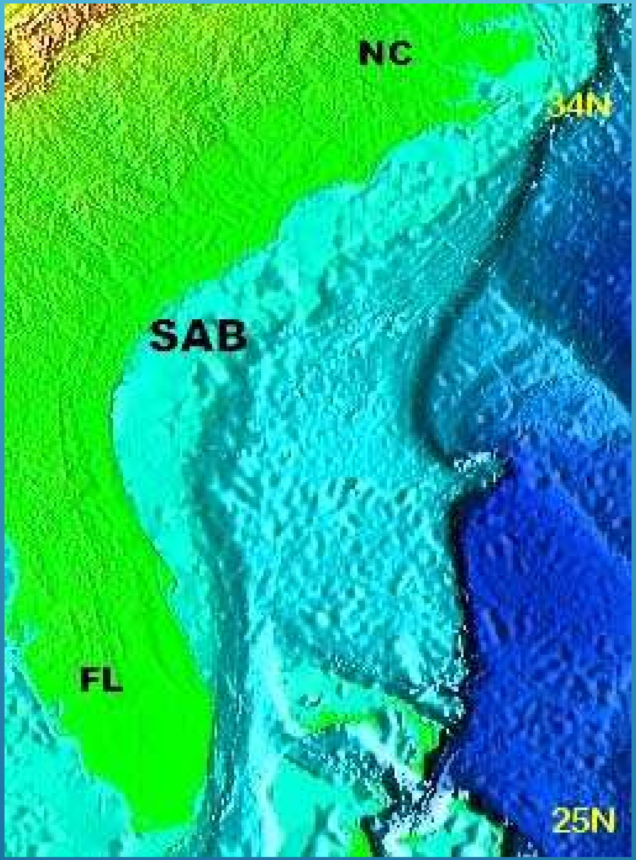
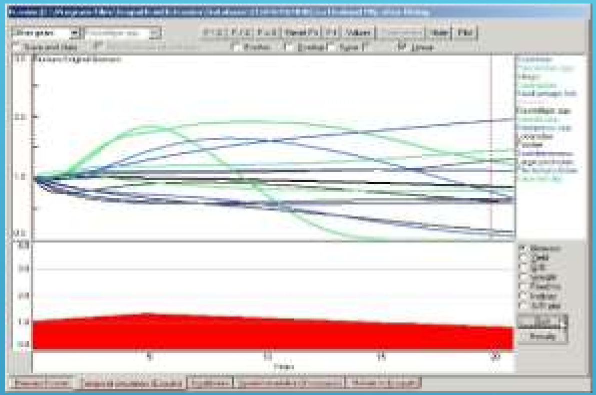
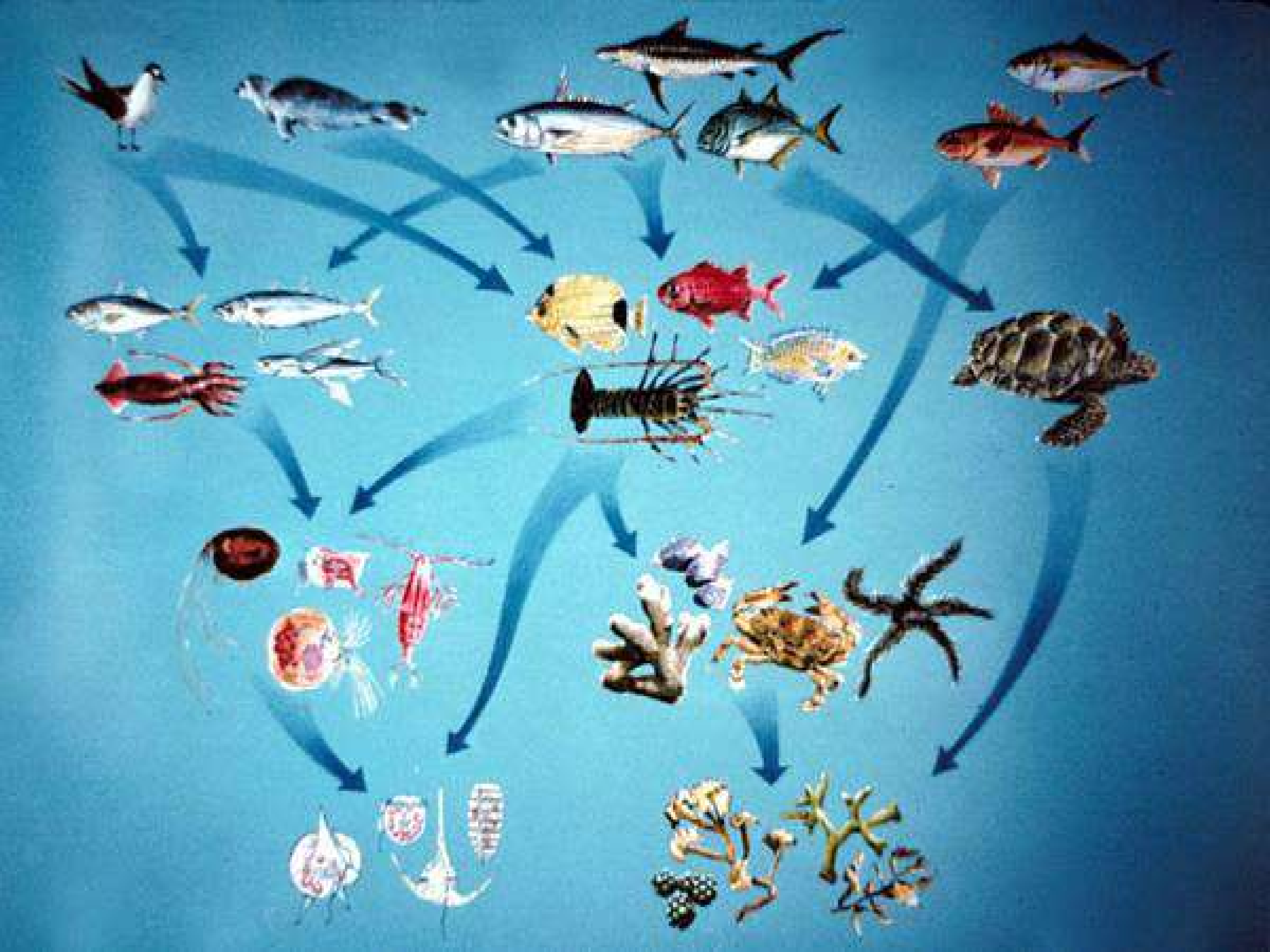
THE ECOPATH MODEL OF THE SOUTH ATLANTIC BIGHT: A FORAGE FISH EMPHASIS



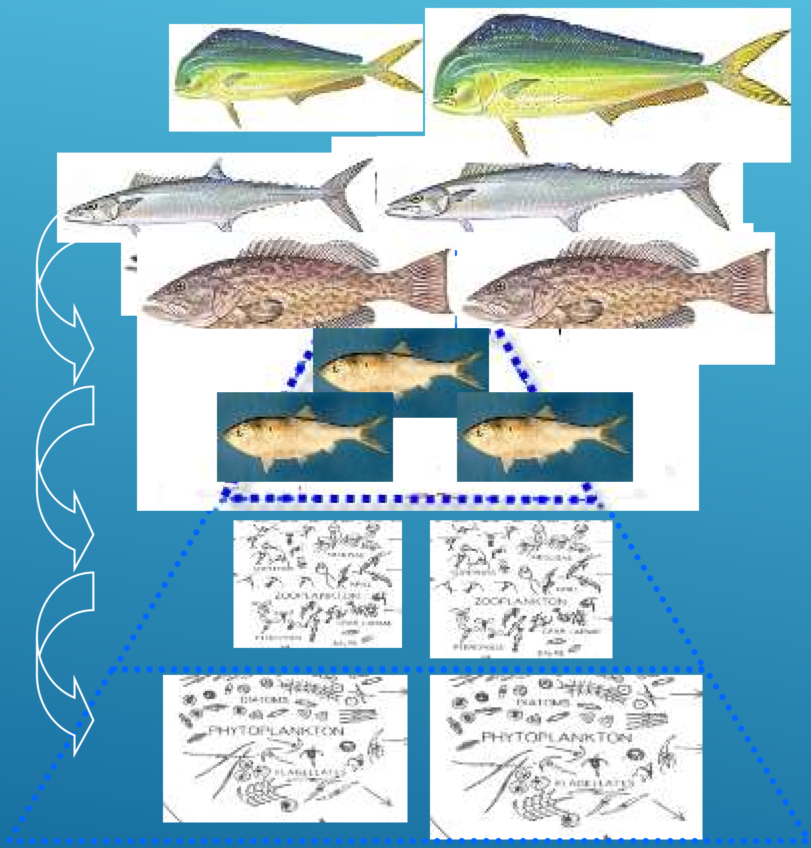


Tom Okey, University of Victoria / Ocean Integrity Research

South Atlantic Ecosystem Model Workshop, 10-11 Feb 2015



FOOD WEB MODELING

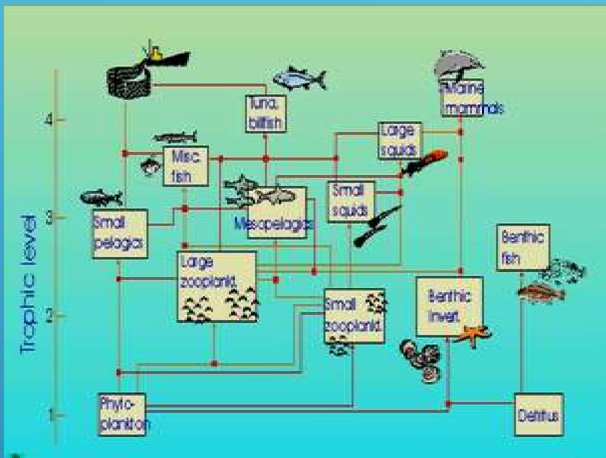


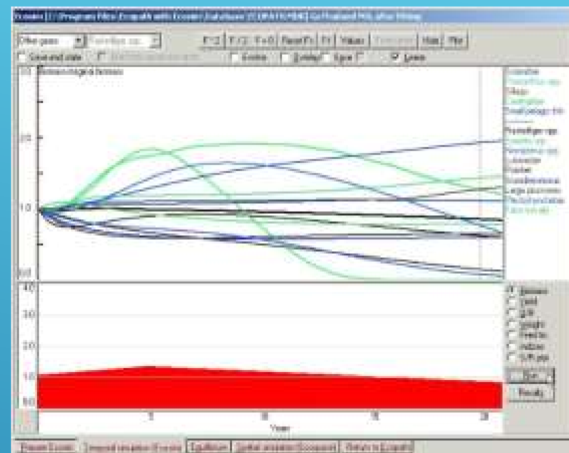
Preliminary Ecopath models have been developed for the South Atlantic Region

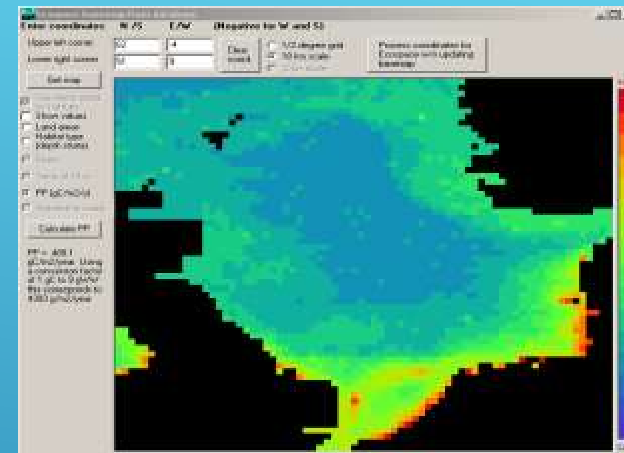
Presently facilitating regional collaboration on future model development including but not limited to a South Atlantic visualized Ecopath with Ecosim model developed through the Pew Charitable Trusts

Adapted from: S. Murawski. 2004. The challenge of Managing Marine Resources in 5 Dimensions. Workshop on GIS Tools Supporting Ecosystem Approaches to Management . NOAA-CSC.

ECOPATH / ECOSIM / ECOSPACE







WHAT IS ECOPATH / ECOSIM / ECOSPACE?

- Ecopath: **A trophodynamic fishery-ecosystem model that accounts for all flows and components**
- Ecosim: **Allows temporal simulation of the ecological and socio-economic effects of changes in fisheries or other stressors**
- Ecospace: **Allows exploration of spatially-explicit questions such as the effects of habitat protection on the ecological and socio-economic values**

PEW INSTITUTE FOR OCEAN SCIENCE

EXAMPLE USES IN THE SAB

- Exploring the effects of fishing on sensitive species
- Exploring the importance forage fishes
- Exploring the ecological effects of climate change
- Exploring the effects of climate importance of habitat

Ecopath master equation

$$\mathbf{B_i \cdot (P/B)_i \cdot EE_i = Y_i + \Sigma\, B_j \cdot (Q/B)_j \cdot DC_{ji} + BA_i + NM_i}$$

B_i and B_j are biomasses of prey ($_i$) and predators ($_j$) respectively;

P/B_i is the production/biomass ratio;

EE_i is the ecotrophic efficiency;

Y_i is the fisheries catch per unit area and time (i.e., Y = F*B);

Q/B_j is the food consumption per unit biomass of j;

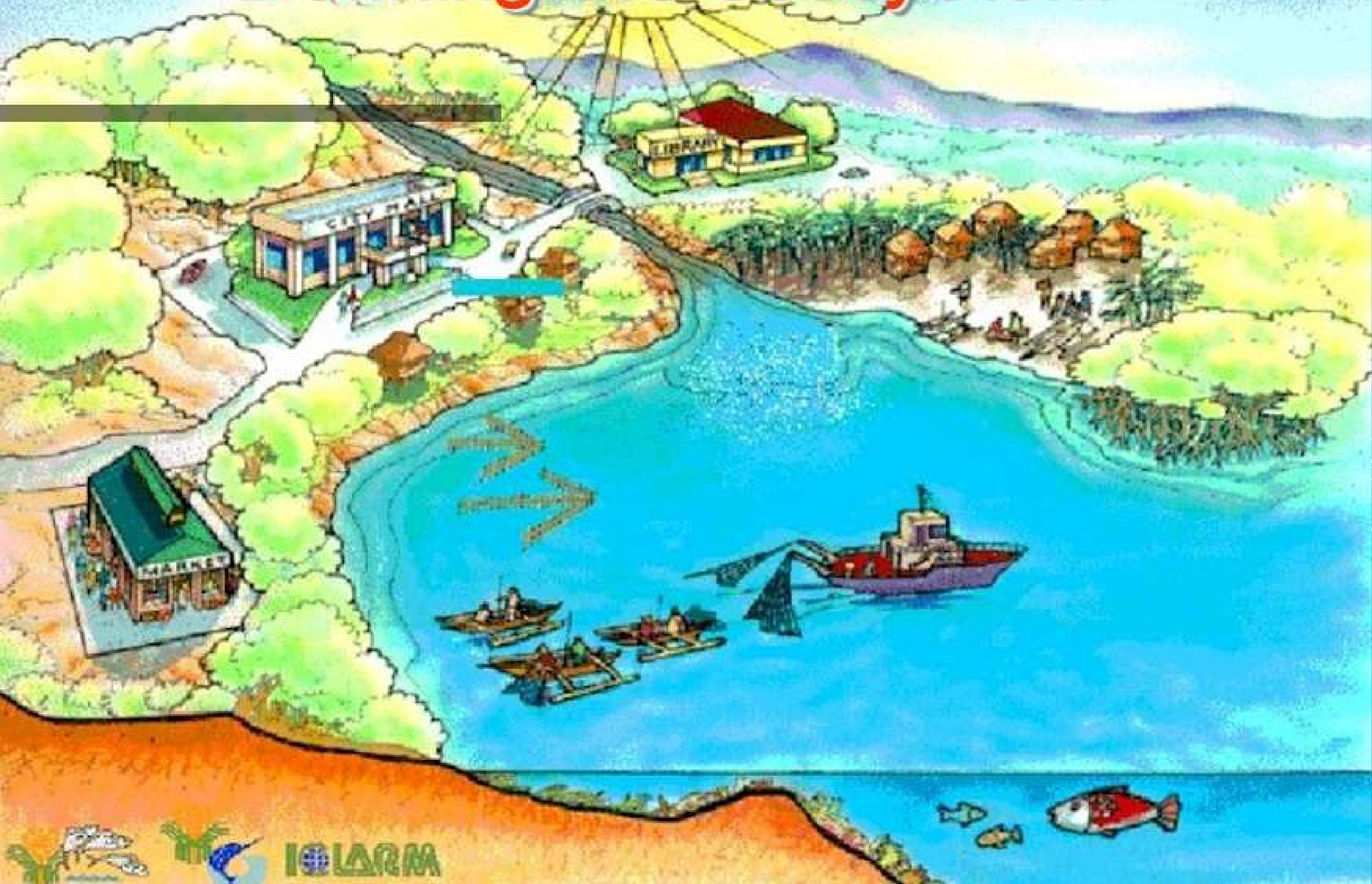
DC_{ji} is the contribution of i to the diet of j;

BA_i is the biomass accumulation of i (positive or negative); and

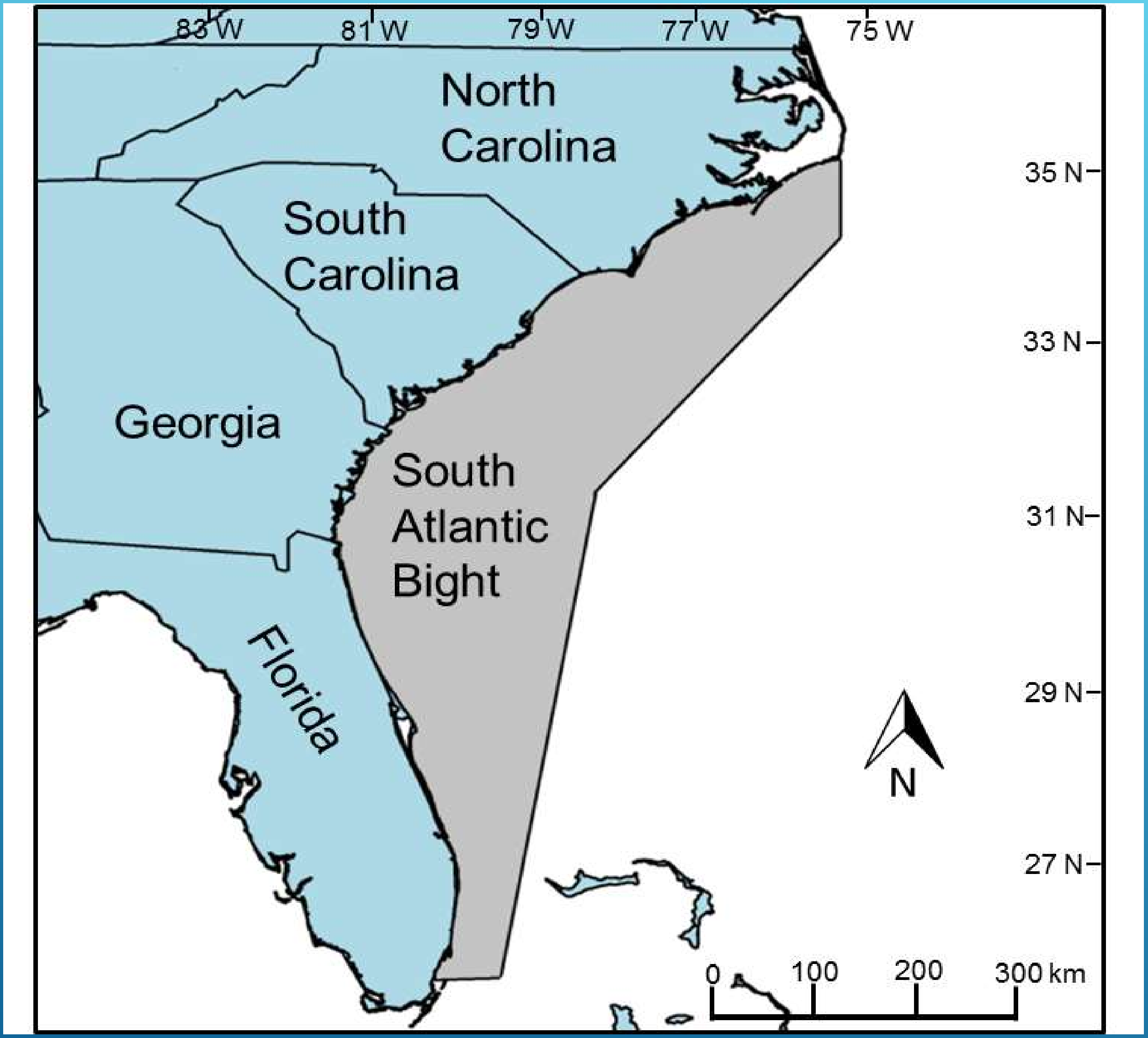
NM_i is the net migration of I (emigration less immigration).

Consumption = production + respiration + unassimilated food

Defining the ecosystem



EXAMPLES FROM SOUTH ATLANTIC BIGHT



Production = predation

+ fishery

+ biomass accumulation

+ net migration

+ other mortality

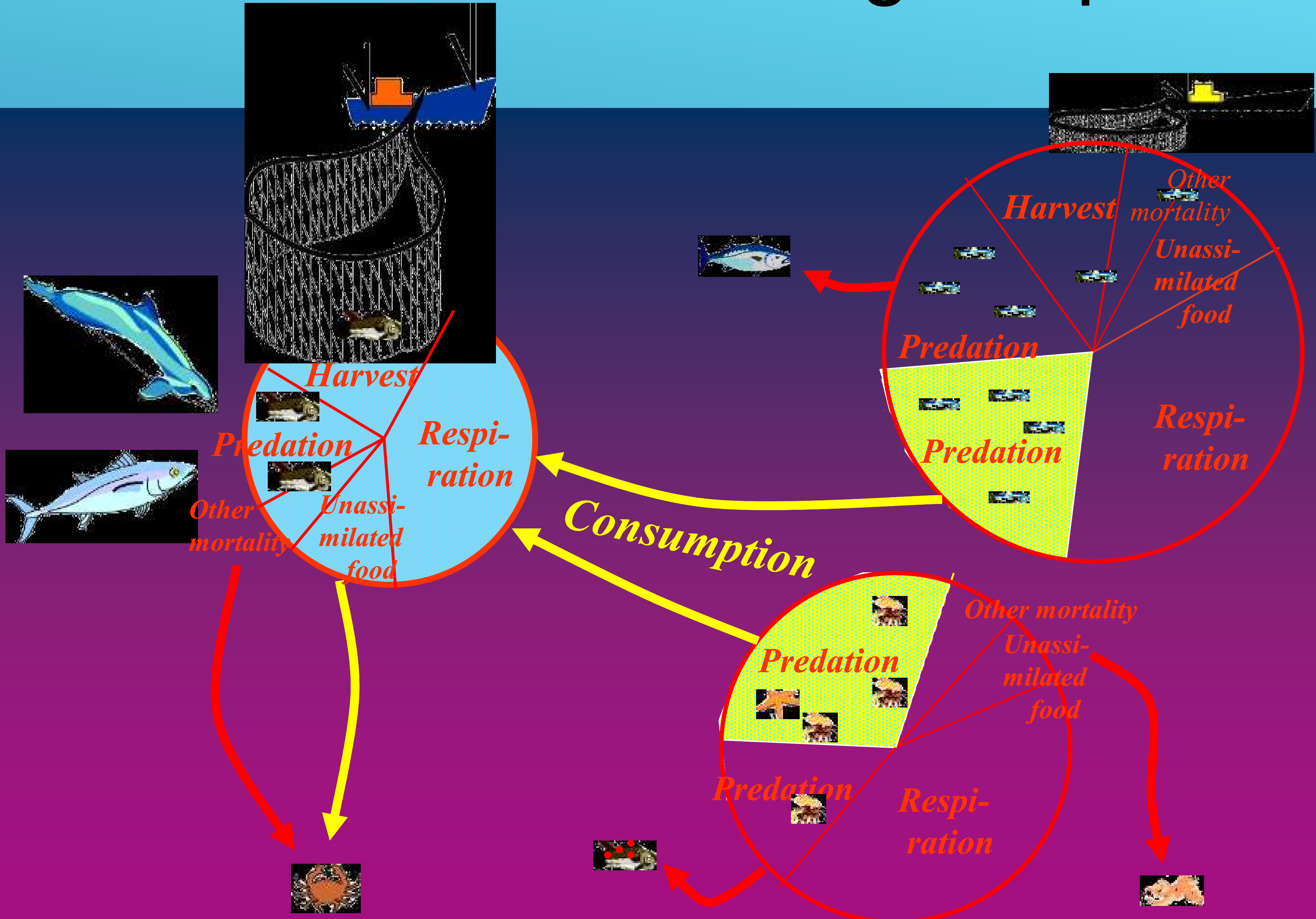
Consumption

= production

+ respiration

+ unassimilated food

Mass balance: cutting the pie



ECOSIM

$$\frac{dB_i}{dt} = f(B_i) - M \cdot B_i - F_i \cdot B_i - \sum_{j=1}^{n} c_{ij}(B_i \cdot B_j)$$

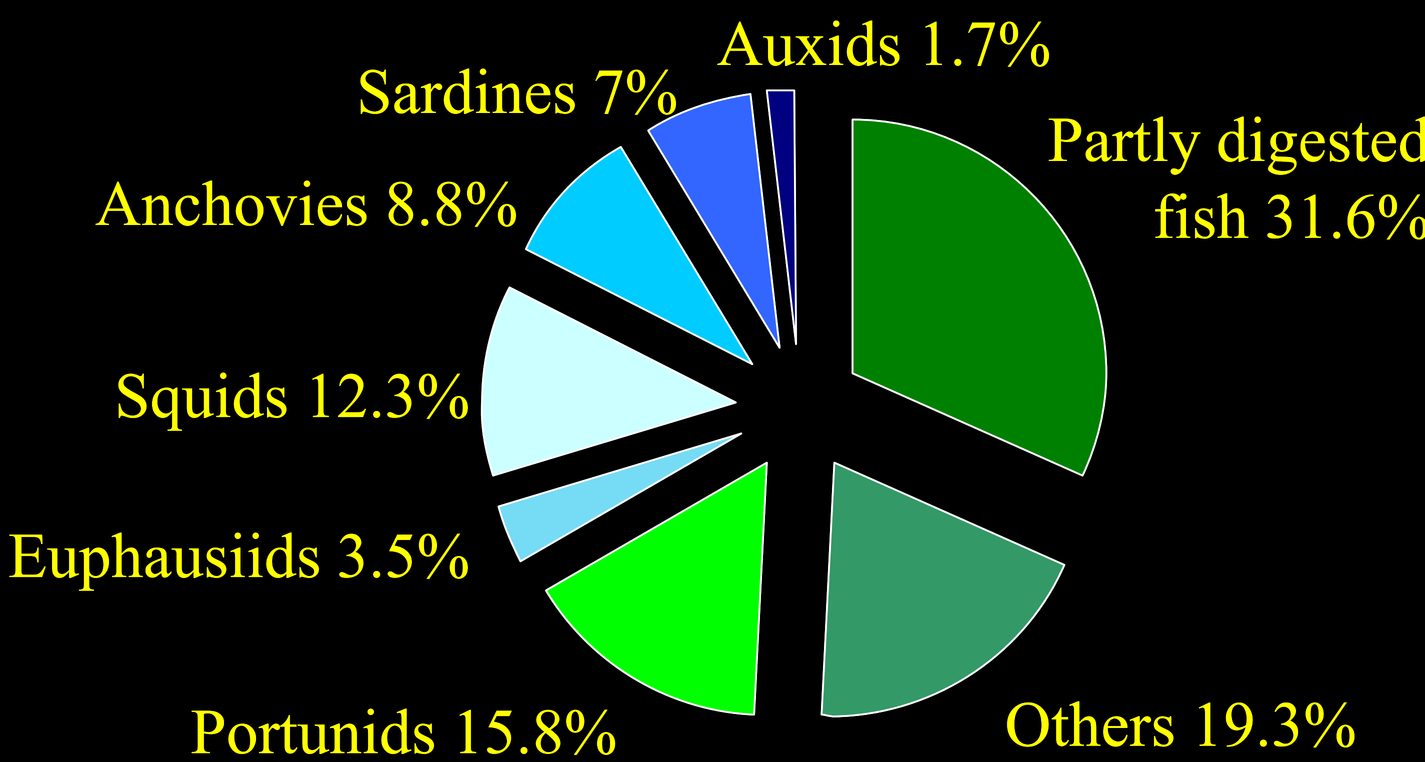
$$C_{ij} = \frac{v_{ij} a_{ij} B_i B_j}{v_{ij} + v'_{ij} + a_{ij} B_j}$$

C_{ij} is the trophic flow of biomass per time, between prey (i) and predato

B_i and B_j are the biomasses of prey and predators, respectively;

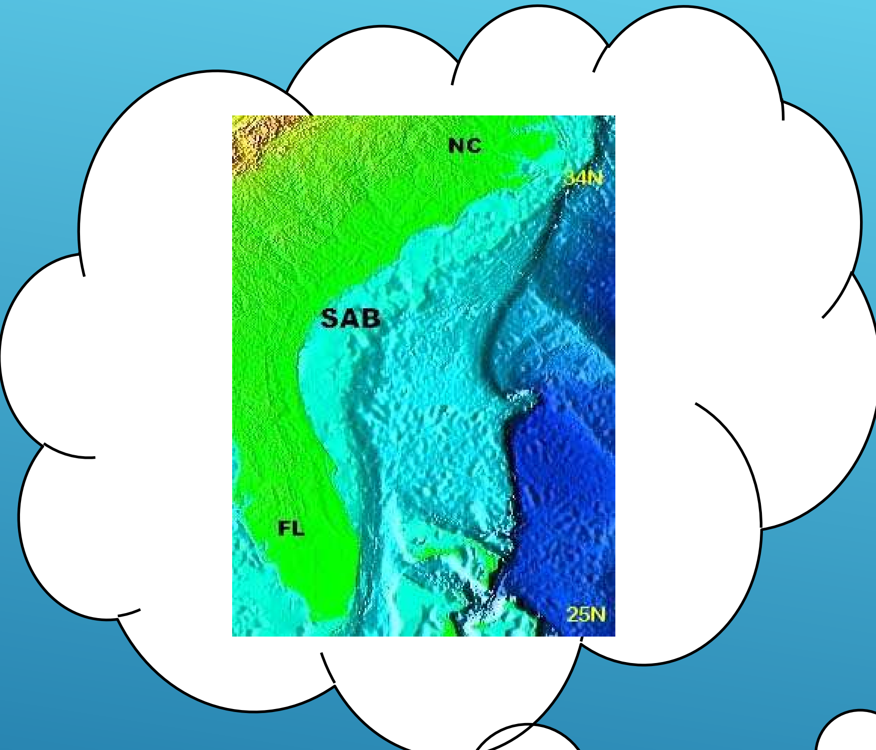
a_{ij} is the rate of effective search for prey i by predator j; and

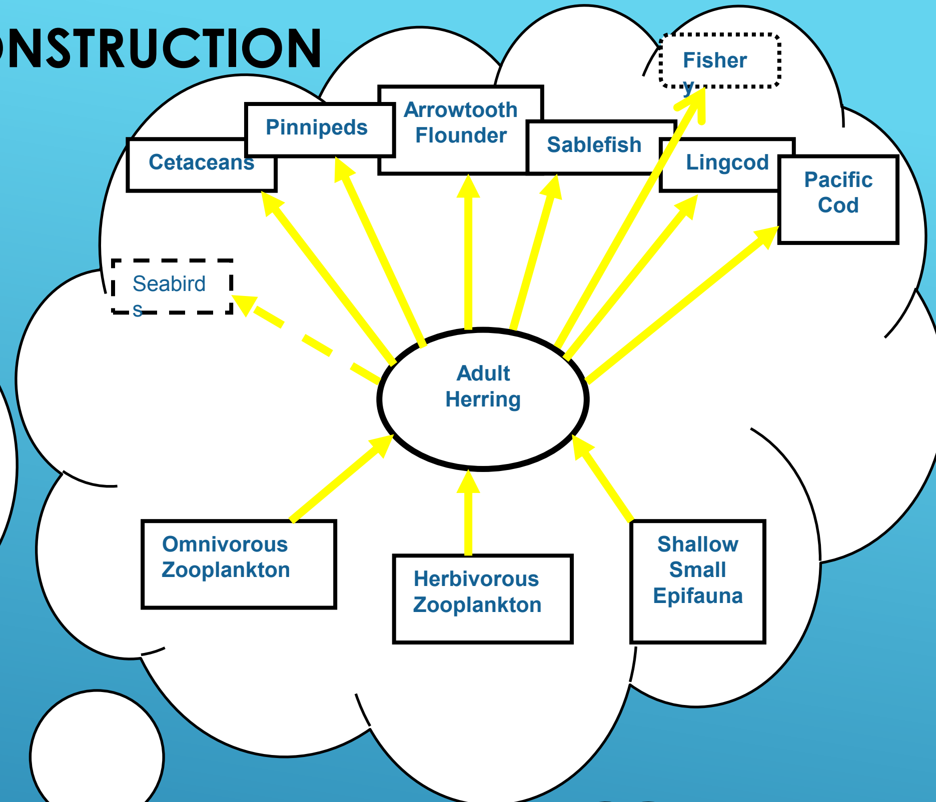
v_{ij} and v'_{ij} are prey vulnerability parameters, with default setting $v_{ij} = v'$



Use volume or weight!

COLLABORATIVE CONSTRUCTION





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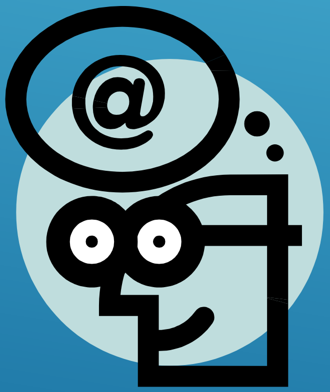

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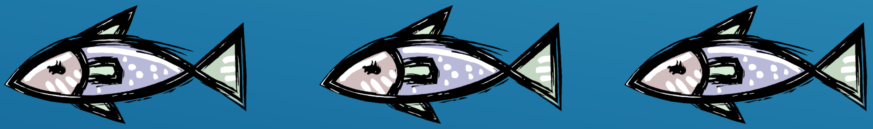

HISTORY OF THE SAB MODEL

- 2001 - Strawman 48-box model constructed
- 2004 - Preliminary 98-box model developed
- 2013 - Model refined to address forage fish questions

Front-loading & refinement

- 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

Application to forage question

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

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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

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Year: 2014

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

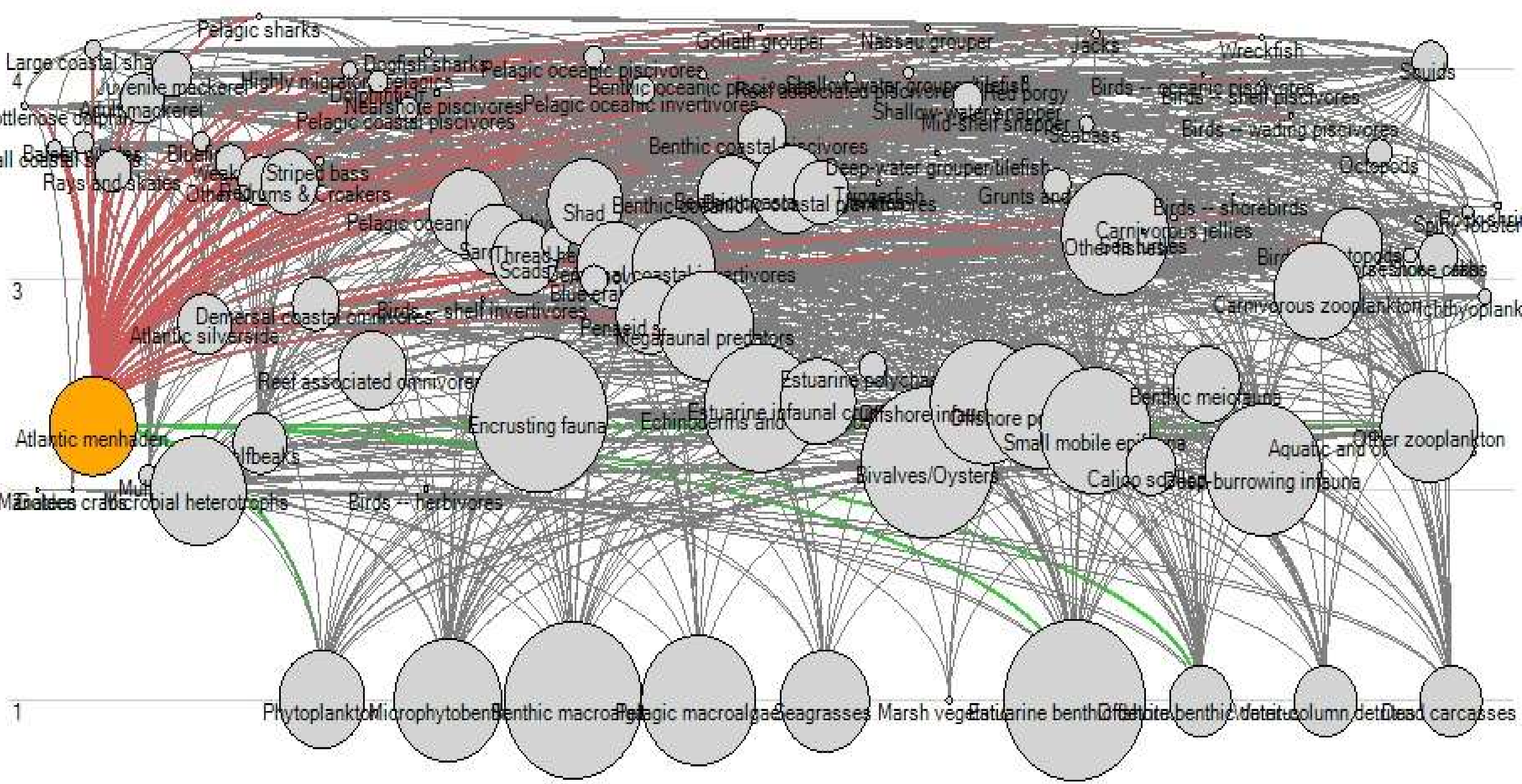
Articulated forage groups in the present 99-box South Atlantic Bight *EwE* model

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

Species / Groups in SAB 99-box model

Dogfish sharks	Demersal coastal omnivores	Birds -- shelf piscivores	Benthic meiofauna
Adult mackerel	Benthic oceanic piscivores	Rock shrimps	Deep-burrowing infauna
Juvenile mackerel	Benthic oceanic invertivores	Penaeid shrimps	Carnivorous zooplankton
Bluefish	Benthic coastal piscivores	Megafaunal predators	Aquatic and other insects
Weakfish	Benthic coastal invertivores	Echinoderms and gastropods	Other zooplankton
Red drum	Benthic coastal planktivores	Estuarine infaunal crustaceans	Ichthyoplankton
Atlantic menhaden	Reef associated piscivores	Birds -- herbivores	Microbial heterotrophs
Mullets	Reef associated omnivores	Birds -- wading piscivores	Phytoplankton
Other Drums & Croakers	Triggerfish	Birds -- shelf invertivores	Microphytobenthos
Striped bass	Shallow water grouper/tilefish	Birds -- raptors	Benthic macroalgae
Highly migratory pelagics	Goliath grouper	Encrusting fauna	Pelagic macroalgae
Dolphinfish	Nassau grouper	Squids	Seagrasses
Pelagic oceanic piscivores	Deep-water grouper/tilefish	Stomatopods	Marsh vegetation
Pelagic coastal piscivores	Shallow-water snapper	Octopods	Estuarine benthic detritus
Nearshore piscivores	Mid-shelf snapper	Blue crabs	Offshore benthic detritus
Pelagic oceanic planktivores	Jacks	Horseshoe crabs	Water-column detritus
Sardines	Red porgy	Golden crabs	Dead carcasses
Scads	Grunts and porgys	Calico scallops	

NEW 99 BOX SAB MODEL (FORAGE)



FORAGE GROUPS IN THE 99 BOX 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 SAB ecosystem model

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

VALUED FISH SPECIES

Table 2. Valued species of predatory fish in the SAB ecosystem model. Commercial landings and commercial values in 2011 from NOAA (2012) for South Atlantic region.

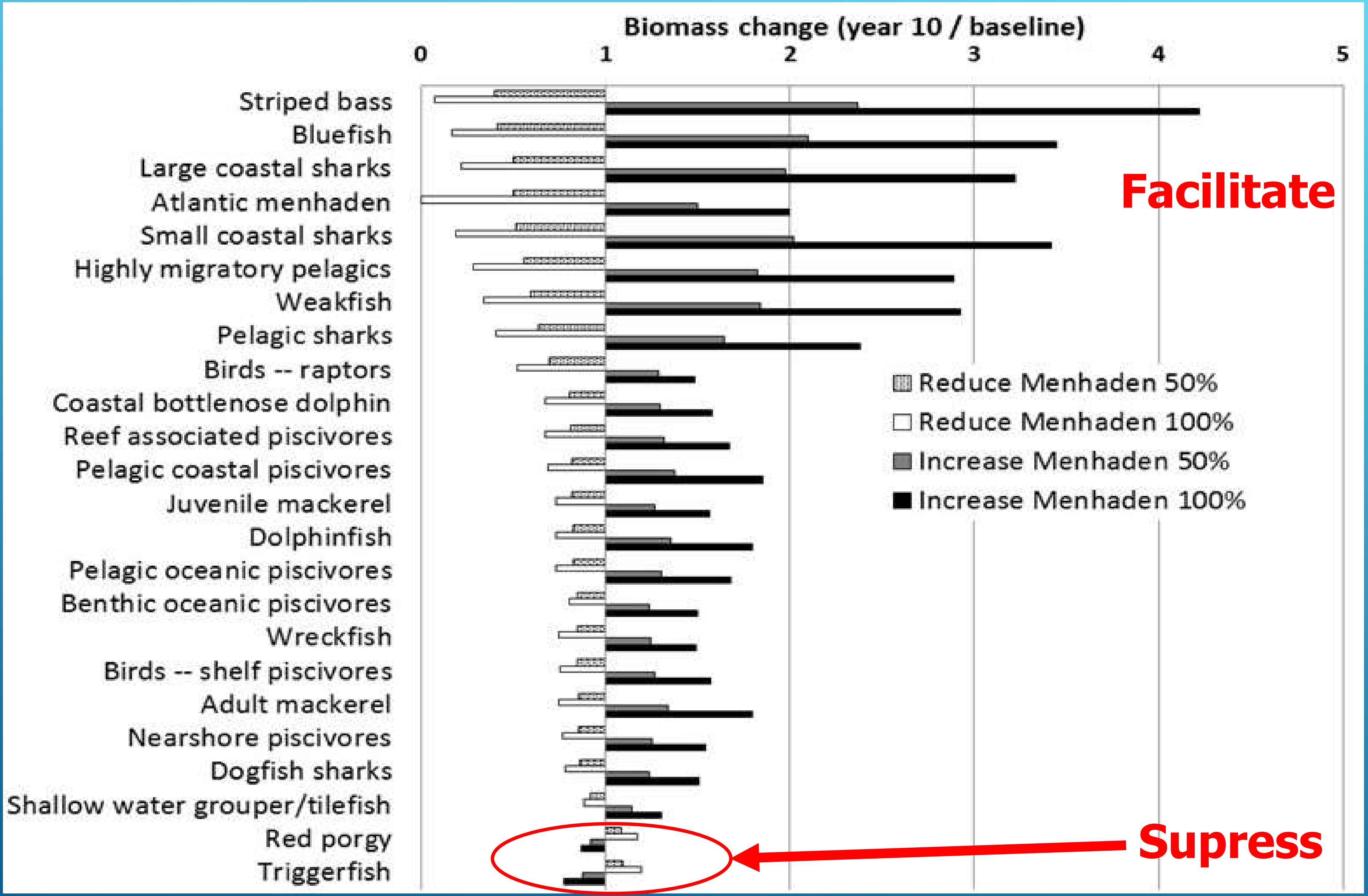
Key predators of interest	**Model functional group**	**Landed value (USD '000)**	**Landings (Tonnes)**
Spanish/king mackerels (*Scomberomorus* spp.)	Adult mackerels	10,417	3,328
Vermillion snapper (*Rhomboplites aurorubens*)	Mid-shelf snappers	2,791	418
Gag grouper (*Mycteroperca microlepis*)	Shallow-water grouper/tilefish	2,051	220
Dolphinfish (*Coryphaena hippurus*)	Dolphinfish	1,268	245
Black seabass (*Centropristis striata*)	Seabass	973	230
Greater amberjack (*Seriola dumerili*)	Jacks	657	295
Cobia (*Rachycentron canadum*)	Pelagic coastal piscivores	534	82
Red snapper (*Lutjanus campechanus*)	Mid-shelf snapper	Closed	

FORAGE SIMULATIONS

- We forced increases and decreases in the biomasses of each of these 12 forage groups individually, all forage fish groups combined, and all forage groups combined including squids, then shrimps, then both.
- Our four treatments for each of 70 scenarios were:

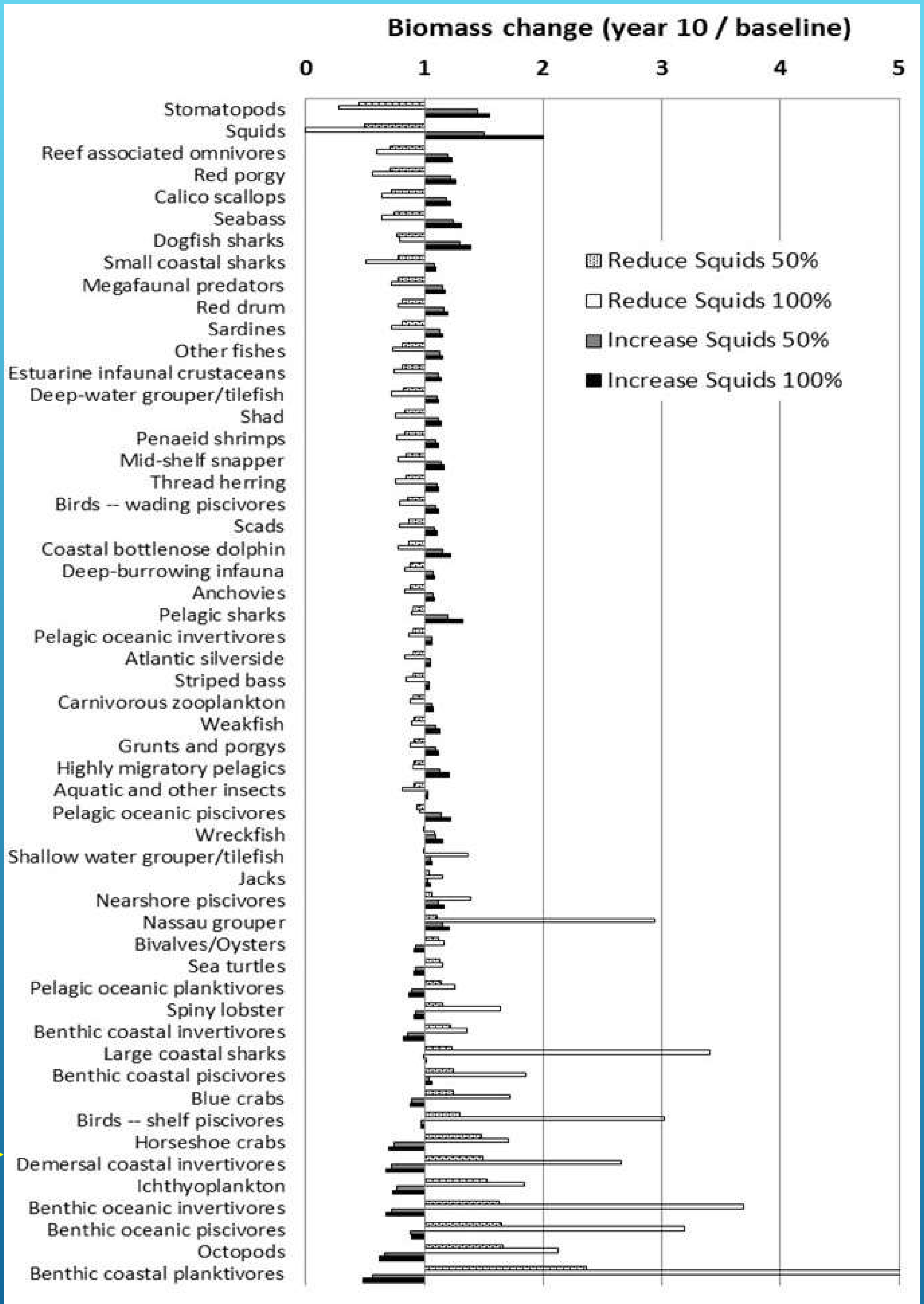
  ✓ 50% reduction
  ✓ 100% reduction
  ✓ 50% increase
  ✓ 100% increase

Atlantic menhaden



Squids

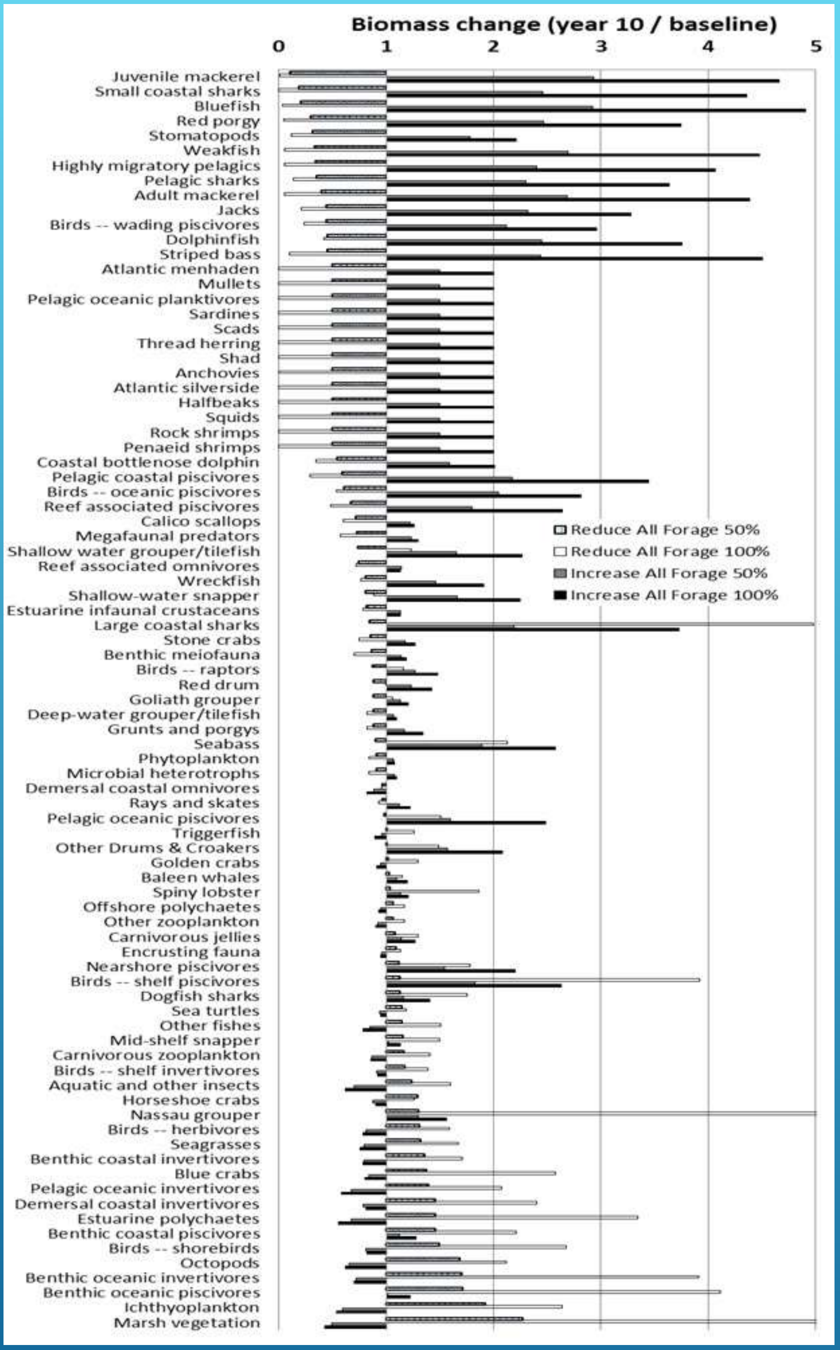
Suppress



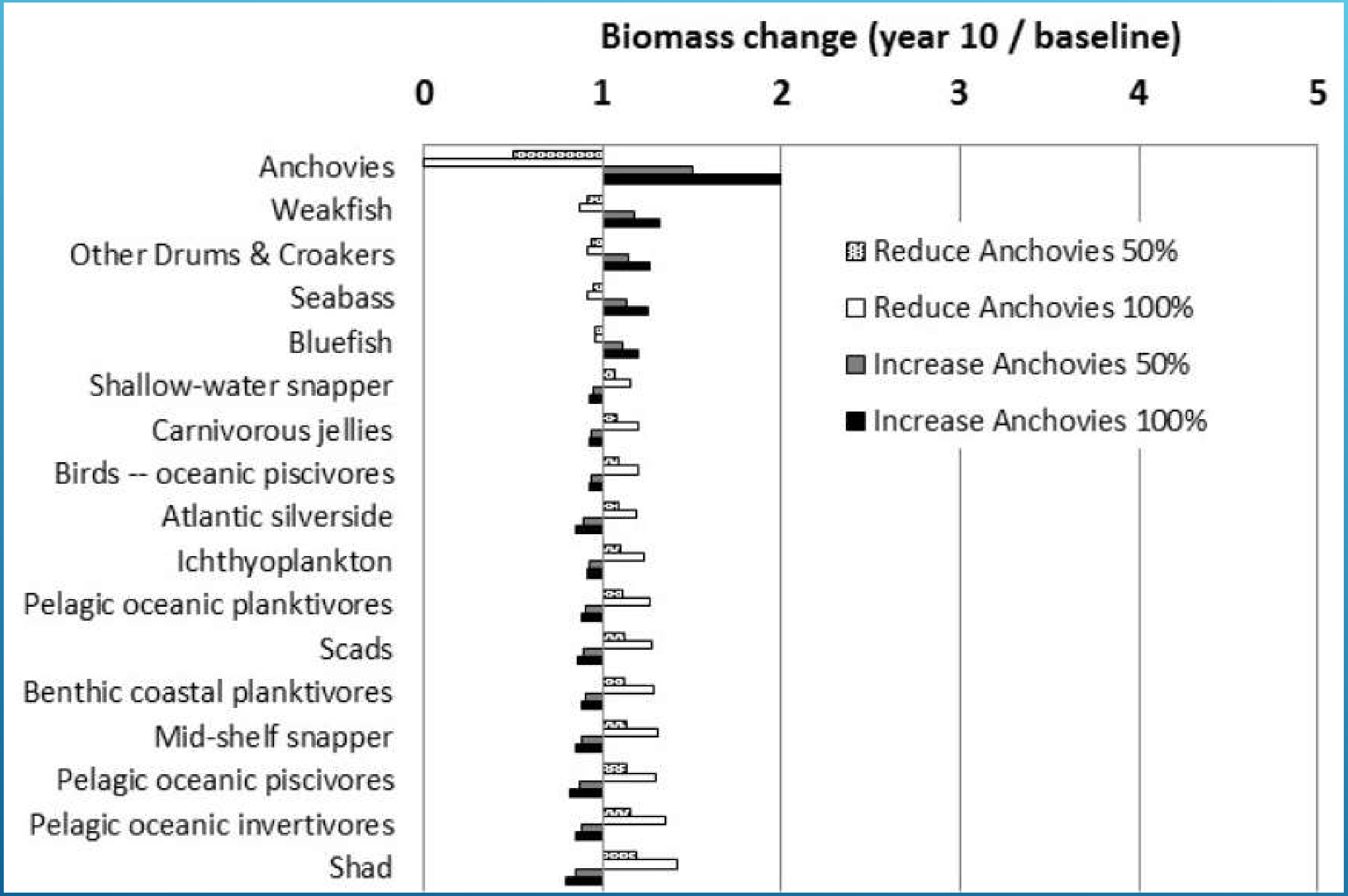
Facilitate

Forage groups overall

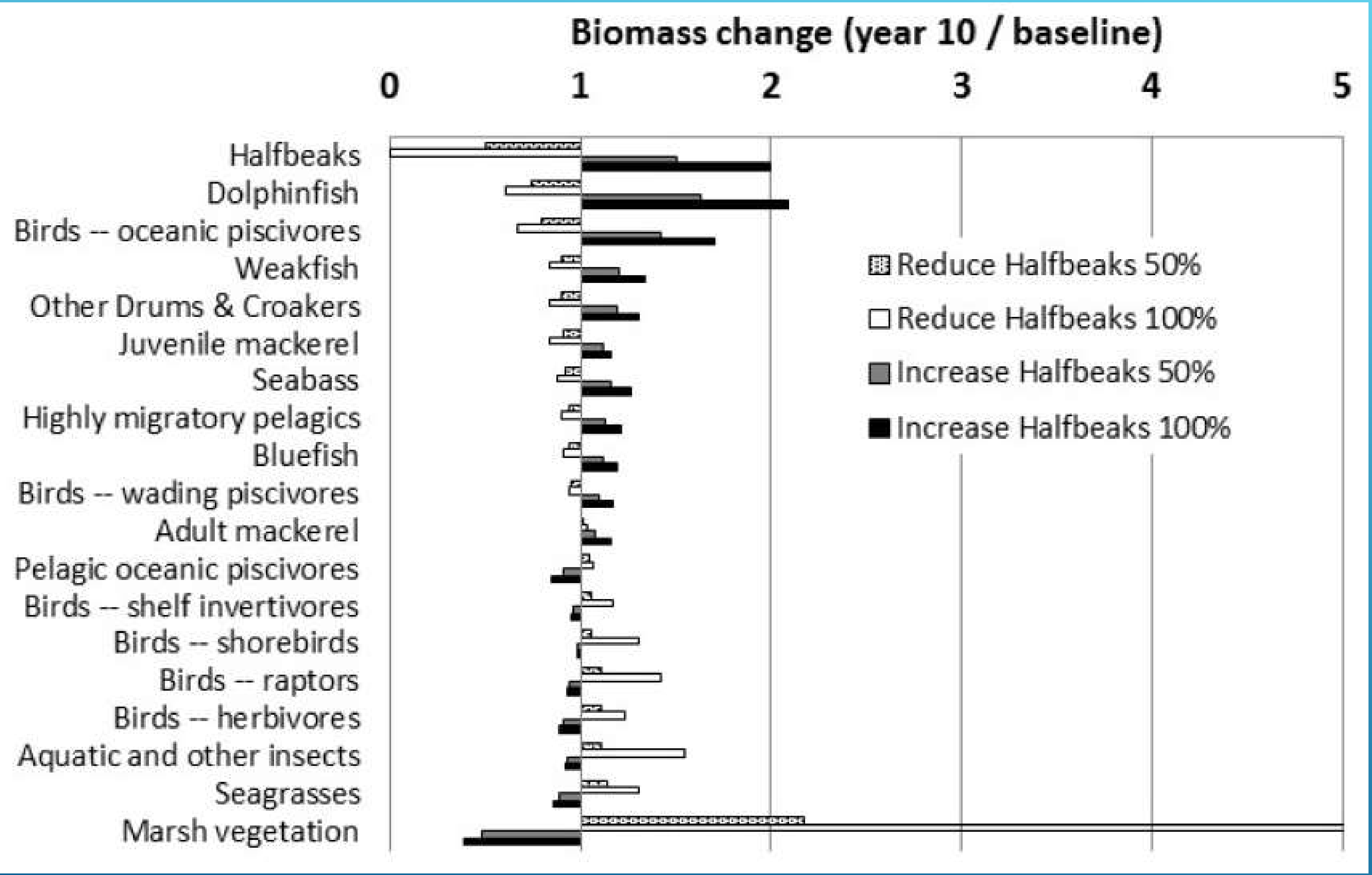
Suppress



ANCHOVIES

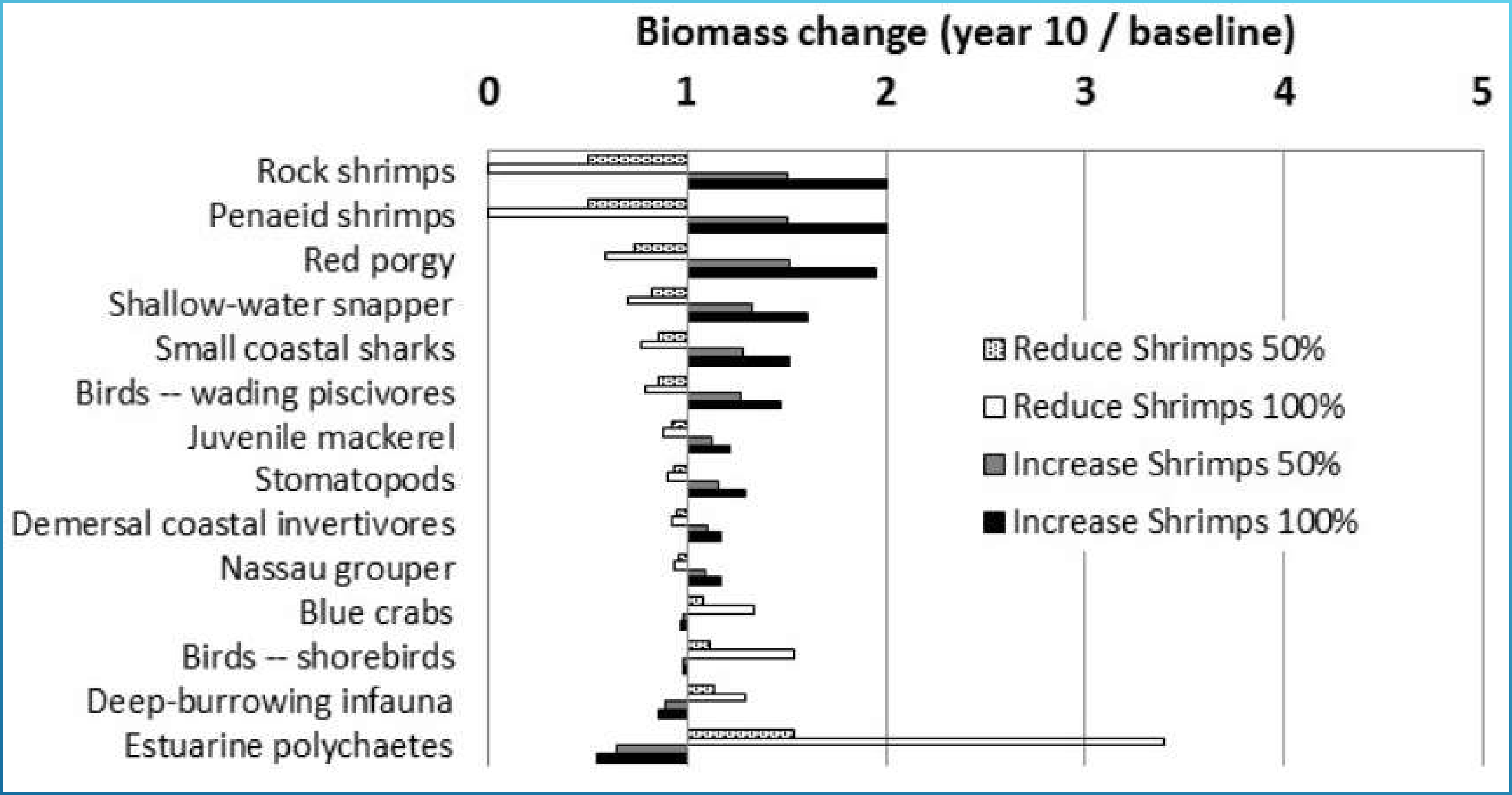

Biomass change (year 10 / baseline)
0
1
2
3
4
5
Anchovies
Weakfish
Other Drums & Croakers
Seabass
Bluefish
Shallow-water snapper
Carnivorous jellies
Birds -- oceanic piscivores
Atlantic silverside
Ichthyoplankton
Pelagic oceanic planktivores
Scads
Benthic coastal planktivores
Mid-shelf snapper
Pelagic oceanic piscivores
Pelagic oceanic invertivores
Shad
Reduce Anchovies 50%
Reduce Anchovies 100%
Increase Anchovies 50%
Increase Anchovies 100%

HALFBEAKS



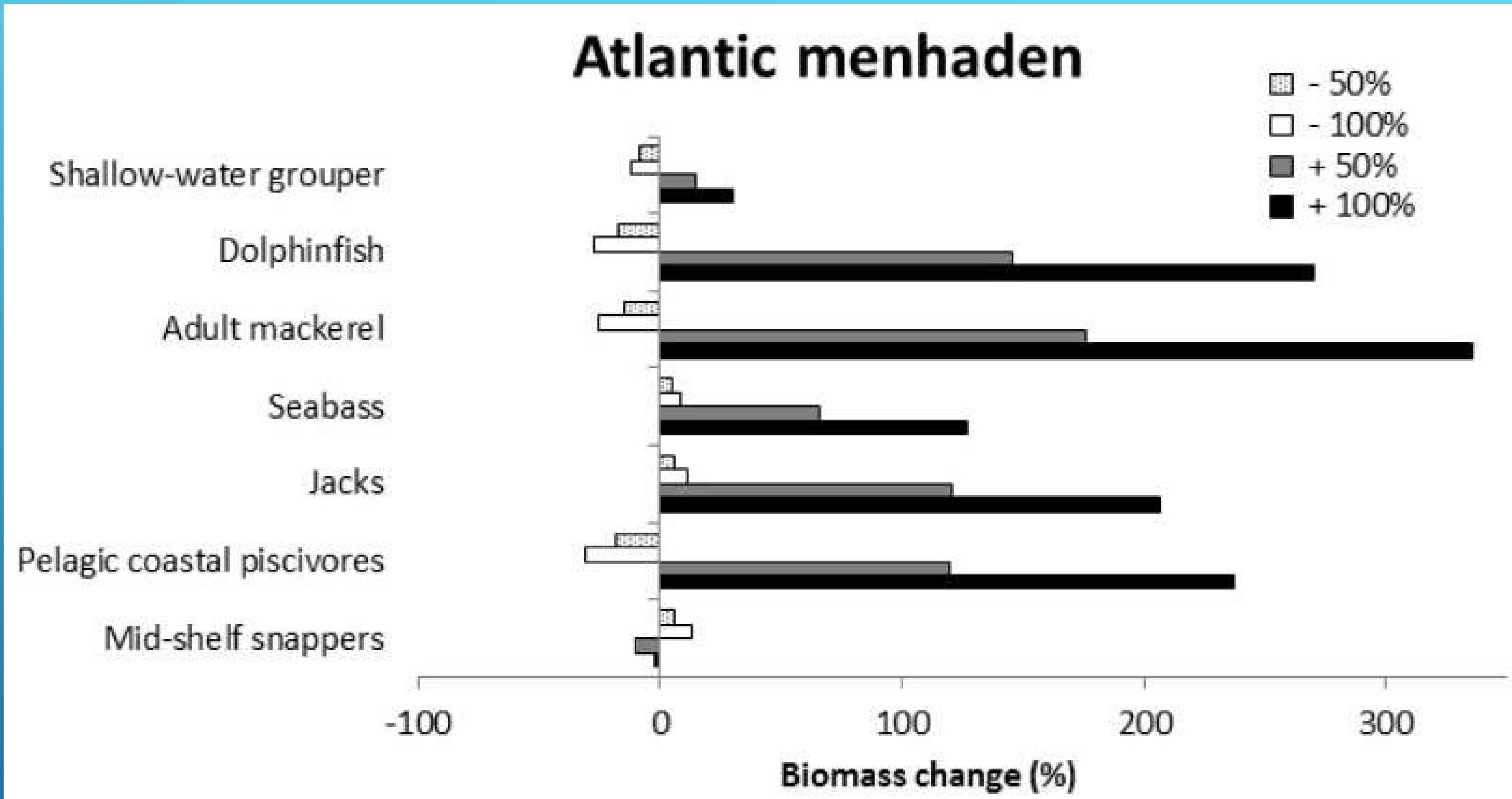
Biomass change (year 10 / baseline)
0
1
2
3
4
5
Halfbeaks
Dolphinfish
Birds -- oceanic piscivores
Weakfish
Other Drums & Croakers
Juvenile mackerel
Seabass
Highly migratory pelagics
Bluefish
Birds -- wading piscivores
Adult mackerel
Pelagic oceanic piscivores
Birds -- shelf invertivores
Birds -- shorebirds
Birds -- raptors
Birds -- herbivores
Aquatic and other insects
Seagrasses
Marsh vegetation
Reduce Halfbeaks 50%
Reduce Halfbeaks 100%
Increase Halfbeaks 50%
Increase Halfbeaks 100%

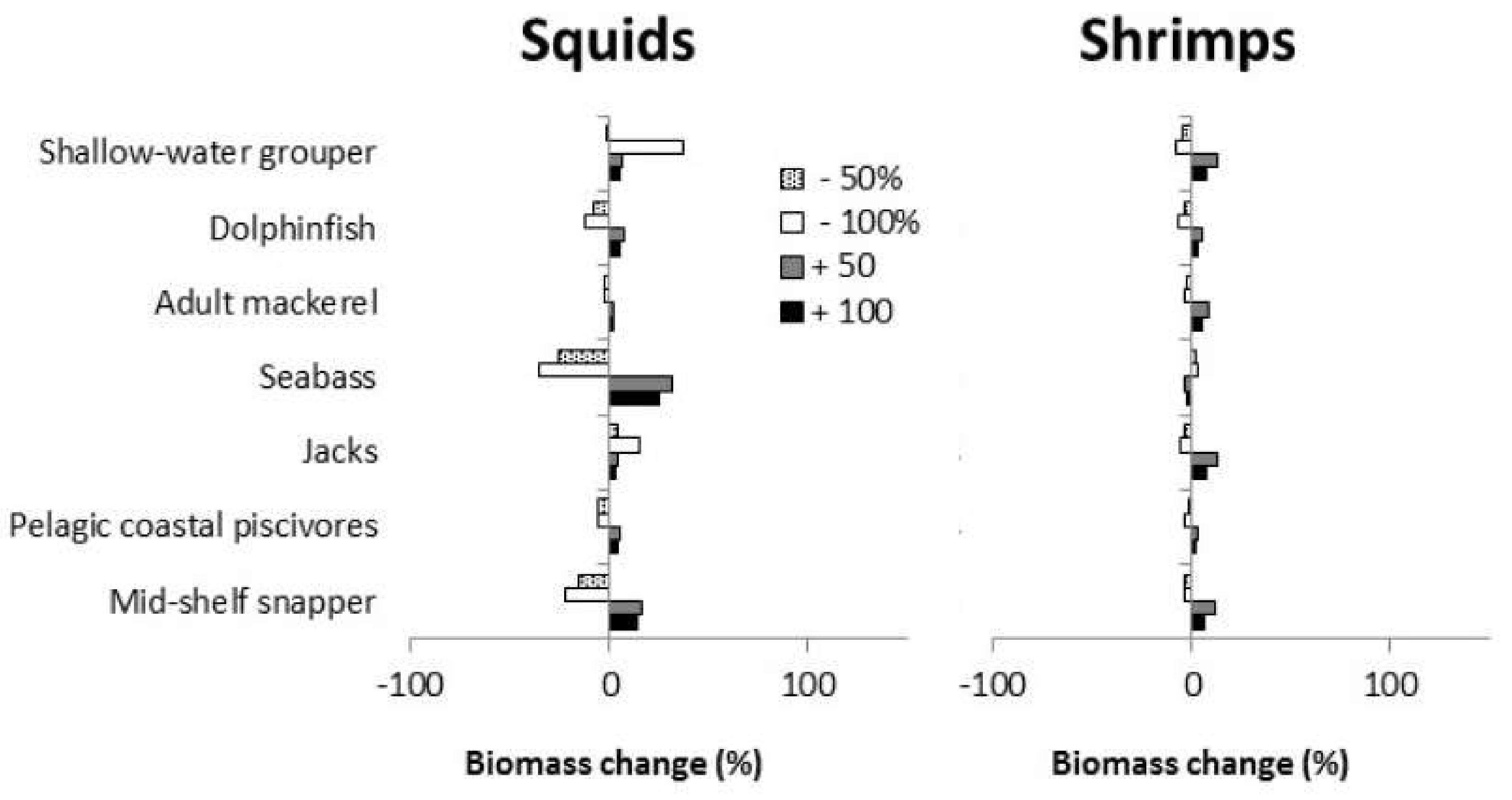
SHRIMPS

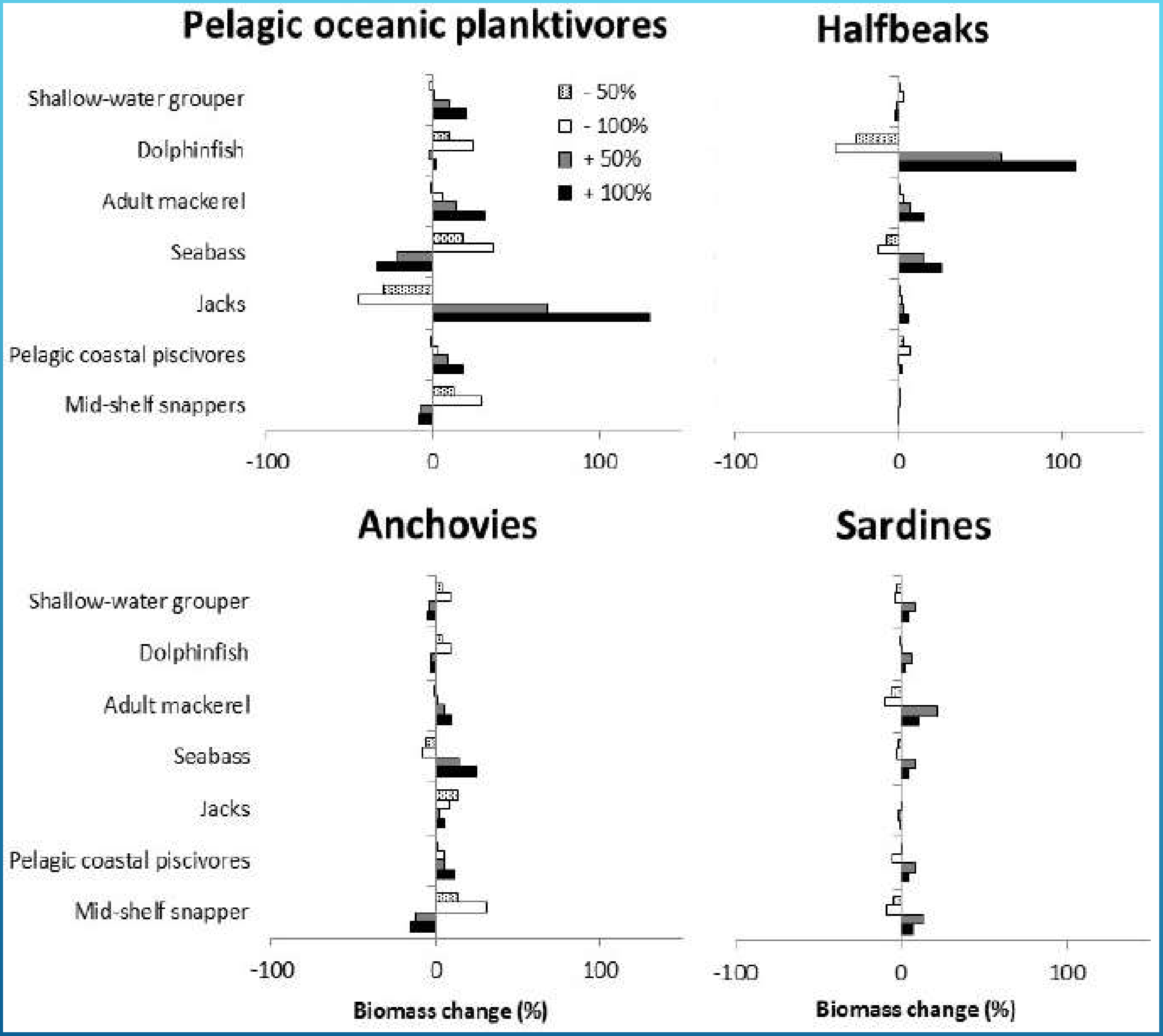


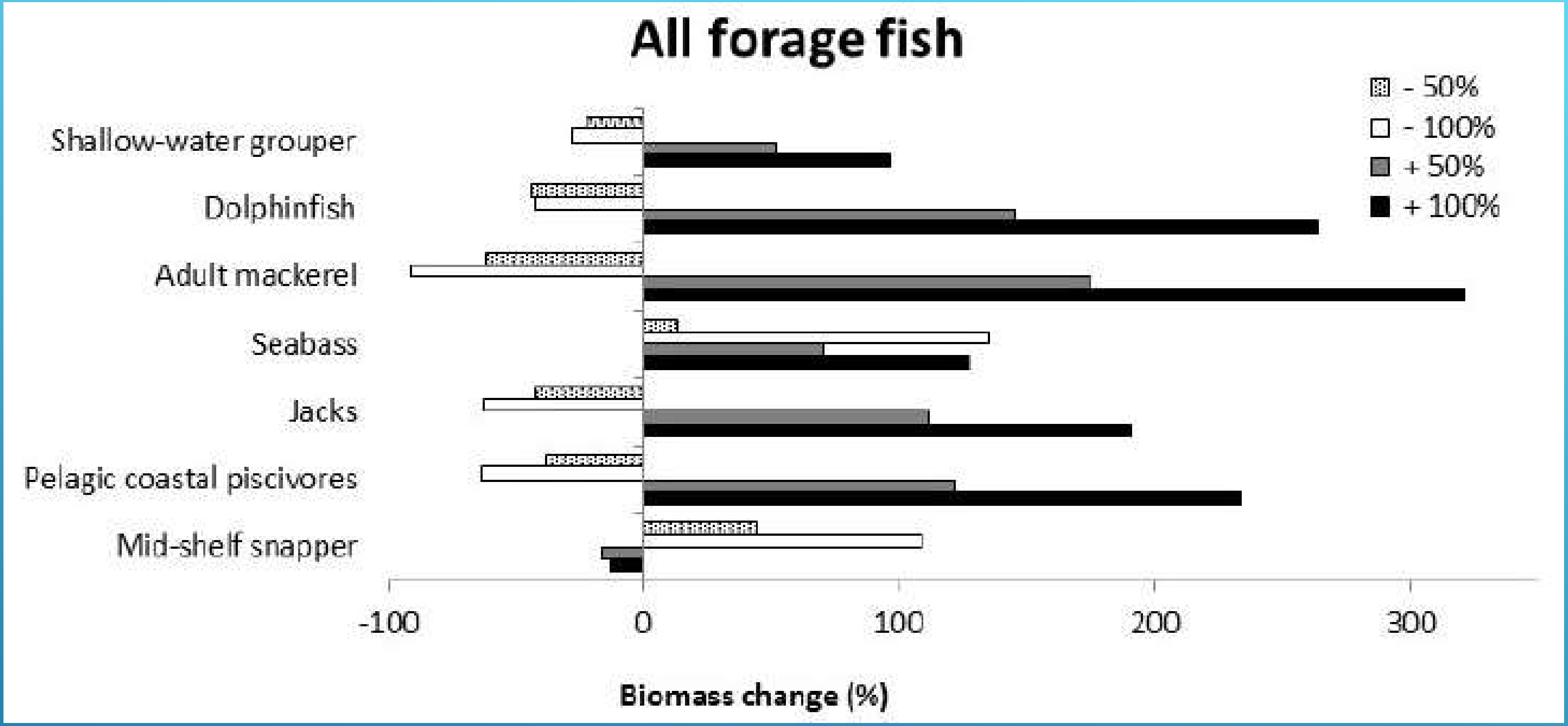
Biomass change (year 10 / baseline)
0
1
2
3
4
5
Rock shrimps
Penaeid shrimps
Red porgy
Shallow-water snapper
Small coastal sharks
Birds -- wading piscivores
Juvenile mackerel
Stomatopods
Demersal coastal invertivores
Nassau grouper
Blue crabs
Birds -- shorebirds
Deep-burrowing infauna
Estuarine polychaetes
Reduce Shrimps 50%
Reduce Shrimps 100%
Increase Shrimps 50%
Increase Shrimps 100%

Forage group	ISI[a]	CLR[b] (%)	Number of groups +10%	-10%	+/-10%
Squids	44	118	33	27	60
Atlantic menhaden	13	91	23	10	33
Halfbeaks	12	103	6	8	14
Pelagic oceanic planktivores	10	108	6	27	33
Shrimps	9	100	9	7	16
Anchovies	7	105	1	21	22
Sardines	4	100	2	5	7
Atlantic silverside	3	101	4	2	6
Scads	3	101	2	2	4
Shad	2	100	0	0	0
Thread herring	1	100	0	0	0
Mullets	0	100	0	0	0
All forage fish	40	110	29	40	69
All forage fish & Shrimps	47	111	32	39	71
All forage fish & Squids	88	146	29	41	70
All forage	90	144	29	41	70


Atlantic menhaden
- 50%
- 100%
+ 50%
+ 100%
Shallow-water grouper
Dolphinfish
Adult mackerel
Seabass
Jacks
Pelagic coastal piscivores
Mid-shelf snappers
-100
0
100
200
300
Biomass change (%)


Squids
Shrimps
Shallow-water grouper
Dolphinfish
Adult mackerel
Seabass
Jacks
Pelagic coastal piscivores
Mid-shelf snapper
- 50%
- 100%
+ 50
+ 100
-100
0
100
-100
0
100
Biomass change (%)
Biomass change (%)


Pelagic oceanic planktivores
Halfbeaks
Anchovies
Sardines
Shallow-water grouper
Dolphinfish
Adult mackerel
Seabass
Jacks
Pelagic coastal piscivores
Mid-shelf snappers
Mid-shelf snapper
- 50%
- 100%
+ 50%
+ 100%
-100
0
100
Biomass change (%)


All forage fish
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- 100%
+ 50%
+ 100%
Shallow-water grouper
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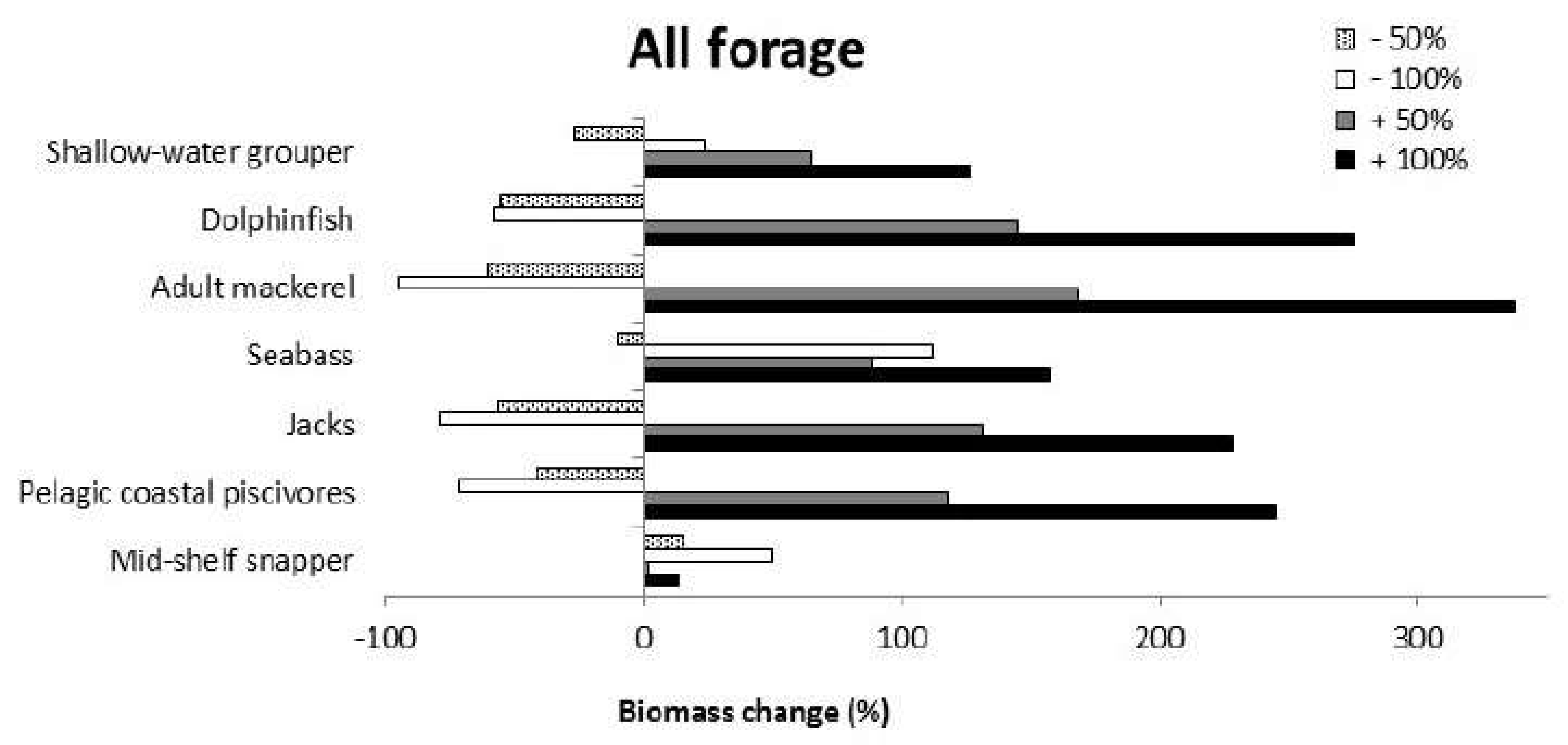
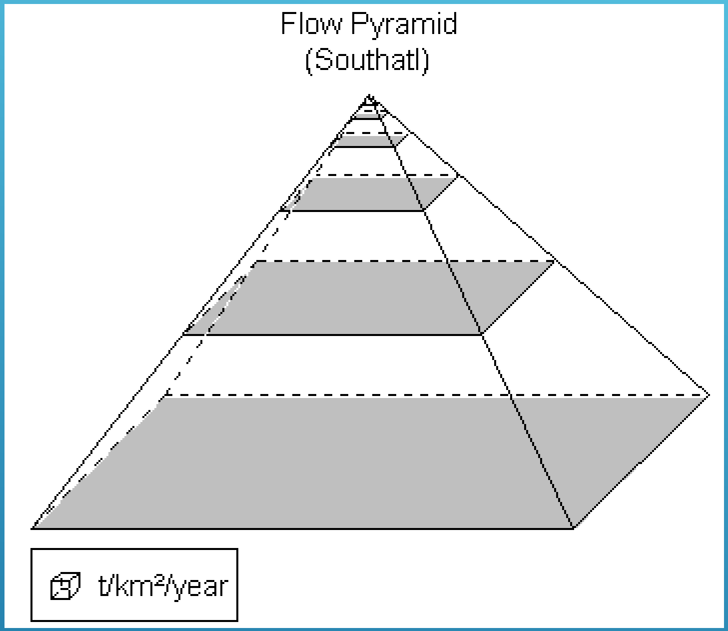
Pelagic coastal piscivores
Mid-shelf snapper
-100
0
100
200
300
Biomass change (%)


All forage
- 50%
- 100%
+ 50%
+ 100%
Shallow-water grouper
Dolphinfish
Adult mackerel
Seabass
Jacks
Pelagic coastal piscivores
Mid-shelf snapper
-100
0
100
200
300
Biomass change (%)

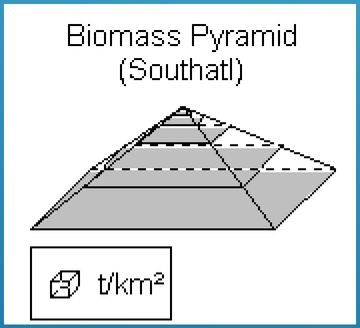
Summary Statistics

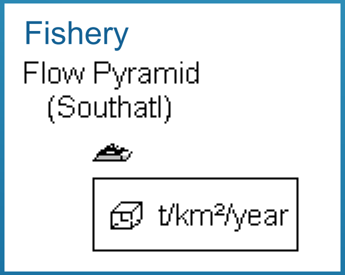
Parameter	Value	Units
Sum of all consumption	8,390	t/km^2/year
Sum of all exports	594	t/km^2/year
Sum of all respiratory flows	3,053	t/km^2/year
Sum of all flows into detritus	4,937	t/km^2/year
Total system throughput	16,974	t/km^2/year
Sum of all production	4,899	t/km^2/year
Mean trophic level of the catch	3.37	
Gross efficiency (catch/net p.p.)	0.000219	
Calculated total net primary production	2,828	t/km^2/year
Total primary production/total respiration	0.93	
Net system production	-225	t/km^2/year
Total primary production/total biomass	5.31	
Total biomass/total throughput	0.031	
Total biomass (excluding detritus)	533	t/km^2
Total catch	0.62	t/km^2/year
Connectance Index	0.134	
System Omnivory Index	0.267	
Total market value	0.495	USD
Total shadow value	0	USD
Total value	0.495	USD
Total fixed cost	0	USD
Total variable cost	0.40	USD
Total cost	0.40	USD
Profit	0.10	USD

SAB Pyramids

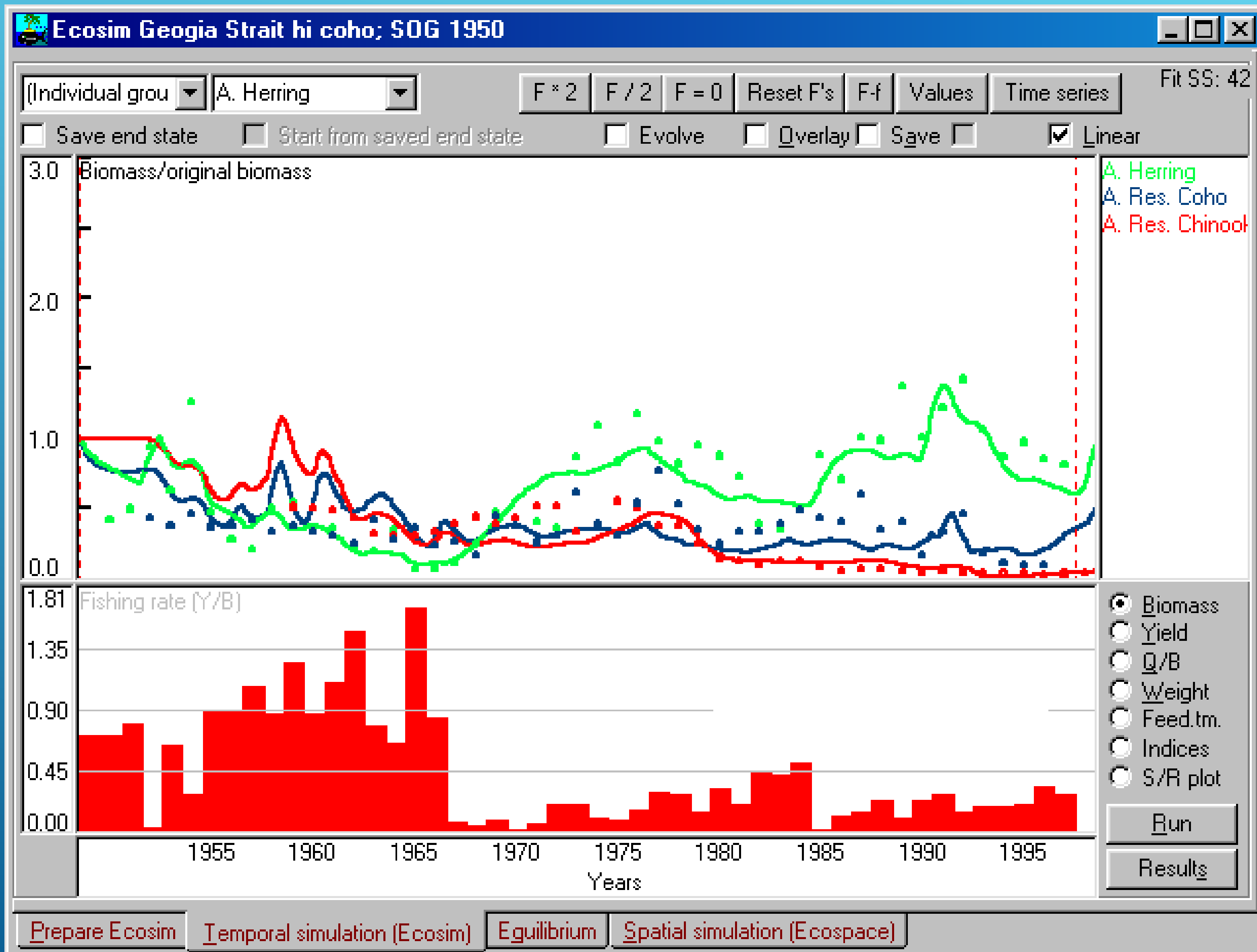


47% of flows from detritus

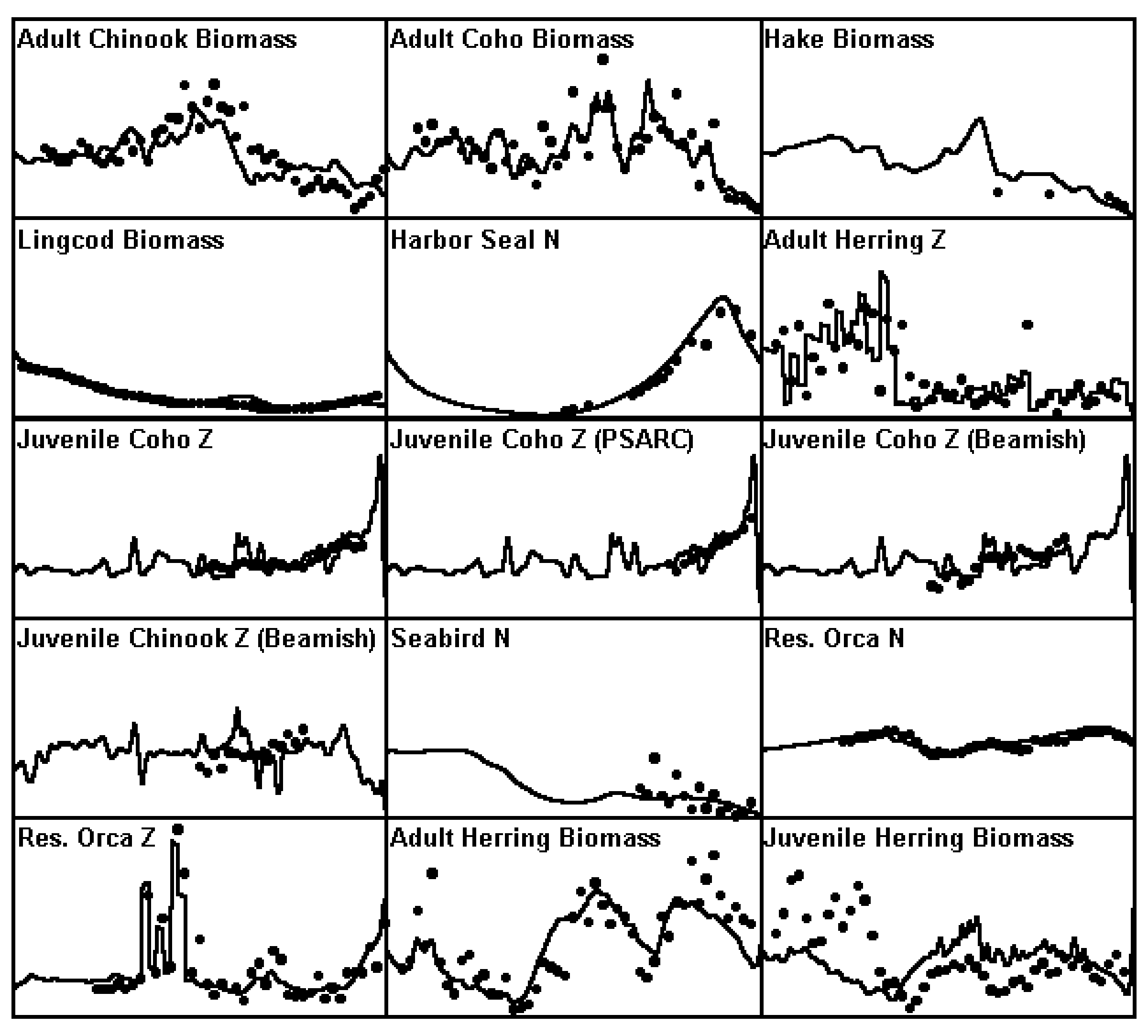




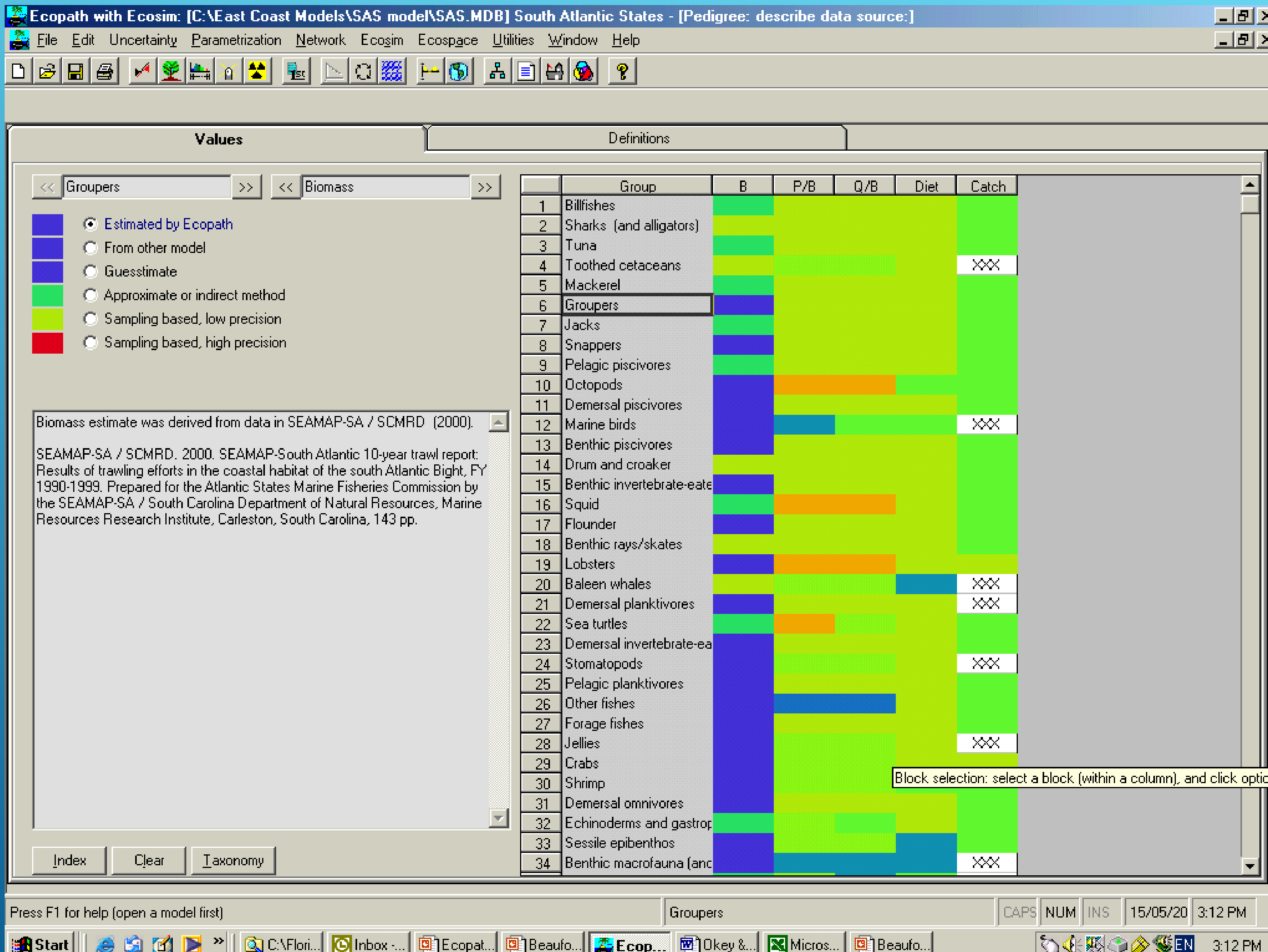
CALIBRATING THE MODEL



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

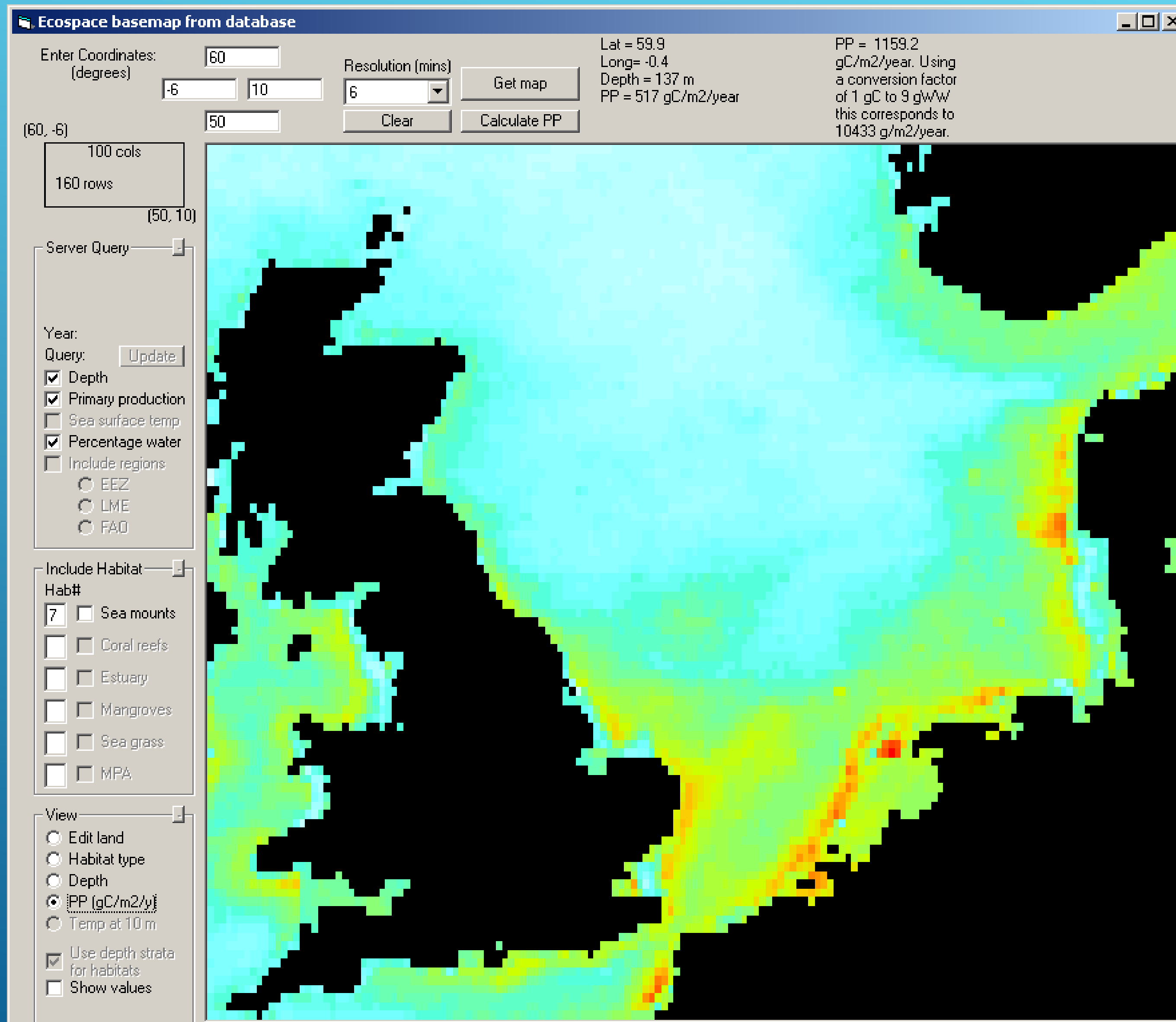


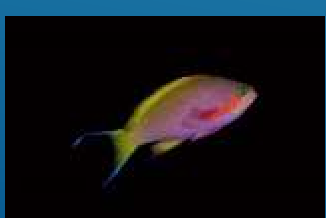
Various approaches to uncertainty



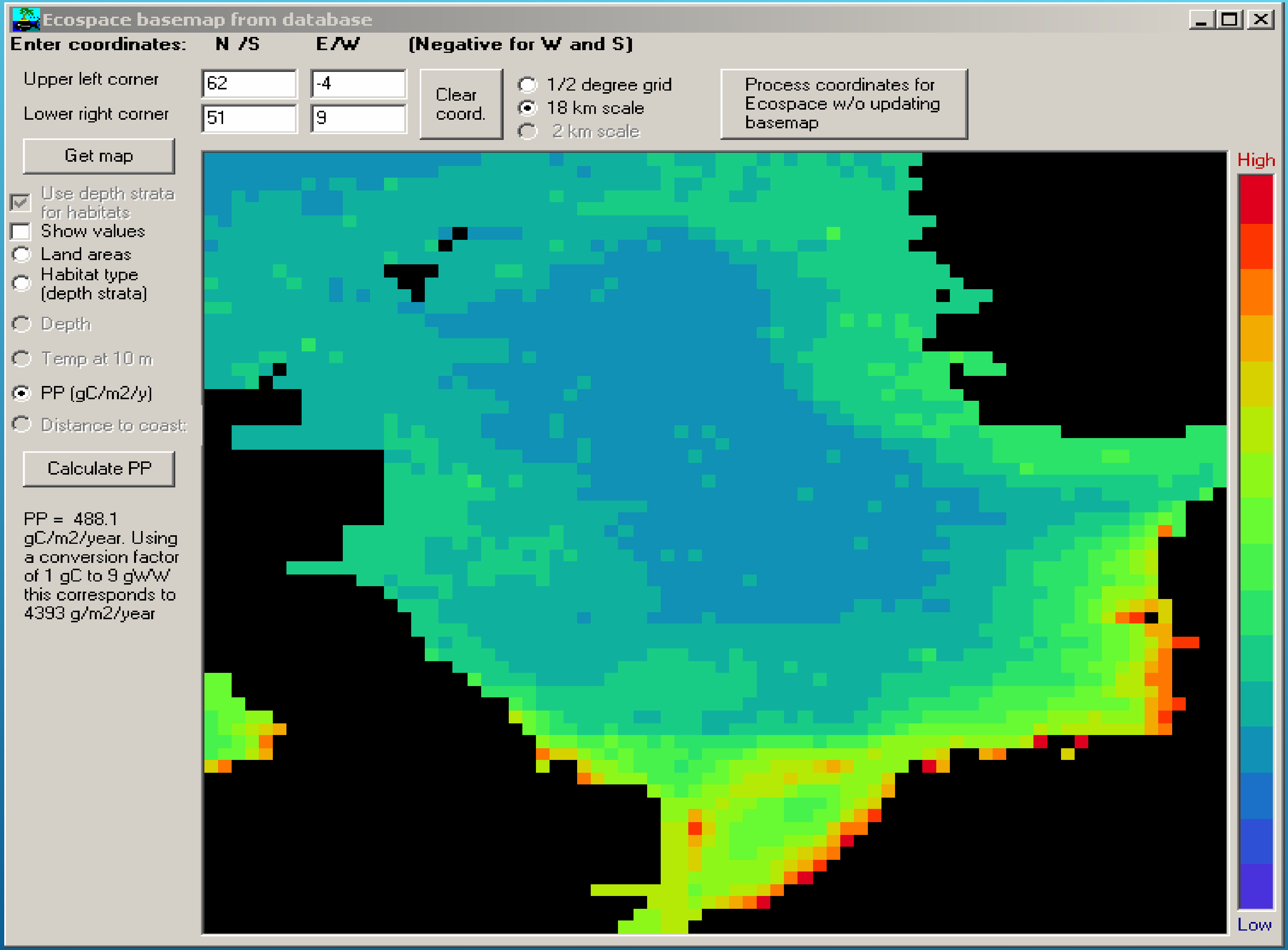
SPATIAL STRUCTURE FROM GIS

Ecospace can pick up map (various resolutions), depth, primary production, …, from GIS via Internet.

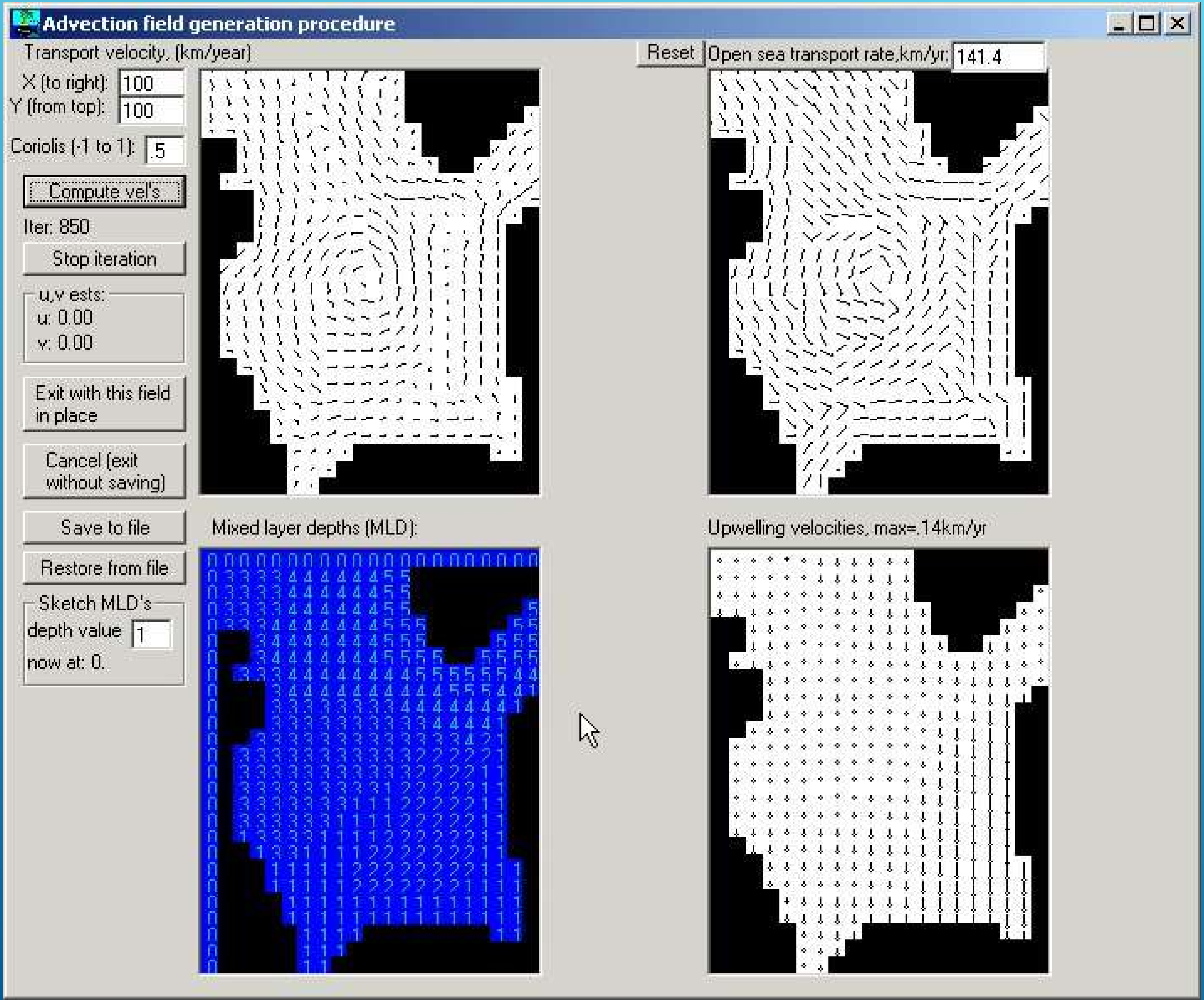




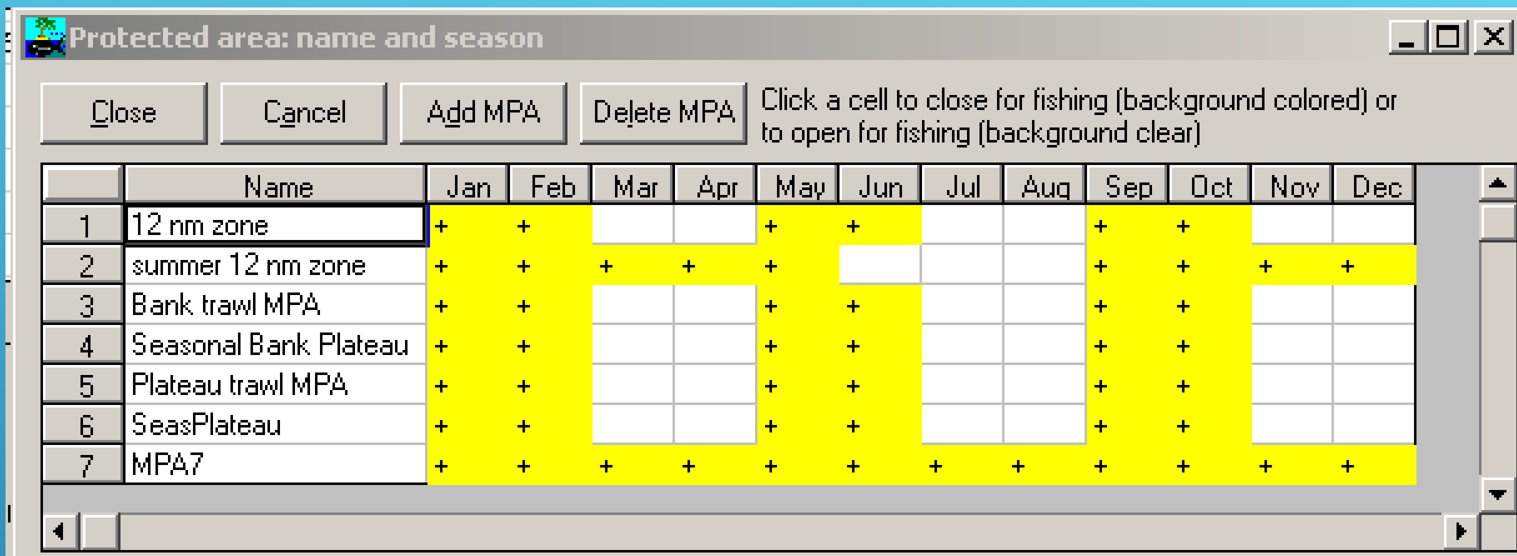
SPATIAL SIMULATION



ECOSPACE: 2D ADVECTION



ECOSPACE: SEASONAL OR FULL-TIME CLOSURES

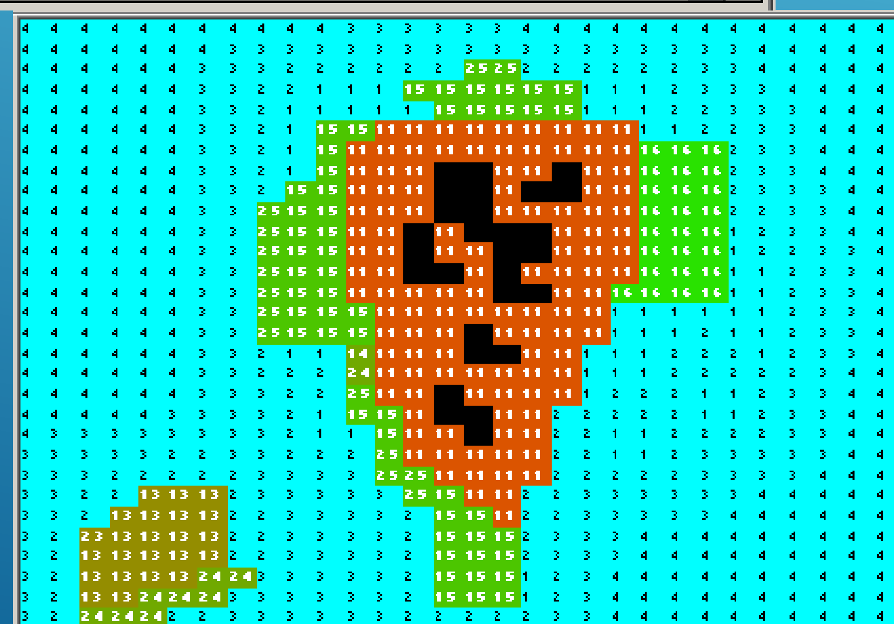


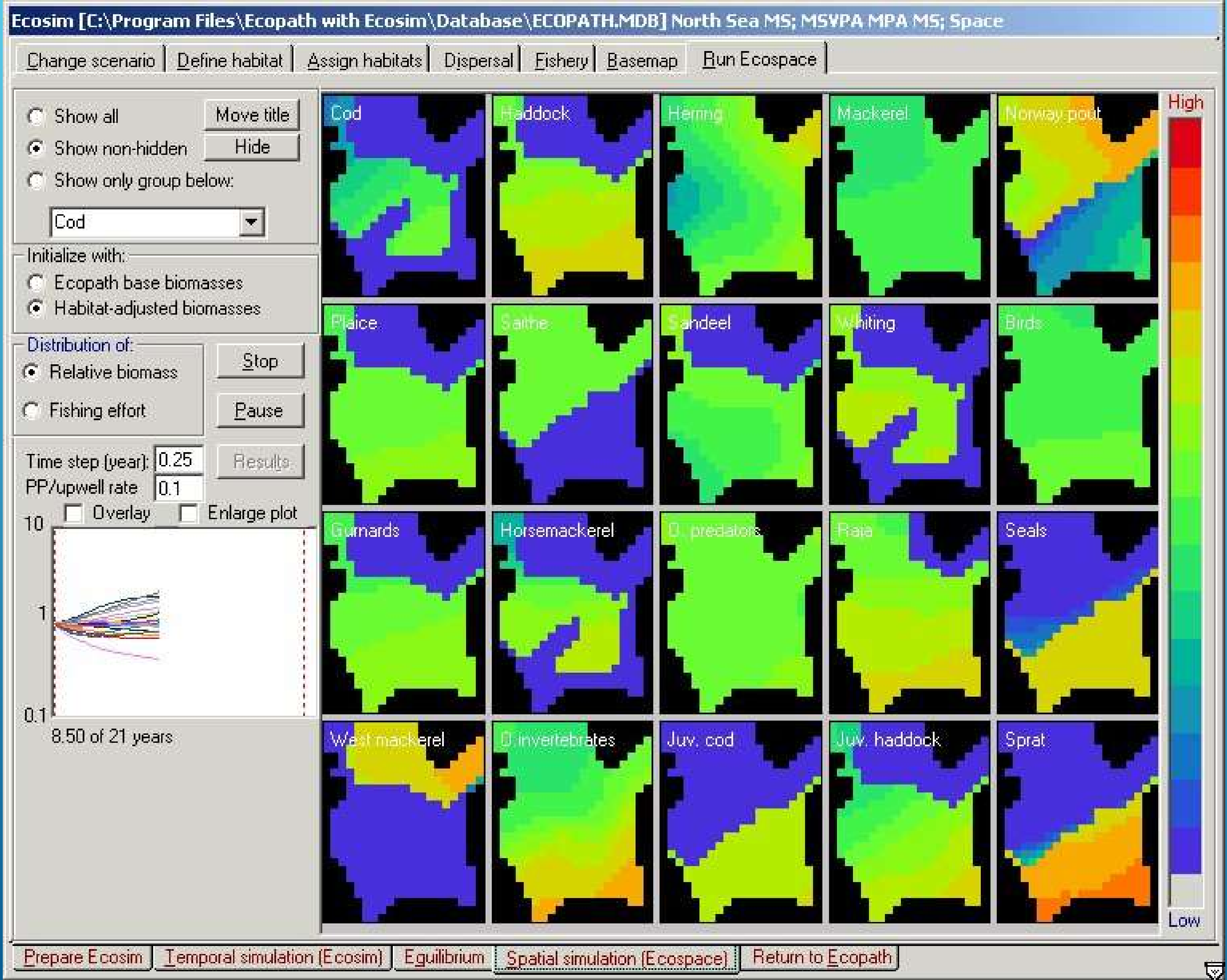
Protected area: name and season

Close | Cancel | Add MPA | Delete MPA

Click a cell to close for fishing (background colored) or to open for fishing (background clear)

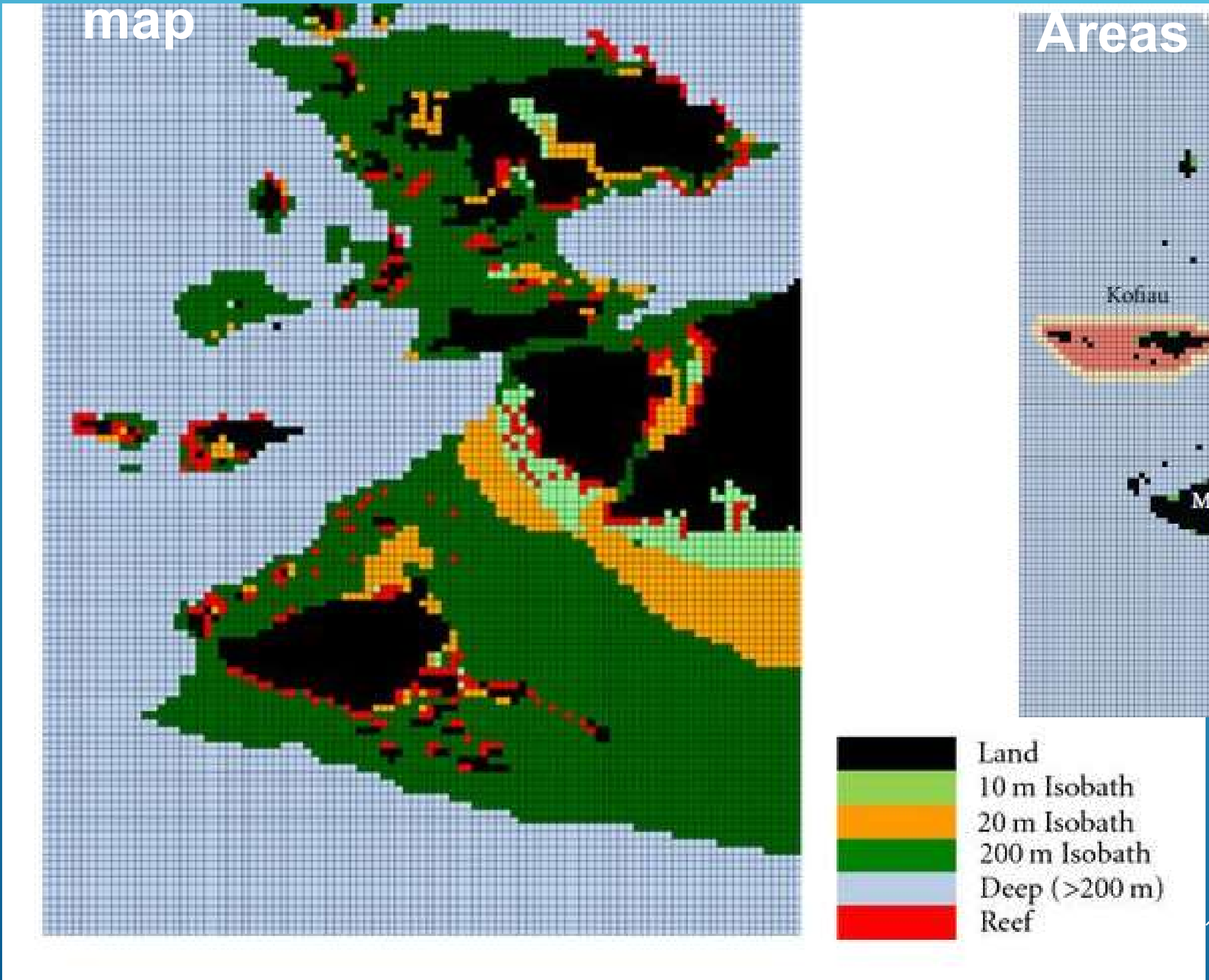
	Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	12 nm zone	+	+			+	+			+	+		
2	summer 12 nm zone	+	+	+	+	+				+	+	+	+
3	Bank trawl MPA	+	+			+	+			+	+		
4	Seasonal Bank Plateau	+	+			+	+			+	+		
5	Plateau trawl MPA	+	+			+	+			+	+		
6	SeasPlateau	+	+			+	+			+	+		
7	MPA7	+	+	+	+	+	+	+	+	+	+	+	+



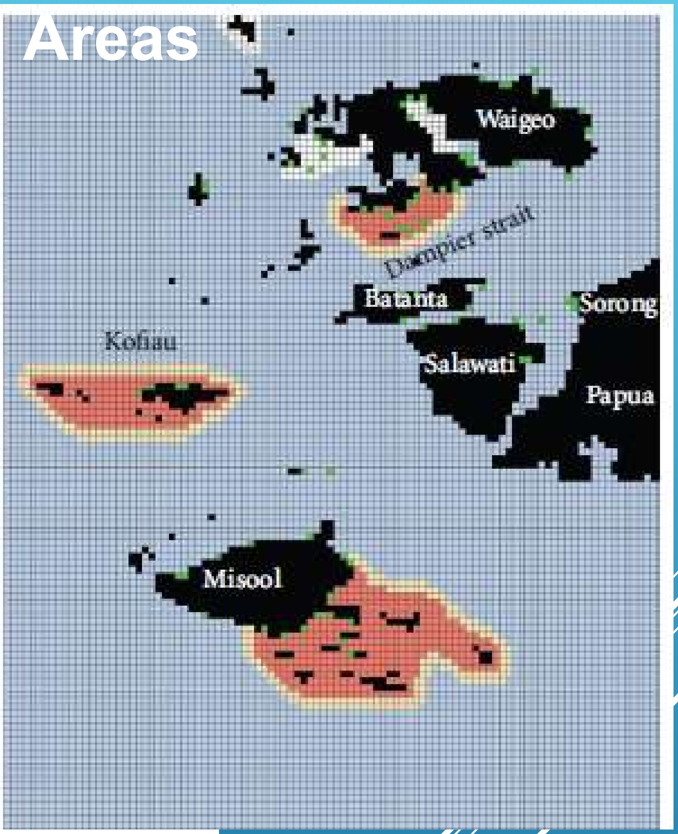

Ecosim [C:\Program Files\Ecopath with Ecosim\Database\ECOPATH.MDB] North Sea MS; MSVPA MPA MS; Space
Change scenario
Define habitat
Assign habitats
Dispersal
Fishery
Basemap
Run Ecospace
Show all
Move title
Show non-hidden
Hide
Show only group below:
Cod
Initialize with:
Ecopath base biomasses
Habitat-adjusted biomasses
Distribution of:
Relative biomass
Fishing effort
Stop
Pause
Time step (year):
0.25
PP/upwell rate
0.1
Results
Overlay
Enlarge plot
10
1
0.1
8.50 of 21 years
Cod
Haddock
Herring
Mackerel
Norway pout
Plaice
Saithe
Sandeel
Whiting
Birds
Gurnards
Horsemackerel
O. predators
Raja
Seals
West mackerel
O.invertebrates
Juv. cod
Juv. haddock
Sprat
High
Low
Prepare Ecosim
Temporal simulation (Ecosim)
Equilibrium
Spatial simulation (Ecospace)
Return to Ecopath

EXAMPLE: EFFECTS OF HABITAT PROTECTION IN RAJA AMPAT

Ecosim habitat map

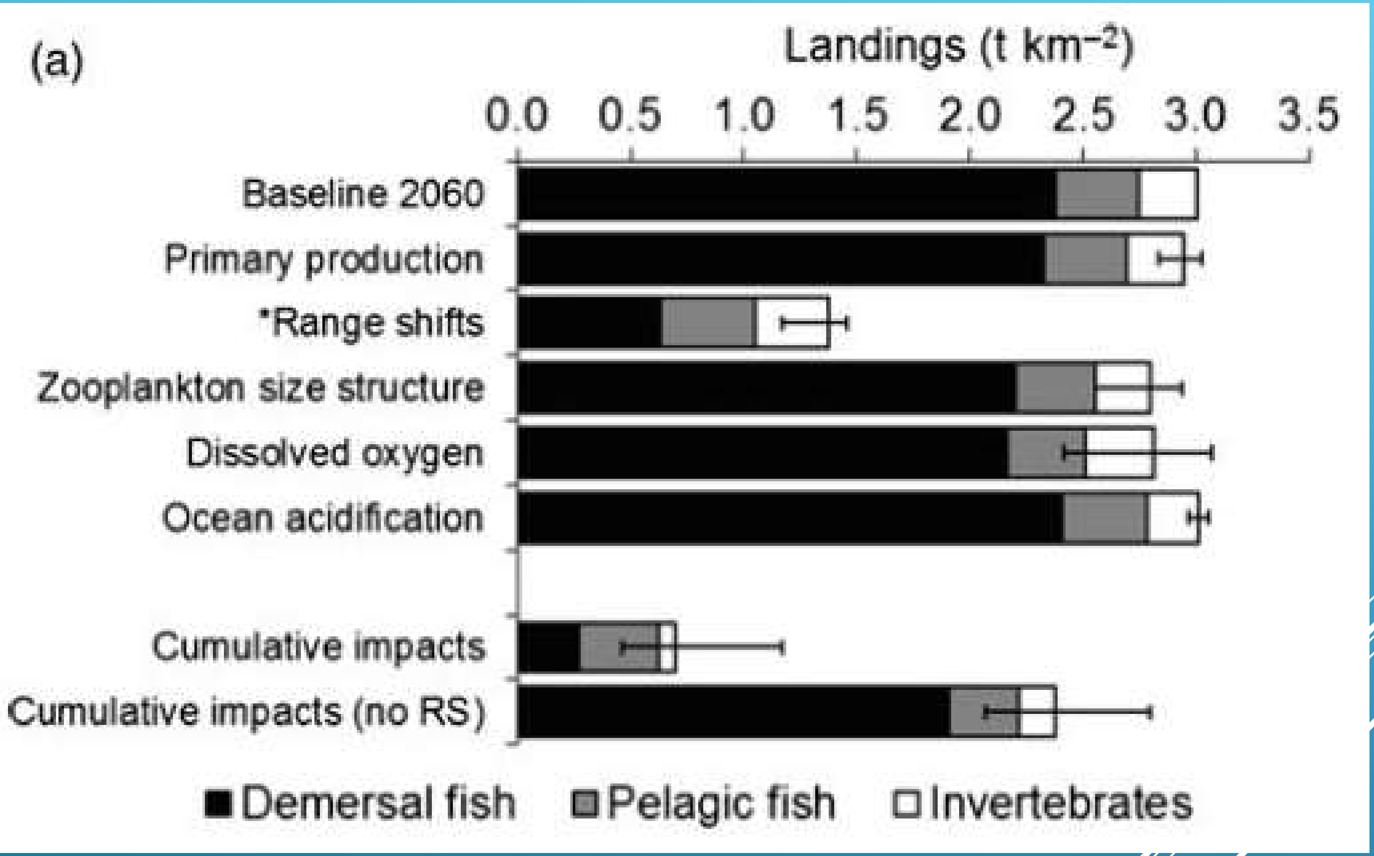


Marine Protected Areas



EXAMPLE: EFFECTS OF CLIMATE CHANGE ON NORTHEAST PACIFIC FOOD WEBS AND FISHERIES

Compare 2060 baseline to cumulative impacts



Ainsworth, C. H., J. F. Samhouri, D. S. Busch, W. W. L. Cheung, J. Dunne, and T. A. Okey. 2011. Potential impacts of climate change on Northeast Pacific marine foodwebs and fisheries. ICES Journal of Marine Science **68**:1217-1229

SOUTH ATLANTIC FISHERIES OCEANOGRAPHY AND MODELING

- **Identifying needs of ecosystem models**
- ***Refining current or water column designations of EFH and EFH-HAPCs (e.g., Gulf Stream and Florida Current)***
- ***Providing oceanographic models linking benthic, pelagic habitats and food webs***
- ***Providing oceanographic input parameters for ecosystem models***
- ***Integration of OOS information into Fish Stock Assessment process in the SA region***
- ***Facilitating OOS system collection of fish and fishery data and other research necessary to support the Council's use of area-based management tools in the SA Region including but not limited to EFH, EFH-HAPCs, Marine Protected Areas, Deepwater Coral Habitat Areas of Particular Concern, Special Management Zones and Allowable Gear Areas.***
- ***Integration of OOS program capabilities and research Needs into the South Atlantic Fishery Ecosystem Plan***
- ***Collaboration with SECOORA to integrate OOS products on the Council's Habitat and Ecosystem Internet Mapping System to facilitate model and tool development***
- ***Expanding IMS will provide permissioned researchers access to data or products including those collected/developed by SA OOS partners***

INCORPORATING THE ECOPATH MODELING APPROACH INTO UNITED STATES FISHERIES MANAGEMENT

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[3] CSIRO MARINE RESEARCH, CLEVELAND MARINE LABORATORIES, PO BOX 120, CLEVELAND, QUEENSLAND 4163, AUSTRALIA

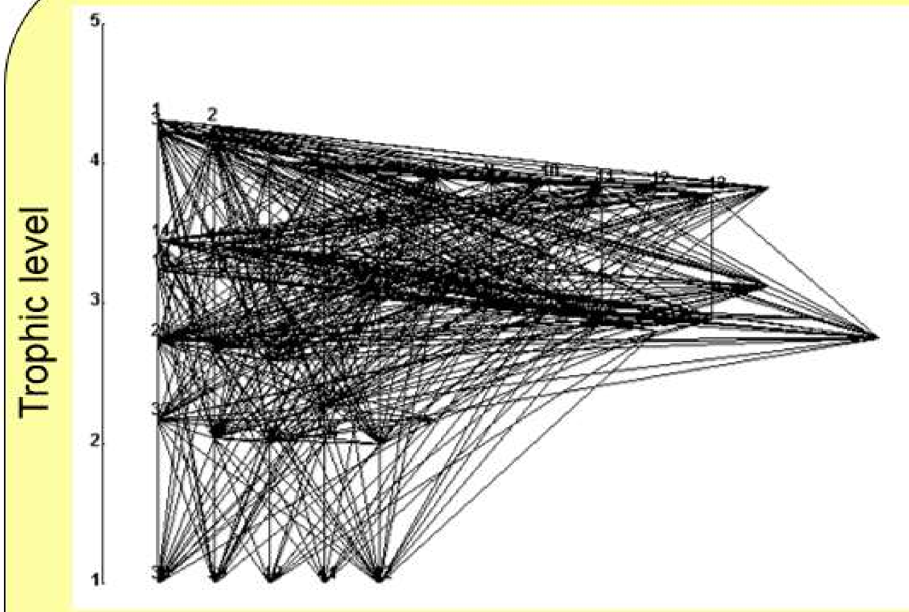


Fig. 1. Preliminary trophic web of the Atlantic continental shelf adjacent to the Southeastern United States

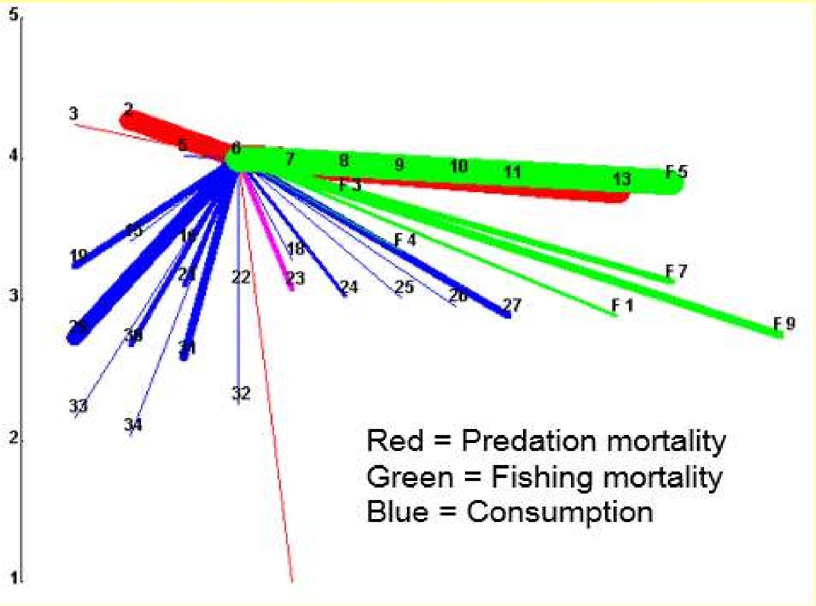


Fig. 2. Trophic interactions of groupers of the Atlantic continental shelf

Atlantic Coast Ecosystem Simulation (ACES)

Model for Assessing Multispecies Fisheries Risks from Exploitation and Environmental Changes

Jerald S. Ault, Jiangang Luo, & Steven G. Smith
University of Miami
Department of Marine Ecosystems & Society

Support SAFMC's mission to manage and sustain South Atlantic coastal, coral reef and pelagic fisheries.

- *Strategy to model regional ecosystem dynamics.*
- *Acquire and assimilate required data.*
- *Produce integrated ecosystem risk assessments.*
- *Improve and modernize decision-making capabilities.*

Thinking about Fisheries Ecosystems

Traditional Stock Assessment Models ► Spatial-Dynamic Multispecies Models

Sustainability Threat
- Directed Fishing on Single Target Species

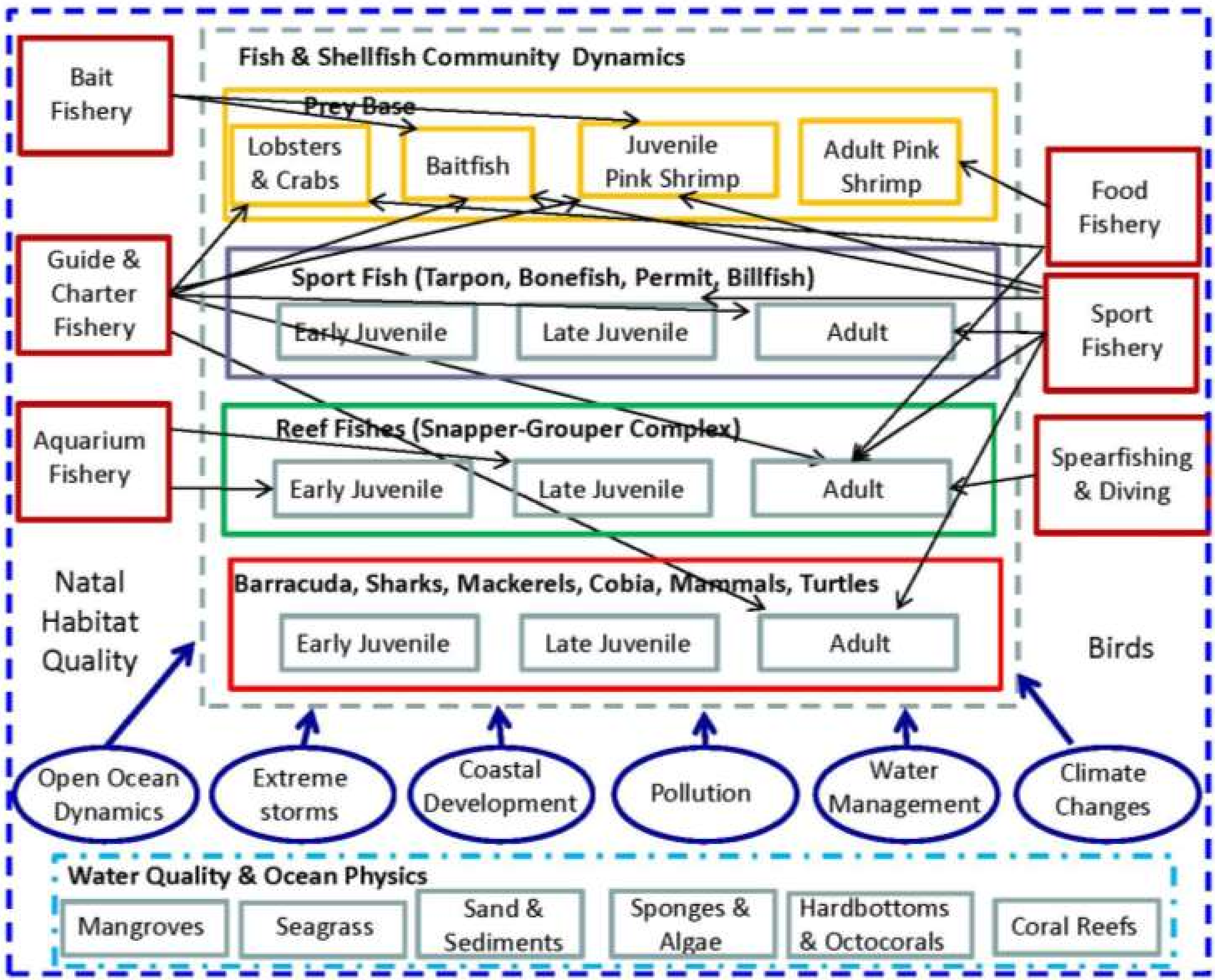
Management Controls, Single Species
- Gear/Size, Effort/Bag Limit Restrictions
- Seasonal Closures

Sustainability Threats
- Directed Fishing on Single Target Species
- Directed Fishing on Multiple Species
- Indirect Fishing on Key Prey Species
- Alterations to Habitats/Water Quality
- Climate Changes & Variability

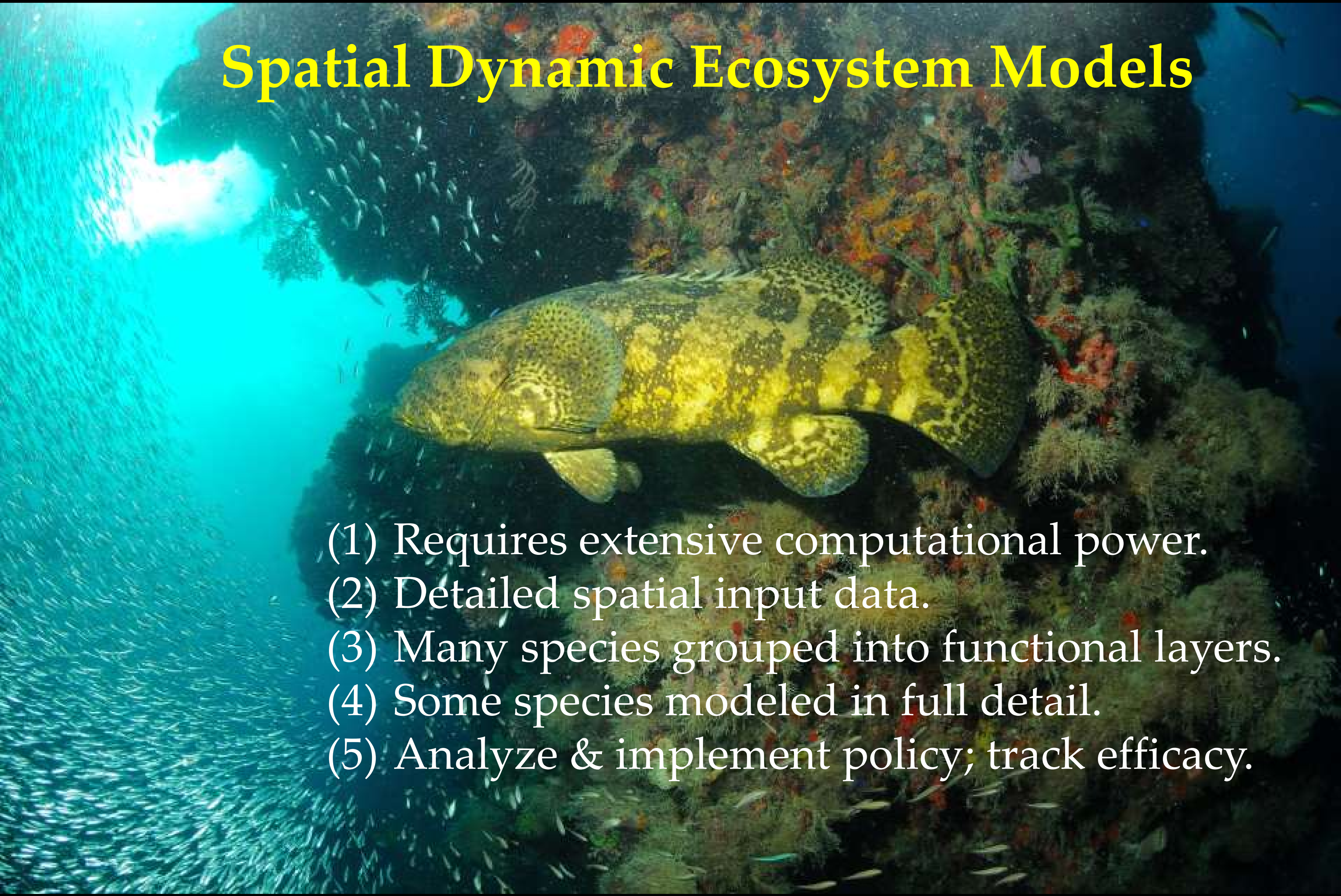
Management Controls, Multiple Target/Prey Species
- Gear/Size, Effort/Bag Limit Restrictions
- Seasonal Closures
- Spatial Zoning, MPAs
- Environmental Controls:
  - Freshwater Inflows
  - Land-based Sources of Pollution, Nutrients
  - Coastal Development
  - Dredging, Beach Re-nourishment
- Longer-Term Management Strategies for Anticipated Climate Changes

Requires greater Agency interaction and cooperation!

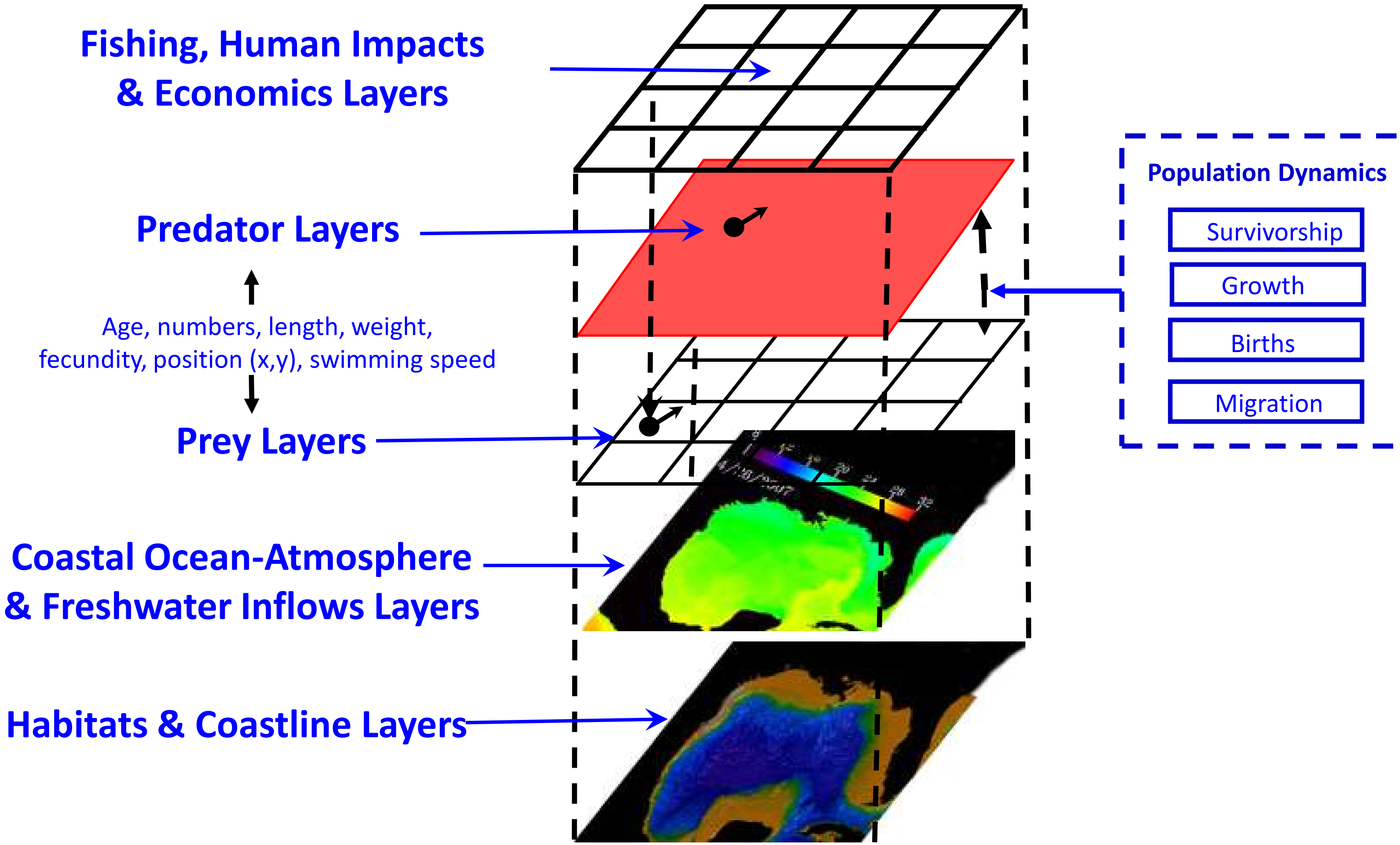
Ecological and fishery inter-relationships - South Atlantic Ecosystem



Ault et al. 2014. Ecological Indicators 44: 164-172.


Spatial Dynamic Ecosystem Models
(1) Requires extensive computational power.
(2) Detailed spatial input data.
(3) Many species grouped into functional layers.
(4) Some species modeled in full detail.
(5) Analyze & implement policy; track efficacy.

21st Century Scientific Challenge to Achieve Fishery Ecosystem Sustainability

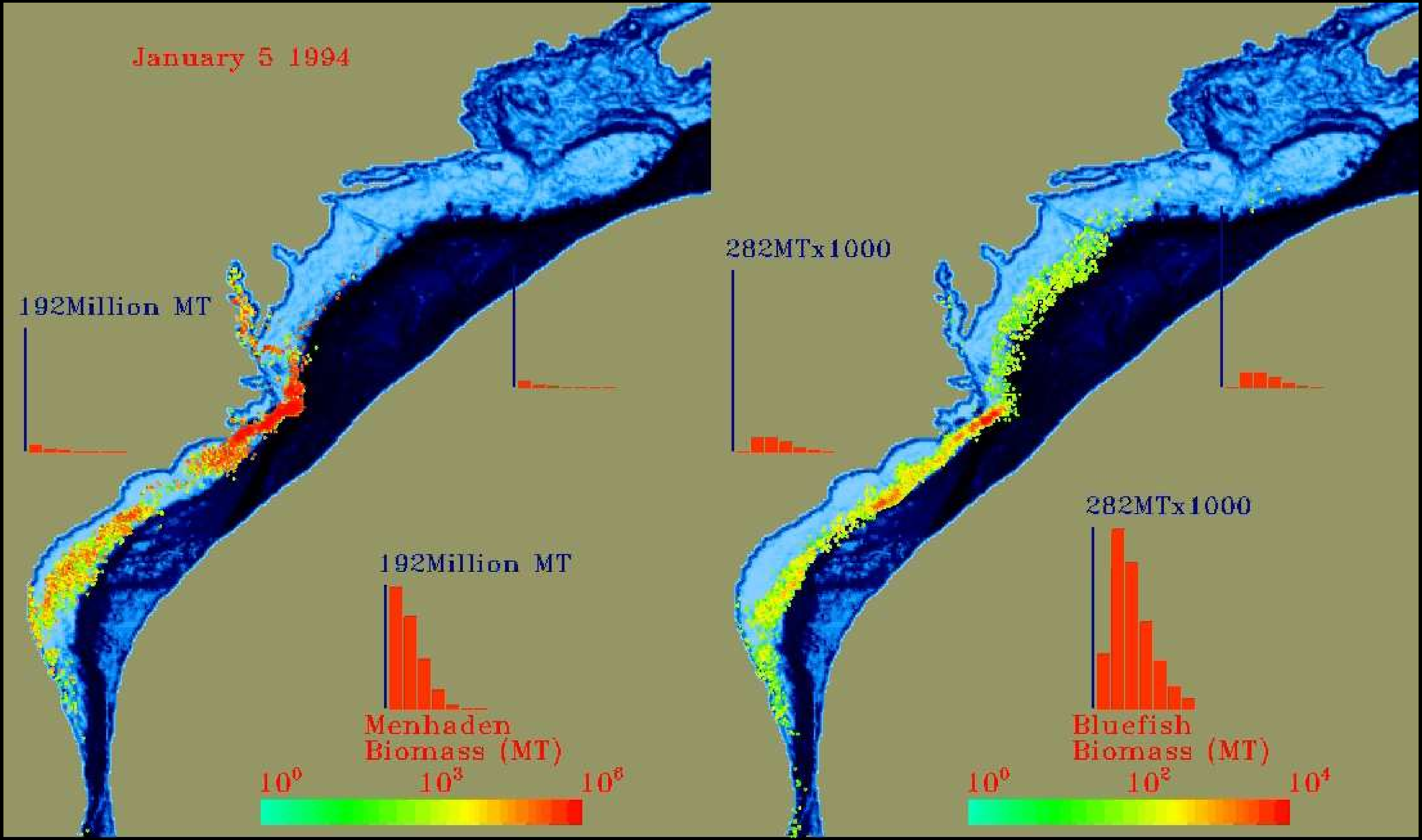


Carefully evaluate management strategy, objectives, functionality and data availability to determine which species can be modeled in detail.

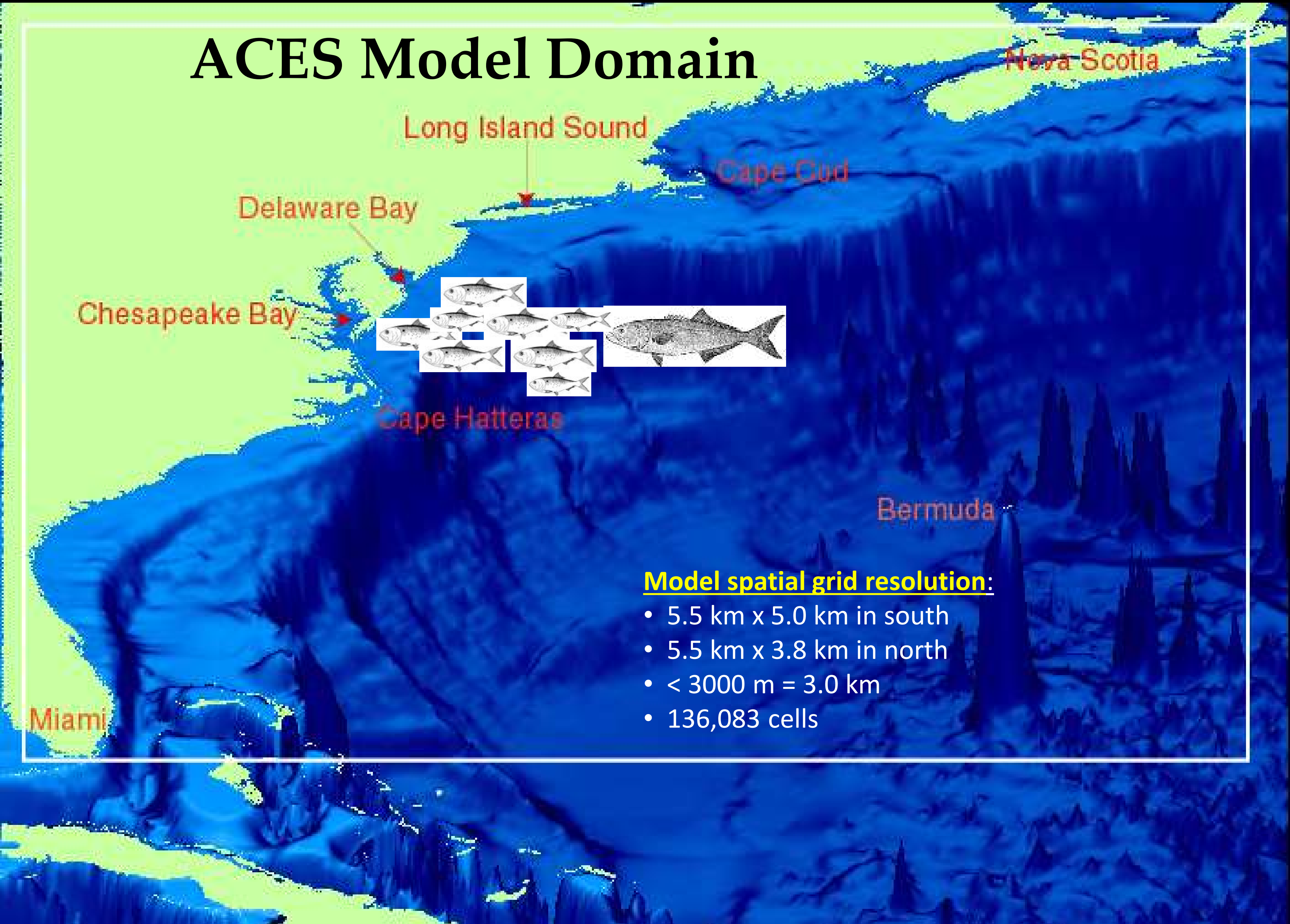
ACES (Atlantic Coast Ecosystem Simulation) Model

Menhaden Biomass

Bluefish Biomass



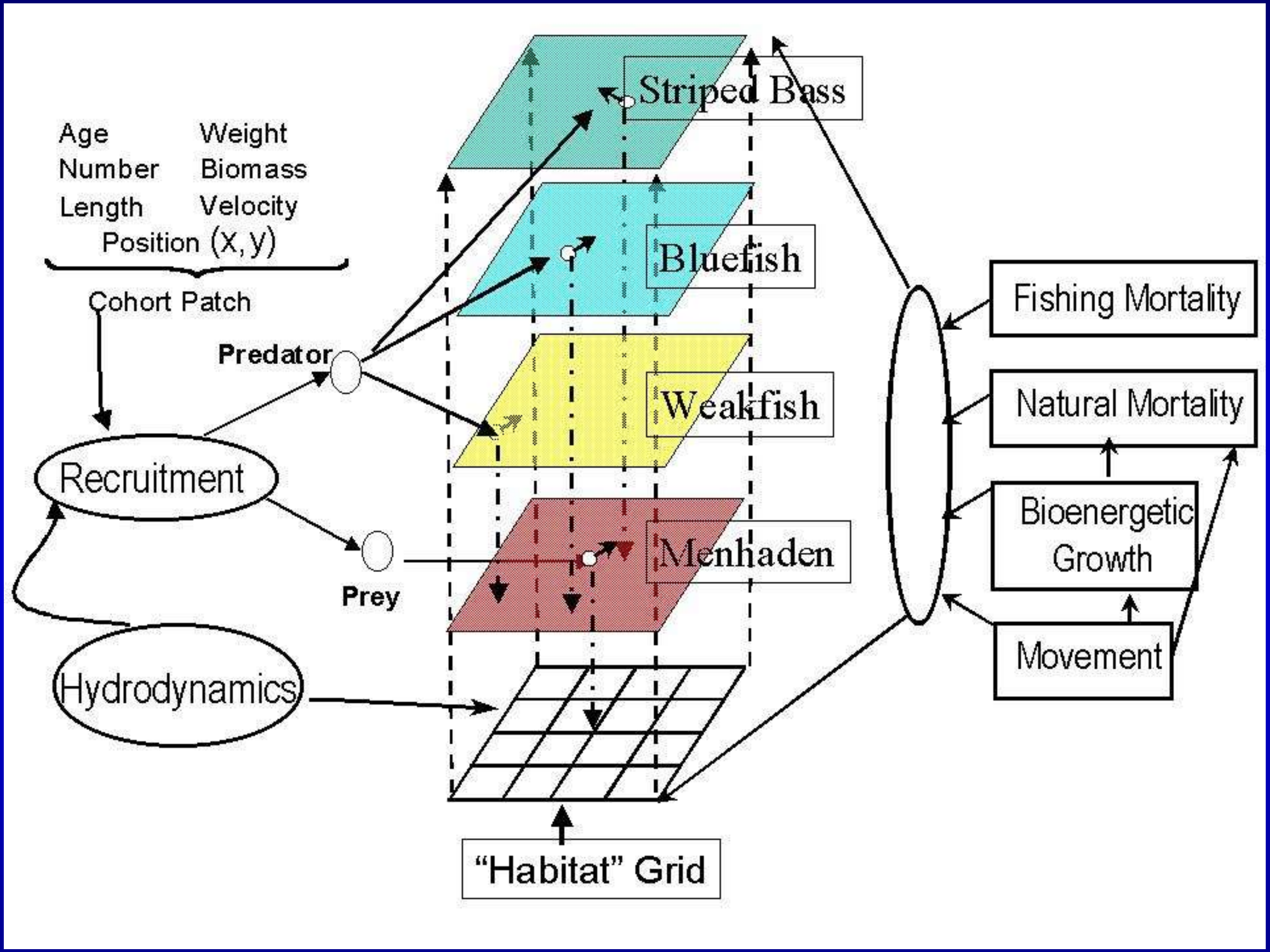
ACES Model Domain



Model spatial grid resolution:

- 5.5 km x 5.0 km in south
- 5.5 km x 3.8 km in north
- < 3000 m = 3.0 km
- 136,083 cells

Atlantic Coast Ecosystem Simulation (ACES) Model



Predator Species: Striped Bass, **Bluefish**, Weakfish
Prey: **Menhaden,** other forage fishes, and invertebrates
Key Impacts: Direct and indirect fishing (both predator & prey)

Multispecies Population Conservation Equations

$$\frac{dN}{dt} = \underbrace{-u_i \frac{\partial N}{\partial x_i}}_{\text{Advection \& Transport}} \underbrace{- \frac{\partial N}{\partial a} - Z(N)N}_{\text{Population Reaction Kinetics}} + \underbrace{\frac{\partial}{\partial x_i}\left[K(N)\frac{\partial}{\partial x_i}N\right]}_{\text{Density-Dependent Diffusion}} \underbrace{-U_i \frac{\partial N}{\partial x_i}}_{\text{Taxis}}$$

Model tracks cohorts of prey, $N(x_i,a,t)$, and predators, $P(x_i,a,t)$, at ages a and time t and space x_i from spawning, through settlement and recruitment, and then as they grow and age, reproduce and ultimately die.

Multicohort-Multispecies Structured Reaction Kinetics

(Ault & Olson. 1996. Trans. Amer. Fish. Soc. 195:321-362.)

$$\frac{dW(a,t)}{dt} = \frac{\partial W(a,t)}{\partial a} + \frac{\partial W(a,t)}{\partial t} = rW(t)^m - \sum_{k=1}^{\lambda} b_k N_k(t) W(t) - \alpha W(t)^n$$

$$\frac{dN(a,t)}{dt} = \frac{\partial N(a,t)}{\partial a} + \frac{\partial N(a,t)}{\partial t} = -\left\langle M(t)\left(1-\delta\left[\frac{W(t)-W_{opt}(a)}{W_{opt}(a)}\right]\right) + F(t)\right\rangle N(a,t)$$

$$\downarrow \qquad \qquad \downarrow$$

$$\ddot{N}(a,t) = \dot{N}^2(a,t)\left(\frac{1}{N(a,t)}\right) - \dot{N}(a,t)\left(\frac{a_1}{N(a,t)} - a_2 N(a,t) + a_3\right) + bN^2(a,t) - cN(a,t) = 0$$

Interesting equation with rich nonlinearities, capable of expressing complex dynamic behaviors.

Population-Community Abundance and Biomass Dynamics

$$dW(a,t) = (anabolism - catabolism)\, dt$$

"Bioenergetic underpinnings"

$$\frac{dW(a,t)}{W(a,t)dt} = (C - C * p_E - C * p_U) - R = C * (1 - p_E - p_u) - R = C * A - R$$

$$\frac{dW(a,t)}{W(a,t)dt} = \alpha_C [f_C(T) * f_C(S) * f_C(N)] W(a,t)^{\beta_C} - \alpha_R [f_R(T) * f_R(S) * f_R(V)] W(a,t)^{\beta_R}$$

$$\frac{dP(a,t)}{dt} = -\left[M \left\langle 1 - \gamma \left(\frac{W(a,t) - W_{opt}(a)}{W_{opt}} \right) \right\rangle + F(a,t) \right] P(a,t)$$

Ault et al. 1999. Canadian Journal of Fisheries & Aquatic Sciences

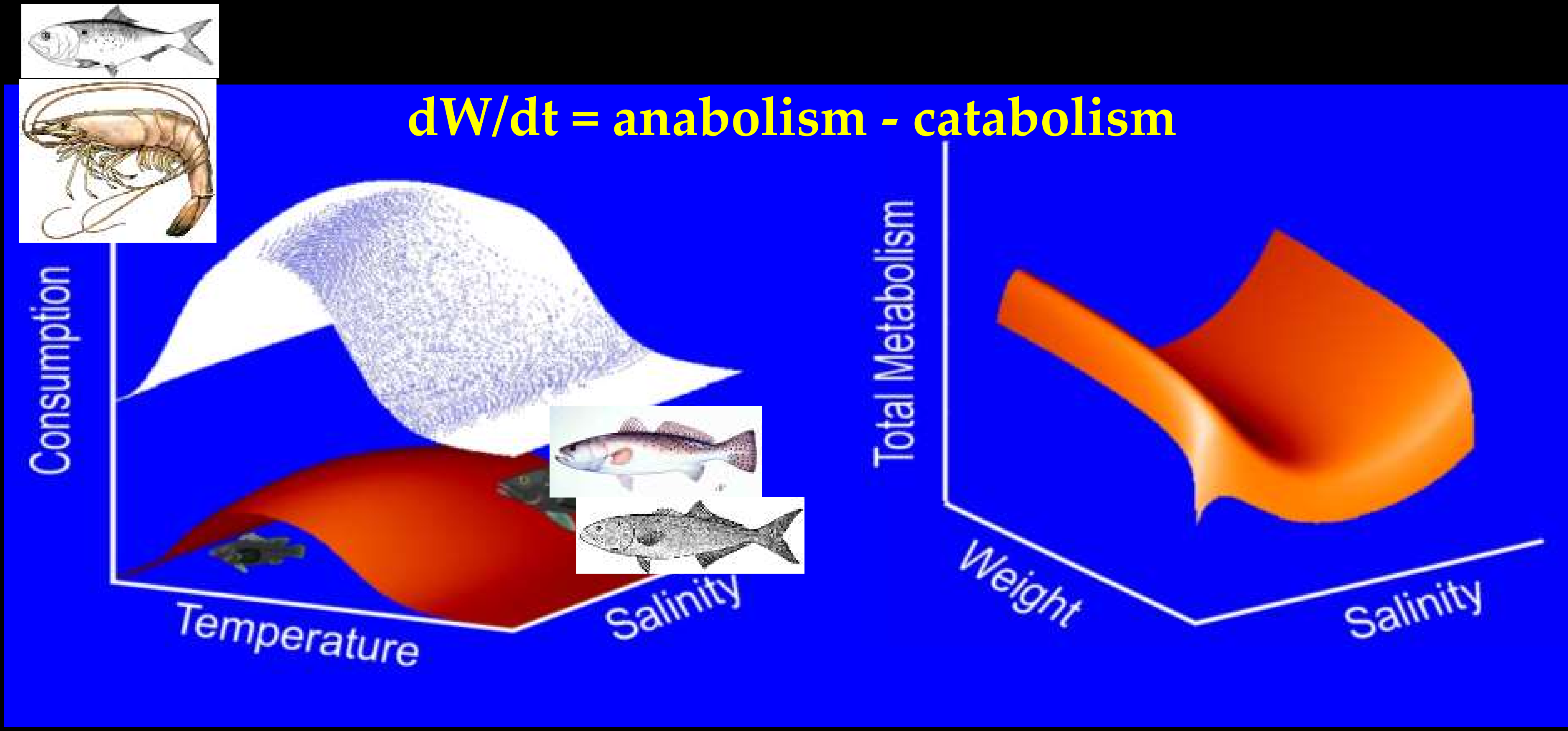
Ault & Olson. 1996. Transactions of the American Fisheries Society

Cosner, DeAngelis, Ault, Olson. 1999. Theoretical Population Biology

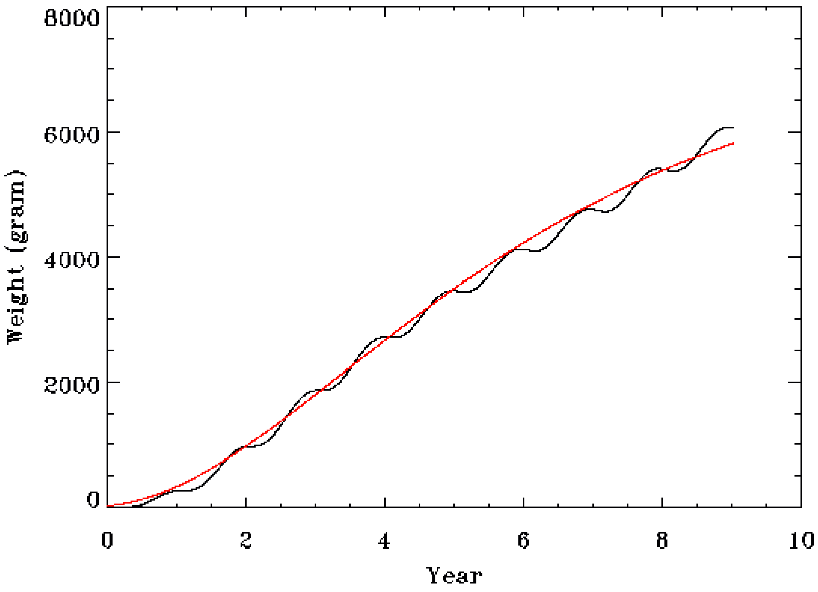
Bioenergetics

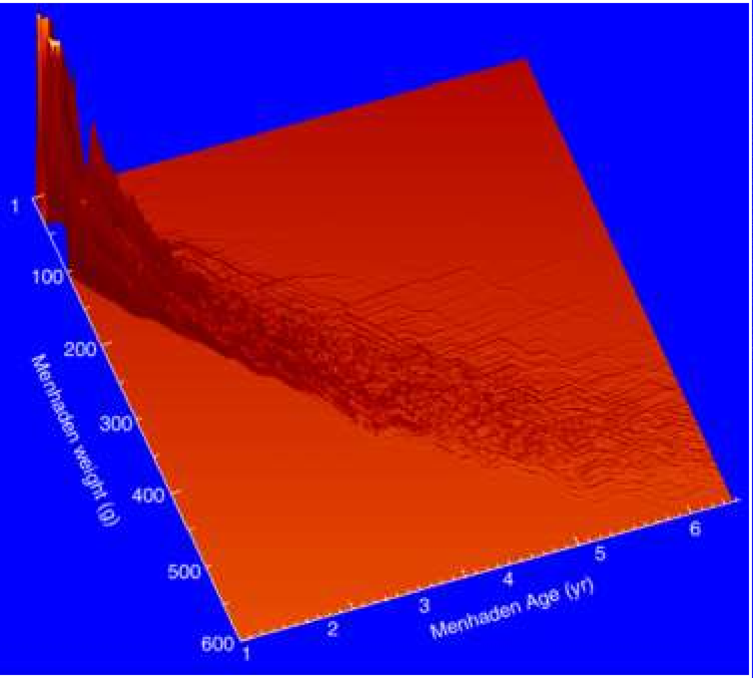
Individual Weight-at-Age

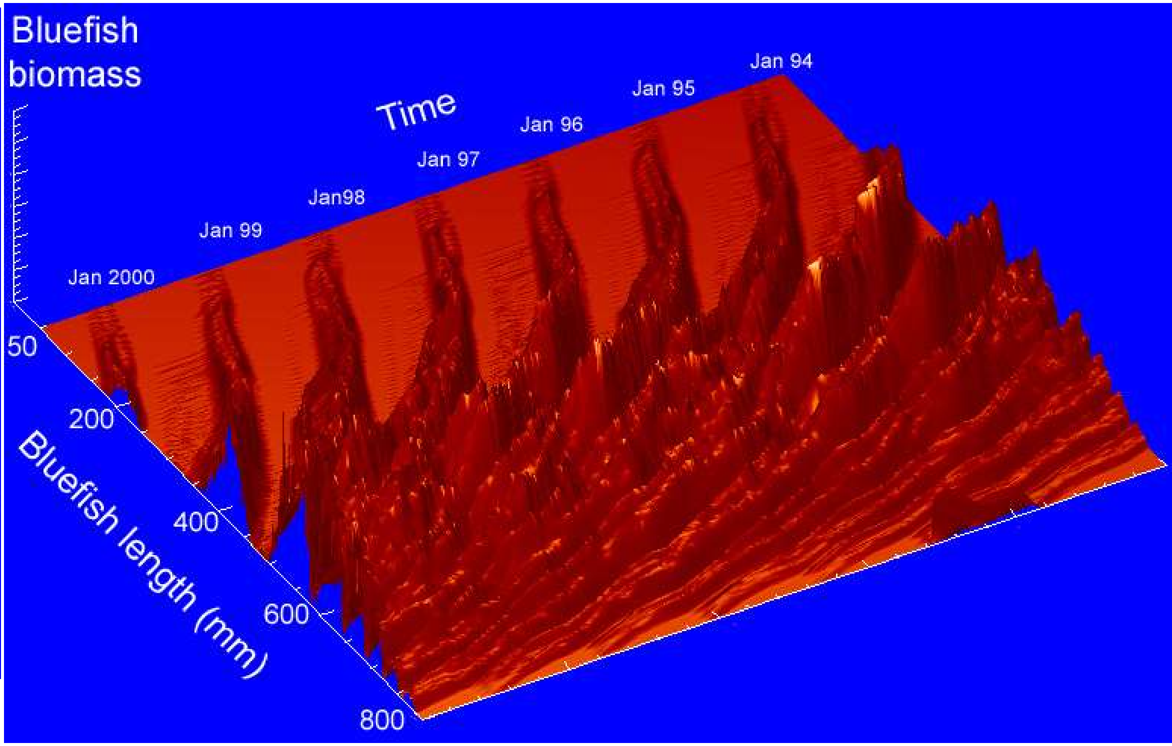
dW/dt = anabolism - catabolism



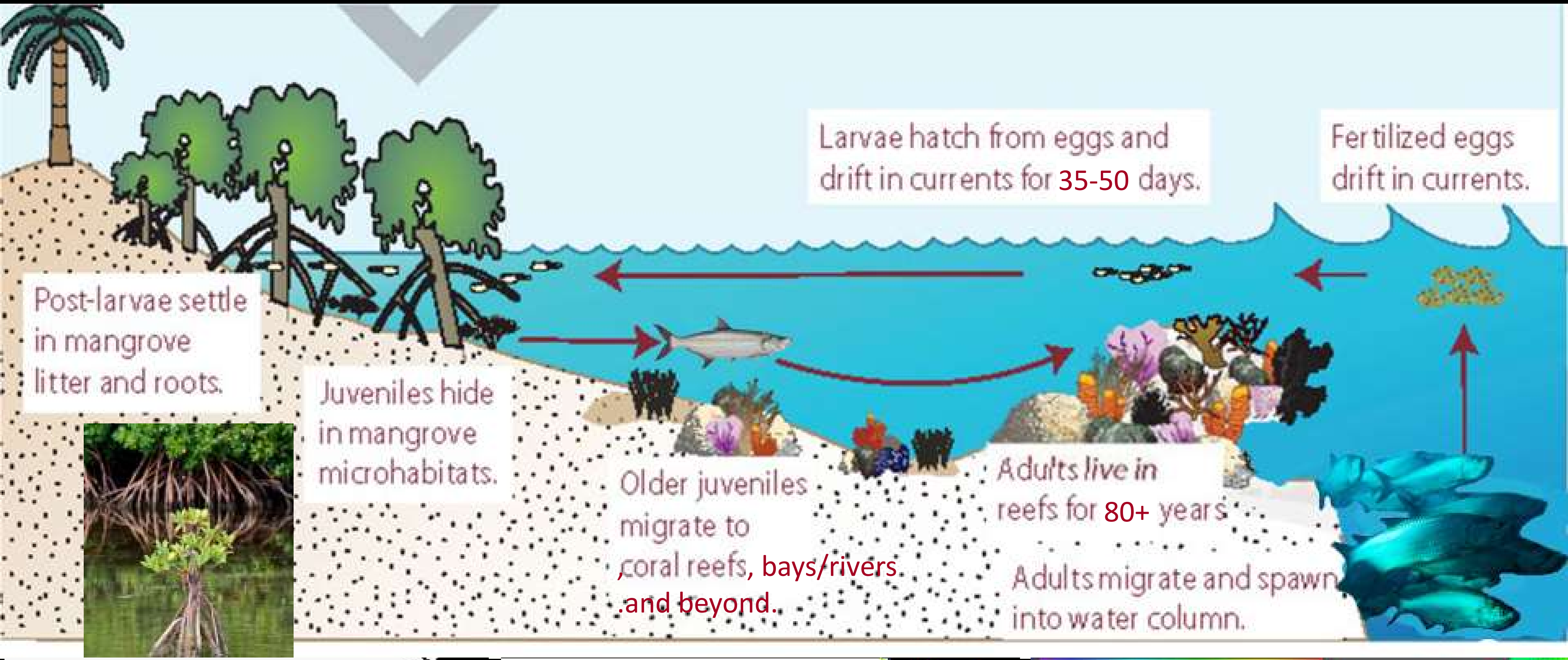
Individual to population bioenergetics

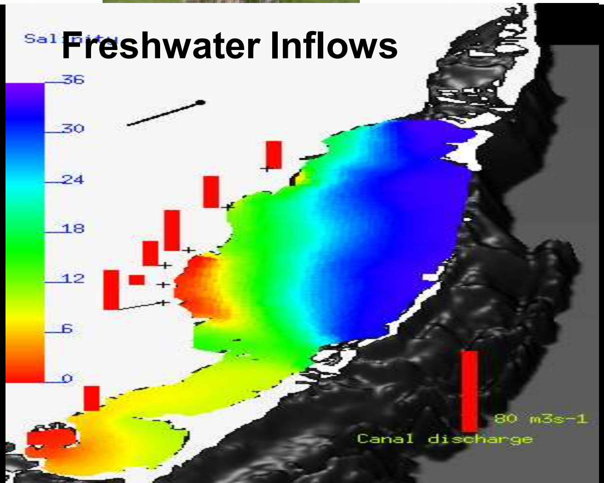


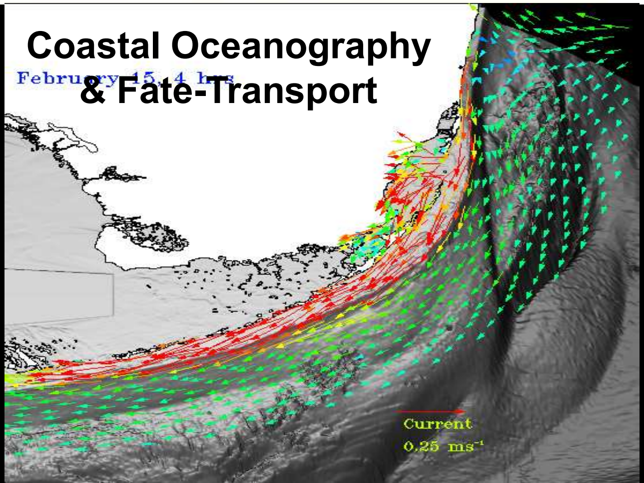


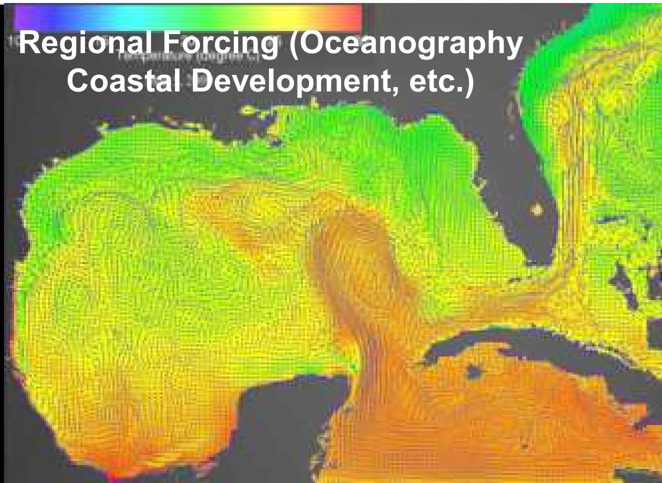


Coastal Oceanography & “Habitat” Use Ontogeny

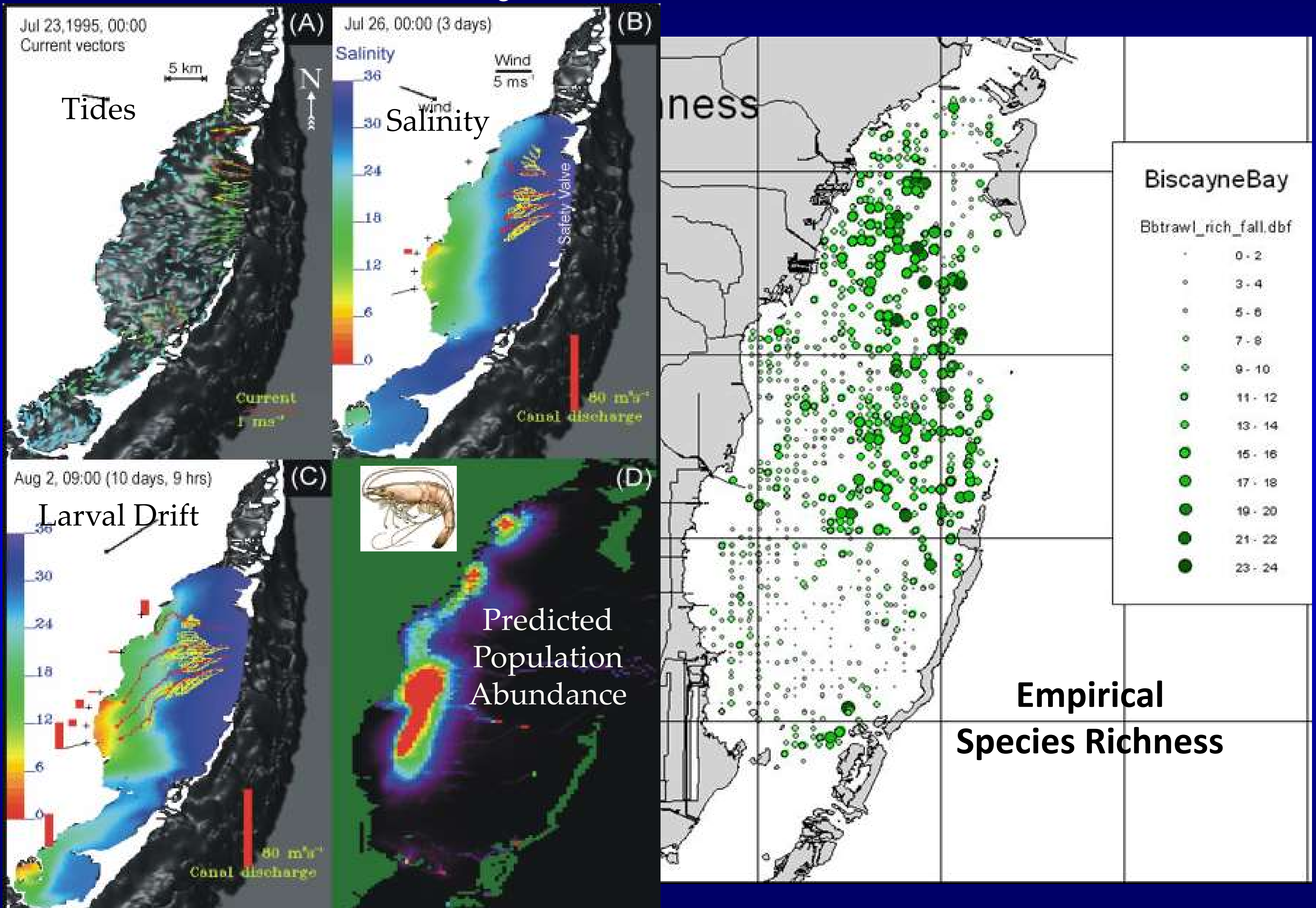




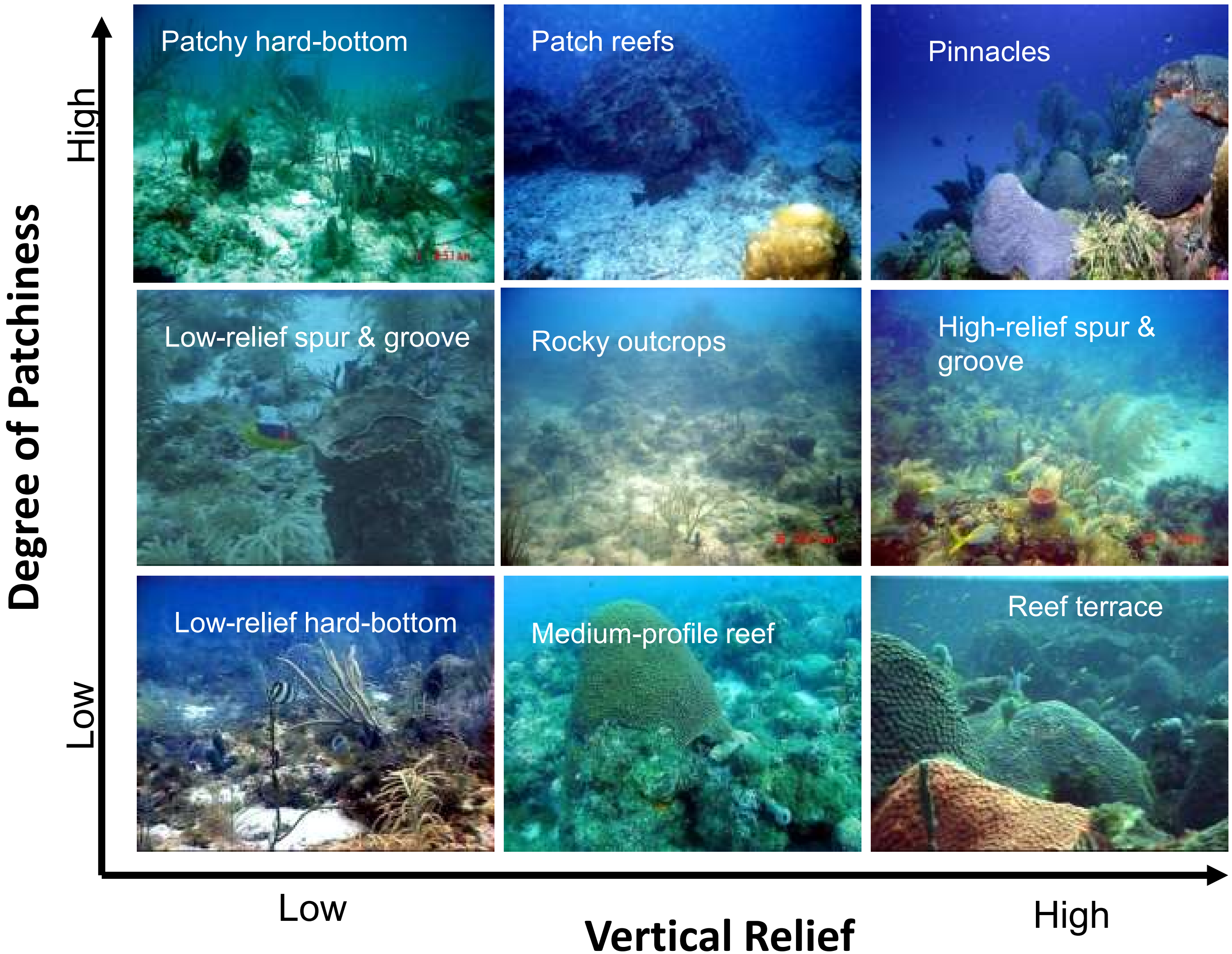




Coastal Bays to the Coral Reefs

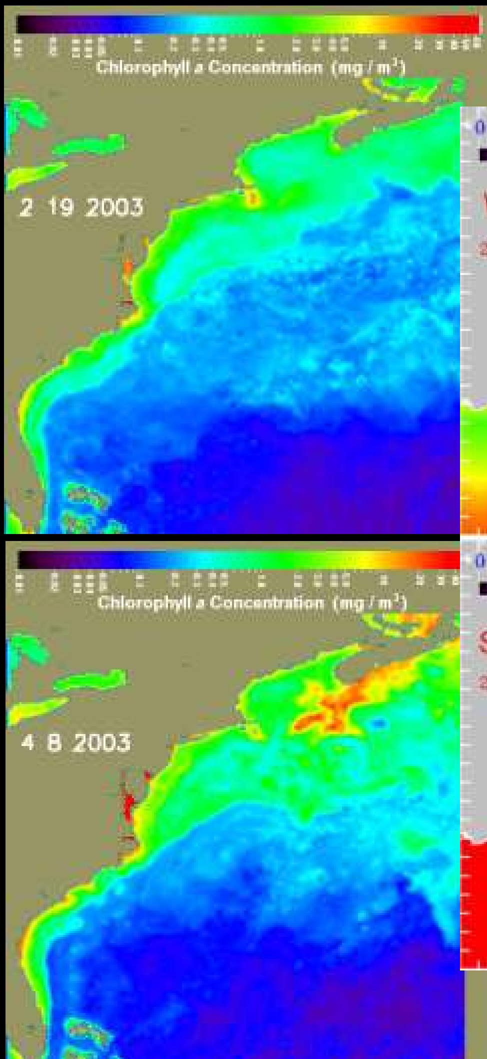


Linking Reef-Fish Spatial Abundance & Benthic Habitats

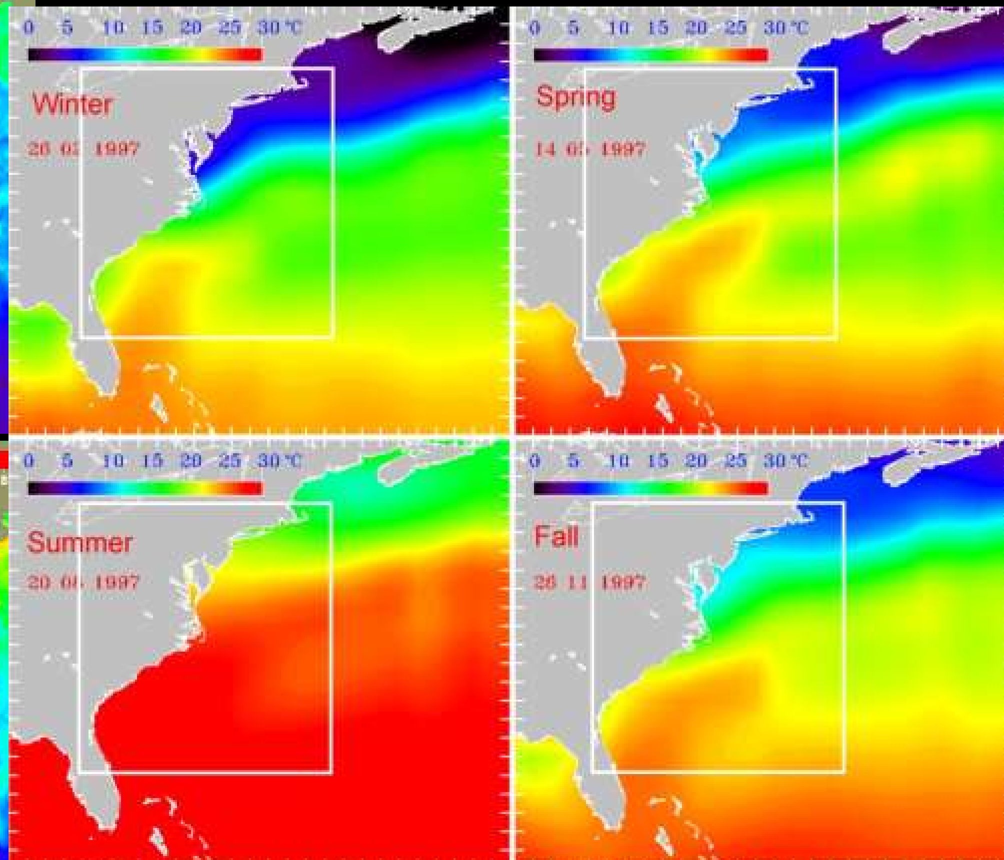


Smith, Ault, Bohnsack et al. 2011. *Fisheries Research*
Franklin, Ault, Smith, Luo, Bohnsack et al. 2003. *Marine Geodesy*

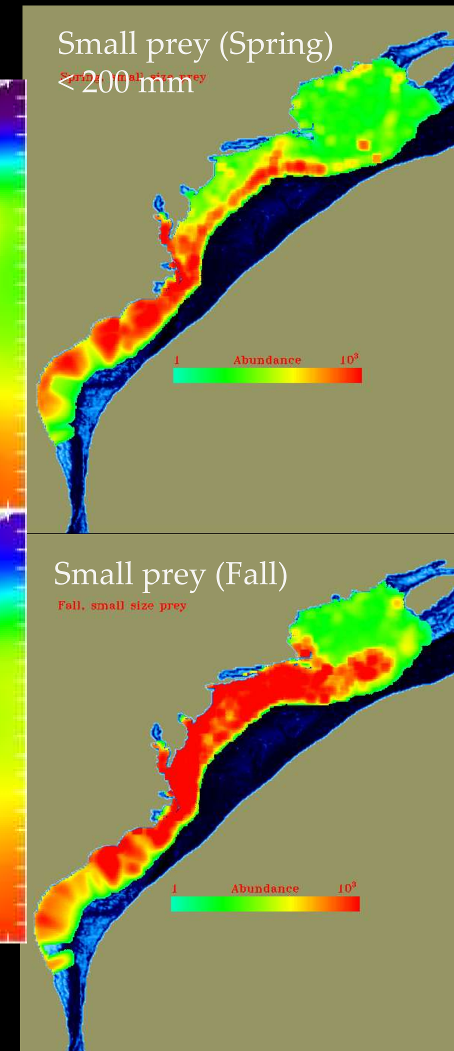
Chlorophyll a



Sea Surface Temperature



Prey Abundance



Governing equations for 2D hydrodynamic and salinity transport numerical model

Fully nonlinear vertically-integrated equations of continuity, conservation of momentum, and conservation of mass:

Continuity

$$\frac{\partial H}{\partial t} + \frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} = q_{in}$$

$$q_x = \int_{-\eta}^{\eta} u \; dz; \quad q_y = \int_{-\eta}^{\eta} v \; dz$$

Momentum

$$\frac{\partial q_x}{\partial t} + \frac{\partial u q_x}{\partial x} + \frac{\partial v q_x}{\partial y} = -gH\frac{\partial \eta}{\partial x} - \frac{gH^2}{2\rho} - \frac{\partial \delta\rho}{\partial x} + f q_y - C_f \mathbf{u} u - \frac{\tau_x}{\rho} + \frac{\partial}{\partial x}\left(HE_{xx}\frac{\partial u}{\partial x}\right) + \frac{\partial}{\partial y}\left[HE_{yy}\left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right)\right]$$

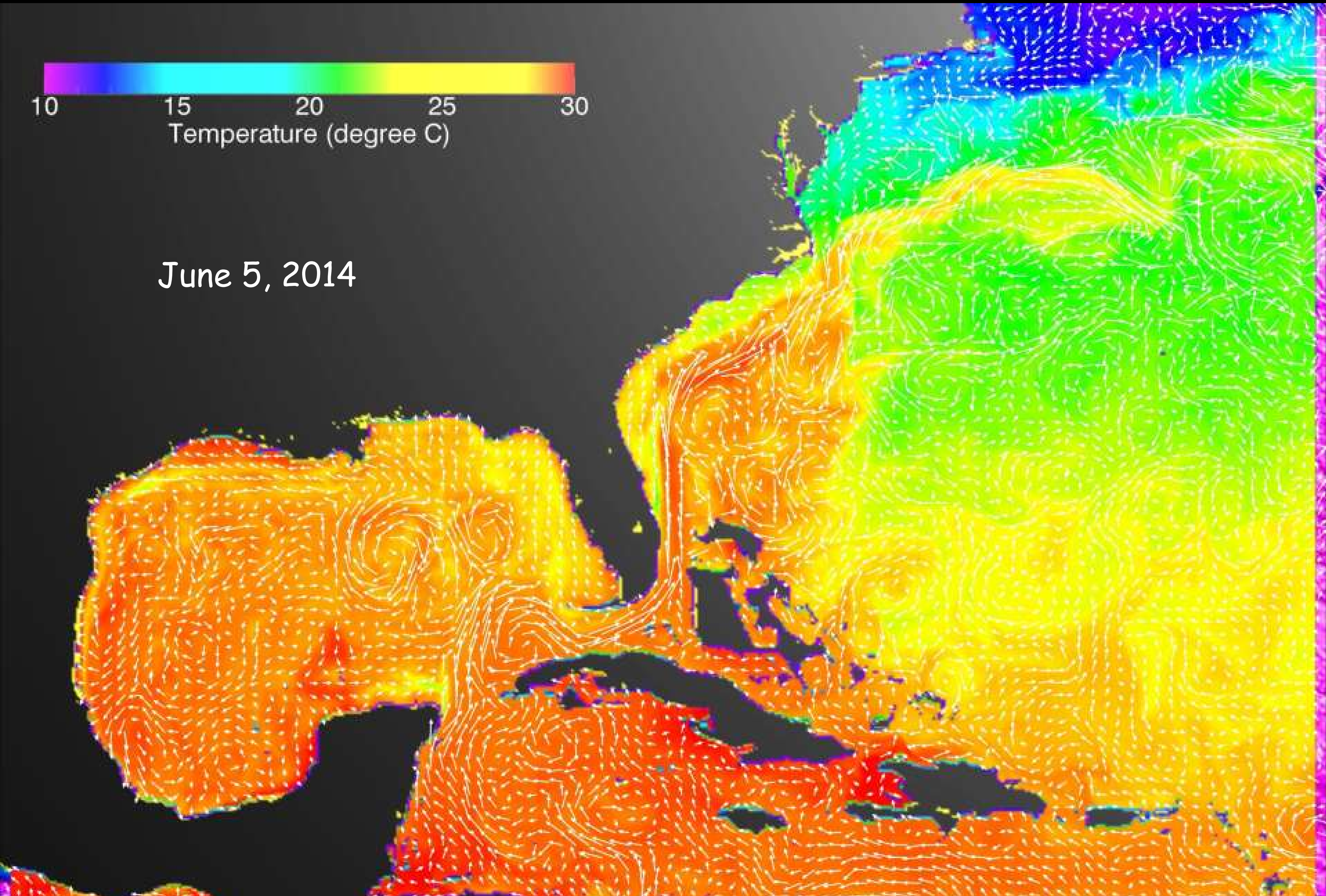
and

$$\frac{\partial q_y}{\partial t} + \frac{\partial u q_y}{\partial x} + \frac{\partial v q_y}{\partial y} = -gH\frac{\partial \eta}{\partial y} - \frac{gH^2}{2\rho} - \frac{\partial \delta\rho}{\partial y} + f q_x - C_f \mathbf{u} v - \frac{\tau_y}{\rho} + \frac{\partial}{\partial y}\left(HE_{yy}\frac{\partial v}{\partial y}\right) + \frac{\partial}{\partial x}\left[HE_{yx}\left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right)\right]$$

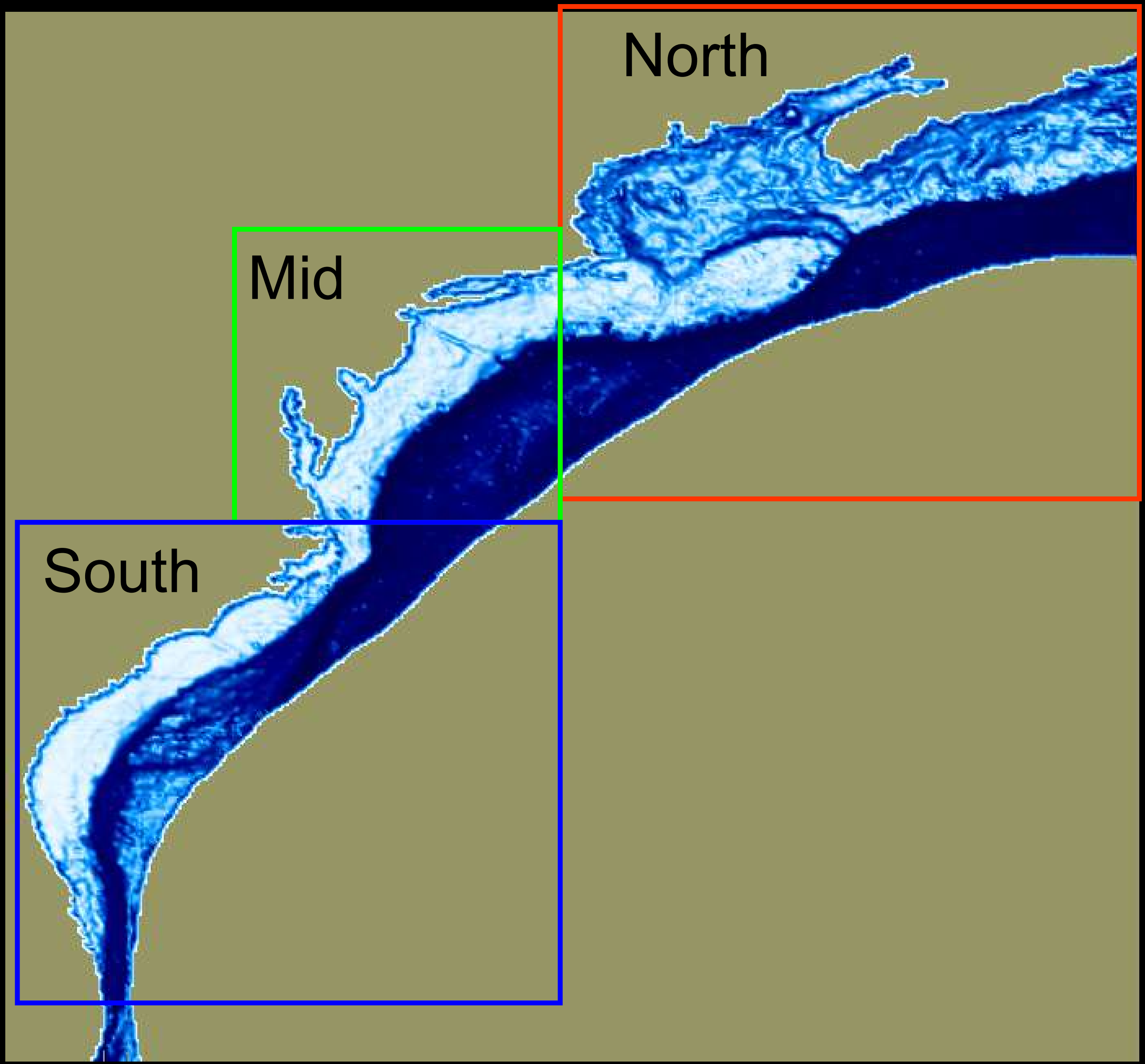
Advection

$$H\frac{\partial c}{\partial t} + uH\frac{\partial c}{\partial x} + vH\frac{\partial c}{\partial y} = \frac{\partial}{\partial x}\left(HD_{xx}\frac{\partial c}{\partial x} + HD_{xy}\right) + \frac{\partial}{\partial y}\left(HD_{yx}\frac{\partial c}{\partial x} + HD_{yy}\frac{\partial c}{\partial y}\right) + q_{in}(c^* - c) + S^*$$

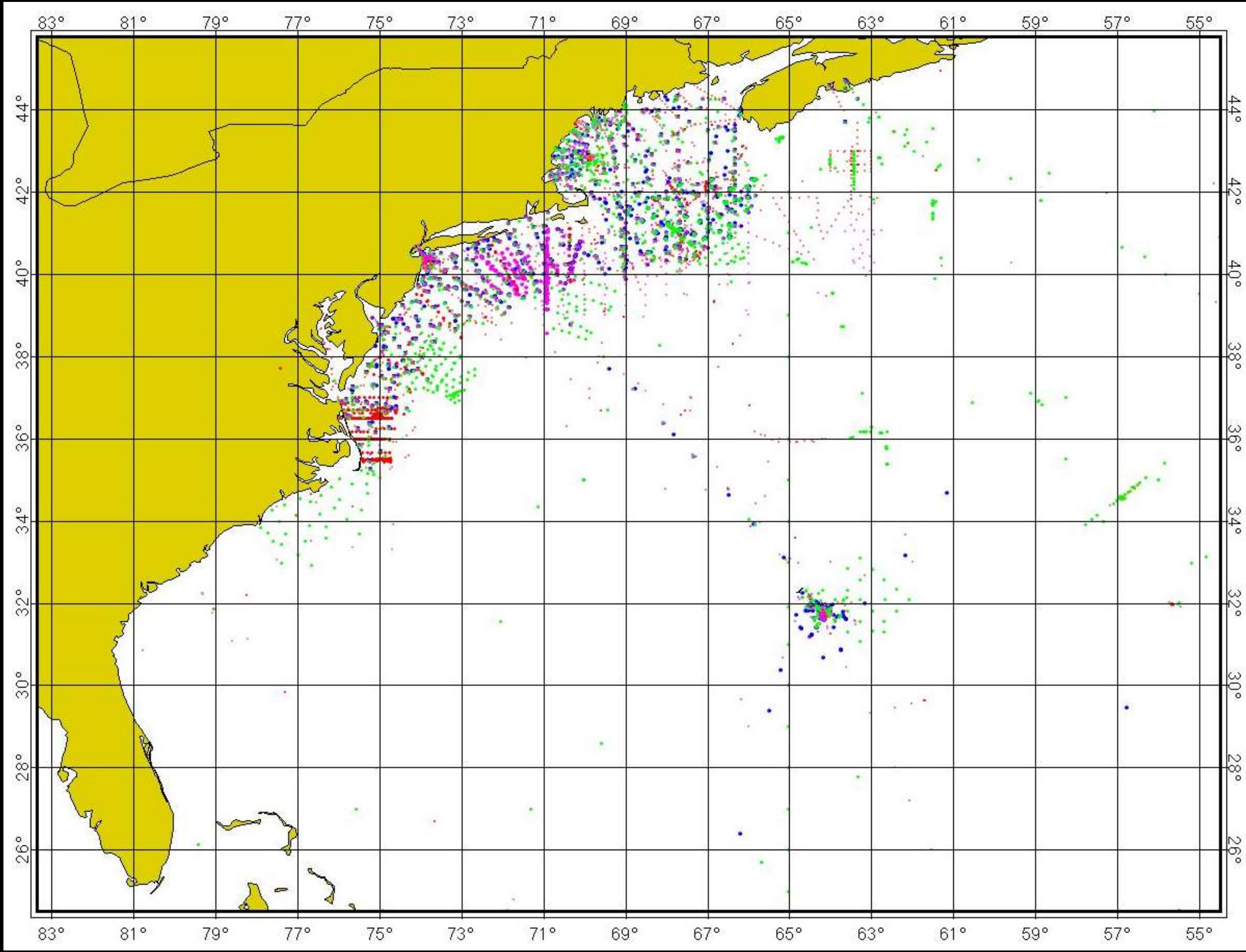
Wang, Luo & Ault. 2003. Bull. Marine Science 72(3):695-723.


10
15
20
25
30
Temperature (degree C)
June 5, 2014

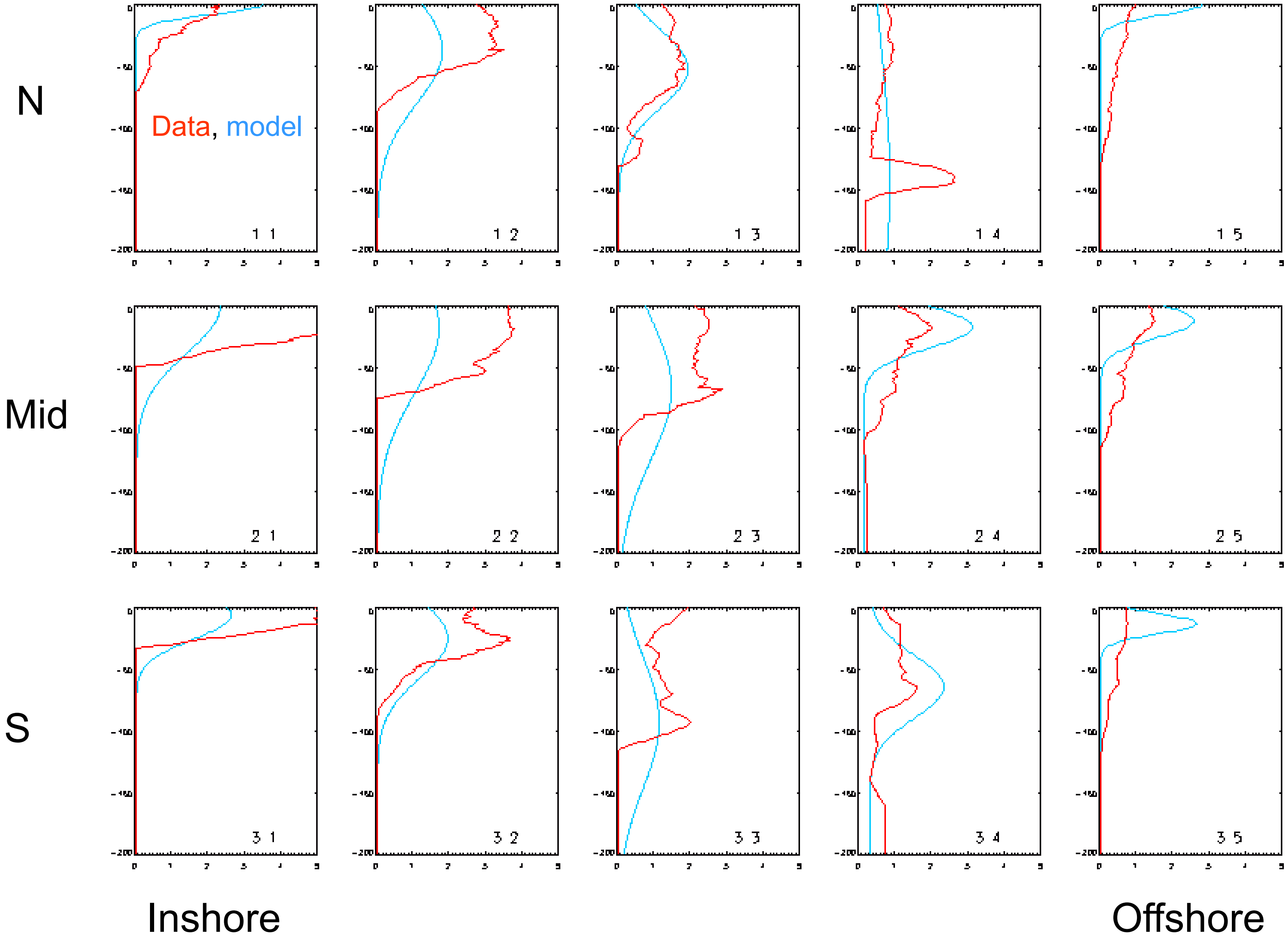
Regions of ACES Model



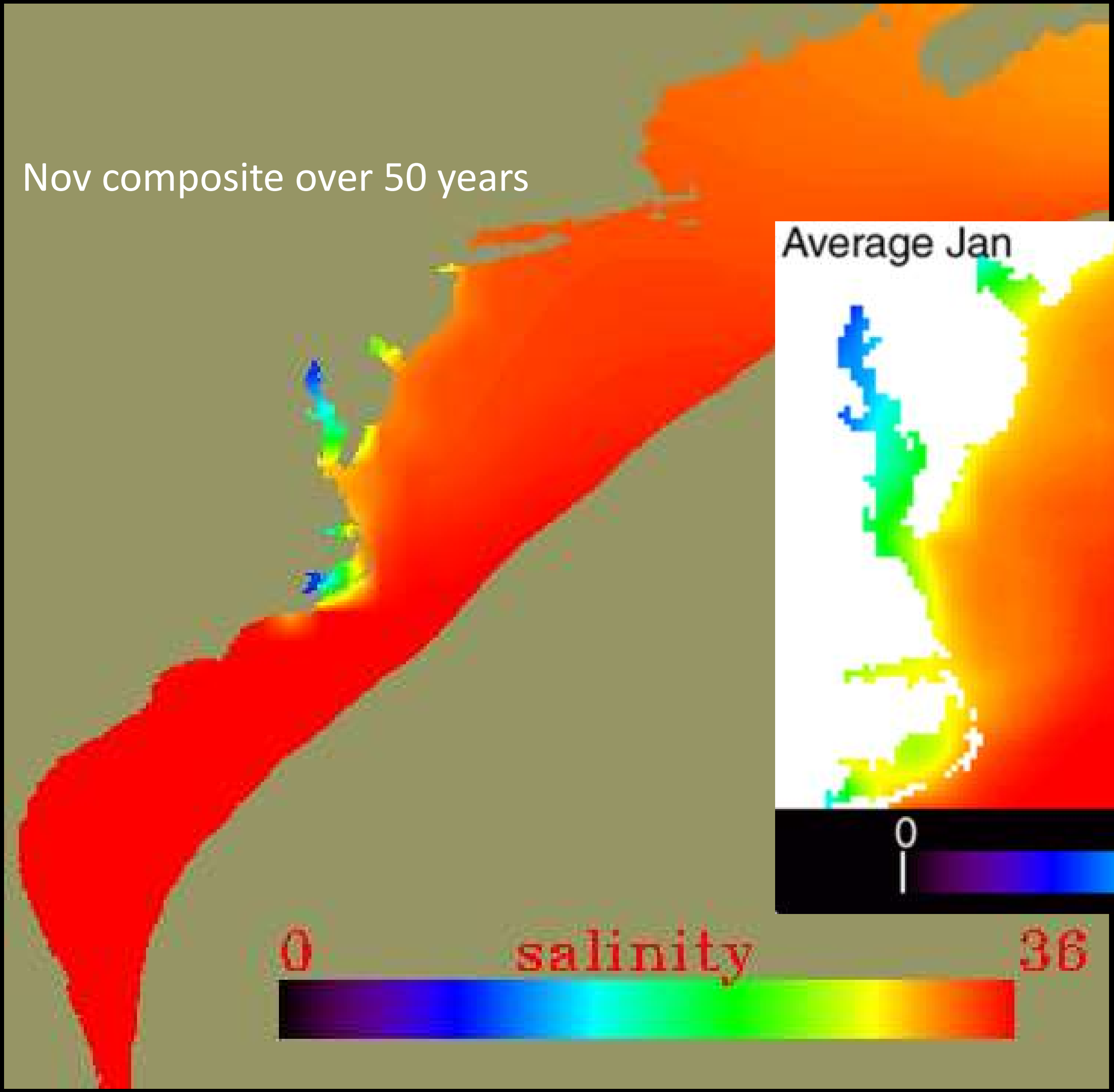
Vertical Profile Sampling for Chlorophyll

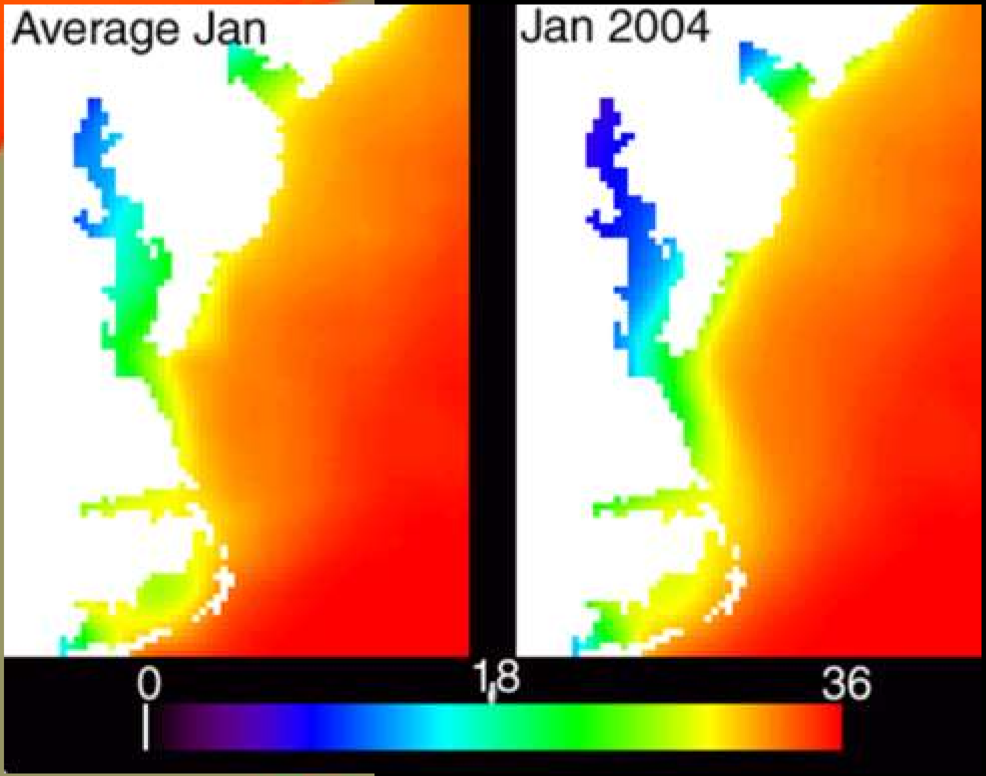


Chlorophyll Vertical Profiles for Winter



Monthly Coastal Salinity Distribution



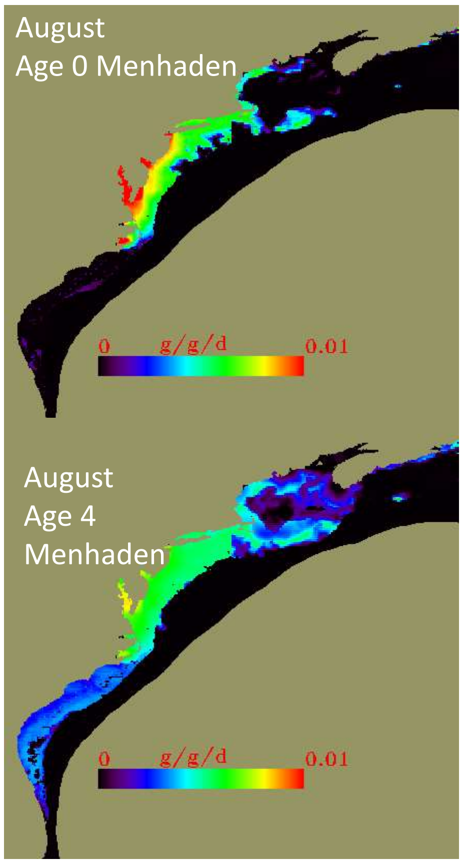


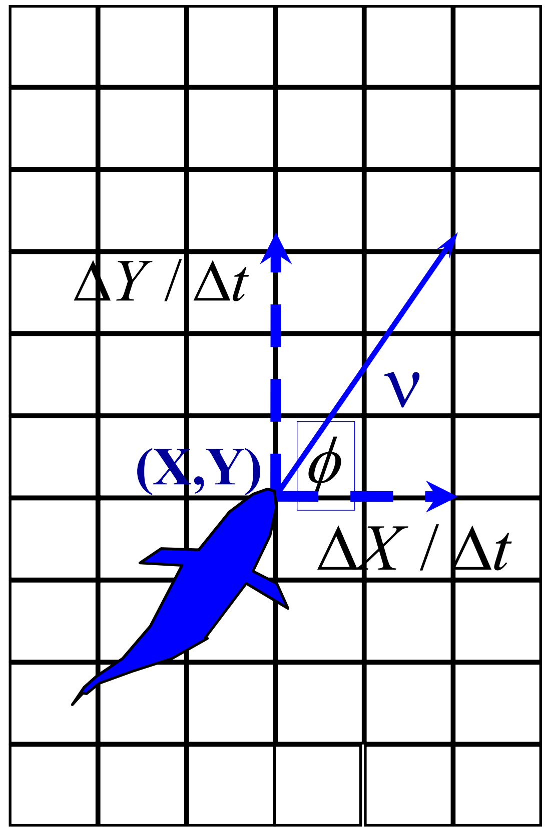
Movements & Transport of Predator & Prey

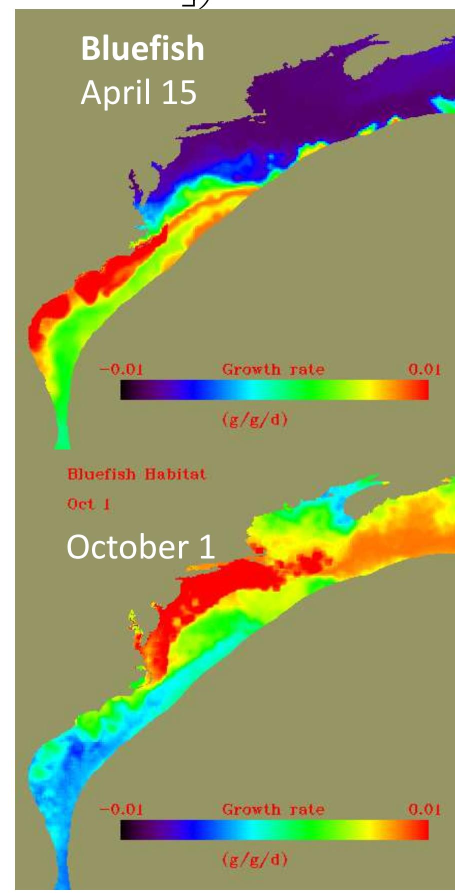
Factors affecting fish "*spatial growth rate potential*" $\frac{dW}{Wdt}$ components of "essential habitat".

$$X_b(\Omega) = \left(\tilde{V}(a,t) * \left[1 - e^{\phi\left(\frac{\Omega(t)-\Omega_{\max}}{\Omega_{\max}}\right)} \right] \right) * \cos(\theta_{\max} + \xi\pi)$$

$$Y_b(\Omega) = \left(\tilde{V}(a,t) * \left[1 - e^{\phi\left(\frac{\Omega(t)-\Omega_{\max}}{\Omega_{\max}}\right)} \right] \right) * \sin(\theta_{\max} + \xi\pi)$$

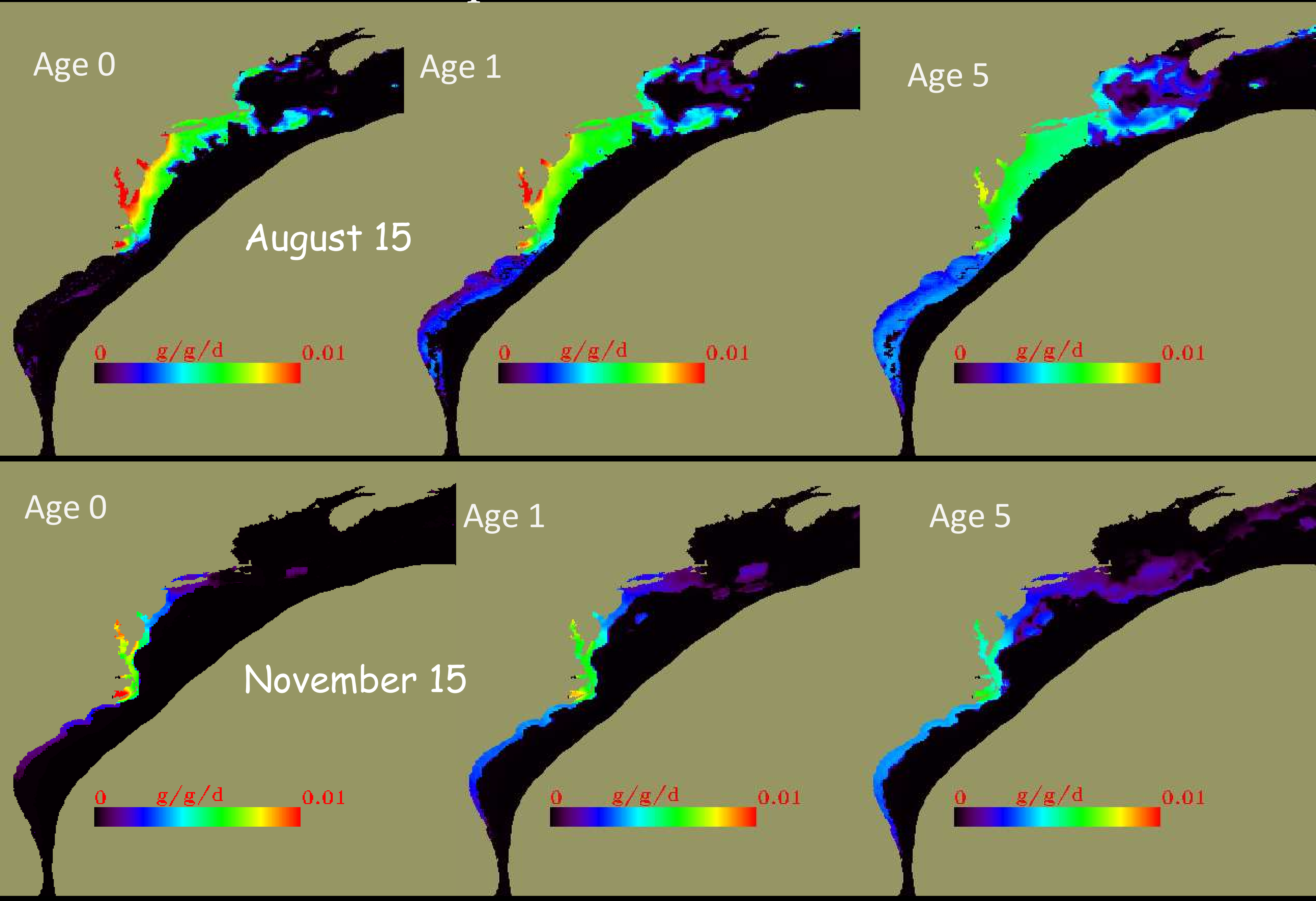


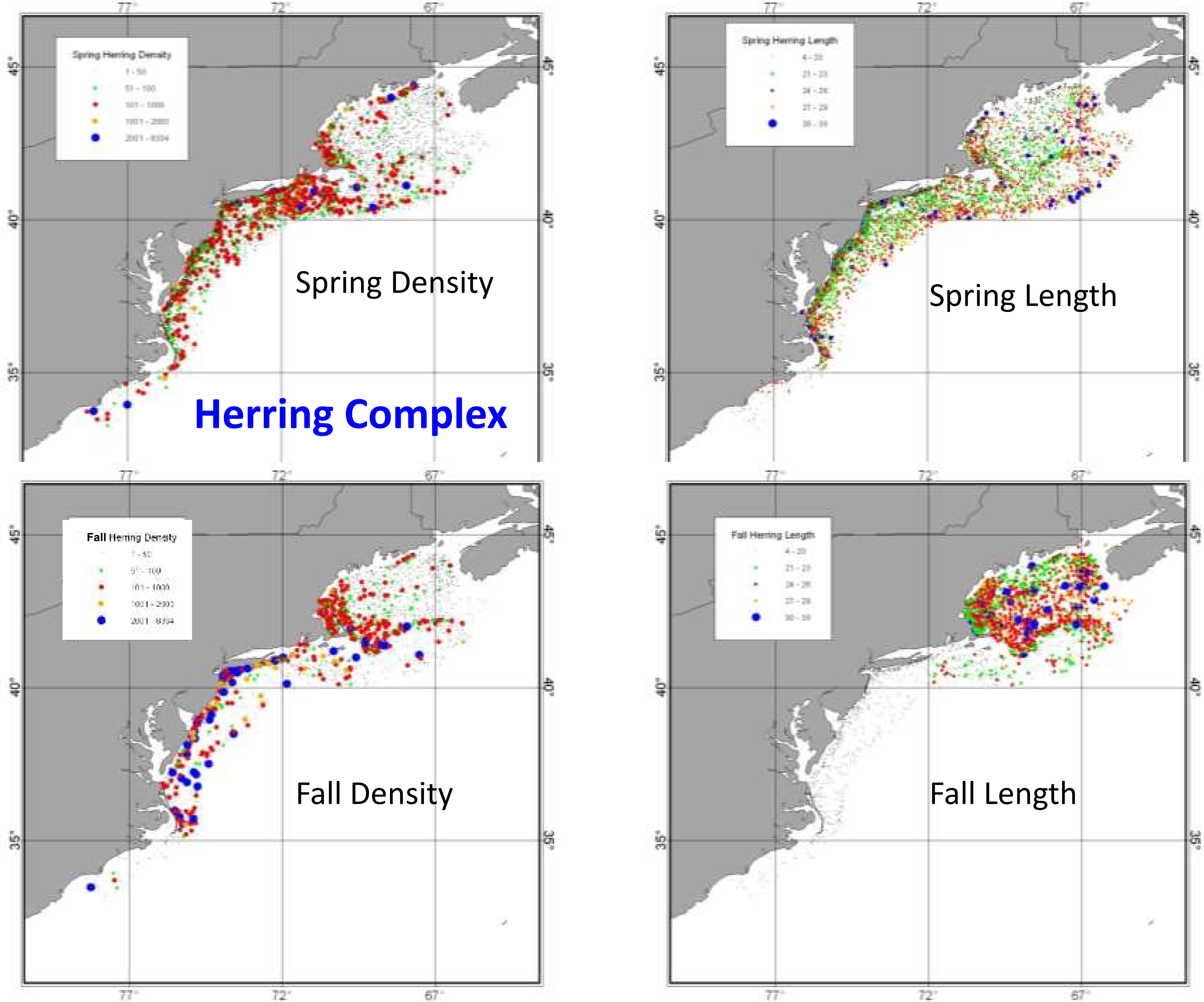


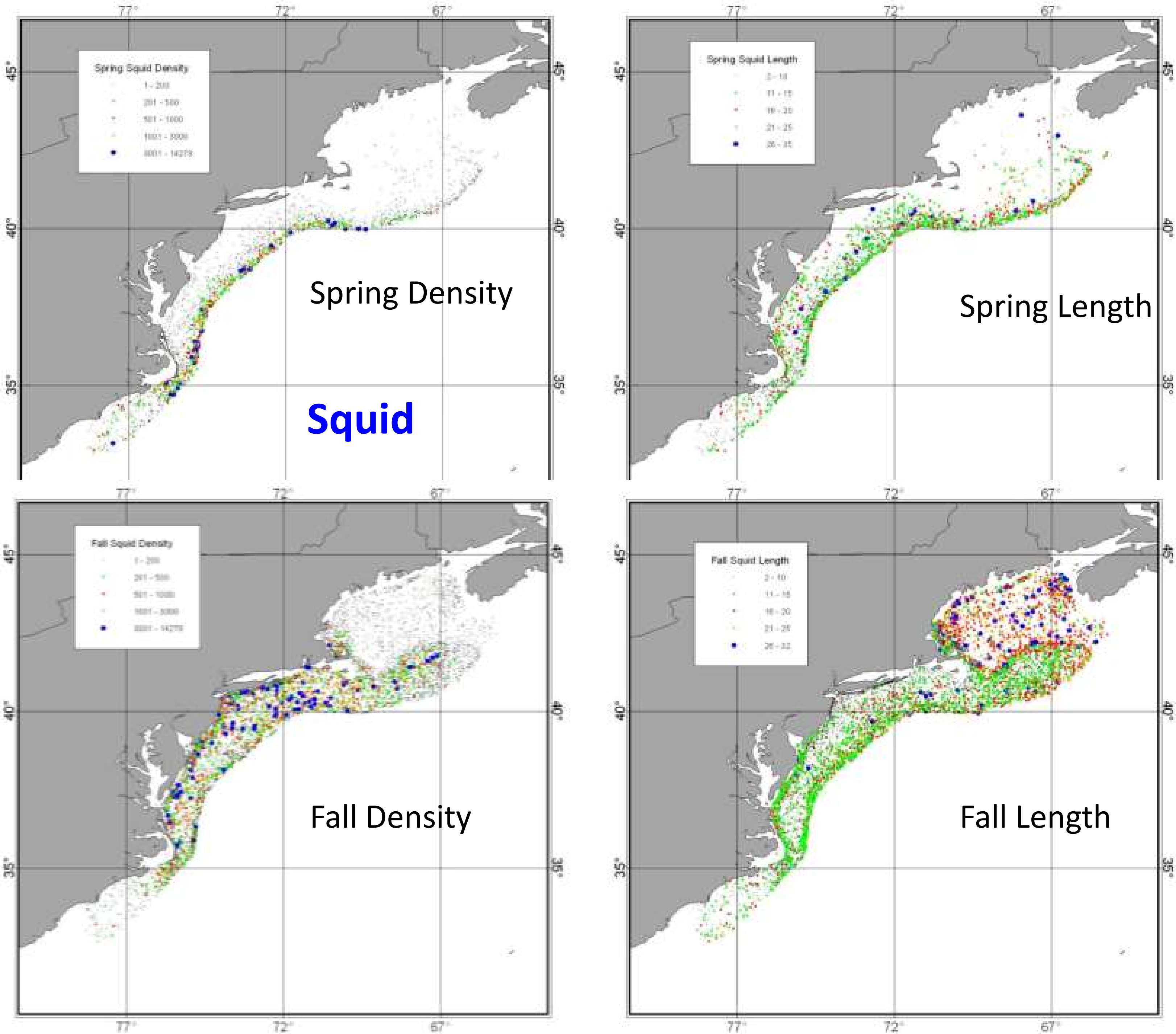


Ault et al. 1999. Canadian J. Fish & Aquat. Sci. 56: 4-25.
Humston et al. 2000. Fisheries Oceanography 9(2): 136-146.

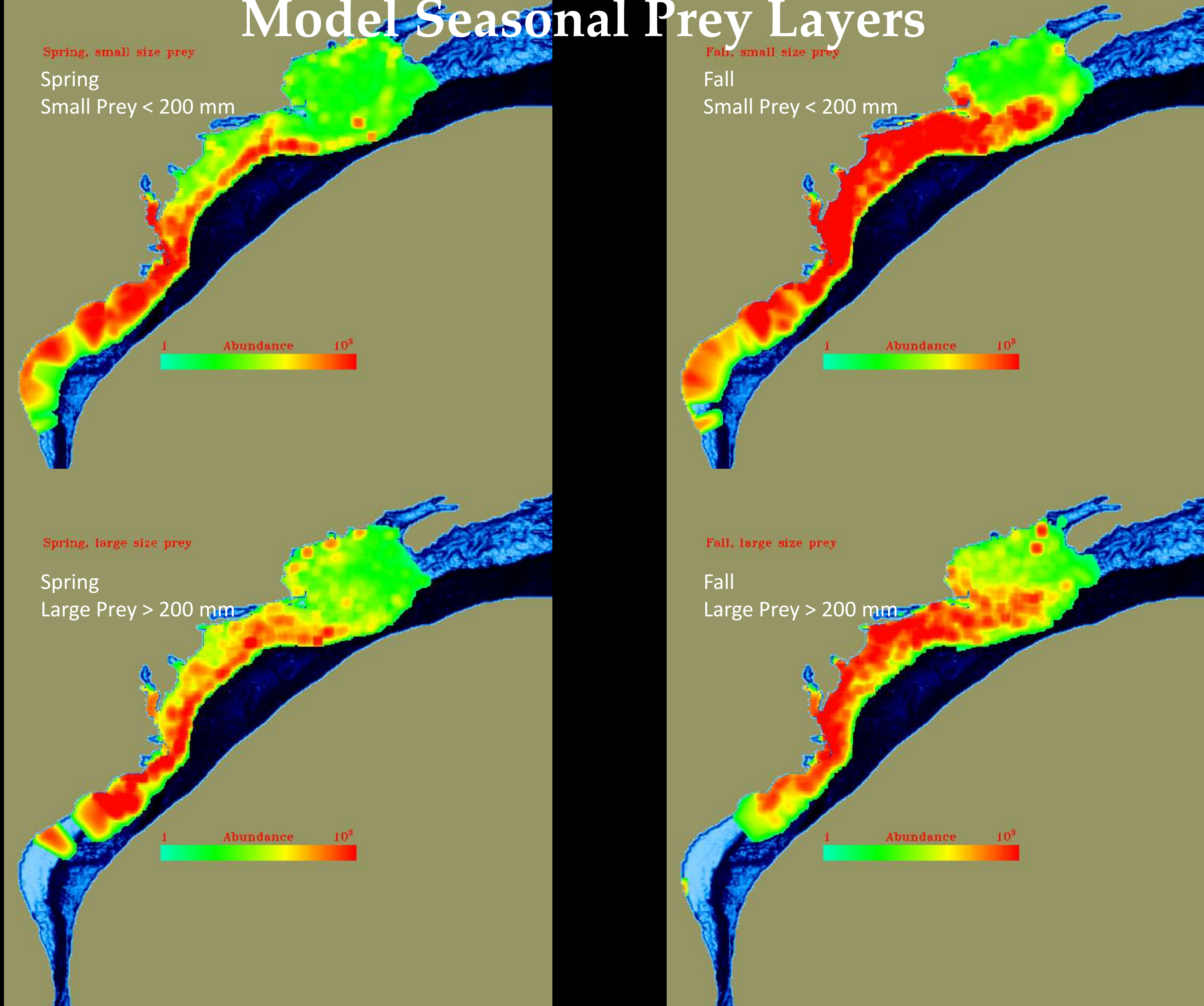
Menhaden Spatial Growth Rate Potential



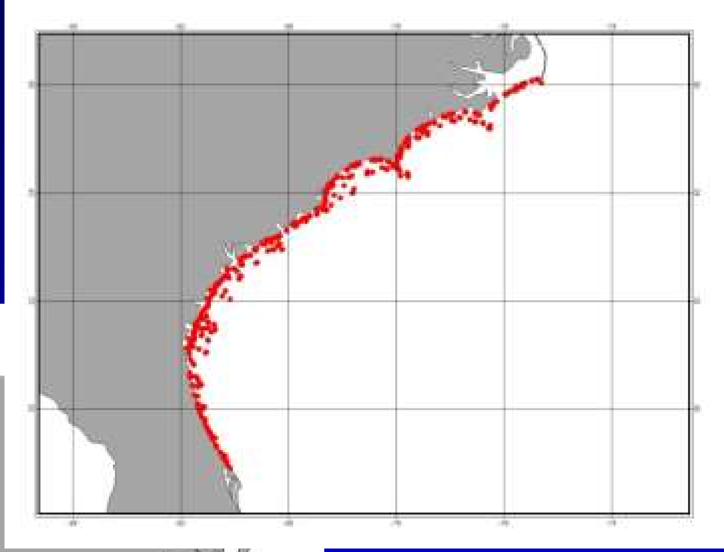

Herring Complex
Spring Density
Spring Length
Fall Density
Fall Length
Spring Herring Density
Spring Herring Length
Fall Herring Density
Fall Herring Length
77°
72°
67°
45°
40°
35°

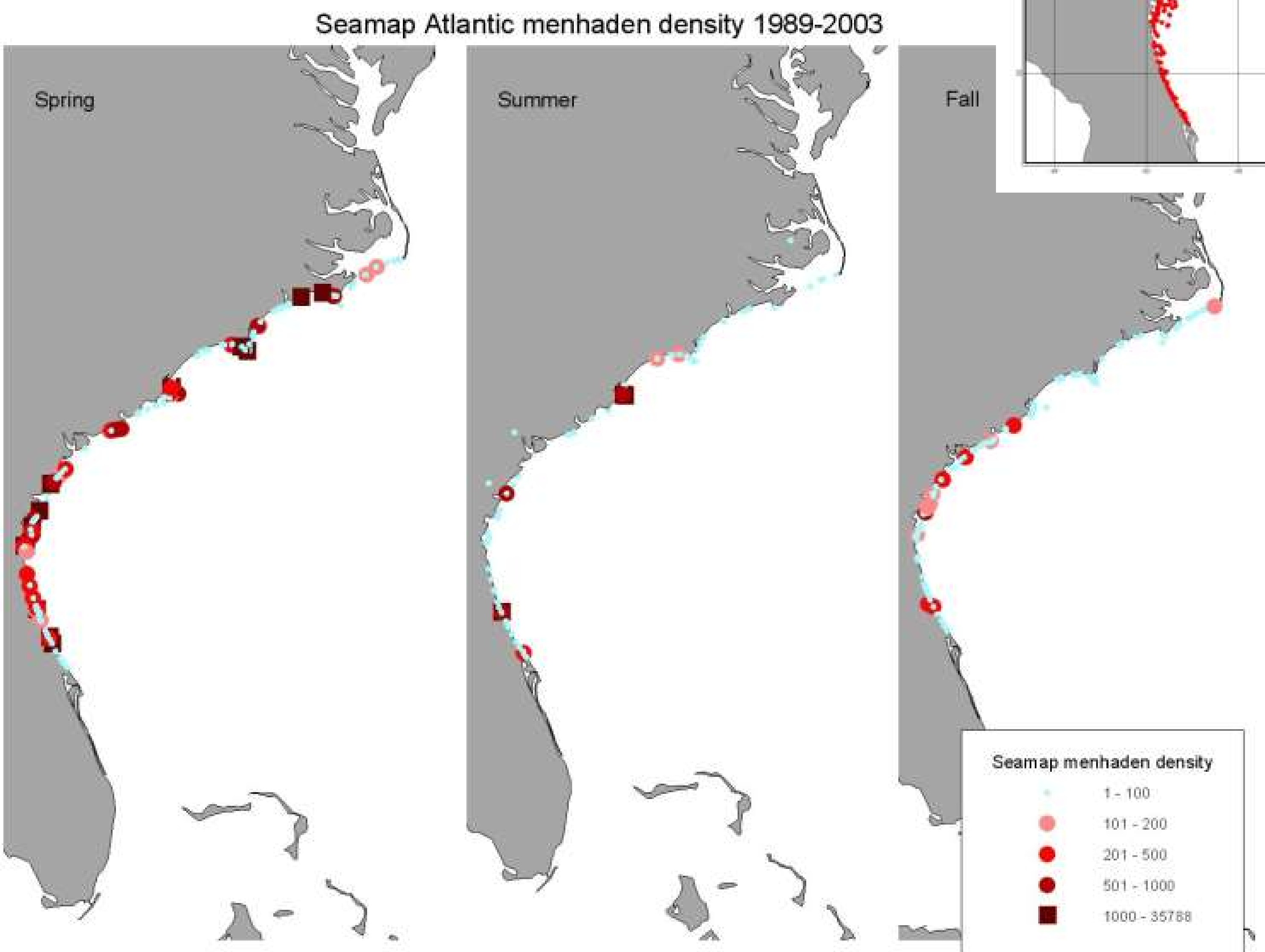

Squid
Spring Density
Spring Squid Density
Spring Length
Spring Squid Length
Fall Density
Fall Squid Density
Fall Length
Fall Squid Length
77°
72°
67°
45°
40°
35°

Model Seasonal Prey Layers

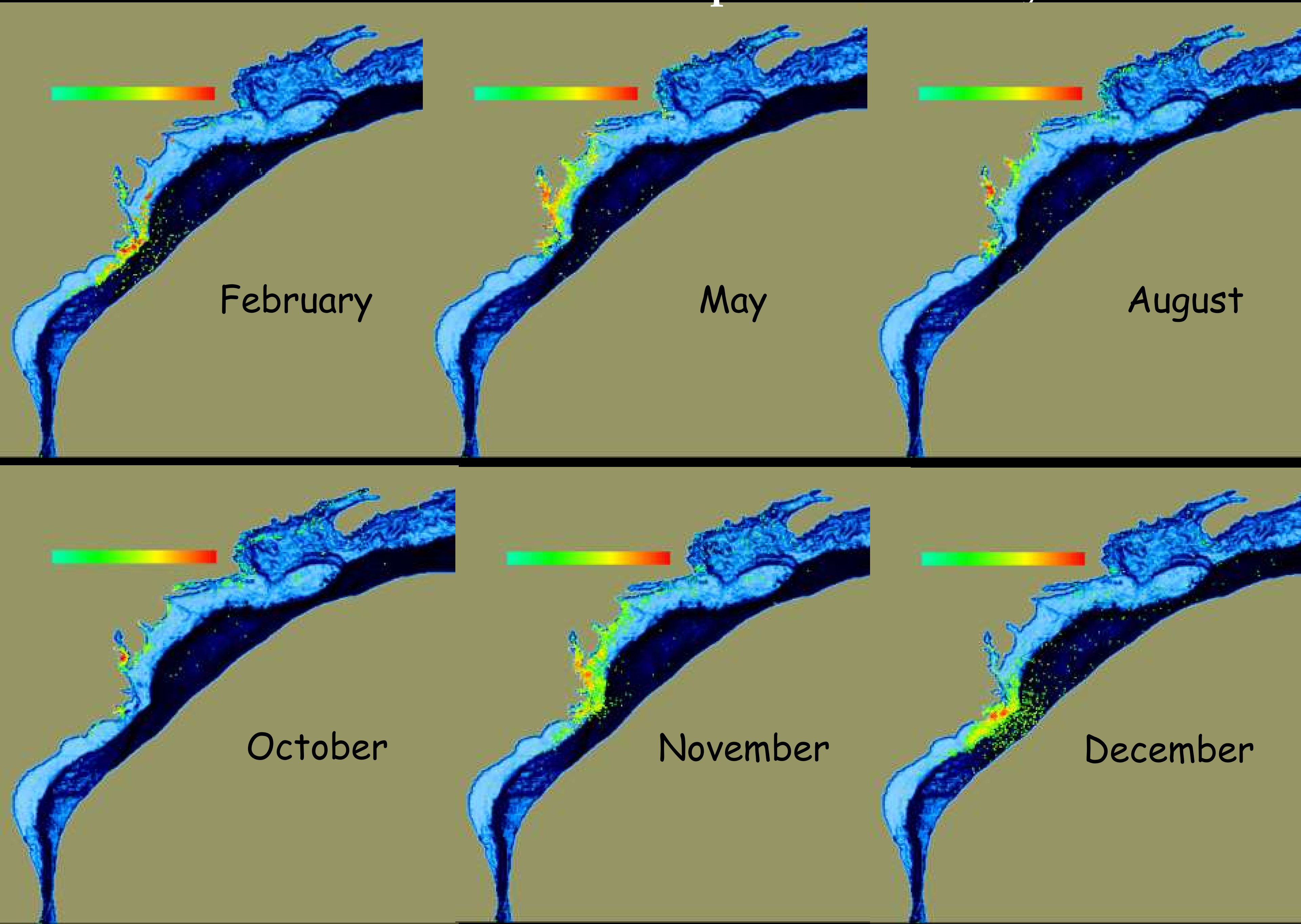


SEAMAP Trawl Survey

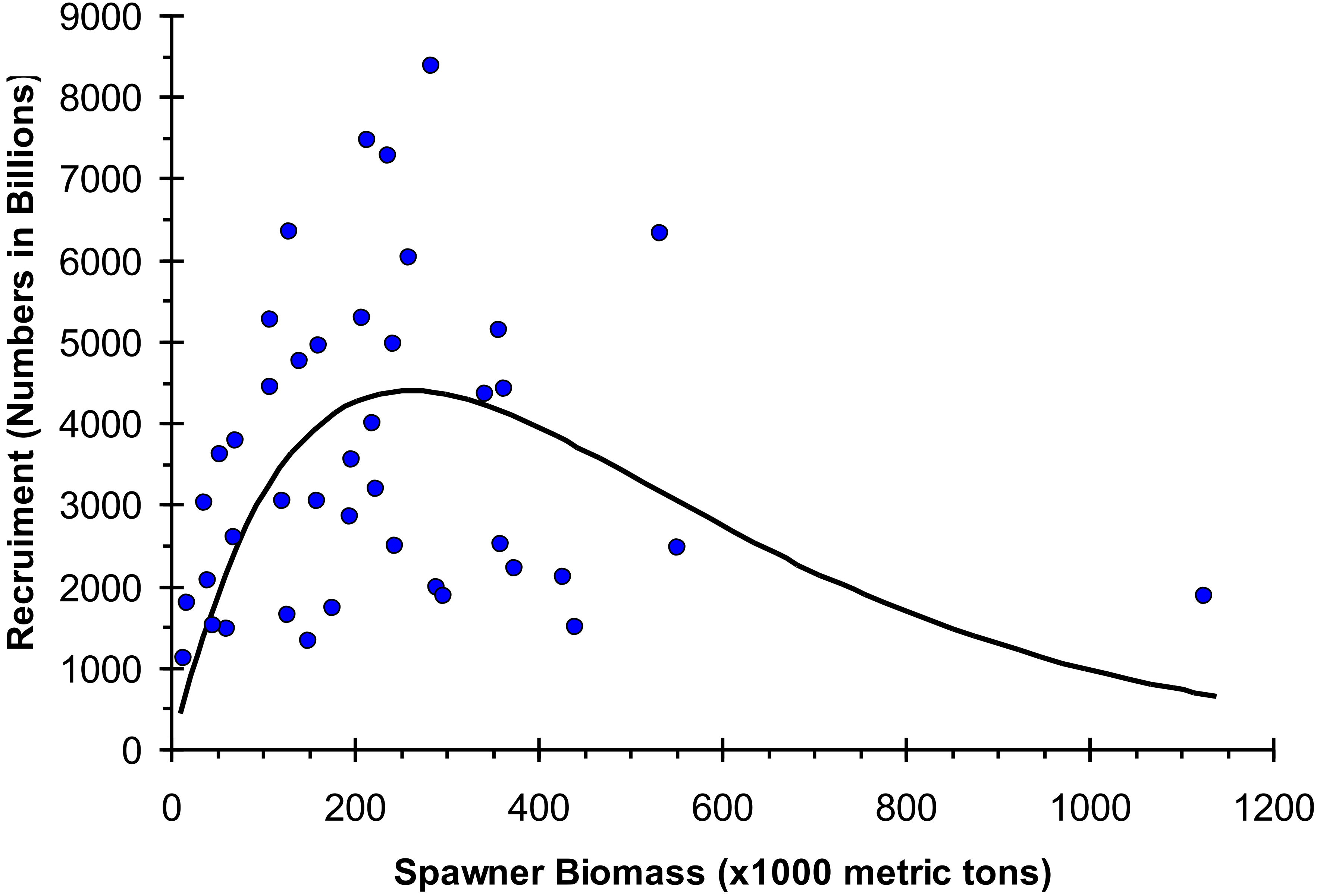




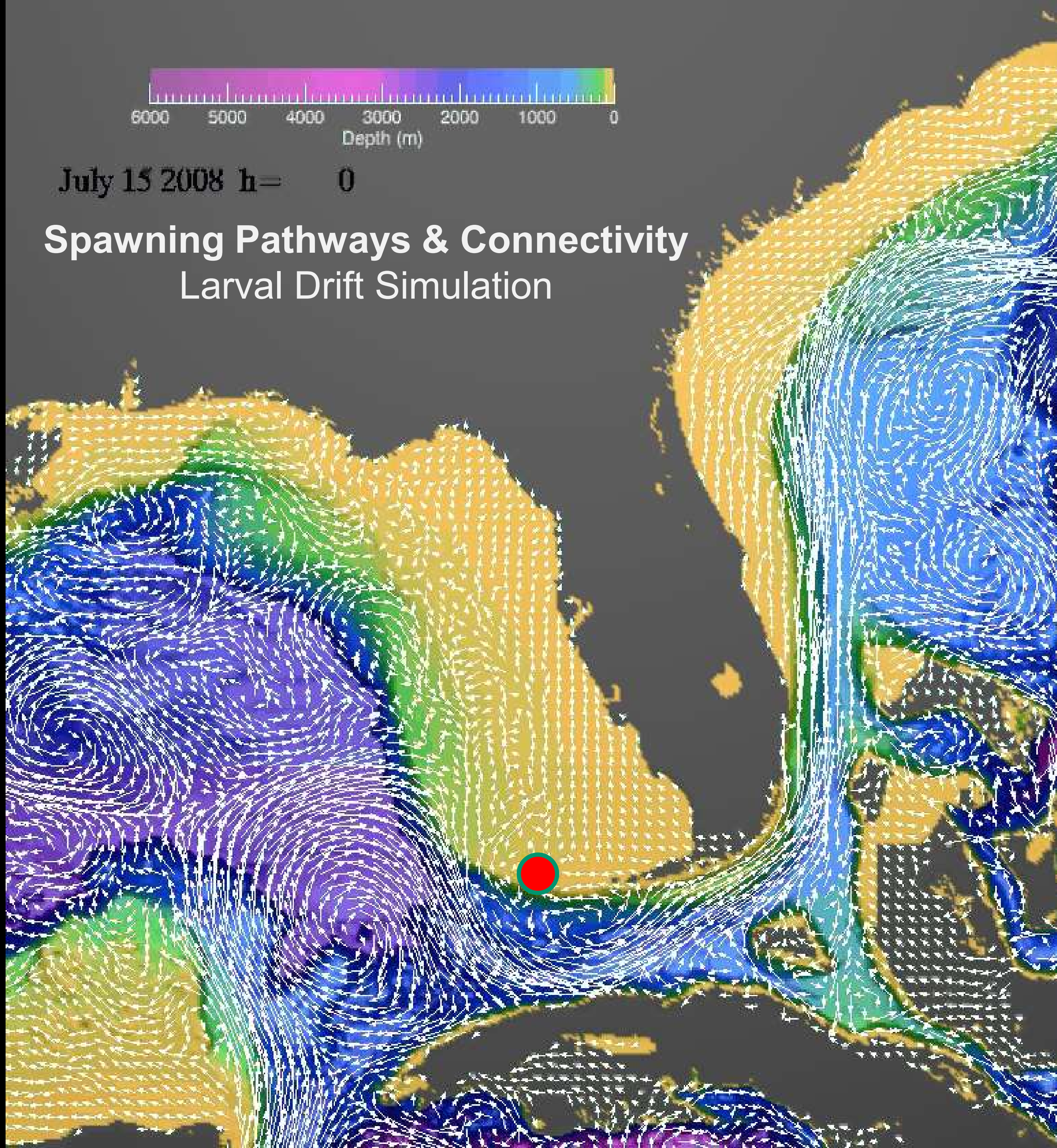
Menhaden Seasonal Population Density



Menhaden "Steepness" & Stock Productivity



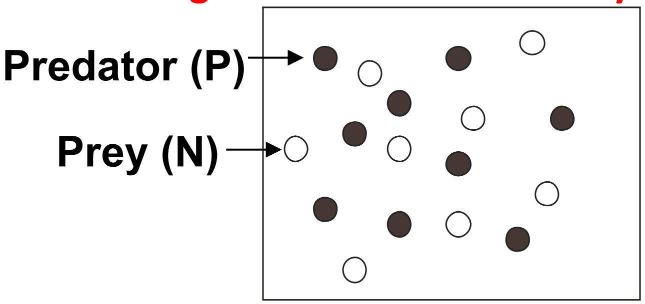
Spawning Pathways & Connectivity
Larval Drift Simulation



Spatial Grouping & the "Functional Response"

(Walter's et al. Foraging Arena)

Homogeneous Predator & Prey



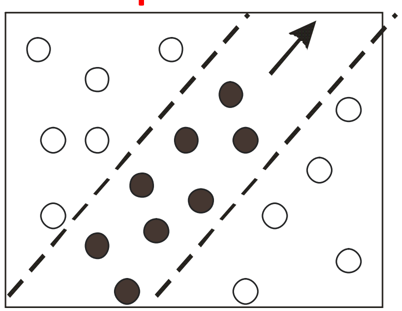
$$E(N,P) = e_0 NP$$ *Law of Mass Balance*

$$g = g(N) = \frac{e_0 N}{1 + h e_0 N}$$

Prey-Dependent

"Holling Type II"

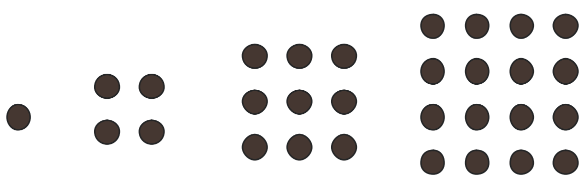
Predators in Groups



$$E(N,P) = e_1 N$$ *Encounter rate depends only on prey density*

$$g = g(N/P) = \frac{e_1 N}{P + h e_1 N}$$

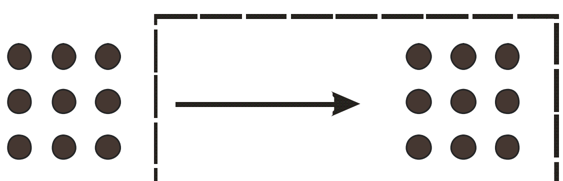
Ratio-Dependent



$$g = g(N,P) = \frac{C e_2 N}{P + h C e_2 N}$$

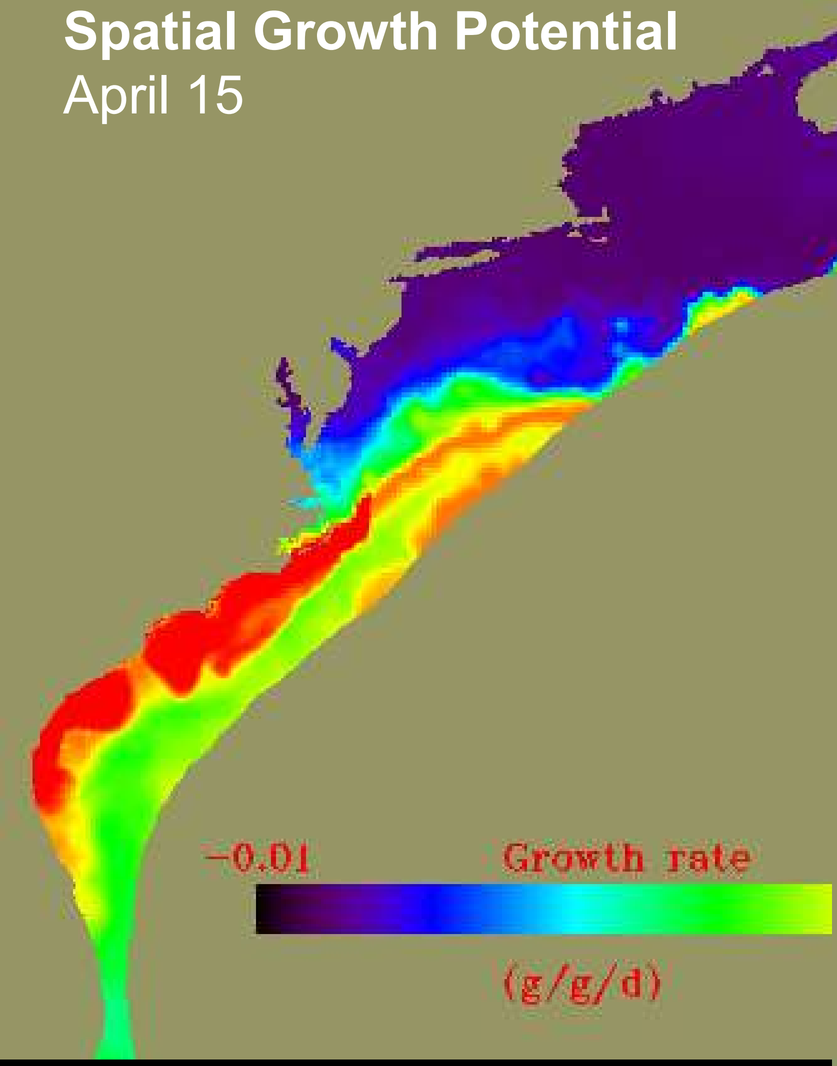
Predator- Dependent

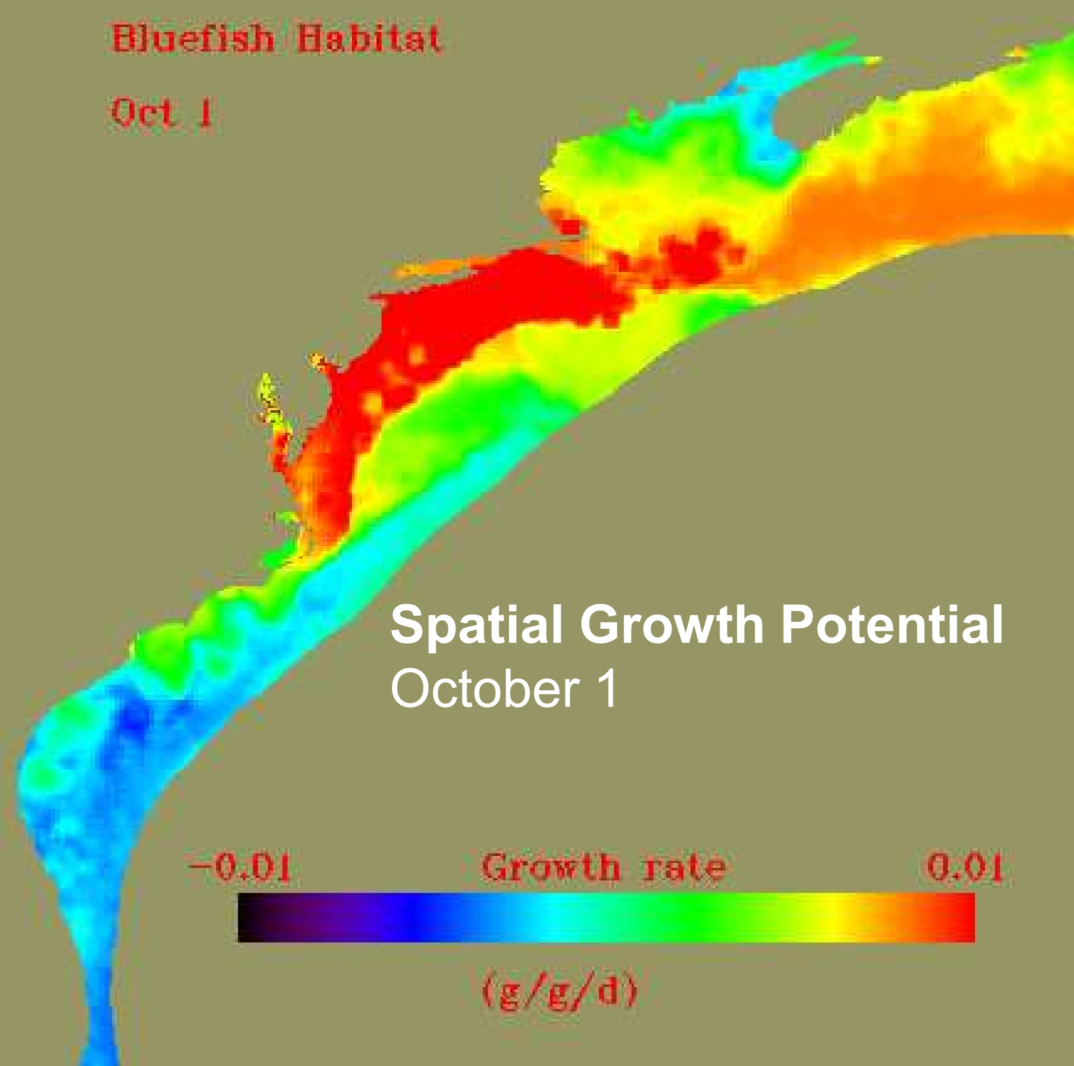
"Pack"



Cosner, DeAngelis, Ault & Olson. (1999). Theoretical Population Biology 56(1):56-65.

Dynamic Habitat Quality



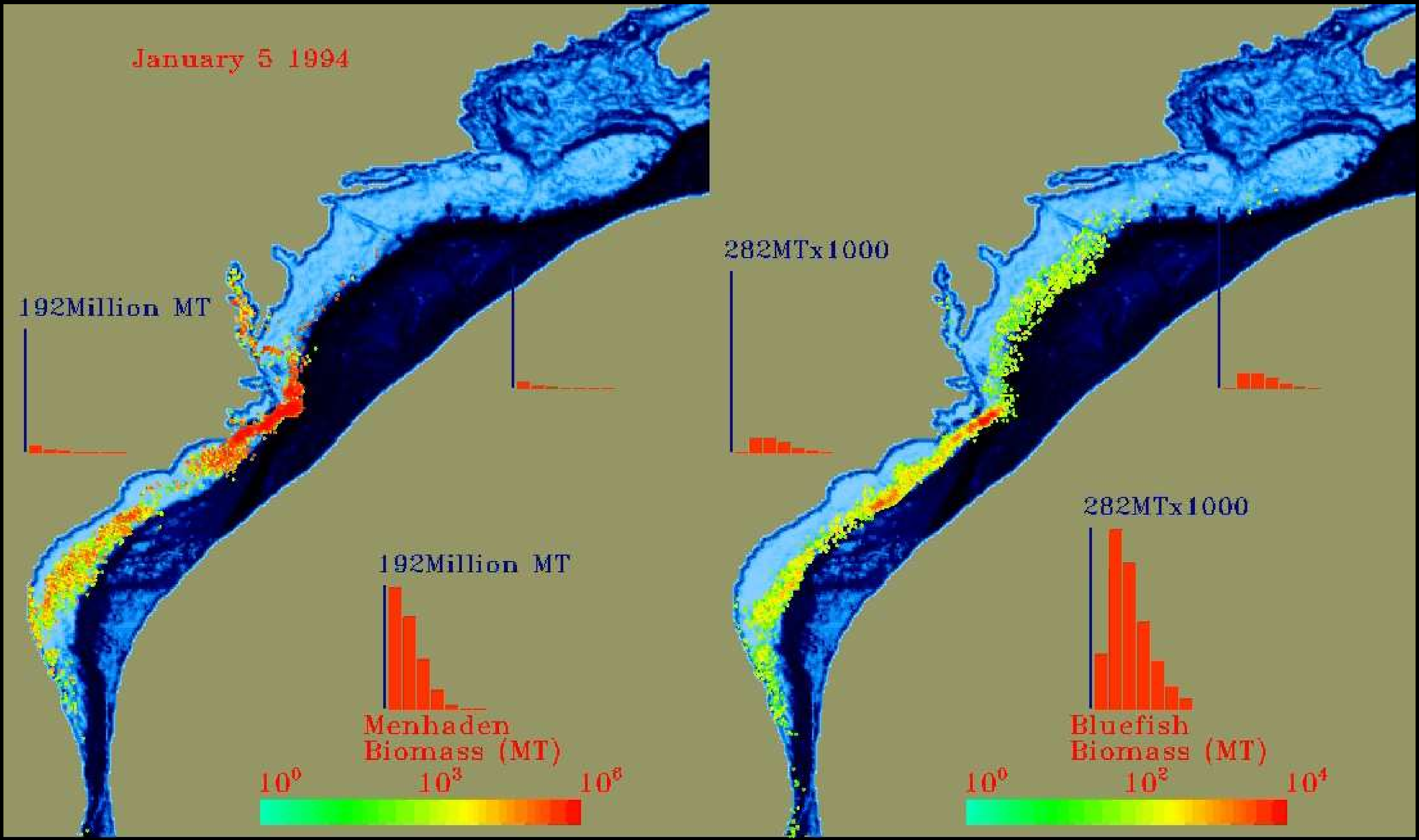


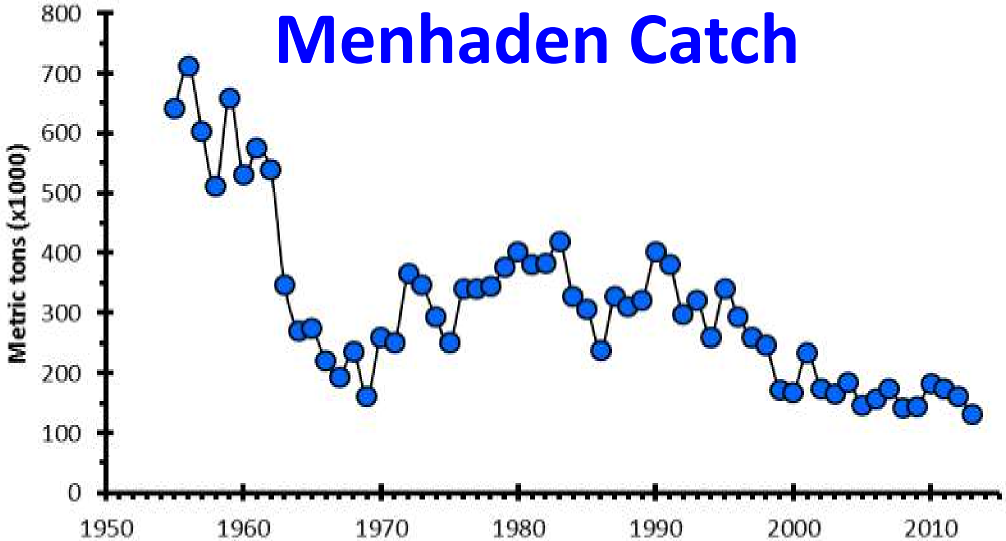
Bluefish

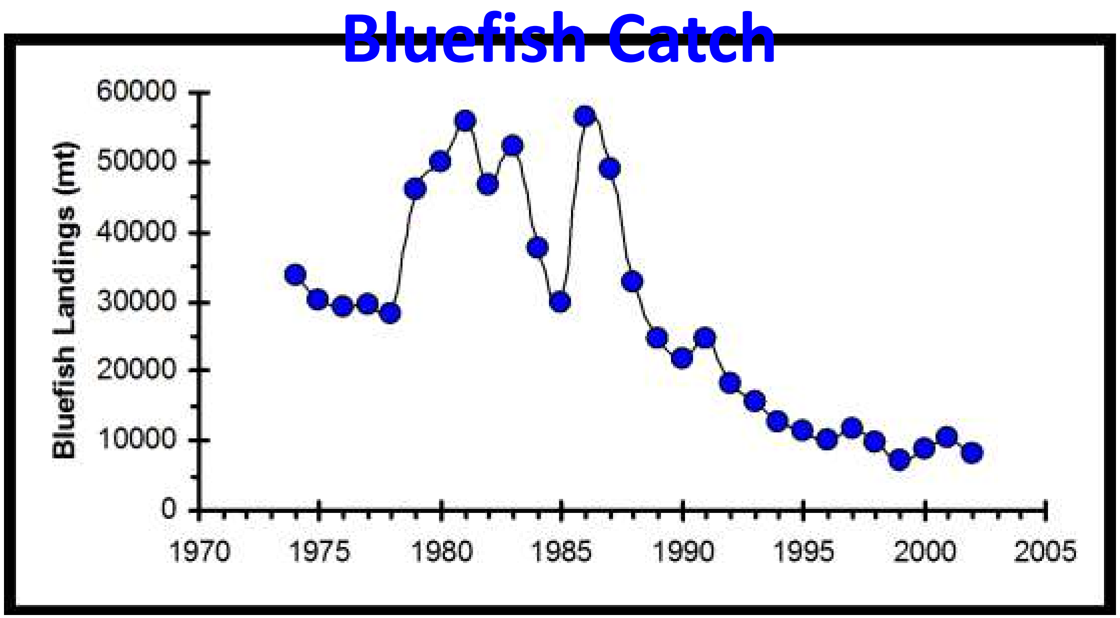
ACES (Atlantic Coast Ecosystem Simulation) Model

Menhaden Biomass

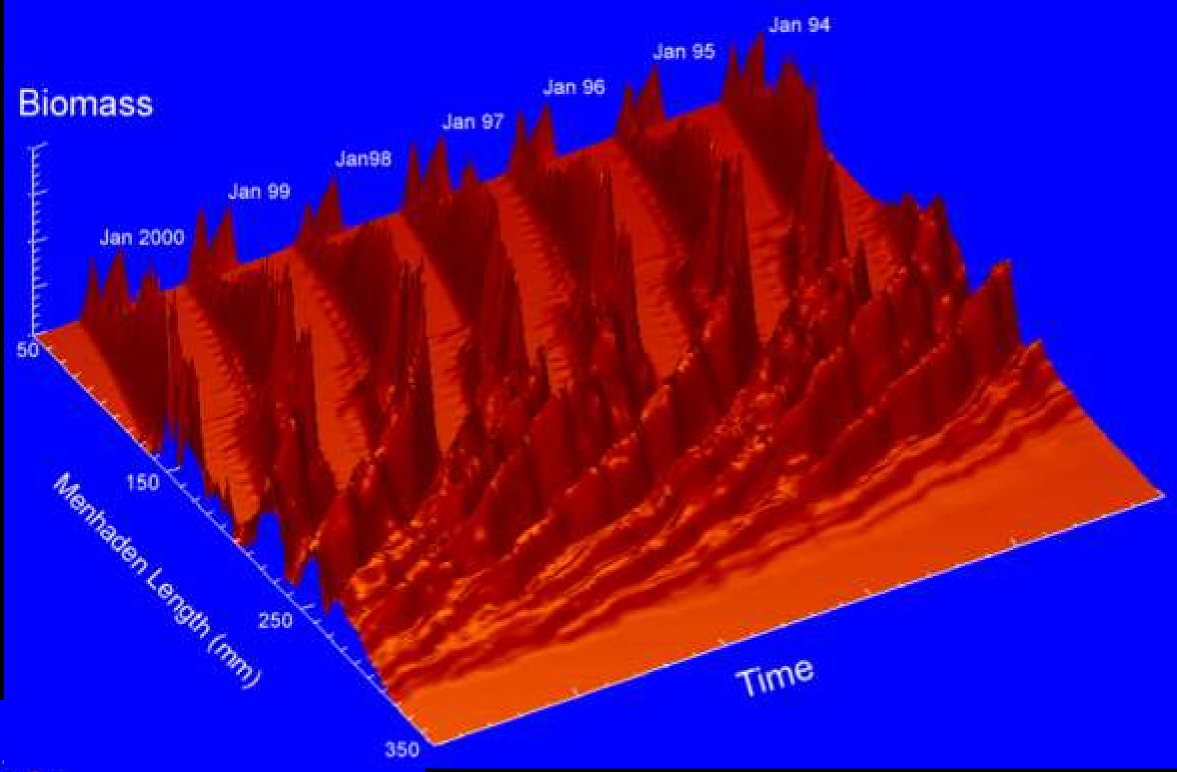
Bluefish Biomass

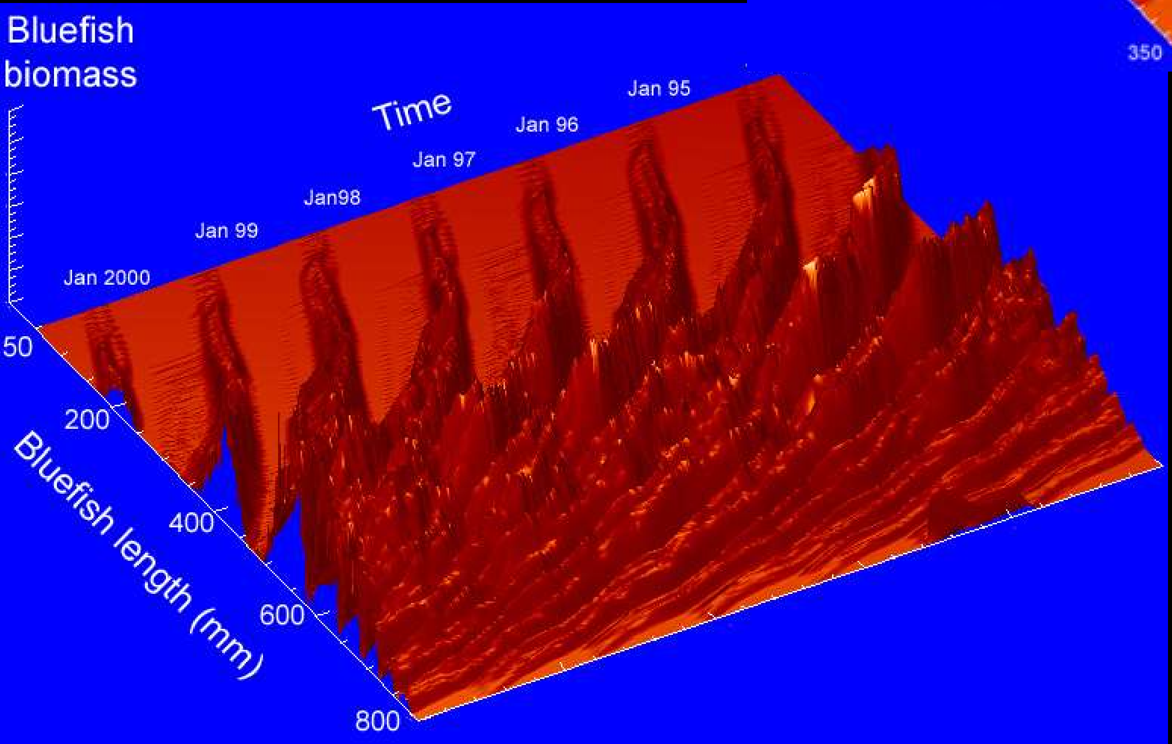


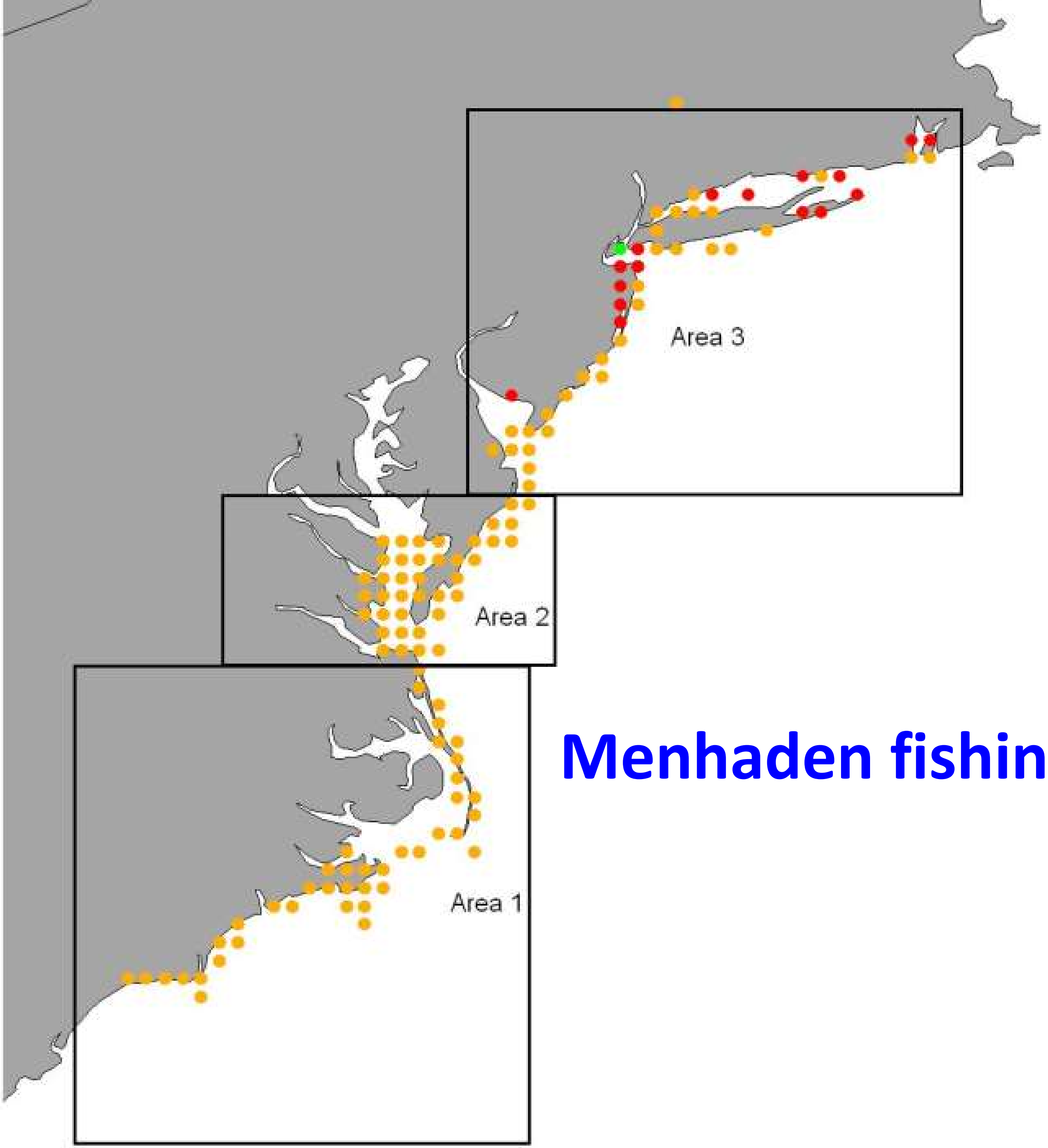

Menhaden Catch
Metric tons (x1000)
0
100
200
300
400
500
600
700
800
1950
1960
1970
1980
1990
2000
2010


Bluefish Catch
Bluefish Landings (mt)
0
10000
20000
30000
40000
50000
60000
1970
1975
1980
1985
1990
1995
2000
2005

Menhaden-Bluefish
Age-structured
Biomass over time

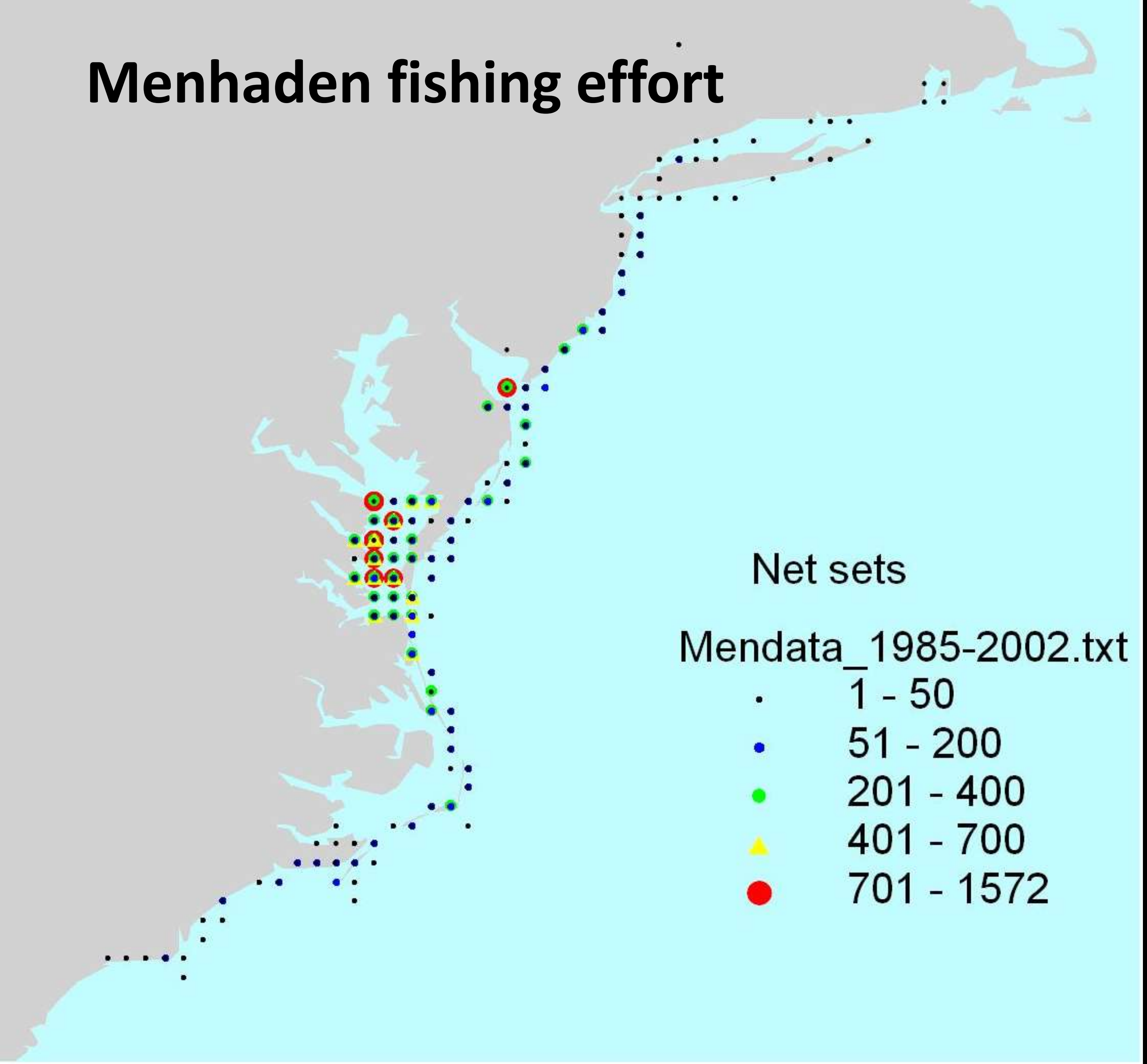




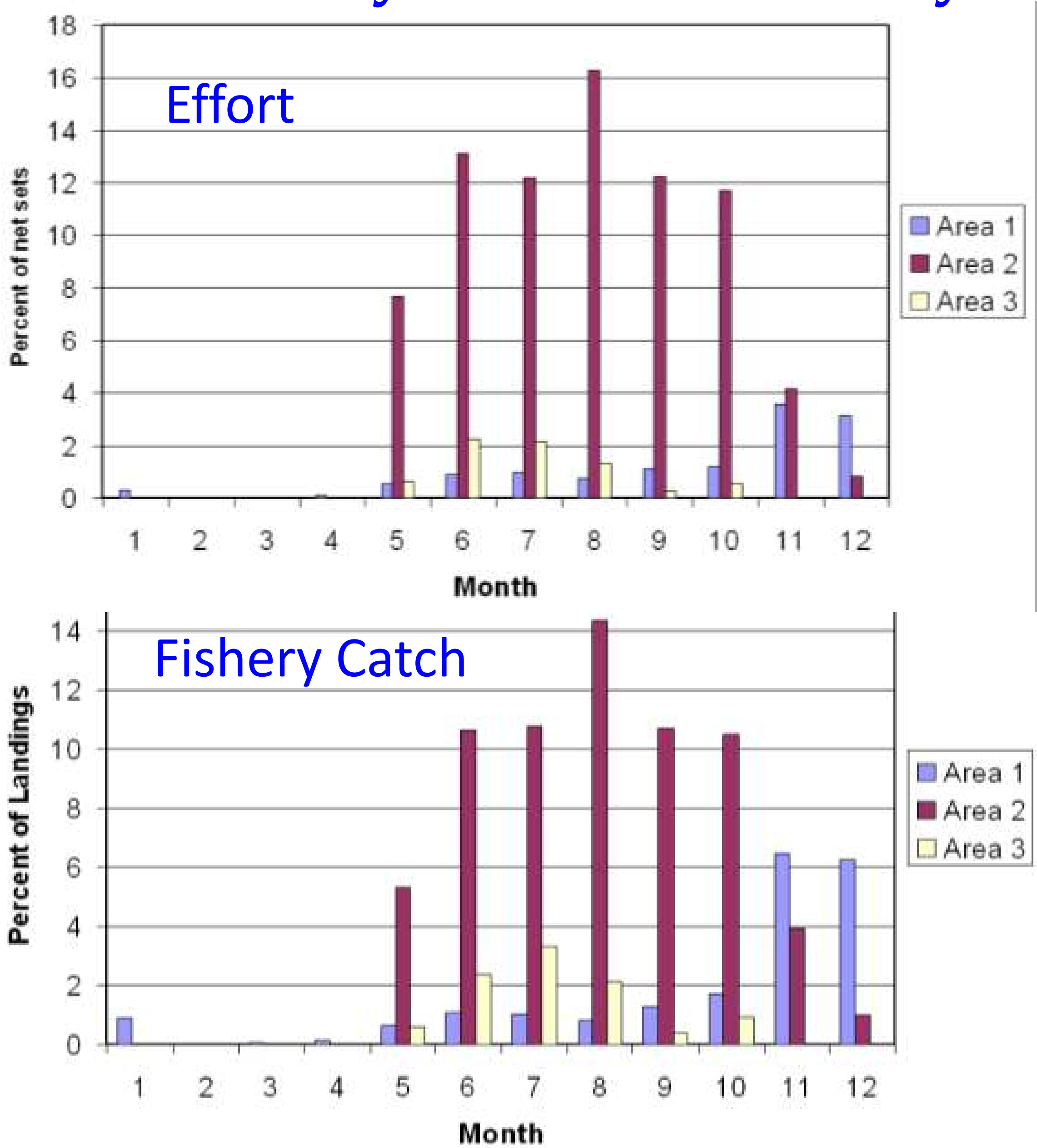


Menhaden fishing areas

Menhaden fishing effort

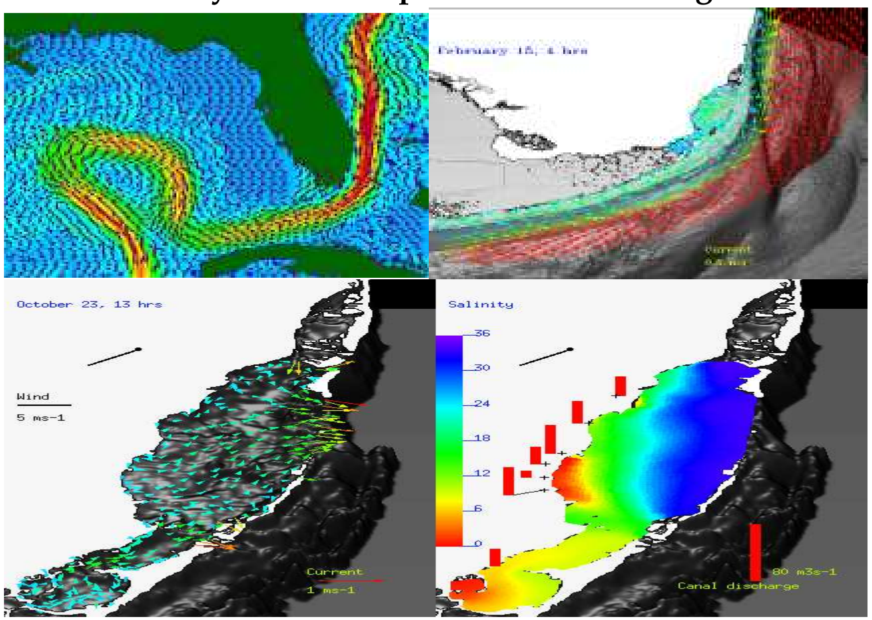


Menhaden Monthly Effort & Catch by Area

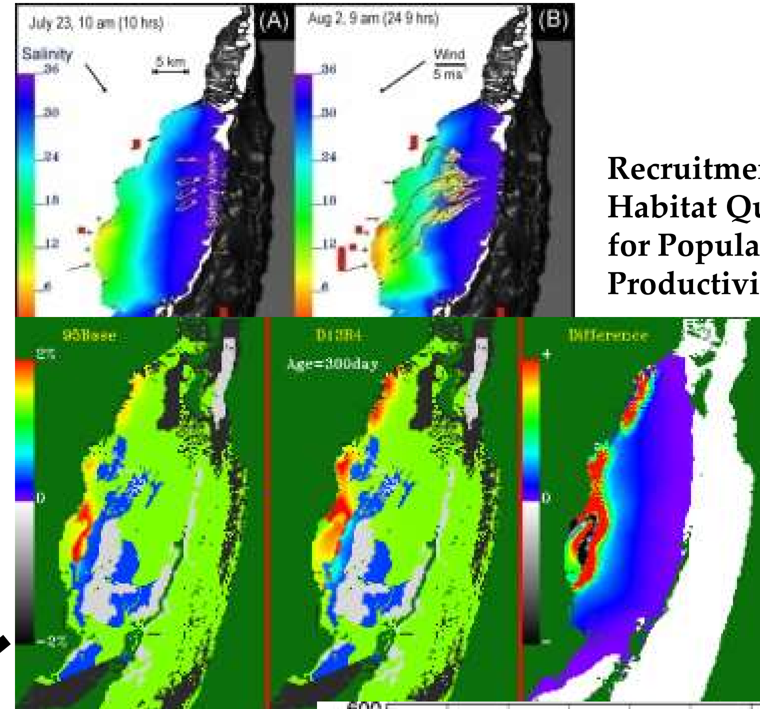


Climate Changes and Fisheries Productivity

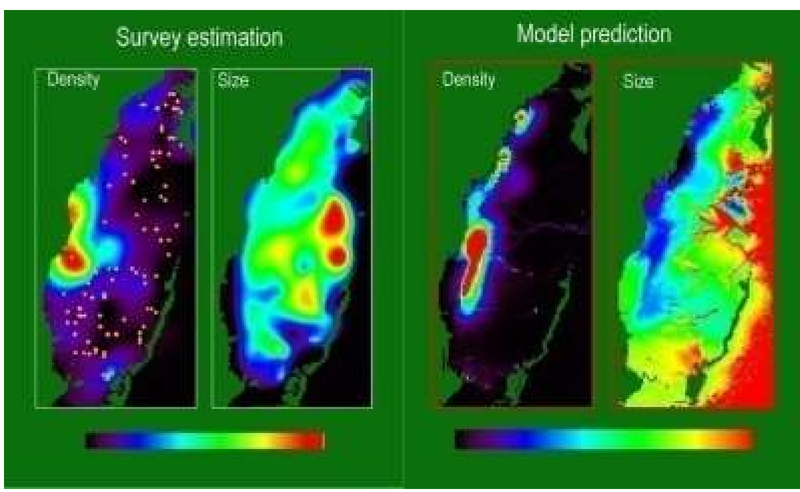
Physical Atmospheric-Ocean Forcing



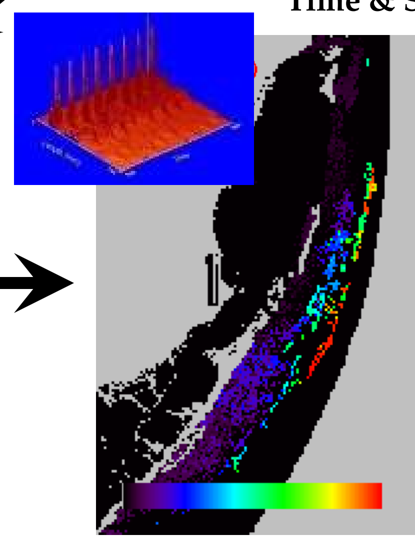
Recruitment & Habitat Quality for Population Productivity

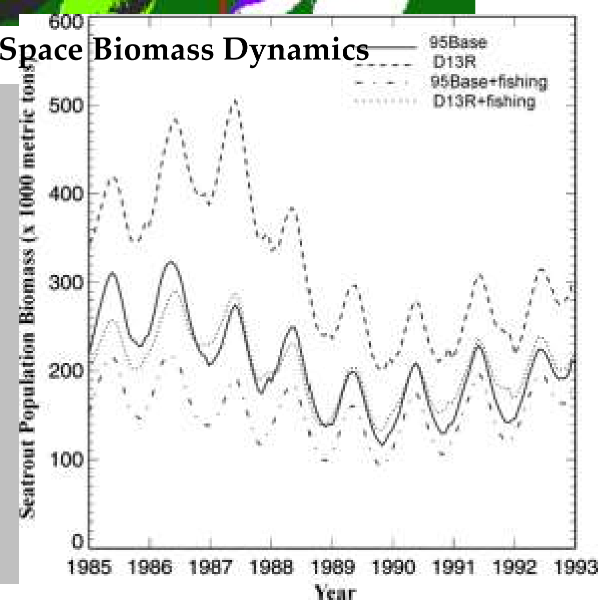


Spatial Population Abundance & Size Structure

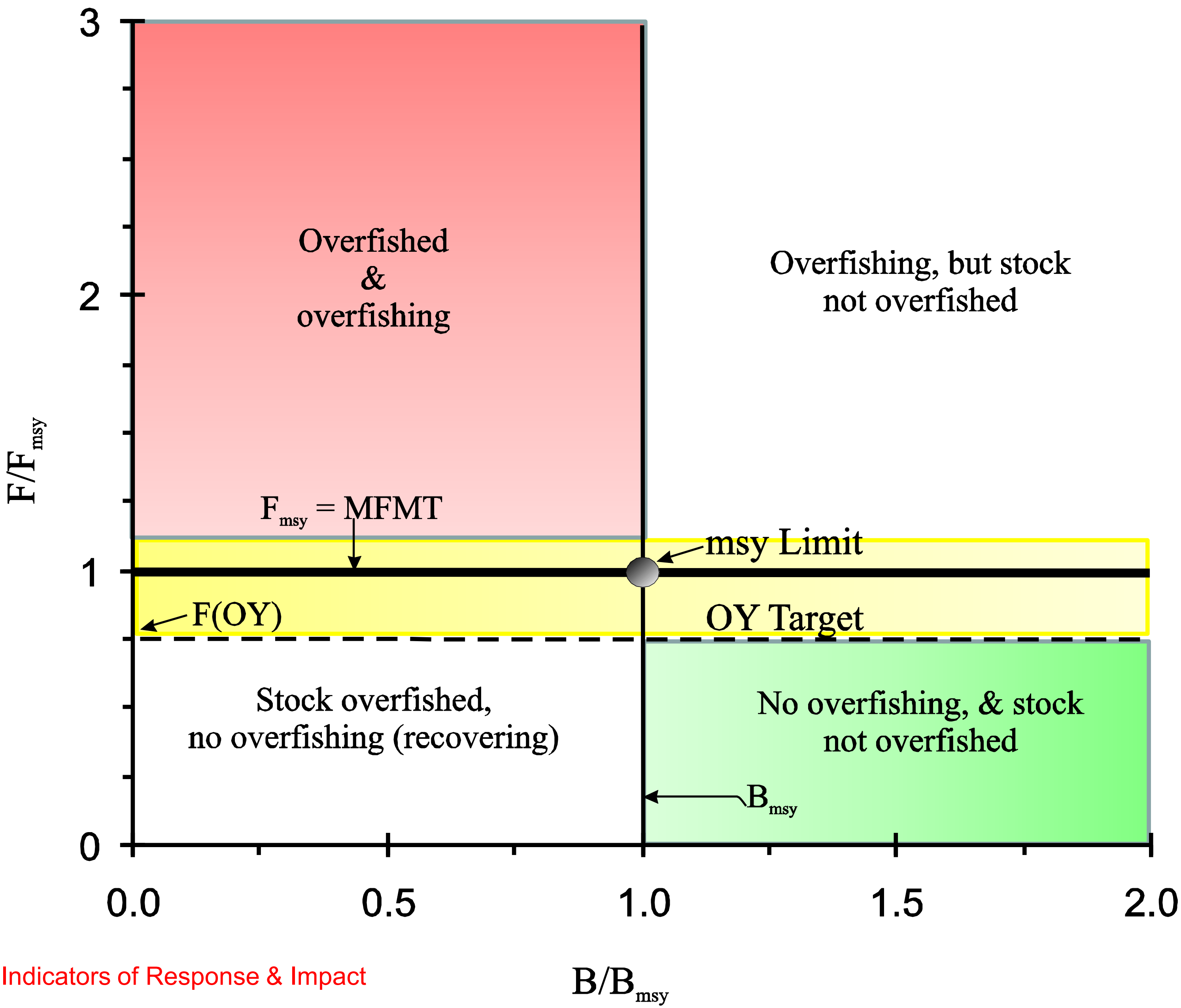


Time & Space Biomass Dynamics

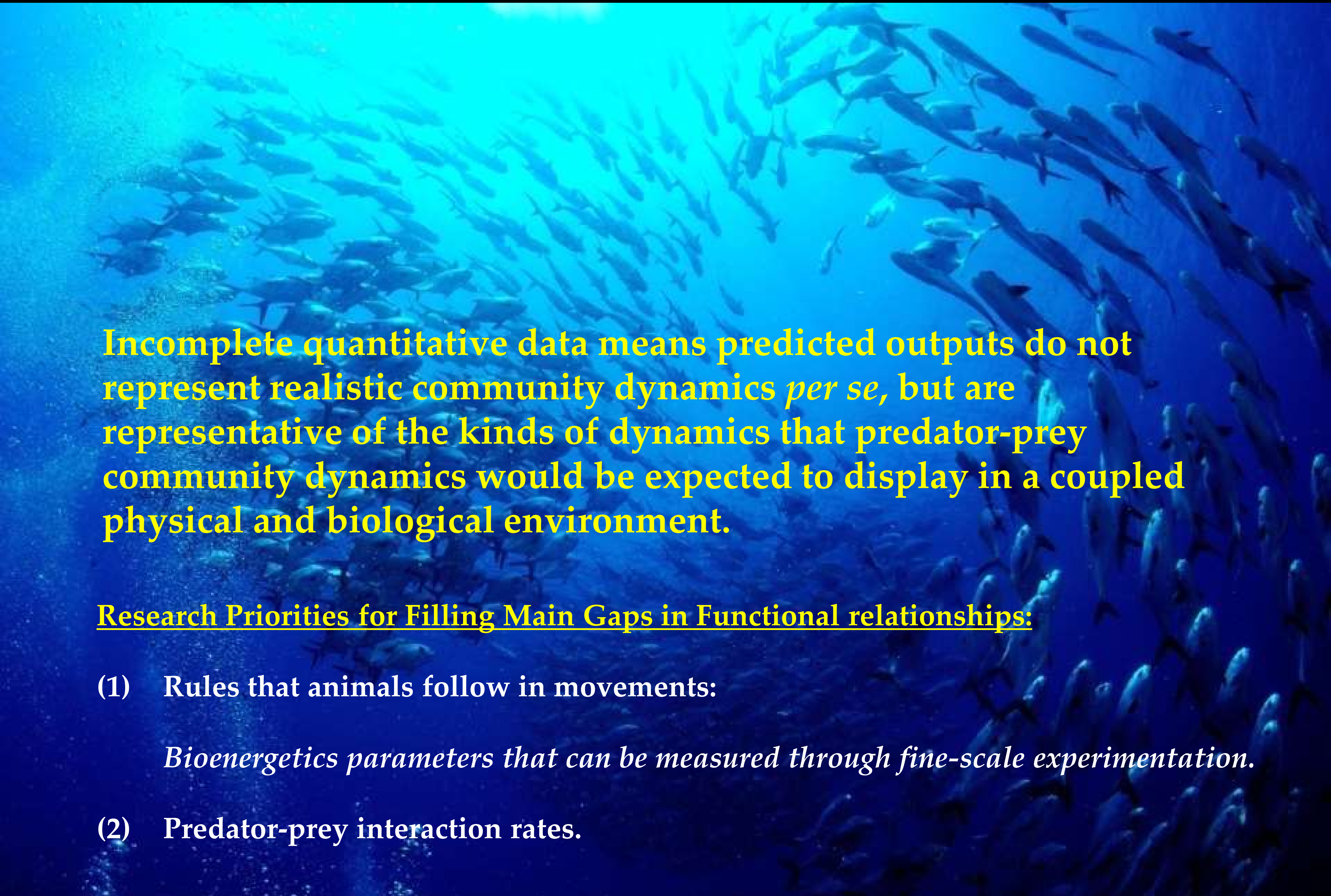




Limit-Control Rule (Kobe) Indicator




WE HAVE TO
CHANGE
THE WAY WE
THINK ABOUT
FISHERIES SCIENCE


Incomplete quantitative data means predicted outputs do not represent realistic community dynamics *per se,* but are representative of the kinds of dynamics that predator-prey community dynamics would be expected to display in a coupled physical and biological environment.
Research Priorities for Filling Main Gaps in Functional relationships:
(1) Rules that animals follow in movements:
Bioenergetics parameters that can be measured through fine-scale experimentation.
(2) Predator-prey interaction rates.

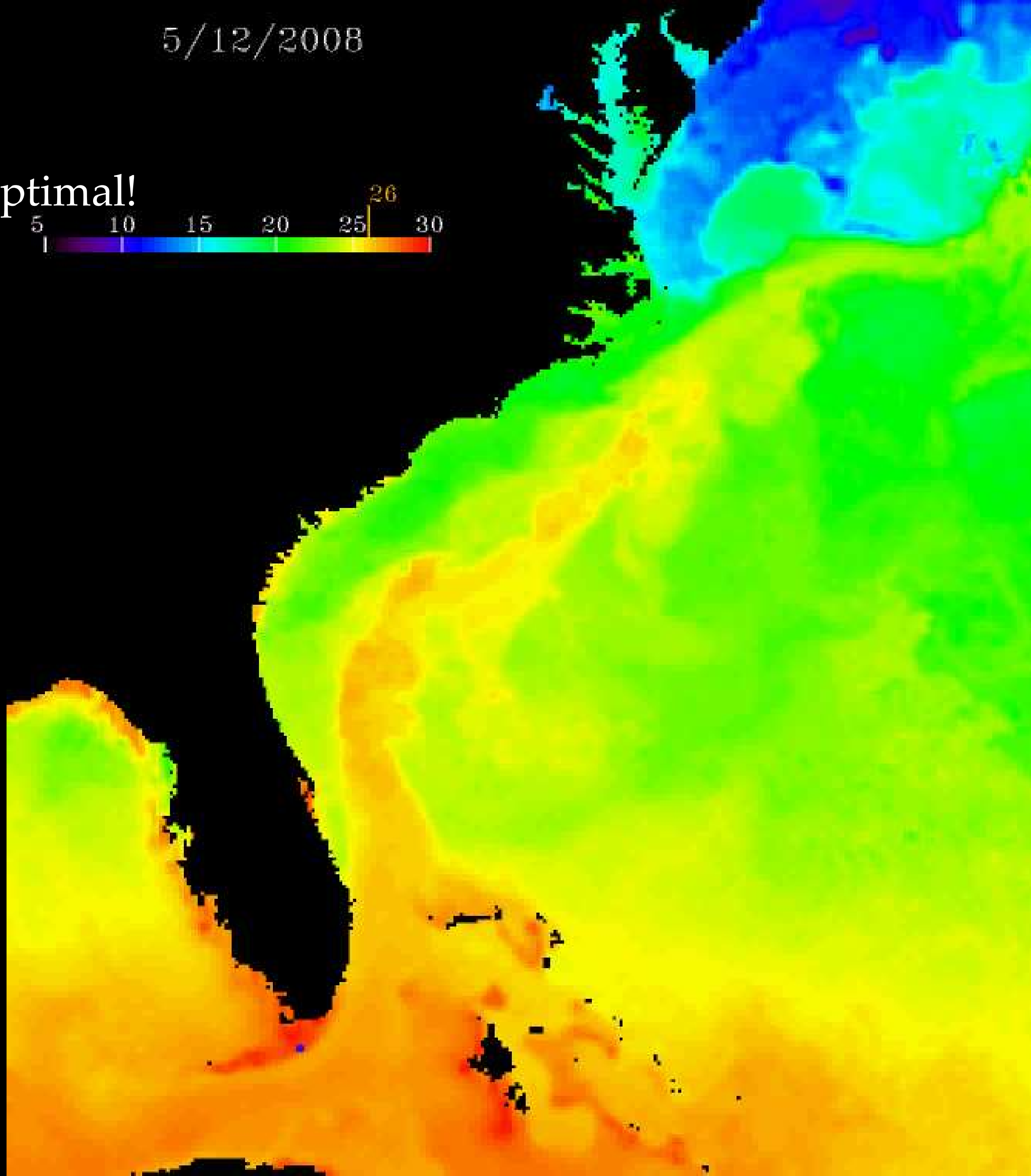
Documented travels of the mighty Atlantic Tarpon

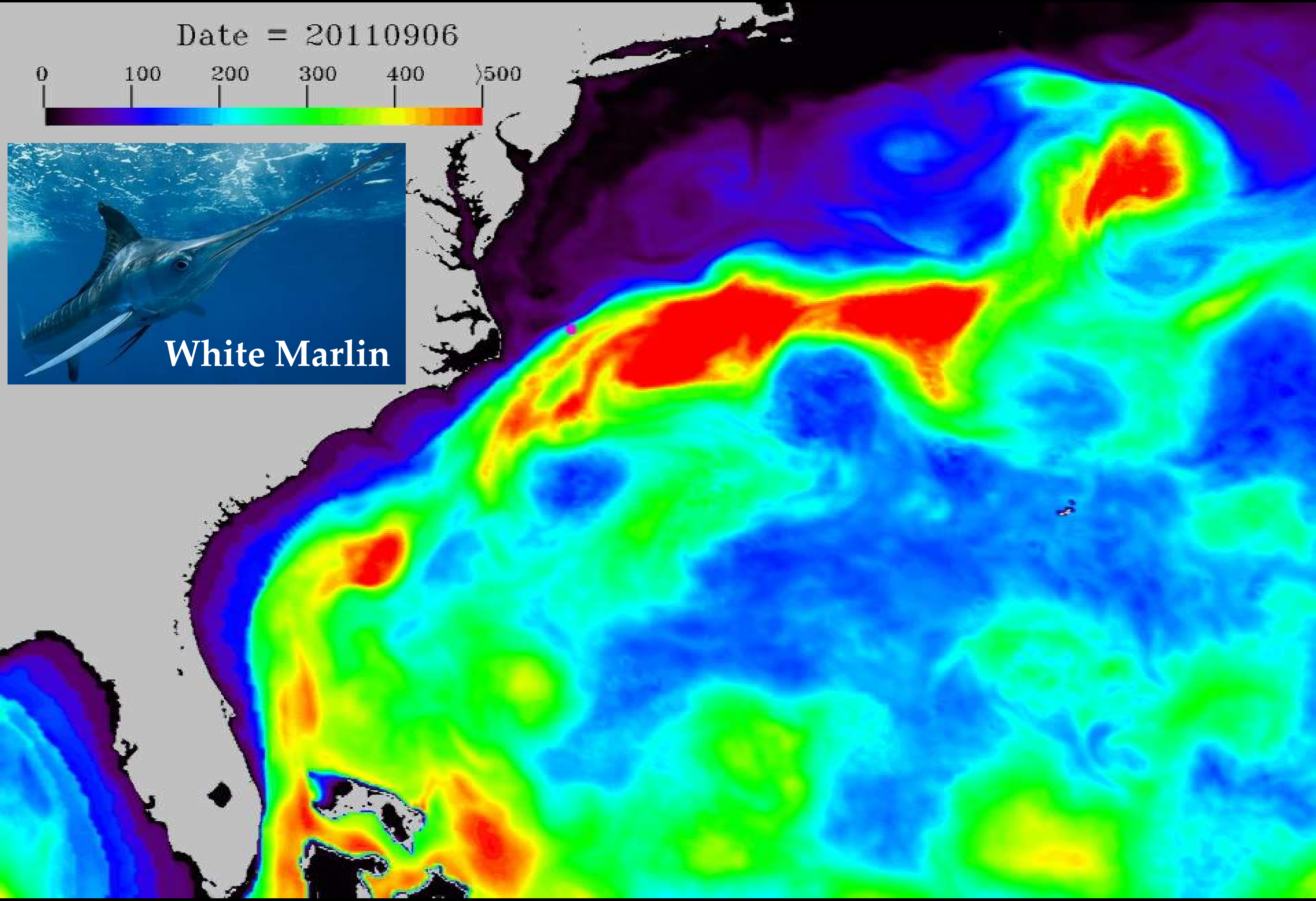
Migrations, ocean habitat use & spawning

Orange is Optimal!

26°C (79°F)

T116



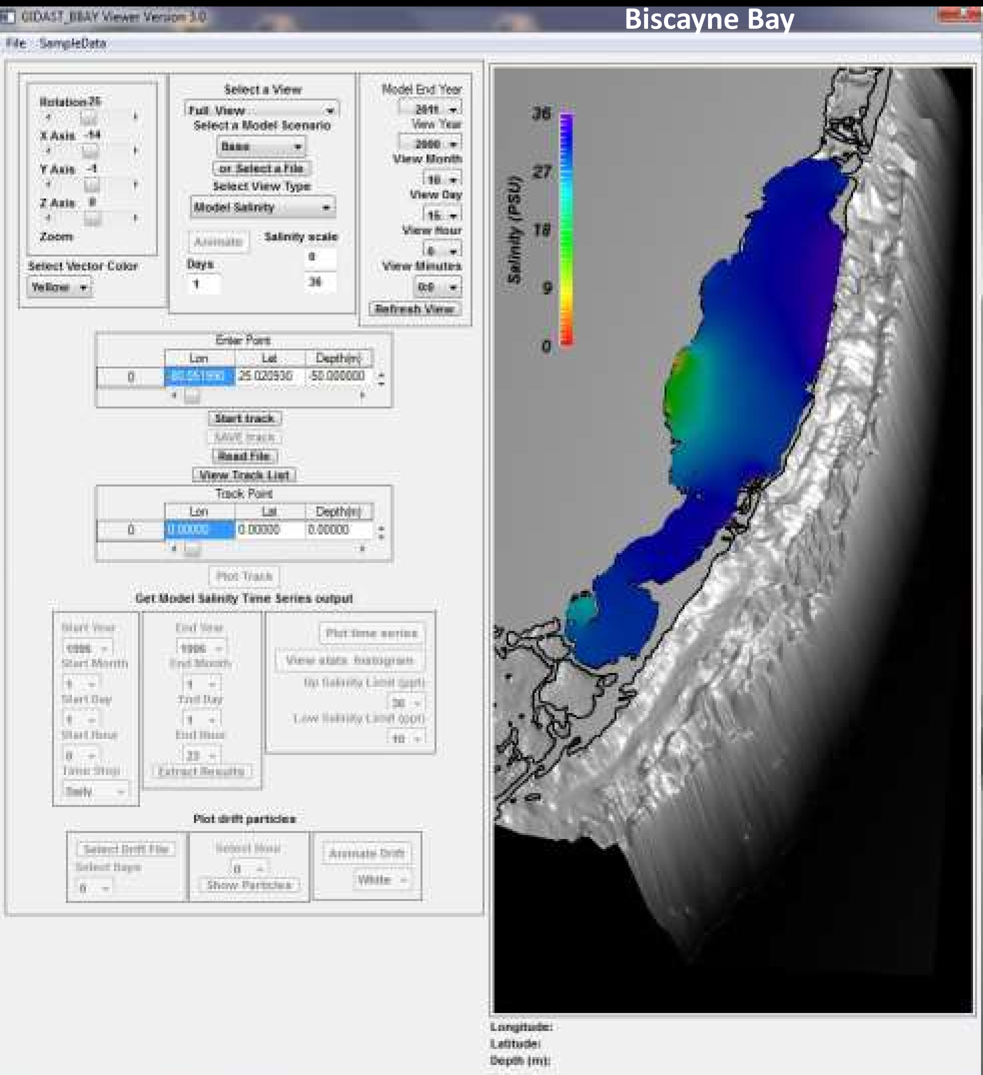


Date = 20110906
0
100
200
300
400
>500
White Marlin

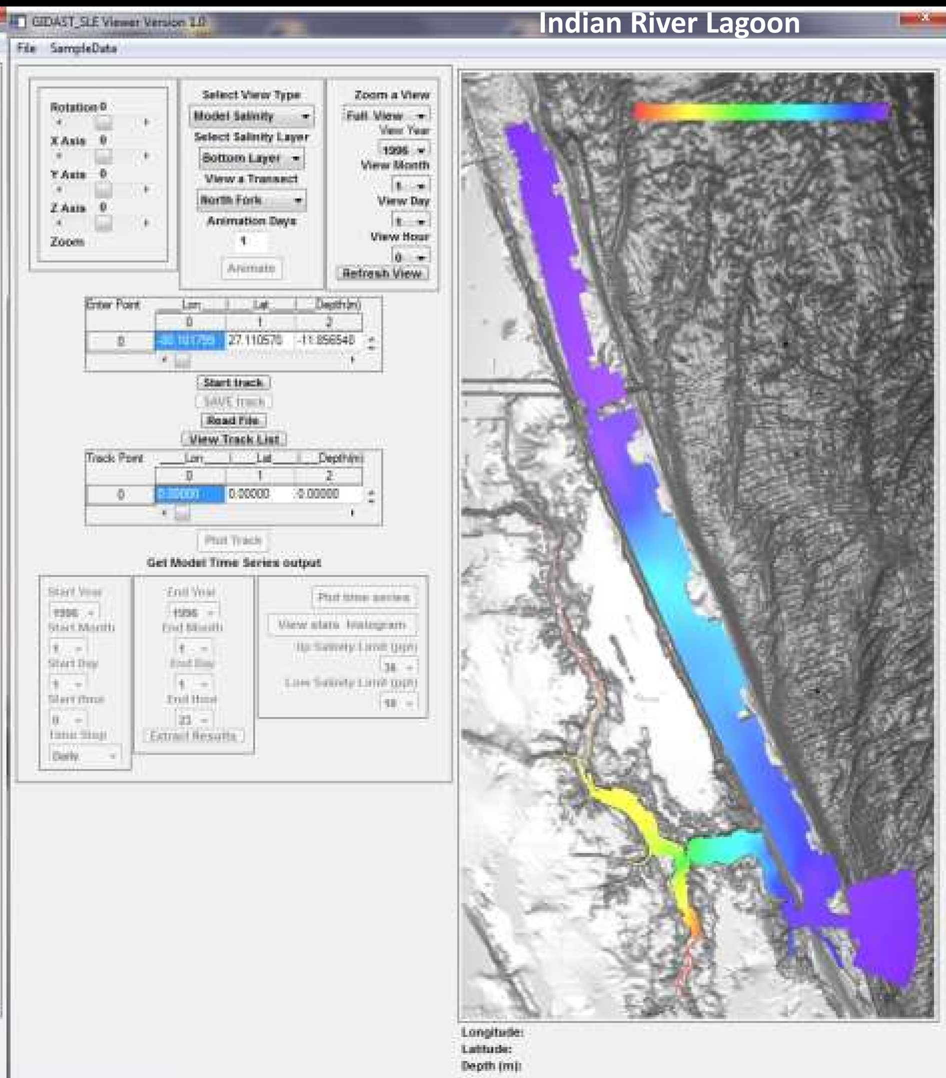
GIDAST

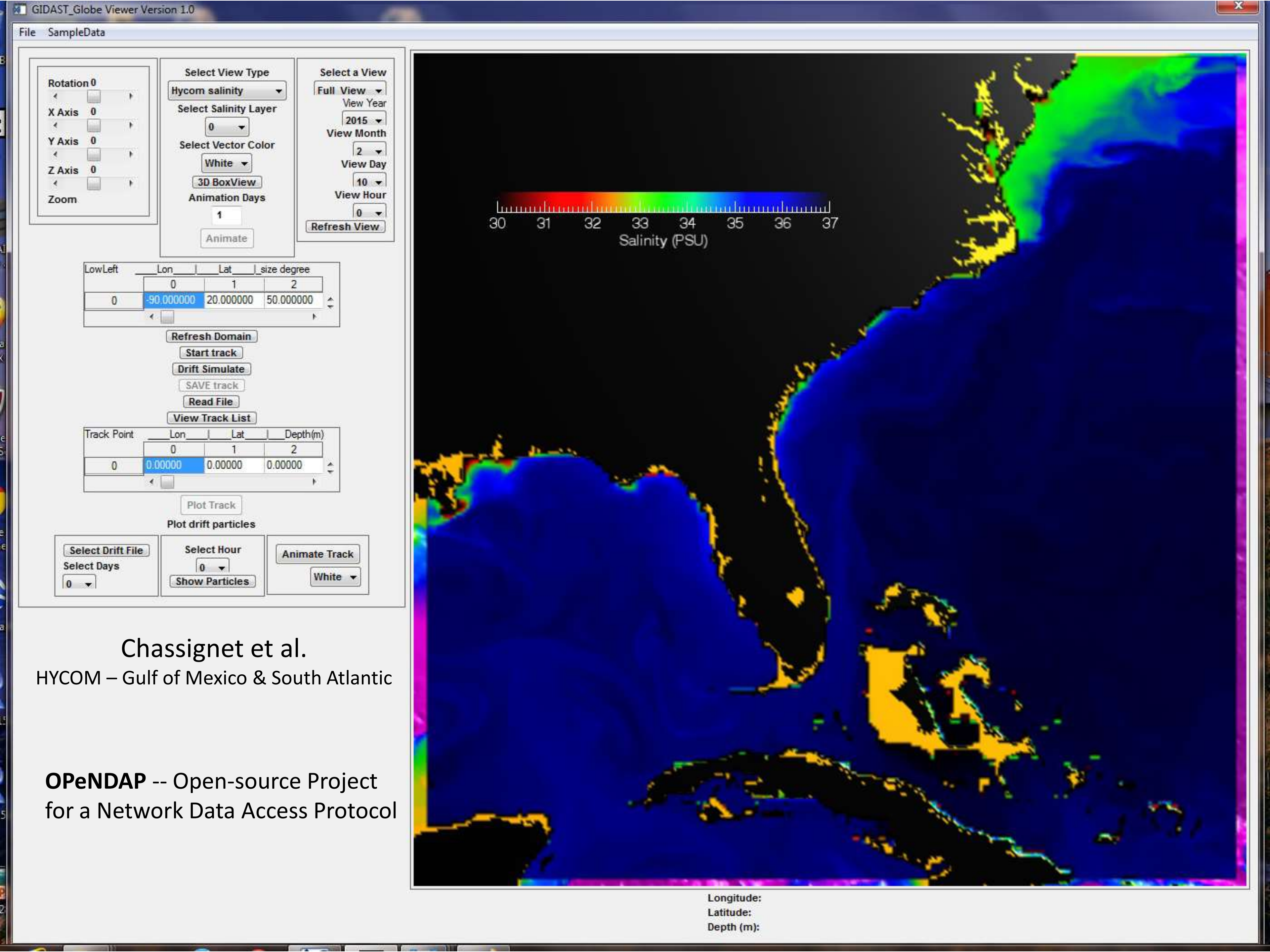
Geo-referenced Interactive Data Analysis System Tool

Wang et al.



Sheng et al.

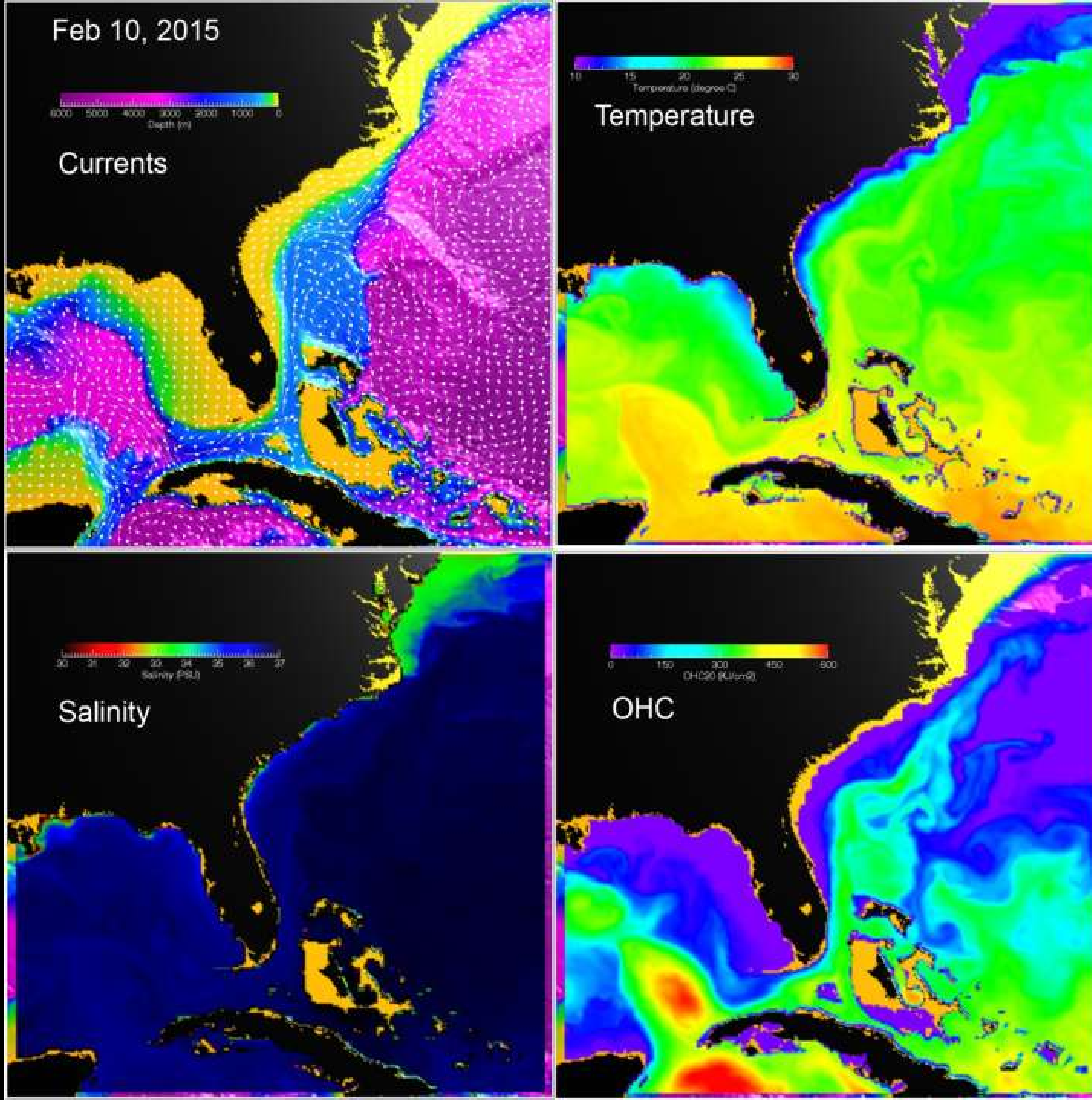




Chassignet et al.

HYCOM – Gulf of Mexico & South Atlantic

OPeNDAP -- Open-source Project for a Network Data Access Protocol



Feb 10, 2015
6000 5000 4000 3000 2000 1000 0
Depth (m)
Currents
10 15 20 25 30
Temperature (degree C)
Temperature
30 31 32 33 34 35 36 37
Salinity (PSU)
Salinity
0 150 300 450 600
OHC

Spatial Ecology of Fisheries

We can meet the modeling challenge of highly detailed ecological representation.

Ball is in court of field and experimental biologists to do a better job with difficult processes.

With future increases in computational power we can do the kind of extensive simulation testing and comparison to data needed to properly evaluate highly detailed models.

This will allow us to see if our models have solved the problems of missing details whose importance was not apparent at the time of model development.

Summary

Fisheries ecosystem models can powerfully illuminate the human and environmental change processes central to the dynamics of fishery resources (i.e., spatial biomass distributions of prey and predators) throughout the entire US Atlantic coast.

Better understanding will greatly enhance management decision-making capabilities and broaden risk strategies that ensure sustainable multispecies fisheries in ways that cannot be achieved with contemporaneous stock assessment methods.

Update on South Atlantic Blueprint 2.0

Feb 2015

Rua Mordecai, Science Coordinator

SOUTH ATLANTIC
LANDSCAPE CONSERVATION COOPERATIVE

LANDSCAPE CONSERVATION COOPERATIVES

The Steering Committee

NORTH CAROLINA Wildlife RESOURCES COMMISSION

DEPARTMENT OF DEFENSE • UNITED STATES OF AMERICA

U.S. FISH & WILDLIFE SERVICE

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION

South Atlantic Fishery Management Council "To Conserve and Manage"

The Nature Conservancy
Protecting nature. Preserving life.

USGS
science for a changing world

GEORGIA DEPARTMENT OF NATURAL RESOURCES
WILDLIFE RESOURCES DIVISION

NORTH CAROLINA DEPARTMENT OF CULTURAL RESOURCES

NATIONAL PARK SERVICE

SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES

VIRGINIA Department of Game & Inland Fisheries

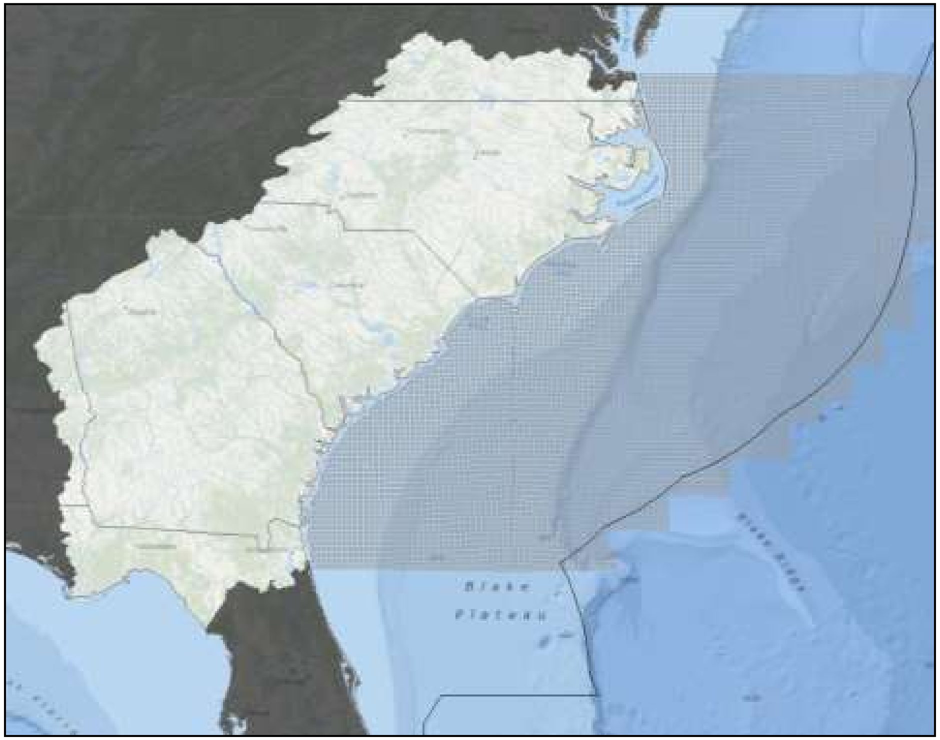
NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

US Army Corps of Engineers®
SOUTH ATLANTIC DIVISION

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

What does the South Atlantic LCC do?

Mission: Create a shared **blueprint** for landscape conservation actions that sustain natural and cultural resources



So, what's different from past efforts?

So, what's different from past efforts?

- Planning for the cooperative, not any one organization

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- An adaptation strategy (incorporating climate change, urban growth, and other future changes)

So, what’s different from past efforts?

- Planning for the cooperative, not any one organization
- An adaptation strategy (incorporating climate change, urban growth, and other future changes)
- Bigger scope and scale

Intended uses

Intended uses

- Finding the best place to use current resources

Intended uses

- Finding the best place to use current resources
- Bringing in new conservation dollars

Intended uses

- Finding the best place to use current resources
- Bringing in new conservation dollars
- Guiding infrastructure development

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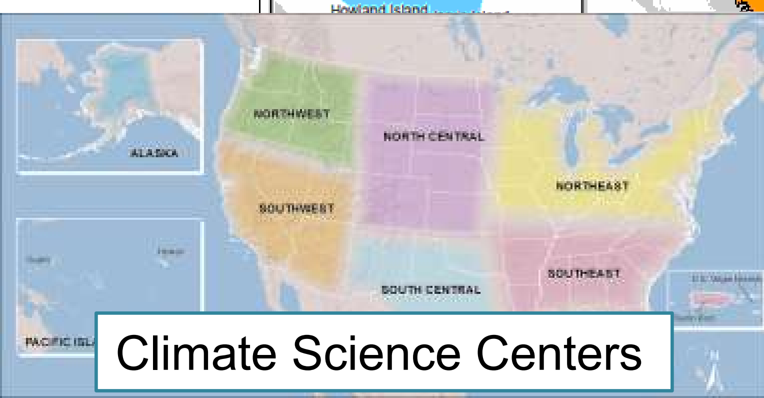
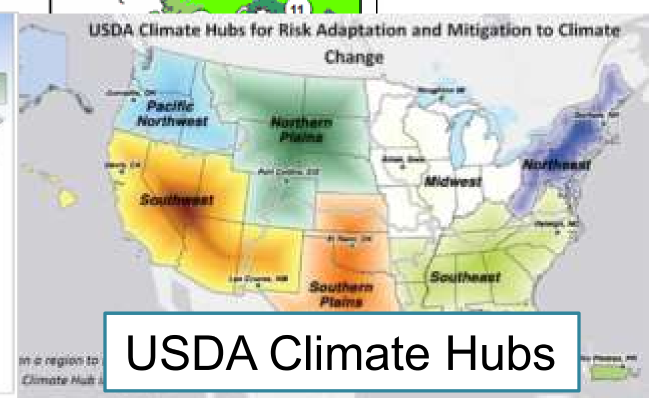
- Finding the best place to use current resources
- Bringing in new conservation dollars
- Guiding infrastructure development
- Creating incentives as an alternative to regulation
- Bringing a landscape perspective to local adaptation
- Responding to major disasters

Part of a larger network





Steps in the Blueprint

- Indicators and targets
- State of the South Atlantic
- Conservation Blueprint

Indicators and targets

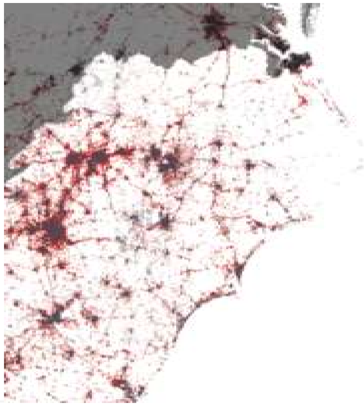
- Ecosystem integrity

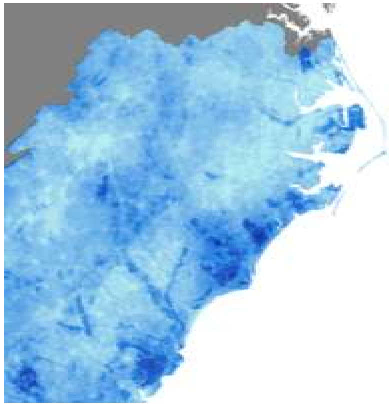
- Intact cultural landscapes

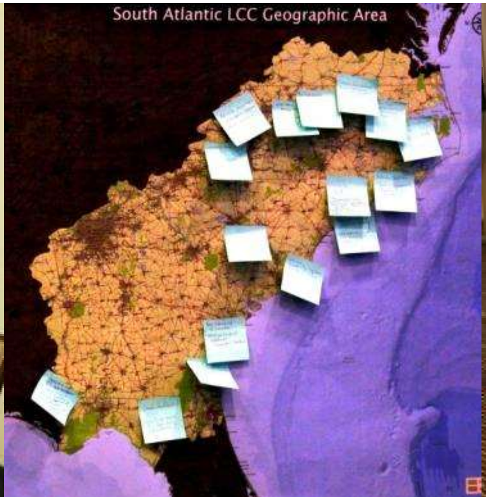
Ecosystems

- Marine
- Estuarine
- Beach and dunes
- Forested wetlands
- Tidal and nontidal freshwater marshes (managed and unmanaged)
- Freshwater aquatic (streams, lakes, ponds)
- Maritime forests
- Pine woodlands, savannas, and prairies (includes longleaf, loblolly, and slash systems)
- Upland hardwood forests
- Landscapes (Habitat aggregate)
- Waterscapes (Habitat aggregate)

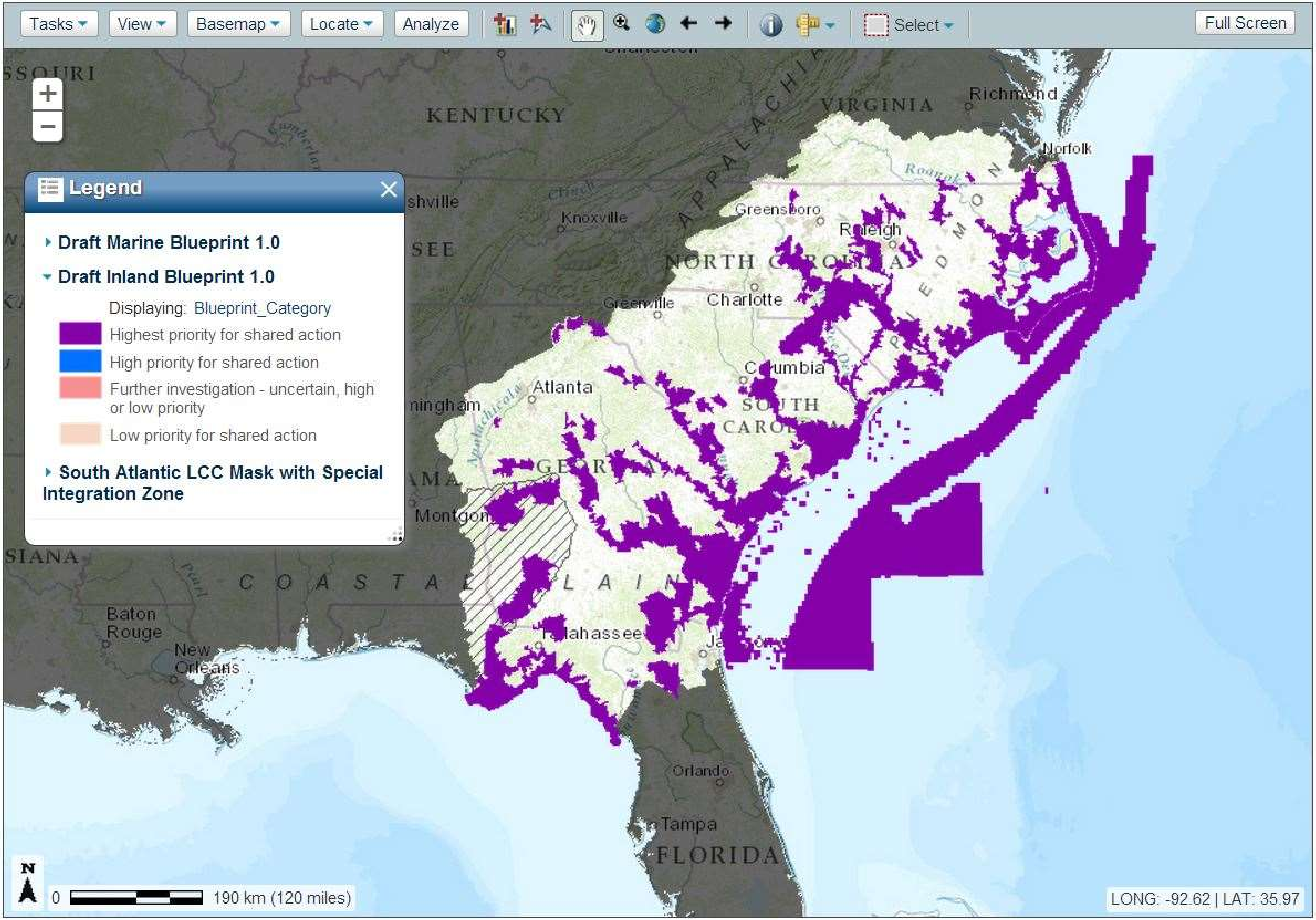
Regional Blueprint workshops





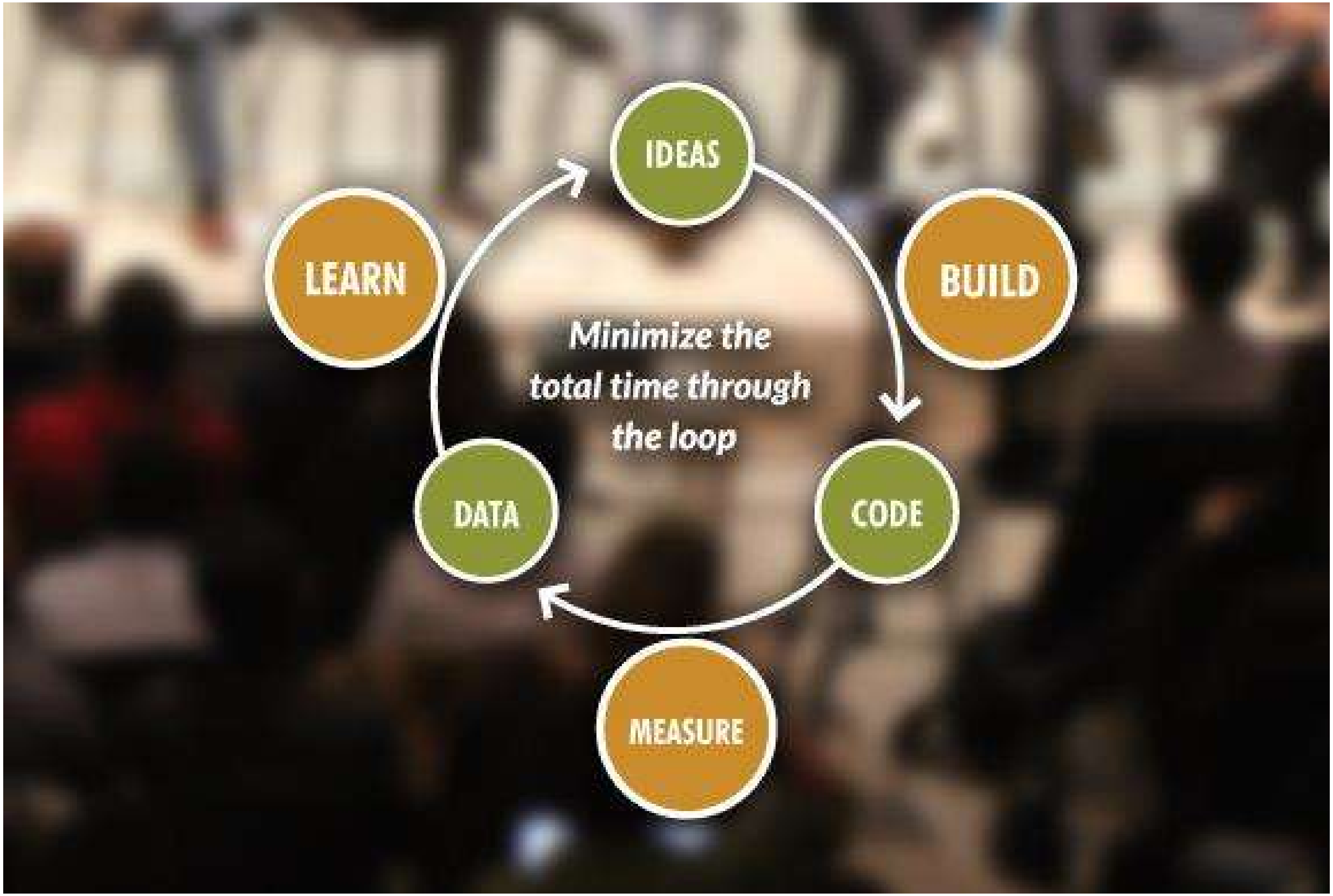


Integrating existing plans



South Atlantic Blueprint 1.0 – http://blueprint.southatlanticlcc.org

The Lean Startup Method



Next steps: building a better Blueprint

Content

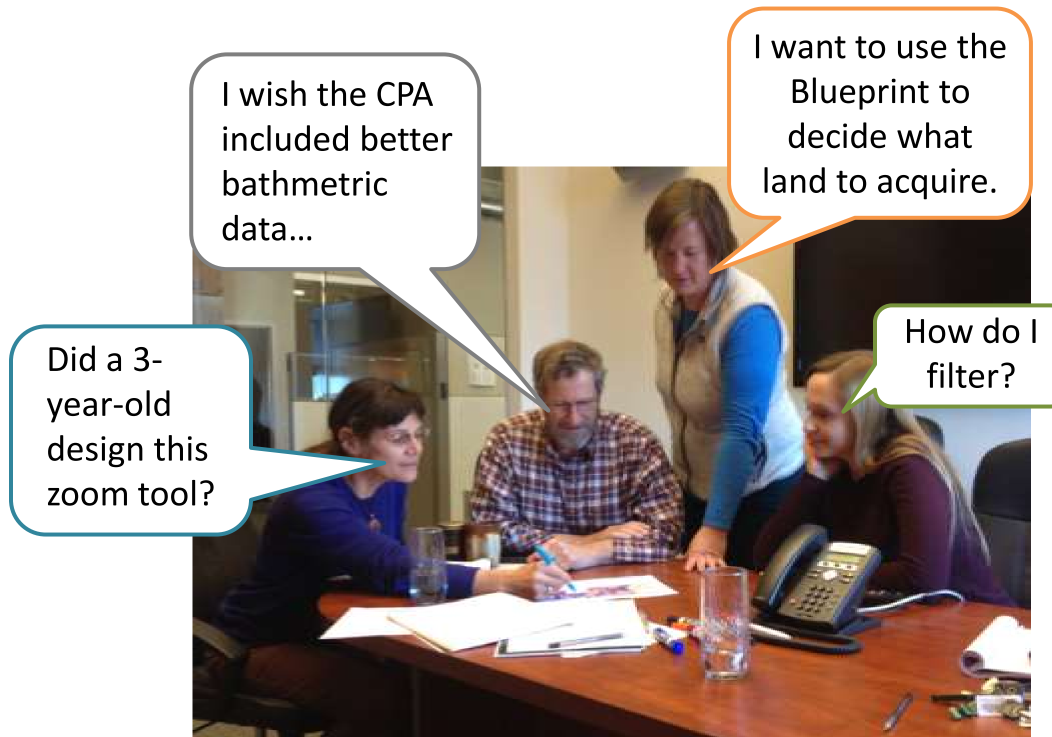
Presentation

Content

- More data-driven
- Finer resolution

Presentation

- New chart/graph features
- Intuitive design



Conservation design team

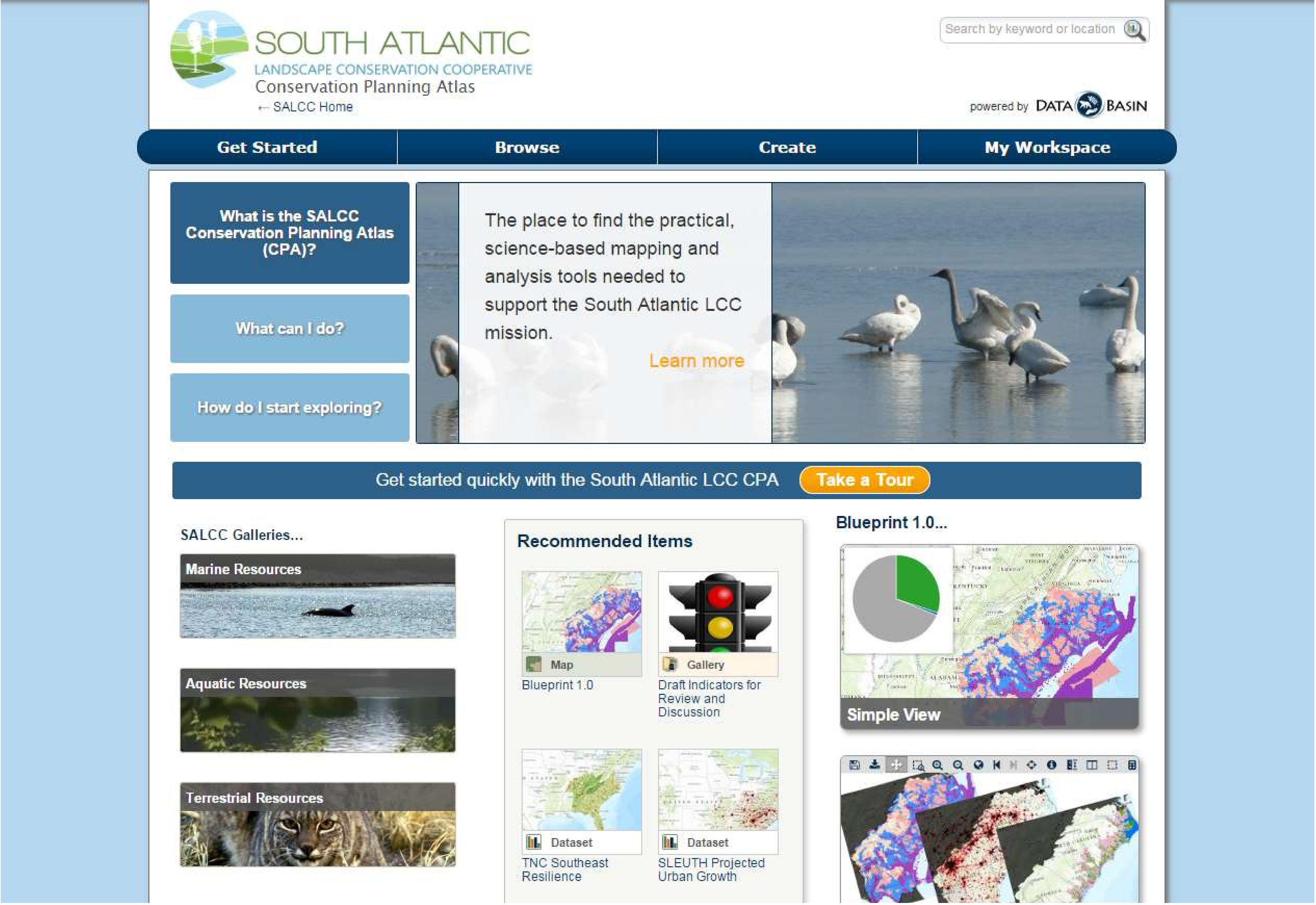
• Mark Anderson	*TNC*
• Jim Fox	*University of NC – Chapel Hill*
• Will Allen	*The Conservation Fund*
• Paul Wagner	*Army Corps*
• Bob Cooper	*UGA*
• Mary Conley	*TNC*
• Barry Grand	*USGS*
• Nate Nibbelink	*UGA*
• Dean Urban	*Duke University*
• Lindsey Smart	*Albermarle-Pamlico Nat'l Estuary Prog.*
• Tim Jones	*Atlantic Coast Joint Venture*
• Mary Davis	*Southeast Aquatic Resources Partn.*
• Jimmy Johnson	*Atlantic Coast Fish Habitat Partn.*

User team

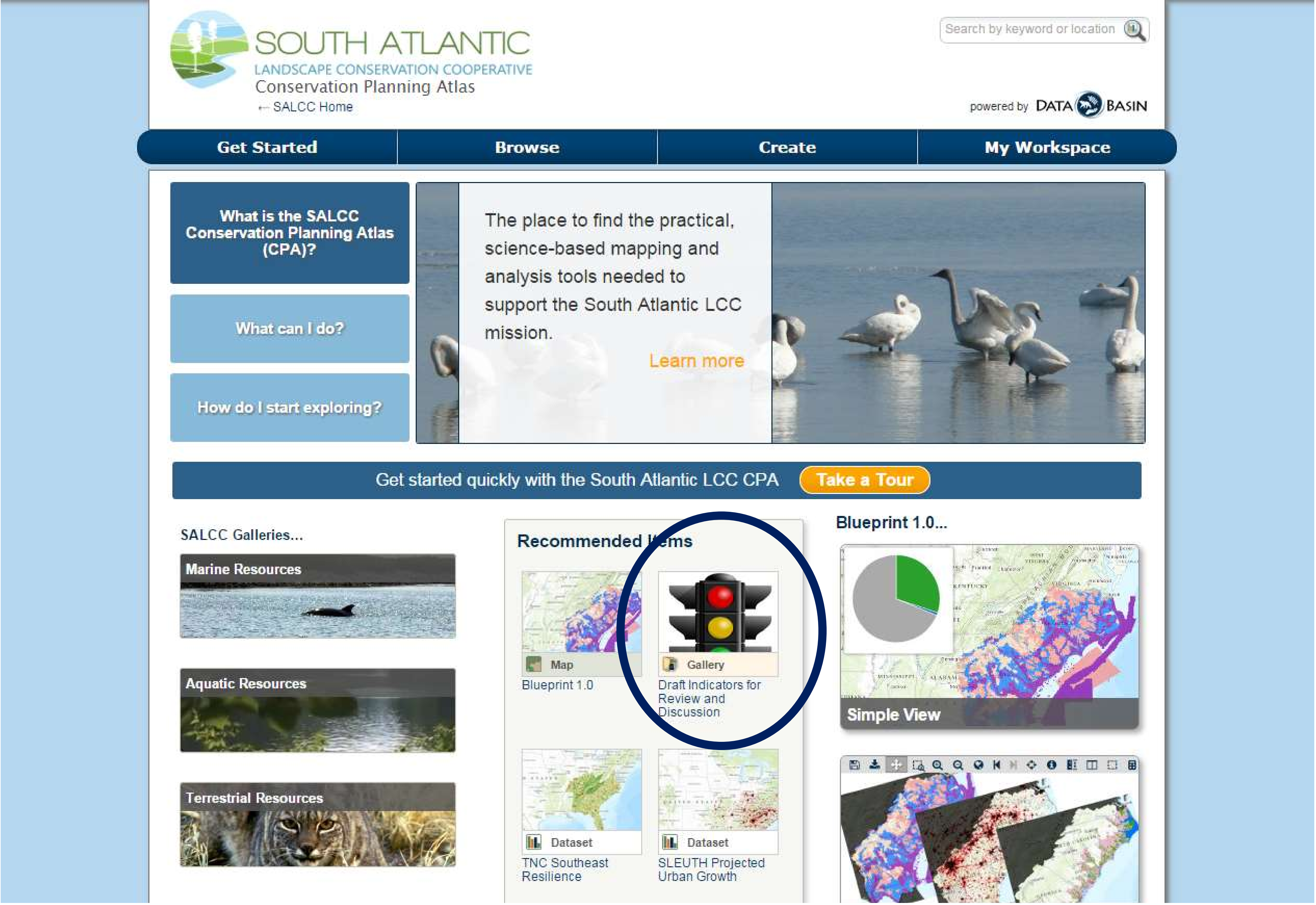
Aleta Hohn	*NOAA*
Anna Toline	*NPS*
Ben Wigley	*NCASI*
Beth Stys	*FL FWC*
Beth Byrd	*NPS*
Billy Dukes	*SC DNR*
Breck Carmichael	*SC DNR*
Brian Watson	*VA DGIF*
Brian Yanchik	*DOT*
Charlotte Gillis	*NPS*
Chris Burkett	*VA DGIF*
Cynthia Walton	*NPS*
Darrell Echols	*NPS*
David Whitaker	*SC DNR*
Don Imm	*FWS*
Emrys Treasure	*USFS*
George Willson	*TCF*
Hervey McIver	*TNC*
Jan MacKinnon	*GA DNR*
Jason Bulluck	*VA DCR*
John Ann Shearer	*FWS*
John Stanton	*FWS*
Jon Ambrose	*GA DNR*
Julie Elmore	*NRCS*
Kacy Cook	*NC WRC*
Lisa Perras-Gordon	*EPA*
Marella Buncick	*FWS*
Maria Whitehead	*TNC*
Mark Cantrell	*FWS*
Mark Scott	*SC DNR*
Mary Morrison	*USFS*
Pace Wilber	*NOAA*
Pam Wingrove	*FWS*
Randy Swilling	*NPS*
Reggie Thackston	*GA DNR*
Rick Durbrow	*EPA*
Roger Pugliese	*SAFMC*
Ryan Heise	*NC WRC*
Ryan Orndorff	*Marines*
Wilson Laney	*FWS*

Indicator testing and revisions

May	June	July	August	September	October	November	December
Landscapes	Beaches & Dunes, Maritime Forest	Estuaries	Pine Woodlands	Forested Wetlands, Freshwater aquatic	Upland Hardwood	Marine	Freshwater Marsh, Waterscapes



http://salcc.databasin.org

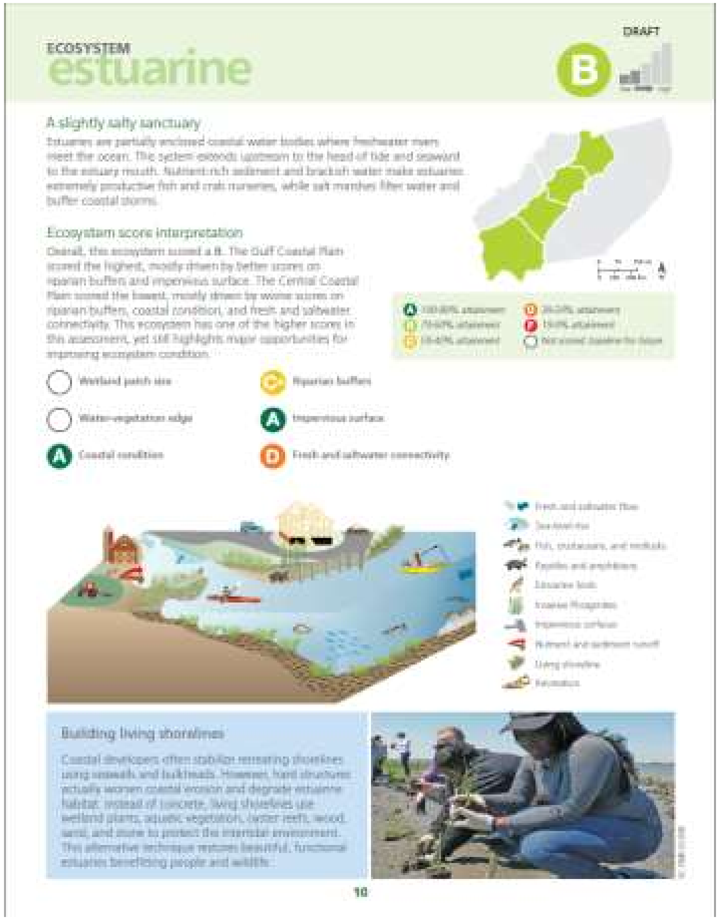


http://salcc.databasin.org

State of the South Atlantic

- Using revised indicators in data-driven ecosystem condition assessment

- Complete by mid-Feb


DRAFT

ECOSYSTEM
estuarine

B

A slightly salty sanctuary

Estuaries are partially enclosed coastal water bodies where freshwater rivers meet the ocean. The system extends upstream to the head of tide and seaward to the estuary mouth. Nutrient-rich sediment and brackish water make estuaries extremely productive fish and crab nurseries, while salt marshes filter water and buffer coastal storms.

Ecosystem score interpretation

Overall, this ecosystem scored a B. The Gulf Coastal Plain scored the highest, mostly driven by better scores on riparian buffers and impervious surface. The Central Coastal Plain scored the lowest, mostly driven by worse scores on riparian buffers, coastal condition, and fresh and saltwater connectivity. This ecosystem has one of the higher scores in this assessment, yet still highlights major opportunities for improving ecosystem condition.

Wetland patch size

Riparian buffers

Water-vegetation edge

Impervious surface

Coastal condition

Fresh and saltwater connectivity

Fresh and saltwater flow

Fish, crustaceans, and mollusks

Reptiles and amphibians

Impervious surface

Nutrient and sediment runoff

Living shoreline

Recreation

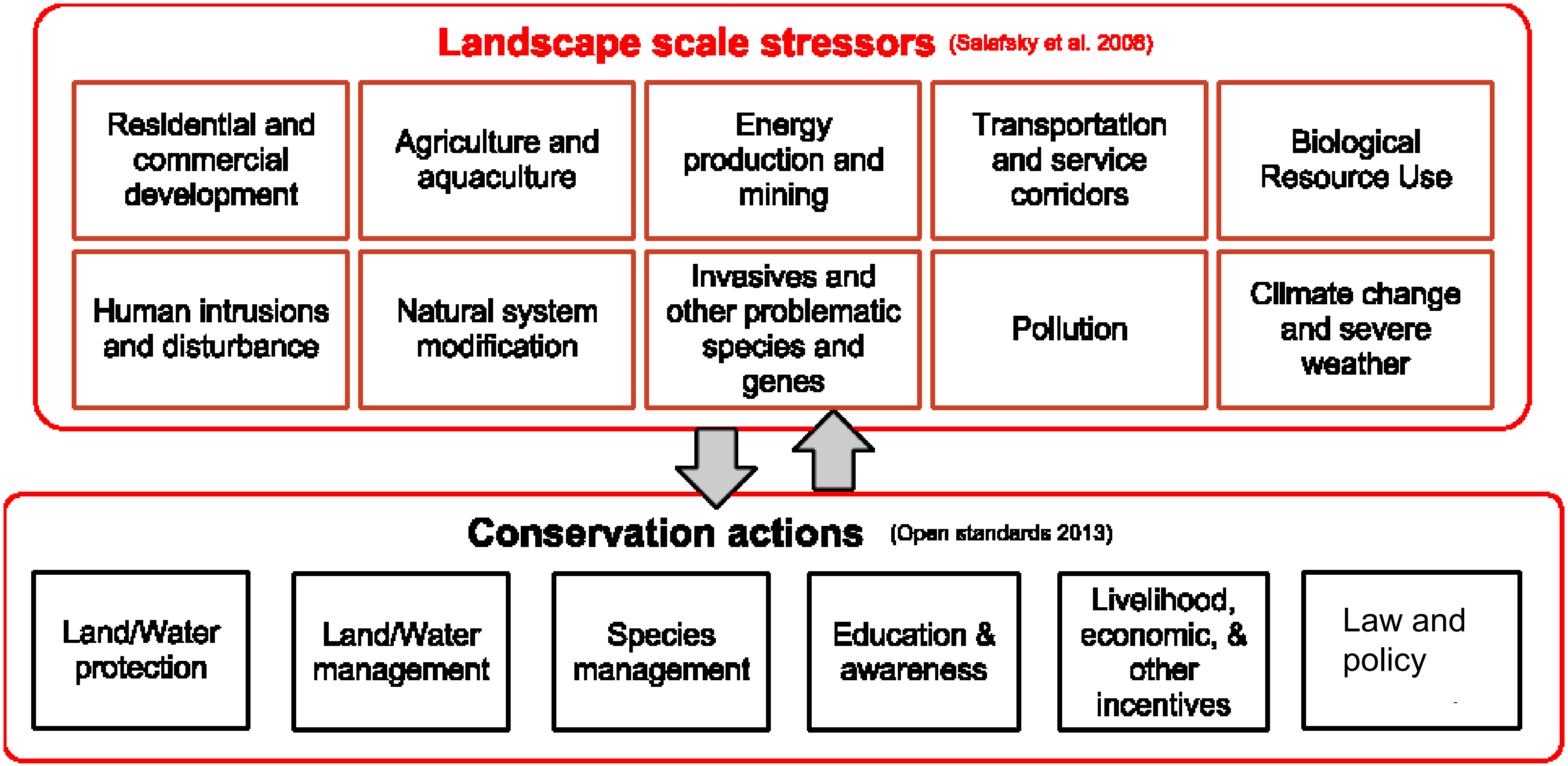
Building living shorelines

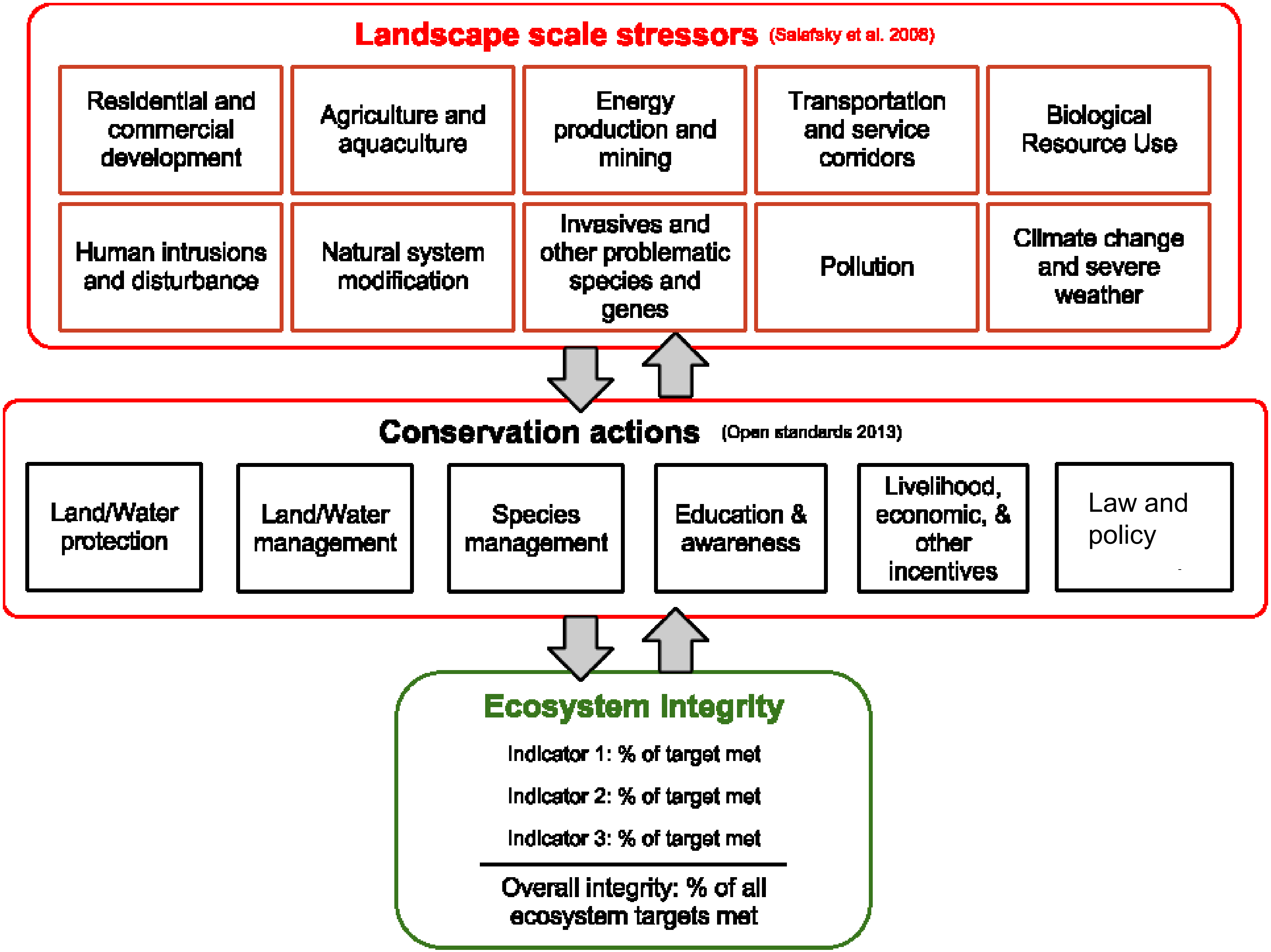
Coastal developers often stabilize retreating shorelines using seawalls and bulkheads. However, hard structures actually worsen coastal erosion and degrade estuarine habitat. Instead of concrete, living shorelines use wetland plants, aquatic vegetation, oyster reefs, wood, sand, and stone to protect the intertidal environment. This alternative technique restores beautiful, functional estuaries benefiting people and wildlife.

10

Landscape scale stressors (Salafsky et al. 2008)

Residential and commercial development	Agriculture and aquaculture	Energy production and mining	Transportation and service corridors	Biological Resource Use
Human intrusions and disturbance	Natural system modification	Invasives and other problematic species and genes	Pollution	Climate change and severe weather


Landscape scale stressors (Salafsky et al. 2008)
Residential and commercial development
Agriculture and aquaculture
Energy production and mining
Transportation and service corridors
Biological Resource Use
Human intrusions and disturbance
Natural system modification
Invasives and other problematic species and genes
Pollution
Climate change and severe weather
Conservation actions (Open standards 2013)
Land/Water protection
Land/Water management
Species management
Education & awareness
Livelihood, economic, & other incentives
Law and policy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Transportation and service corridors
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Human intrusions and disturbance
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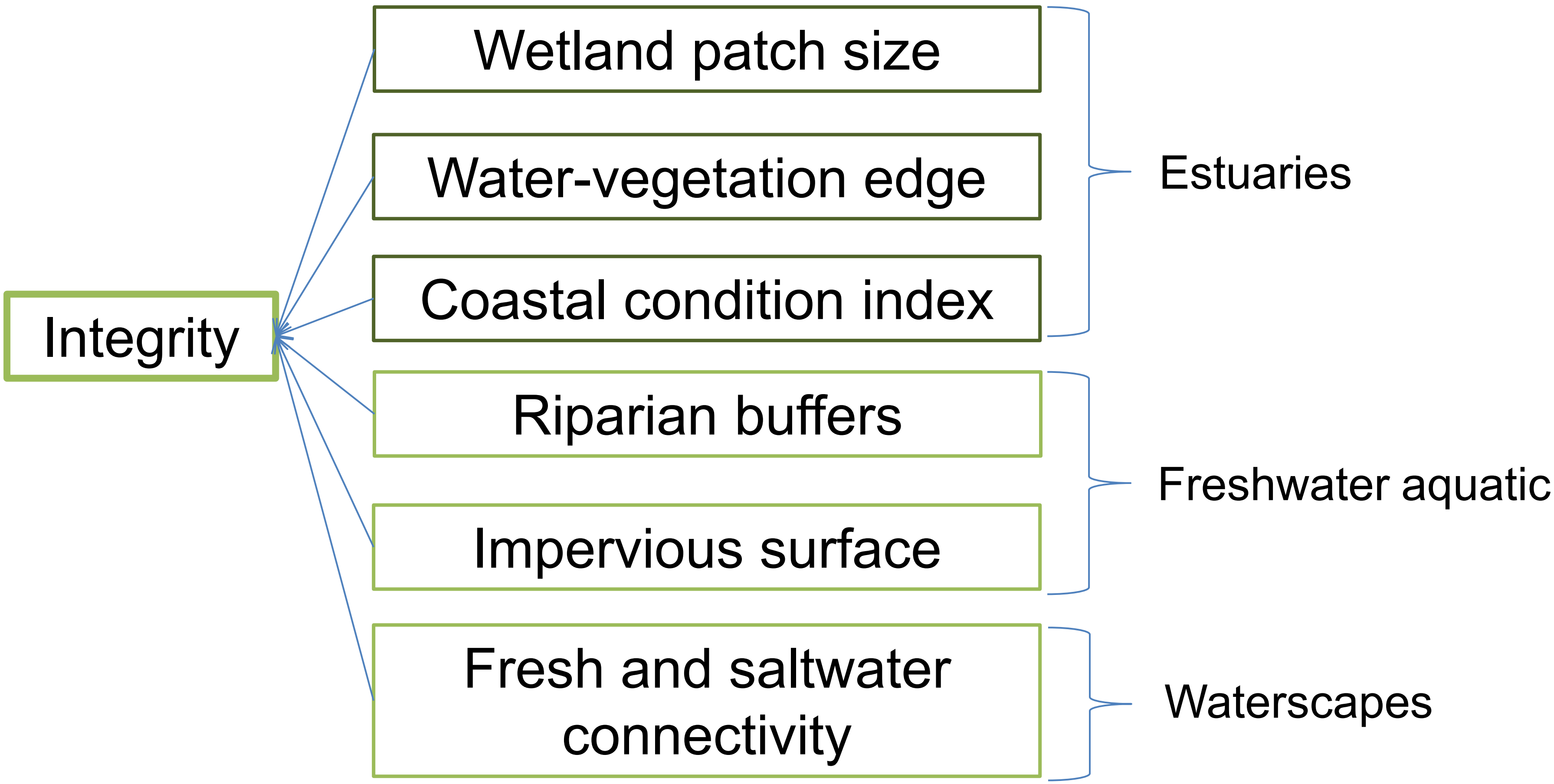
Pollution
Climate change and severe weather
Conservation actions (Open standards 2013)
Land/Water protection
Land/Water management
Species management
Education & awareness
Livelihood, economic, & other incentives
Law and policy
Ecosystem Integrity
Indicator 1: % of target met
Indicator 2: % of target met
Indicator 3: % of target met
Overall integrity: % of all ecosystem targets met

Estuarine integrity



Indicator

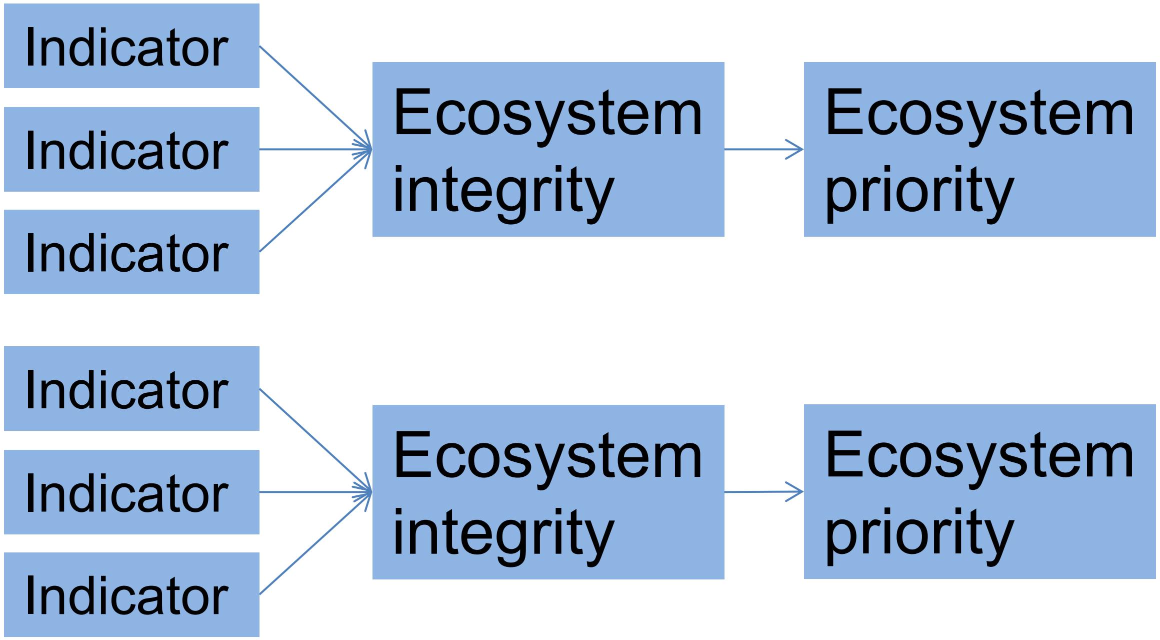
Indicator

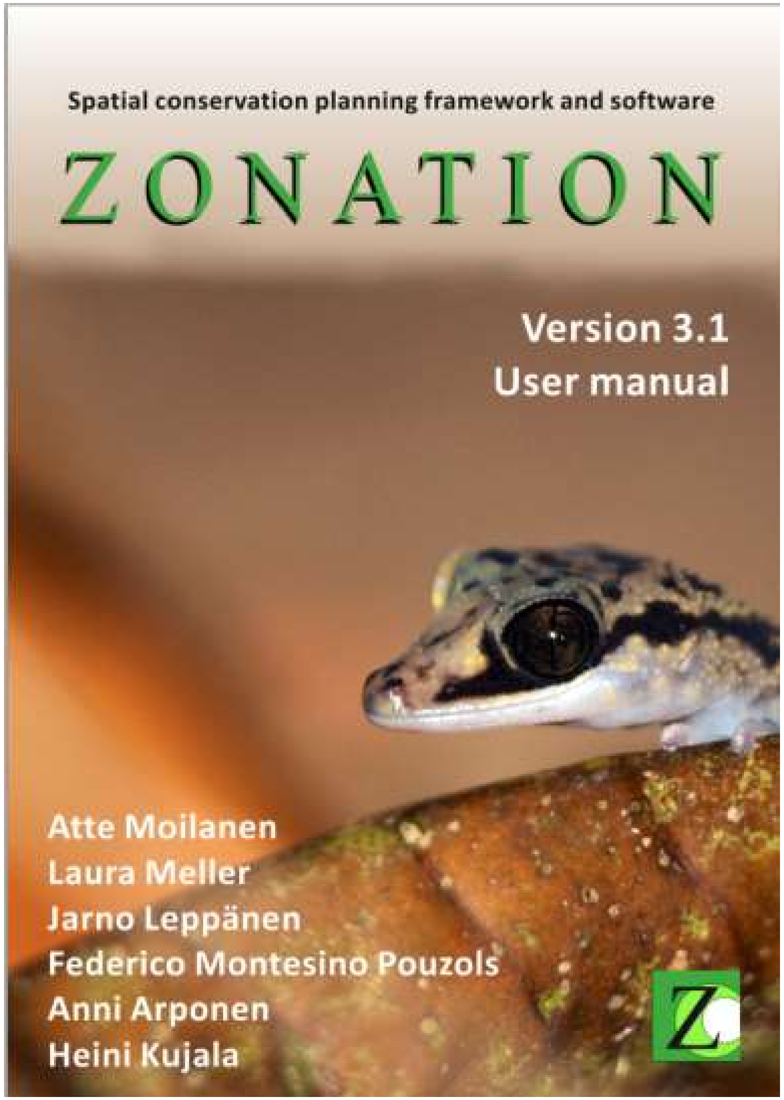
Indicator

Indicator

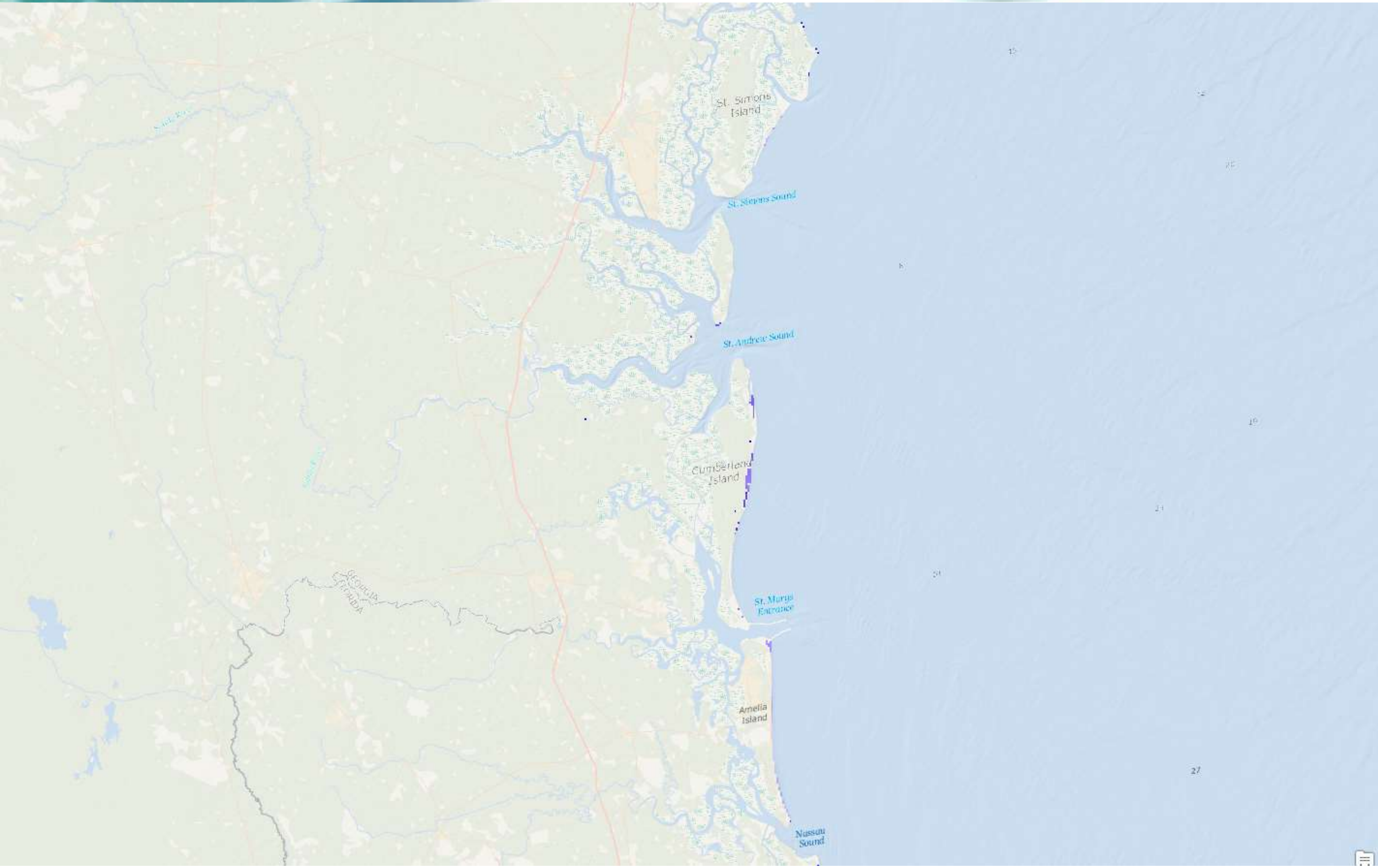
Indicator

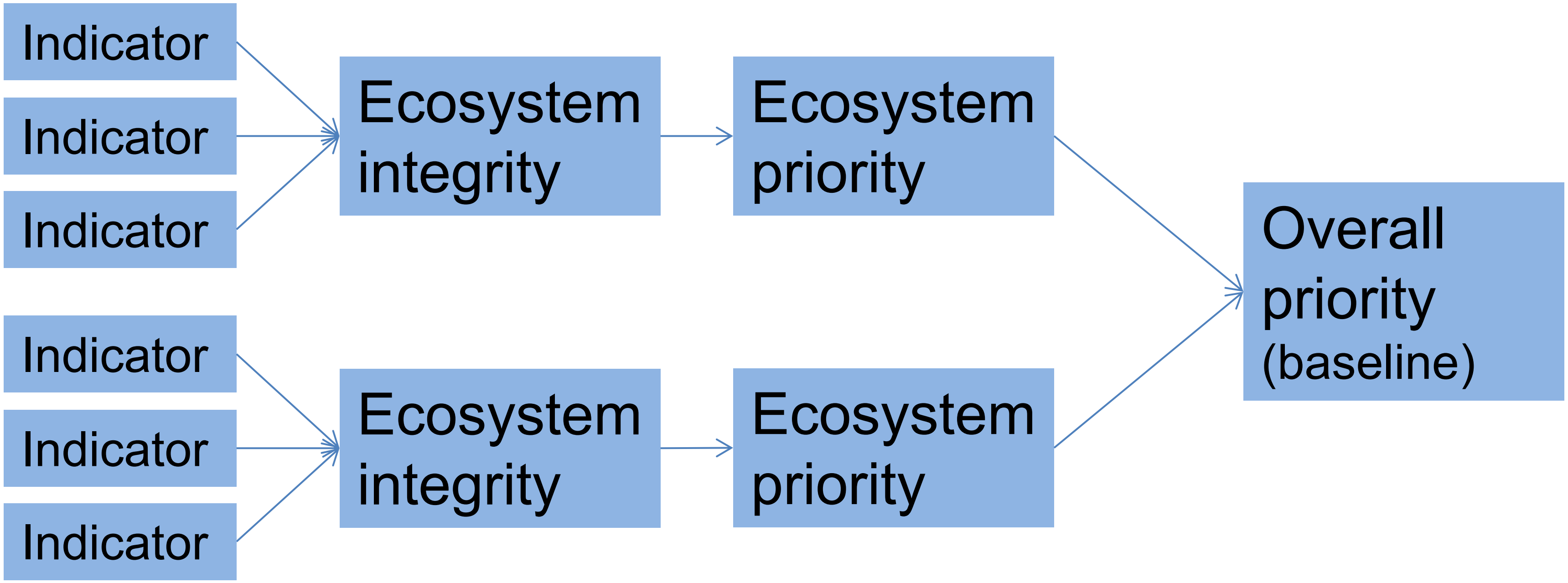
Indicator

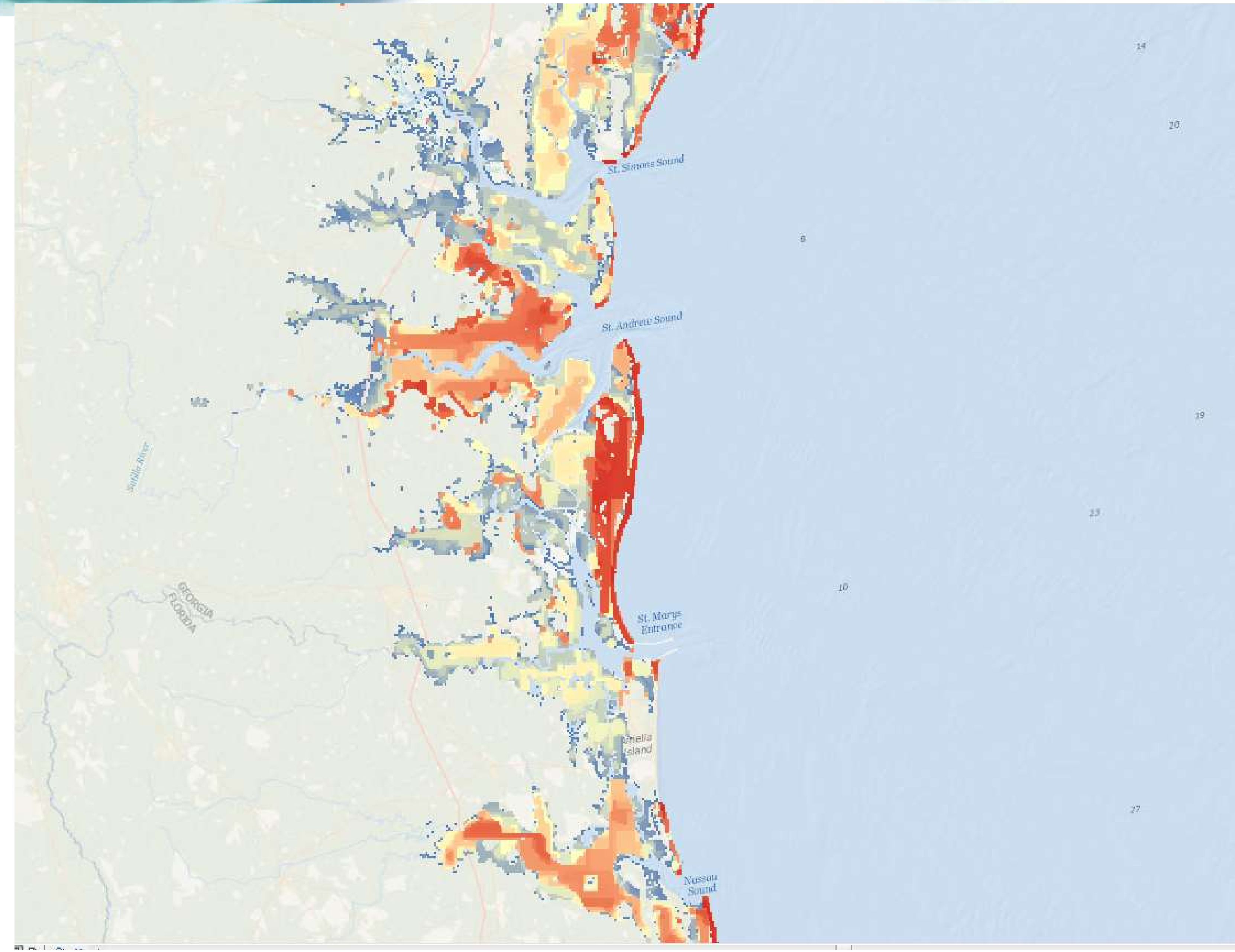

Indicator
Indicator
Indicator
Ecosystem integrity
Ecosystem priority
Indicator
Indicator
Indicator
Ecosystem integrity
Ecosystem priority

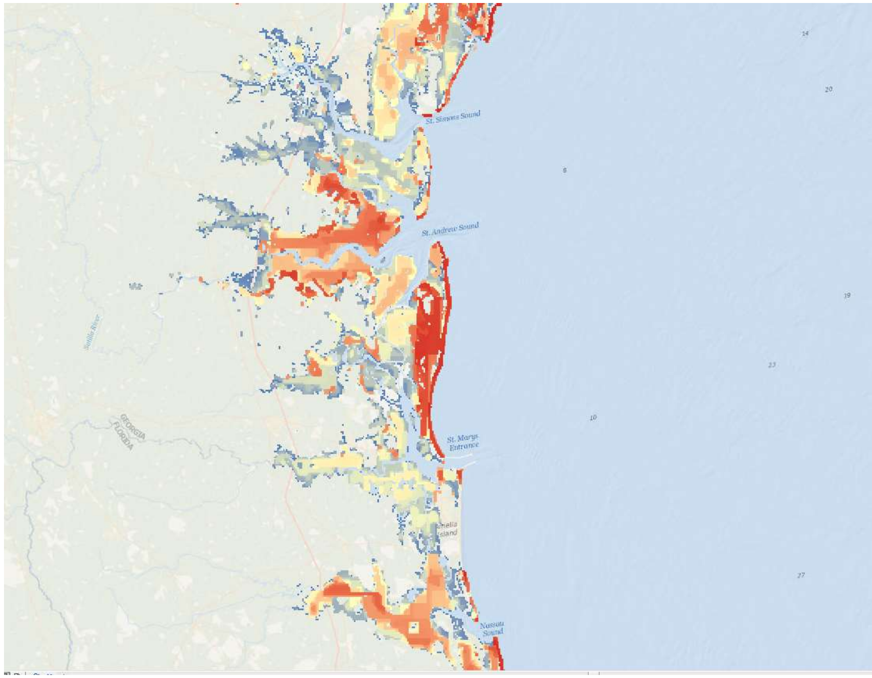


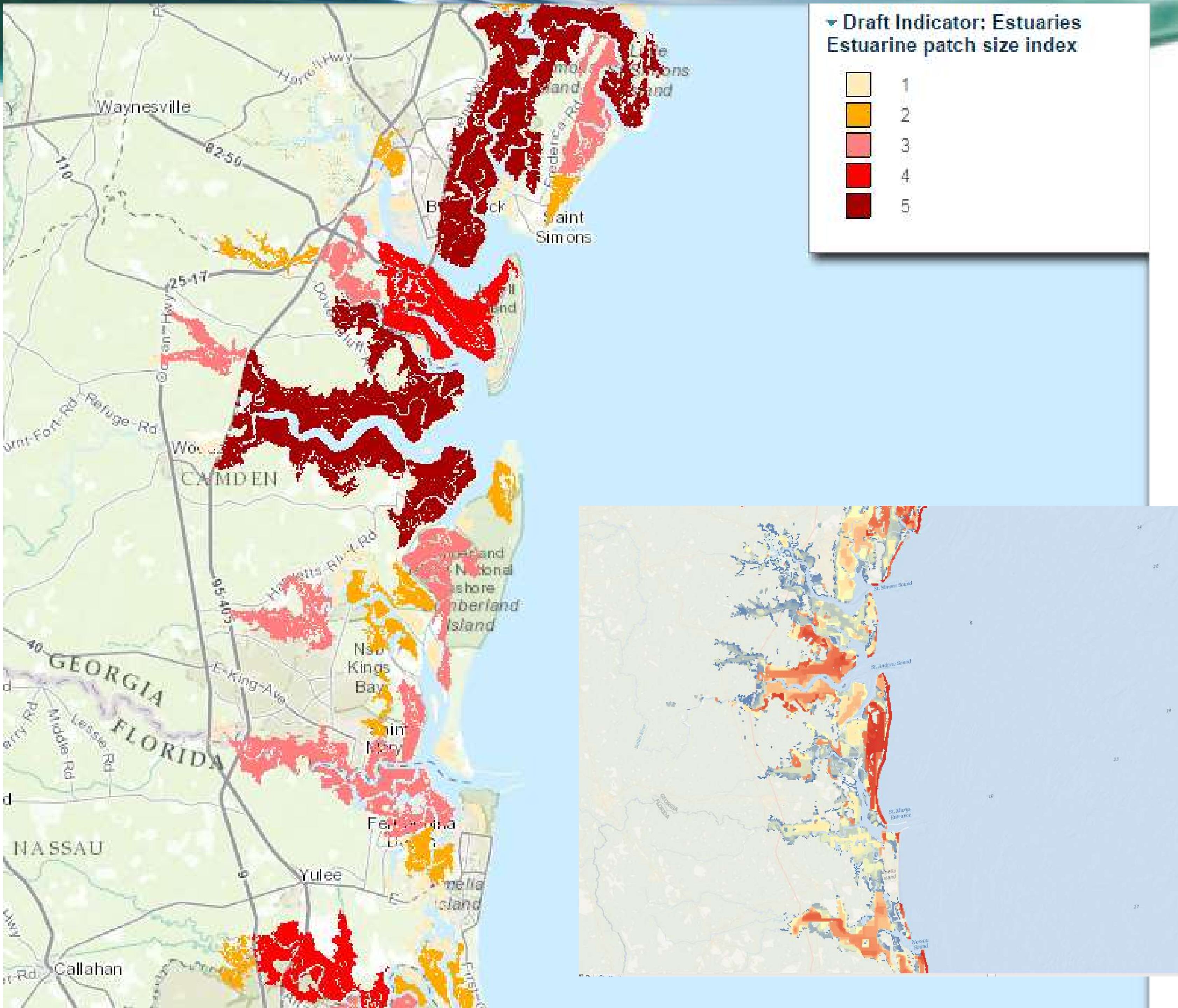
- Originally developed in 2004 and is regularly updated
- Used globally for diverse applications
  - Terrestrial, freshwater, marine
  - Climate resilience
  - Urban conservation
- Algorithm is easy to understand


St. Simons Island
St. Simons Sound
St. Andrew Sound
Cumberland Island
GEORGIA
FLORIDA
St. Marys Entrance
Amelia Island
Nassau Sound
27

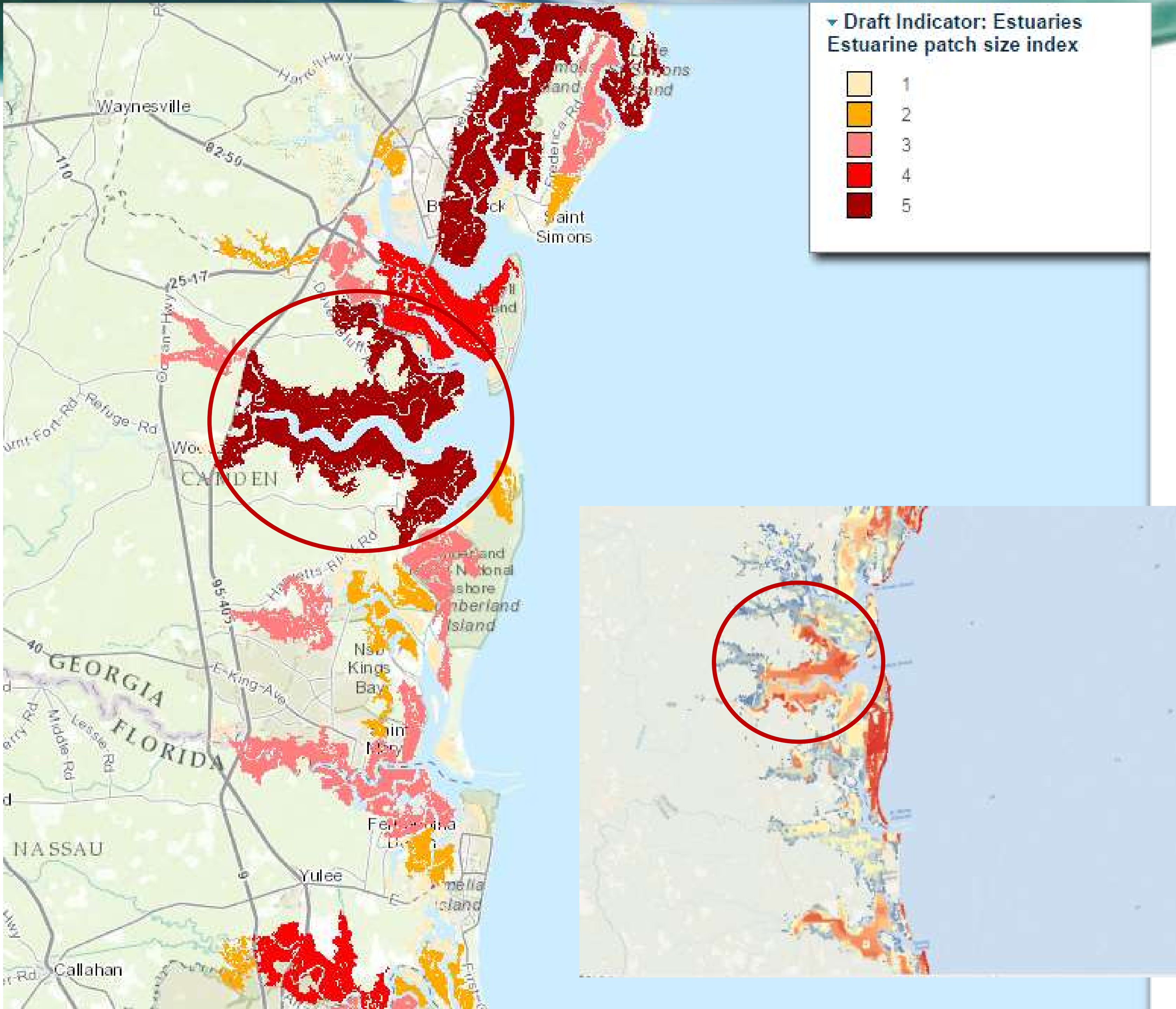

Indicator
Indicator
Indicator
Ecosystem integrity
Ecosystem priority
Indicator
Indicator
Indicator
Ecosystem integrity
Ecosystem priority
Overall priority (baseline)


St. Simons Sound
St. Andrew Sound
St. Marys Entrance
Amelia Island
Nassau Sound
GEORGIA
FLORIDA
Satilla River


St. Simons Sound
St. Andrew Sound
Satilla River
GEORGIA
FLORIDA
St. Marys
Entrance
Nassau
Sound



Draft Indicator: Estuaries
Estuarine patch size index
1
2
3
4
5
Waynesville
Saint Simons
CAMDEN
GEORGIA
FLORIDA
NASSAU
Yulee
Callahan
Kings Bay
Refuge Rd
E King Ave
Middle Rd
Lessie Rd



Draft Indicator: Estuaries
Estuarine patch size index
1
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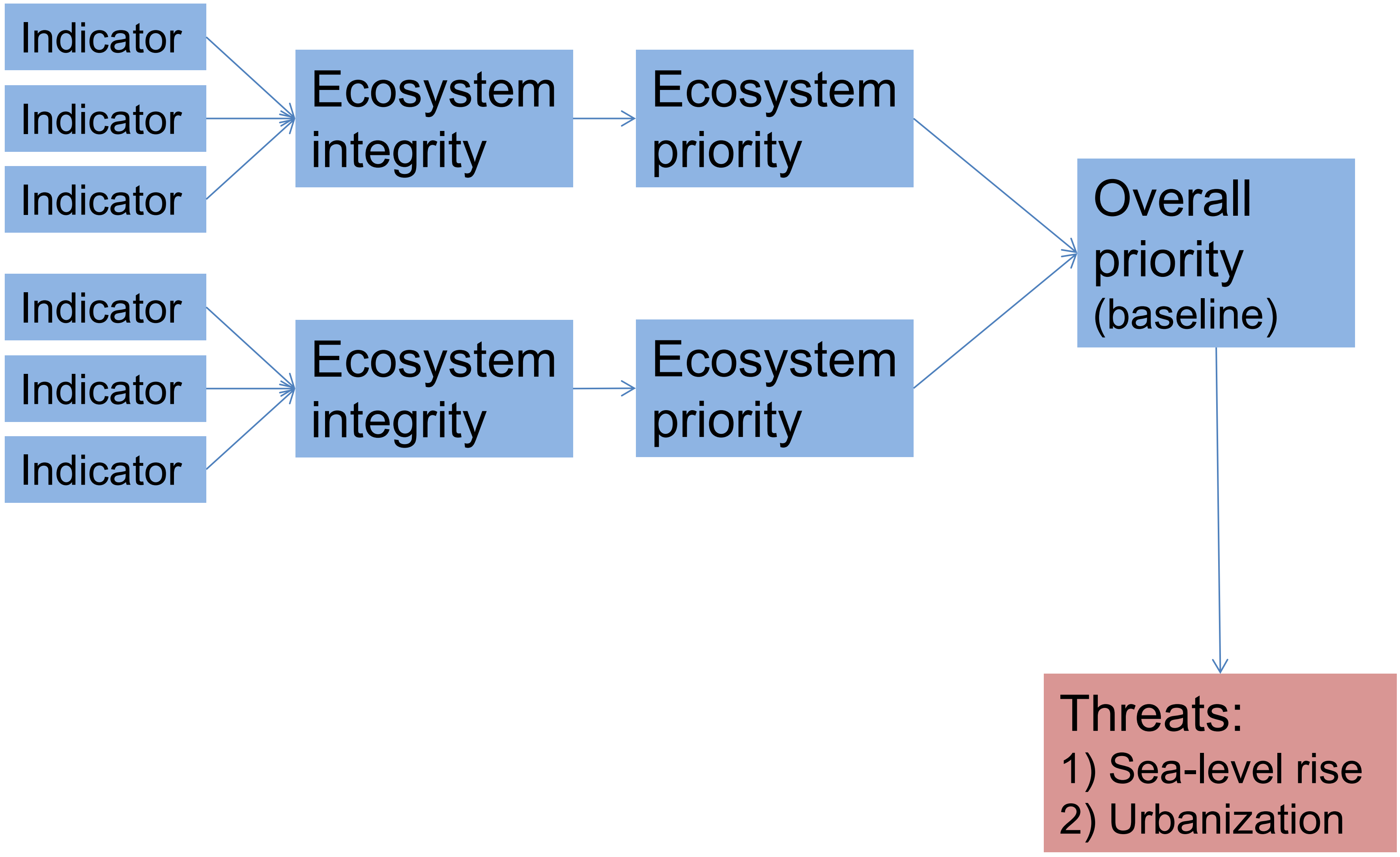
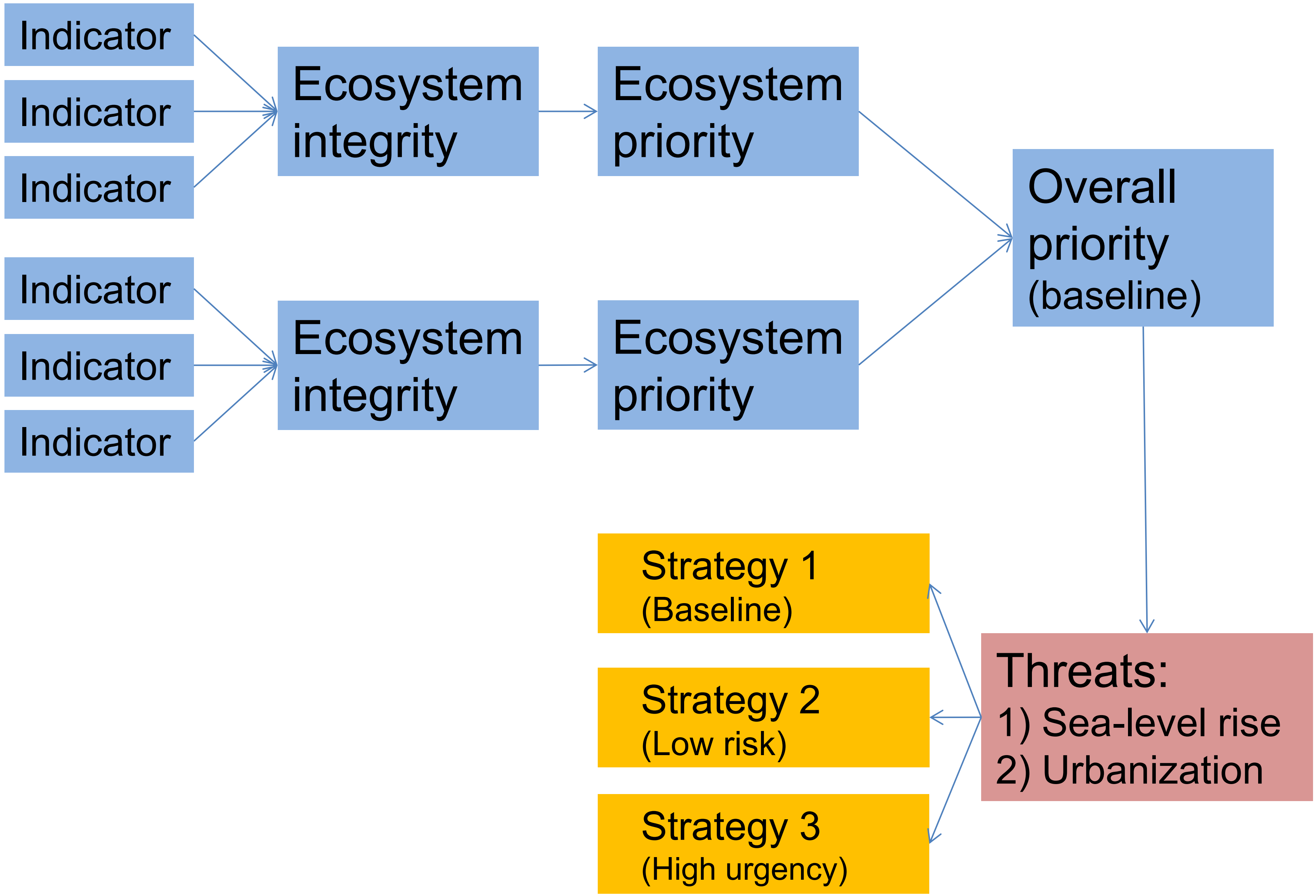
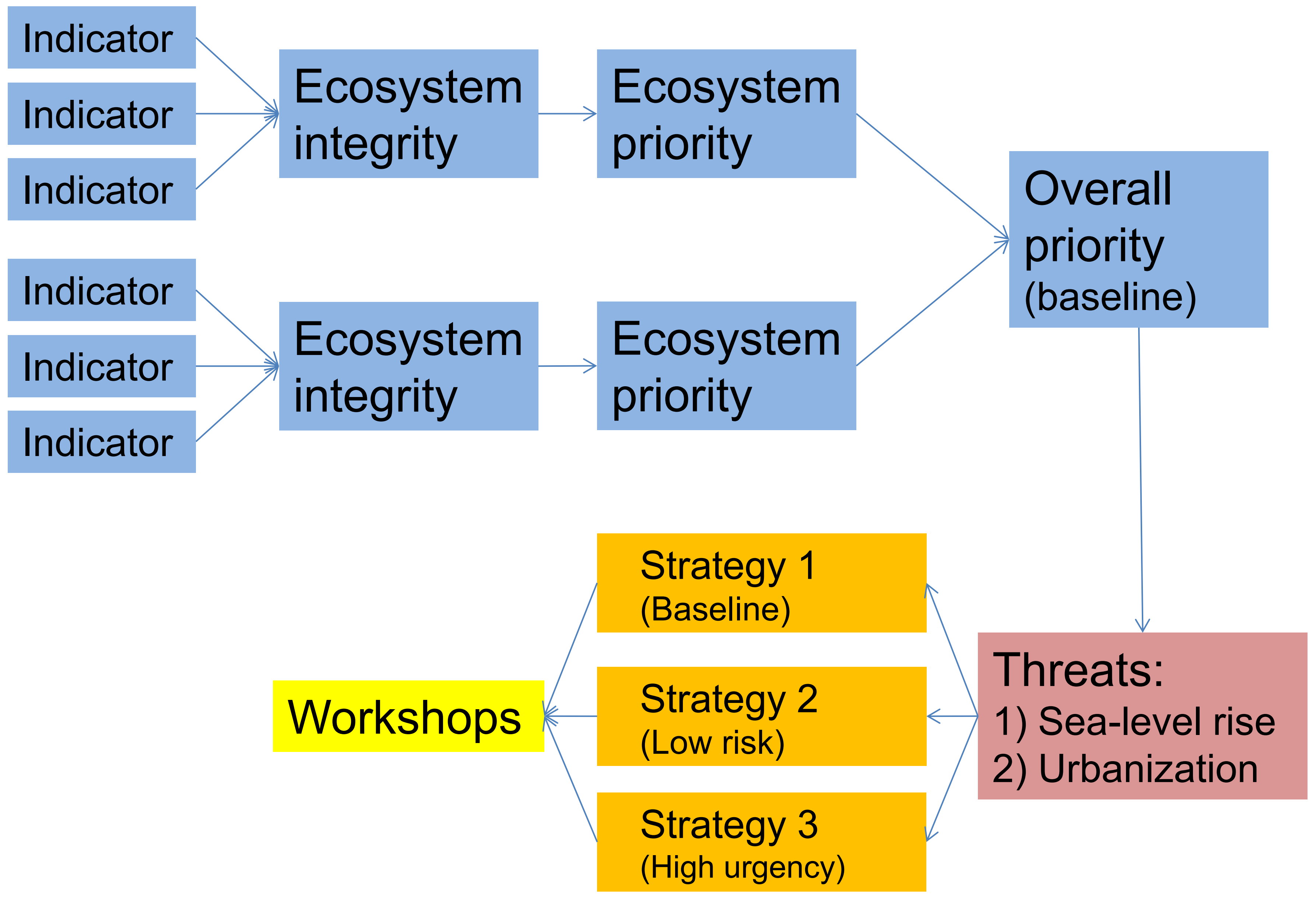
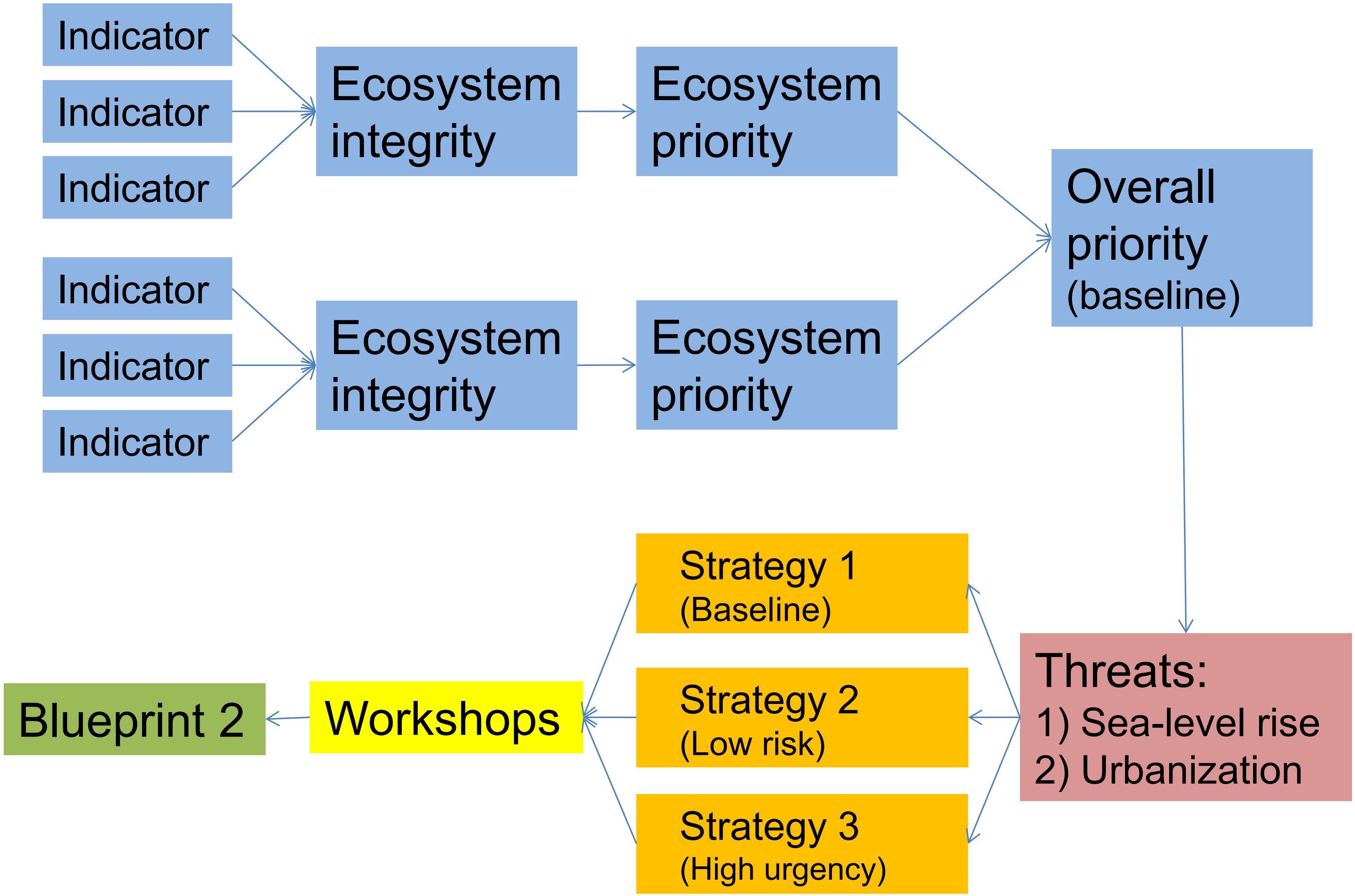
Waynesville
Saint
Simons
CAMDEN
GEORGIA
FLORIDA
NASSAU
Yulee
Callahan
Kings
Bay
Refuge Rd
E King Ave


Indicator
Indicator
Indicator
Ecosystem integrity
Ecosystem priority
Indicator
Indicator
Indicator
Ecosystem integrity
Ecosystem priority
Overall priority (baseline)
Threats:
1) Sea-level rise
2) Urbanization


Indicator
Indicator
Indicator
Ecosystem integrity
Ecosystem priority
Indicator
Indicator
Indicator
Ecosystem integrity
Ecosystem priority
Overall priority (baseline)
Strategy 1 (Baseline)
Strategy 2 (Low risk)
Strategy 3 (High urgency)
Threats:
1) Sea-level rise
2) Urbanization



Indicator
Indicator
Indicator
Ecosystem integrity
Ecosystem priority
Indicator
Indicator
Indicator
Ecosystem integrity
Ecosystem priority
Overall priority (baseline)
Strategy 1 (Baseline)
Strategy 2 (Low risk)
Strategy 3 (High urgency)
Workshops
Threats:
1) Sea-level rise
2) Urbanization


Indicator
Indicator
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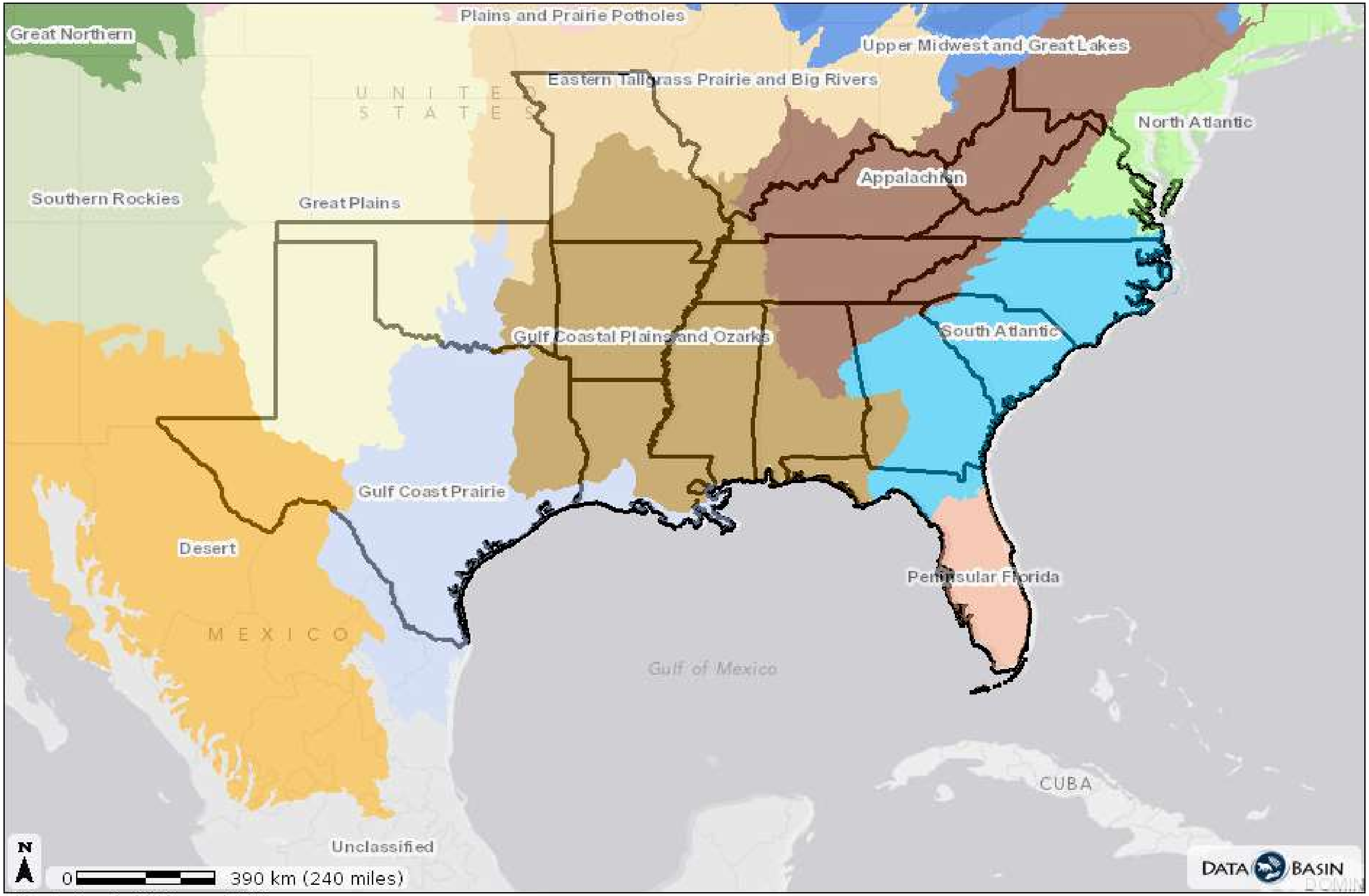
Ecosystem integrity
Ecosystem priority
Indicator
Indicator
Indicator
Ecosystem integrity
Ecosystem priority
Overall priority (baseline)
Threats:
1) Sea-level rise
2) Urbanization
Strategy 1 (Baseline)
Strategy 2 (Low risk)
Strategy 3 (High urgency)
Workshops
Blueprint 2

Southeast Conservation Adaptation Strategy



Created by: Ken McDermond, 2013

Workshops

- Raleigh, NC
  - Workshop #1: Feb 18, 2015 (9am – 3:30pm)
  - Workshop #2: Feb 19, 2015 (9am – 3:30pm)
- Atlanta, GA
  - Workshop #3: March 9, 2015 (9am – 3:30pm)
  - Workshop #4: March 10, 2015 (9am – 3:30pm)
- Tallahassee, FL
  - Workshop #5: March 11, 2015 (9am – 3:30pm)
  - Workshop #6: March 12, 2015 (9am – 3:30pm)
- Charleston, SC
  - Workshop #7: March 17, 2015 (9am – 3:30pm)
  - Workshop #8: March 18, 2015 (9am – 3:30pm)

Free registration: http://www.southatlanticlcc.org/page/workshops

State of SECOORA

Regional Coastal Ocean Observing System (RCOOS)

Tuesday, February 10, 2015

SECOORA Funded Activities – Presentation Outline

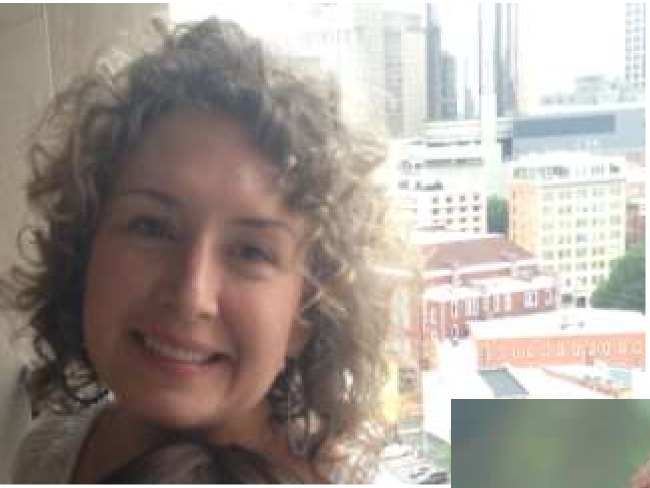
1. SECOORA Program Development
2. IOOS Cooperative Agreement
   - Funding Allocations
   - SECOORA Principal Investigators
3. Regional Coastal Ocean Observing System (RCOOS)
4. Accomplishments
5. Challenges

SECOORA

- Membership-based nonprofit (501(c)3)
- 46 Members
- 17 Directors on Board
- 14 PIs
- Staff: 3 Full-time and 2 Part-time
- Funding:
  - 85-98%: IOOS
  - 2-15%: Membership dues and other grants

SECOORA Staff

Executive Director
Debra Hernandez



RCOOS Manager
Vembu Subramanian

Business Manager
Megan Lee

Communications
Specialist
Abbey Wakely

1. Program Development: Governance, management and operations

Goal: Sustain SECOORA as a Regional Information Coordination Entity

- Board and stakeholder engagement
- Staff operations
- Grant management
- Proposal development
- Financial operations
  - Payroll, invoice management, etc.
  - Annual audit, 990, indirect cost rate proposal
- RCOOS PI coordination
- DMAC activities coordination
- US IOOS Program Office
- IOOS Association
  - Congressional engagement
  - OMB, Administration, etc.

2. IOOS Cooperative Agreement

Proposal Title:

Southeast Coastal Ocean Observing Regional Association (SECOORA): A Framework for Monitoring, Prediction and Assessment to Support Decision-Makers Needs for Coastal and Ocean Data and Tools

Award Type: Cooperative Agreement ($20M total)

- Annual Budget Notification and Descope Proposal

Project Duration: June 1, 2011 – May 31, 2016

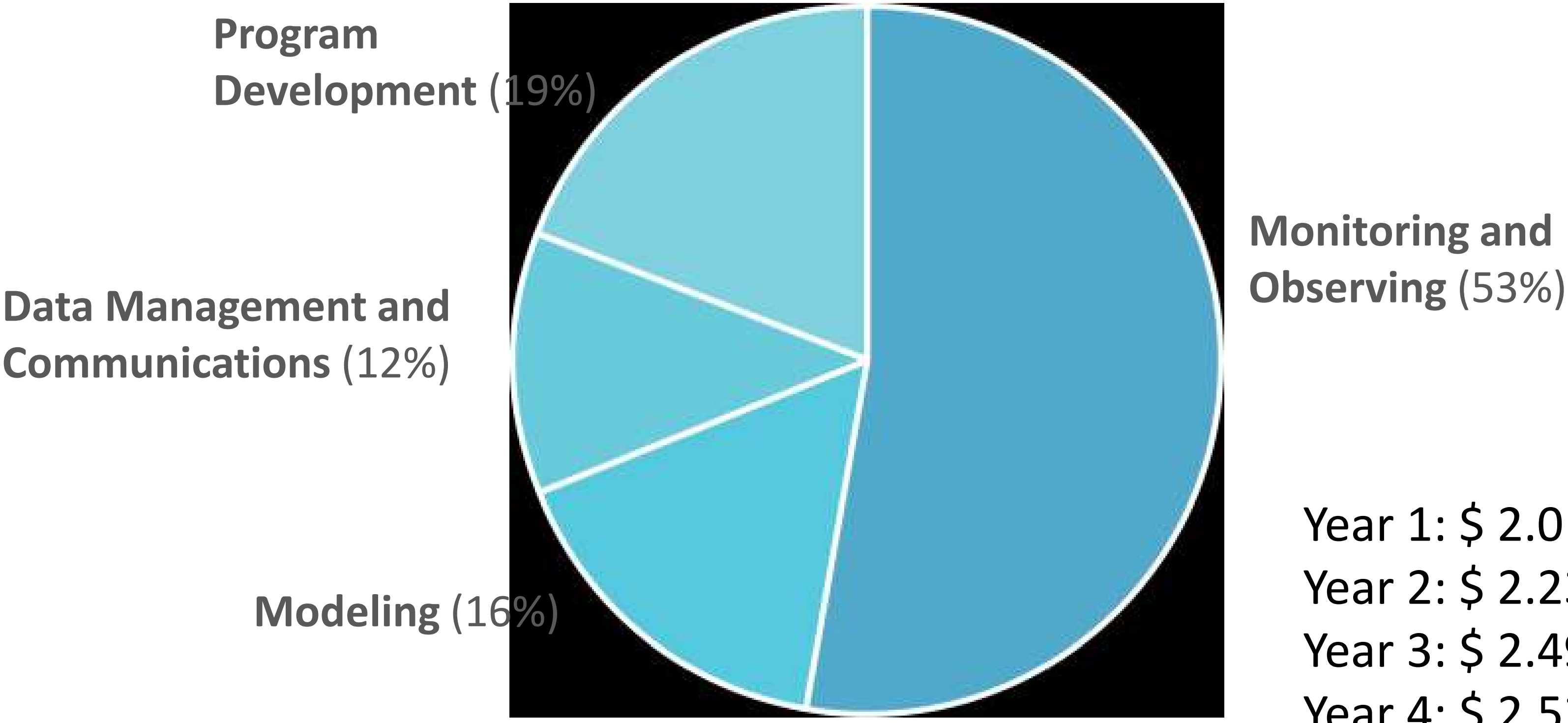
Current Award Year: Year 4 (June 1, 2014 – May 31, 2015)

Proposal Documents:

http://secoora.org/about/theme_areas/projects

2. Funding Allocations

IOOS Funds - Year 4



Year 1: $ 2.01 M
Year 2: $ 2.23 M
Year 3: $ 2.49 M
Year 4: $ 2.53 M

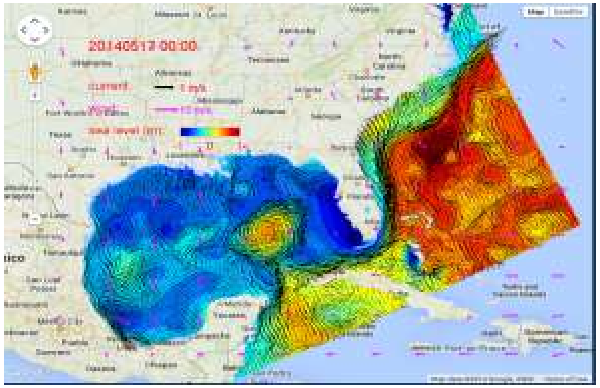
2. Principal Investigators

1. University of Miami
   High Frequency Radars
2. University of South Florida
   Coastal Stations; Offshore Buoys; High Frequency Radars
3. ROFFS™
   Fisheries Habitat Modeling
4. University of Florida
   Storm Surge Modeling
5. University of Georgia's Skidaway Institute of Oceanography
   High Frequency Radars
6. University of Georgia
   NOAA's Ocean Acidification Program NDBC
   Gray's Reef National Marine Sanctuary Buoy
7. University of South Carolina
   High Frequency Radars; Beach Water Quality Modeling; Data Management Infrastructure
8. University of North Carolina at Wilmington
   Coastal Stations; Offshore Buoys
9. North Carolina State University
   Storm Surge and Ocean Circulation Modeling
10. University of North Carolina at Chapel Hill
    High Frequency Radars; U.S. IOOS DMAC Vocabulary Efforts

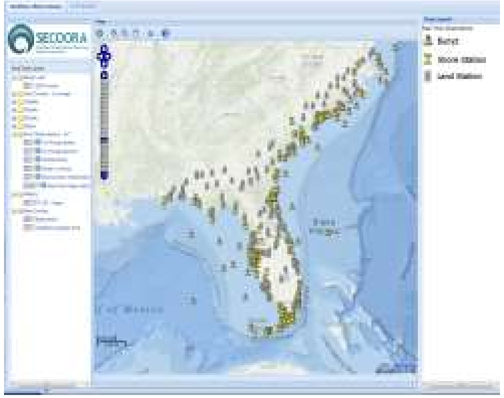
3. RCOOS Subcomponents

Monitoring and Observing

Modeling



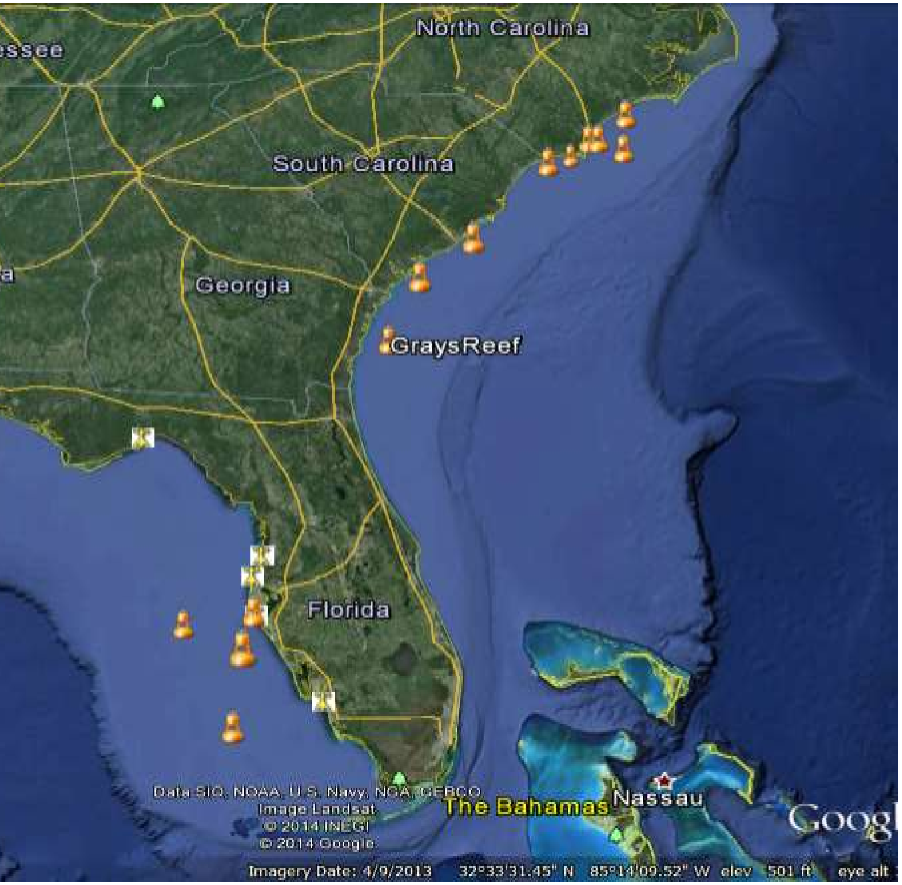
Data Management



Outreach and Education

3(a) Monitoring & Observing

Goal: Sustain an Observing Subsystem for the SE



In-situ Moored and Coastal Stations

University of N. Carolina Wilmington (8)

University of South Florida (9)

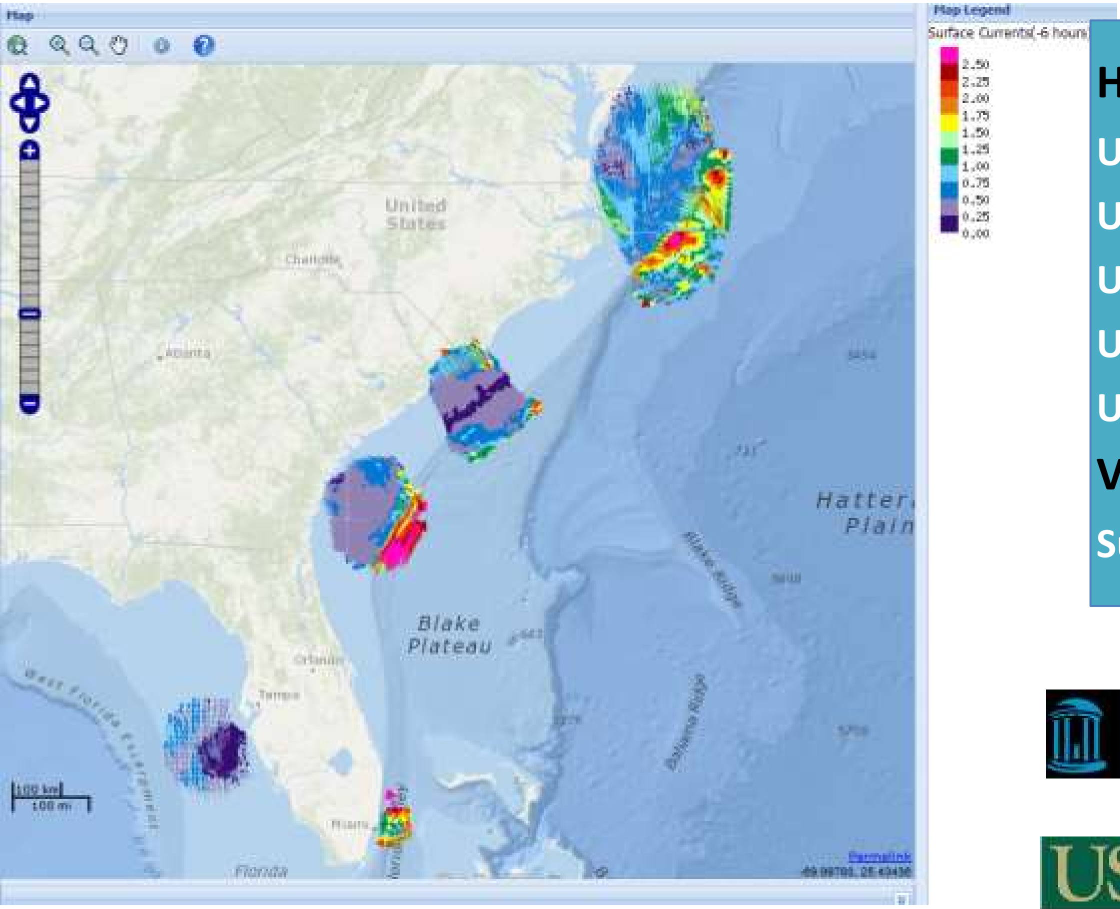
University of Georgia (Gray's Reef buoy) (1)

Variables measured

Meteorological: winds, air temperature and relative humidity, barometric pressure and short and long wave radiations

Oceanographic: water level, currents, in-water temperature, waves, pCo2, pH, DO

3(a) Monitoring & Observing



High Frequency Radar Stations

University of South Florida (4)

University of Miami (4)

University of Georgia (2)

University of South Carolina (2)

University of N. Carolina Chapel Hill (3)

Variables measured

Surface currents and waves

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

SOUTH CAROLINA

USF UNIVERSITY OF SOUTH FLORIDA

MIAMI ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

Skidaway Institute of Oceanography

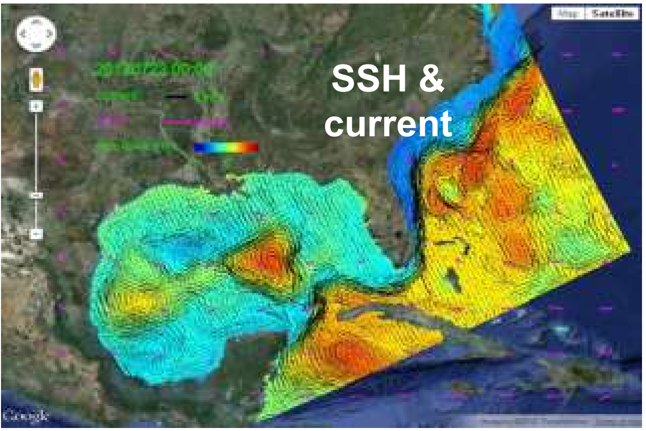
IOOS INTEGRATED OCEAN OBSERVING SYSTEM

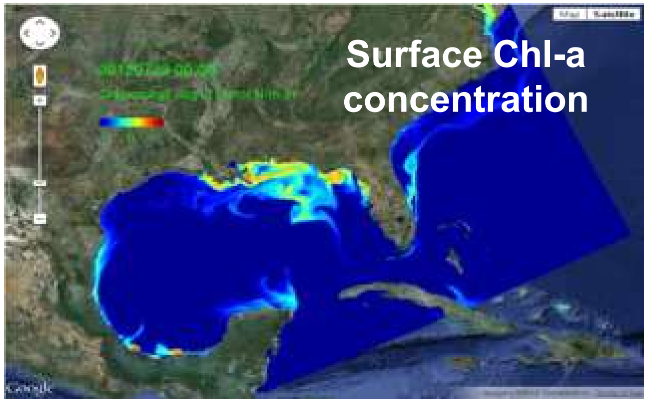
SECOORA Southeast Coastal Ocean Observing Regional Association

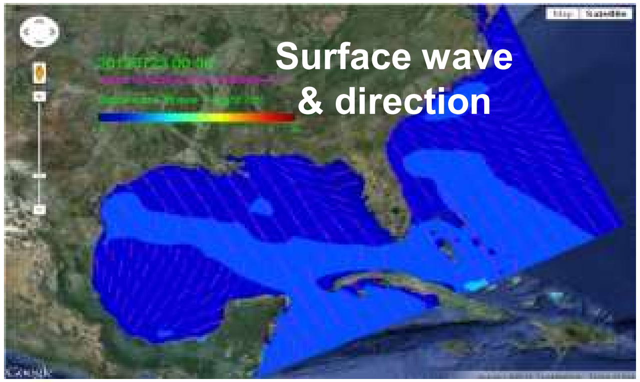
3(b) Modeling

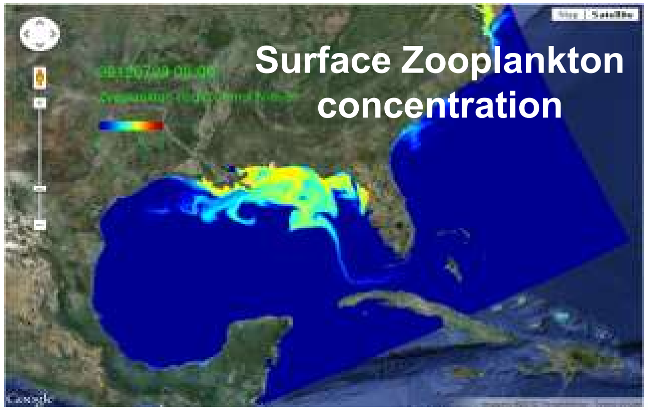
Goal: Support a Multi-Scale Multi-Resolution Modeling Subsystem

Regional scale ocean modeling (SABGOM)





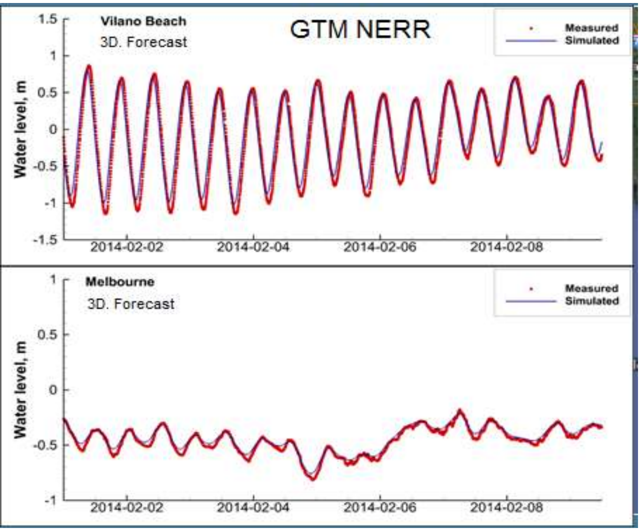


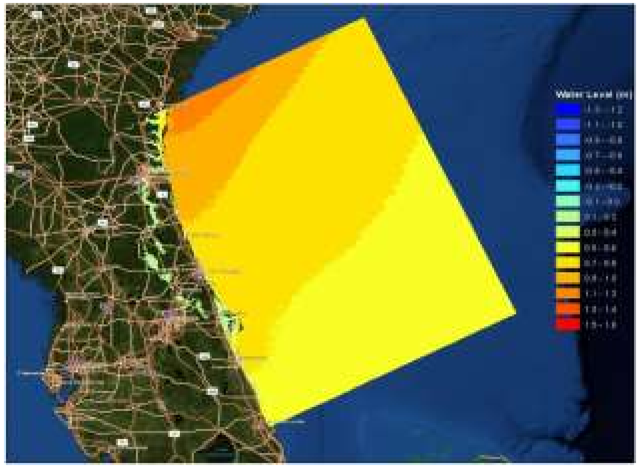


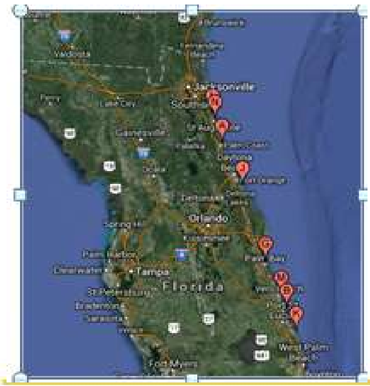
Daily 84-Hour Nowcast/ Forecast

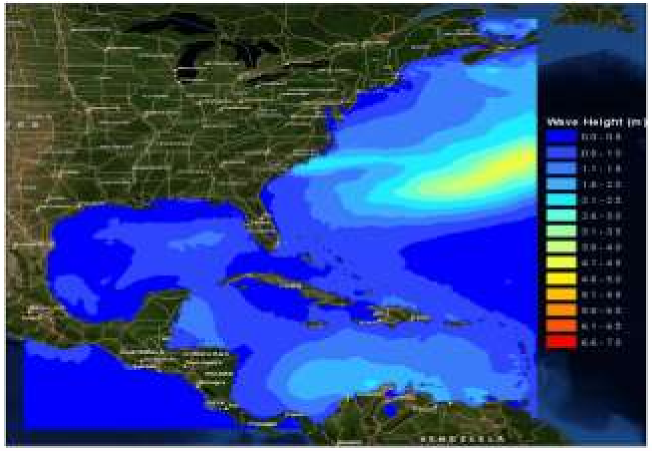
3(b) Modeling

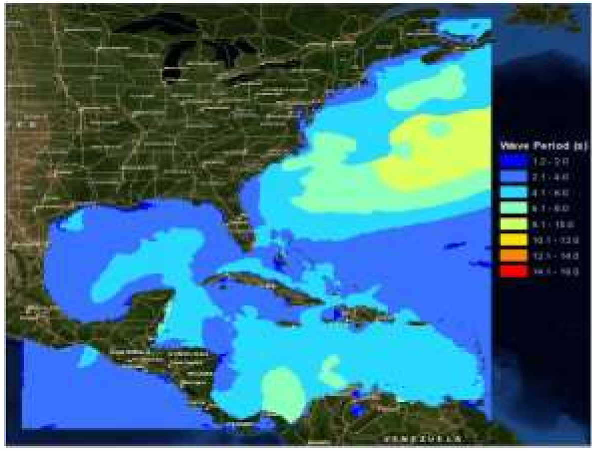
Storm surge inundation modeling





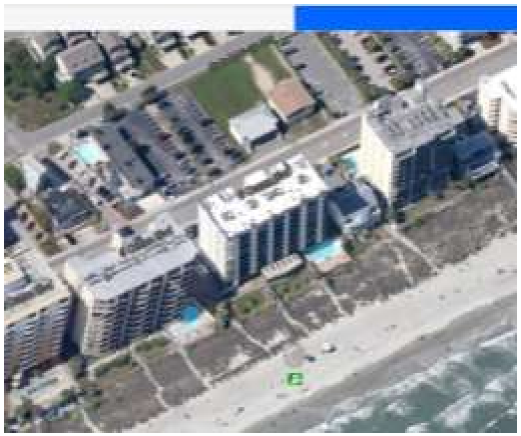


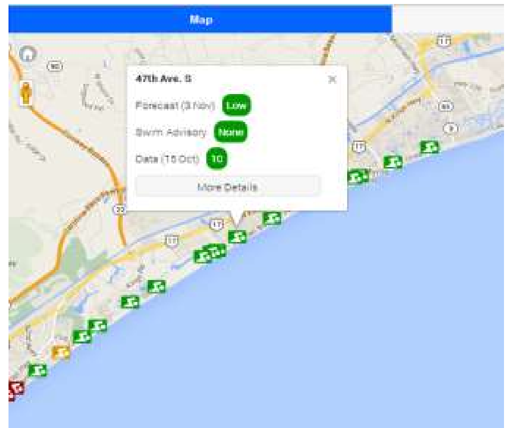


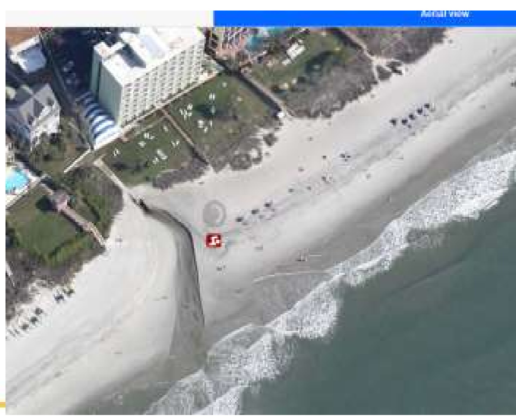


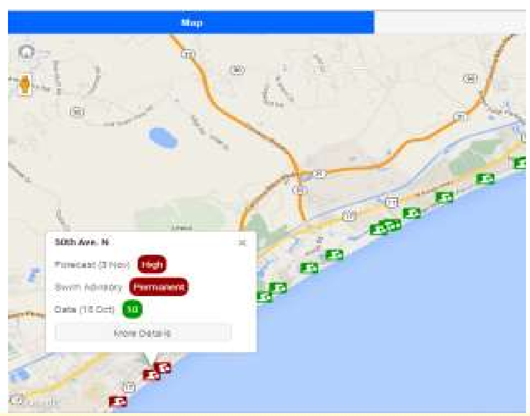
3(b) Modeling

Beach water quality modeling









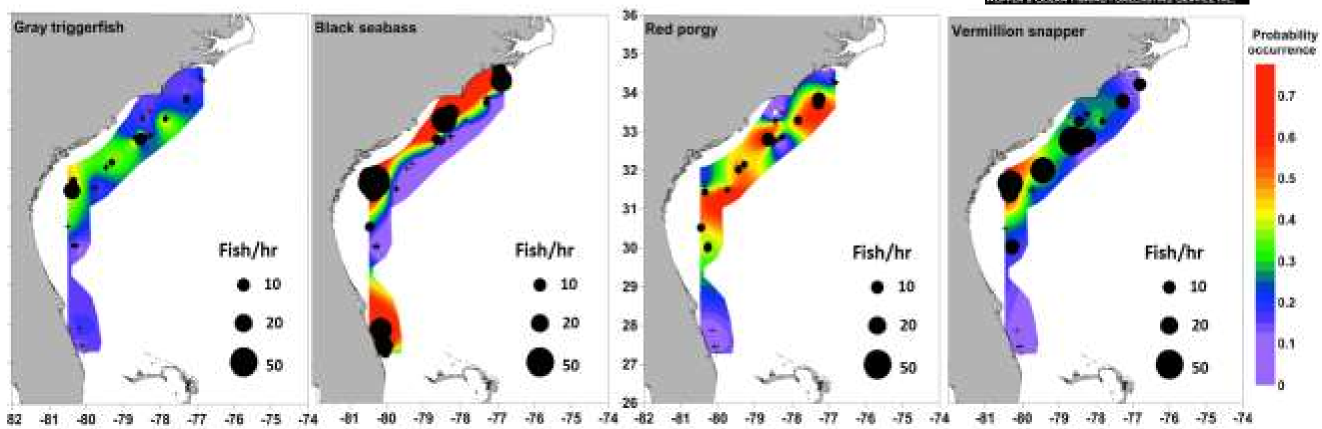
3(b) Modeling

Fisheries habitat modeling

ROFFS™

Help develop better fisheries management tools (models, stock assessment analyses) for managers and policy makers that incorporate "real-time" oceanographic observations

Habitat Model from MARMAP Chevron Fish Trap Data (1990-2008)



Gray Triggerfish		Black Seabass		Red Porgy		Vermillion Snapper	
Variable	*Importance*	*Variable*	*Importance*	*Variable*	*Importance*	*Variable*	*Importance*
Bottom temperature	100	Water depth	100	Water depth	100	Longitude	100
Latitude	76.1	Longitude	16.2	Latitude	50.4	Water depth	97.9
Water depth	56.8	Latitude	9.8	Longitude	42.7	Latitude	85.6
Date	29.0	Date	5.4	Date	10.2	Bottom temperature	82.3
Predator biomass	26.4	Surface temperature	4.4	Time	7.8	Date	39.2
Longitude	23.2	Predator biomass	3.1	Surface temperature	7.5	Wind speed	38.0
Soak duration	16.5	Time	2.3	Moon phase	7.4	Time	31.9

Positional variables   Sampling variables   Environmental variables   Biological variables

IOOS INTEGRATED OCEAN OBSERVING SYSTEM

SECOORA Southeast Coastal Ocean Observing Regional Association

3(c) Data Management

Goal: Enhance the DMAC Subsystem

SOUTH CAROLINA

Maintain SECOORA DMAC infrastructure (hardware and software)

Data aggregation and warehousing

Maintain SECOORA interactive maps and data portal

Provide support and guidance to data providers and SECOORA staff

Engage in IOOS DMAC (SOS, Catalog, System integration test etc.)

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Support IOOS vocabulary efforts

EXPLORE DATA PORTALS

http://secoora.org/data

3(d) Outreach and Education

Goal: Support targeted and leveraged outreach and education

Ecological Forecasting webinar
WFOs (Chas., Tampa, Miami)
Nat'l Hurricane Center
Wilmington sector USCG
NC Sea Grant
SE Fisheries Science Center
Ocean Acidification Office
GSAA meetings
Our Global Estuary (HBOI)
Congressional offices
SRI International
UNCW, NCSU, FGCU, UM, AOML, USF
NC Coastal Management & Sentinel Site programs
SC Maritime Association (2014)
NOAA EPP internship (USF/FGCU/SECOORA/IOOS)

125,288 PEOPLE VISITED OUR WEBSITE
↑ 27% FROM 2012

62 OUTREACH EVENTS
↑ 58% FROM 2012

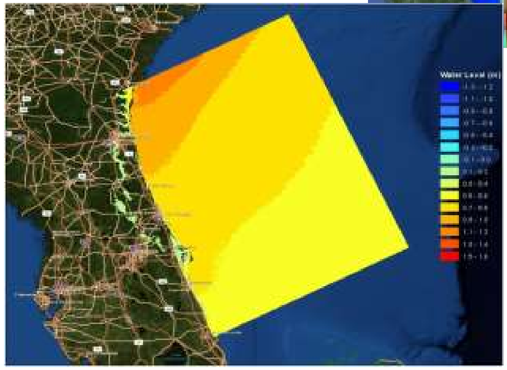
4. Accomplishments

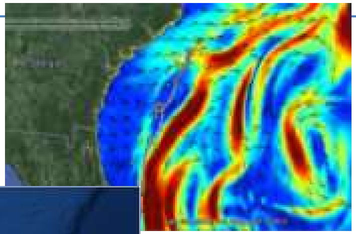
Observations

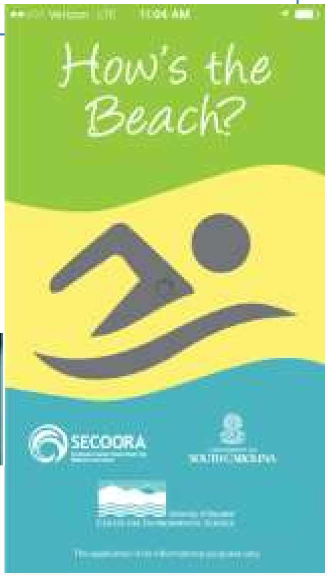
- 22% real-time surface variables and 71% subsurface variables in the region
- Data portal provides access to regional real-time observations and model data
- Dissemination to National data assembly centers

Modeling

Models support user needs in SECOORA's four theme areas: Eco-systems, Living Marine Resources and Water Quality, Coastal Hazards, Marine Operations and Climate Variability







4. Accomplishments

Data Management

- Data Assembly, warehousing and delivery
- Data Visualization
- Standards development (QA/QC, Interoperability etc.)
- NODC data archival
- Support data providers and users

Outreach

- In-person and digital outreach
- Support to student internships
- Meetings and workshops to engage stakeholders
- NOAA Weather Ready Nation (WRN) Ambassador
- NOAA EPP internship

5. Challenges

Funding:

- Maintaining existing observations
- Increasing observations
- Non-IOOS funding

Engaging PIs:

- Effective integration
- Collaboration on non-IOOS FFOs

Stakeholder / User Engagement:

- Defining product requirements
- Selecting priorities
- Aligning with local, state and federal agencies needs and priorities

Keeping it all going with existing funding level!!!!

SECOORA

Southeast Coastal Ocean Observing Regional Association

secoora.org

IOOS®

INTEGRATED OCEAN OBSERVING SYSTEM

NC STATE UNIVERSITY

Marine Environmental
(Ocean Circulation, Wave, Atmosphere and Marine Ecosystem)
prediction system for the South Atlantic Bight and Gulf of Mexico (SABGOM) in support of Ecological Forecasting efforts

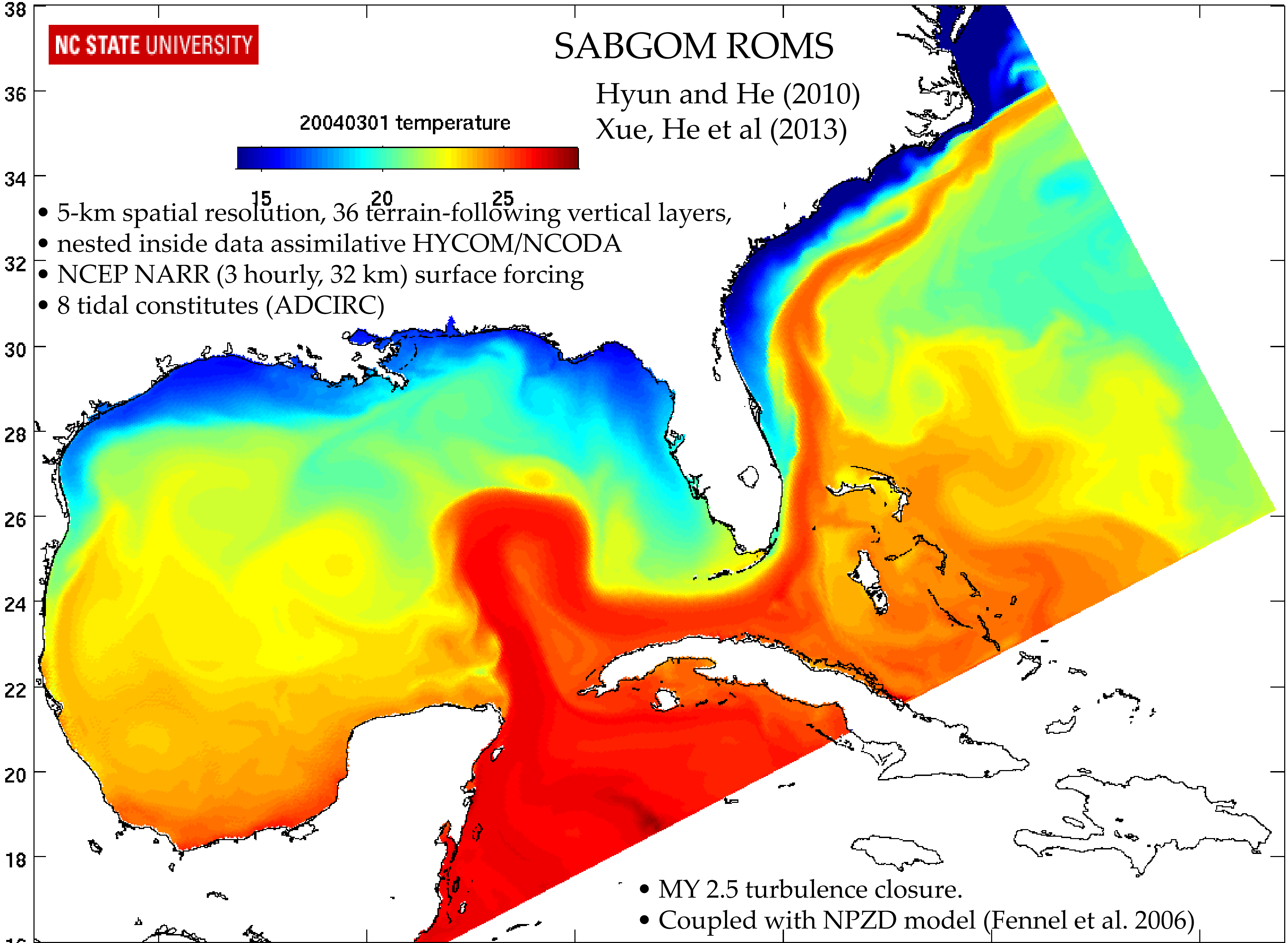
Ruoying He

Ocean Observing and Modeling Group

Dept. of Marine, Earth, and Atmospheric Sciences

North Carolina State University


serving and Modeling Group at NCSU - Mozilla Firefox
ew History Bookmarks Tools Help
rving and Modeling Group at NC...
grhe.meas.ncsu.edu/Group/index.html
Google
Getting Started Latest Headlines http://www.google.co... Customize Links Free Hotmail Windows Marketplace Windows Media Windows
Current members
Ocean Observing and Modeling Group
Home | People | Project | Facility | Publication | Opportunity | Photo |
Welcome
to the Ocean Observing and Modeling Group (OMG) in the Department of Marine, Earth & Atmospheric Sciences, North Carolina State University. The research interests in our group include:
• coastal and estuarine circulation dynamics
• bio-physical interactions
• air-sea interactions
• numerical modeling and data assimilation
• design and implementation of coastal ocean observing system
Our approach is to use in-situ and satellite remote sensing observations, data analysis and numerical modeling to explain fundamental coastal ocean physical dynamics, and to gain an integrated, quantitative understanding of their impacts on coastal ocean biological, geological, and chemical processes.
We welcome interested students and researchers to visit and join OMG.
NC STATE UNIVERSITY
Mailing Address
Office 4149
Lab 4133
Jordan Hall
2800 Faucette Dr.
Dept. Of Marine, Earth & Atmospheric Sci.
NCSU
Raleigh, NC 27695
>>More info...
37°F/ 3°C 02:09
Weather Underground
Group Alumni
Student and postdoc accomplishments
➢ 4 faculty members (LSU, OUC, ECNU)
➢ 2 WHOI postdoc scholars
➢ 3 best paper awards at AGU, Ocean Science Mtgs
➢ 5 industry scientists (Google, SAS, Horizon Marine, INC)
2



NC STATE UNIVERSITY
SABGOM ROMS
Hyun and He (2010)
Xue, He et al (2013)
20040301 temperature
15
20
25
• 5-km spatial resolution, 36 terrain-following vertical layers,
• nested inside data assimilative HYCOM/NCODA
• NCEP NARR (3 hourly, 32 km) surface forcing
• 8 tidal constitutes (ADCIRC)
• MY 2.5 turbulence closure.
• Coupled with NPZD model (Fennel et al. 2006)
38
36
34
32
30
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24
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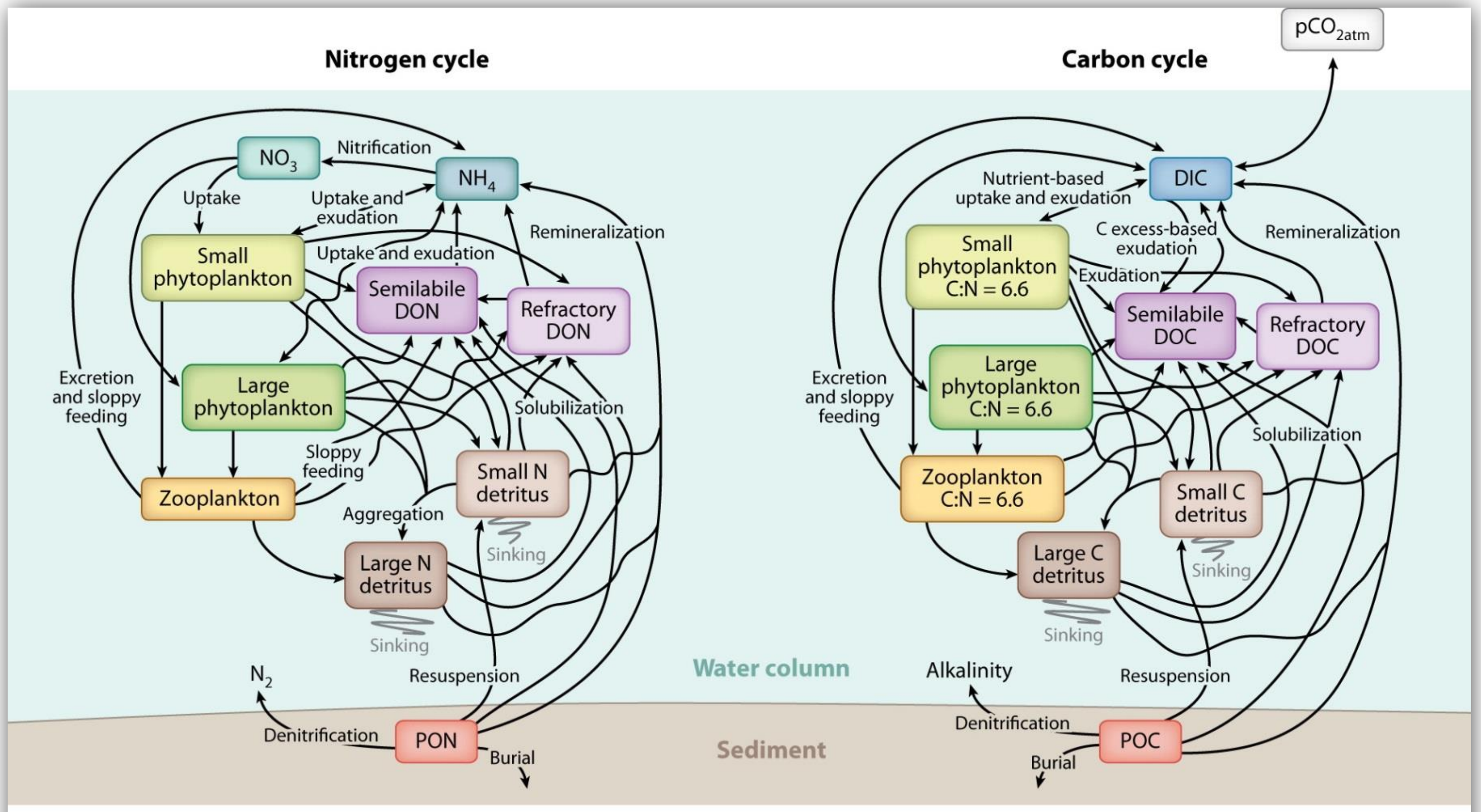
18
16

Biogeochemical Model:



Hofmann EE, et al. 2011.
Annu. Rev. Mar. Sci. 3:93–122

Fennel et al., 2006, 2011

Biogeochemical Model Setup

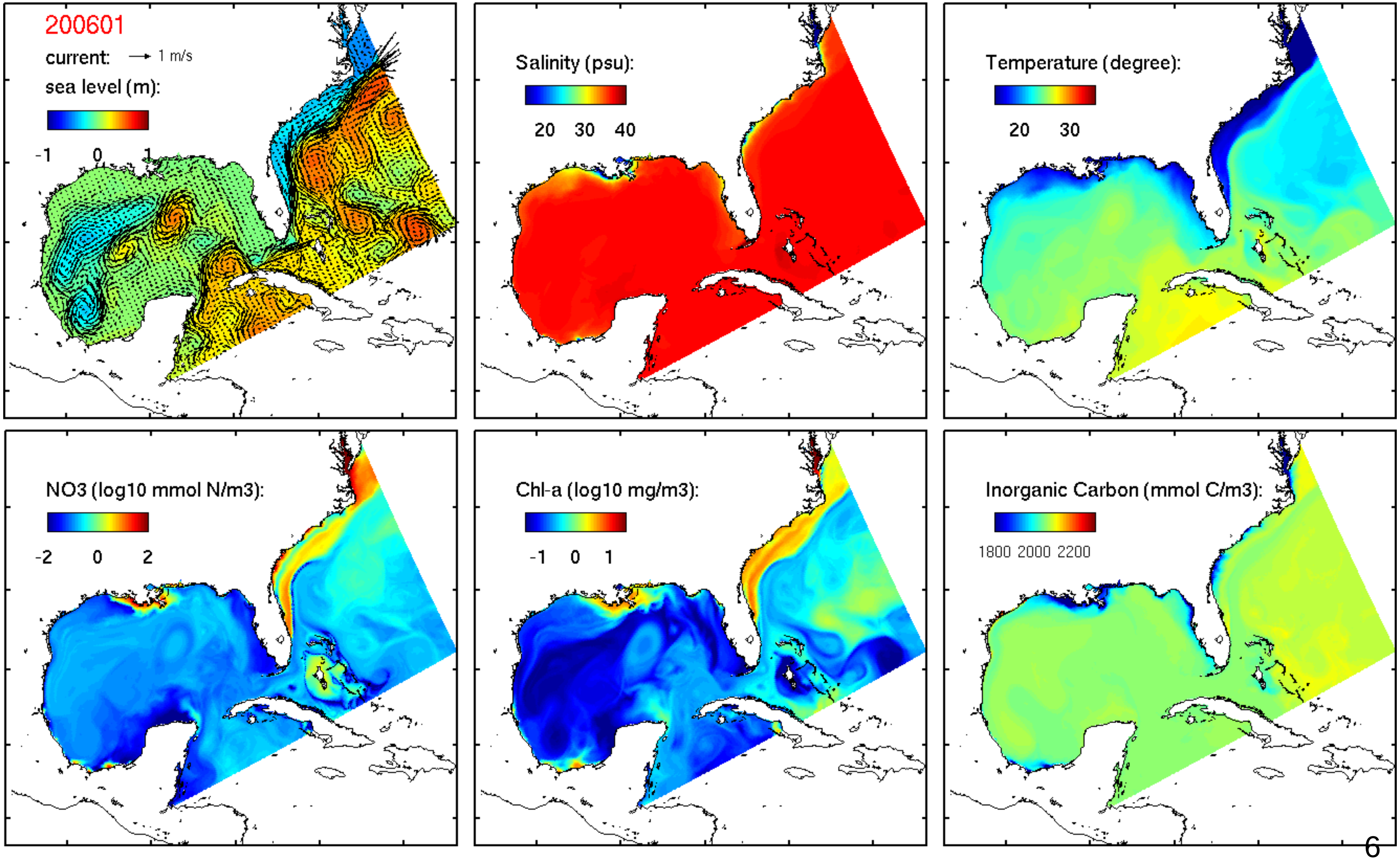
- **Initial & Boundary Conditions:**
  - NO_3: NODC (Levitus) World Ocean Atlas 2009;
  - Alkalinity and DIC (*Lee et al., 2000 and 2006*);
- **63 River Forcing (38 US rivers USGS):**
  - Runoff, NO3, NH4, Alkalinity
  - DIC=Alkalinity+50 (*Guo et al., 2012*);
  - USGS observations used for 38 U.S. rivers
  - Climatology (*Milliman and Farnsworth, 2011)* for 23 Mexico and 2 Cuba rivers

Multi-year Hindcast covering 2003-2010

(NO_3, NH_4, Primary Production, Chl-a, Phytoplankton, Zooplankton, TIC, Alkalinity, pCO2, CO2-airsea, Oxygen)

Results

SSH, SST, SSS, NO_3, Chl-a, and Inorganic Carbon



Validations: Physical Model

coastal sea level anomaly

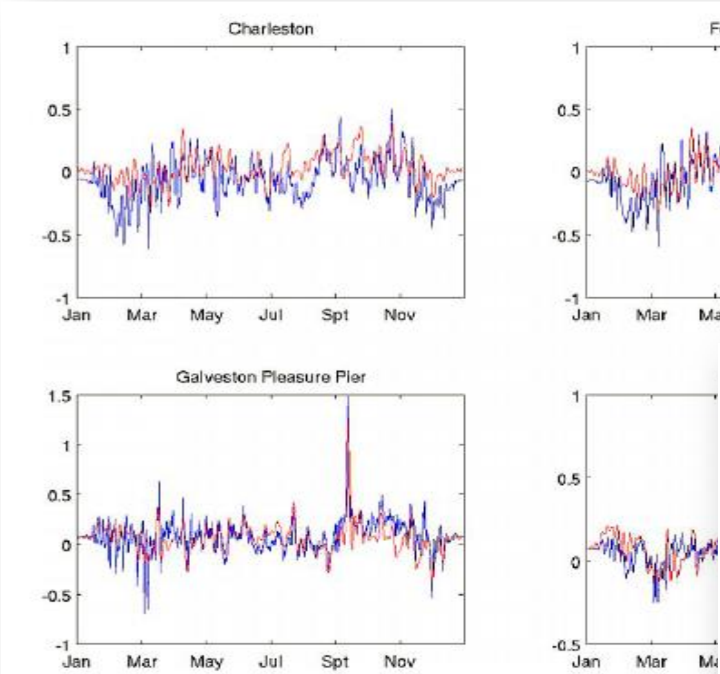
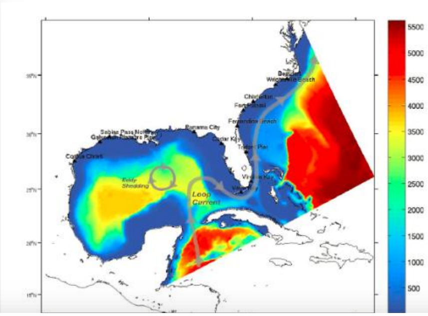
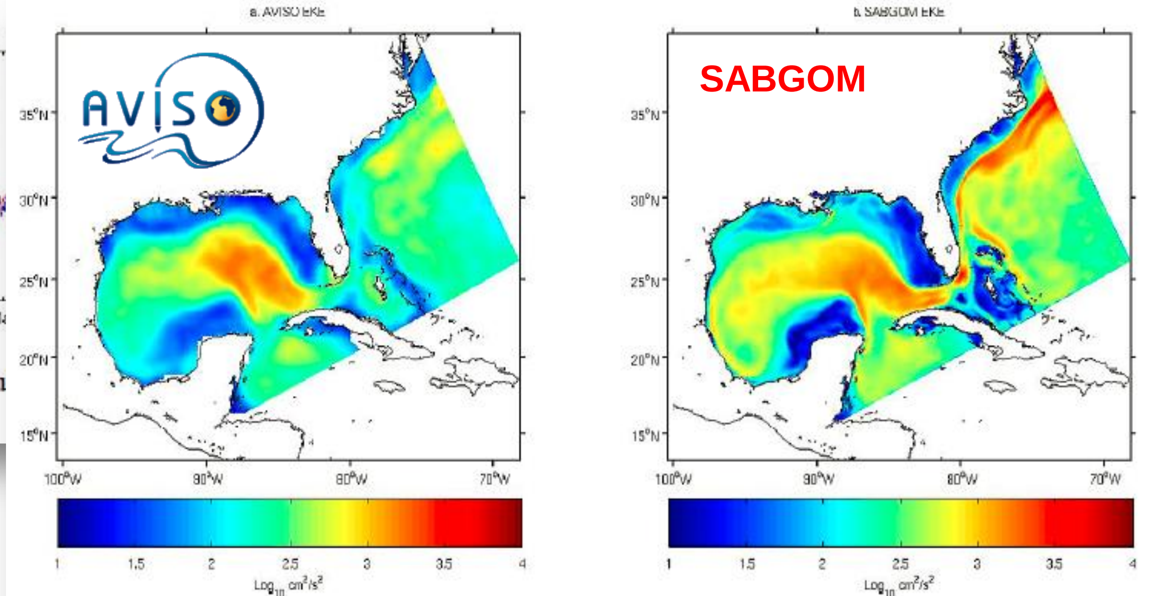


Fig. 3. Comparisons between observed and simu
series at four tidal stations in 2008.



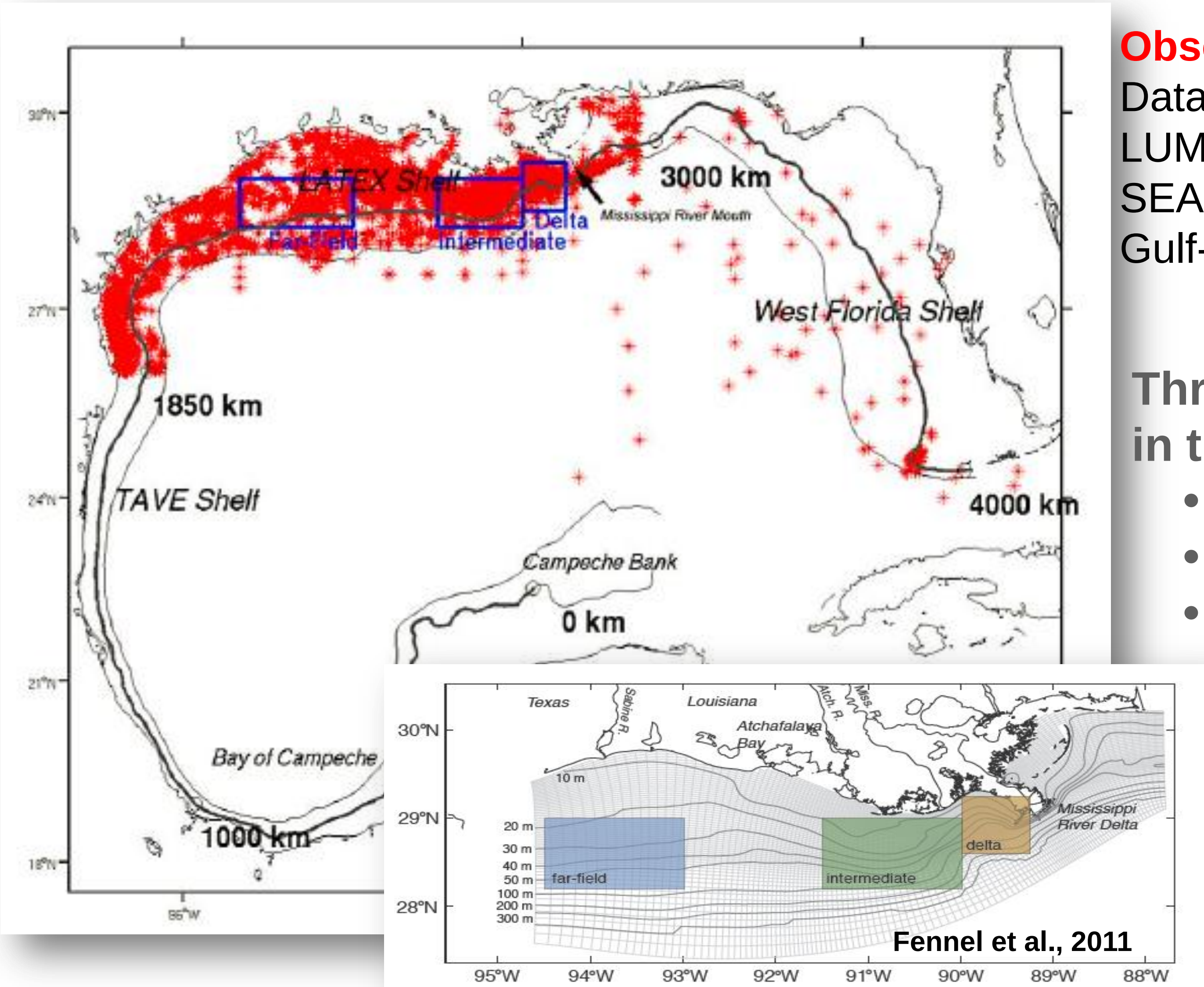


Eddy Kinetic Energy

Fig. 5. Comparison of 7 yr (2004–2010) mean eddy kinetic energy calculated based on **(a)** AVISO SSH observation and **(b)** SABGOM model simulated SSH.

Validations: biogeochemical model

ship survey physical-biogeochemical data (2003-2010)



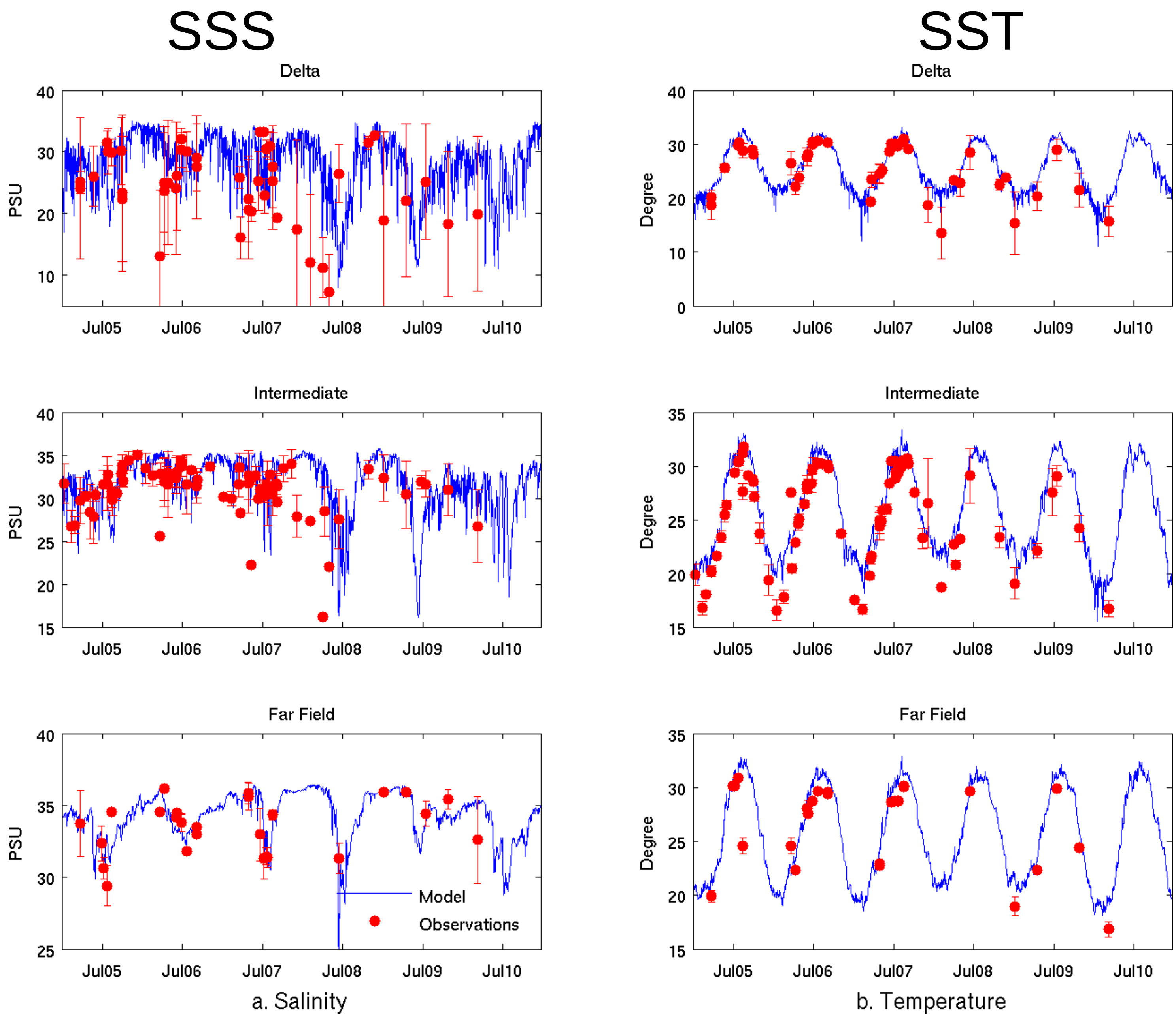
Observations (n > 9000)

Data Source:
LUMCON, EPA, MCH, SEAMAP, Gulf-Carbon, and MMAGMIX

Three sub-regions in the northern GOM

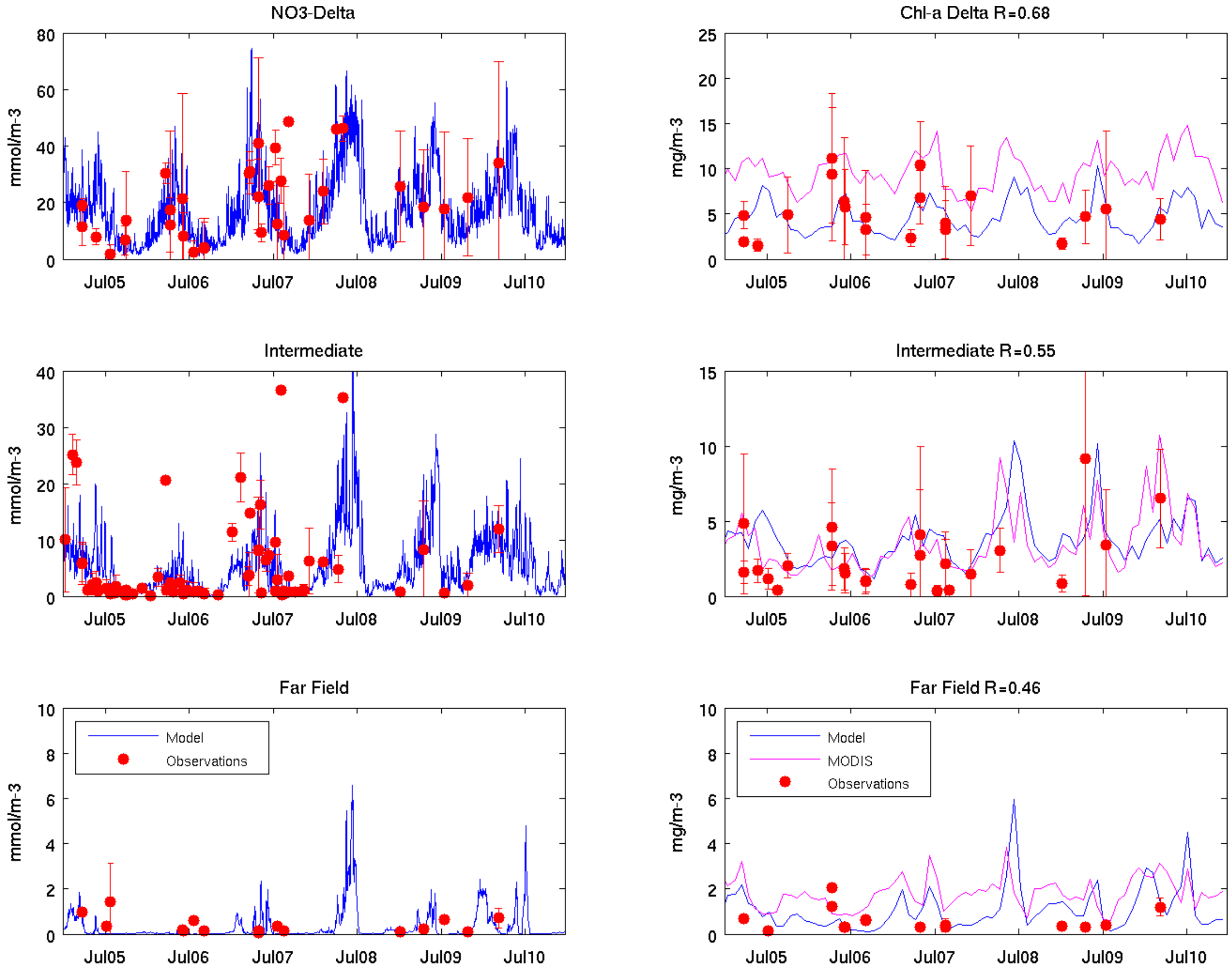
- **Delta**
- **Intermediate**
- **Far-Field**

Validations (cont'd)



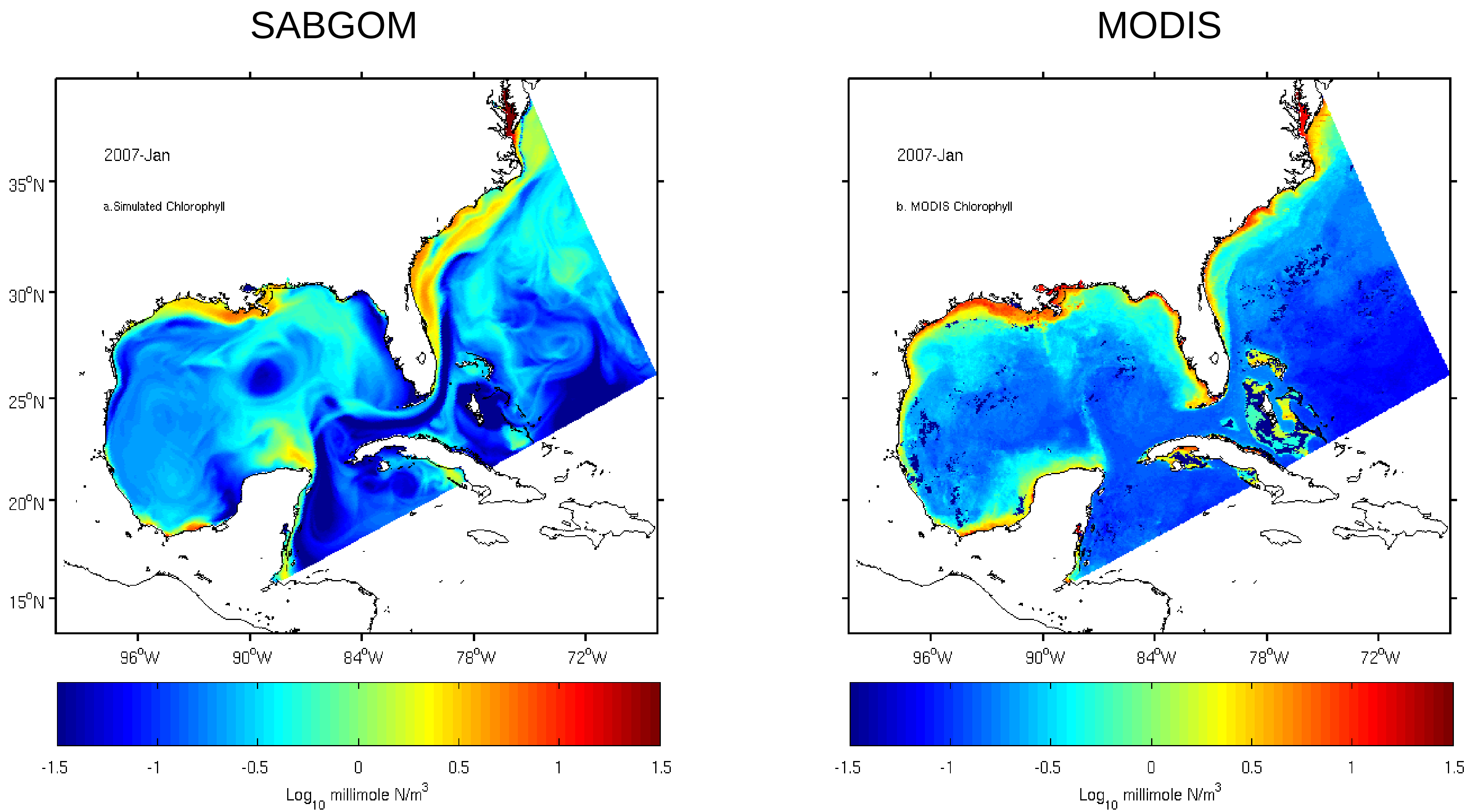
Validations (cont'd)

NO3 Chl-a



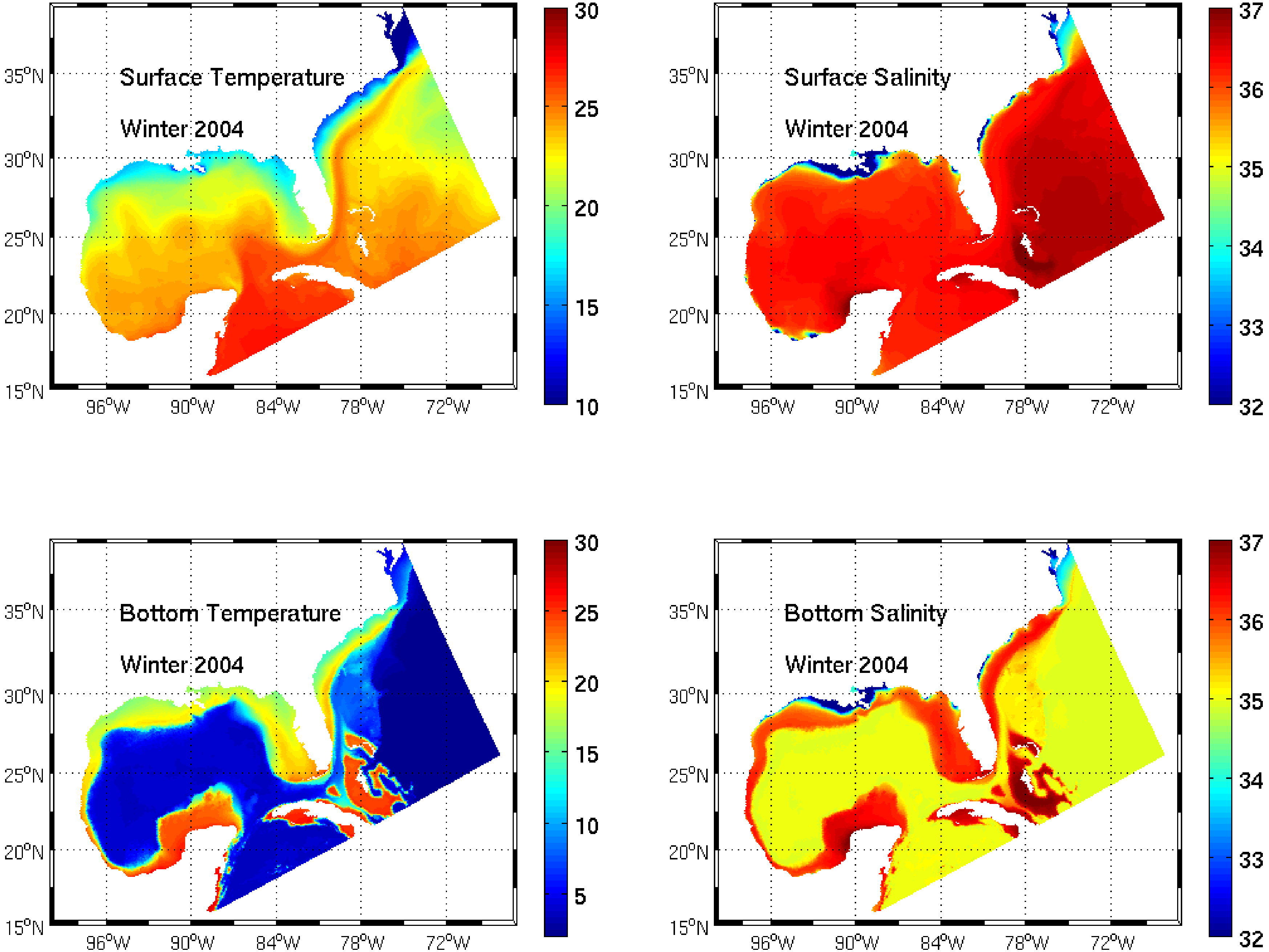
a. NO3 b. Chlorophyll

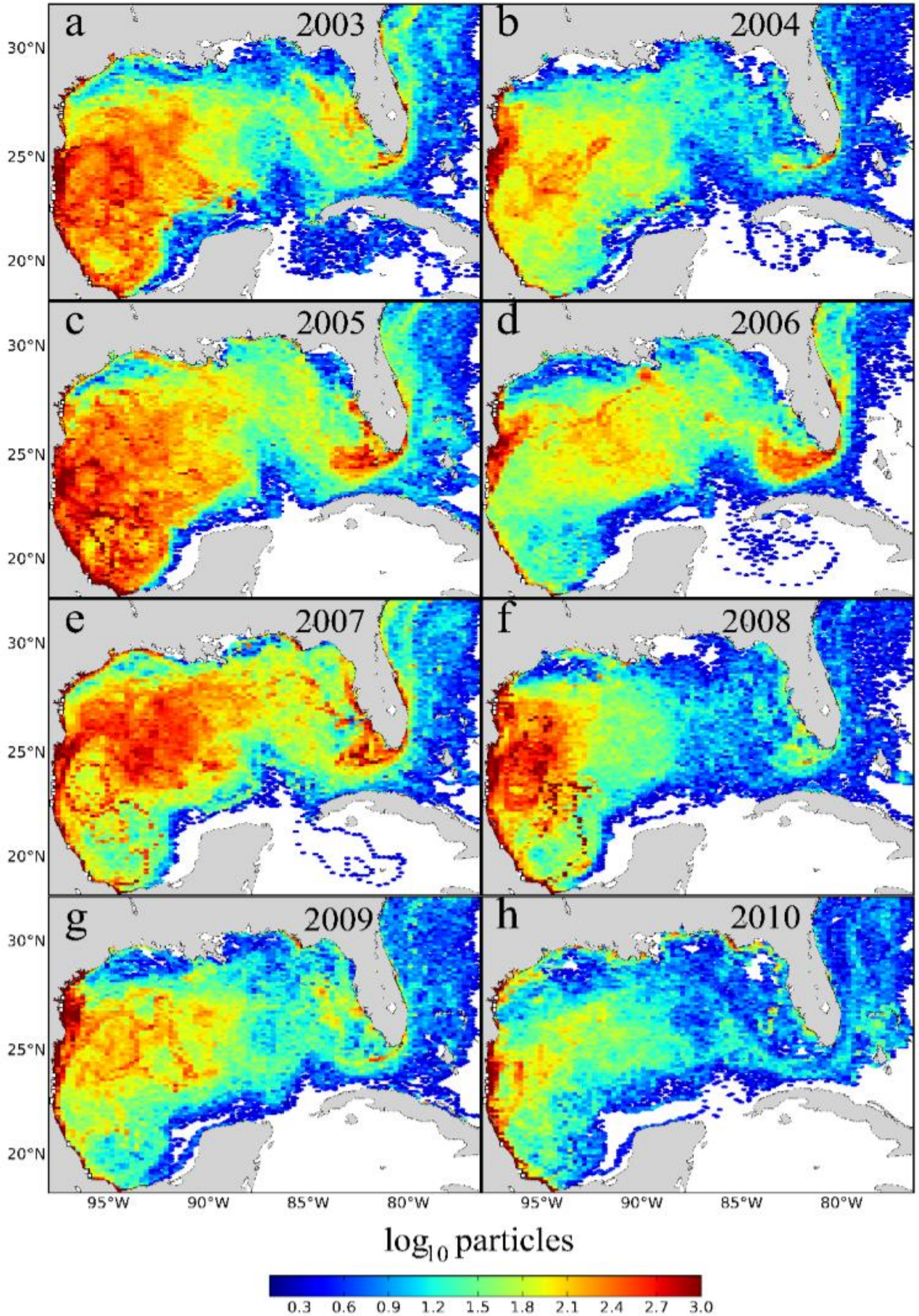
Monthly Surface Chl-a Comparison



Other variables: NO_3, NH_4, Primary Production, Phytoplankton, Zooplankton, TIC, Alkalinity, pCO2, CO2-airsea, Oxygen

Xue, He, Fennel et al. (2013)


Surface Temperature
Winter 2004
Surface Salinity
Winter 2004
Bottom Temperature
Winter 2004
Bottom Salinity
Winter 2004
35°N
30°N
25°N
20°N
15°N
96°W
90°W
84°W
78°W
72°W
30
25
20
15
10
5
37
36
35
34
33
32

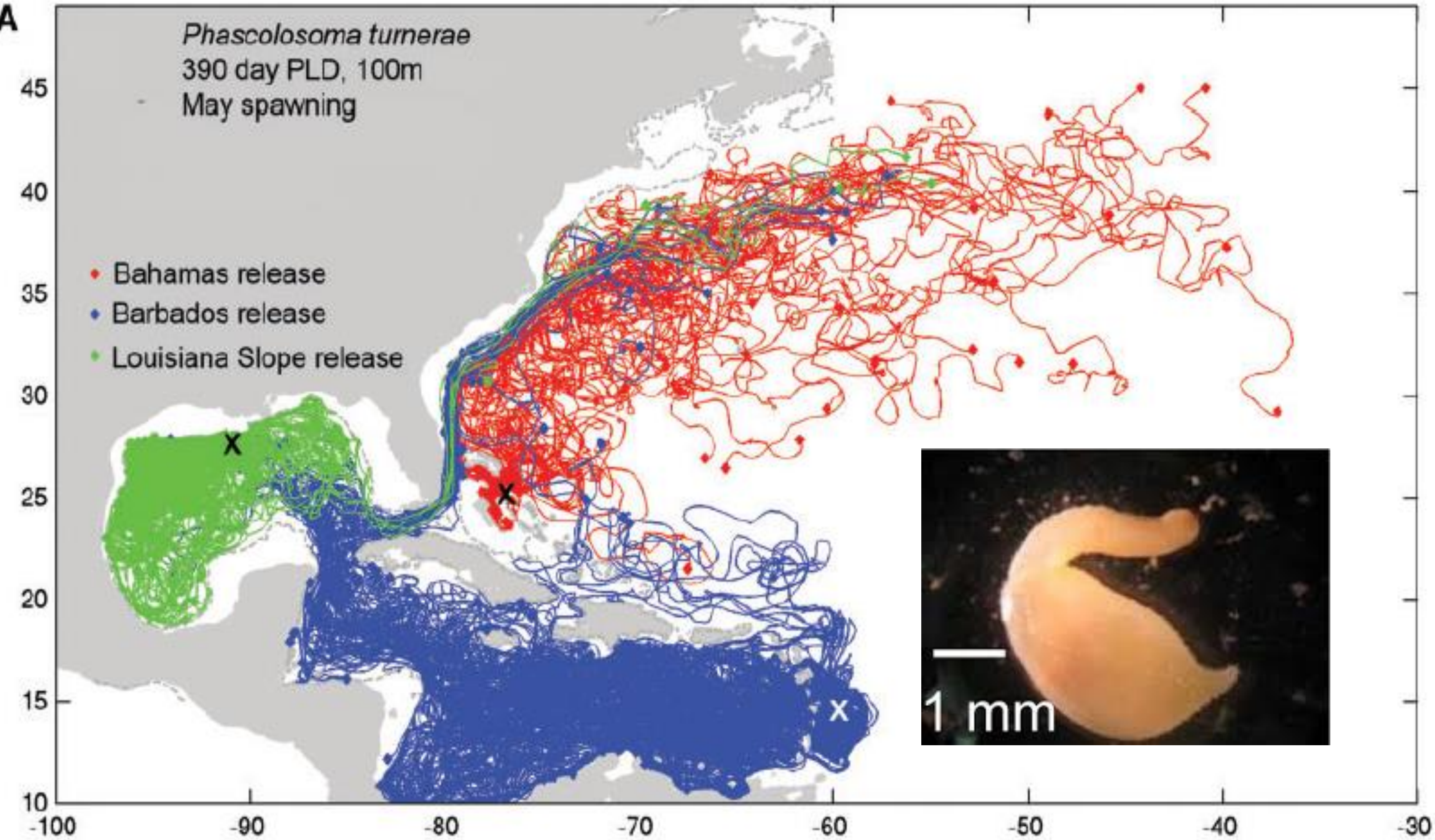


Predicted early oceanic-stage Kemp's ridley turtles in the Gulf of Mexico

The information is used to estimate the early survival of this endangered turtle species, which nests almost exclusively in the western Gulf of Mexico

Putman and He (2013)

Putman et al. (2013)



Young, He et al. (2012)
Qian et al. (2014)

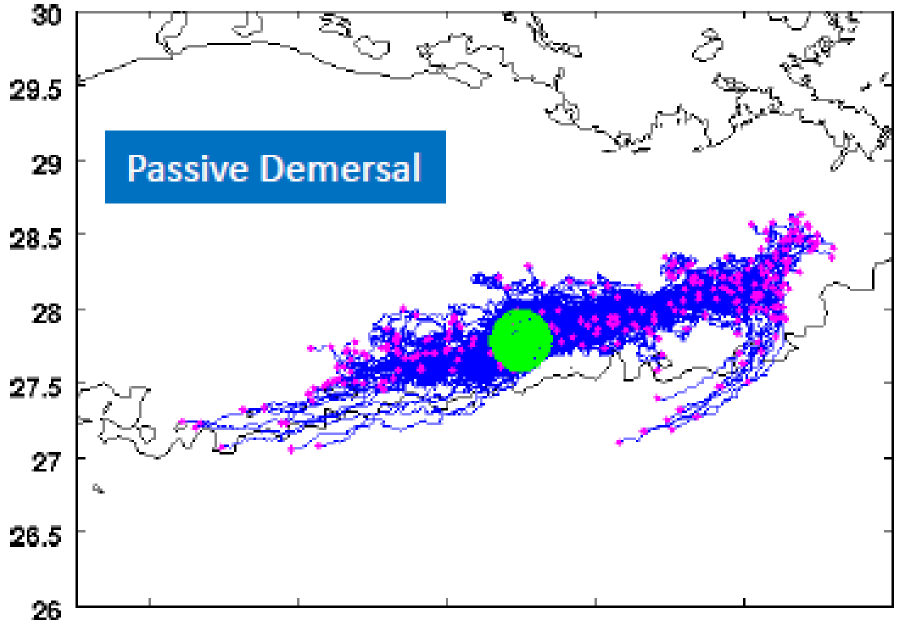
NC STATE UNIVERSITY

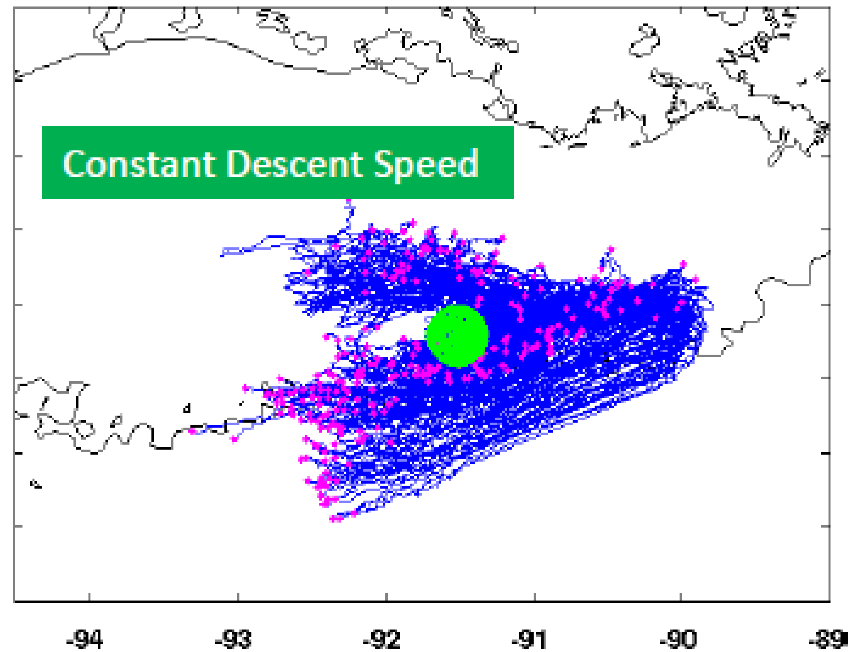
UNIVERSITY OF OREGON

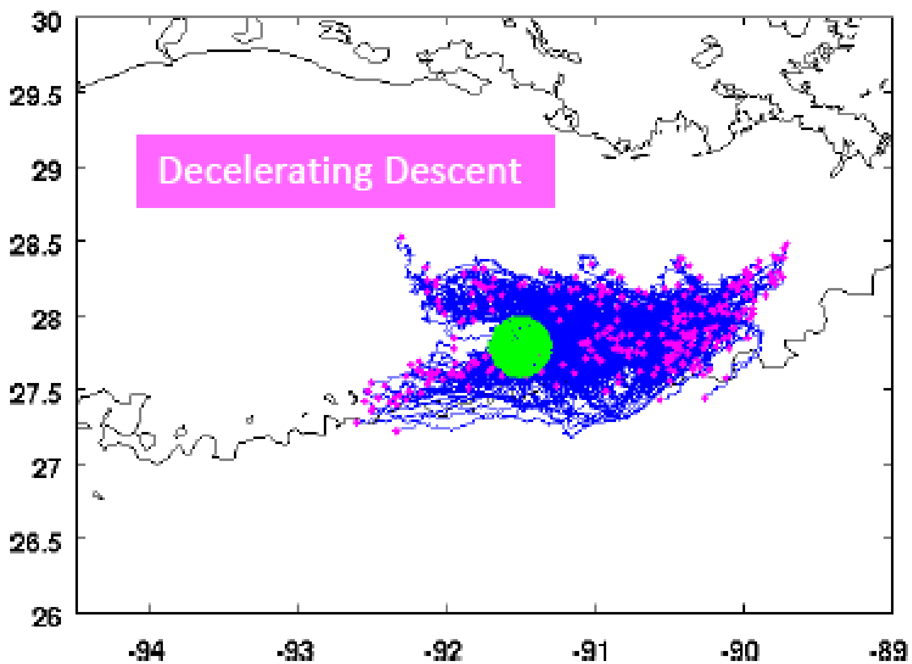
Duke UNIVERSITY

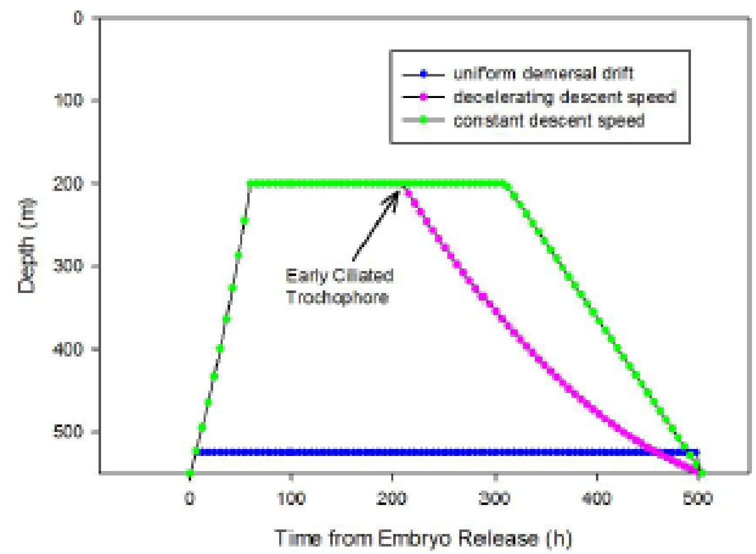
NC STATE UNIVERSITY

Modeling Lamellibrachia Luymesi distribution

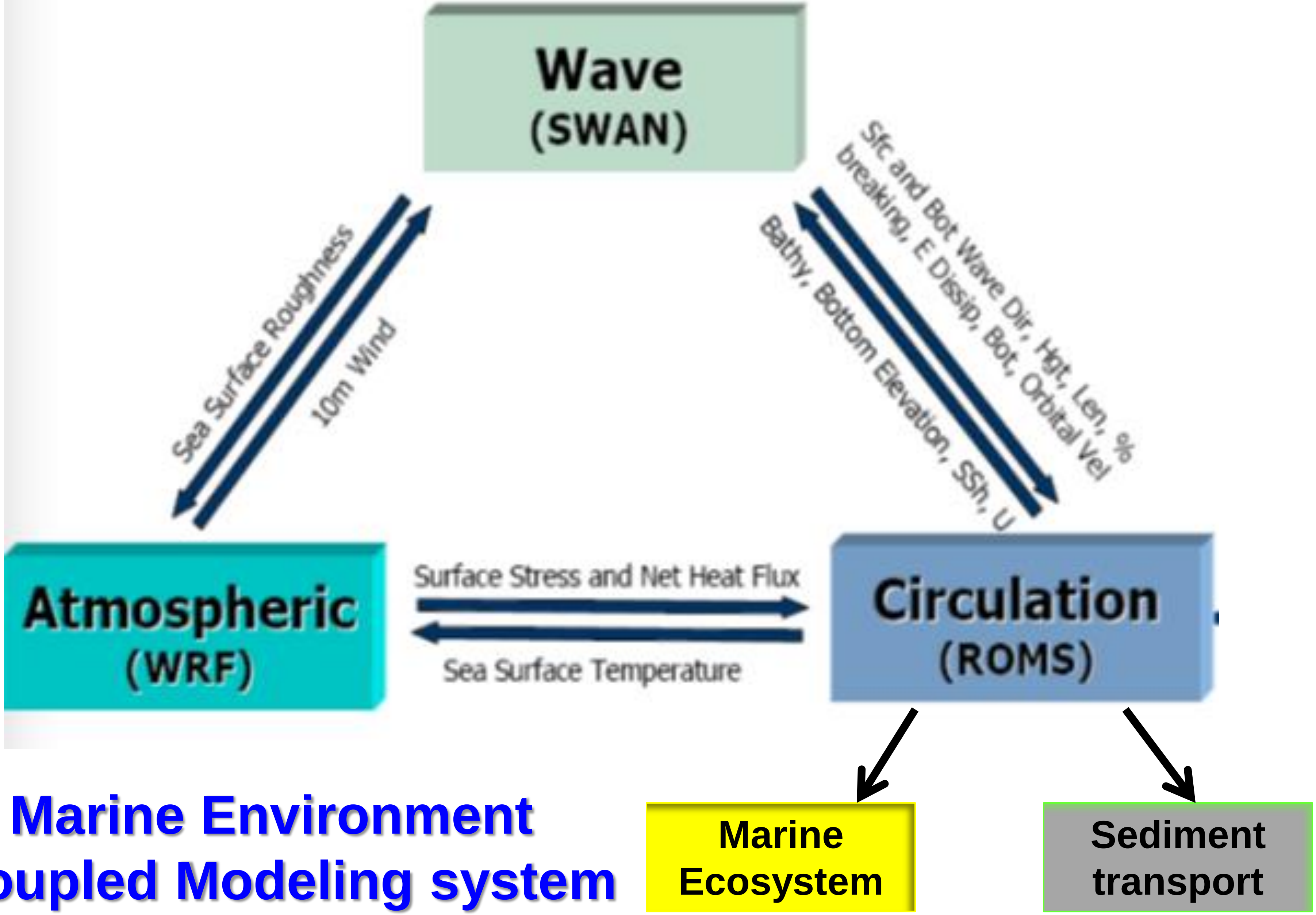








Young, He et al. (2012)



Marine Environment Coupled Modeling system

He et al. (2015)

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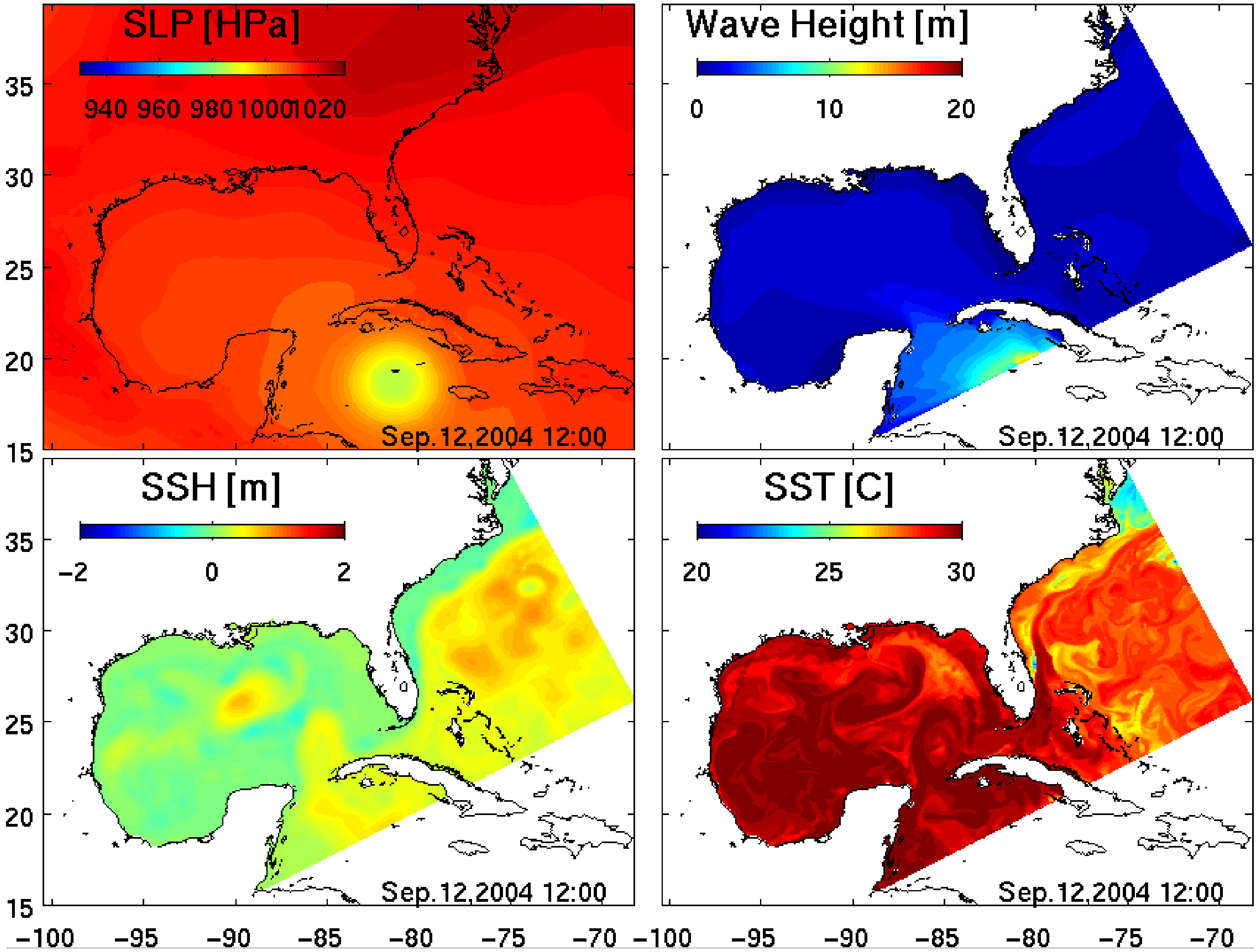
WRF-ROMS-SWAN Coupled Simulation: Hurricane Ivan



Zambon, He and Warner (2014)

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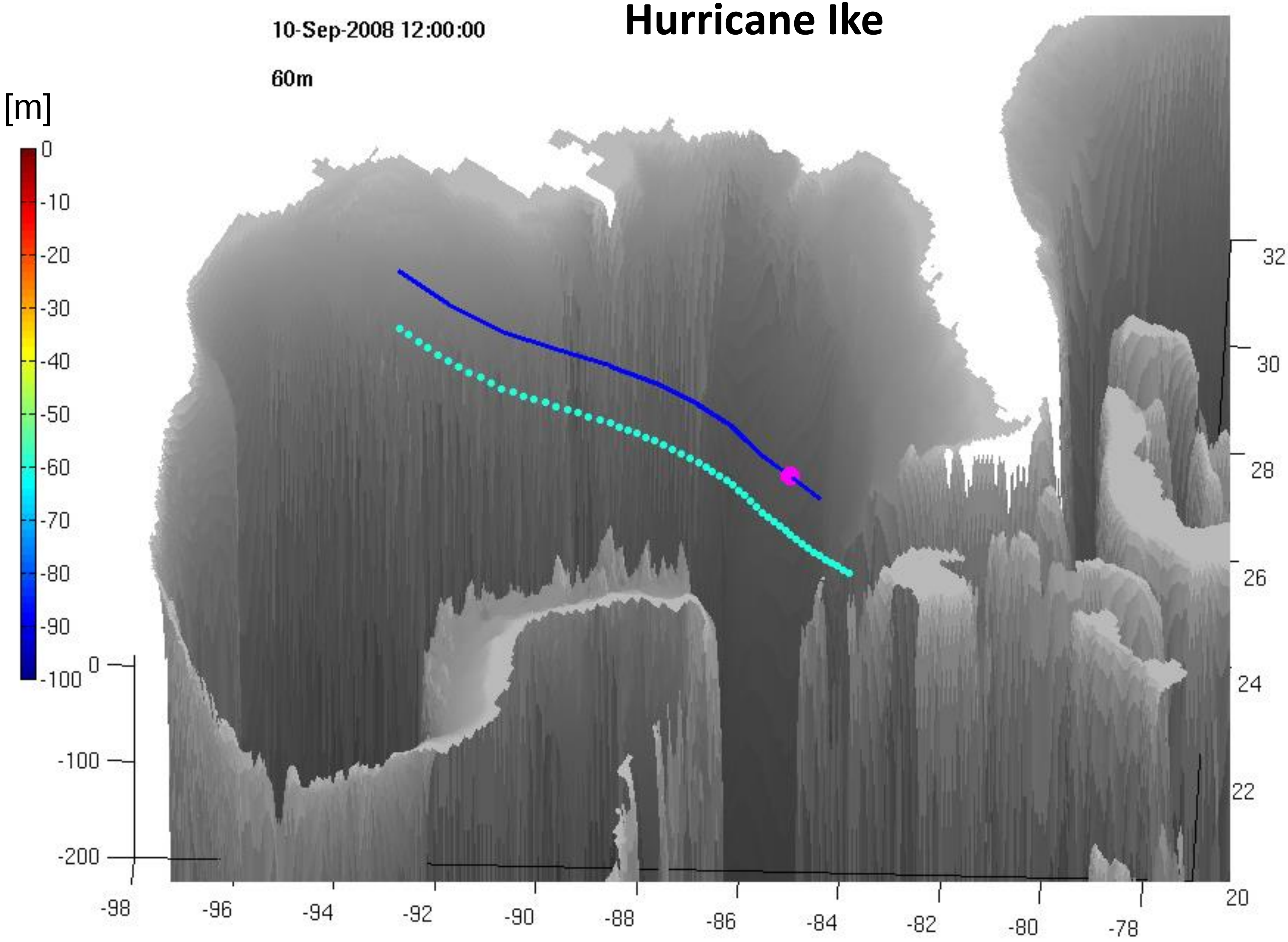
Hurricane Ike



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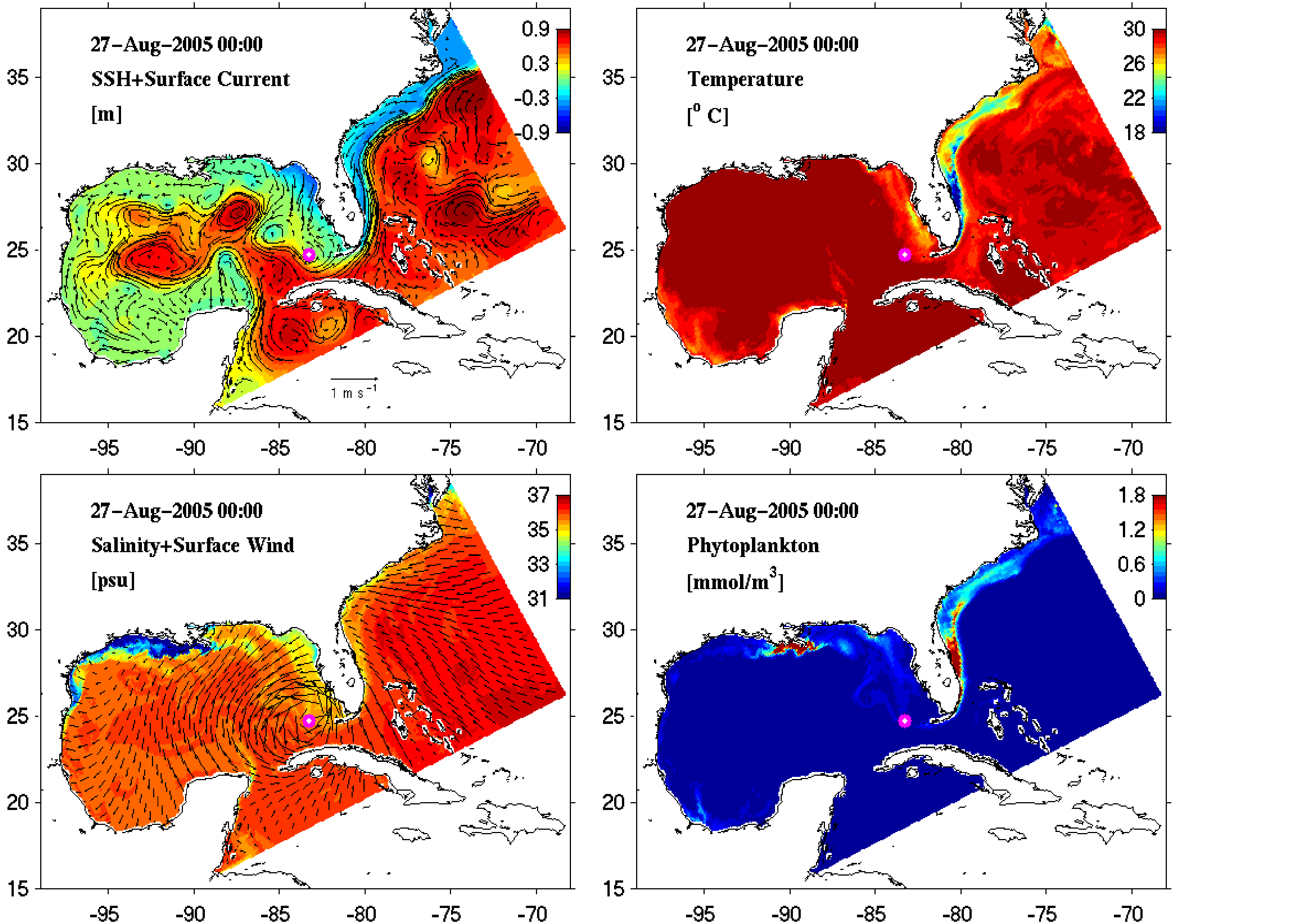
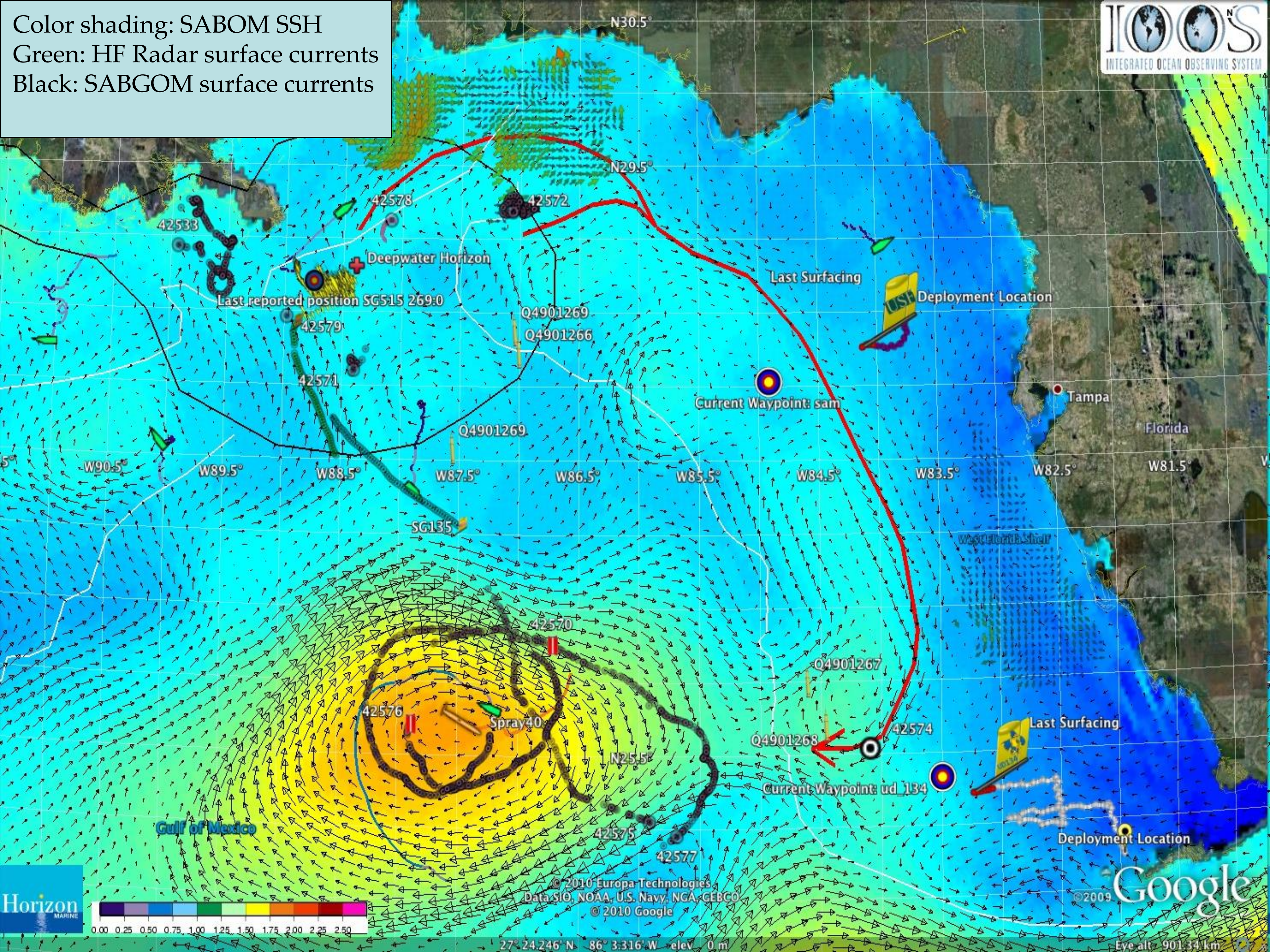
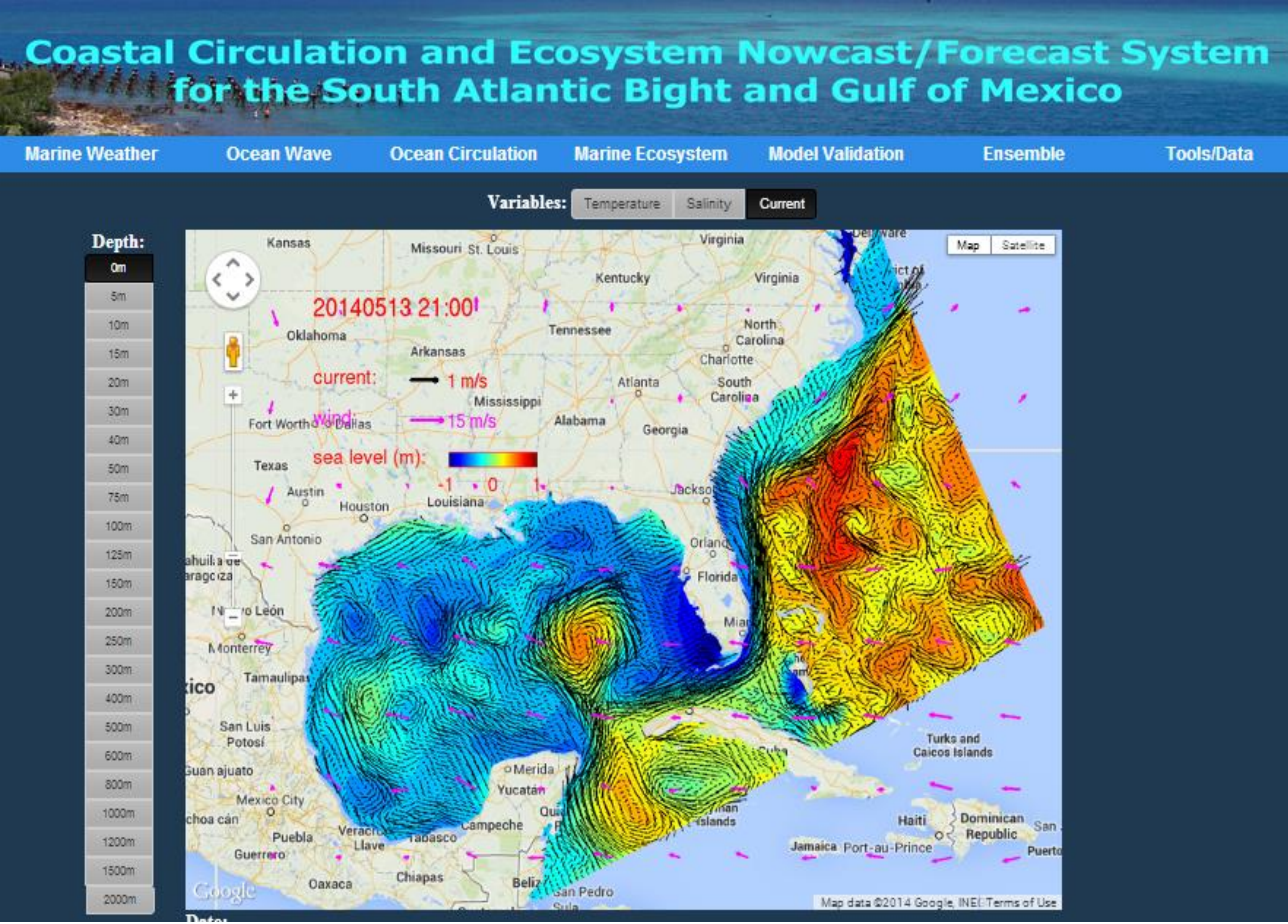
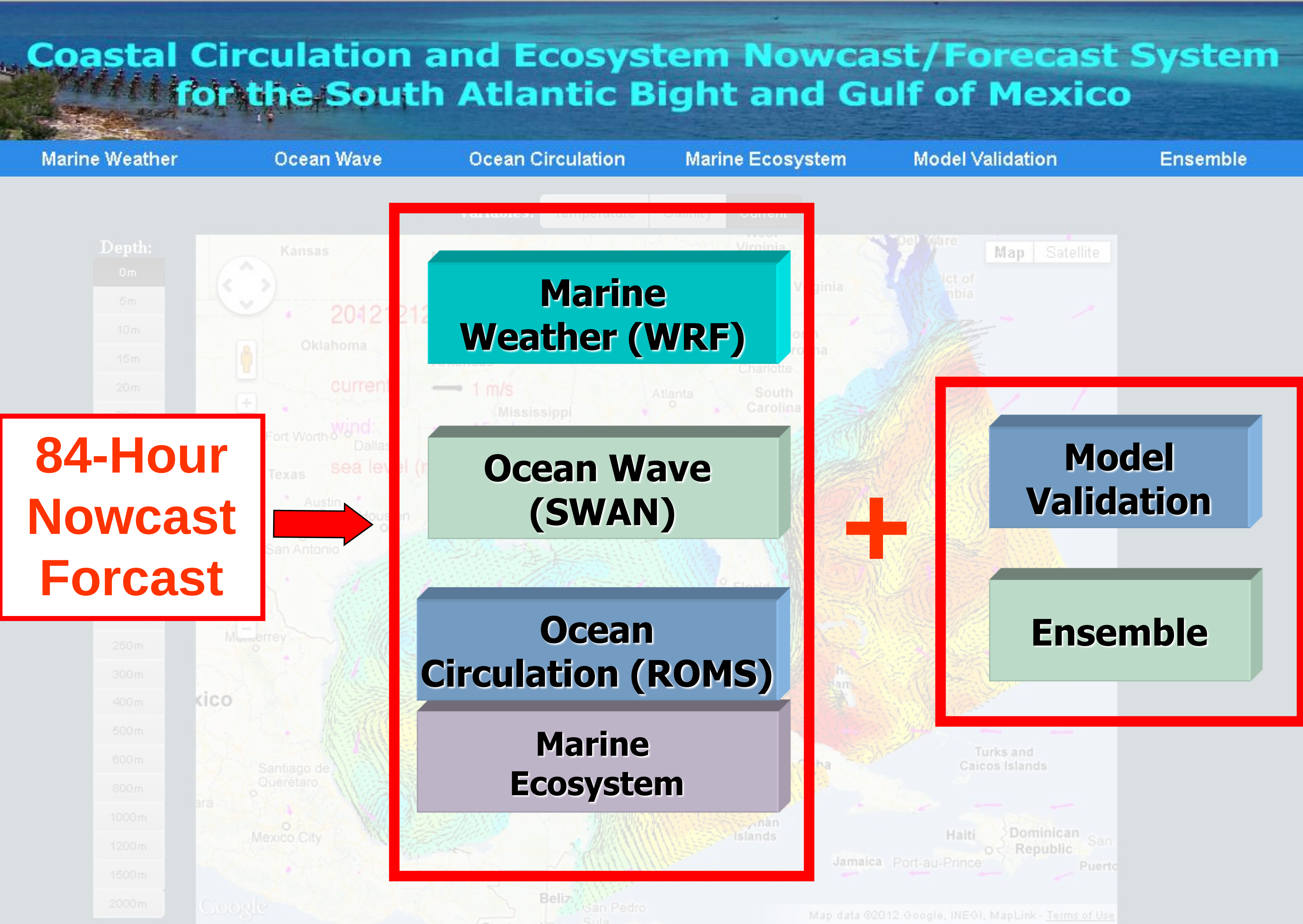
Hurricane Katrina




Color shading: SABOM SSH
Green: HF Radar surface currents
Black: SABGOM surface currents
IOOS
INTEGRATED OCEAN OBSERVING SYSTEM
N30.5°
N29.5°
42578
42572
42533
Deepwater Horizon
Last reported position SG515 269:0
42579
Q4901269
Q4901266
42571
Last Surfacing
Deployment Location
Current Waypoint: sam
Tampa
Florida
Q4901269
W90.5°
W89.5°
W88.5°
W87.5°
W86.5°
W85.5°
W84.5°
W83.5°
W82.5°
W81.5°
SG135
West Florida Shelf
42570
Q4901267
42576
Spray40
42574
Q4901268
Last Surfacing
N25.5°
Current Waypoint: ud_134
Gulf of Mexico
42575
42577
Deployment Location
© 2010 Europa Technologies
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2010 Google
©2009
Google
Horizon MARINE
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50
27° 24.246' N 86° 3.316' W elev 0 m
Eye alt 901.34 km

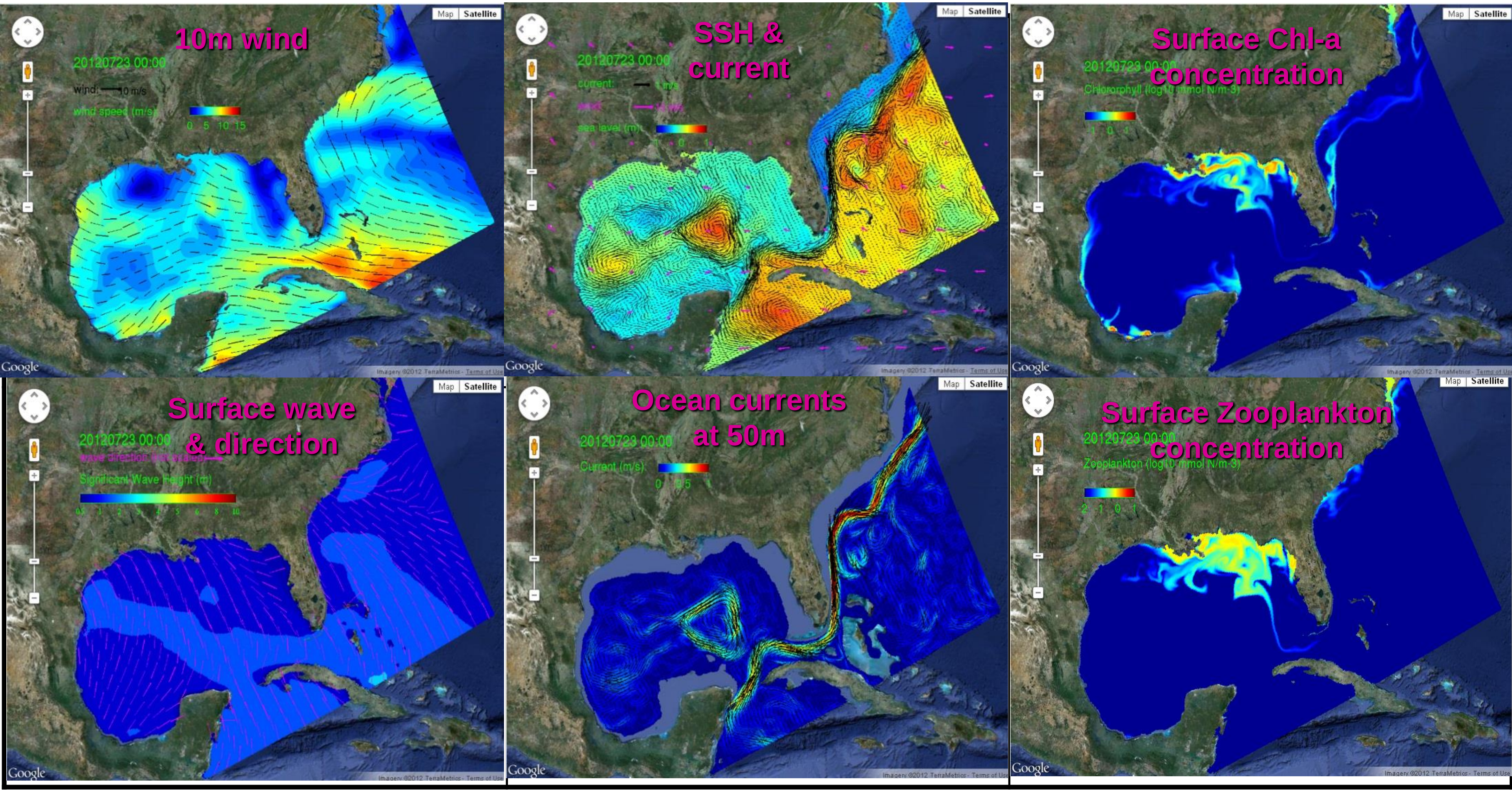


SABGM website: http://omgarch1.meas.ncsu.edu:8080/ocean-circulation/


Coastal Circulation and Ecosystem Nowcast/Forecast System
for the South Atlantic Bight and Gulf of Mexico
Marine Weather
Ocean Wave
Ocean Circulation
Marine Ecosystem
Model Validation
Ensemble
84-Hour Nowcast Forcast
Marine Weather (WRF)
Ocean Wave (SWAN)
Ocean Circulation (ROMS)
Marine Ecosystem
+
Model Validation
Ensemble

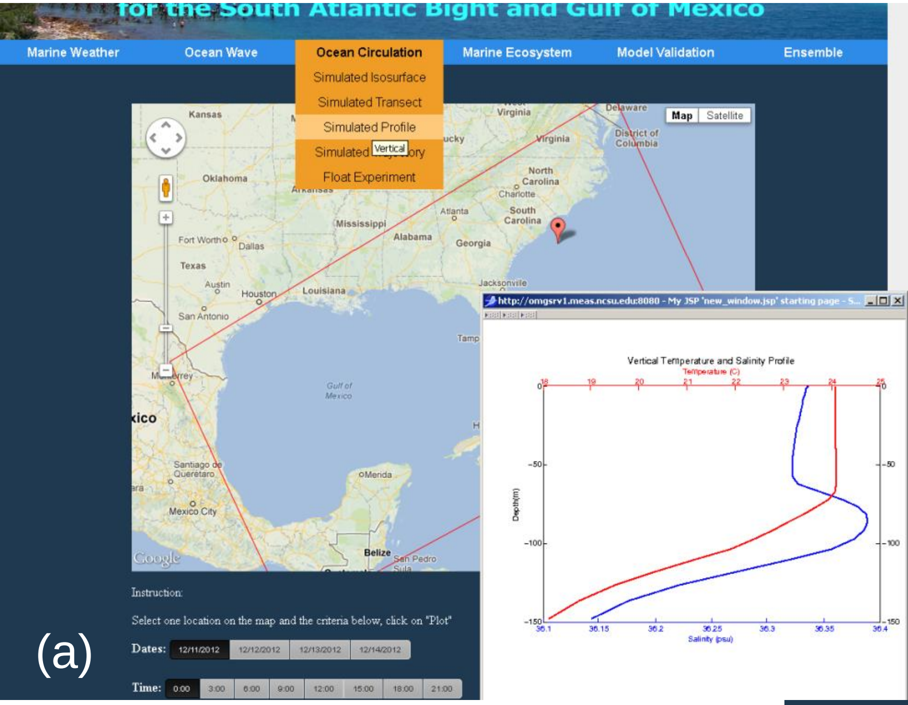
Daily Nowcast and Forecast of Marine Environmental Conditions

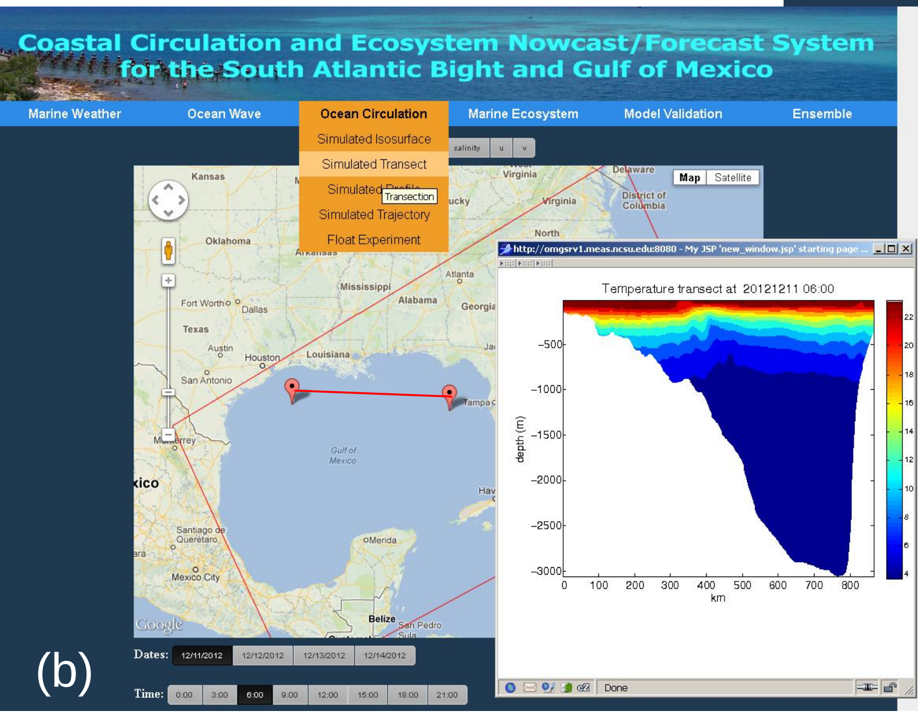
Marine Weather & Ocean Wave | Ocean Circulation | Marine Ecosystem

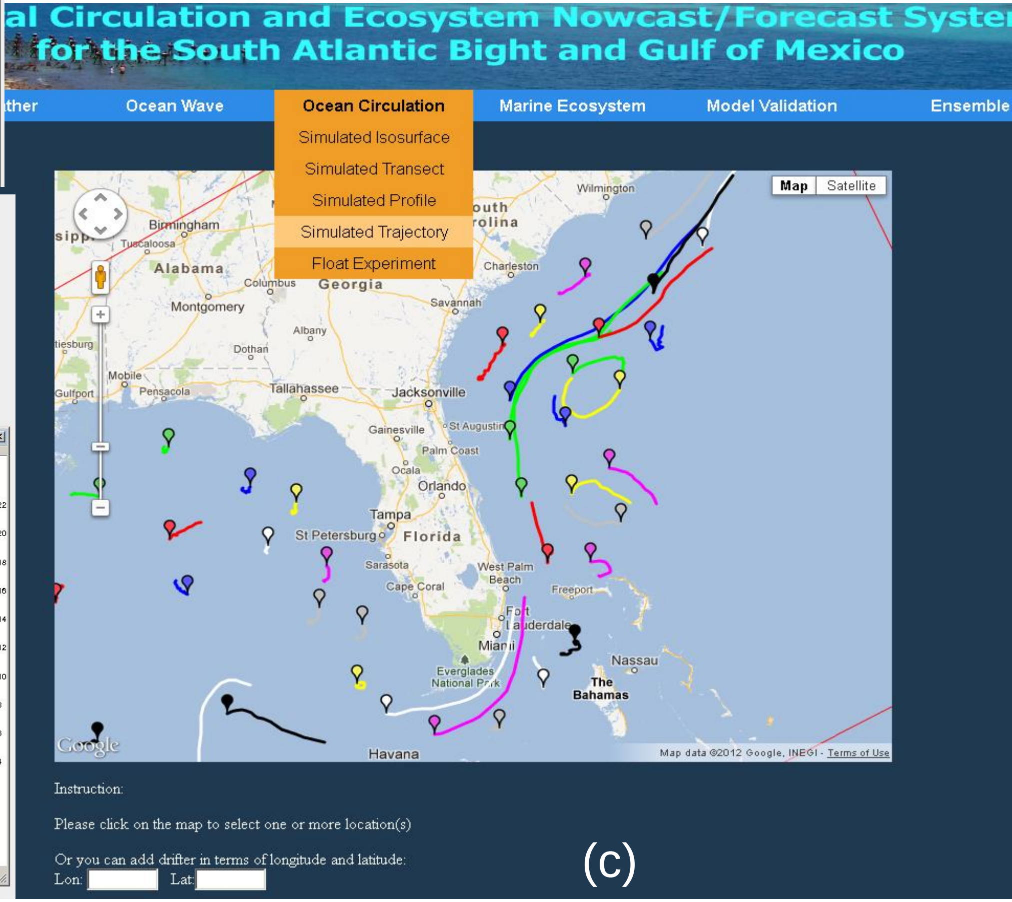


Online user-defined functions

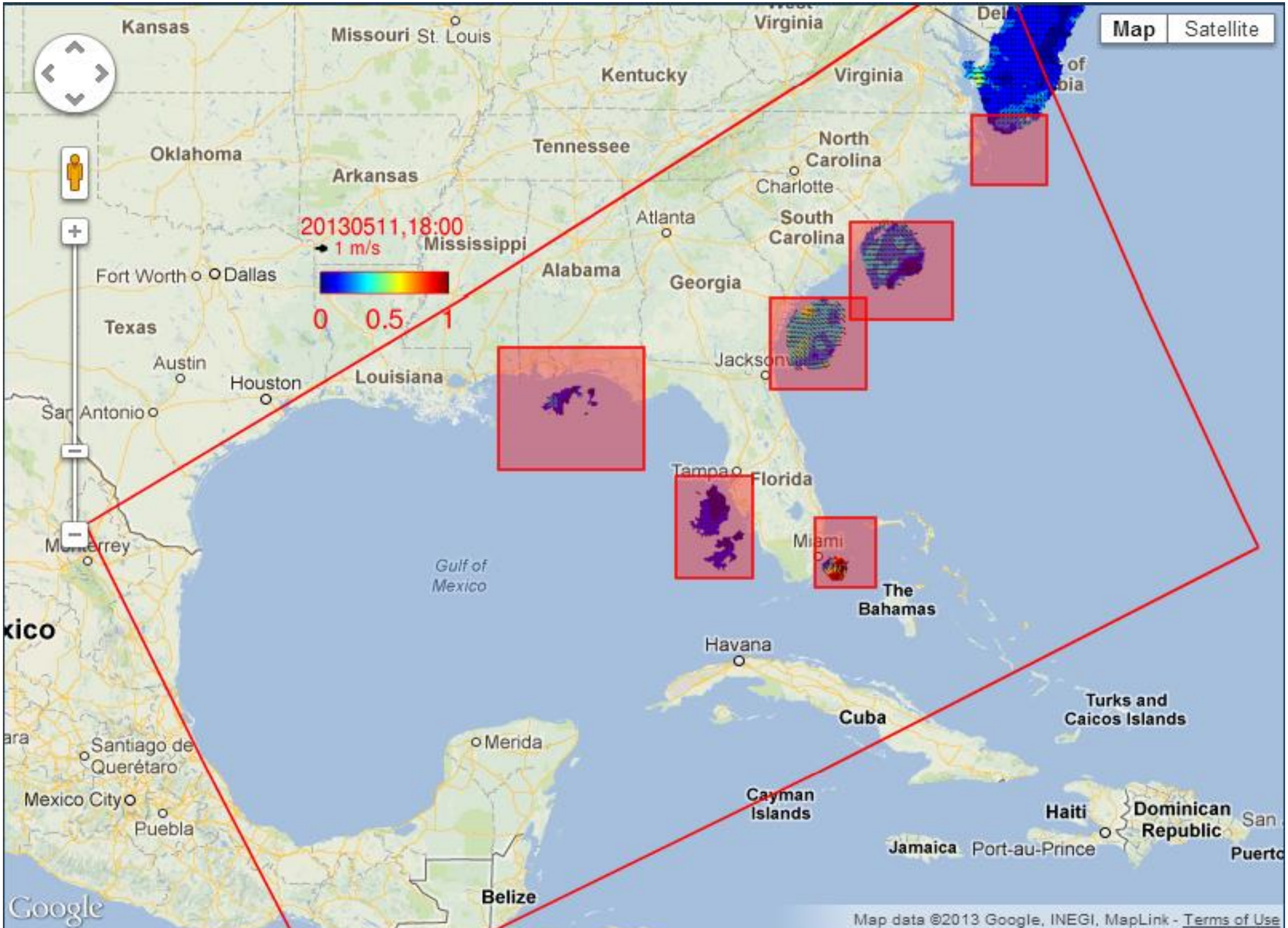
a) virtual mooring profile (T/S/V)
b) virtual transect (T/S/V)
c) 84-hour virtual drifter trajectory



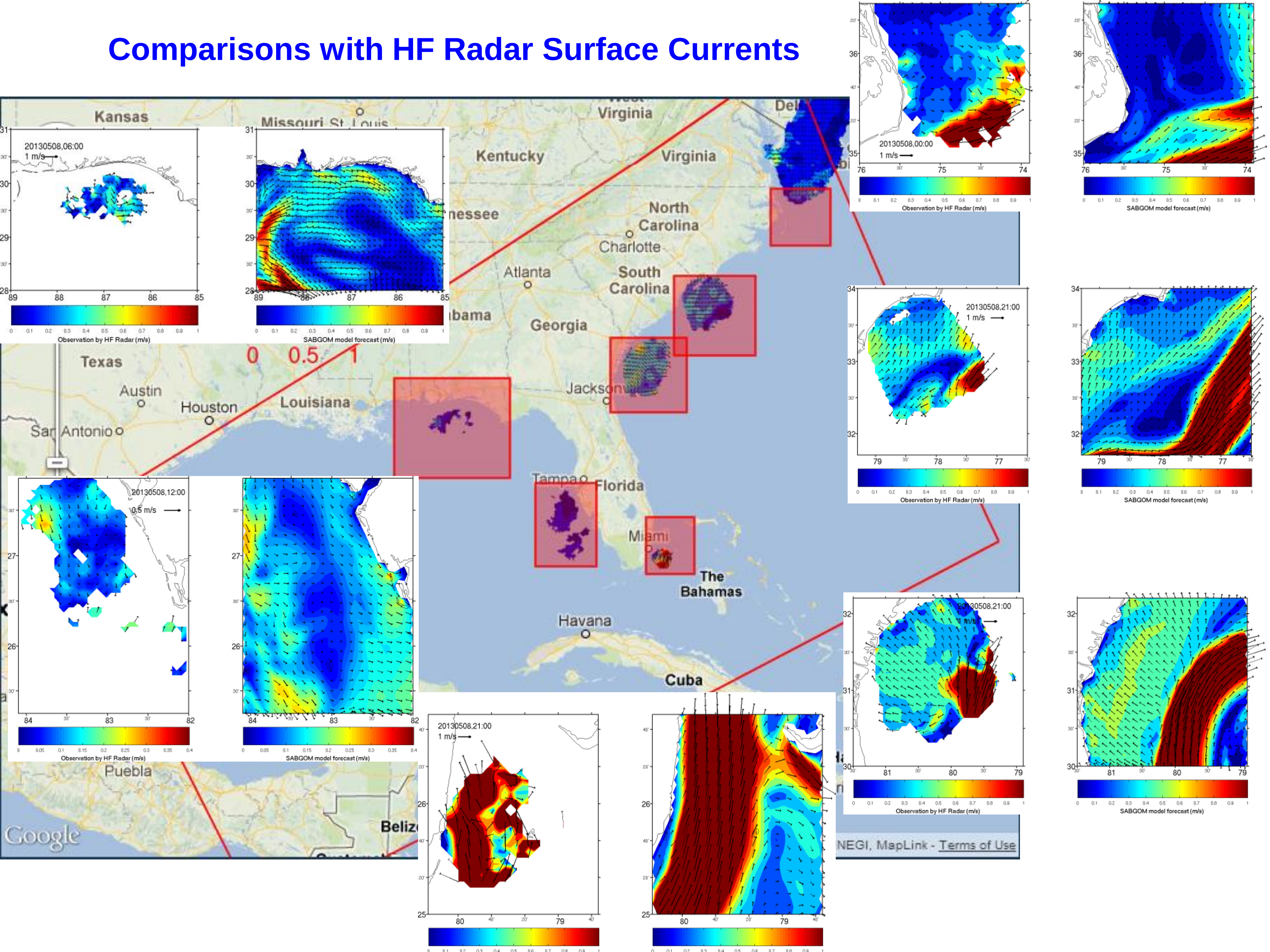




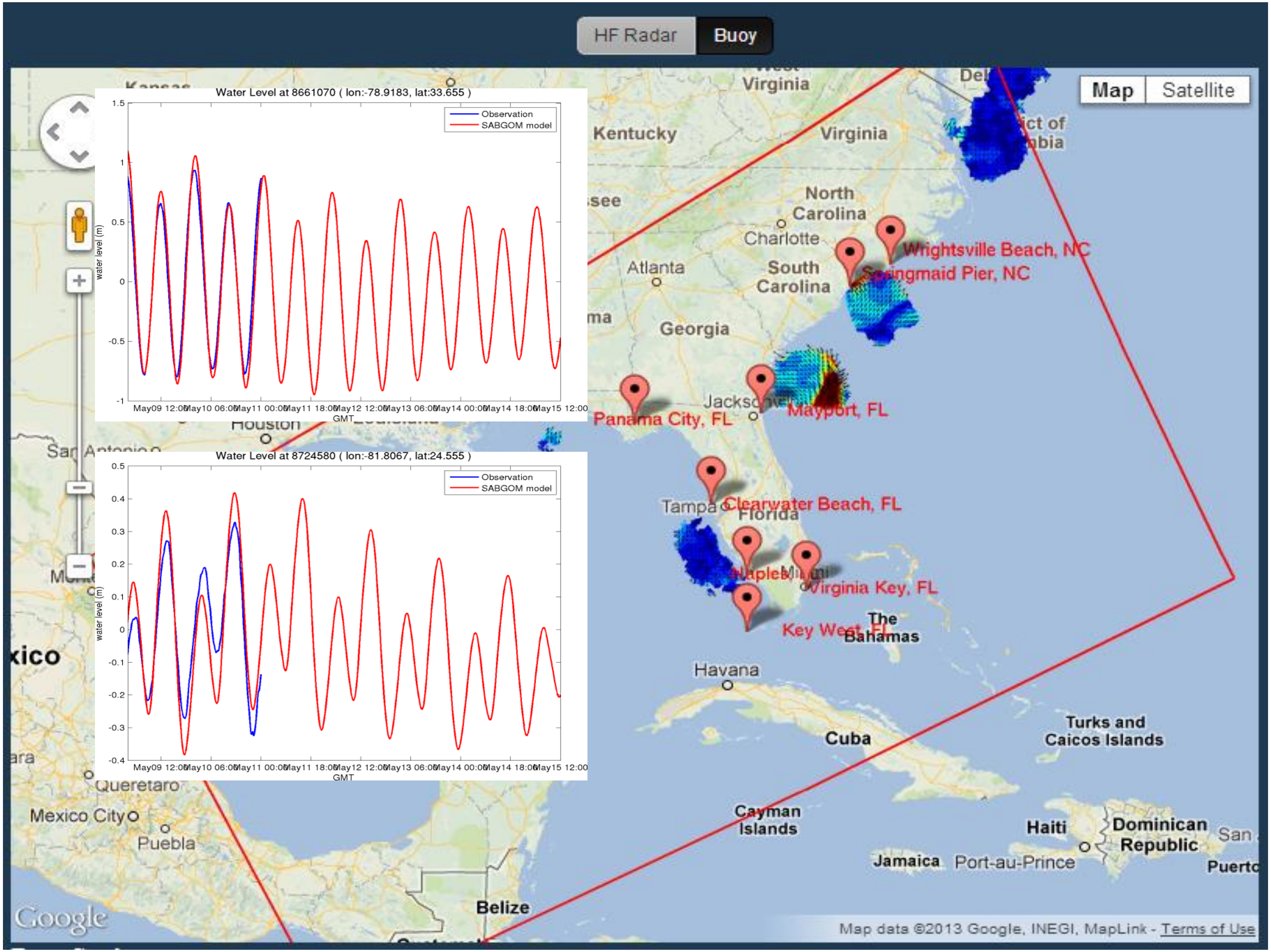
Online Skill Assessment: Comparisons with HF Radar Surface Currents



Comparisons with HF Radar Surface Currents



Online Skill Assessment: Comparisons with NOS Sea Level Observations



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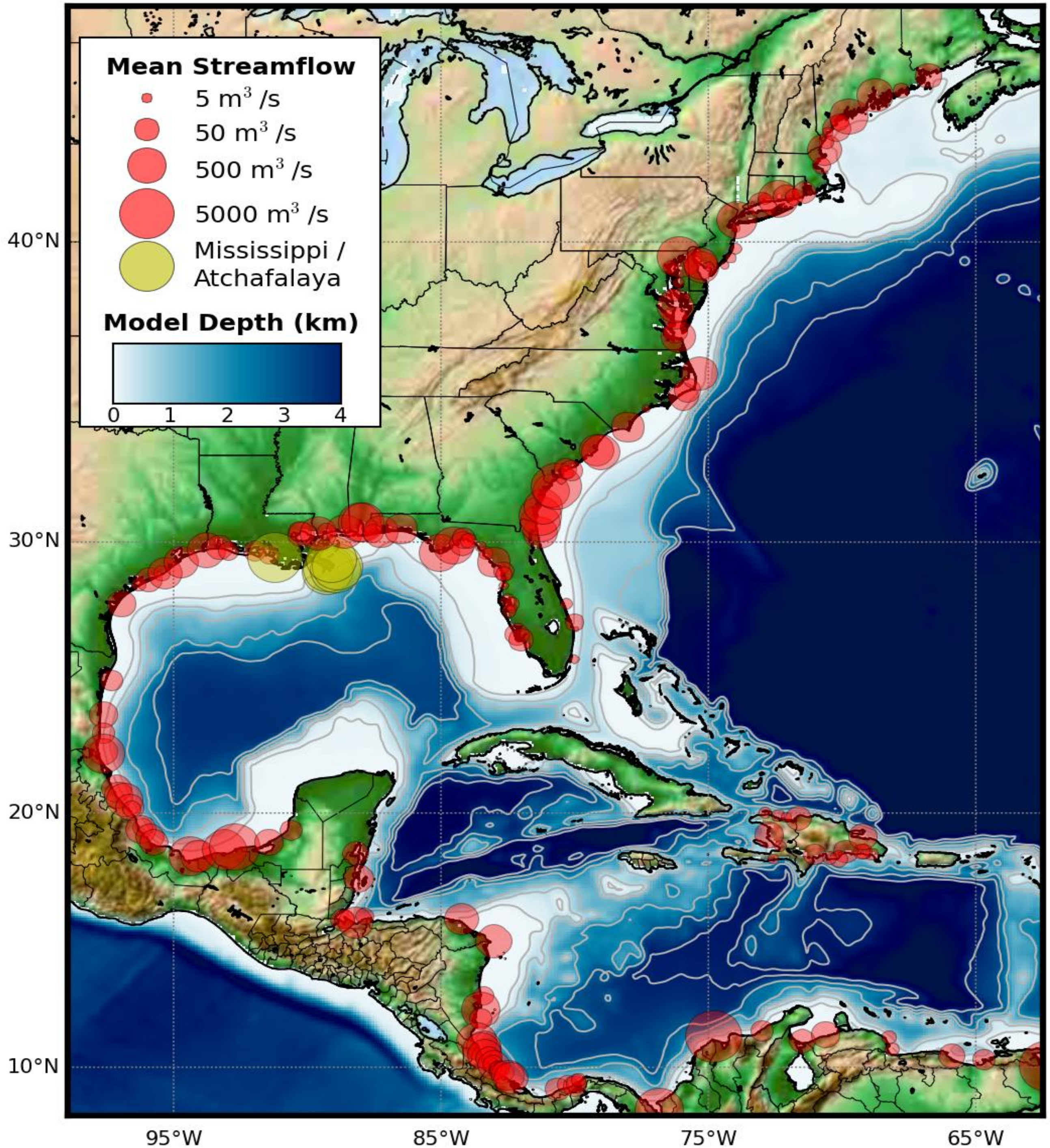
NW Atlantic Marine Environmental Prediction System

7-km resolution

Yao, He, et al. (2015)

Considering 196 rivers In the region



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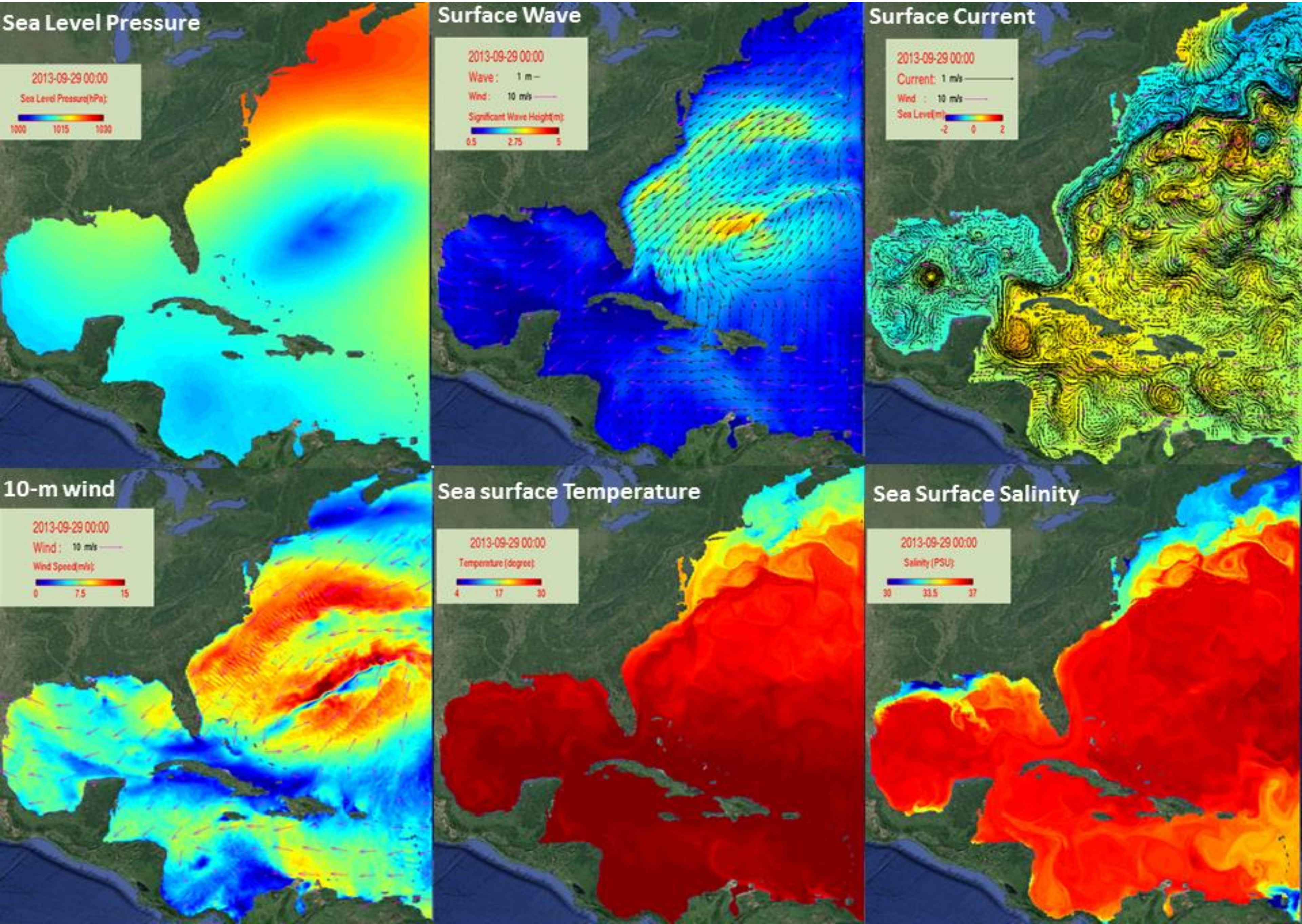
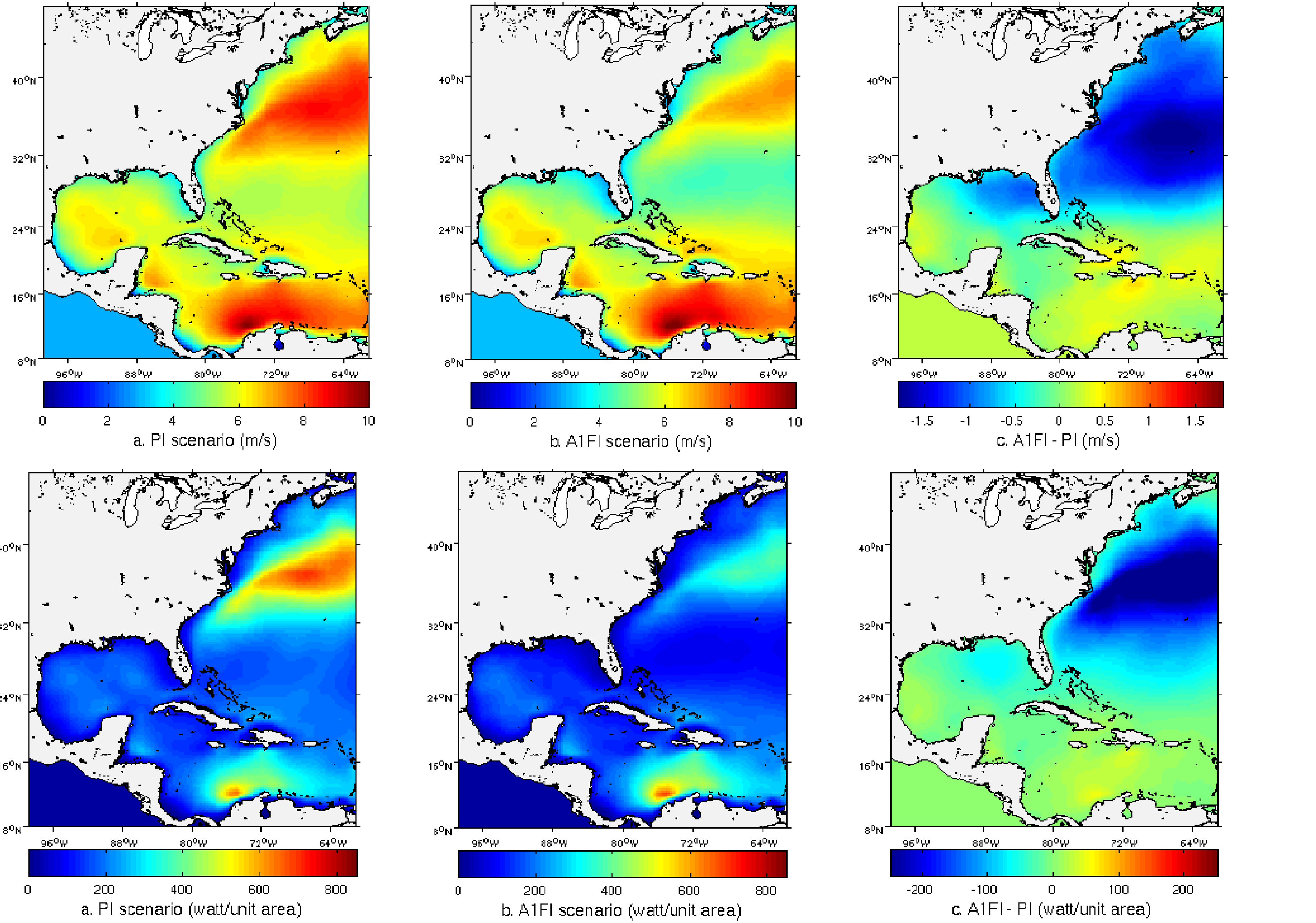
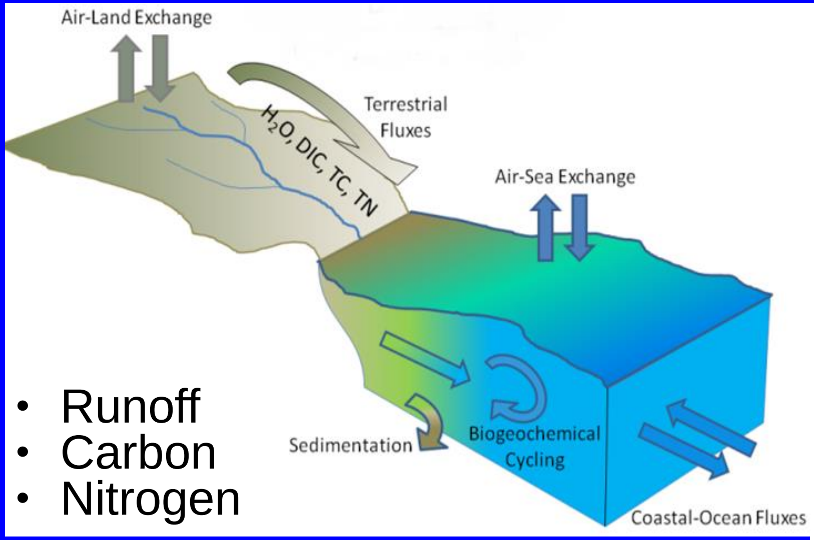
NW Atlantic Marine Environmental Prediction



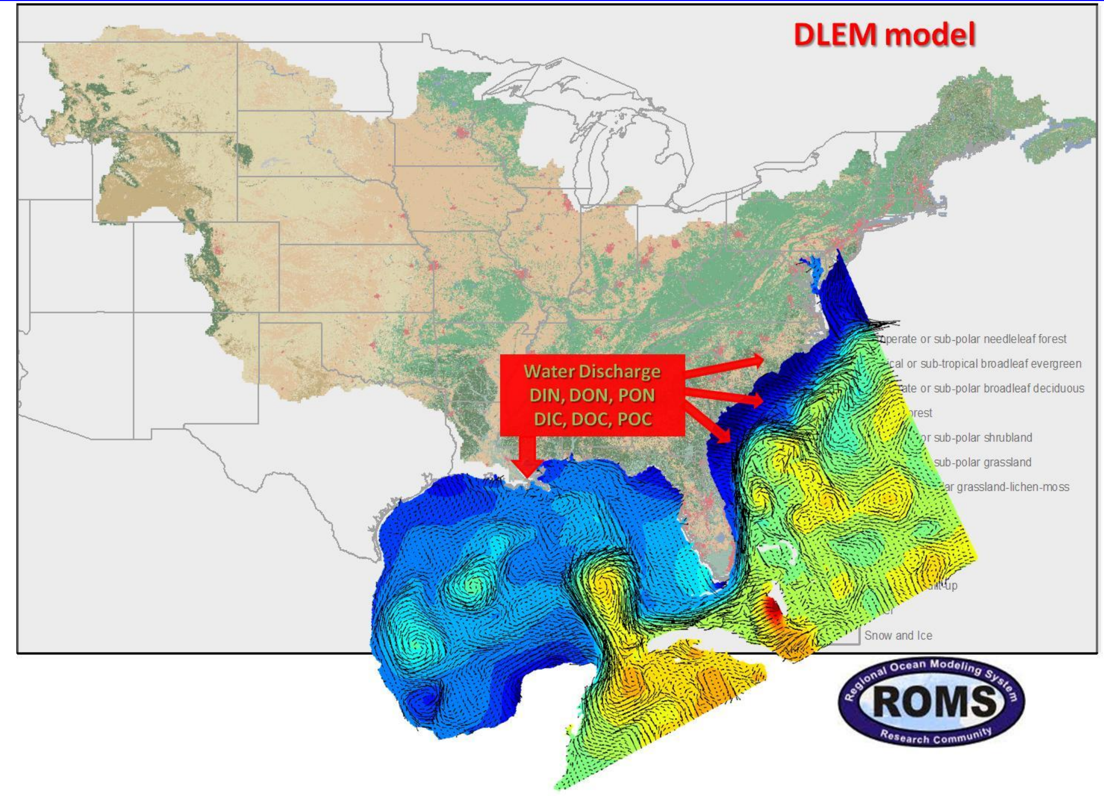
Regional downscaling of IPCC climate model scenarios (Yao & He, 2015)



Physical-Biogeochemical Interactions In a warming climate



- Runoff
- Carbon
- Nitrogen



Assessing Impacts of Climate and Land Use Change on Terrestrial-Ocean Fluxes of Carbon and Nutrients and Their Cycling in Coastal Ecosystems

Past, Present, Future

UMass Dartmouth

AUBURN UNIVERSITY

NC STATE UNIVERSITY

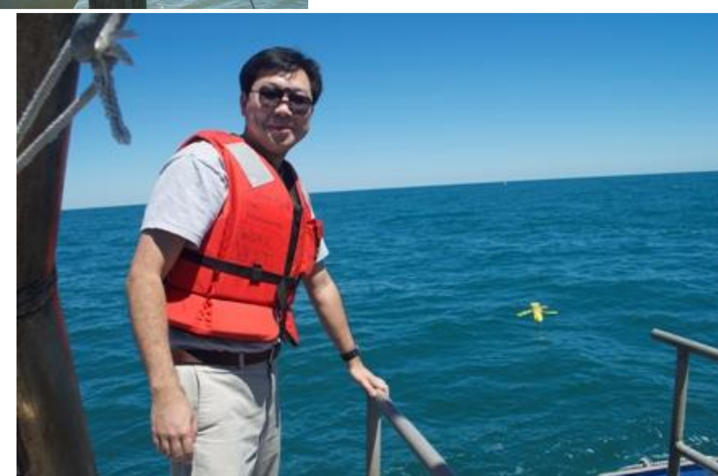
UNIVERSITY of DELAWARE

NC STATE UNIVERSITY

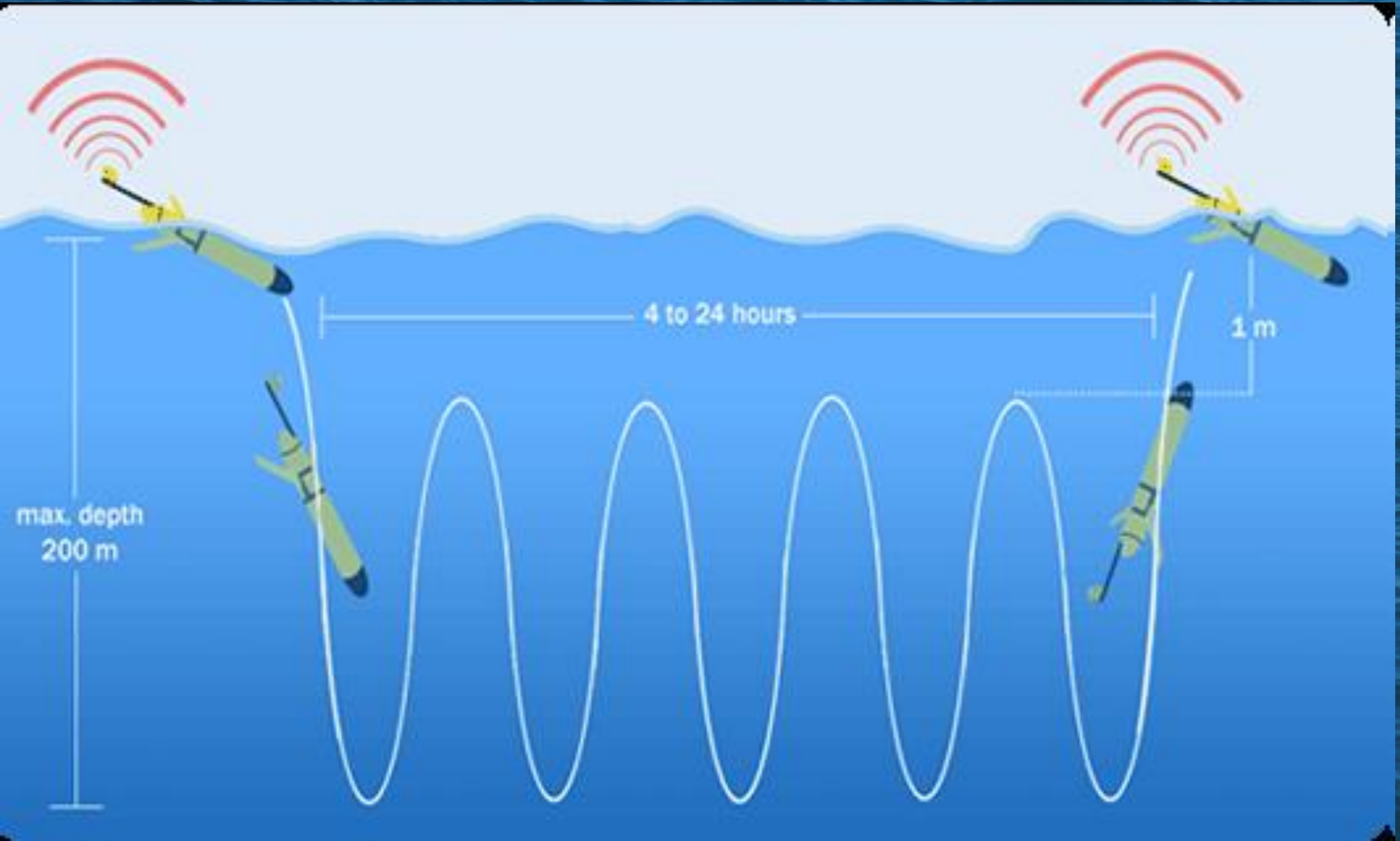
SAB shelf-wide observations using coastal ocean glider

NCSU OMG group has been running glider surveys in the South Atlantic Bight on a seasonal basis. Active research are being carried out to assimilate glider data along with other coastal ocean observations (satellite SST and SSH, mooring time series, HF Radar surface currents) into SABGOM ocean model using advanced variational data assimilation schemes.

- Validation
- Uncertainty/ sensitivity
- Assimilation



Iridium Satellite



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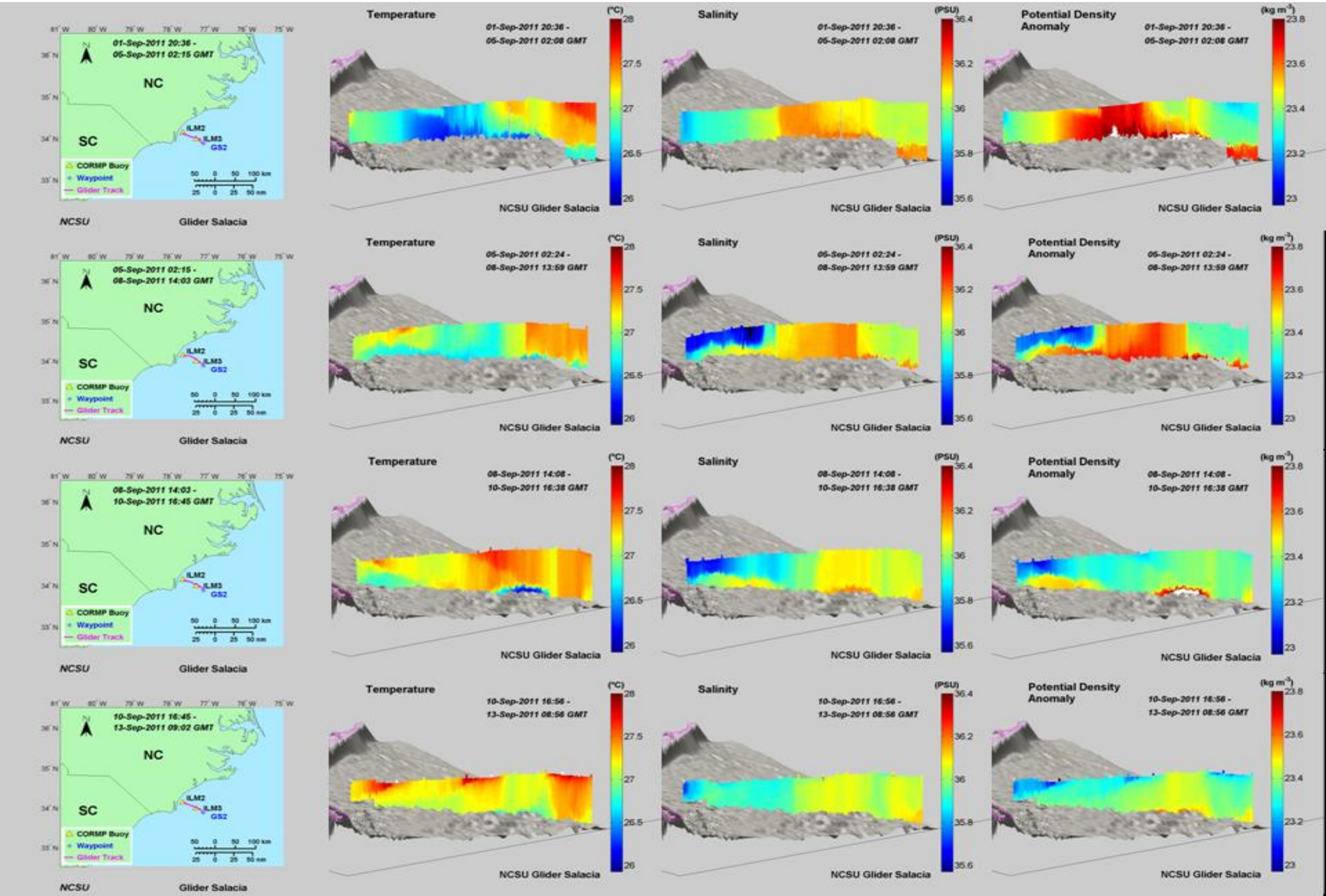
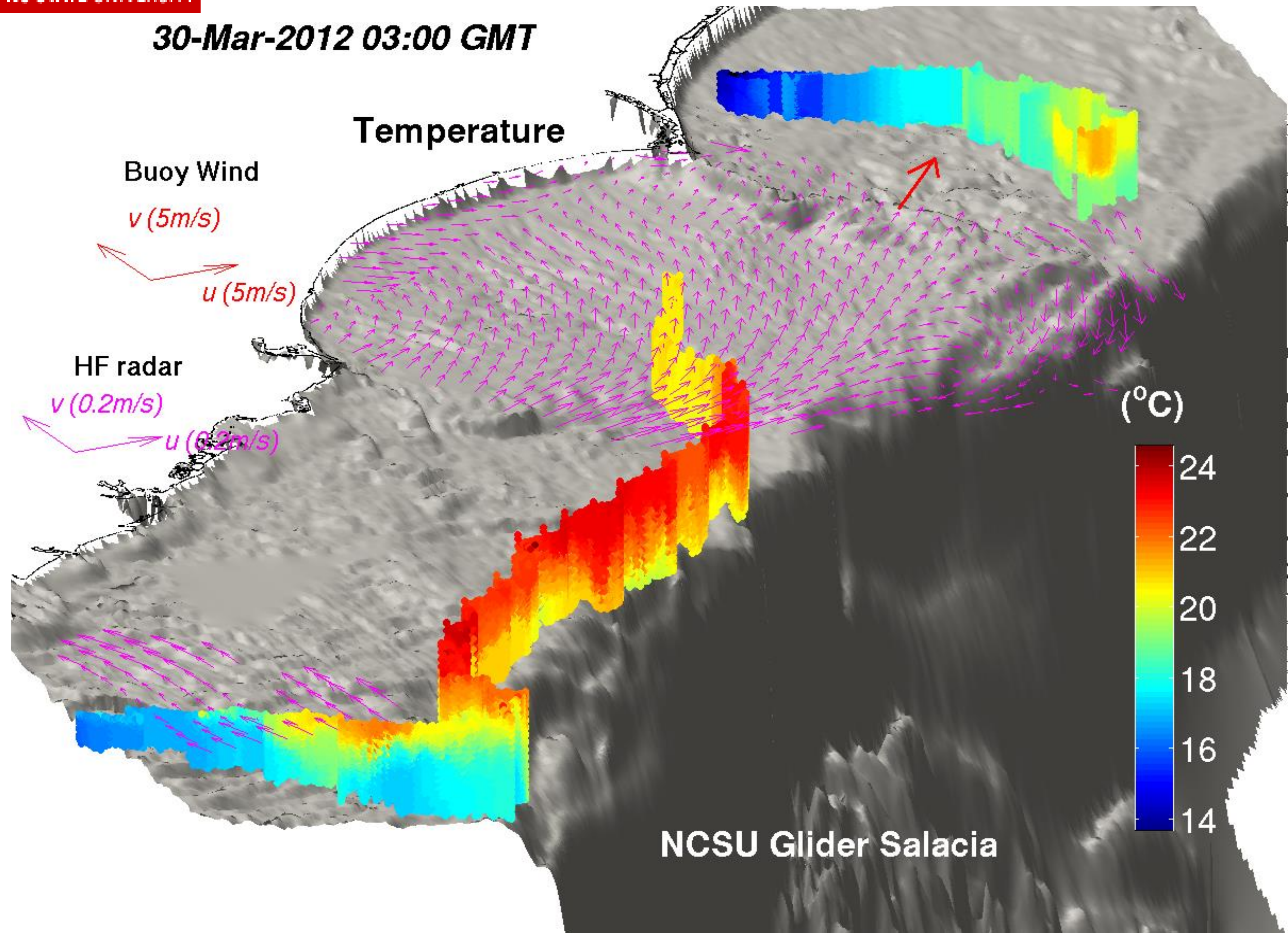
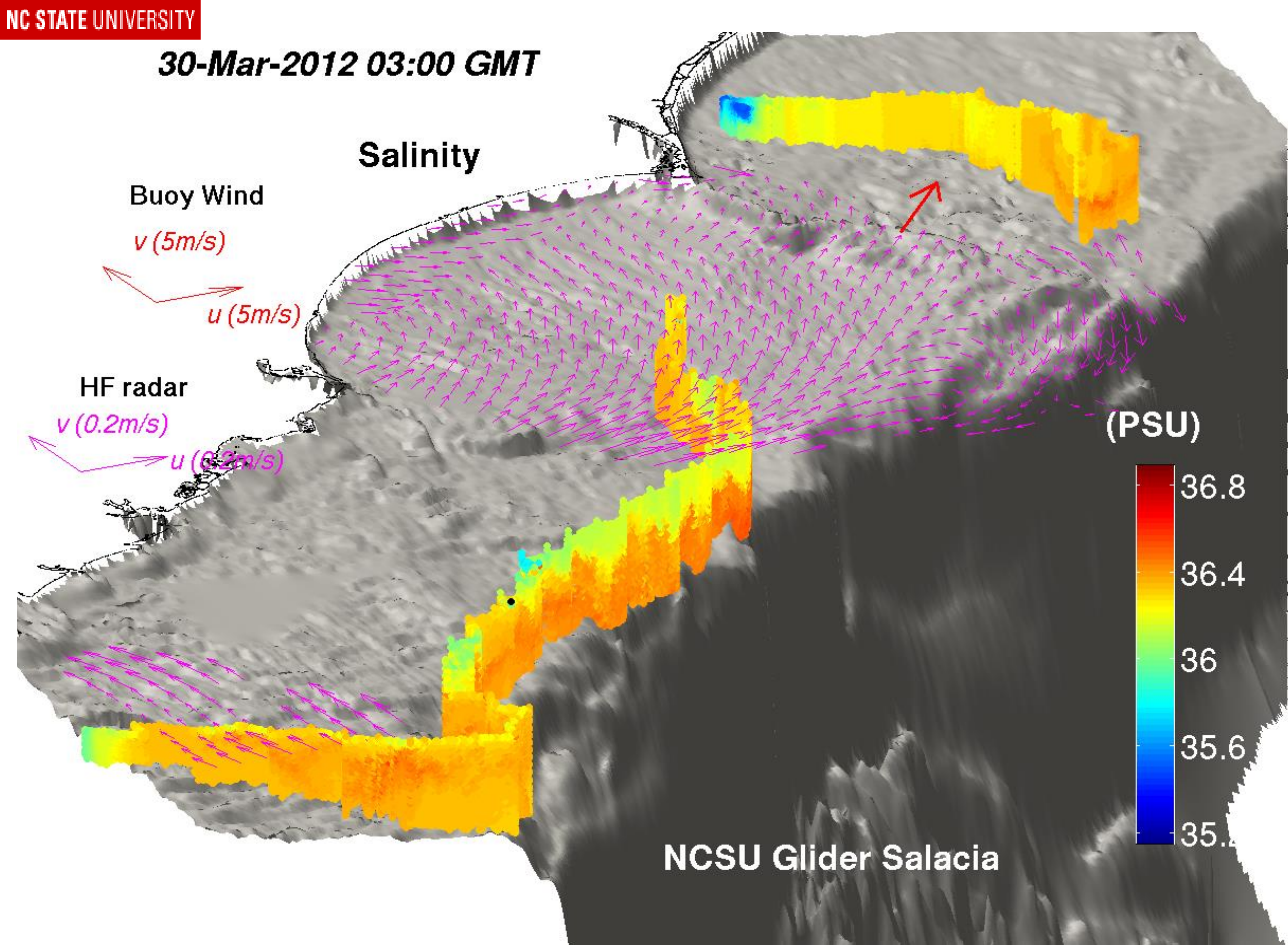
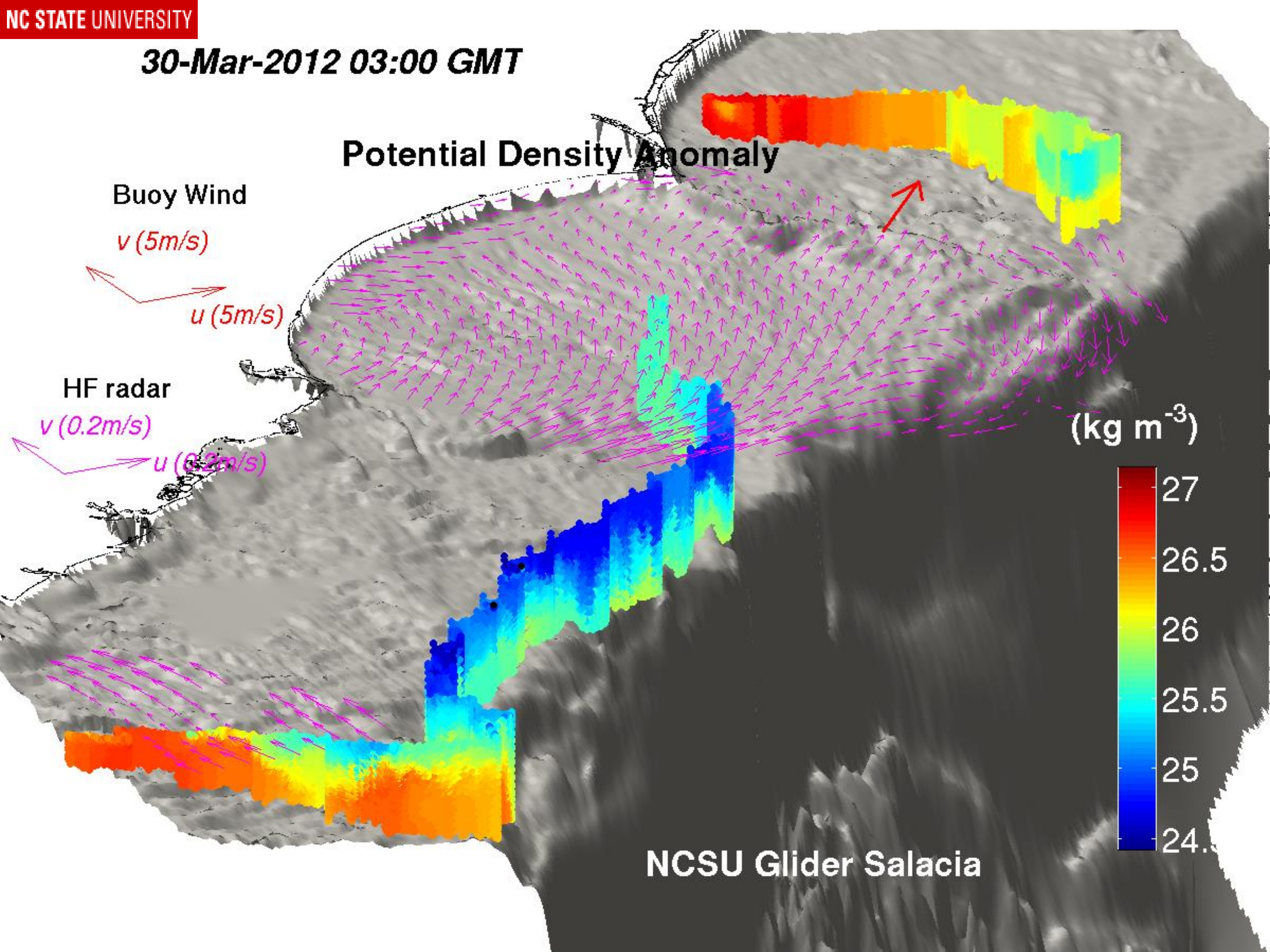
Glider survey in September 2011

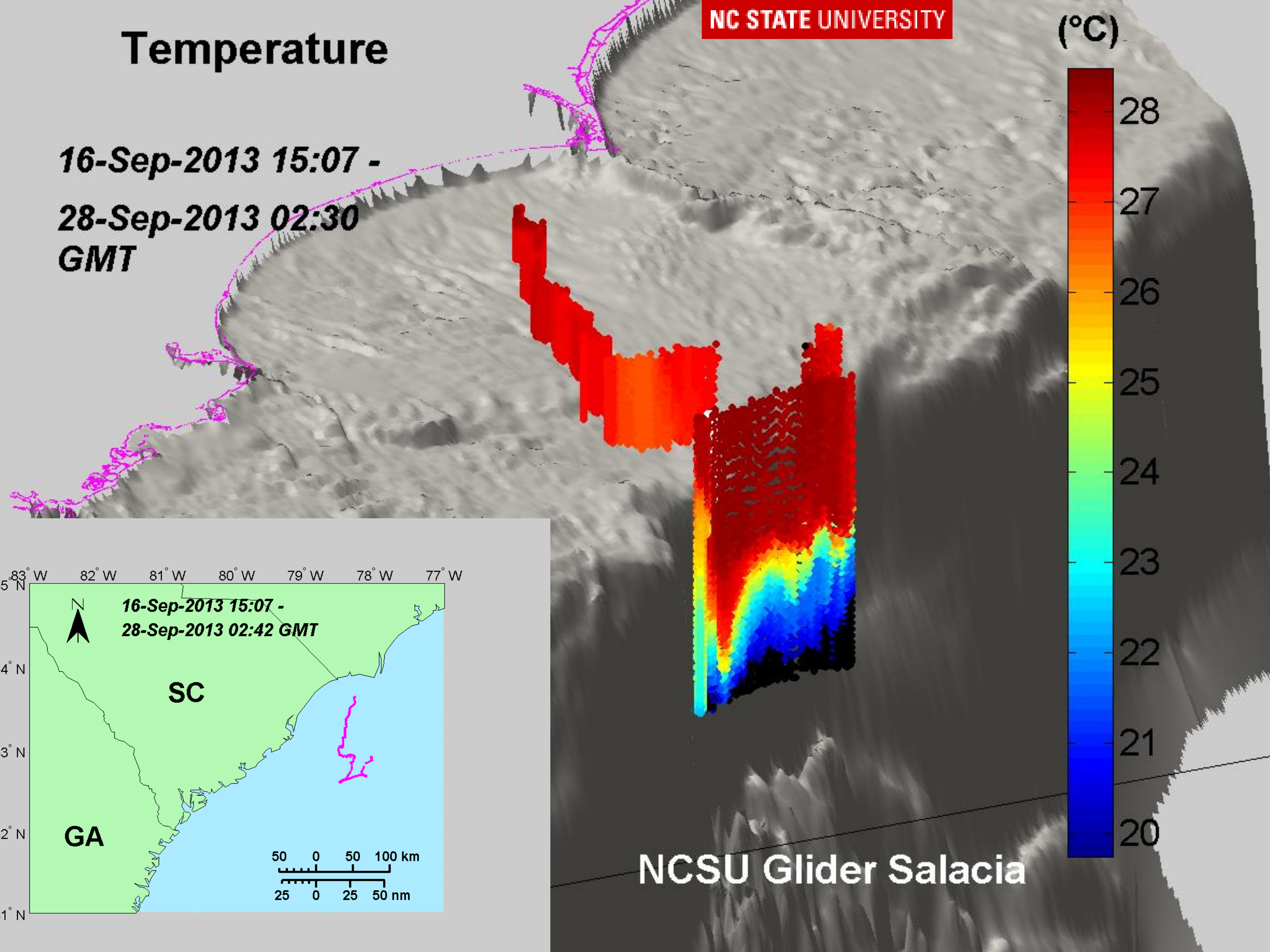



30-Mar-2012 03:00 GMT
Temperature
Buoy Wind
v (5m/s)
u (5m/s)
HF radar
v (0.2m/s)
u (0.2m/s)
(°C)
24
22
20
18
16
14
NCSU Glider Salacia



NC STATE UNIVERSITY
30-Mar-2012 03:00 GMT
Salinity
Buoy Wind
v (5m/s)
u (5m/s)
HF radar
v (0.2m/s)
u (0.2m/s)
(PSU)
36.8
36.4
36
35.6
NCSU Glider Salacia


NC STATE UNIVERSITY
30-Mar-2012 03:00 GMT
Potential Density Anomaly
Buoy Wind
v (5m/s)
u (5m/s)
HF radar
v (0.2m/s)
u (0.2m/s)
(kg m^{-3})
27
26.5
26
25.5
25
NCSU Glider Salacia

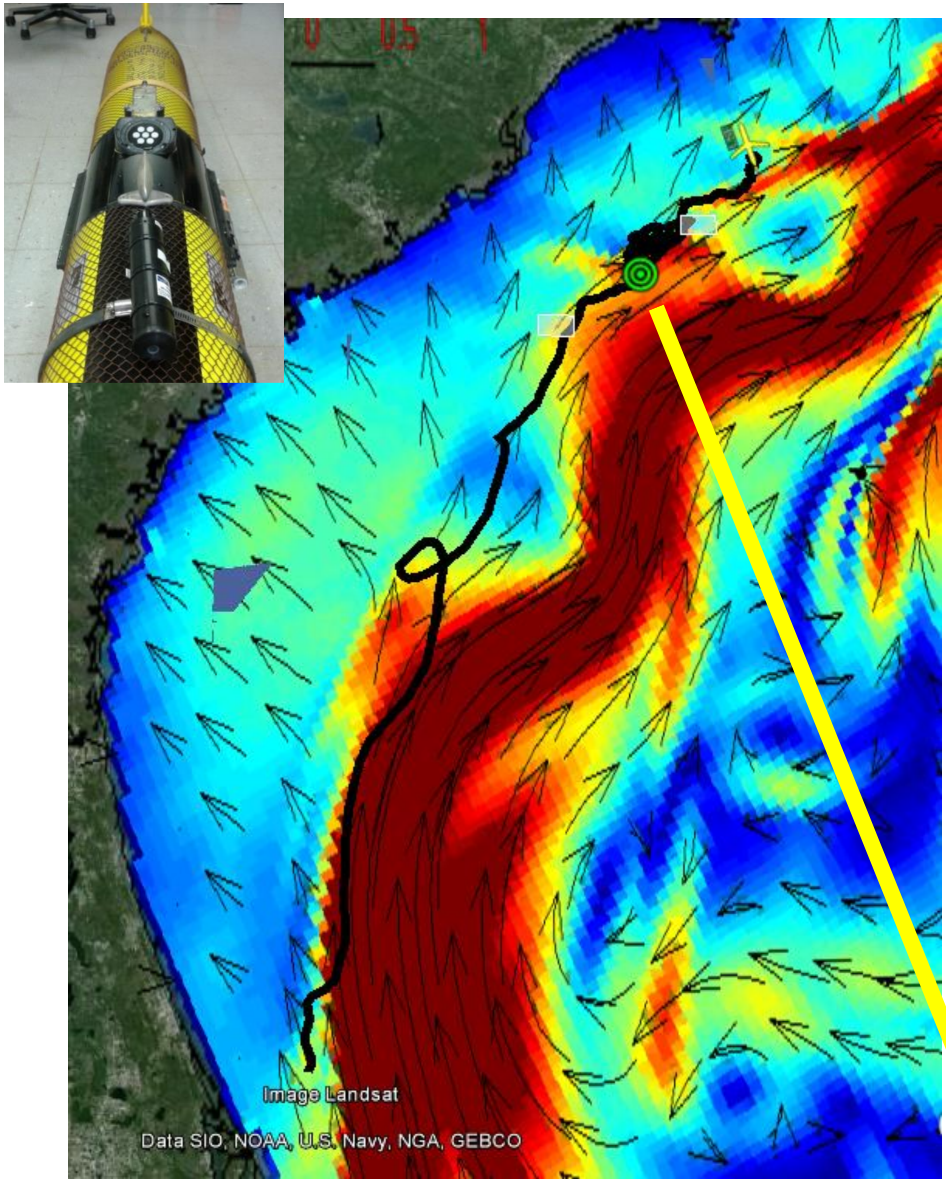


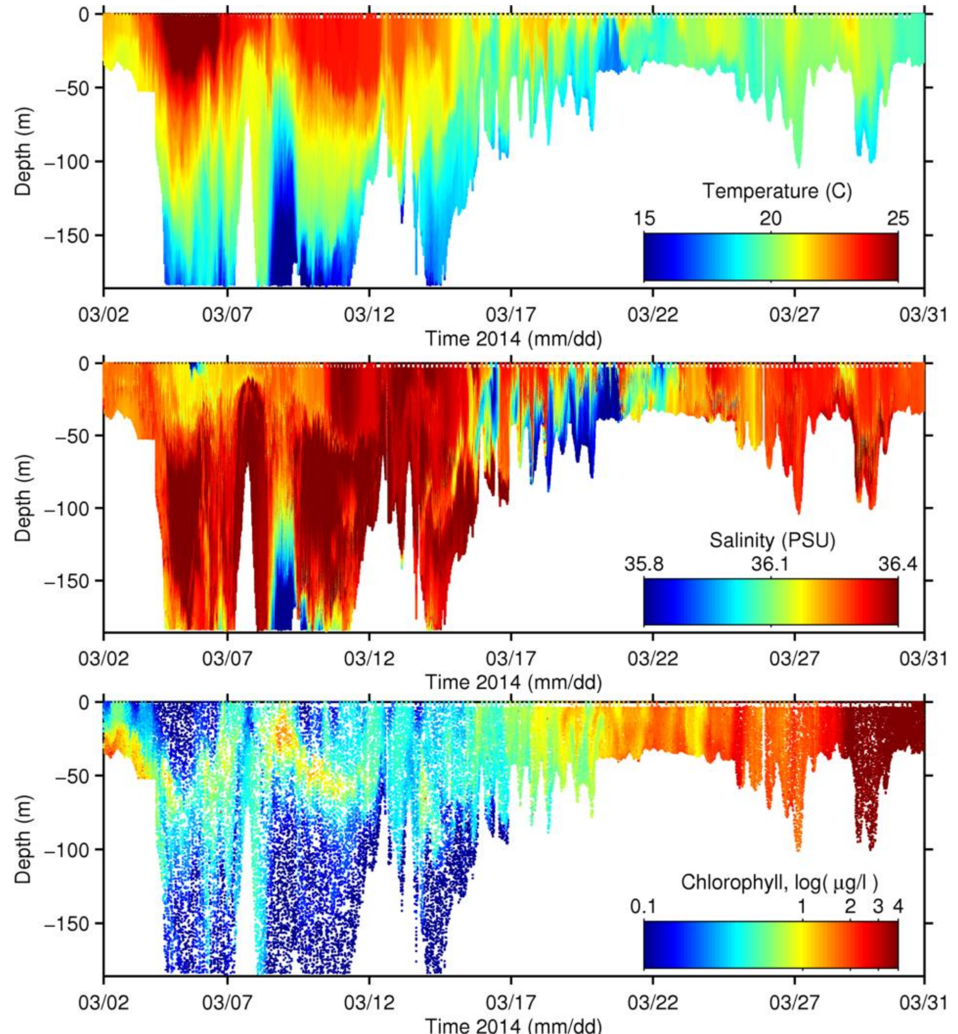
Temperature
NC STATE UNIVERSITY
16-Sep-2013 15:07 -
28-Sep-2013 02:30
GMT
(°C)
28
27
26
25
24
23
22
21
20
83° W
82° W
81° W
80° W
79° W
78° W
77° W
16-Sep-2013 15:07 -
28-Sep-2013 02:42 GMT
N
SC
GA
50 0 50 100 km
25 0 25 50 nm
NCSU Glider Salacia

NC STATE UNIVERSITY

Study of fish/mammal migrations

- Vemco hydrophone receivers attached to the glider
- use sounds to track locations of species and their abundance
- Key Species: Right Whales, tiger sharks, Atlantic sturgeon, Atlantic Salmon



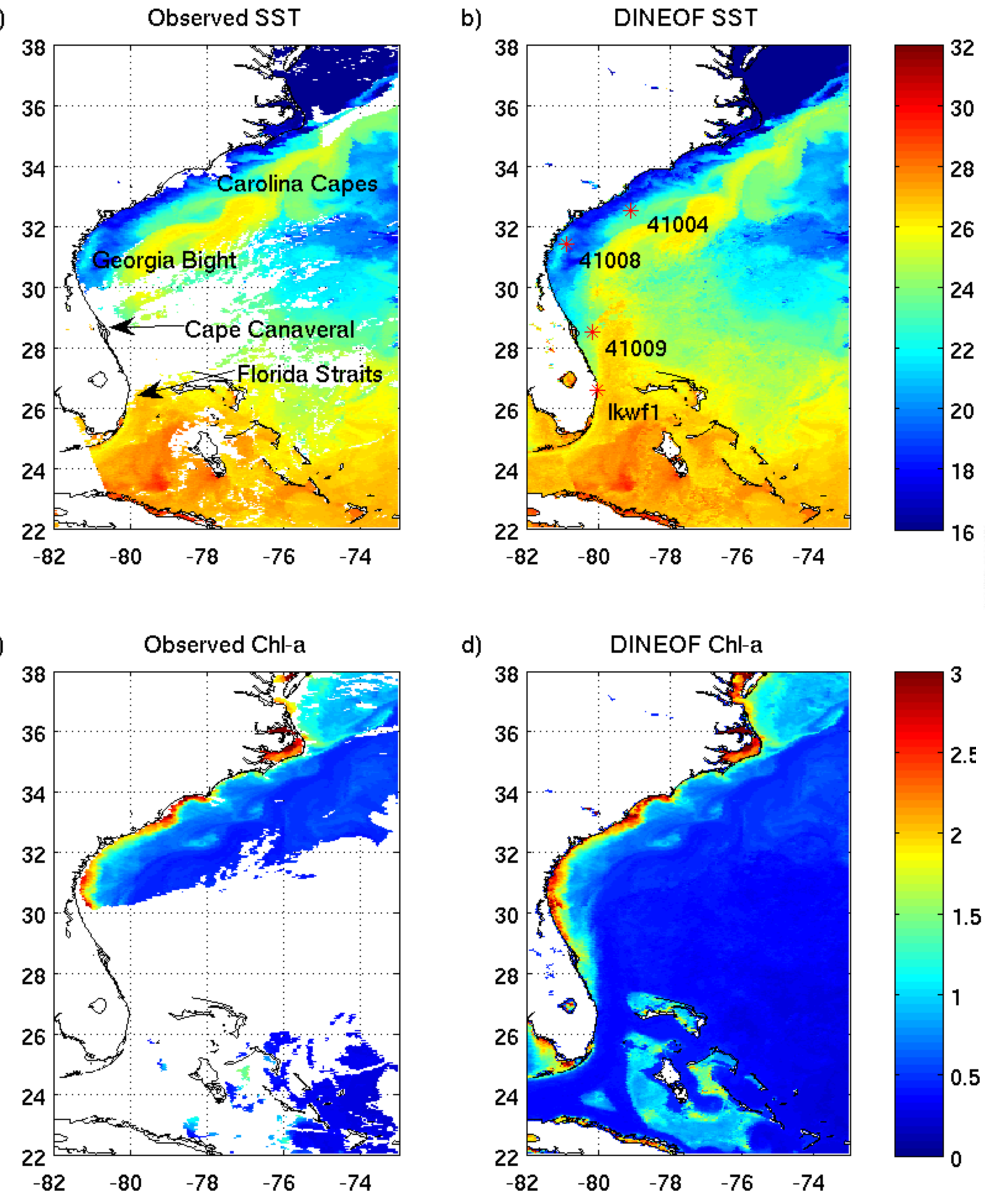


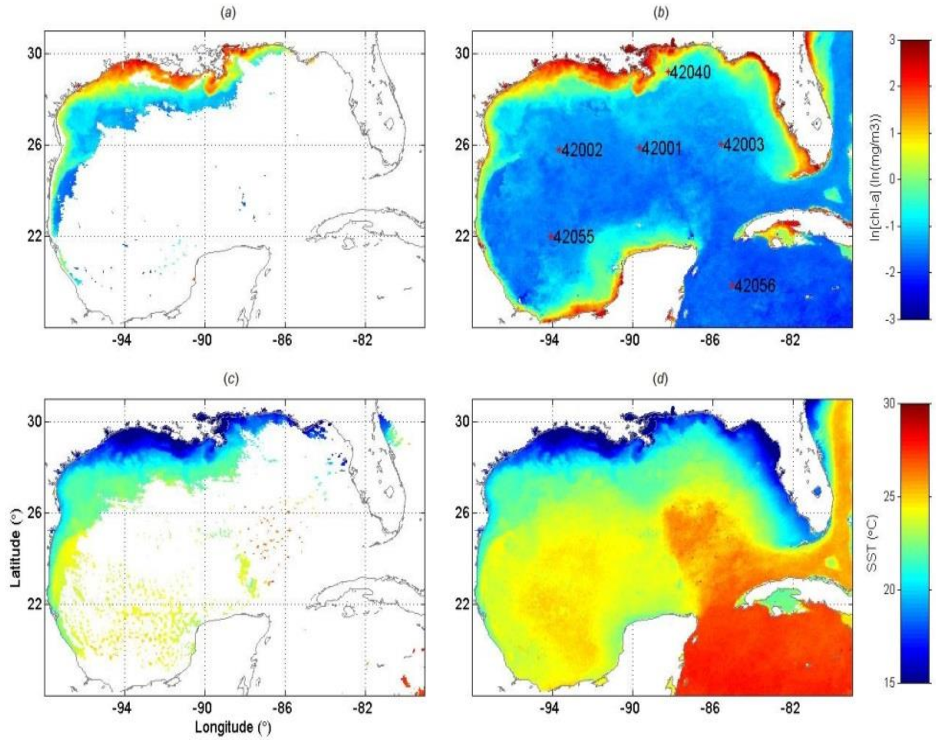
March 1 – 30 , 2014

USF

NC STATE UNIVERSITY

EOF based Daily Cloud–free SST and Chl-a reanalysis





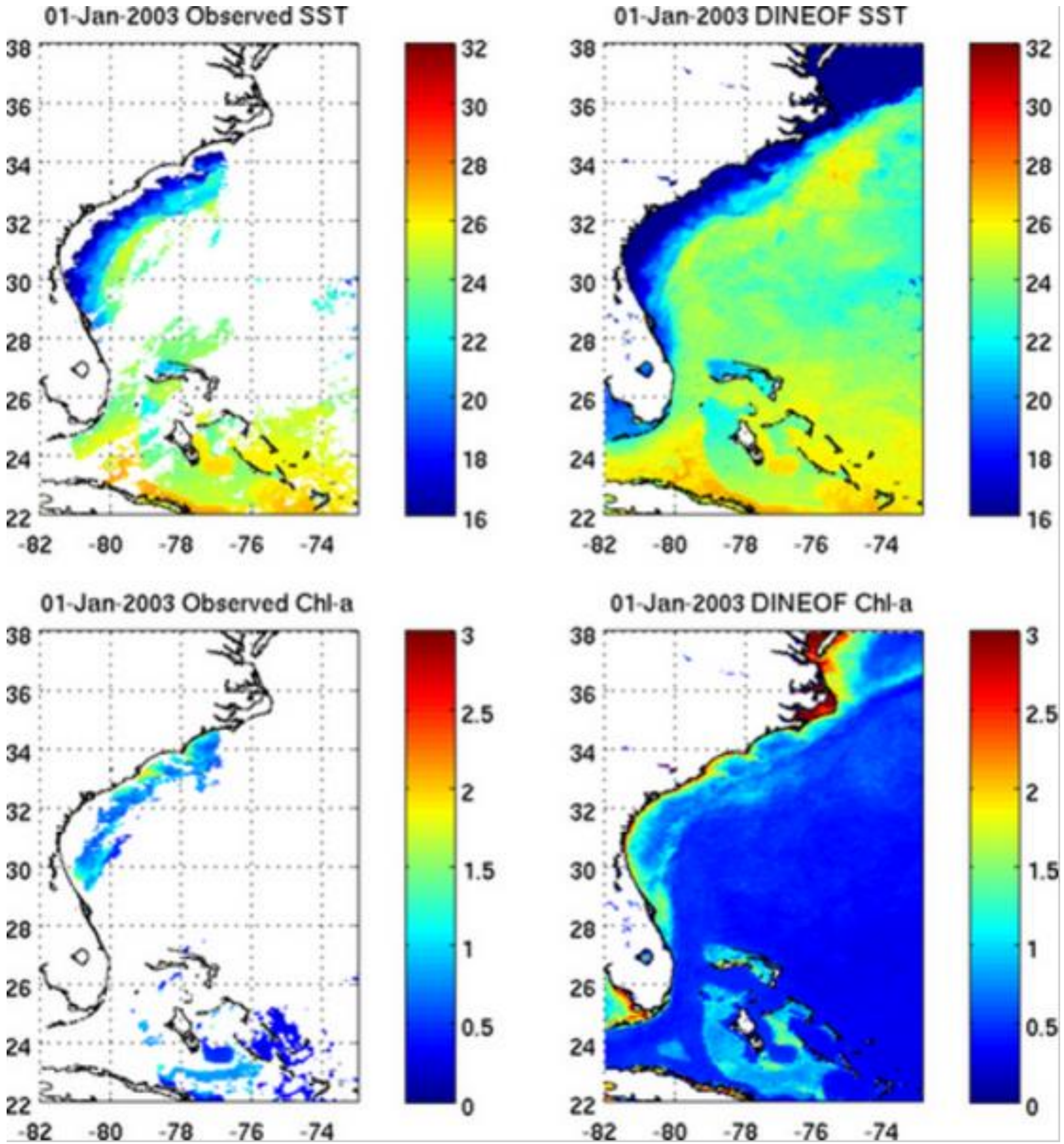
Period: 11 years (2003- 2013)

Miles, Moore and He (2009);
Miles and He (2010);
Zhao and He (2012)
Shropshire, Li and He (2015)

Raw and Reconstructed SST and Chl-a

Raw

SST



Reconstructed SST

Raw

Chl-a

Reconstructed Chl-a

NC STATE UNIVERSITY

Summary

- Marine Environmental Hindcast, Nowcast Forecast System for 1) the Gulf of Mexico and South Atlantic Bight and 2) NW Atlantic Ocean
  - 3-dimensional baroclinic ocean circulation (T/S/V/sea level)
  - ocean wave (height and direction)
  - marine meteorology (U10, SLP, air temp, etc)
  - marine ecosystem (NO_3, NH_4, phytoplankton, Zooplankton, TIC, Alkalinity, pCO2, Oxygen)
  - Hindcast solution available since 2003

- Value added product
  - online model skill assessment
  - online user defined virtual mooring, virtual transect, virtual drifter trajectory simulations
  - model ensembles and data assimilation
  - seasonal forecast and regional downscaling of climate scenarios

- Glider based hydrography and marine species observations
  - in situ, subsurface, AUV and acoustic technology

- Cloud-free satellite data reanalysis
  - daily SST and chl-a data since 2003

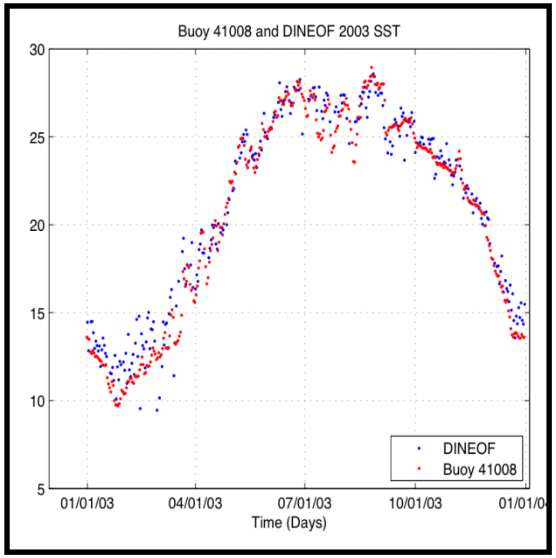
Marine Ecosystem Forecasting Service:

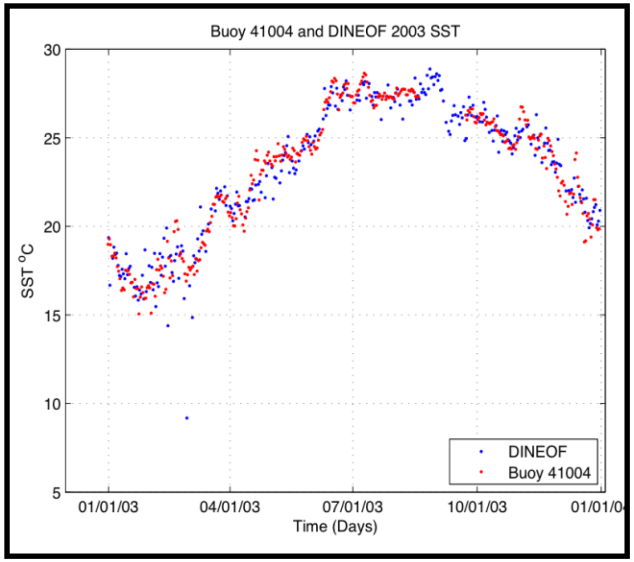
- Fishery habitat/ species distribution
- Hypoxia
- Harmful Algal Bloom
- Pathogens

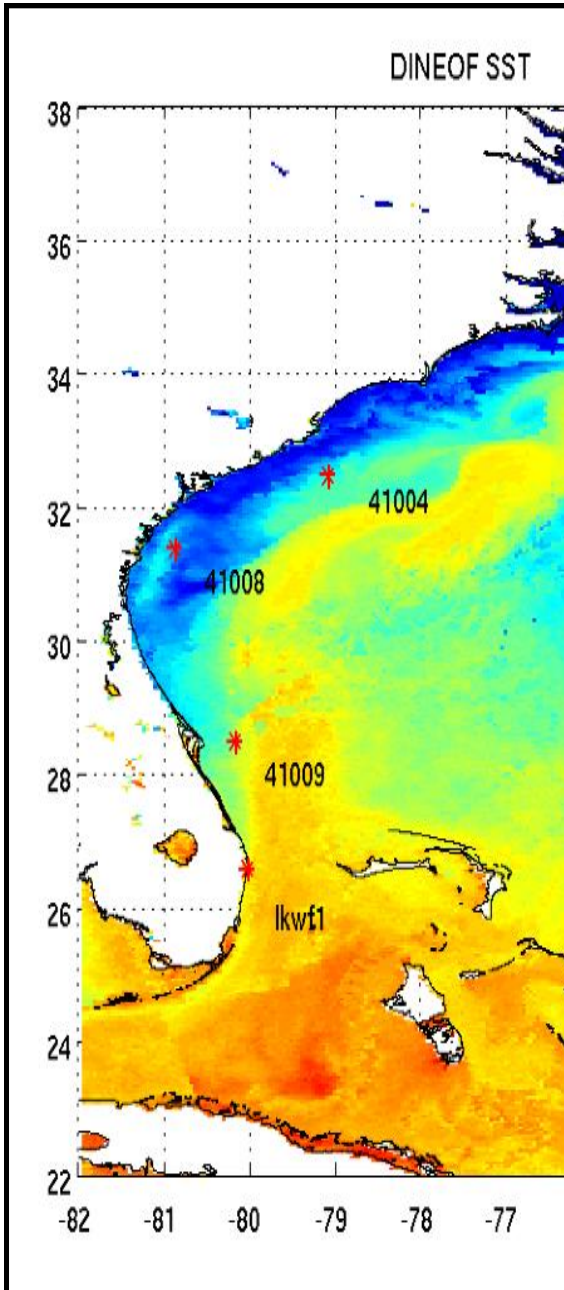
Point of contact: Dr. Ruoying He
email: rhe@ncsu.edu tel: 919-513-0249

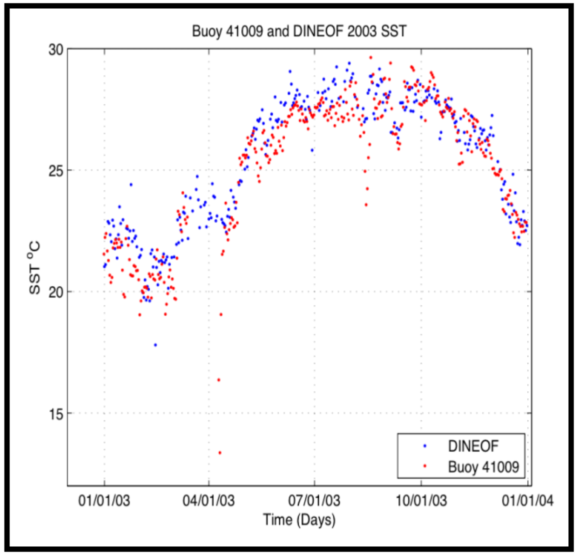
group website: http://www4.ncsu.edu/~rhe
SABGOM site: http://omgsrv1.meas.ncsu.edu:8080/ocean-circulation

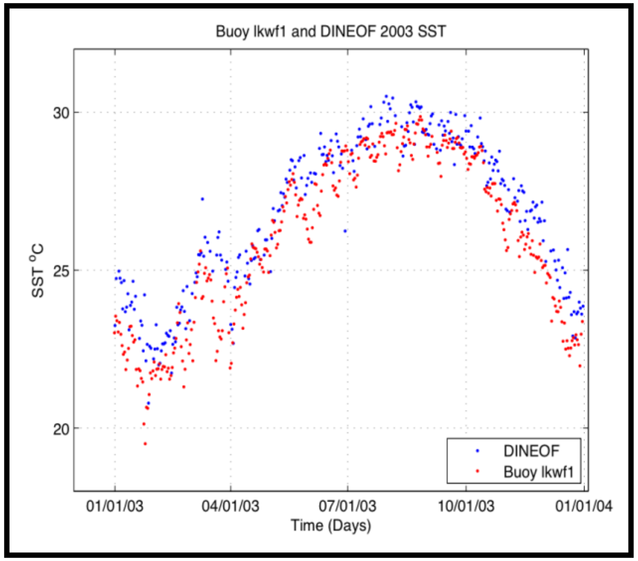
Comparisons between Buoy measured and DINEOF reconstructed SST











INTEGRATED OCEAN OBSERVING SYSTEM

High-Resolution Coastal and Estuarine Hydrodynamic and Ecosystem Modeling

South Atlantic
Ecosystem Modeling
Workshop

Y. Peter Sheng,
V. A. Paramygin, J.R. Davis,
Ruizhi Zou and Kun Yang
Advanced Coastal Environment Simulations Laboratory
Coastal and Oceanographic Engineering Program
University of Florida

February 10-11, 2015

Coastal and Estuarine Modeling

- Modeling activities......(CH3D-SSMS and CH3D-IMS)
  - Simulating storm surge and inundation
    (H. Charley, Dennis, Isabel, Katrina, Wilma, Ike, Sandy, etc)
  - Simulating salinity and baroclinic circulation including response to storms (e.g.,TS Fay, 2008)
  - Simulating sediments, water quality, light, seagrass, larvae, oil spill
- Forecasting for different parts of Florida
  - Mostly storm surge nowcasts/forecasts
  - 3D and baroclinic nowcasts/forecasts
- Climate change and coastal resiliency
  - Global/Regional climate model-->coastal model
  - Mitigation of flooding by coastal wetlands

Forecasting activities....

– Provide real-time forecasting to support operational management of water control structures and utility infrastructure

– Provide real-time forecasting of flow and salinity inside of the regional National Estuarine Research Reserves (GTM, Apalachicola and Rookery Bay).

– Provide real-time forecasting to support emergency management (e.g. WFO and FDEM) during hurricane season

– Provide real-time forecasting products to the SECOORA community

Forecasting Objectives

Completing A Quasi-Operational Forecasting System with

- 4 forecasts per day (00, 06, 12 and 18Z)
- Forecasts ranging up to 48 to 72 hr depending on wind source
- Coupling to a regional scale model (SABGOM ROMS run by NCSU)
- Coupling to a wave model (SWAN)
- Custom datasets (data formats, subsetting, etc) for stakeholders
- Wind sources:
  - NAM
  - Synthetic hurricane wind model driven by National Hurricane Center advisories
- Nowcasts / forecasts of water level, currents and salinity
- Results available via a TDS and visualization via the SECOORA portal

Progress and Accomplishments

Forecasting system

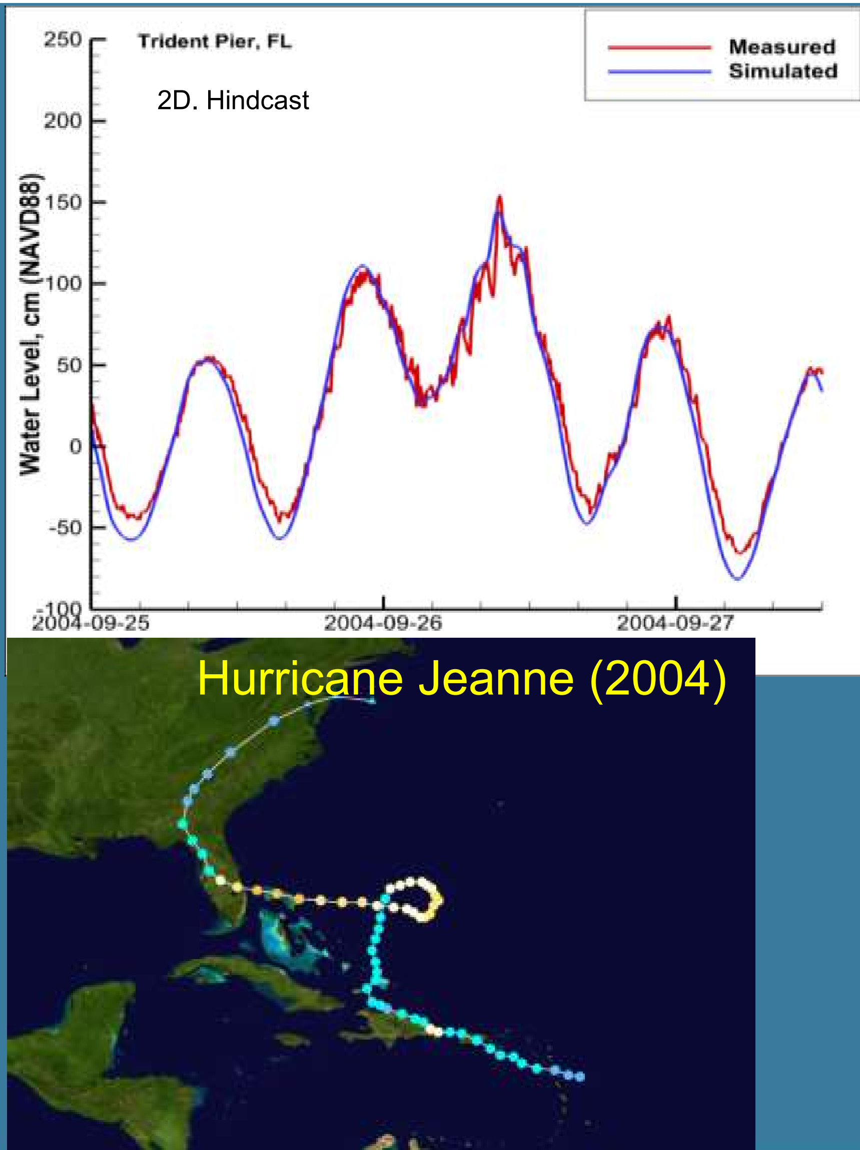
- 4 Domains
- 3D model with baroclinic circulation
- Forced by wind, tides, river flows
- Nowcasts / forecasts
  - Currently uses NAM wind field
  - Four times daily (00, 06, 12, 18Z)
  - Forecast cycle length up to 48 to 72 hrs depending on wind
- Each domain coupled to a SWAN wave model
- Boundary conditions based on SABGOM ROMS or HYCOM model
- Model – data comparisons for different domains / conditions
- Data is available via THREDDS
- Visualization on SECOORA portal - Now we are creating a "client-site"
- visualization GUI

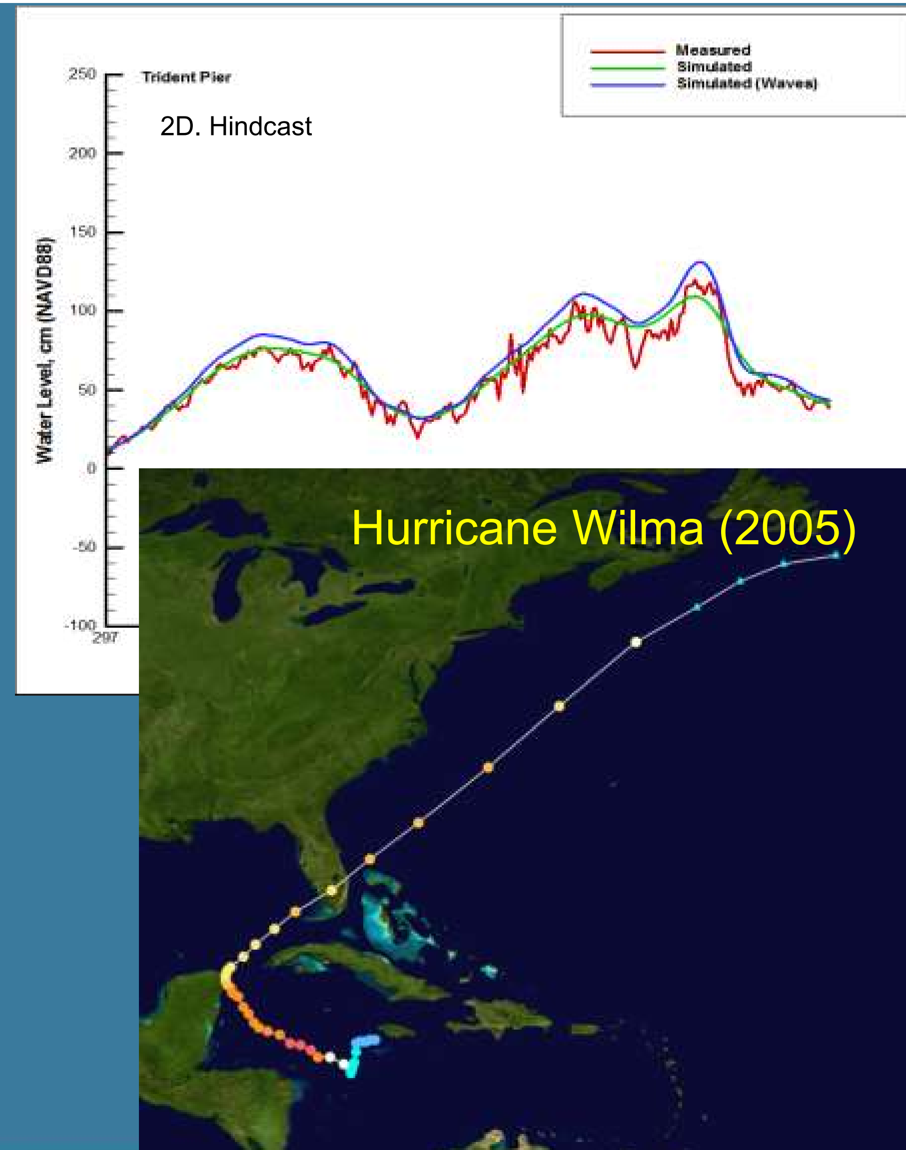
Comparisons to Observations

- East Coast of Florida
  - Hurricanes Jeanne (2004), Wilma (2005), TS Fay (2008)
- Southeast Florida
  - HF Radar surface currents near North Miami
  - Hurricane Andrew (1992)
- Northwest Florida (Northern Gulf of Mexico)
  - Salinity in the Apalachicola Bay
- Southwest Florida
  - Water levels, salinity. Naples/Rookery Bay

*Due to limitations of SECOORA mapping these are internal comparisons.

East Florida Coast

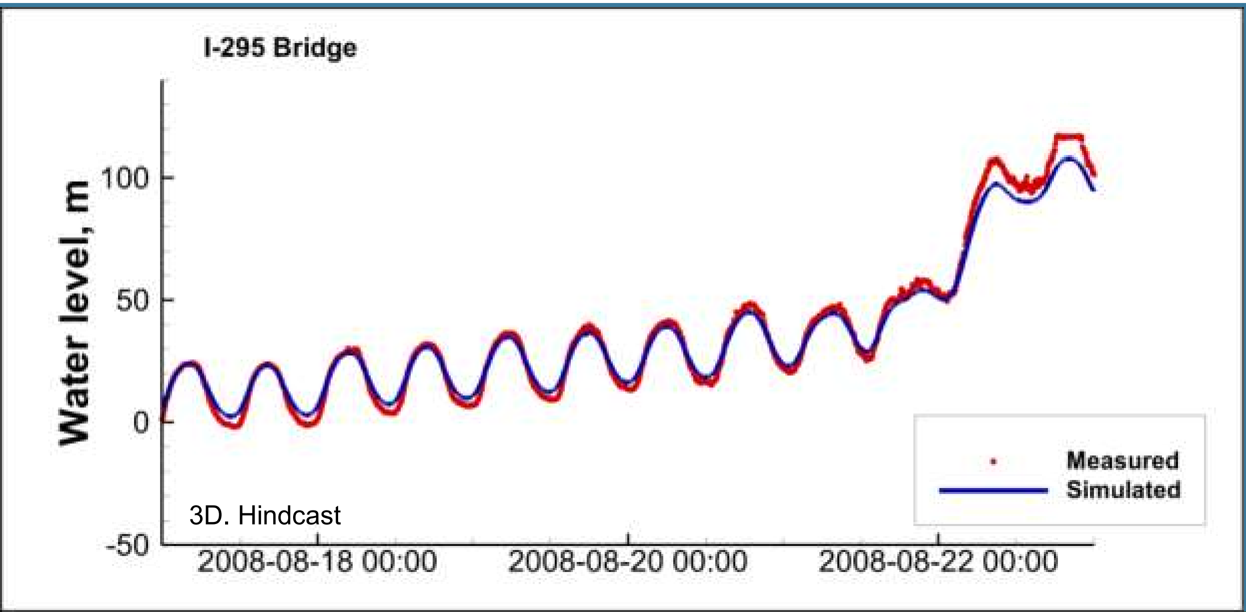


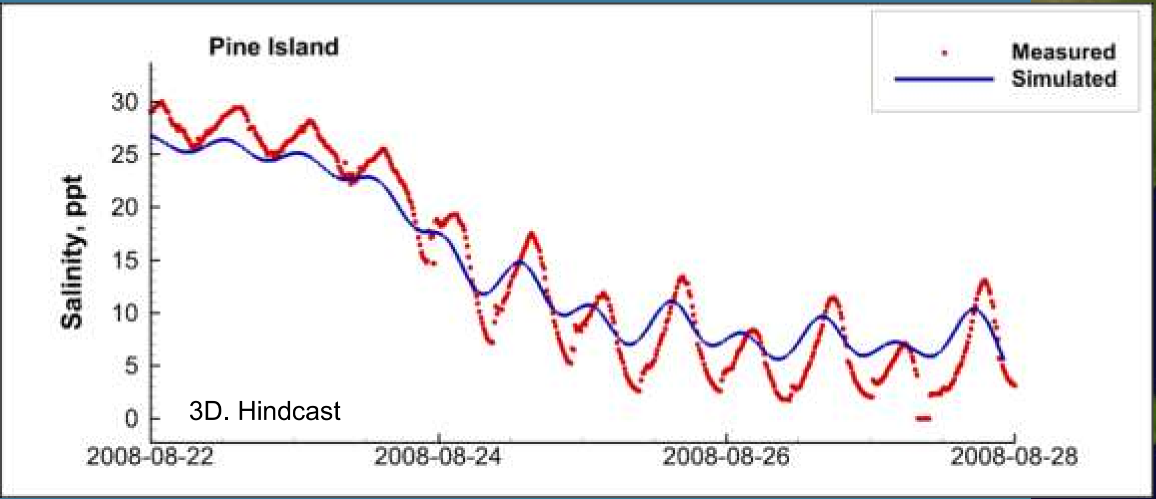


IOOS

SECOORA
Southeast Coastal Ocean Observing Regional Association

East Florida Coast



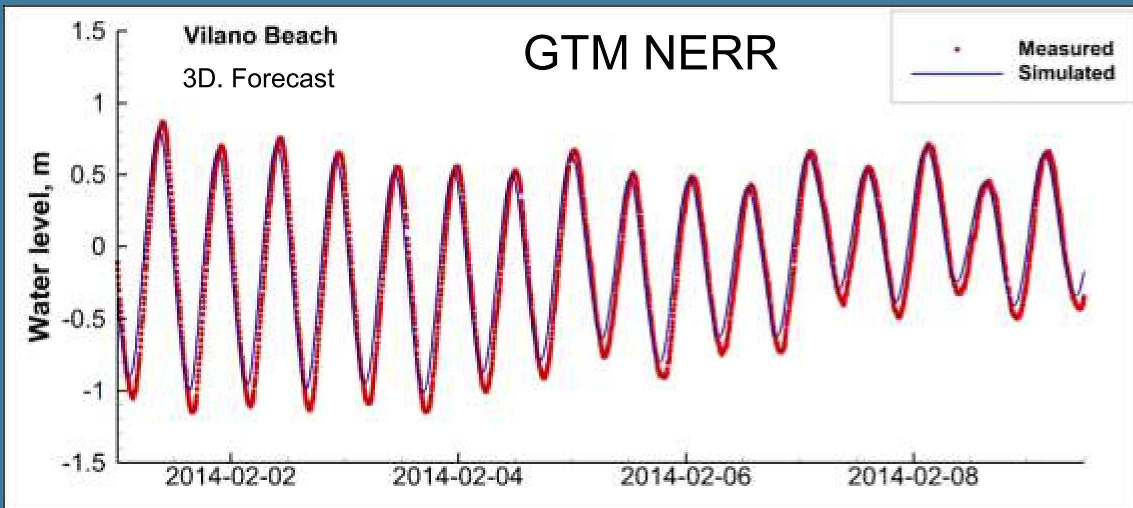


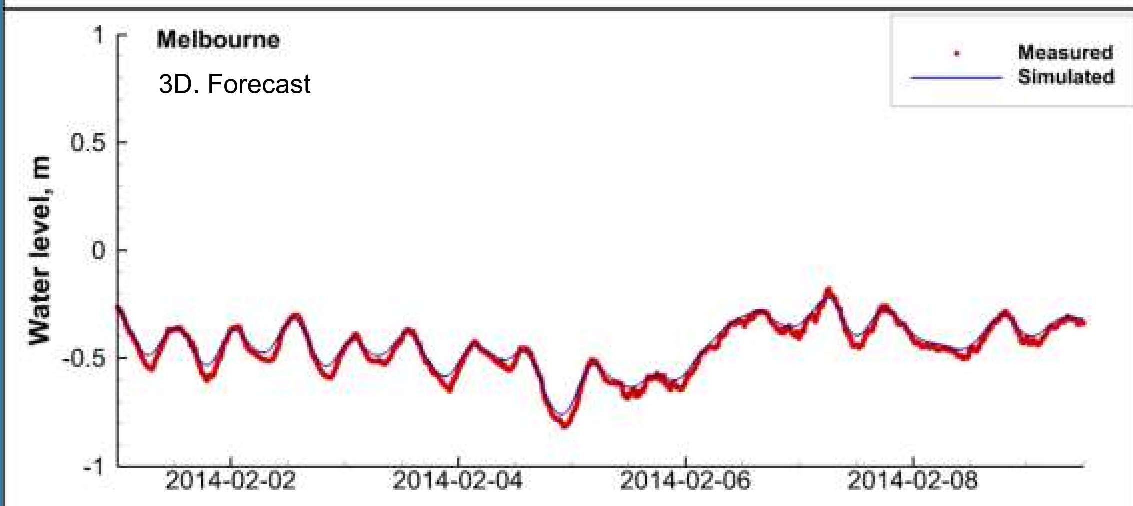
IOOS

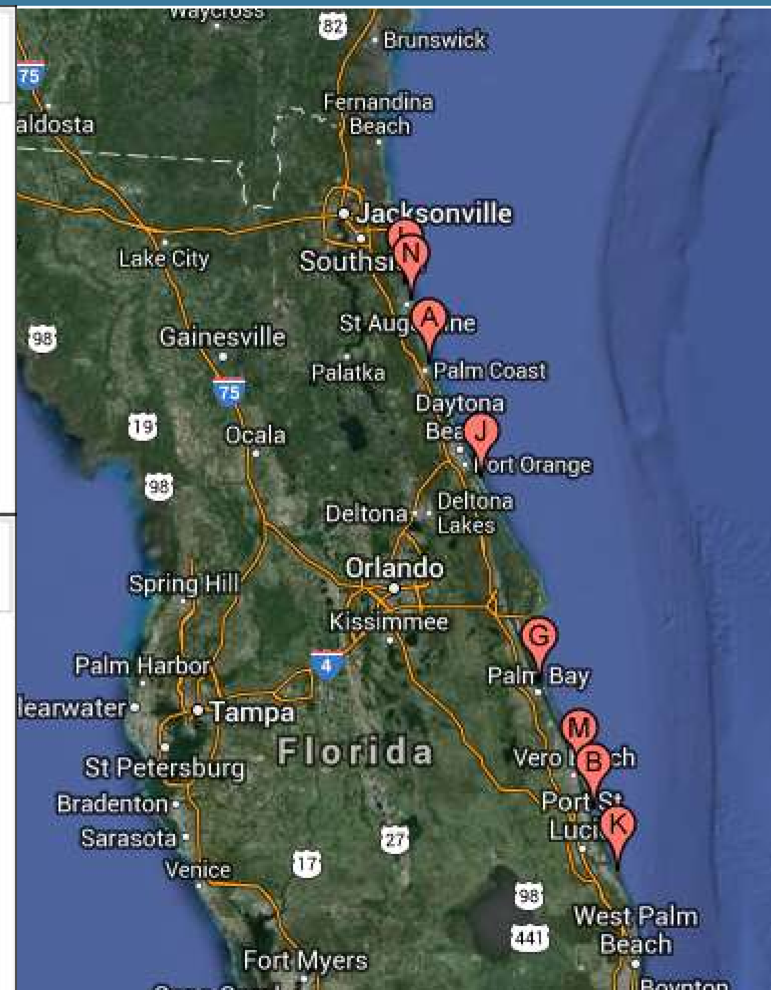
SECOORA
Southeast Coastal Ocean Observing Regional Association

East Florida Coast

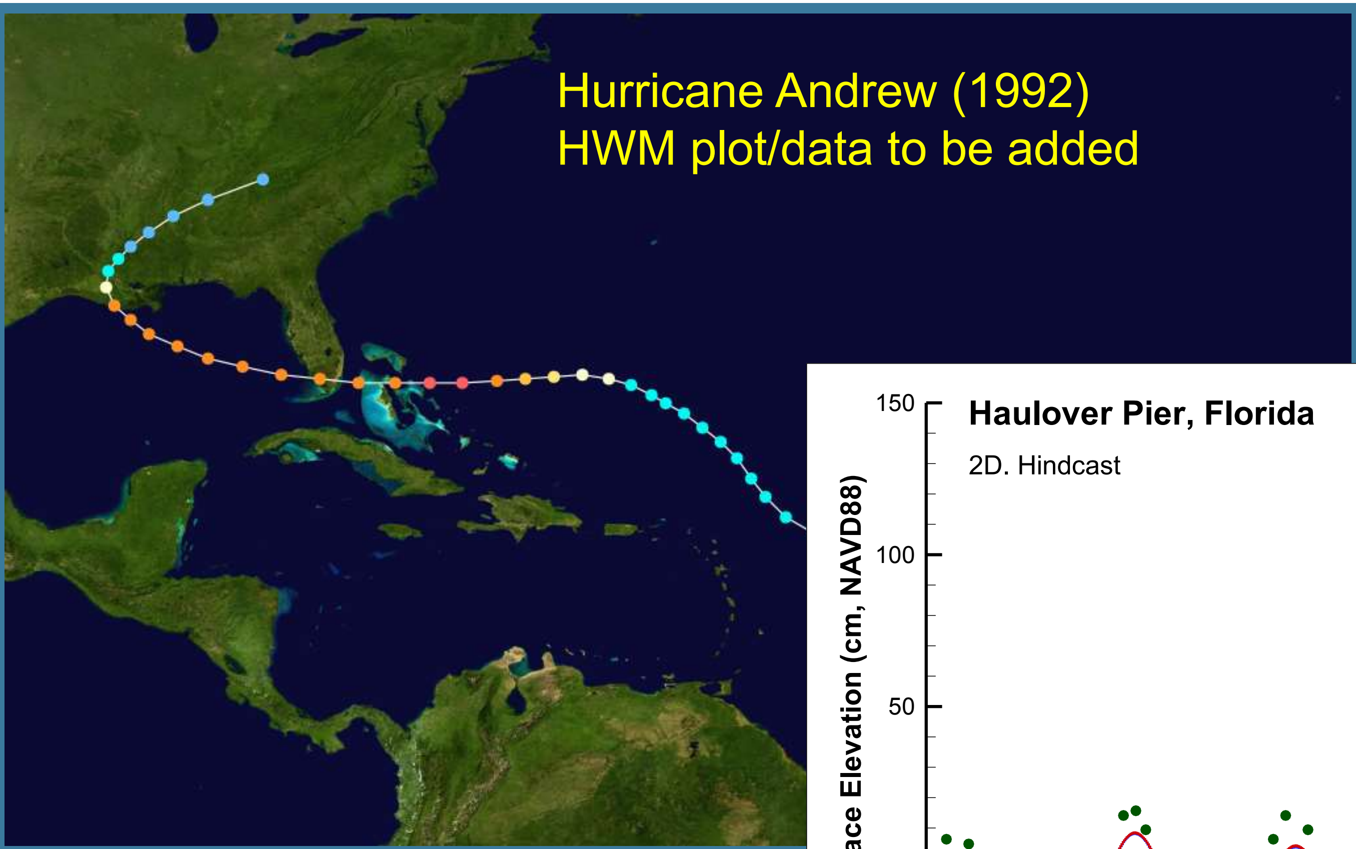
FDEP Water Level Stations

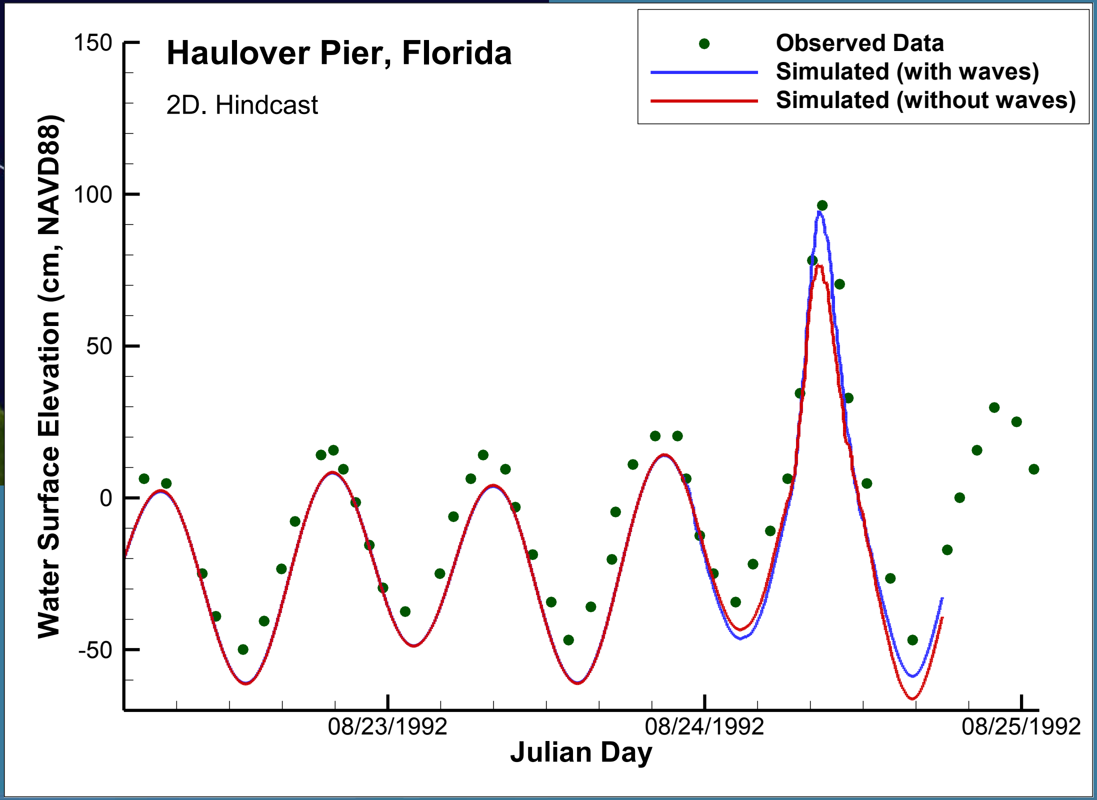






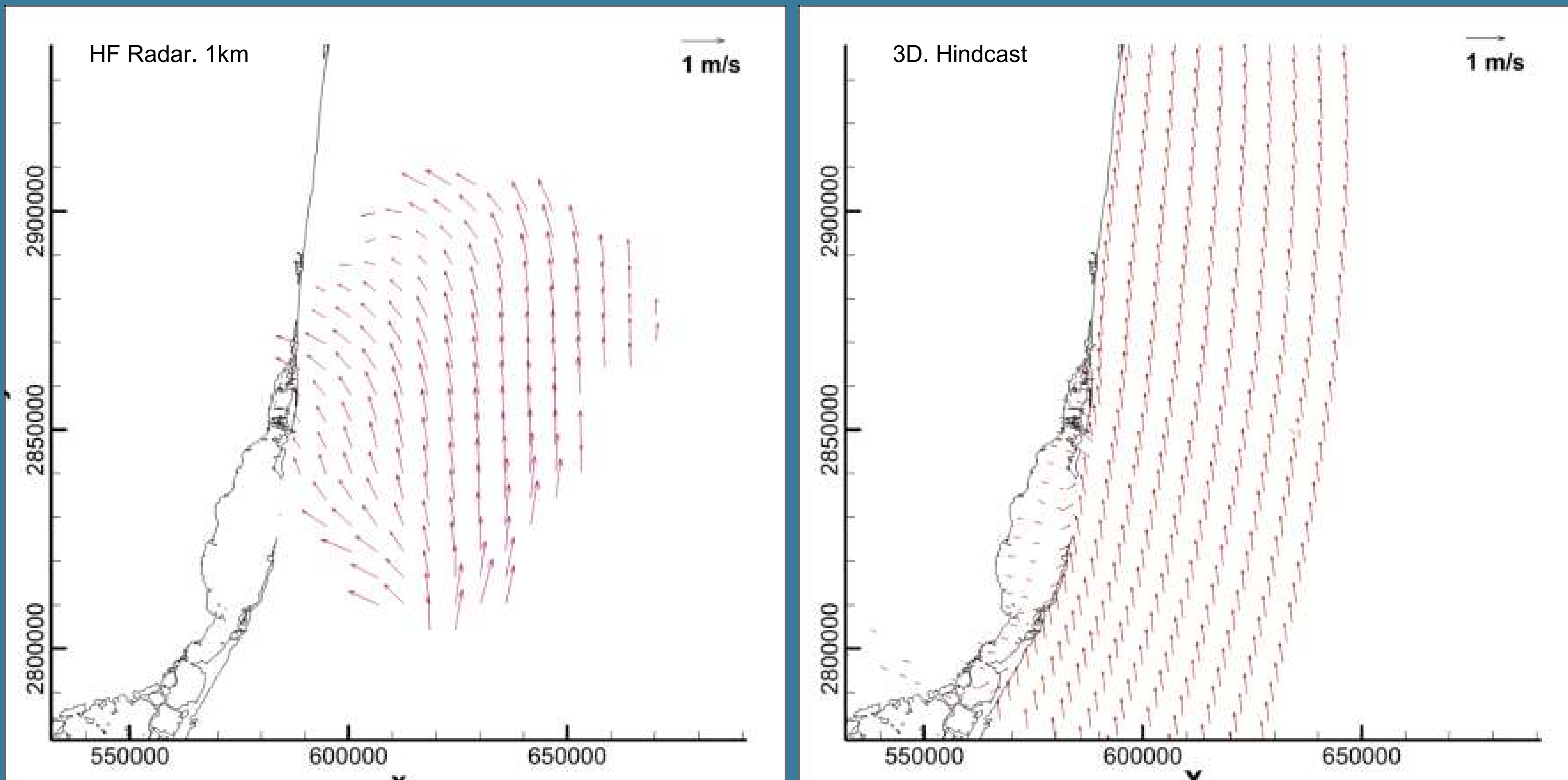
Southeast Florida Coast



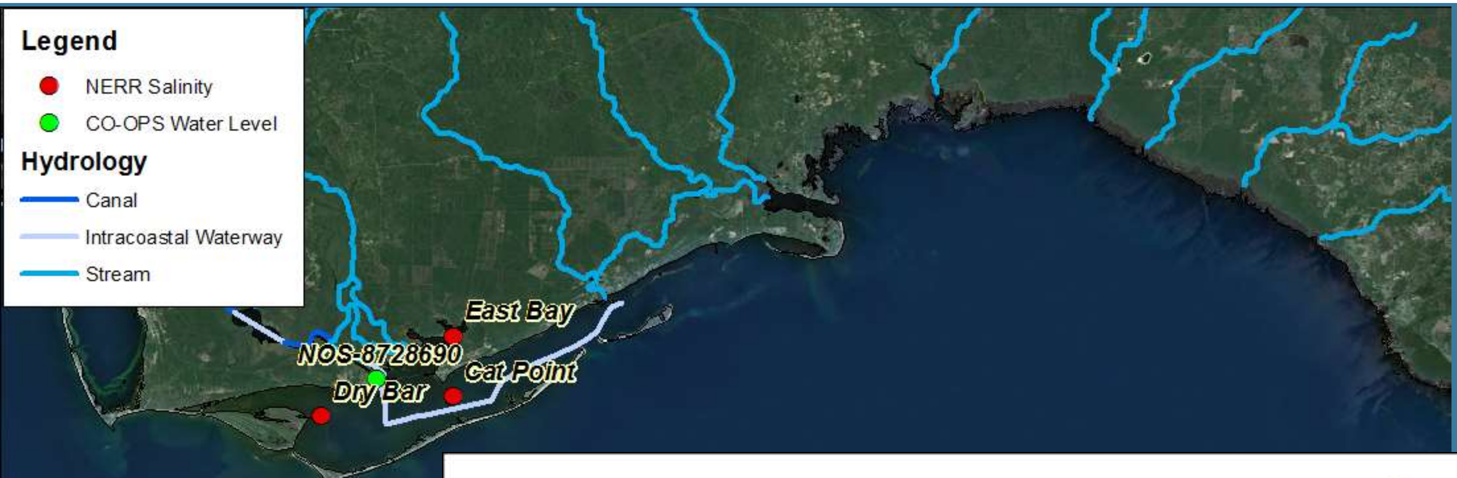


Southeast Florida Coast

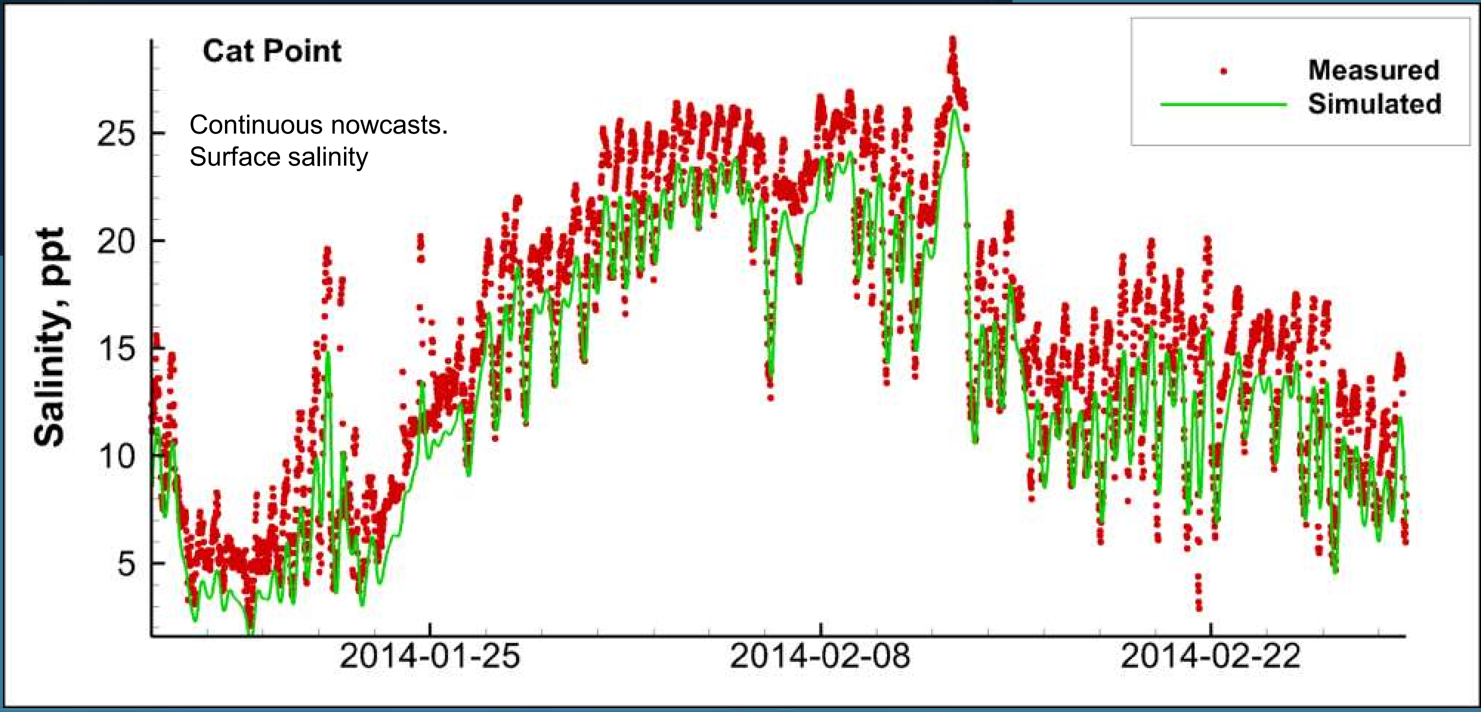
Surface currents



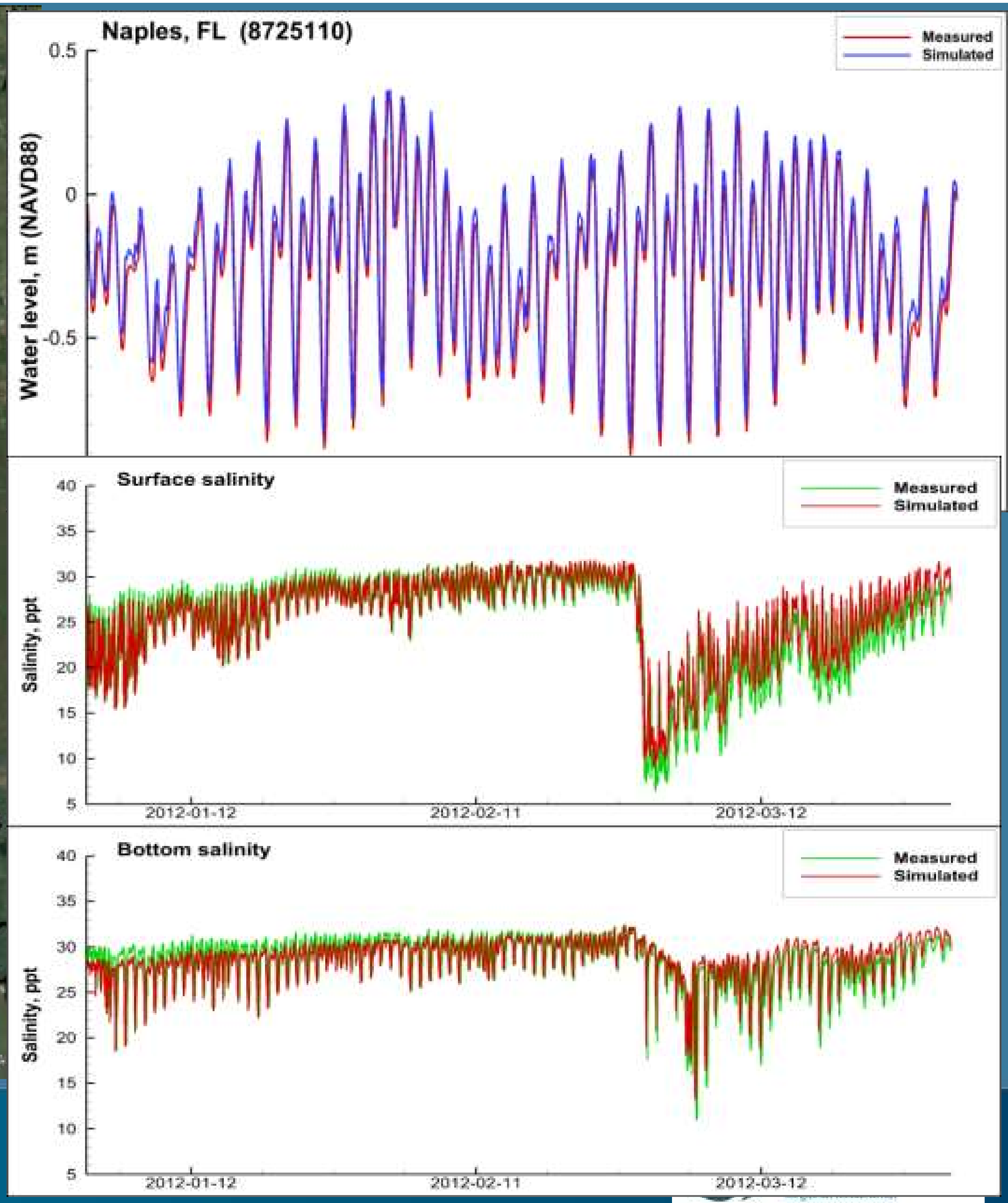
MW Florida Coast - Northern Gulf of Mexico



Apalachicola Bay

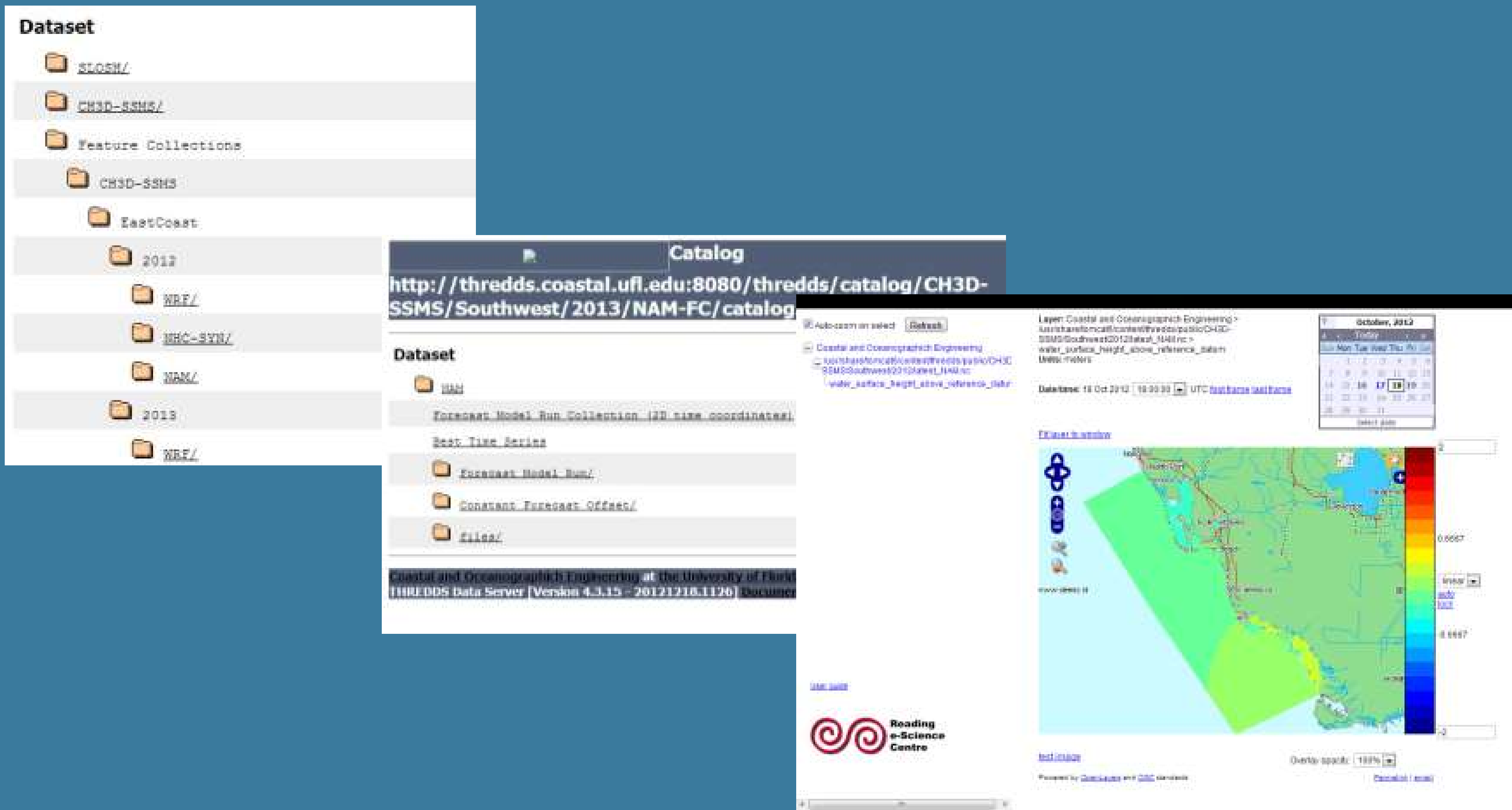


Southwest Florida Coast



Forecast Model Data Availability

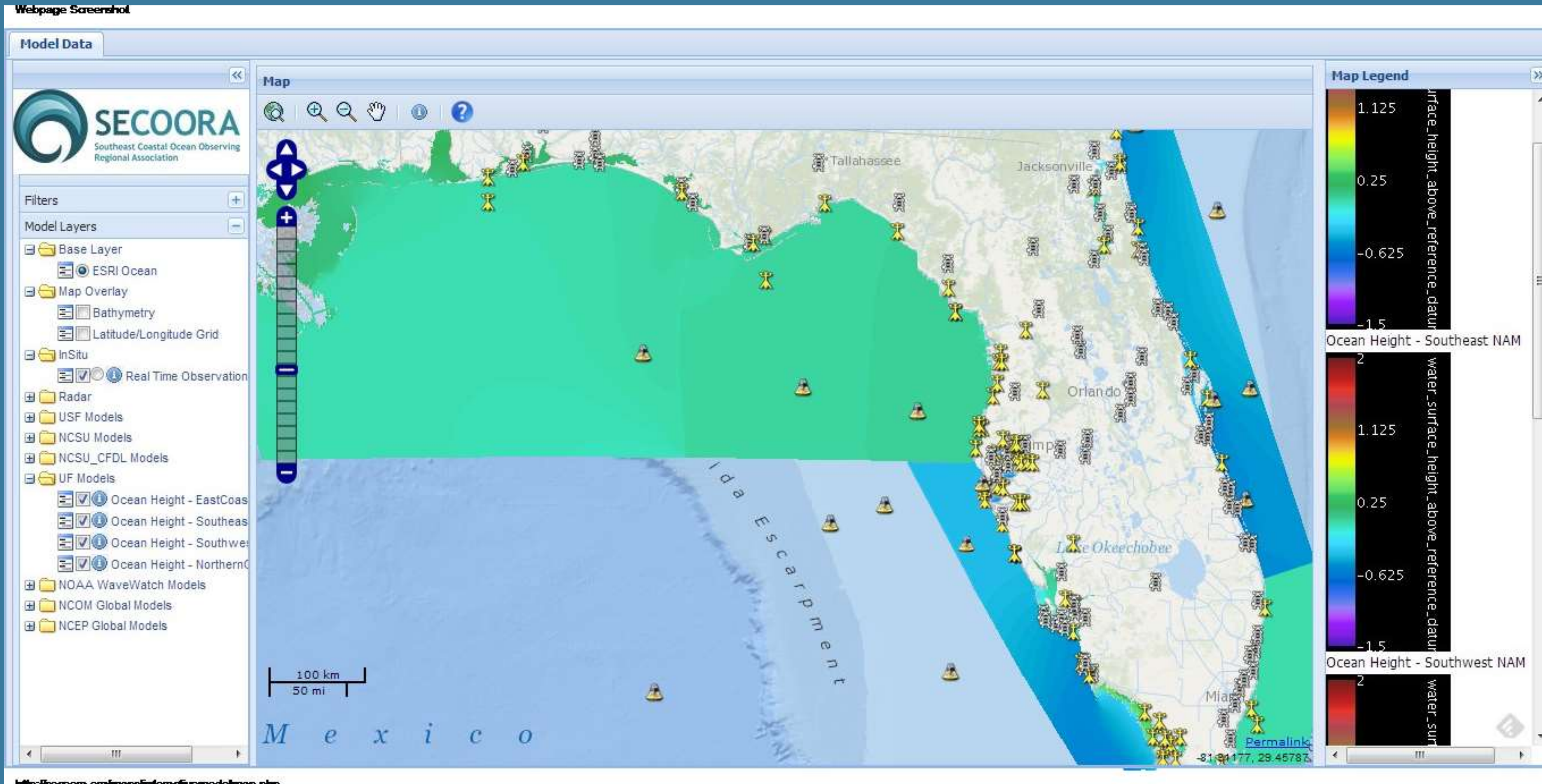
Model output available via THREDDS data server



thredds.coastal.ufl.edu:8080/thredds/catalog/CH3D-SSMS/catalog.html

Data Availability (Visualization)

- Data is picked up by SECOORA portal for visualization

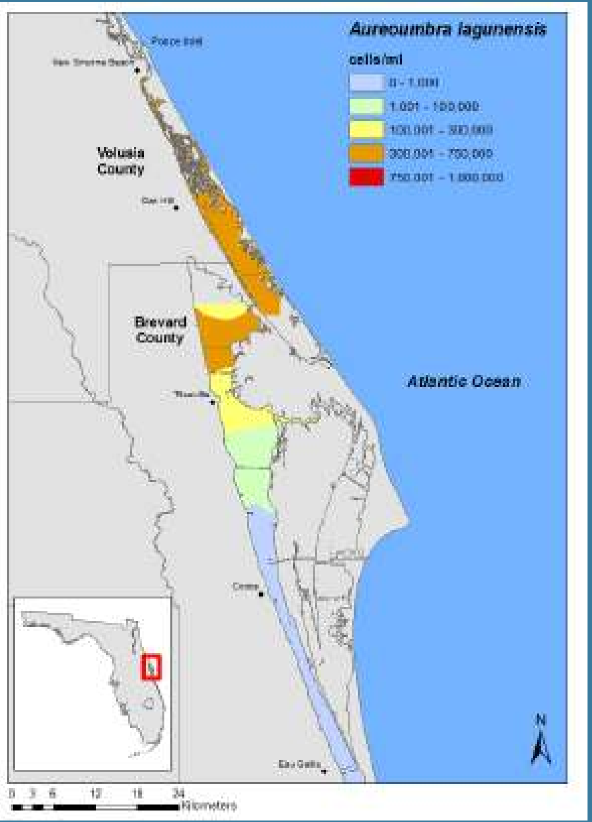


Superbloom in Indian River Lagoon
(Phlips et al., 2014)

Three bloom events:

- *Red Tides* bloom in 2006
  elevated **rainfall** (increase in **TN/TP**) and **water temperatures**>20° C
- *Green Tides* bloom in 2011
  exceptionally cold **water temperatures**
  low **rainfall** and high **salinities** > 30 psu in BRL
- *Texas Brown Tides* bloom in 2012
  a major **rainfall** event in June with increase in **TN/TP**
  salinities > 35 psu

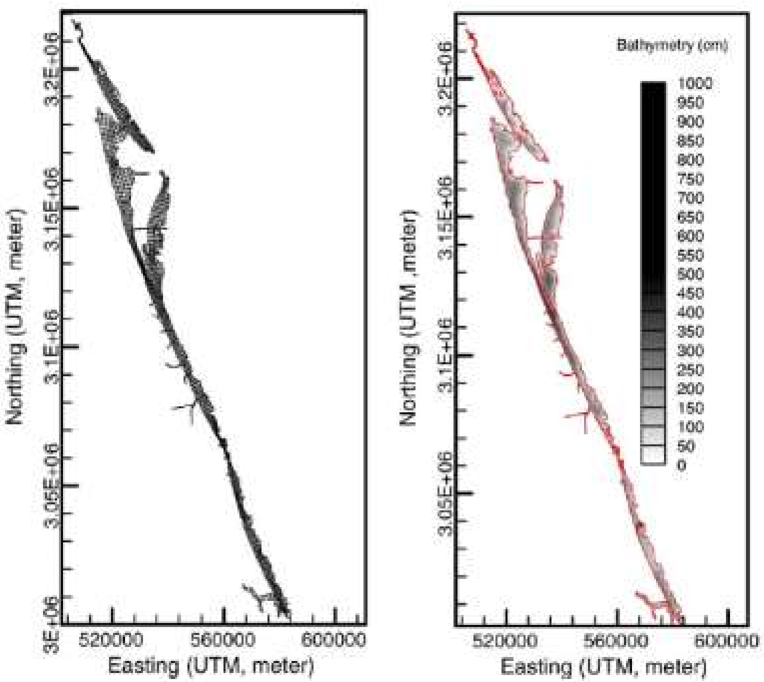
Brown Tide in July 2013



Banana River Lagoon has extremely long residence/flushing time ~ 1 year

The problem is worsening!

Skill assessment of an integrated modeling system for shallow coastal and estuarine ecosystems
Y. Peter Sheng and Taeyun Kim, J. Marine Systems, 2009



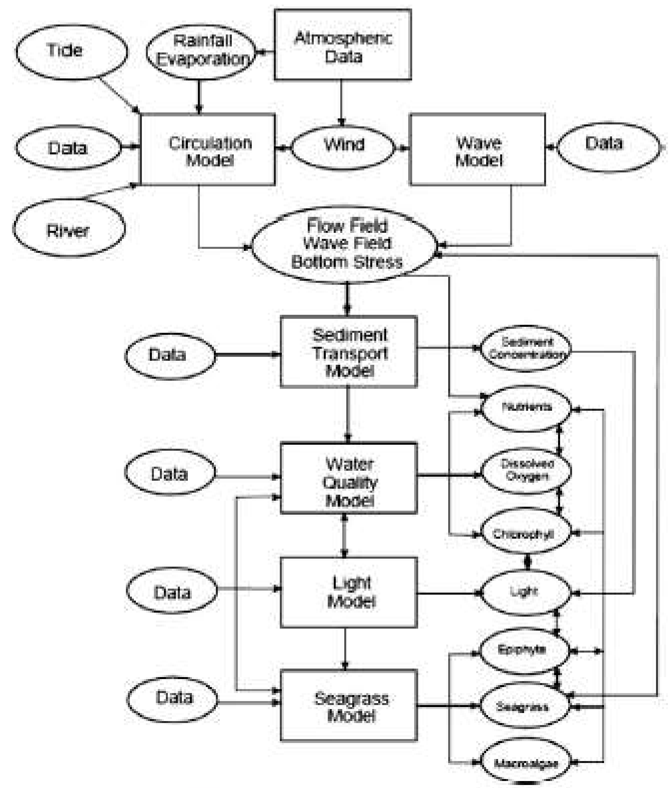
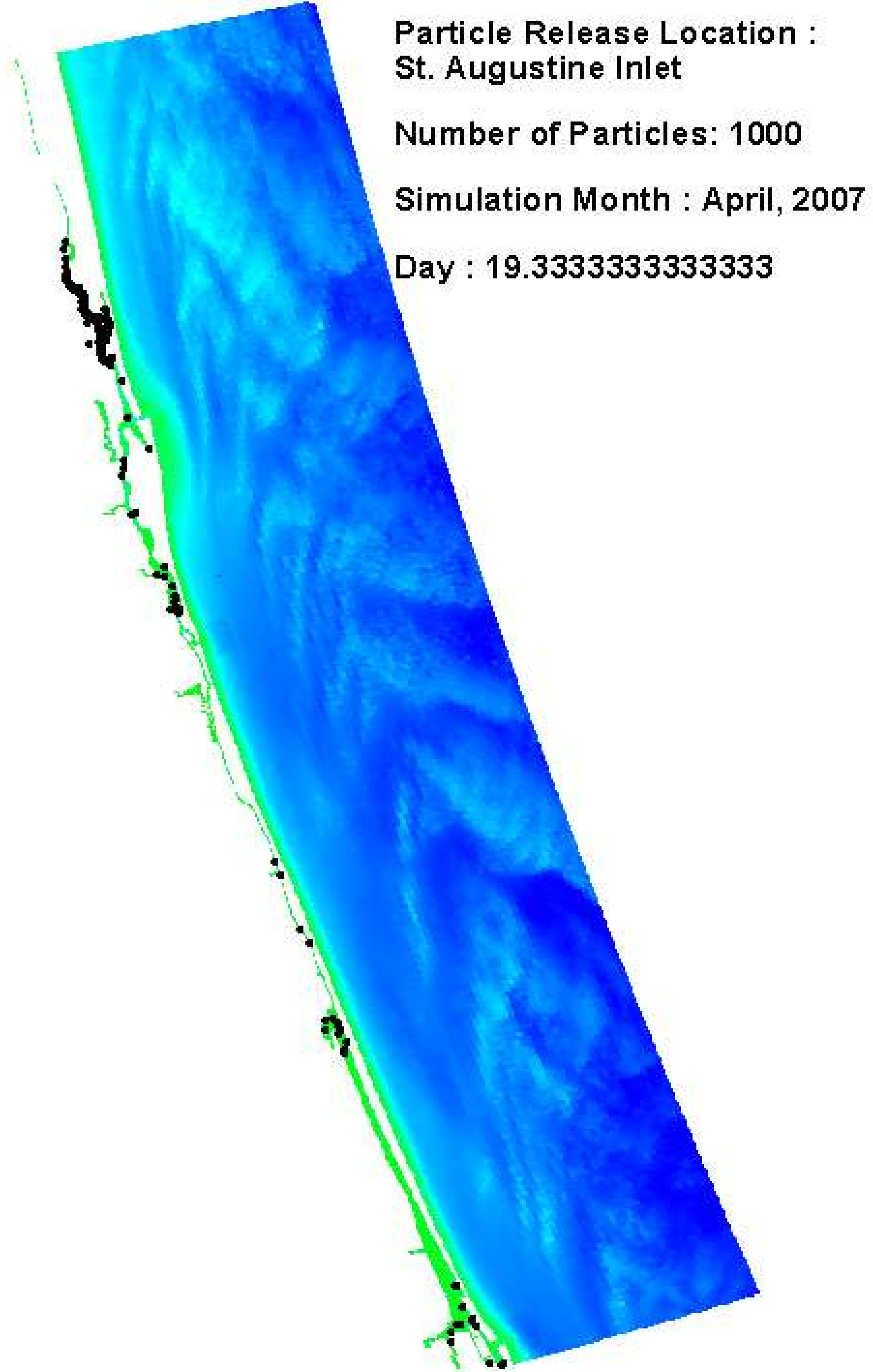
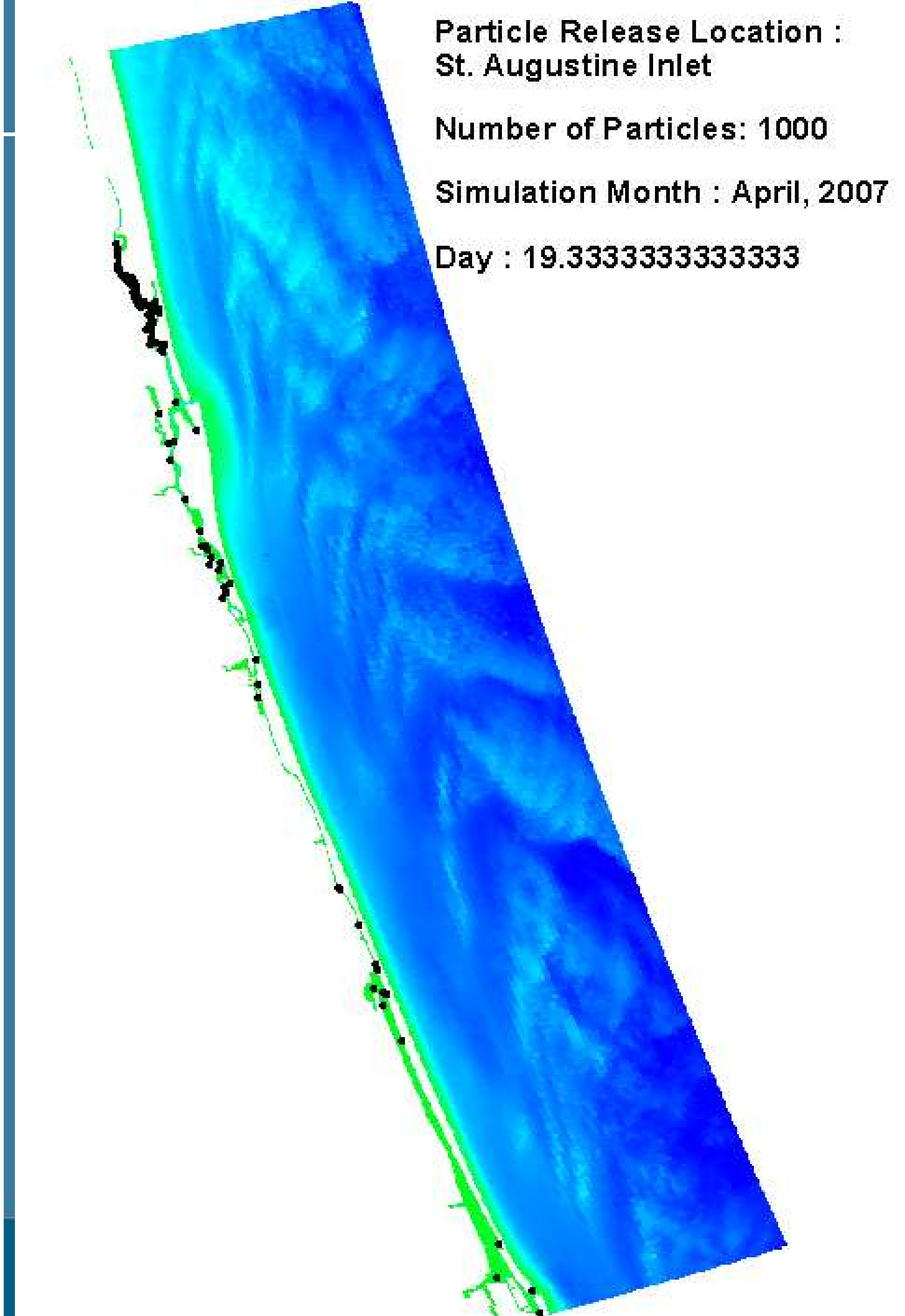
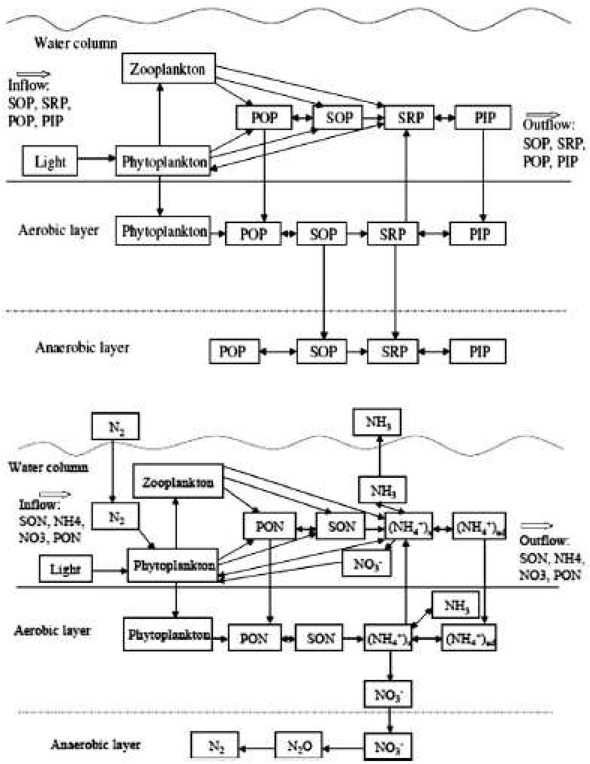
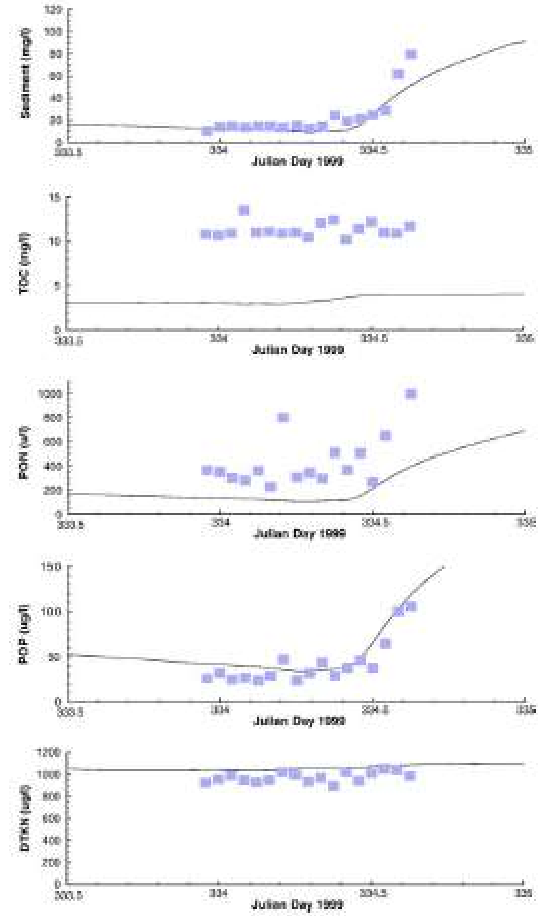


Fig. 6. The CH3D-IMS integrated modeling system.

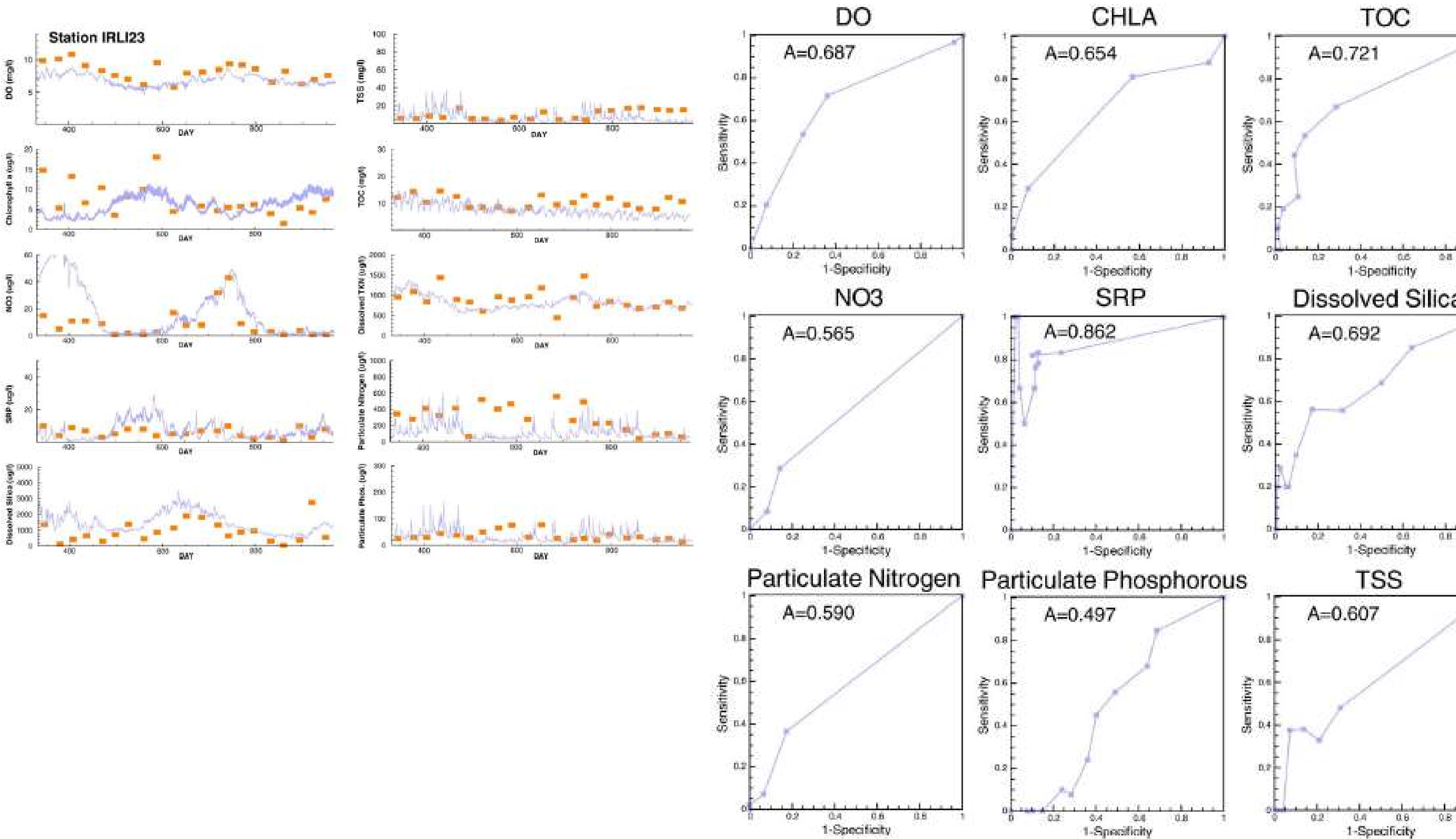

Particle Release Location :
St. Augustine Inlet
Number of Particles: 1000
Simulation Month : April, 2007
Day : 19.3333333333333

Particle Release Location :
St. Augustine Inlet
Number of Particles: 1000
Simulation Month : April, 2007
Day : 19.3333333333333

Resuspension of sediments and nutrients is important





Coupled hydrodynamic-biogeochemical model tested with 2-year data

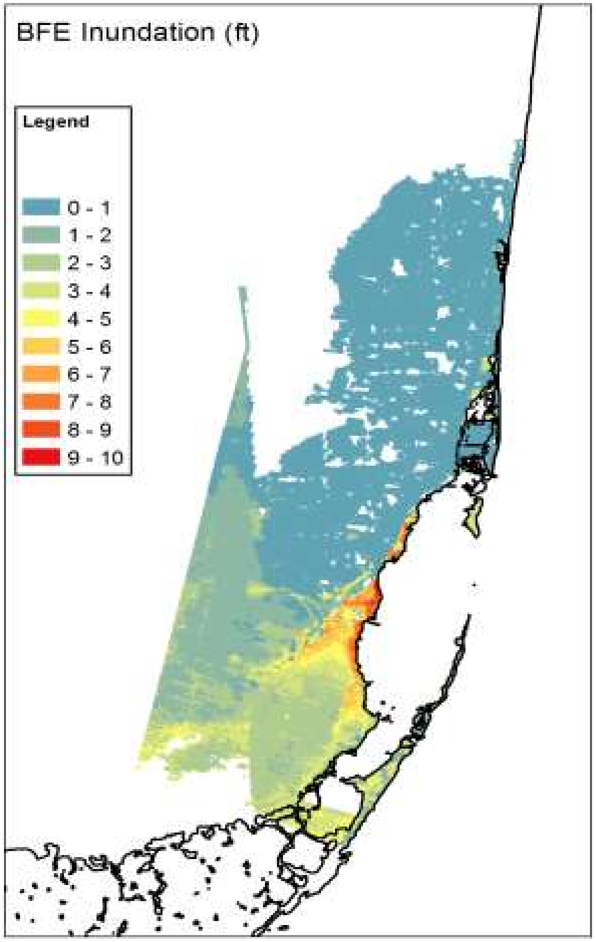


Forecasting of conditions favorable for red, green, and brown tides in IRL?

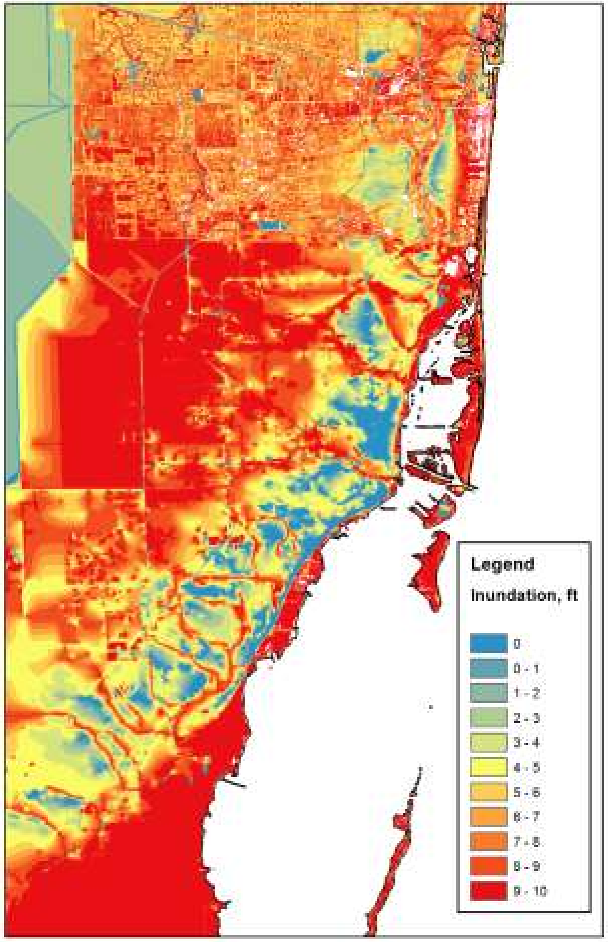
- Currently forecasting 3D circulation in IRL
- Add nutrient/water quality components to the forecasting model

1% Annual Probability Inundation Map for Miami-Dade & Broward by 2080-2100 (including 100cm Sea Level Rise and Hurricanes in future climate)

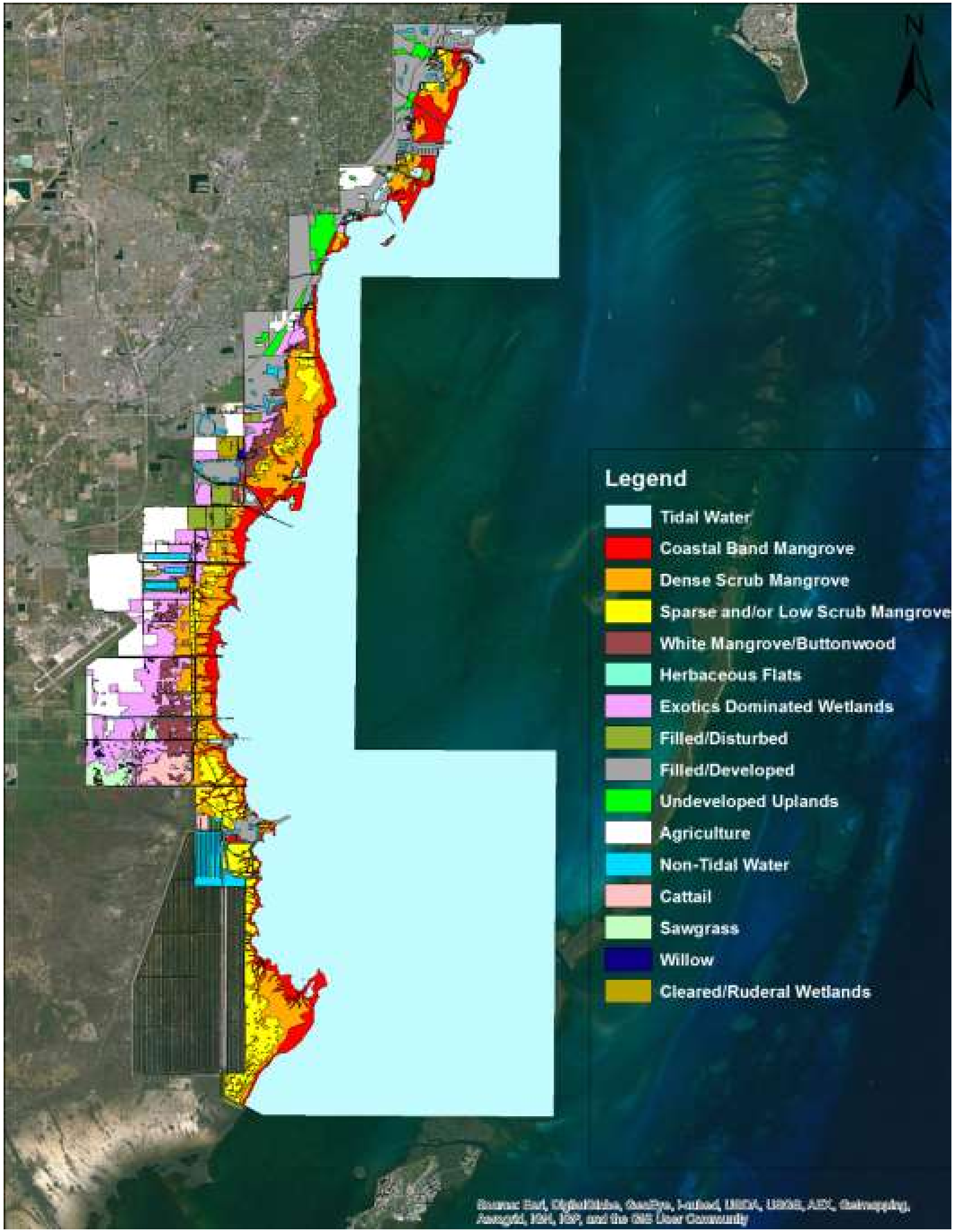
Dynamic Climate+Coastal Models

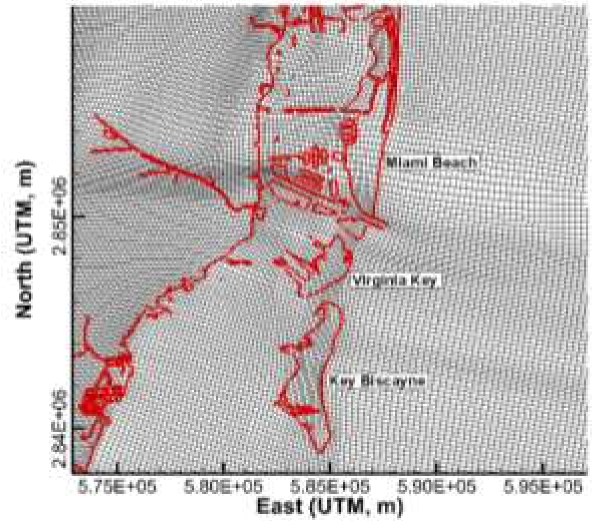


"Bathtub" model (max surge + SLR)

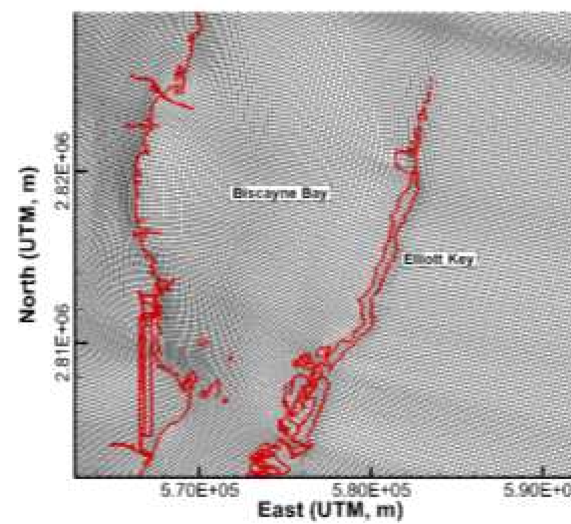


Over-estimate Inundation!



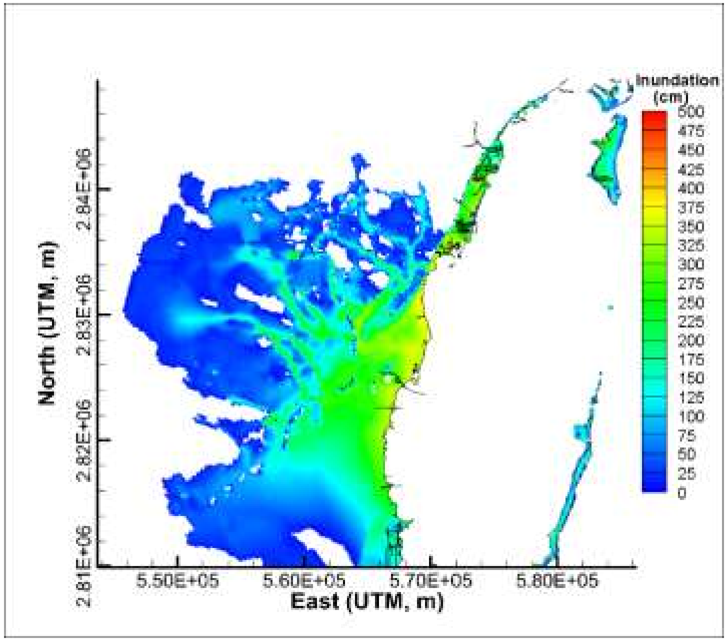


Wetlands of Miami-Dade County,

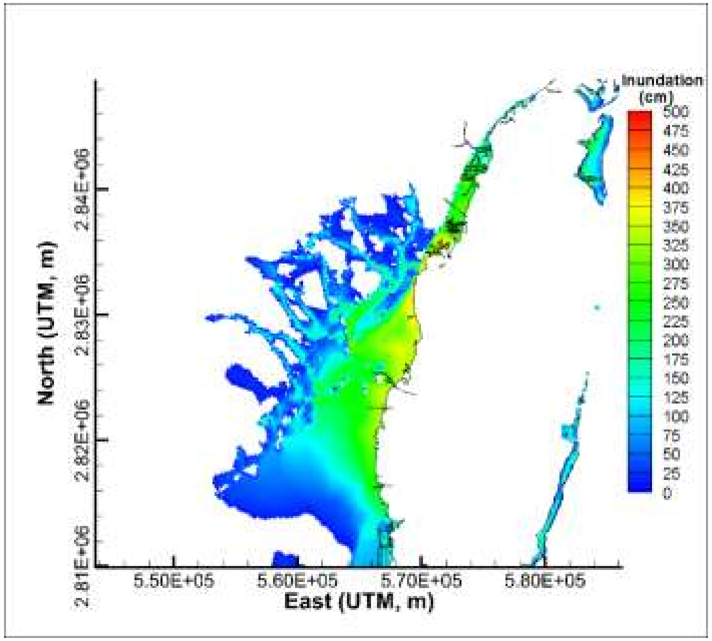


Vegetation reduces flooding in Miami-Dade County

(maximum inundation map during Hurricane Andrew)



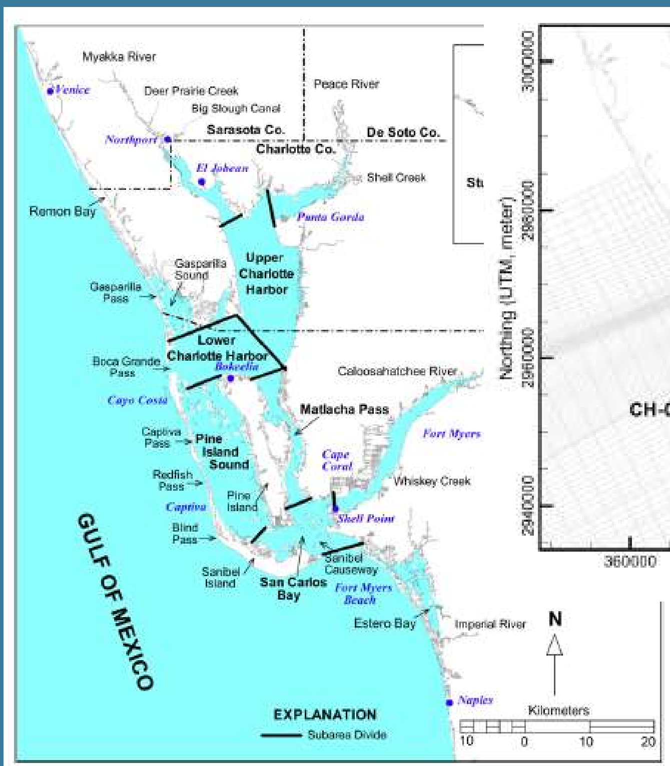
Vegetation Free

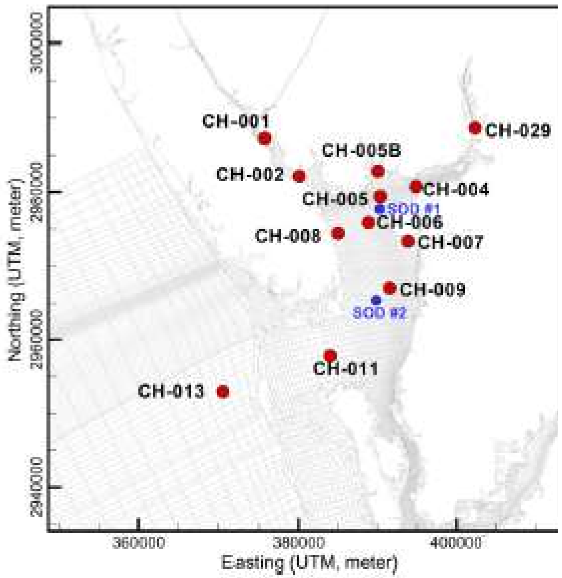


Mangroves – Case 1: 300 stems/m2, 150 cm

Modeling water quality and hypoxia dynamics in Upper Charlotte Harbor, Florida, U.S.A. during 2000

Taeyun Kim 1, Y. Peter Sheng*, Kijin Park, ECSS, 2010





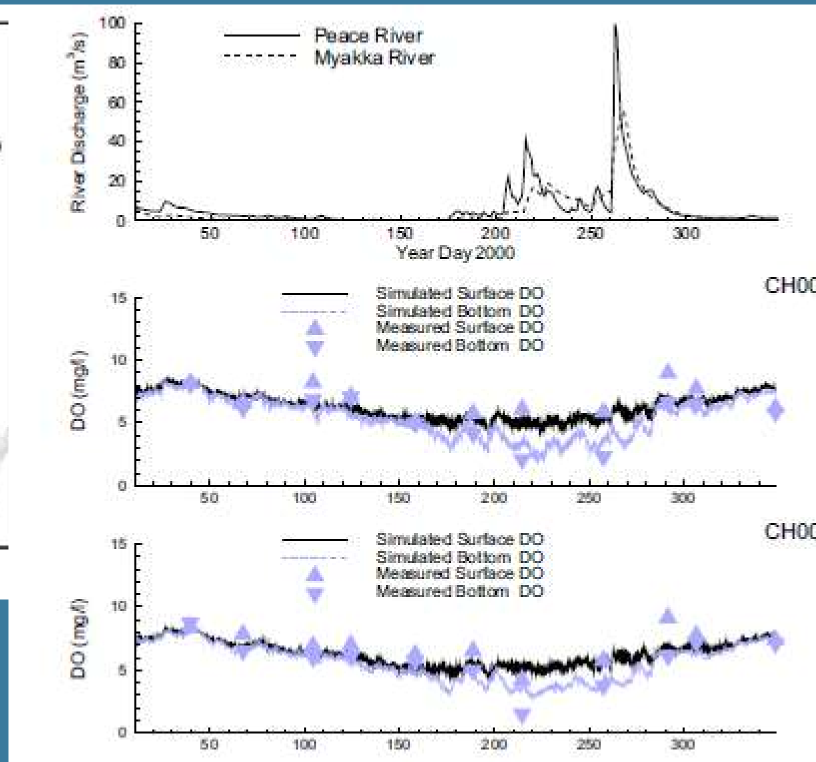


Fig. 5. River discharge and DO at CH005 and CH006 in 2000.

Forecasting of Hypoxia in Charlotte Harbor?

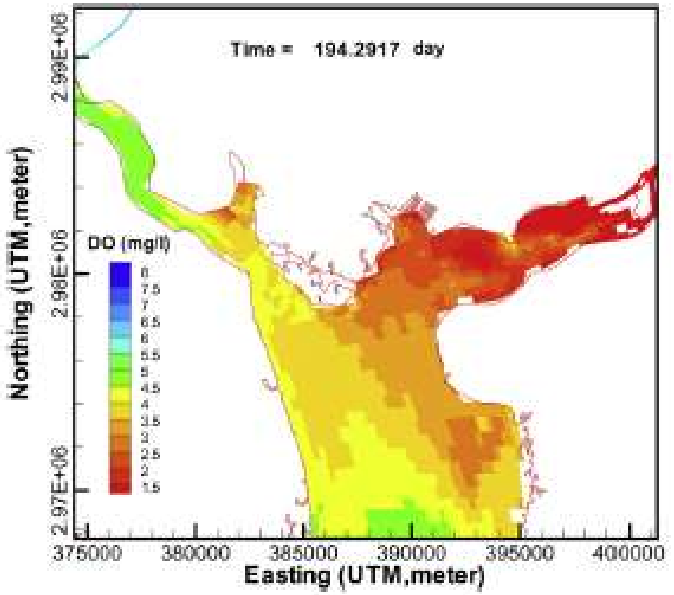
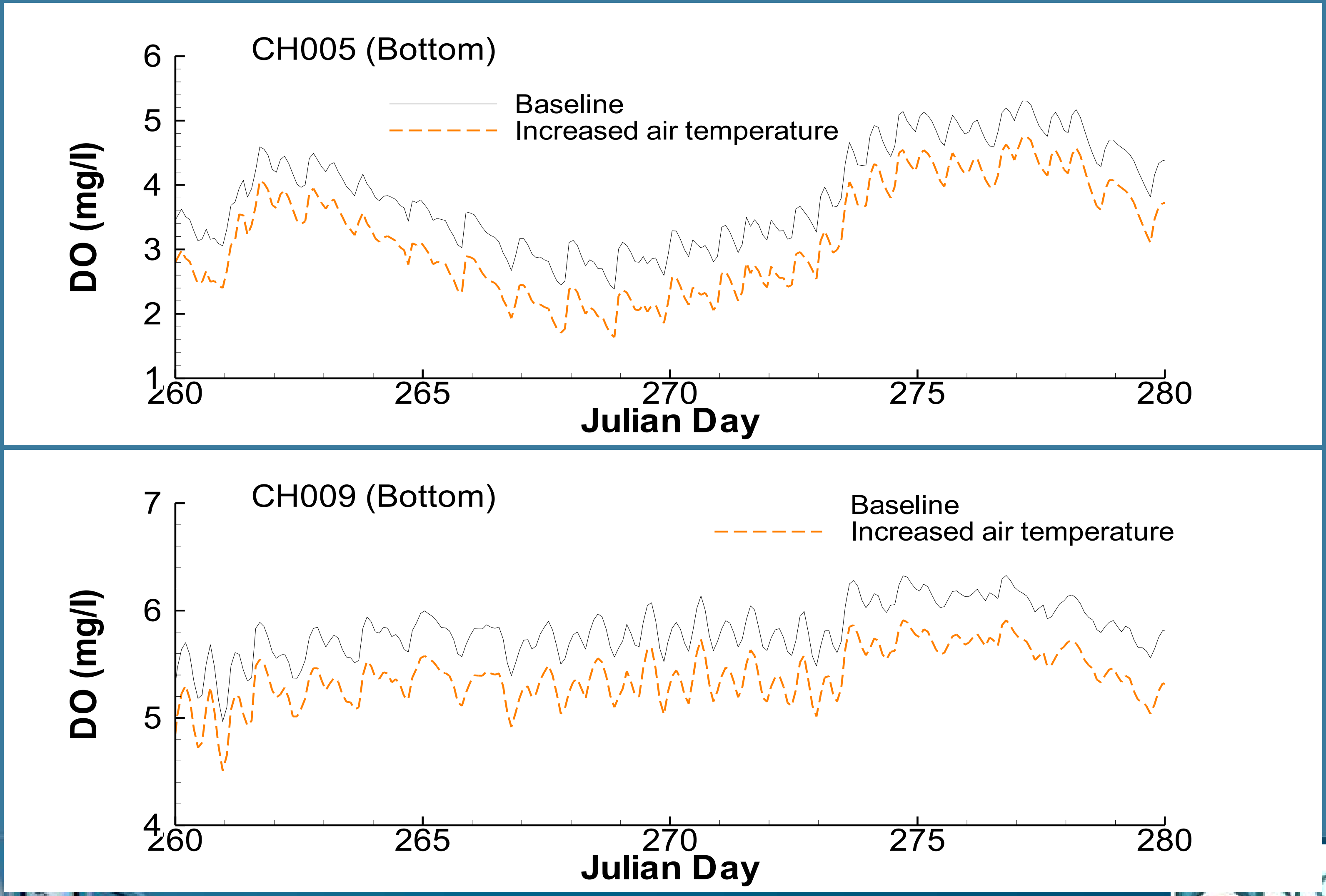


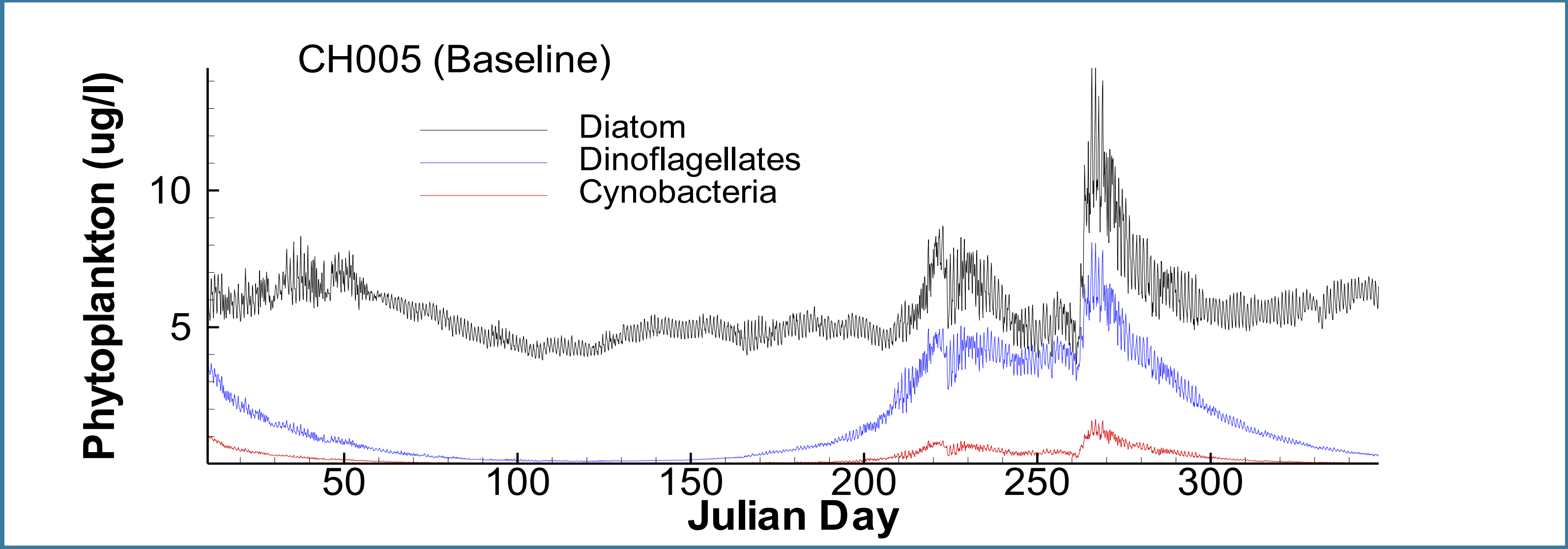
Fig. 7. Simulated near-bottom dissolved oxygen concentration in Upper Charlotte Harbor on July 12, 2000.

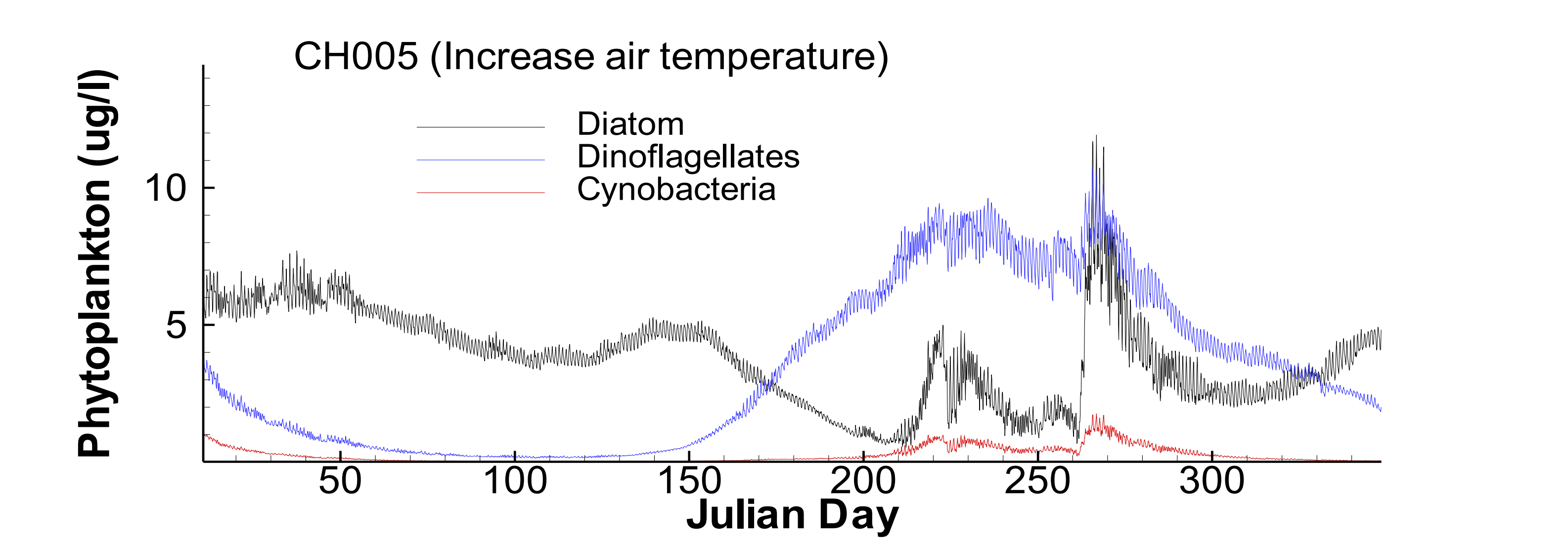
- **Currently forecasting 3D circulation**
- **Add nutrient/water quality forecasting**

DO in the Upper Charlotte Harbor
(Increased air temperature of 3°)



Phytoplankton in the Upper Charlotte Harbor
(Increased air temperature of 3°)





Thank You!

Questions?

Habitat Modeling for Fisheries

South Atlantic Ecosystem Modeling Workshop February 10-11, 2015

Mitchell Roffer

Two Projects

- Highly Migratory Species in Gulf of Mexico
- Reef Species in South Atlantic Bight

Management And Conservation Of Atlantic Bluefin Tuna (*Thunnus Thynnus*) And Other Highly Migratory Fish In The Gulf Of Mexico Under IPCC Climate Change Scenarios: A Study Using Regional Climate And Habitat Models.

- PI: M. A. Roffer – ROFFS™
- Co-I: J.T. Lamkin (NOAA), F.E. Muller-Karger (USF), S-K Lee (UM CIMAS), B.A. Muhling (UM CIMAS), G.J. Goni (NOAA)
- Other Investigator: Y. Liu (UM CIMAS), M.A. Upton, (ROFFS™) & G. Gawlikowski (ROFFS™), G.W. Ingram (NOAA)
- Other collaborators added: W. Nero (NOAA), J. Franks (USM), J. Quattro (USC) D. Enfield (NOAA), John F. Walter (NOAA), A. Bakun (UM RSMAS), K. Ramirez (INAPESCA), F. Alemany (IEO), A. Garcia (IEO) . . and growing
- Start date September 06, 2011 – End date September 05, 2015

Habitat Modeling for Fisheries-Independent Trap Surveys

South Atlantic Ecosystem Modeling Workshop February 10-11, 2015

Mitchell Roffer, Barbara Muhling, Roger Pugliese and Marcel Reichert

SECOORA
Southeast Coastal Ocean Observing Regional Association

CIMAS

South Atlantic Fishery Management Council
"To Conserve and Manage"

DNR

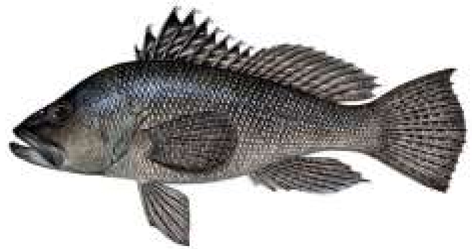
ROFFS™

Project Aims: Habitat Modeling

- Provide species-specific habitat models that integrate remotely sensed and *in situ* data to enhance SAFMC stock assessments through the SEDAR stock assessment program
- Incorporate environmental factors into fishery independent indices of abundance

Ecosystem-based Approach to Fisheries Management

Species of interest



- **Gray triggerfish** (*Balistes capriscus*)
- Max length 60cm, common 44cm
- Depth range 1 - 100m, commonly 0-55m
- Distributed eastern and western Atlantic coasts

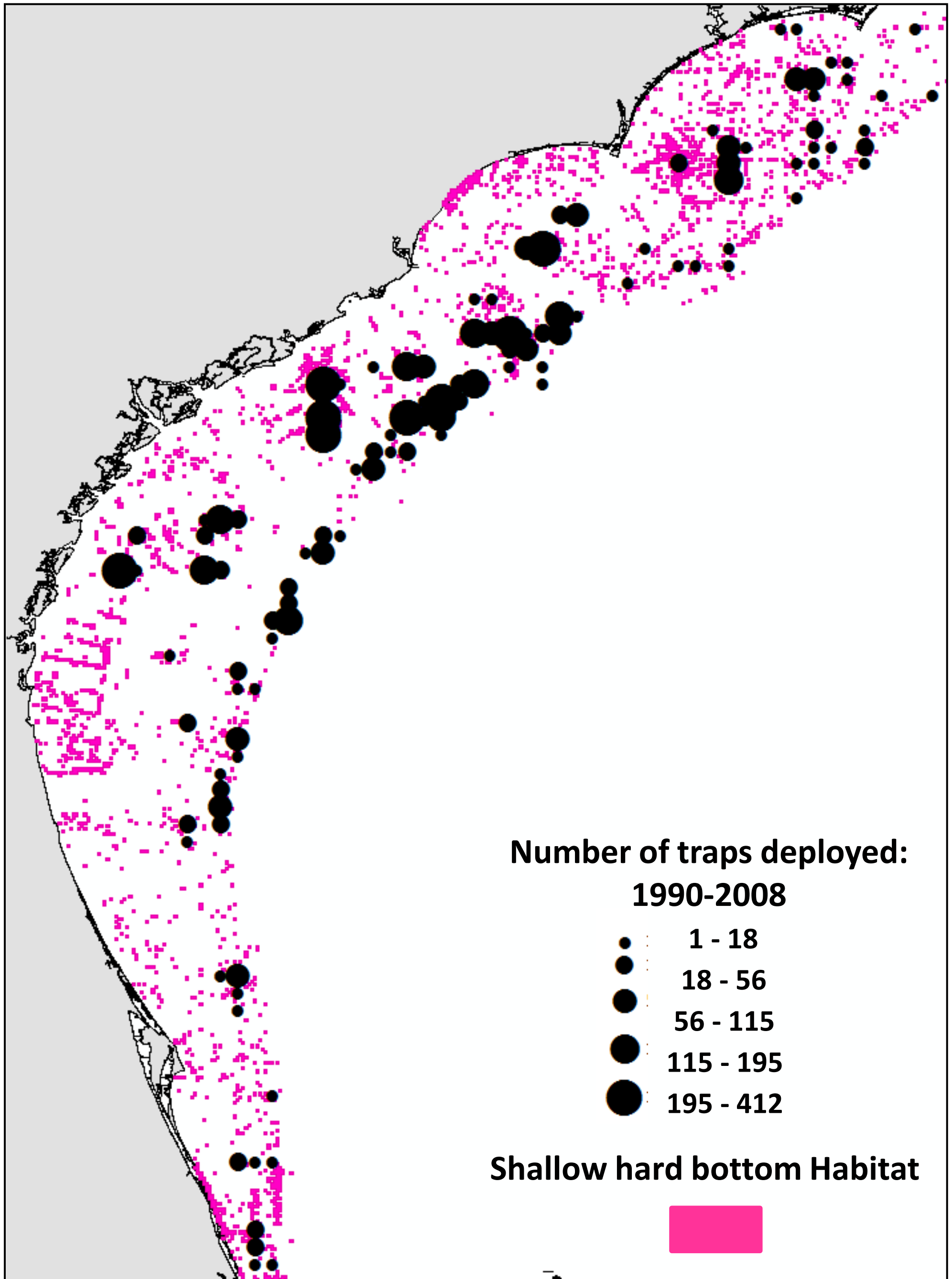
- **Black seabass** (*Centropristis striata*)
- Max length 66cm, common 30cm
- Depth range 1 -?m, mostly shallow
- Distributed western Atlantic coasts south to South Florida

- **Red porgy** (*Pagrus pagrus*)
- Max length 91cm, common 35cm
- Depth range 0 - 250m, commonly 10 - 80m
- Distributed eastern and western Atlantic coasts

- **Vermillion snapper** (*Rhomboplites aurorubens*)
- Max length 60cm, common 35cm
- Depth range 40-300m, commonly 40-100m
- Distributed western Atlantic coasts North Carolina to Brazil

All of ecological and economic significance to fisheries

Chevron Trap Sampling



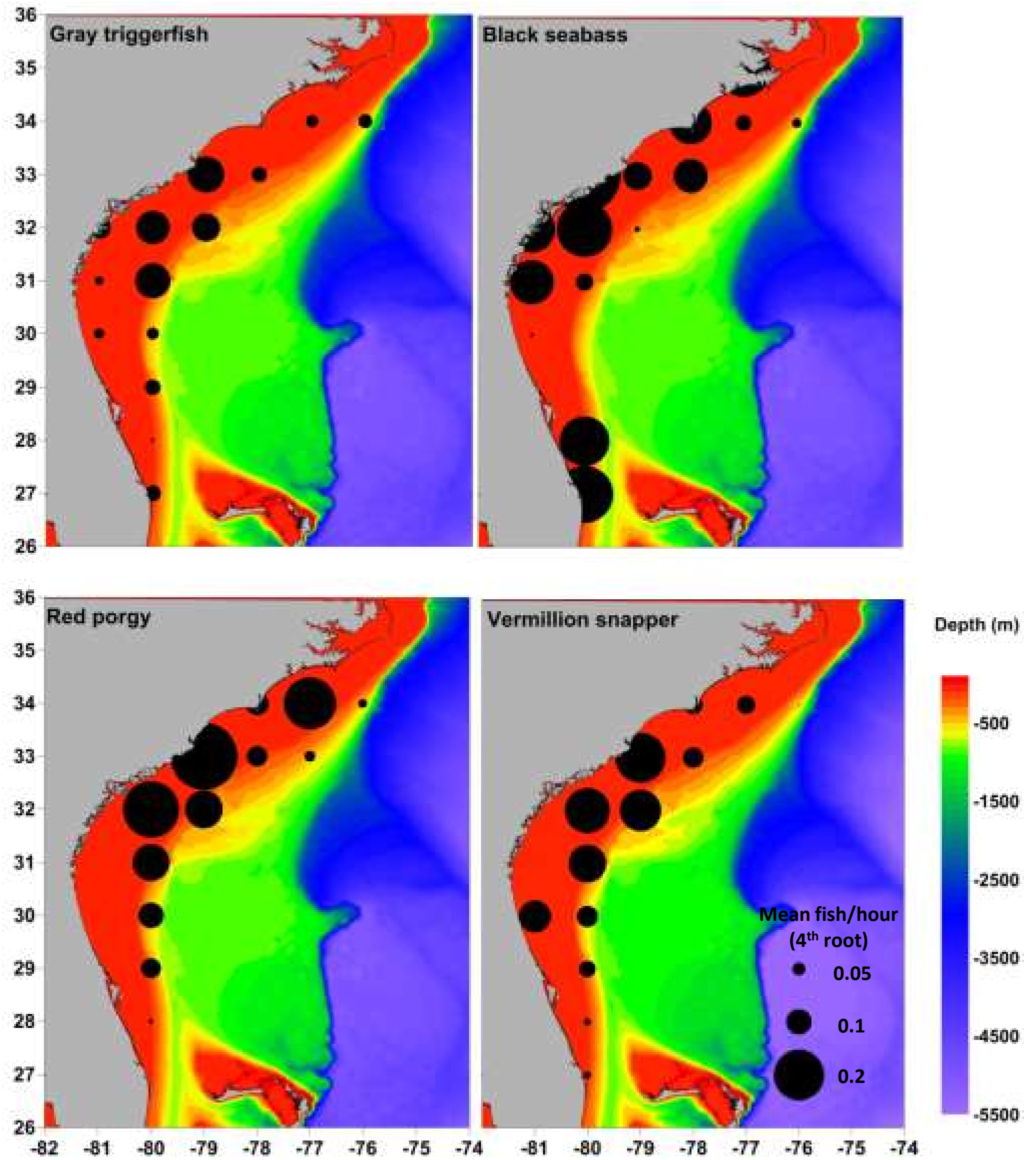
- MARMAP program has been using chevron traps for fisheries-independent sampling since 1990
- Includes continental shelf and shelf edge waters from Cape Hatteras, NC to St Lucie Inlet, FL
- Traps deployed during spring and summer field cruises, in groups of six on hardbottom habitat
- Catches used to form abundance indices for stock assessment

A chevron fish trap

Photo: NOAA

General distribution

- Most species collected across study range
- Black seabass more abundant off Florida



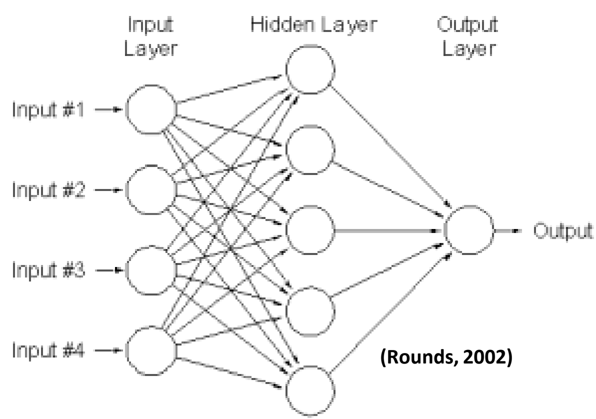
Using environmental and habitat data in stock assessments

- **Pros:**
  - Can account for unexplained variability in catch time series
  - Can improve predictions of future stock sustainability
- **Cons:**
  - Can increase model complexity
- **Methods**
  - Habitat based standardization (HBS)
  - Statistical habitat based models (statHBS)
  - Additional variables in a GLM
- **Examples**
  - Pacific sardine and sea surface temperature
  - Pacific billfish and vertical habitat/hook depths
  - Not many examples from the Atlantic

Habitat Modeling Methods

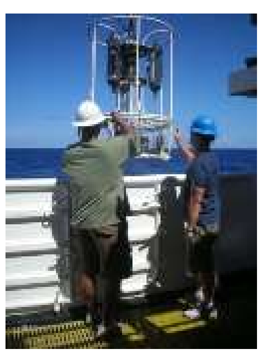
- Biological responses to environmental variables are frequently non-linear, and include strong interactions
- Multivariate, non-parametric methods are therefore a good choice for habitat models
- In this project, we used artificial neural networks, and boosted classification trees
- Both methods are well suited are well suited for large datasets containing complicated nonlinear relationships
- We initially used models to predict probabilities of occurrence

Habitat model

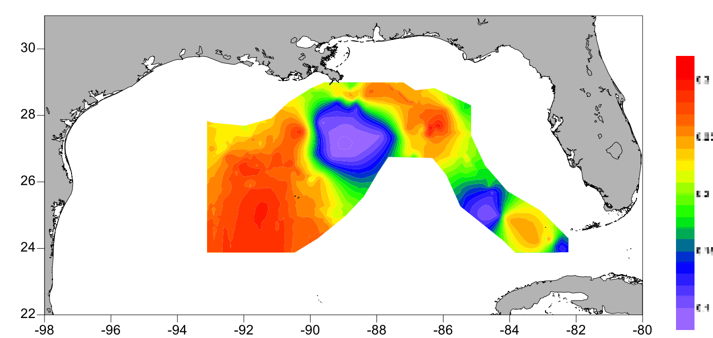


(Rounds, 2002)

Environmental Data



Predictive Outputs



Predictor Variables

- **Positional Variables**
  - Longitude
  - Latitude
  - Water Depth
- **Sampling Variables**
  - Soak Duration
  - Deployment Time
  - Date
- **Environmental Variables**
  - Bottom Temperature
  - Surface Temperature
  - Surface – Bottom Temperature
  - Bottom Salinity
  - Wave Height
  - Wind Speed
  - Moon Phase
- **Biological Variables**
  - Biomass of predatory fish species (larger groupers/snappers/eels)

Habitat Modeling Results

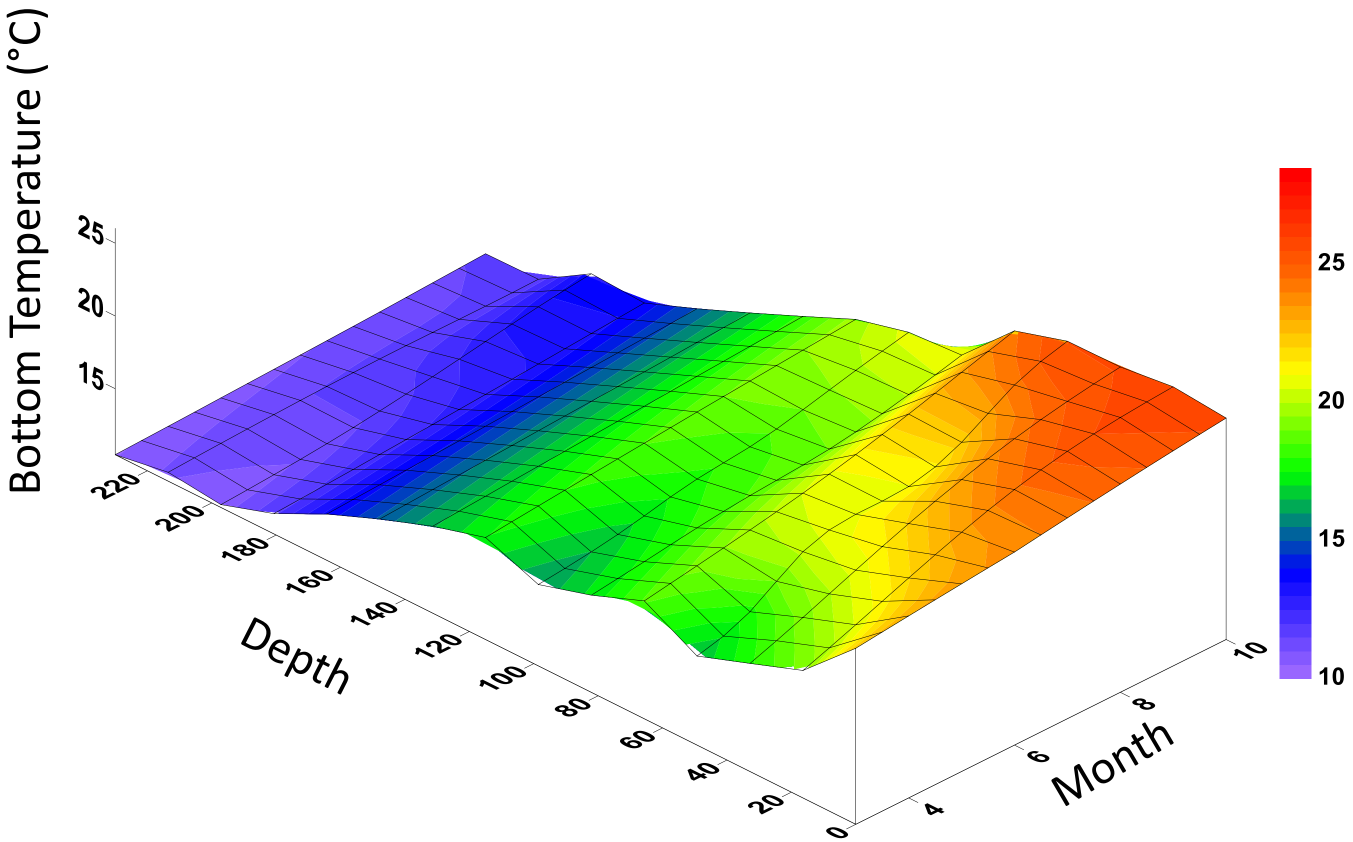
- Black seabass and red porgy were best predicted by positional variables: water depth, longitude and latitude
- Bottom temperature was also important to occurrences of gray triggerfish and vermillion snapper

Gray Triggerfish		Black Seabass		Red Porgy		Vermillion Snapper	
Variable	***Importance***	***Variable***	***Importance***	***Variable***	***Importance***	***Variable***	***Importance***
Bottom temperature	100	**Water depth**	100	**Water depth**	100	**Longitude**	100
Latitude	76.1	**Longitude**	16.2	**Latitude**	50.4	**Water depth**	97.9
Water depth	56.8	**Latitude**	9.8	**Longitude**	42.7	**Latitude**	85.6
Date	29.0	**Date**	5.4	**Date**	10.2	**Bottom temperature**	82.3
Predator biomass	26.4	**Surface temperature**	4.4	**Time**	7.8	**Date**	39.2
Longitude	23.2	**Predator biomass**	3.1	**Surface temperature**	7.5	**Wind speed**	38.0
Soak duration	16.5	**Time**	2.3	**Moon phase**	7.4	**Time**	31.9

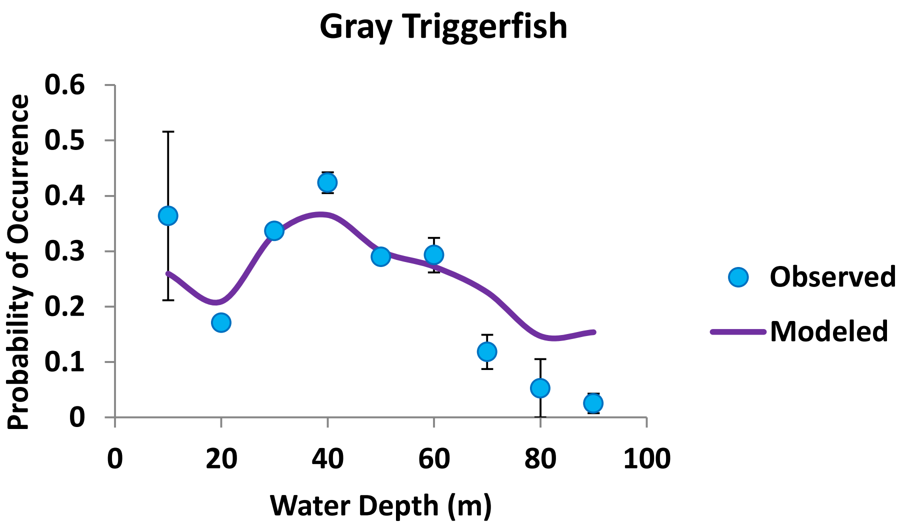
Positional variables   Sampling variables   Environmental variables   Biological variables

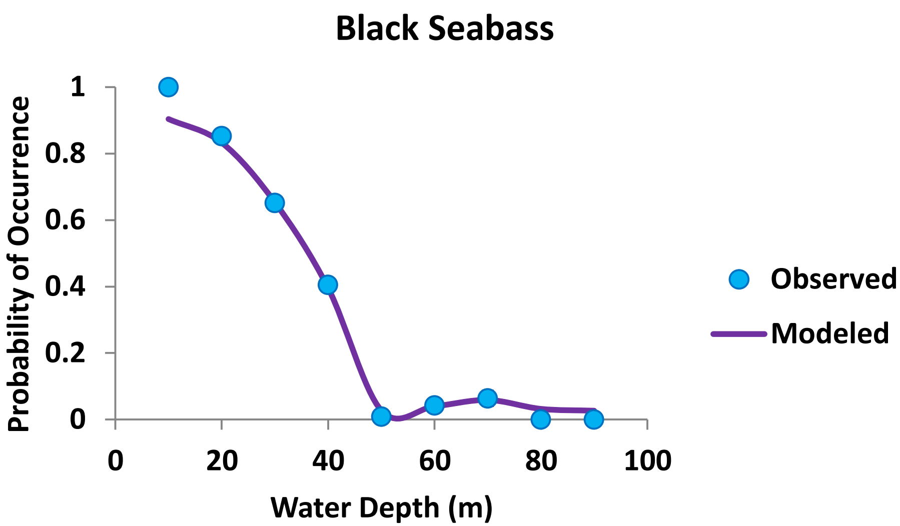
Interactions among predictor variables

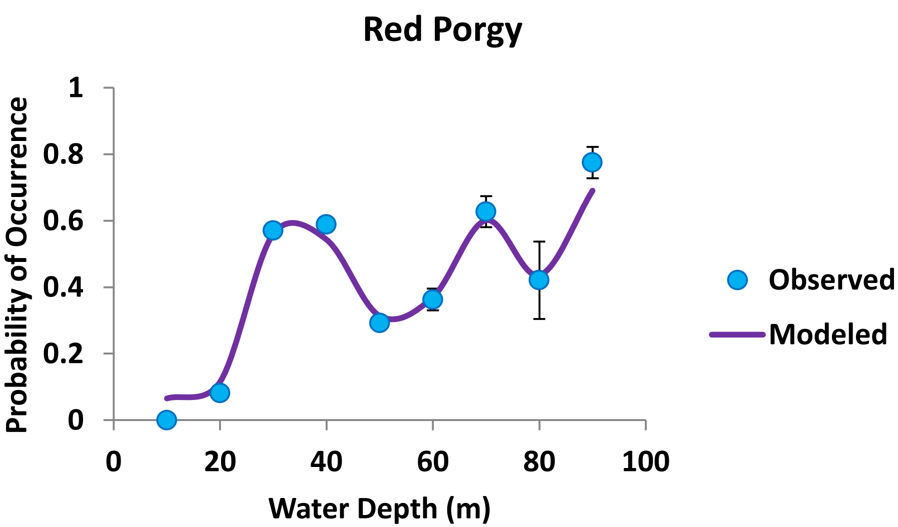
- Bottom temperatures were seasonal in shallower waters, reaching a maximum in late summer and fall
- At deeper depths, temperatures were cooler, and more constant
- Multivariate habitat models which can cope with interactions among predictor variables are therefore helpful

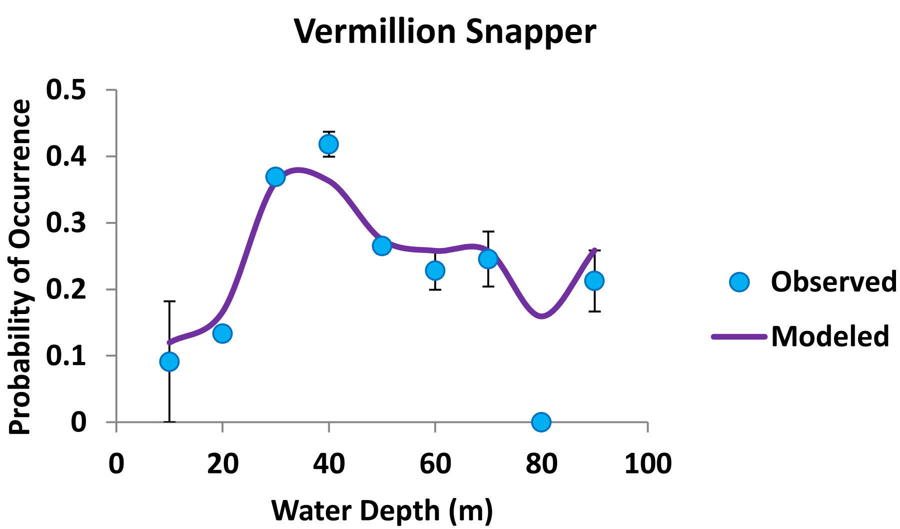


Habitat Modeling Results: Depth

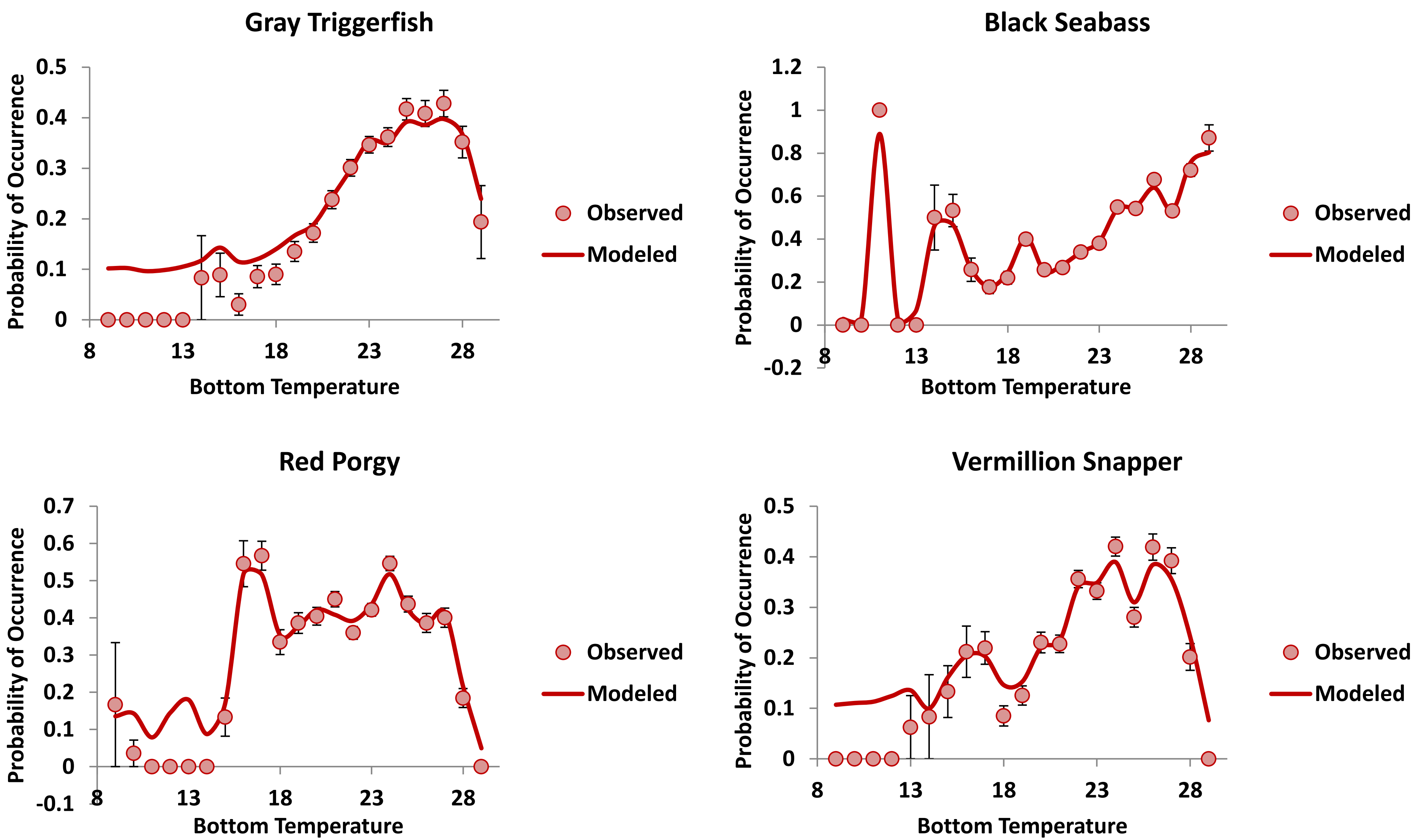






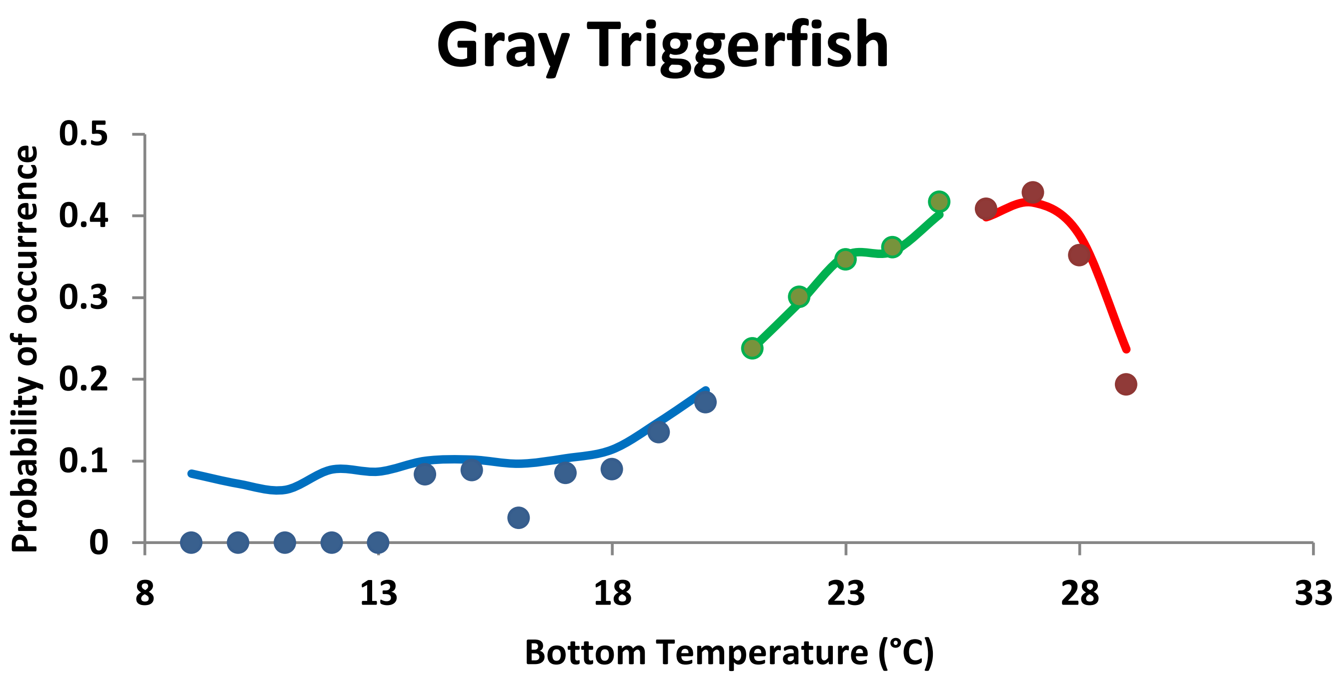


Habitat Modeling Results: Bottom temperature

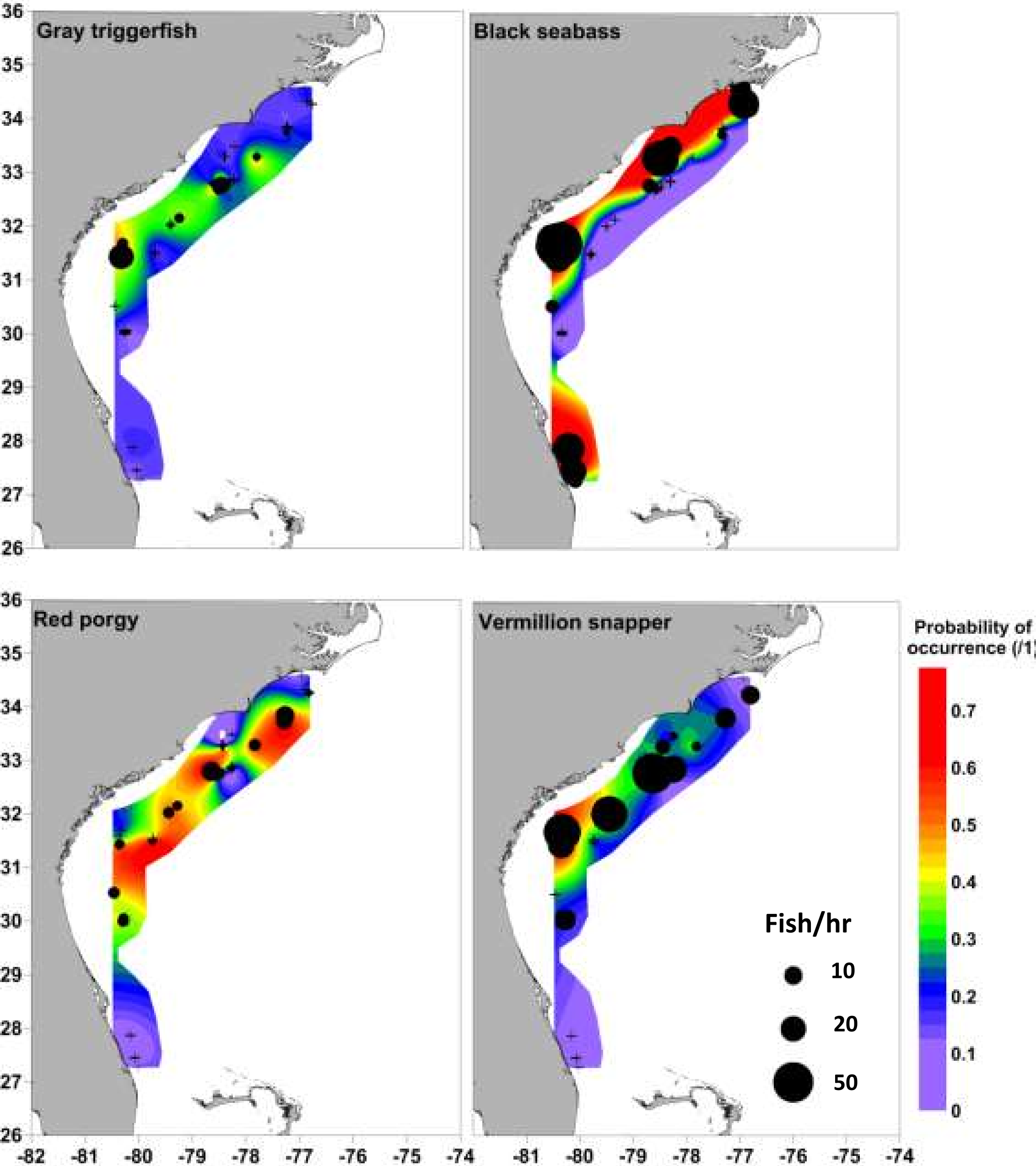


Temperature: binned vs. continuous

- The current delta GLM standardization for catches of gray triggerfish uses bottom temperature data separated into three bins: <20°C, 21-25°C and >25°C
- Results from this study suggest that an alternative binning system may be worth investigating



Spatial results: summer 2008



- Habitat model predictions were overlaid on observed catches for June – August 2008
- Gray triggerfish, red porgy and vermillion snapper were most abundant in the central-northern study area
- Black sea bass was most common in shallower waters throughout the region, including central Florida

Habitat model with dataset currently used for stock assessment index formulation

Gray Triggerfish		Black Seabass		Red Porgy		Vermillion Snapper	
Variable	*Importance*	*Variable*	*Importance*	*Variable*	*Importance*	*Variable*	*Importance*
Bottom temperature	100	Water depth	100	Water depth	100	Longitude	100
Latitude	76.1	Longitude	16.2	Latitude	50.4	Water depth	97.9
Water depth	56.8	Latitude	9.8	Longitude	42.7	Latitude	85.6
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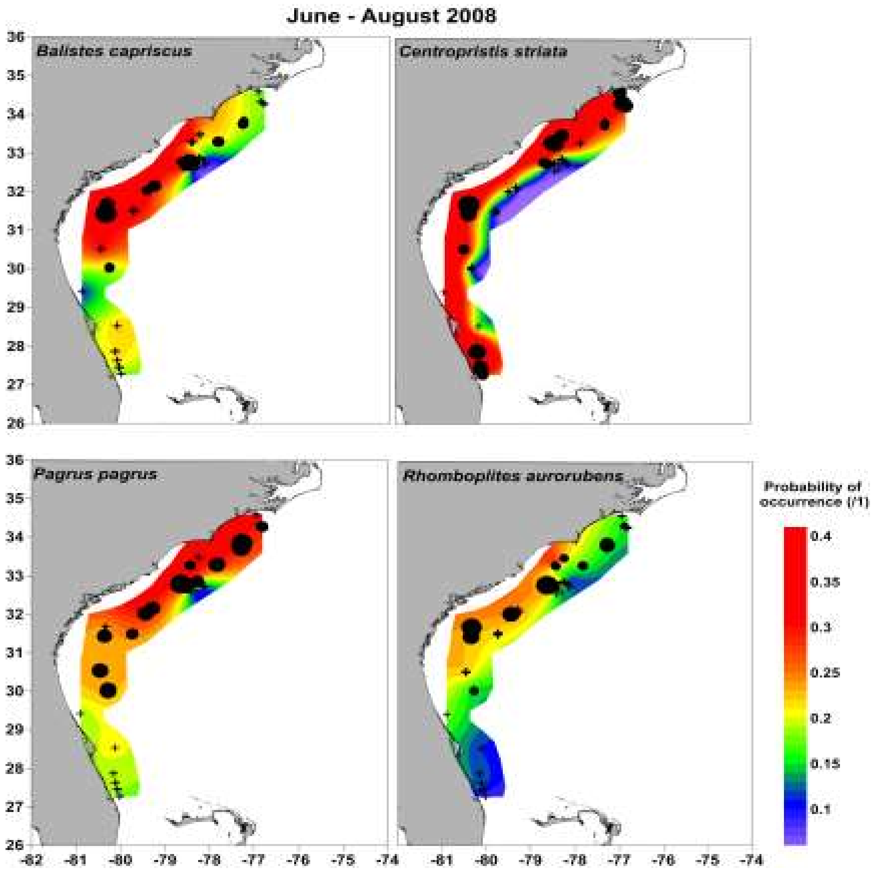
Predator biomass	26.4	Surface temperature	4.4	Time	7.8	Date	39.2
Longitude	23.2	Predator biomass	3.1	Surface temperature	7.5	Wind speed	38.0
Soak duration	16.5	Time	2.3	Moon phase	7.4	Time	31.9

Positional variables Sampling variables Environmental variables Biological variables

Predicted probabilities of occurrence of each predictor variable scored in order of importance (/100). For each species the important variables were found to be different.



June to August 2008

Warmer colors represent higher probabilities of occurrence. The predictive models showed the influence of location on catches of each of the four species. *C. striata* (black sea bass) was strongly influenced by water depth, with positive catches only occurring in shallower water. The other three species were more influenced by longitude and latitude, with higher catches at more north-eastern locations.

Balistes

Variable	Importance
Longitude	100
Latitude	91.692
Temp	54.907
DateNoYr	4.775
Samp_Depth	2.411
Salinity	1.889

Centro

Variable	Importance
Samp_Depth	100
Longitude	10.533
DateNoYr	7.691
Temp	3.647
Latitude	1.582
Salinity	0.353

Pagrus

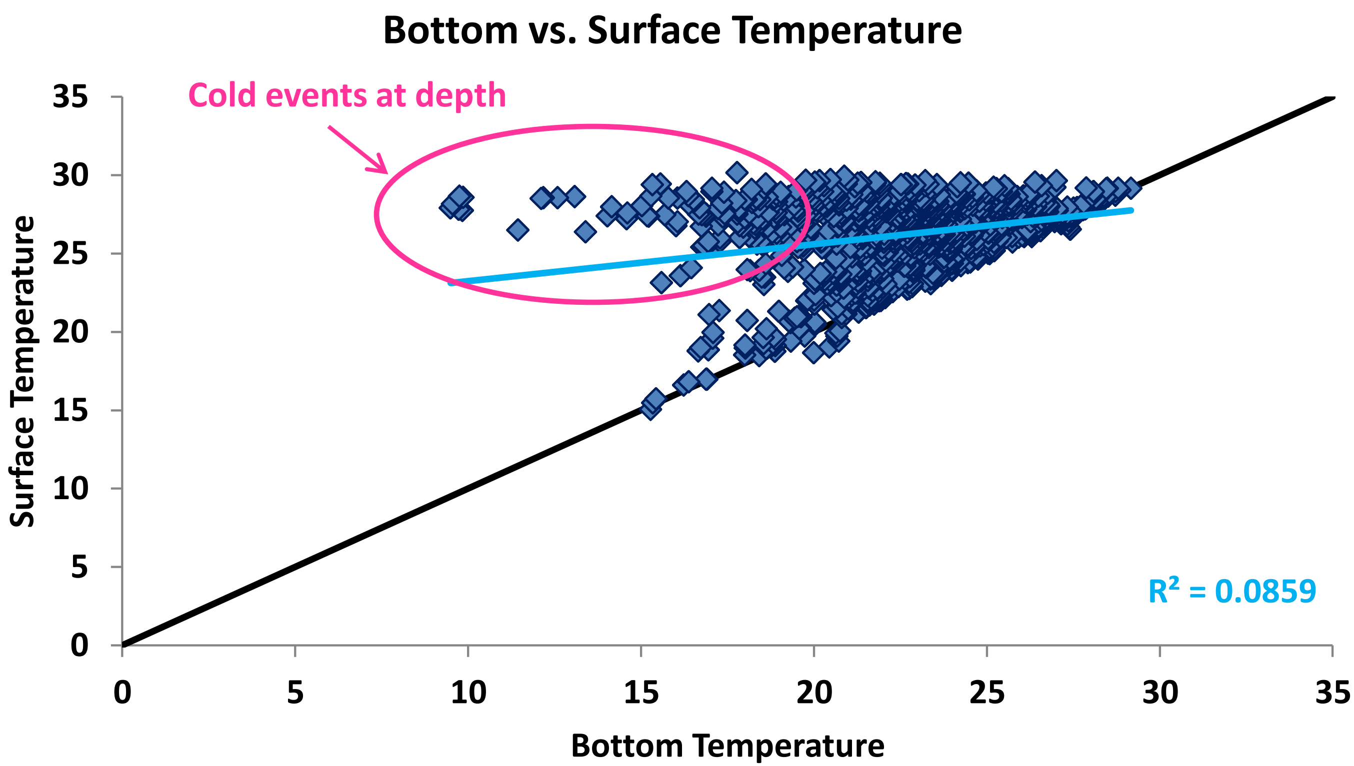
Variable	Importance
Longitude	100
Latitude	72.5
DateNoYr	34.145
Samp_Depth	28.068
Temp	21.687
Salinity	4.196

Rhombo

Variable	Importance
Longitude	100
Temp	93.625
Latitude	18.624
Samp_Depth	2.549
DateNoYr	1.704
Salinity	0.126

Bottom temperature anomalies

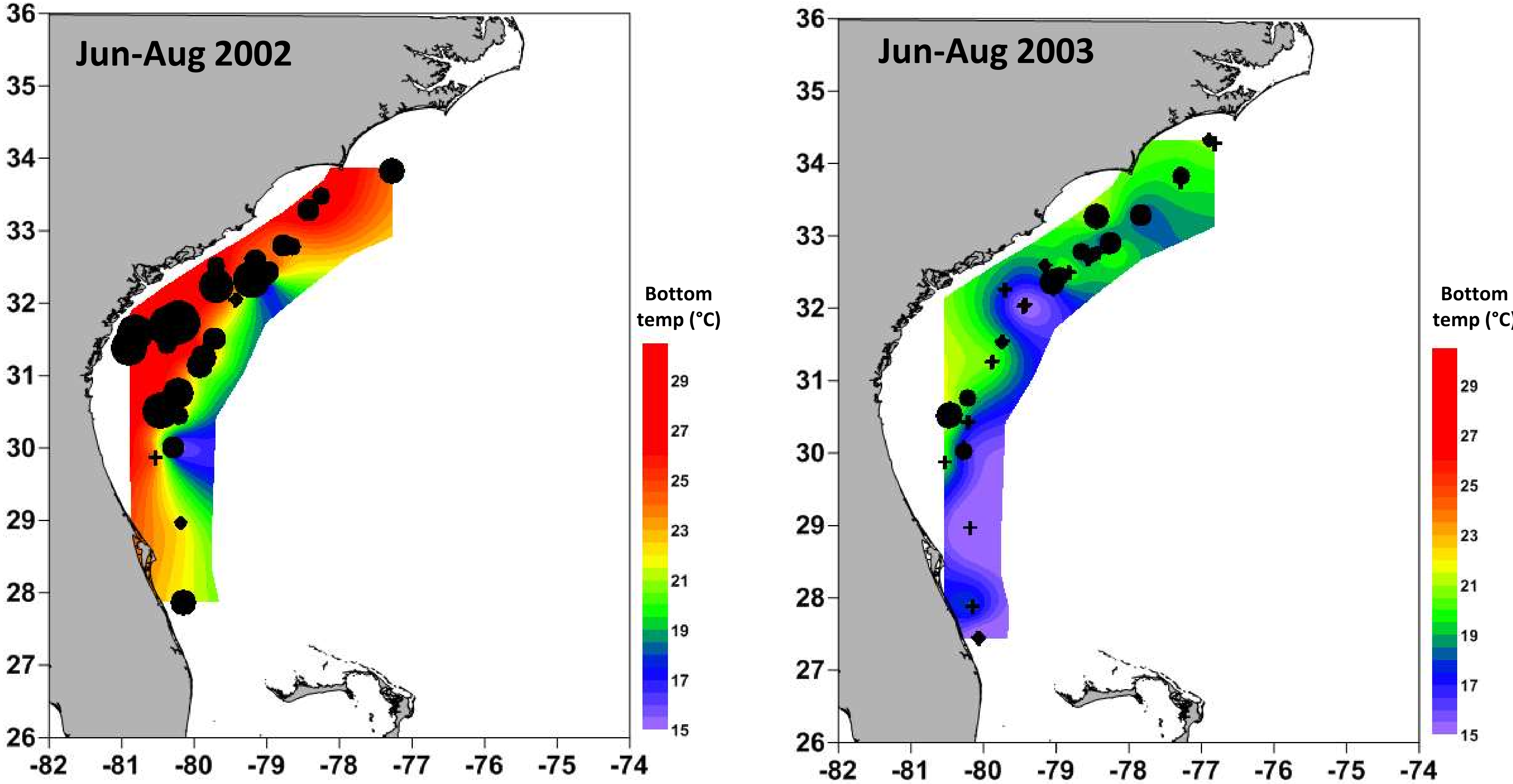
- Surface temperatures on the continental shelf are strongly seasonal, with maximum values in late summer, and minimums in winter
- However, temperatures at the bottom were not well correlated with those at the surface
- At times, temperatures on the seafloor were > 10°C cooler than at the surface



Gray triggerfish and bottom temperature

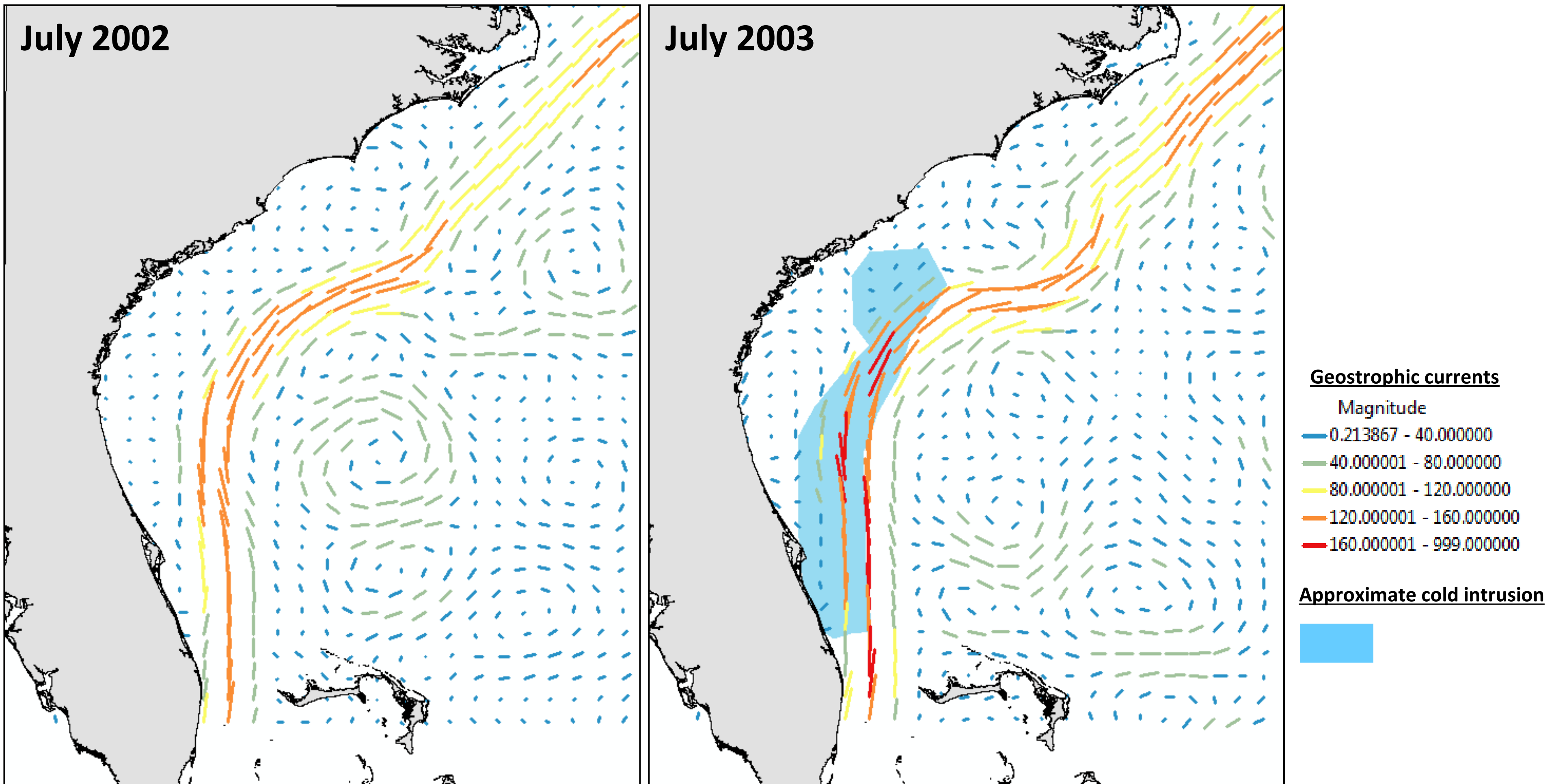
- Gray triggerfish were rare at bottom temperatures <18°C
- Periodic incursions of cold water appeared to exclude them from otherwise suitable habitat

Gray triggerfish catches and bottom temperature



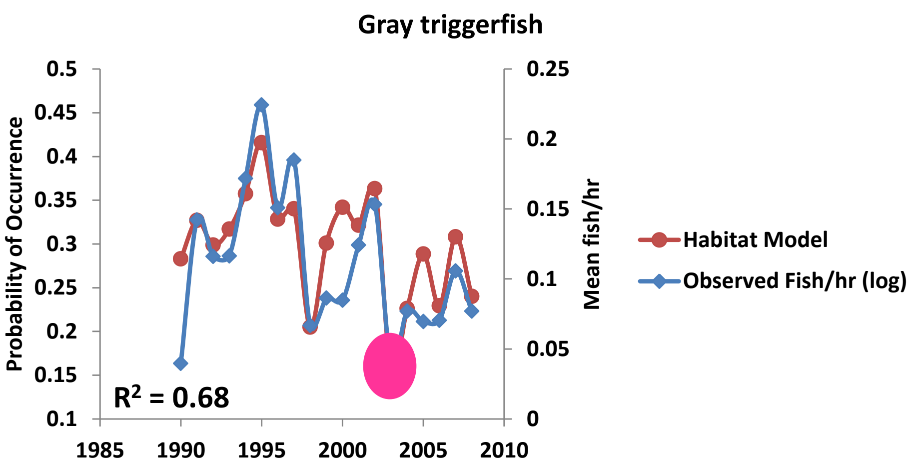
Gulf Stream and upwelling

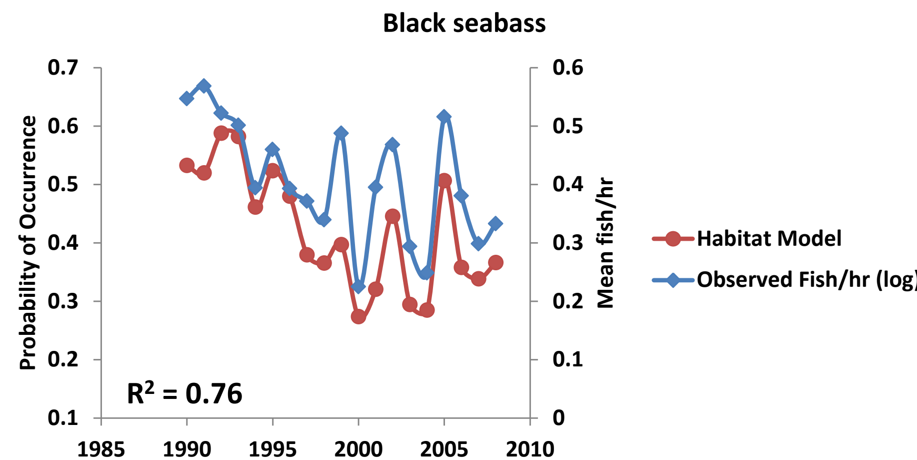
- A stronger Gulf Stream during 2003 appeared to result in cool bottom temperatures along the continental shelf edge
- Blanton et al. (1981) and others show that topographically induced upwelling can cause cold intrusions onto the shelf during summer
- This has implications for cold-intolerant fish species

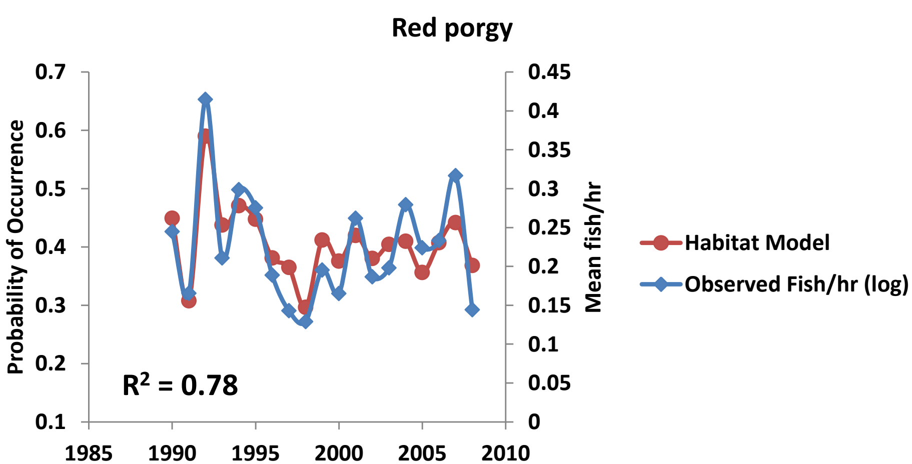


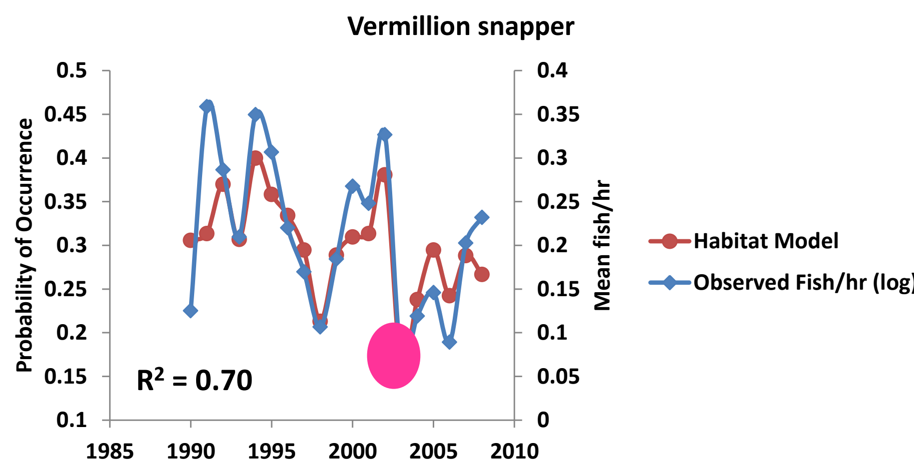
Inter-Annual Series

- Habitat indices were generally well correlated with observed fish/hr on an annual basis, for the months of June - August
- The effect of cooler bottom temperatures during summer 2003 was visible for gray triggerfish and vermillion snapper









Incorporating habitat into indices

- Current standardization of fisheries-independent survey data is done using *delta GLM* models and/or *zero-inflated negative binomial* models
- Environmental variables are binned, and included as categorical factors
- In the coming months, we will compare standardization performance between existing models, and those using an additional “habitat” covariate, derived from results from this study
- Simulations studies may also be used

Conclusions and future analyses

- Occurrences of four target species were influenced by several interacting environmental and geographic variables
- Bottom temperature was important to distributions of gray triggerfish and vermillion snapper
- Occasional upwelling of cold water onto the continental shelf affects availability of fish to traps, and potentially index behavior
- Upcoming activities will test the performance of the inclusion of a habitat metric in existing index standardization models

Acknowledgments

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  - Joseph Ballenger
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- SAFMC
  - Roger Pugliese
- NOAA-NMFS
  - South East Fisheries Science Centre
    - Early Life History Group
- ROFFS™ Ocean Fishing Forecasting Service
  - Greg Gawlikowsi
  - Matt Upton
- Marine Geospatial Ecology Toolbox – Duke University
  - Jason Roberts
- SECOORA Funded most
- NASA Funded part
- MARMAP

South Atlantic Ecosystem Modeling Workshop
Feb. 10-11, 201

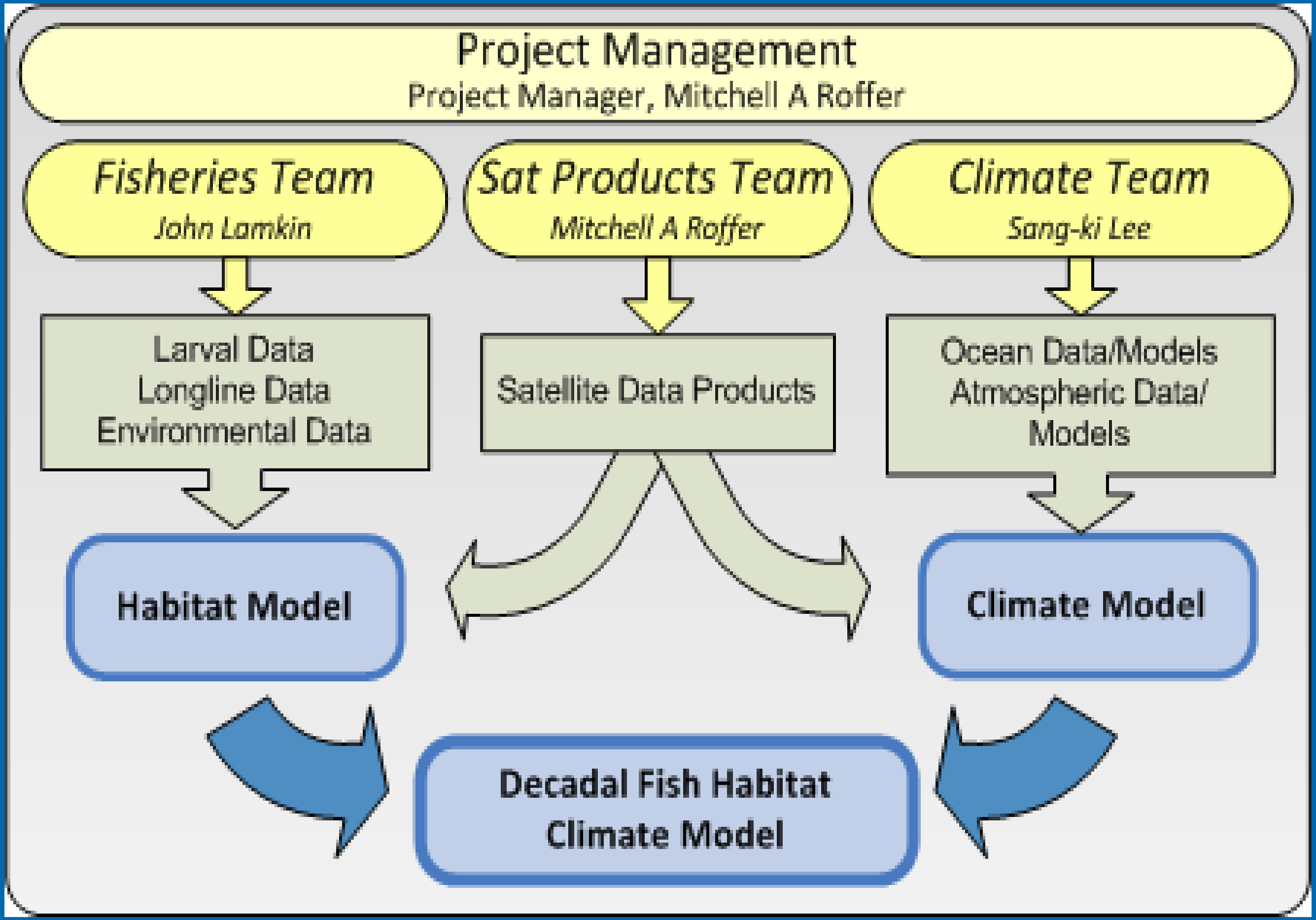
NASA PROJECT

Management And Conservation Of Atlantic Bluefin Tuna (*Thunnus Thynnus*) And Other Highly Migratory Fish In The Gulf Of Mexico Under IPCC Climate Change Scenarios: A Study Using Regional Climate And Habitat Models.

- **PI: M. A. Roffer – ROFFS™**
- **Co-I: J.T. Lamkin (NOAA), F.E. Muller-Karger (USF), S-K Lee (UM CIMAS), B.A. Muhling (UM CIMAS), G.J. Goni (NOAA)**
- Other Investigator: Y. Liu (UM CIMAS), M.A. Upton, (ROFFS™) & G. Gawlikowski (ROFFS™), G.W. Ingram (NOAA)
- Other collaborators added: W. Nero (NOAA), J. Franks (USM), J. Quattro (USC) D. Enfield (NOAA), John F. Walter (NOAA), A. Bakun (UM RSMAS), K. Ramirez (INAPESCA), F. Alemany (IEO), A. Garcia (IEO) . . and growing
- Start date September 06, 2011 – End date September 05, 2015

Multi-sector and multi-disciplinary partnership, including government fishery scientists and managers

Core Team Approach



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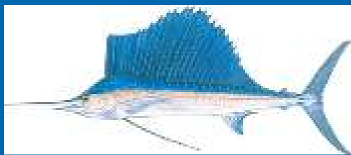
NASA Applications Research

- Focuses on **enhancing the management** of Atlantic bluefin tuna (*Thunnus thynnus*) and other highly migratory tunas and billfishes in the Gulf of Mexico and surrounding waters considering climate change.
  - Using data with differing scales.
    - MM to M to KM to 1000 KM scales
    - Hourly to daily to 100 year time scales
  - Transition the routine use of satellite data

Charismatic Mega Fauna

1. Atlantic bluefin tuna (Thunnus thynnus)
2. Atlantic blue marlin (*Makaira nigricans*),
3. Atlantic sailfish (*Istiophorus platypterus*),
4. Atlantic white marlin (*Tetrapturus albidu*
5. Blackfin tuna (*Thunnus atlanticus*),
6. Bullet mackerel (*Auxis rochei*),
7. Frigate mackerel (*Auxis thazzard*),
8. Longbill spearfish (*Tetrapturus pfluegeri*),
9. Swordfish (*Xiphias gladius*),
10. Yellowfin tuna (*Thunnus albacares*)
11. Skipjack tuna (Katsuwonis pelamis)



Significance to Fisheries Management

Bluefin tuna and other highly migratory fish species that use the Gulf of Mexico as their essential habitat are still largely **managed under the assumption that ecosystem parameters do not change over time**.

The research is significantly contributing already in understanding some **functional links** between climate variability, oceanographic processes, and recruitment at oceanic, regional, local, and smaller scales.

3D T°, S%, O_2, currents, chl., predator - prey

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Importance

- The expected outcomes of the research include essential enhancements to NOAA fisheries management applications:

  1: Improved fisheries assessments;

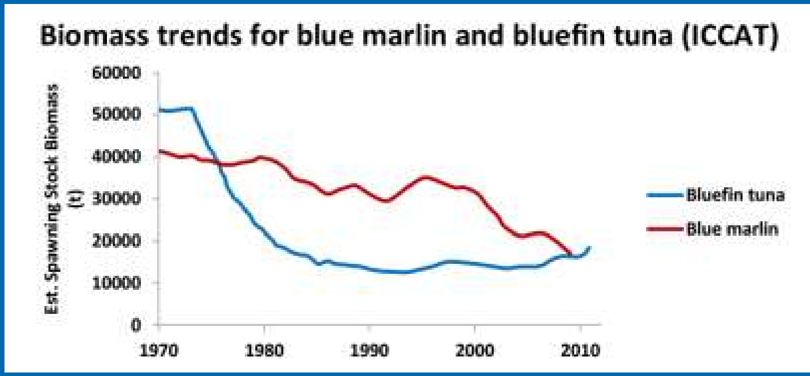
  a. Catchability (availability and vulnerability)

  2: Adaptive harvest management strategies;

  3: A better understanding of possible scenarios for future stock rebuilding under climate change.

Increased Importance

- ✓ Managed internationally International Commission for the Conservation of Atlantic Tunas
- ✓ Convention on International Trade In Endangered Species (CITES) continues threat for an Endangered Species Listing: a“CITES Listing” for Atlantic bluefin tuna and Atlantic marlins
- ✓ Effects of the Deepwater Horizon oil spill and ?
- ✓ Effects of climate change



Specific NOAA NMFS Management Needs In A Varying Environment

- Reproduction and recruitment processes.
  - Improved larval indices.
  - Improved adult spawning stock size estimates.
  - Location & timing spawning grounds.
    - Will it change over time?
- Changes in distribution.
- Varying vulnerability and availability.
- Varying fishing and natural mortality.

Studying entire life cycle which is complicated by age/size/sex specific physiological requirements – behavior. Problem of lumping catch data.

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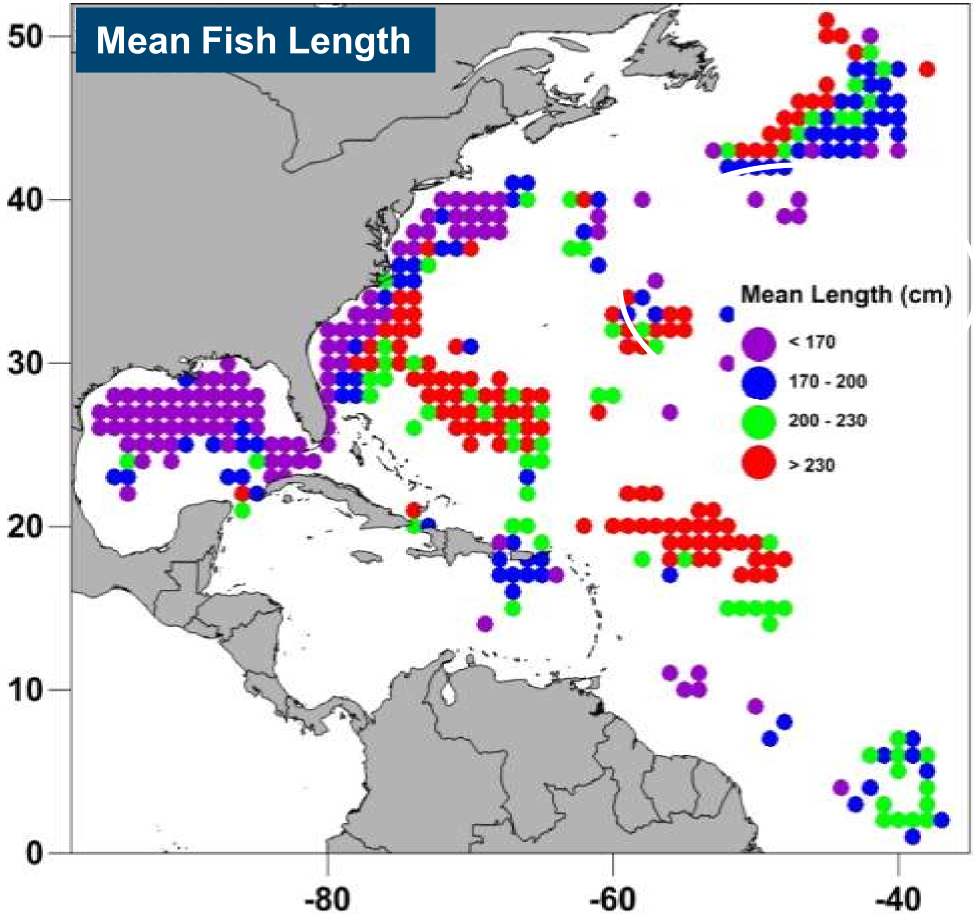
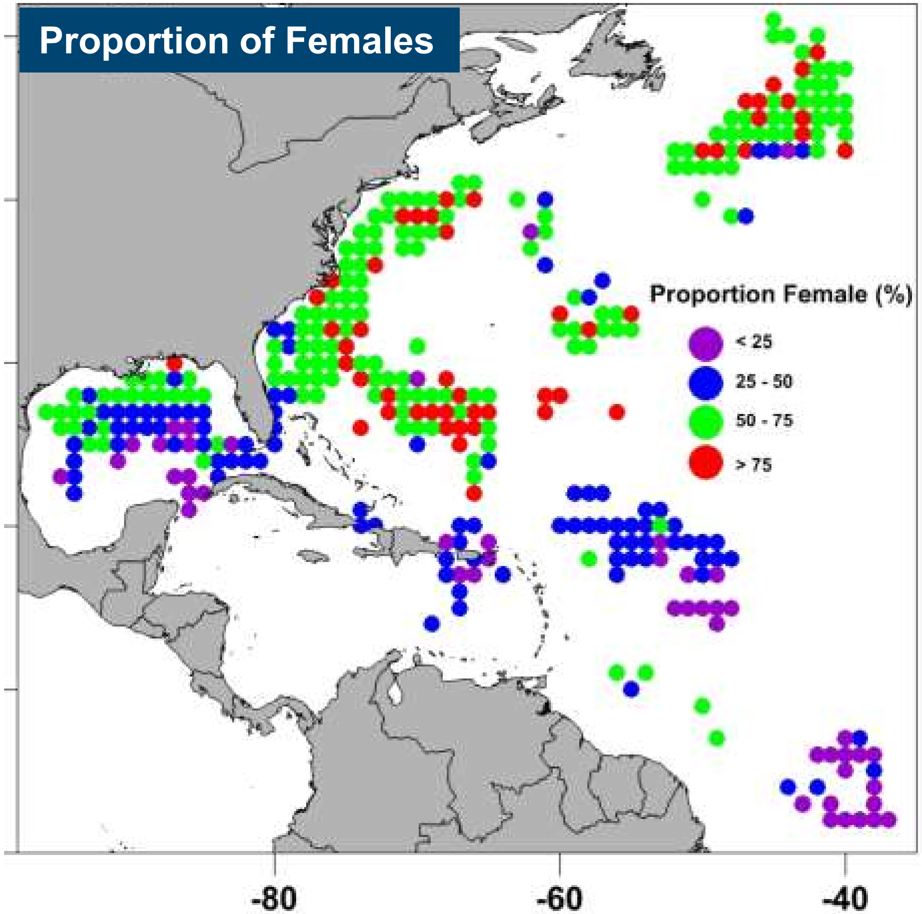
Habitat modeling: Size & Sex Considerations

1) Swordfish occupy different regions and habitats depending on their life stage

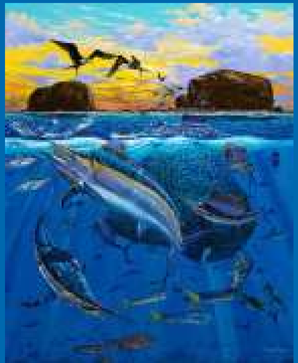


2) Males and females grow at different rates, and occur in different places



Always Thinking About: Fisheries Managers & Possible Effects of Climate

1. **Changes in lengths of spawning seasons (dates of spawning commencement and end)**
2. **Changes in spatial and temporal extent of 3D habitat of adult fish.**
3. **Implications for potential effects on recruitment, species – species guilds and sustainability of stocks.**



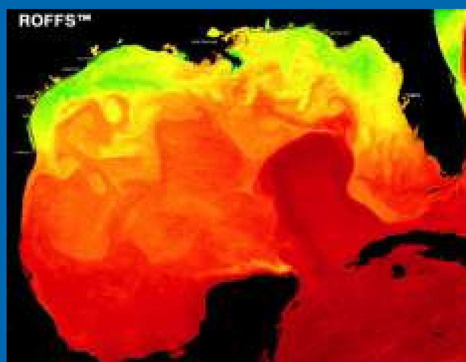
Results

1. **Will enhance our nation's input to the International Commission for the Conservation of Atlantic Tunas (ICCAT) the international governing organization for tunas and billfishes.**
2. **The approach developed here can then be applied by others (e.g. NOAA, fish management councils) to assess options for other important fisheries, as well as, to the management of other resources including marine protected areas*.**

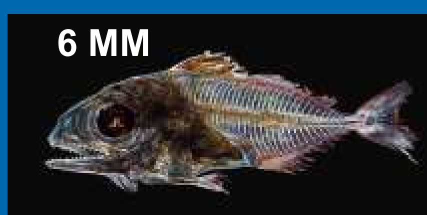
***1) Already happening: IOOS SECOORA Project South Atlantic Fisheries Management Council with reef species (triggerfish, porgy, snapper, sea bass).**
2) Spanish and Mexican colleagues
3) Others: e.g. HI Ocean Sciences Meeting 2014

Initial Project Focus:
Gulf of Mexico Reproduction and Climate Change

But we learned that we had to look at their primary range to better understand the adult dynamics

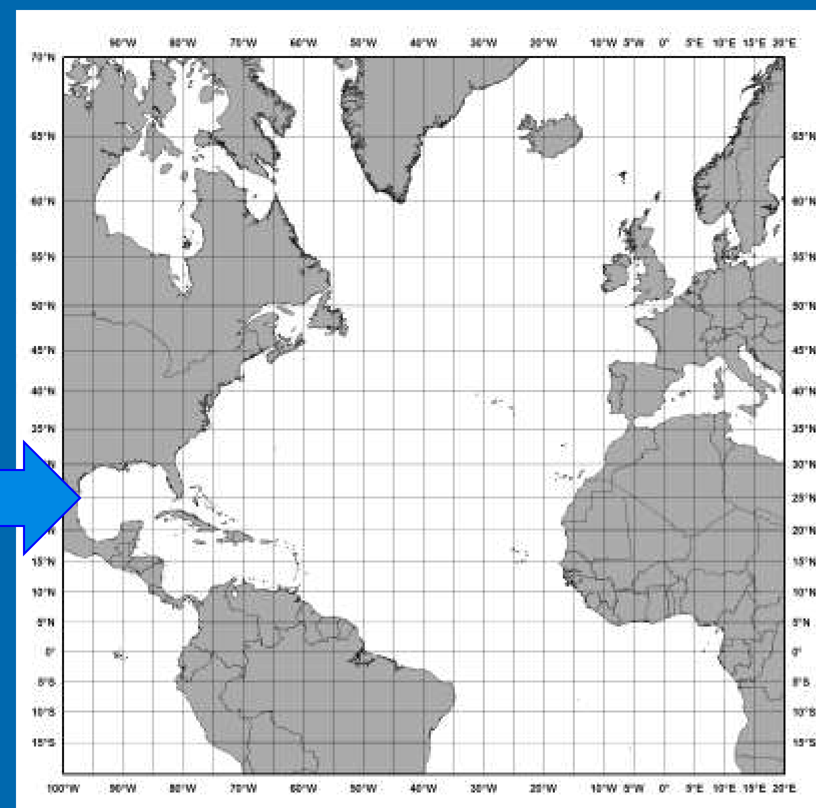


30+ years of larvae cruise data (larvae, in situ, satellite)



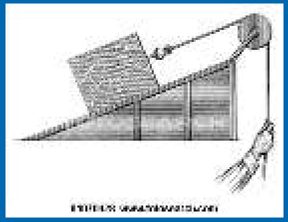
23 years commercial longline data

Climate model domain



Summary of Methods

1. Developed habitat models of larvae and adults using boosted classification tree and neural network models.
   a. Multivariate, non-parametric methods
2. Downscaling climate models
   a. CMIP5 simulations using MOM4 (GFDL Modular Ocean Model) – Grid: 0.1° in GOM, 0.25° outside
   b. Now MOM4-TOPAZ biogeochemical model.
3. Satellite IR, ocean color, (NASA-MODIS, NOAA, JPSS-VIIRS), altimetry
   a. In habitat model development
   b. Provide strategic and tactical cruise work
   c. Climatology of GOM
   d. Validation of climate models



Downscaling simulations with MOM4* in Gulf of Mexico

- **First three separate runs:**

1. Late 20C run (1981-2000) -> no larger than 0.5°C bias !
2. Mid 21C run (2041-2060) under RCP4.5 and RCP8.5
3. Late 21C run (2081-2100) under RCP4.5 and RCP8.5

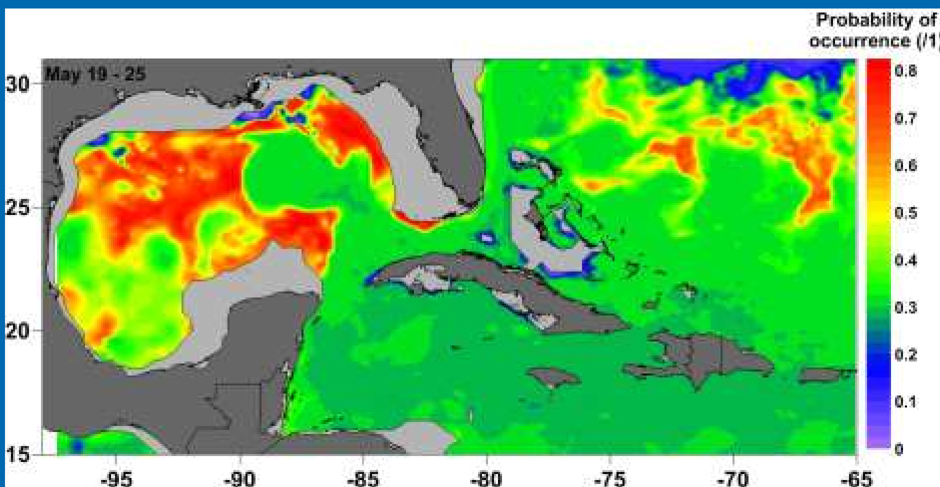
*Representative concentration pathways of CO_2 representing radiative forcing values 4.5 and 8.5 Watts/m^2





Liu et. al, 2012 (J. Geophys. Res: 117)

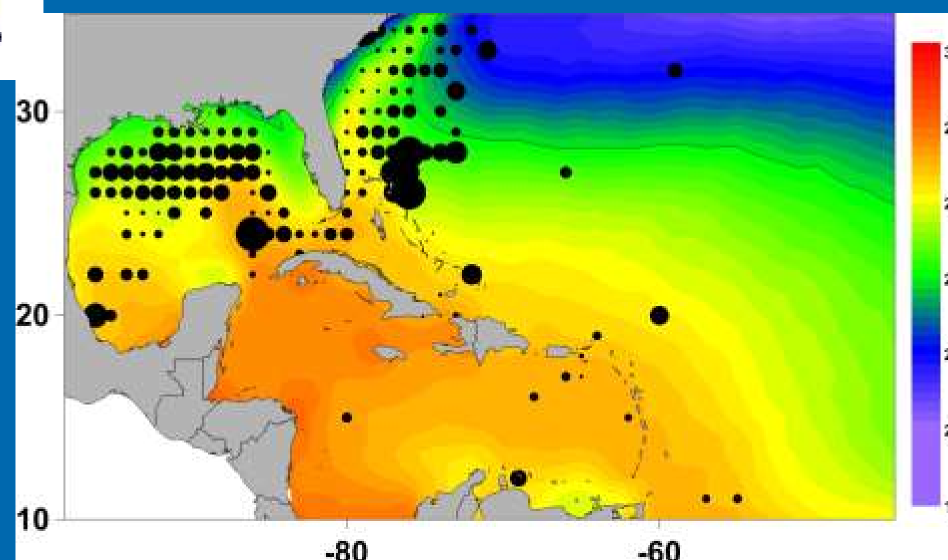
Use of Habitat Models for Finding Alternative Spawning Areas Other Than Gulf of Mexico With Satellite Derived Oceanographic Guidance



ABT larvae habitat model product : (satellites 1-4km + other ocean data + larvae)

May 19-25, 2013

Adult Catches 1987-2012



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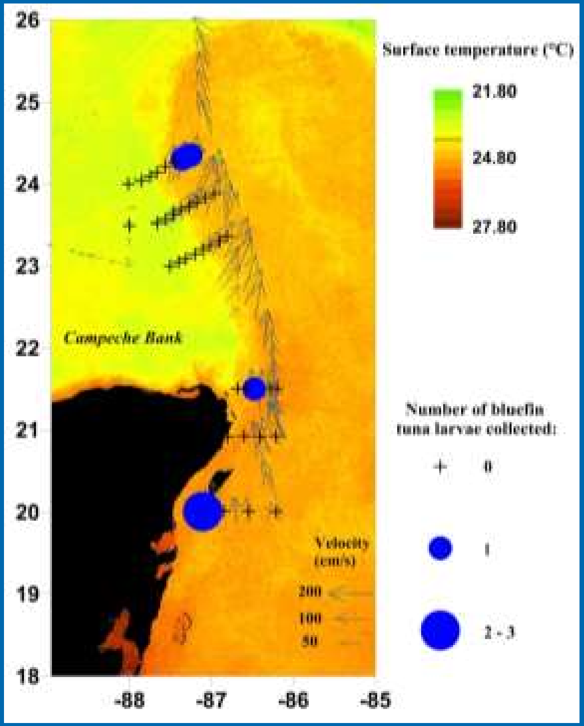
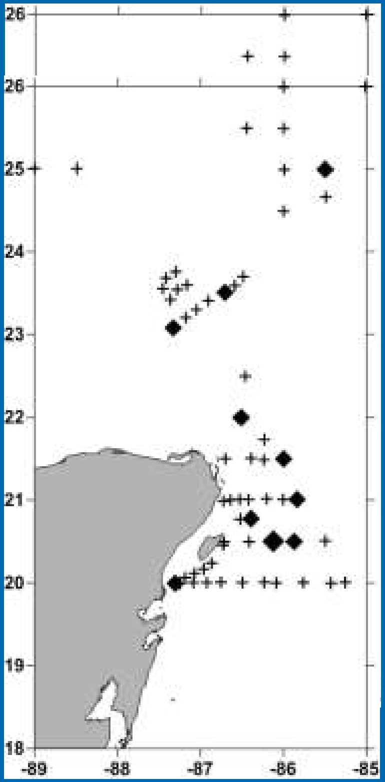
Previous Project Results

Catch locations of larval bluefin tuna in April 2009 (left) and April 2010 (right)



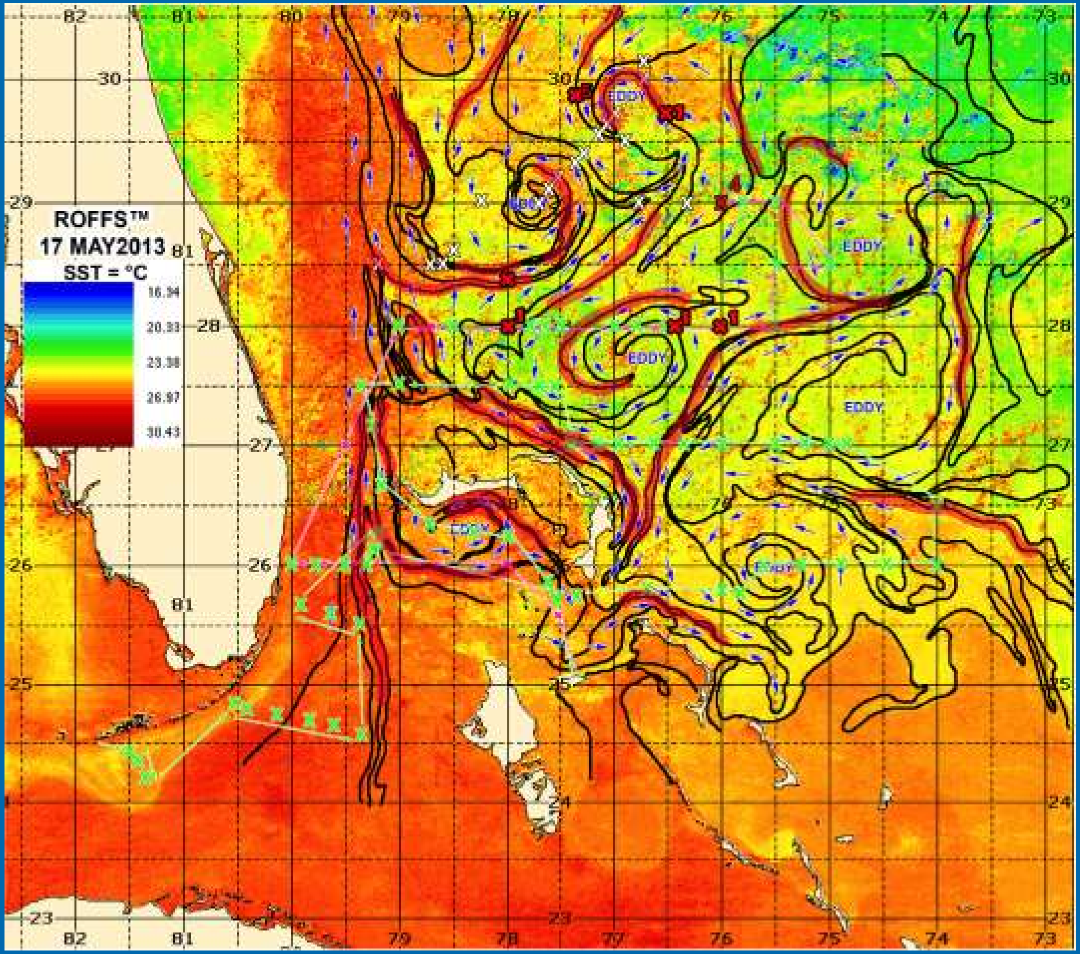


1

1+

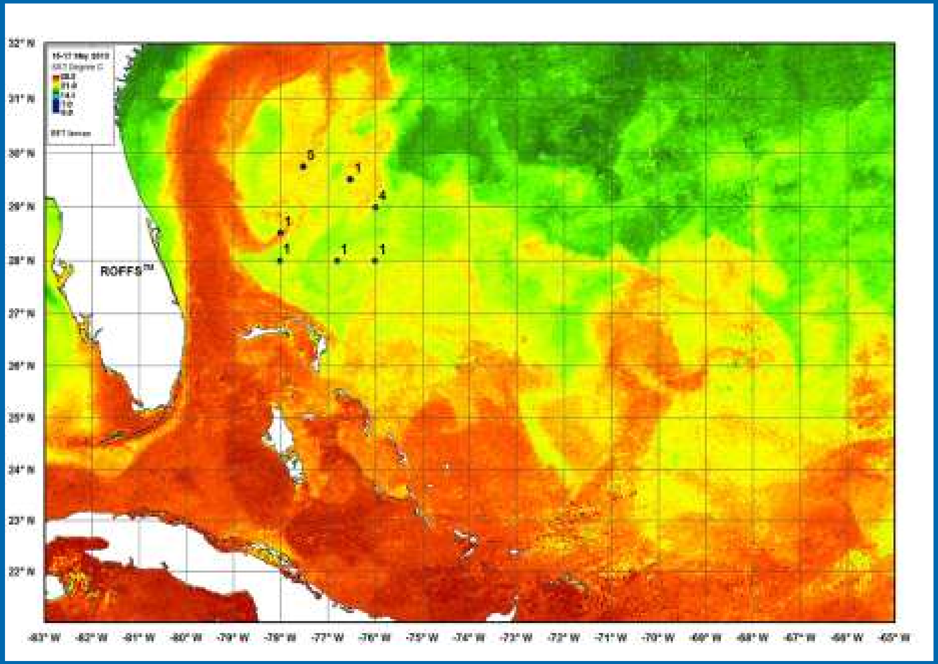
April 2009 **April 2010**

Results:
Tactical & Strategic Cruise Planning



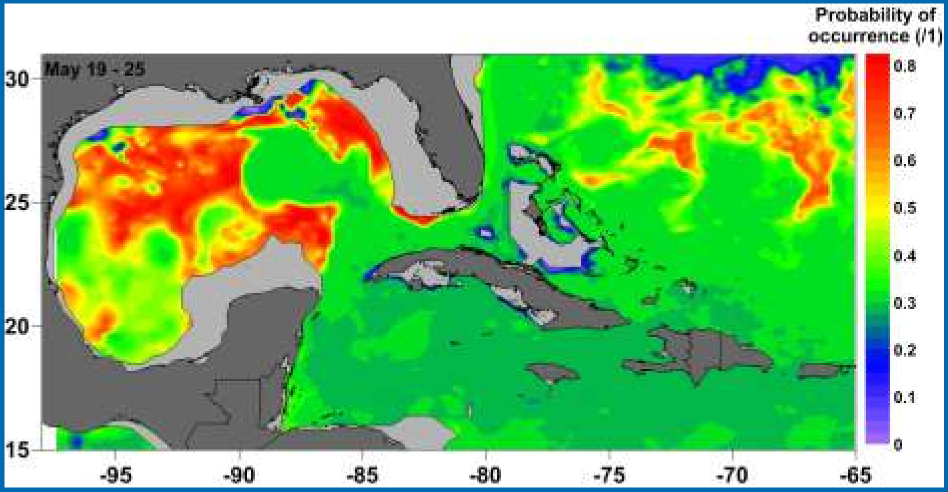
14 ABT larvae

Raises Additional Questions

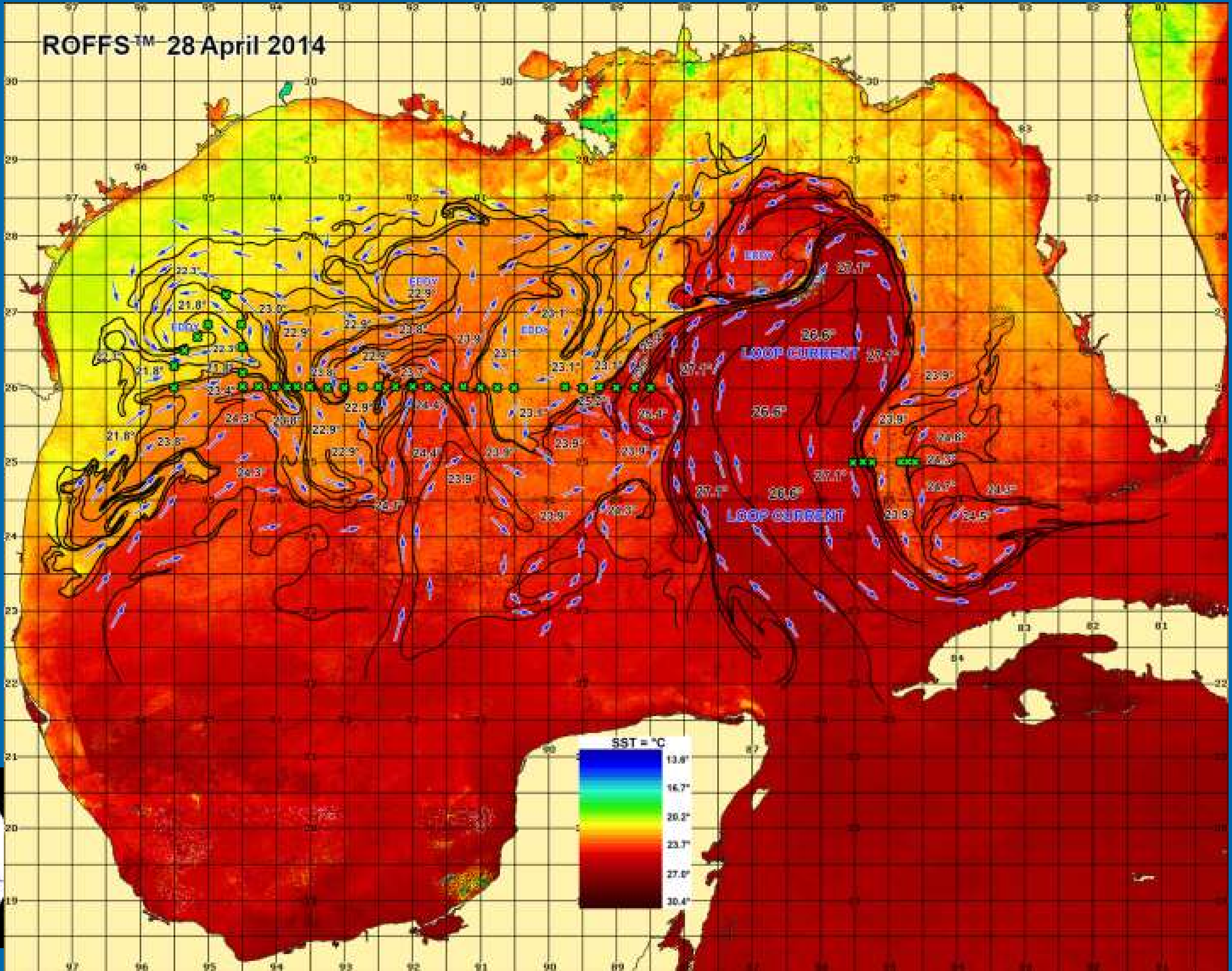


Are they spawning east?
Is this a sub-population?
Will it flourish when the the habitat in GOM changes?
How do species survive over millennia when habitats change?

What are the conditions that affect larval survival? Patch size, patch component species? Will survival benefit from earlier spawning or fail?

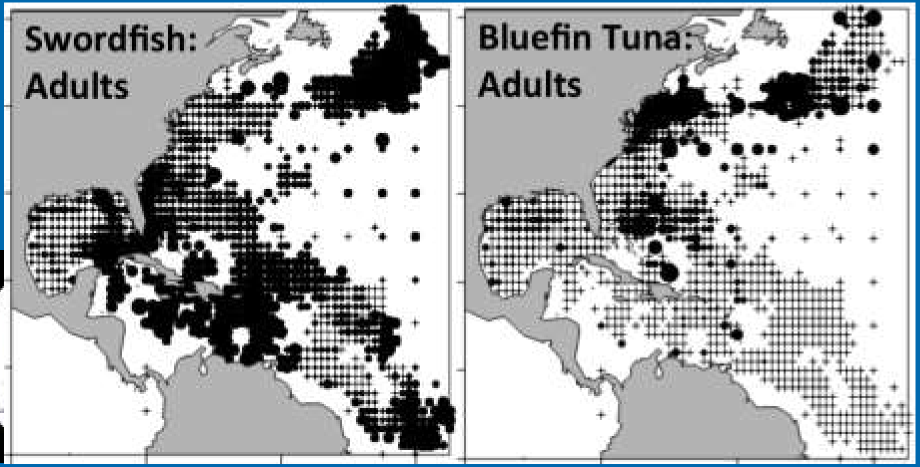


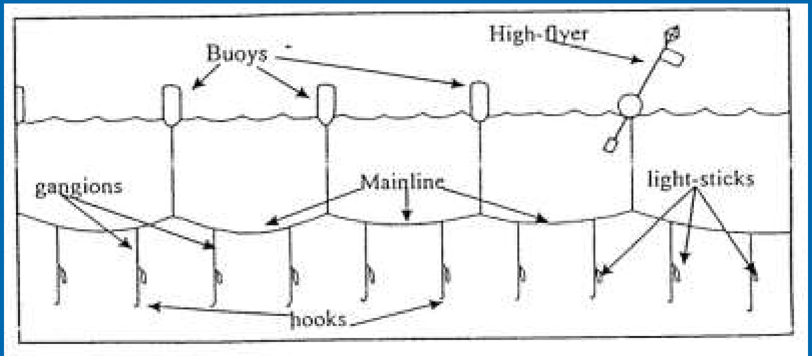
2014 Targeted Sampling Leg One



Habitat Modeling: Adults

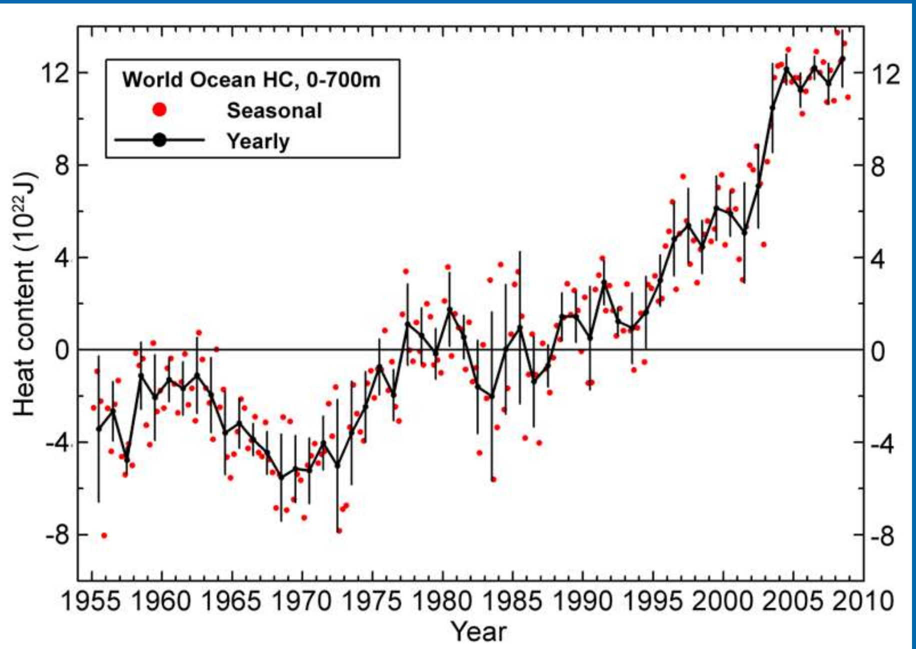
- The most comprehensive source of adult data is from fisheries-dependent records
  - *Logbook program*: all US fishing vessels are required to submit catch logbooks detailed catch composition and gear deployed for each longline set. Mandatory since 1992
  - *Observer program*: government observers are placed on fishing vessels, and record more detailed information on size, weight and sex of fish. Program began in 1992, but coverage is very limited
  - ICCAT Task 2 database
- Many issues with the data, target species, reliability, gear changes, management changes (e.g. quotas, closed areas), not include recreationally caught fish…….., but it is the primary data one uses.

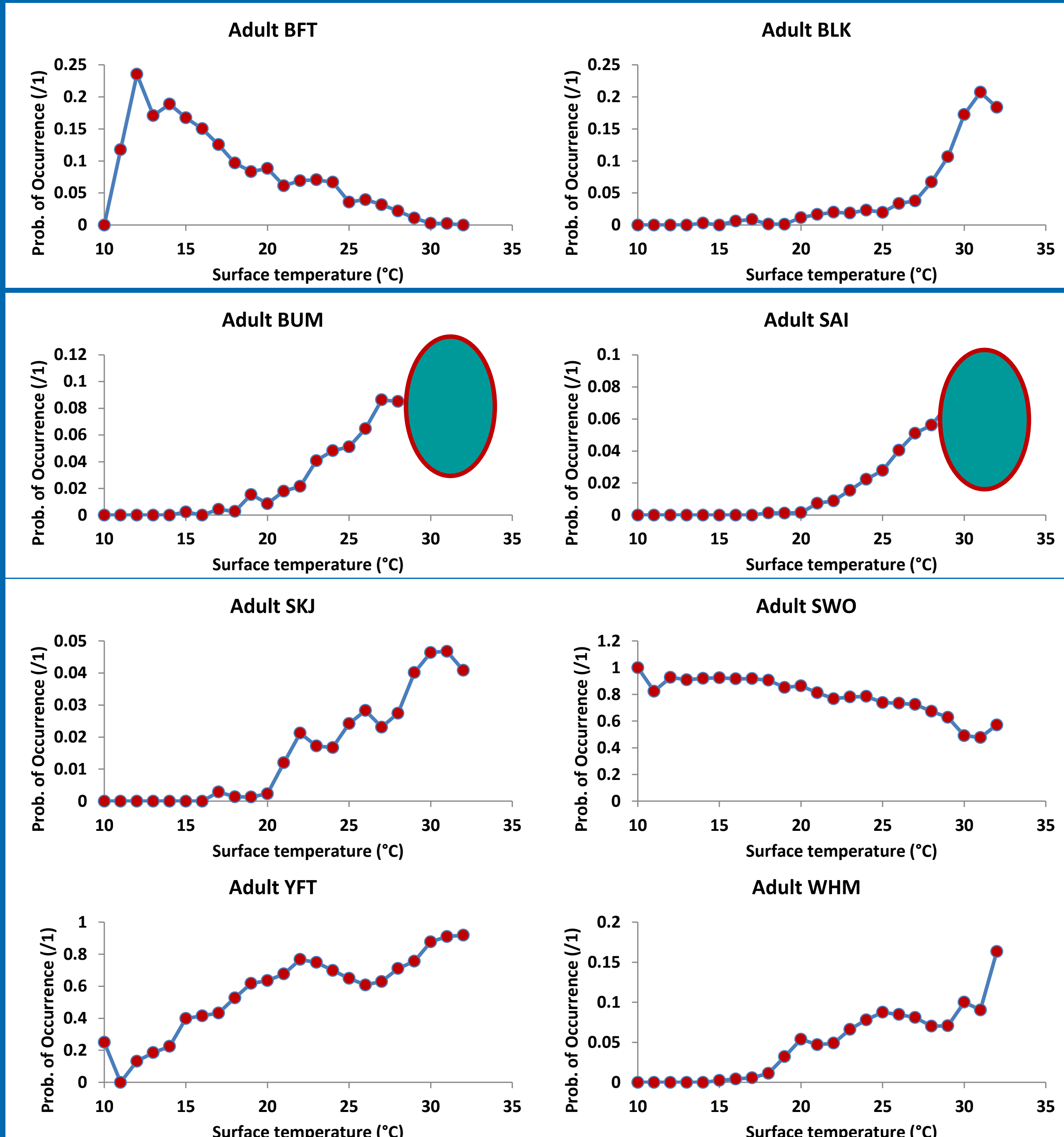




Temperature limits on adult distribution

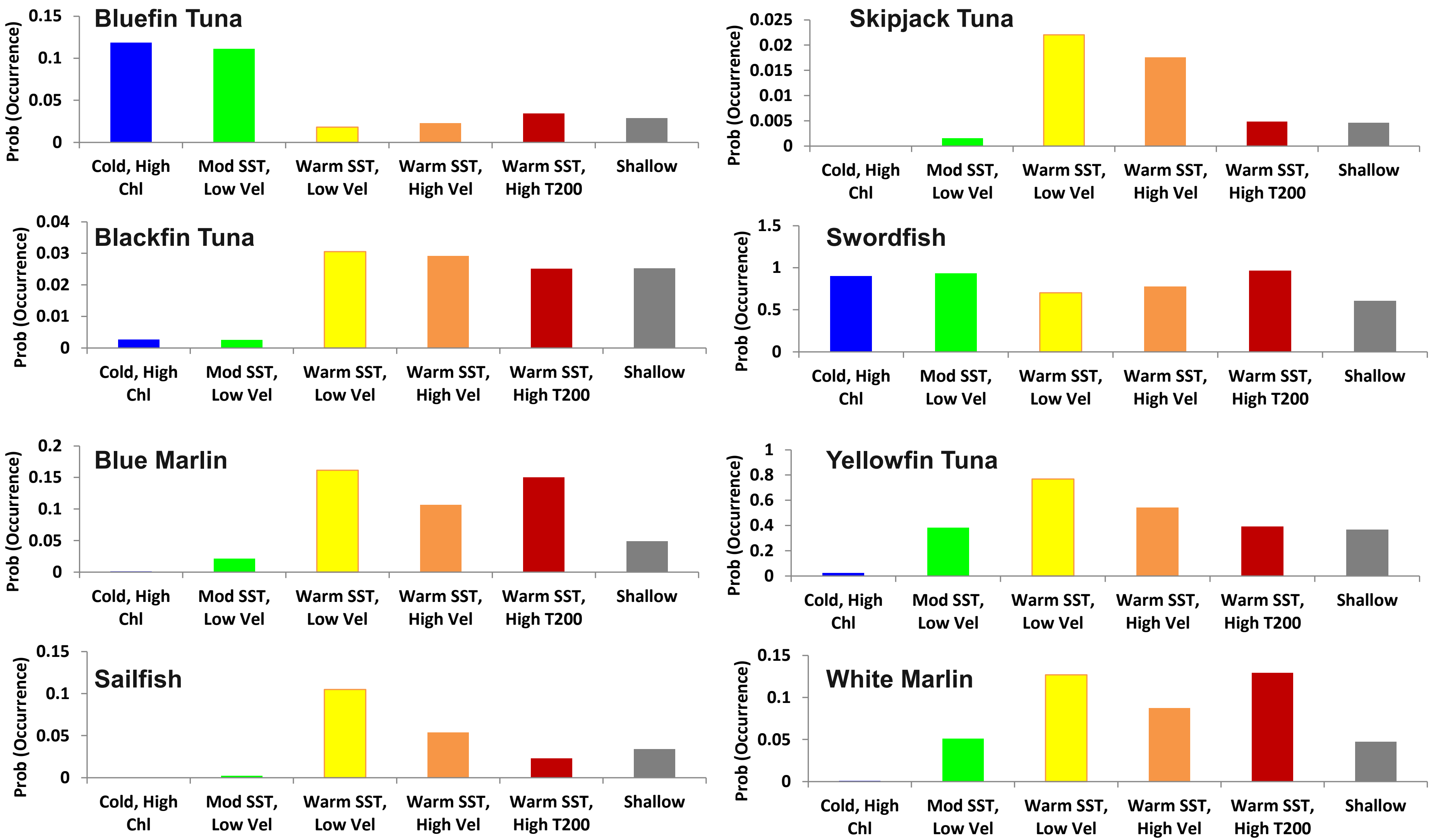
- All fish species have physiological limits to both cold and warm temperatures
- South->North Warming oceans could result in:
  - A *northwards* shift of *southern* distribution limits, due to upper temperature limits (southern waters get too warm)
  - A *northwards* shift of *northern* distribution limits, to lower temperature limits (northern waters no longer too cold)

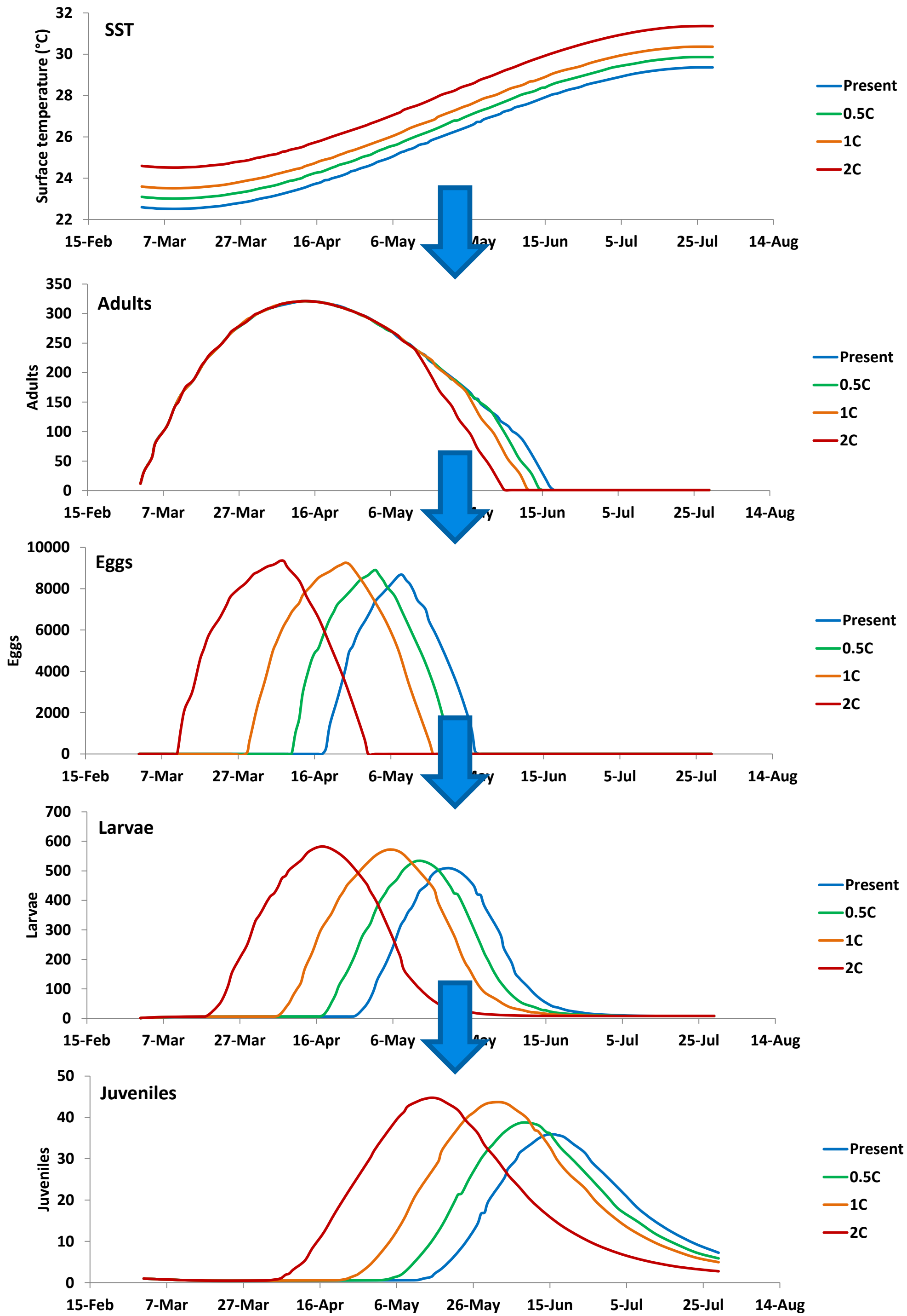



Adult BFT
Adult BLK
Adult BUM
Adult SAI
Adult SKJ
Adult SWO
Adult YFT
Adult WHM
Prob. of Occurrence (/1)
Surface temperature (°C)

Use of biogeographic zones by adult fish

- Mean probability of occurrence for each species of interest varied widely among zones
- Bluefin tuna and swordfish were much more likely to use colder, higher chlorophyll habitats
- Blackfin tuna, blue marlin, sailfish and skipjack tuna used warm tropical habitats nearly exclusively



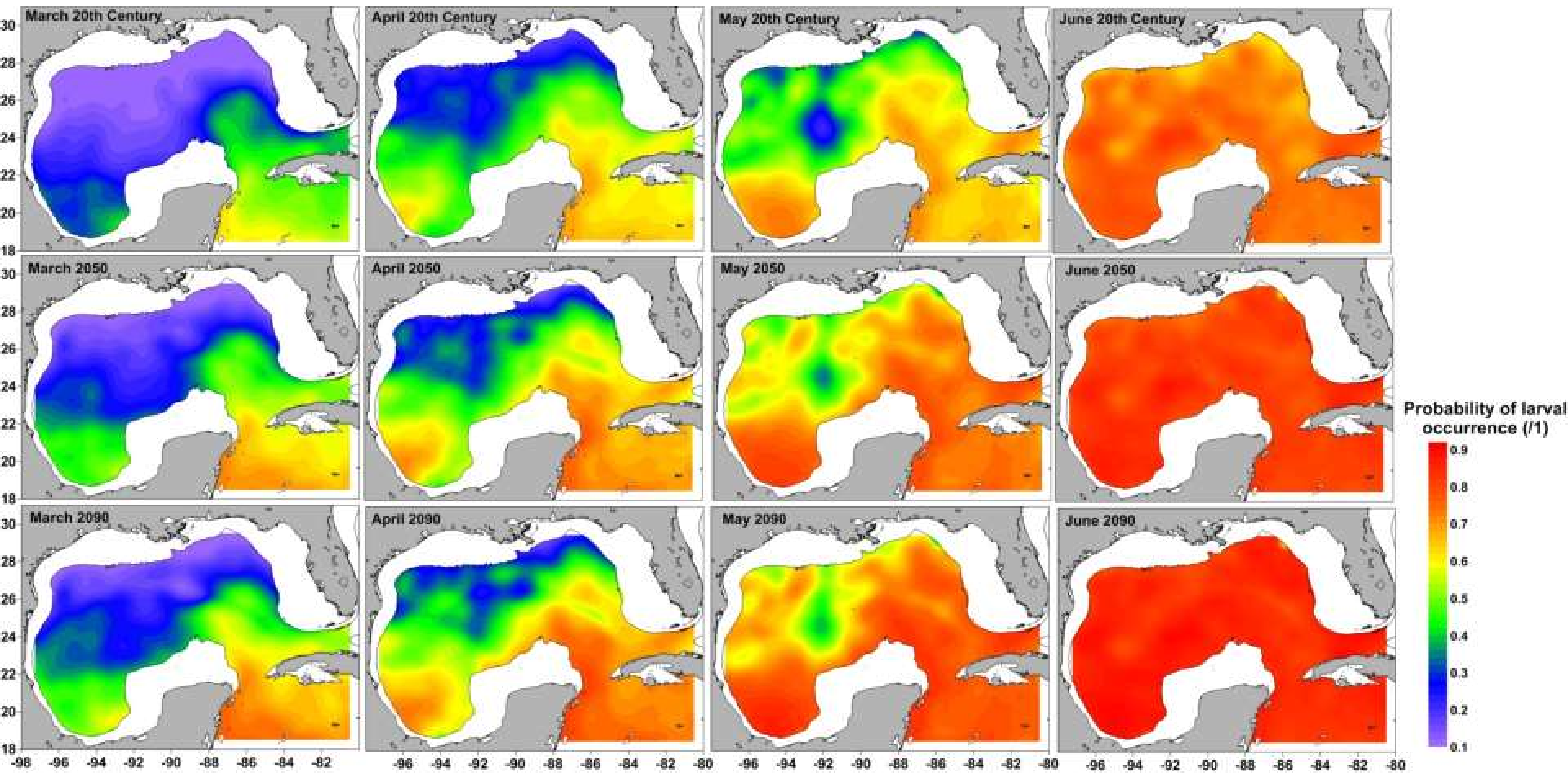


A simple 1D model

- A simple model of temperature → bluefin tuna adults → eggs → larvae → juveniles was created using delayed differential equations in Matlab
- Published values of adult distributions, spawning activity, mortality and effects of temperature were parameterized
- Results were re-run for future temperature increases of 0.5, 1.0 and 2.0°C
- Preliminary results suggest an earlier spawning season under climate change conditions, but fish must be ready or will they move to another area?

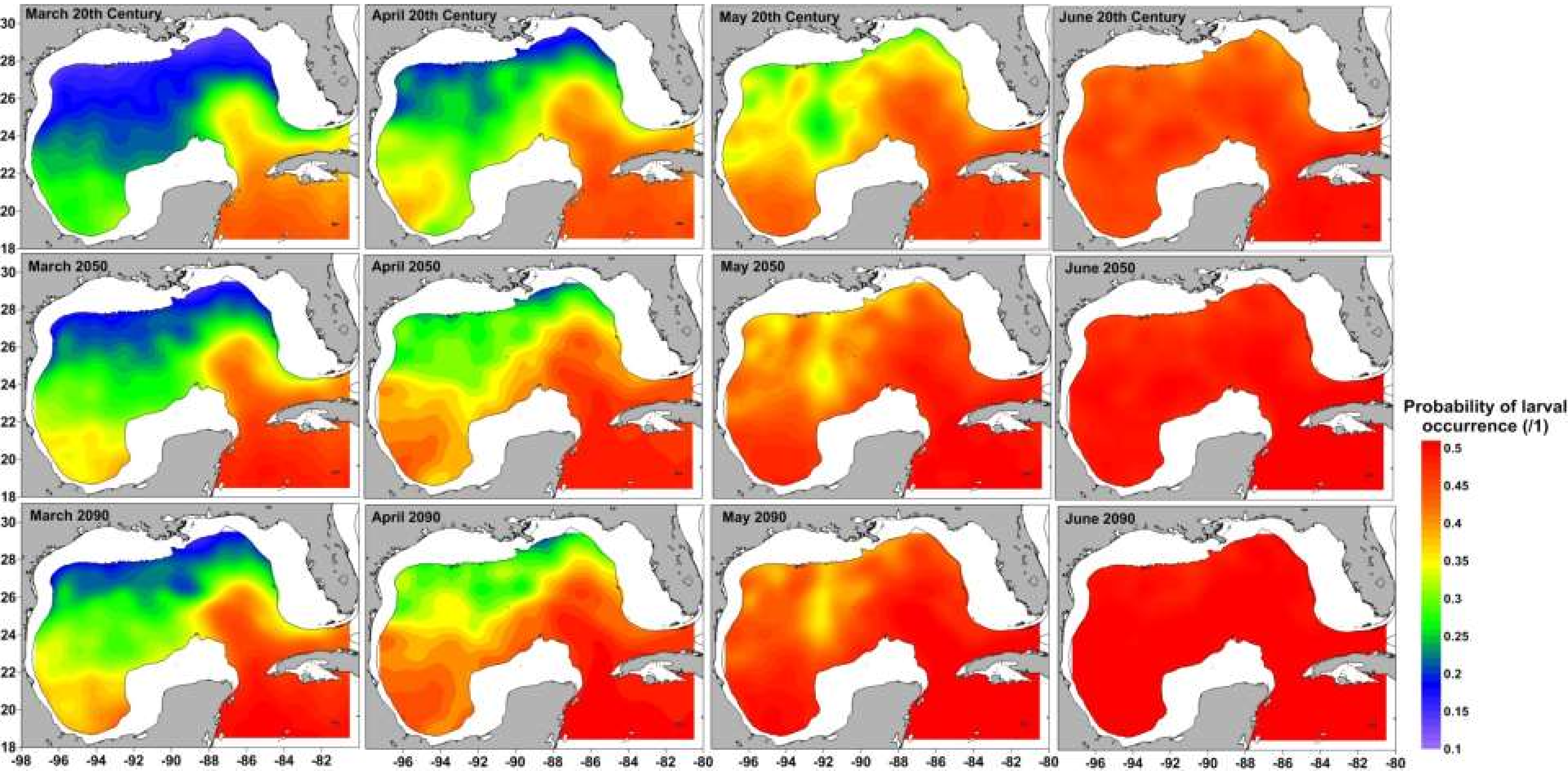
Larvae Habitat Results: Yellowfin/Blackfin

- During the late 20th century, *Thunnus* spp. increased spawning activity throughout spring
- By the end of the 21st century, warming temperatures are predicted to increase the suitability of spawning habitat in all spring months



Larvae Habitat Results: Skipjack

- Similarly to yellowfin/blackfin tuna, skipjack tuna spawning grounds were predicted to increase in suitability through to the end of the 21st century



Always Thinking About Transition & Outreach !

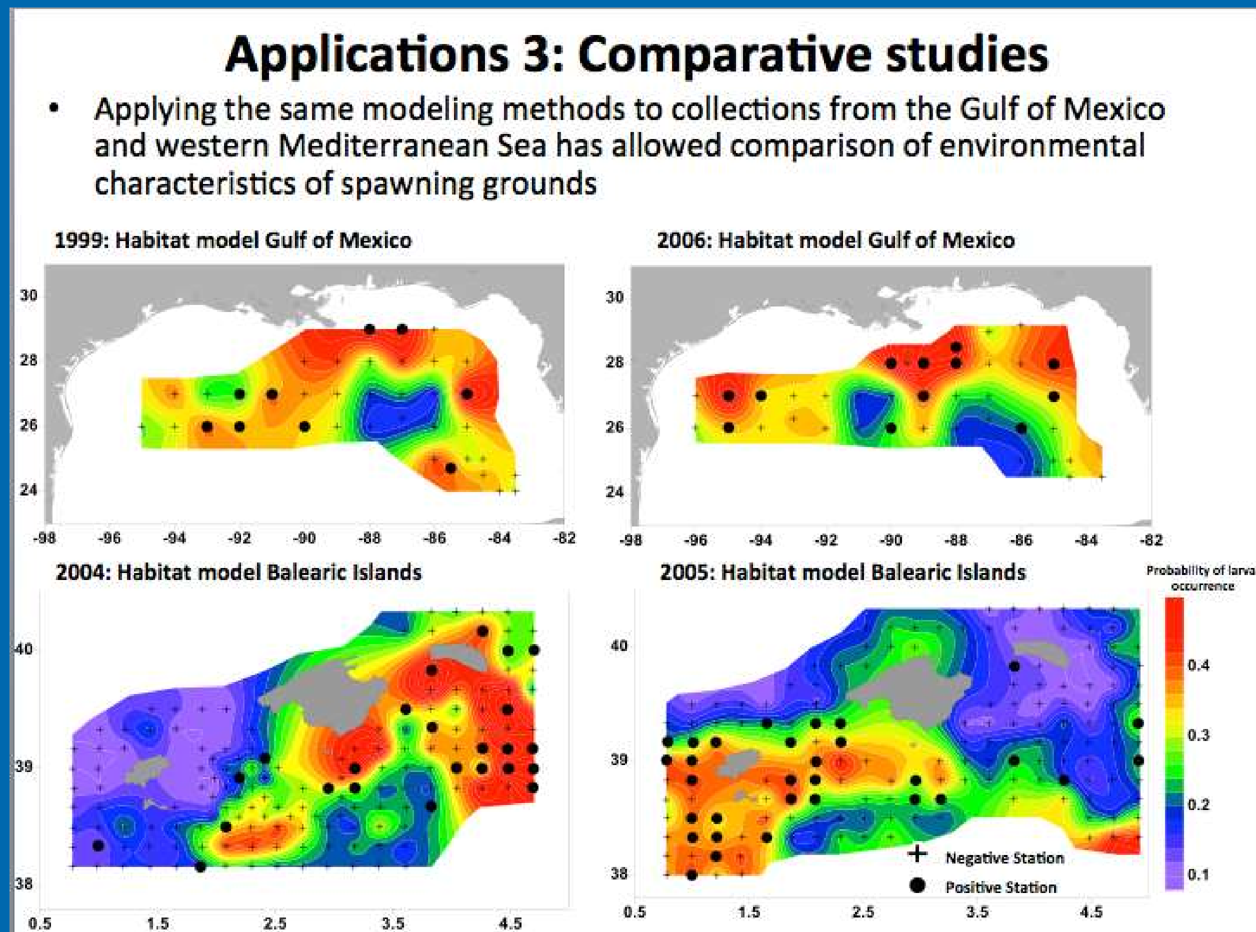
The goal at the end of the third year is to pass on the basic knowledge of satellite oceanography so that our <u>partner</u> NOAA researchers can routinely use satellite data for this and future projects.

This has been reached!

Publications

- Muhling, B.A., Lamkin, J.T., Roffer, M.A. (2010) Predicting the occurrence of bluefin tuna (*Thunnus thynnus*) larvae in the northern Gulf of Mexico: Building a classification model from archival data *Fisheries Oceanography* 19: 526-539.
- Muhling, B.A., Lamkin, J.T., Quattro, J.M., Smith, R.A., Roberts, M.A., Roffer, M.A., Ramirez, K.A. (2011) Collection of larval bluefin tuna (*Thunnus thynnus*) outside documented western Atlantic spawning grounds. *Bulletin of Marine Science* 87: 687-694.
- Muhling, B.A., Lee, S-K, Lamkin, J.T. (2011) Predicting the effects of climate change on bluefin tuna (*Thunnus thynnus*) spawning habitat in the Gulf of Mexico. *ICES Journal of Marine Science* 68: 1051-1062.
- Muhling, B.A., Roffer, M.A., Lamkin, J.T., Ingram, G.W. Jr., Upton, M.A., Gawlikowski, G., Muller-Karger, F., Habtes, S., Richards, W.J. (2012) Overlap between Atlantic bluefin tuna spawning grounds and observed Deepwater Horizon surface oil in the northern Gulf of Mexico. Marine Pollution Bulletin, doi:10.1016/j.marpolbul.2012.01.034.
- Liu Y., S.-K. Lee, B. A. Muhling, J. T. Lamkin and D.B. Enfield, 2012: Significant reduction of the Loop Current in the 21st century and its impact on the Gulf of Mexico. J. Geophys. Res., 117, C05039, doi:10.1029/2011JC007555
- Liu, Y., S.-K. Lee, C. Wang, D. B. Enfield, B. A. Muhling and J. T. Lamkin, 2013: Impact of the Atlantic Multidecadal oscillation on North Atlantic Ocean gyre circulation variability. Being revised for re-submission.
- Muhling, B.A., P. Reglero, L. Ciannelli, D. Alvarez-Berastegui, F. Alemany, J.T. Lamkin, and M. A. Roffer. 2013. A comparison between environmental characteristics of larval bluefin tuna (Thunnus thynnus) habitat in the Gulf of Mexico and western Mediterranean Sea. Marine Prog. Ser. 486:257-276.
- Muller-Karger, F.; Roffer, M.; Walker, N.; Oliver, M.; Schofield, O.; Abbott, M.; Graber, H.; Leben, R.; Goni, G., 2013. "Satellite Remote Sensing in Support of an Integrated Ocean Observing System," Geoscience and Remote Sensing Magazine, IEEE , 1 (4):8-18, 2013 doi: 10.1109/MGRS.2013.2289656

Thanks - Questions



Part II Climate Modeling

Need Another 15 Minutes

- What we have done:
  CMIP5 simulations under historical, RCP4.5, and RCP8.5 scenarios are downscaled for the GoM and CBN using MOM4.

- Highlight of our findings:
  CMIP5 downscaling results are mainly consistent with CMIP3 downscaling simulations.
  →
  Both the Loop Current (LC) and Caribbean Current (CC) are significantly reduced during the 21st century, consistent with a similar rate of reduction in the AMOC.

Year 3

- **Reprioritized task:**
  Downscale CMIP5 model simulations for the 21st century using MOM4-TOPAZ
- **Justification for the new task:**
  Preliminary model simulations show that the volume transport across the Yucatan Channel is not realistic in ROMS

PART I:

Integrating Ecosystems Factors Into Single Species Assessments

Red tide mortality modeling

$$Z_{a,2005} = F_{a,2005} + M_{a,2005} + M_{rt}$$

$Z_{a,2005}$ Total mortality in 2005

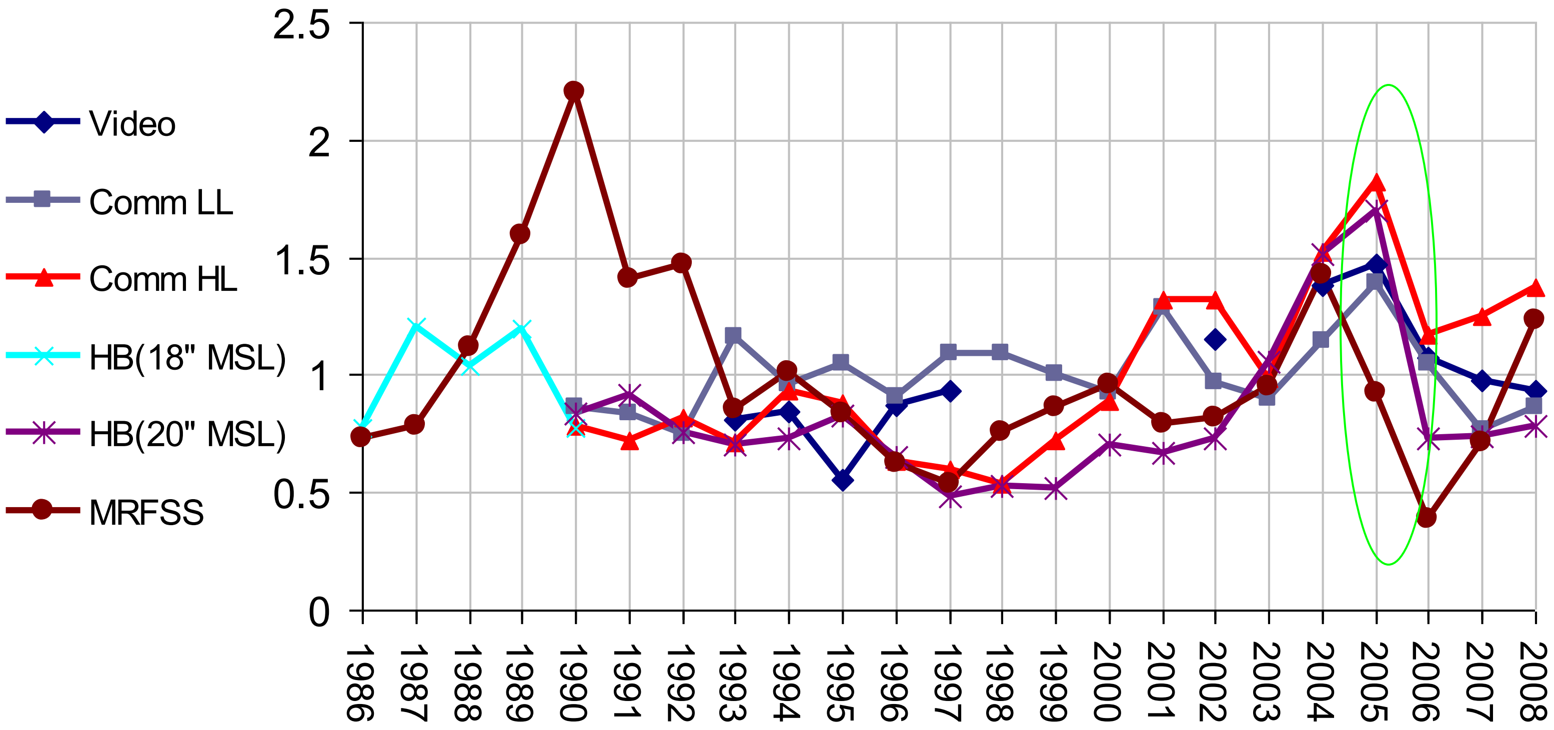
$F_{a,2005}$ Fishing mortality in 2005

$M_{a,2005}$ Natural mortality at age, scaled Lorenzen function

M_{rt} Mortality due to red tide, implemented over the entire year, rather than episodic

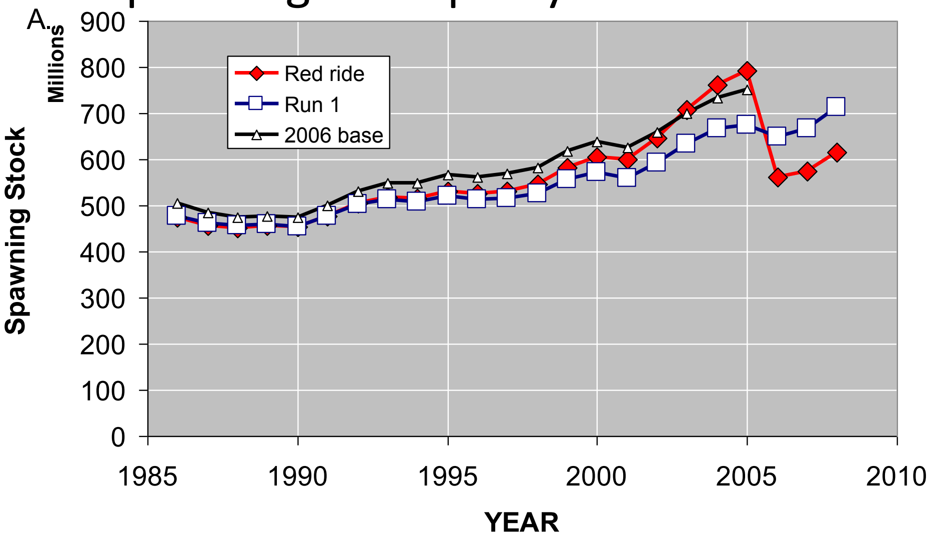
Red tide modeling, continued

Changed timing of video, LL, HL, HB indices to beginning of year, rather than average year to match with timing of mortality event.

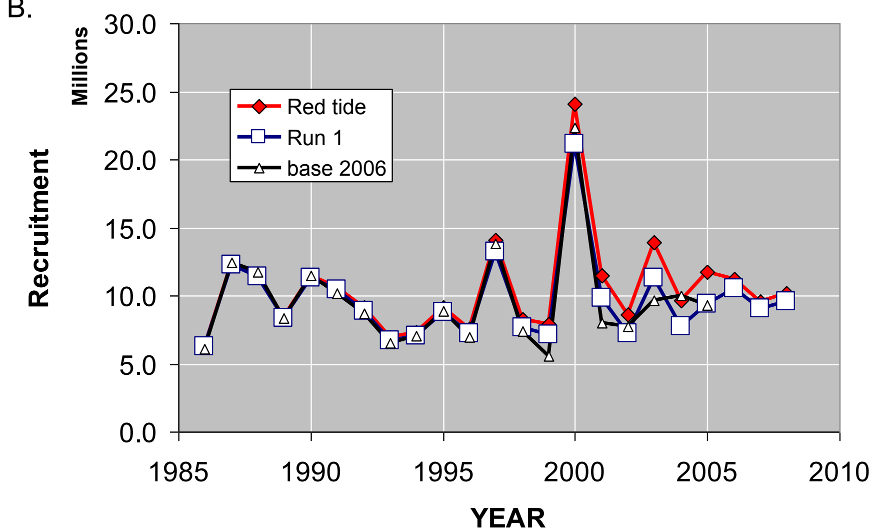


Comparison with red tide model

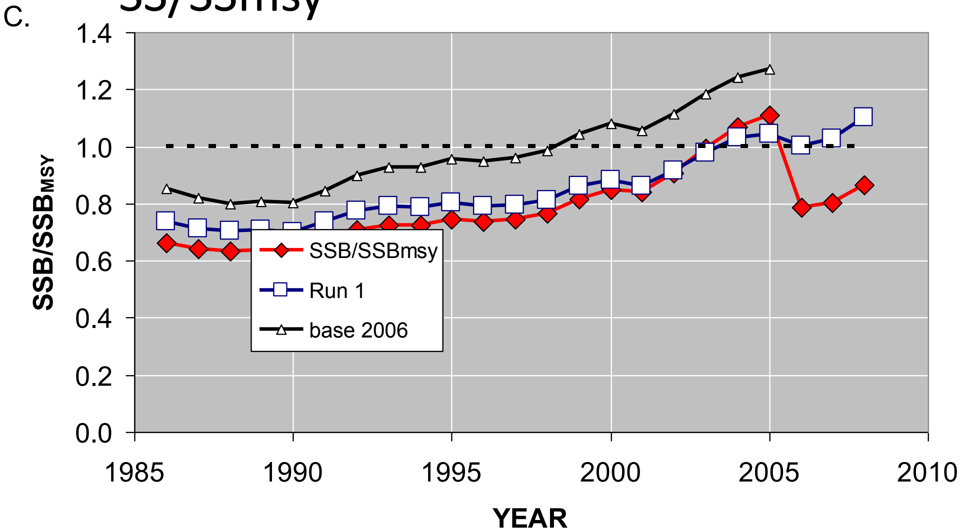
Spawning stock proxy



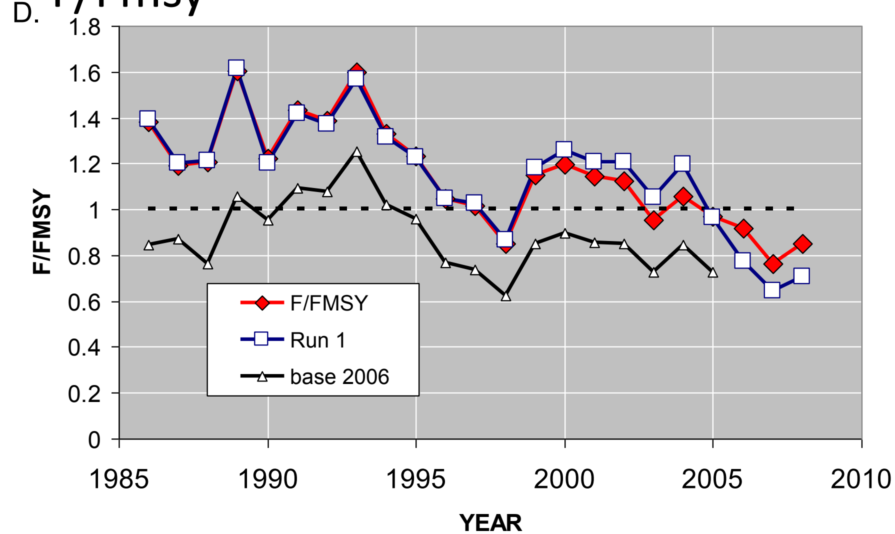
Recruitment



SS/SSmsy



F/Fmsy



Background

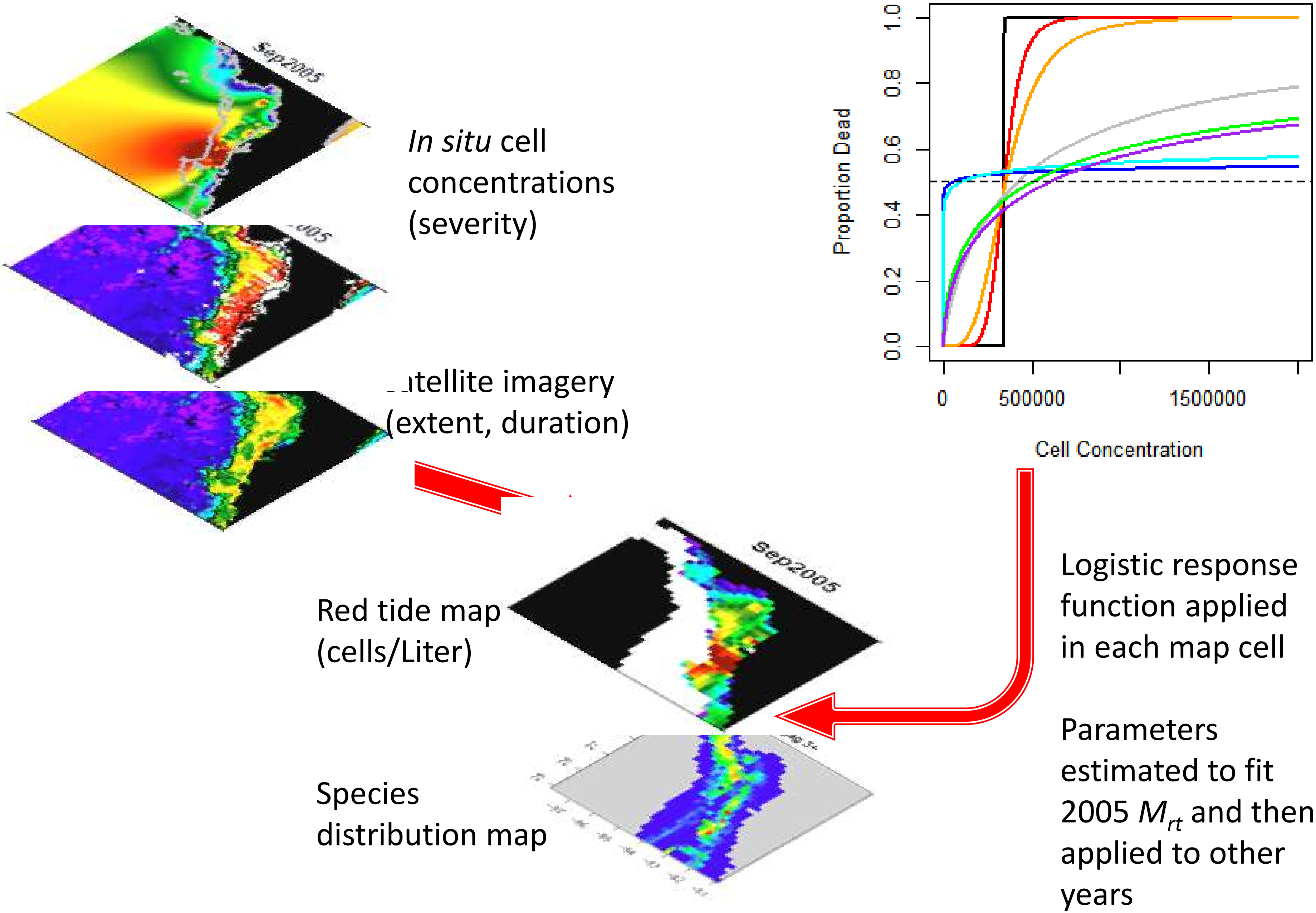
- 2009 gag SEDAR 10 Update Assessment
  - CASAL model
  - Estimated constant Mrt for 2005
    - applied equally across all ages
  - Estimated an episodic mortality rate of 0.35
    - 1.8 million gag, or 23% of population

- 2014 gag SEDAR 33 Assessment
  - Red tide modeled as a fishing fleet only operating in 2005
    - equal selectivity across all ages
  - Estimated mortality was 0.708
    - 3.4 million gag
    - 5,899 mt or **<u>50% of total biomass</u>**

Objective

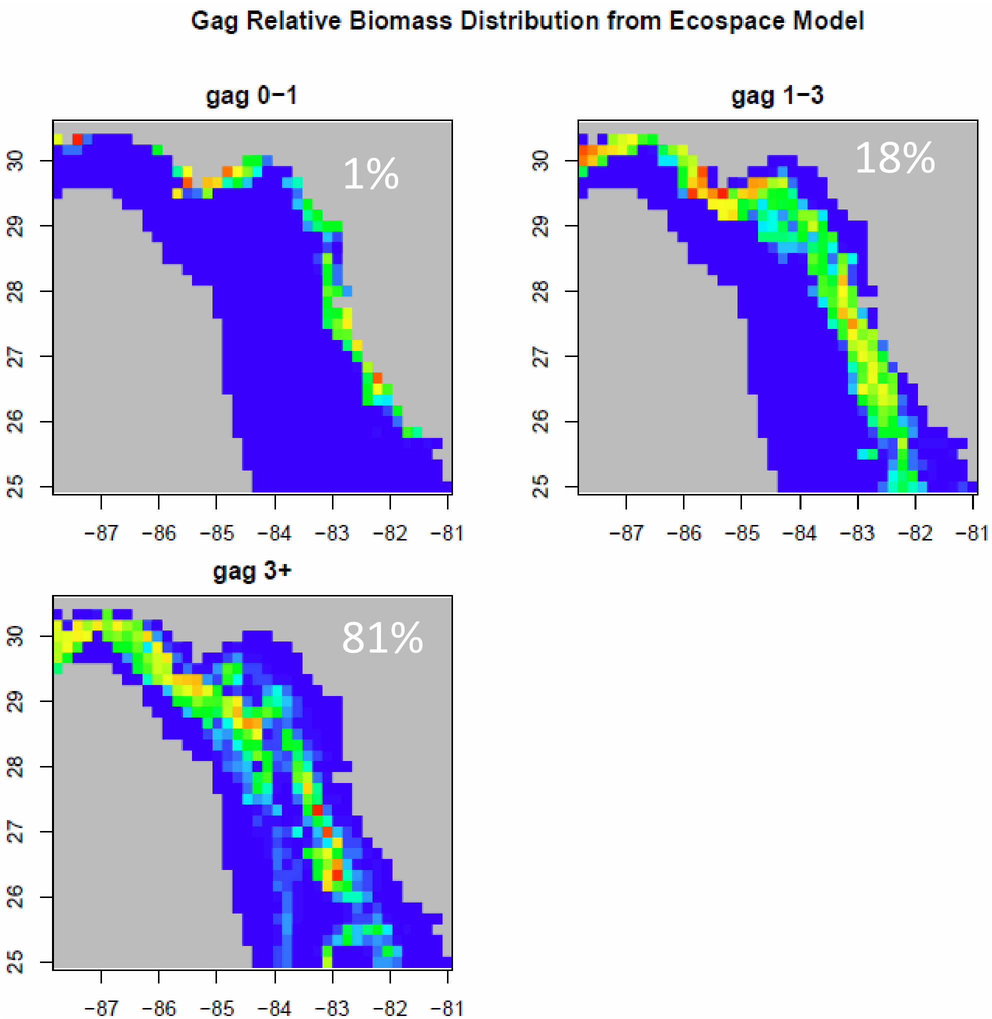
To estimate the mortality rate of gag grouper caused by red tides from 2002-2014

- Spatial extent and duration – satellite imagery
- Severity – cell concentration samples
- Species distribution patterns – ecosystem model
- Mortality – logistic response function



Sep2005
In situ cell concentrations (severity)
atellite imagery (extent, duration)
Red tide map (cells/Liter)
Sep2005
Species distribution map
Proportion Dead
0.0
0.2
0.4
0.6
0.8
1.0
0
500000
1500000
Cell Concentration
Logistic response function applied in each map cell
Parameters estimated to fit 2005 M_{rt} and then applied to other years

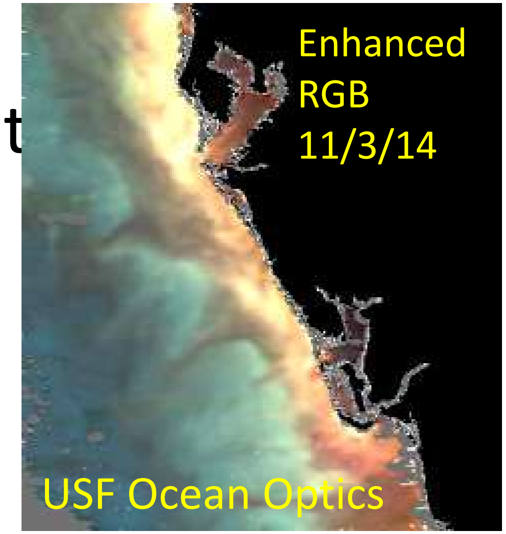
Gag Biomass Distribution Maps



- Output from Ecospace model
- Using relationships to depth & rugosity
  - Also influenced by food availability and proximity to younger life stages
- Total biomass distributed to age groups based on biomass distribution across ages from assessment

Satellite Imagery

- MODIS-Aqua 9km normalized fluorescent line height (FLH) monthly composite satellite imagery from NASA Giovanni website
- 0.02 mW cm^{-2} um^{-1} sr^{-1} used as threshold for detection of red tide (Hu *et al*. 2005, personal communications)
- FLH is an indicator of algal blooms (both harmful and not) and also influenced by sediment resuspension
  - Must be validated with cell concentrat and/or enhanced RGB imagery
- Provides extent, but not severity



Logistic Response Function

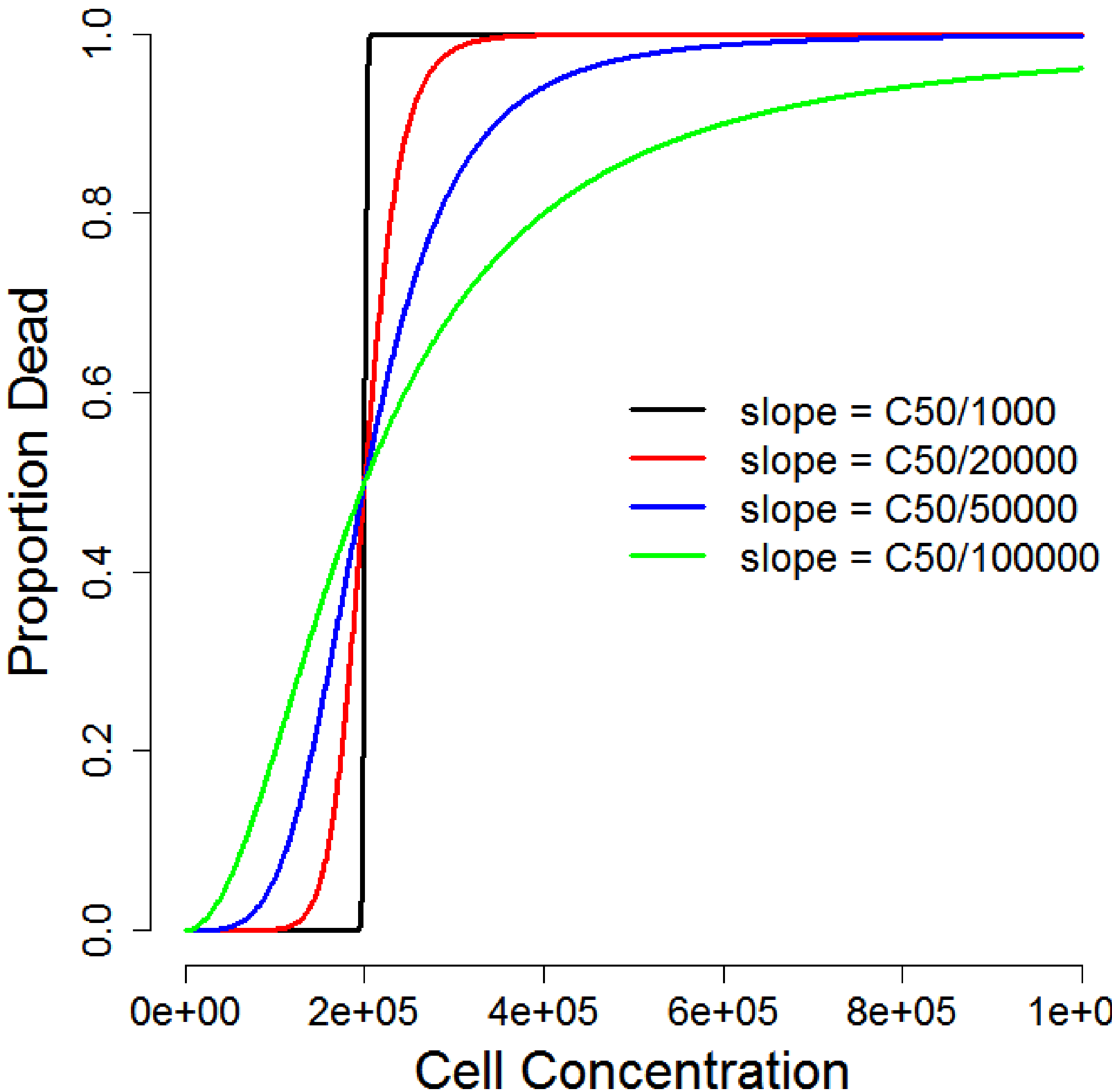
- Logistic function used to determine the proportion of biomass that is killed in each grid cell

$$P_{dead} = min + \frac{max - min}{1 + \left(\frac{x}{C_{50}}\right)^{-slope}}$$

$$P_{dead} = \frac{1}{1 + \left(\frac{x}{C_{50}}\right)^{-\left(\frac{C_{50}}{a}\right)}}$$

- Estimated the inflection point, C_{50} and slope (*a*) that would result in 2005 mortality from stock assessment
  - Can only estimate 1 parameter at a time because only fitting to 1 value (the Mrt in 2005)
  - *min* and *max* fixed at 0 and 1;
  - Estimated C_{50} with fixed slope (denominator, *a* was fixed at 4 levels)
  - Estimated *a* with fixed C_{50} (fixed at four levels)
  - Multiple possible response functions that could lead to 2005 mortality
- Applied response function in grids on a monthly time step
  - Gag maps updated each month to “mine” down the biomass in each grid cell
- Mortality rate calculated as the total biomass killed over entire year divided by starting biomass for that year (proportion biomass killed)

Logistic Response Function: examples



$$P_{dead} = min + \frac{max - min}{1 + \left(\frac{x}{C_{50}}\right)^{-slope}}$$

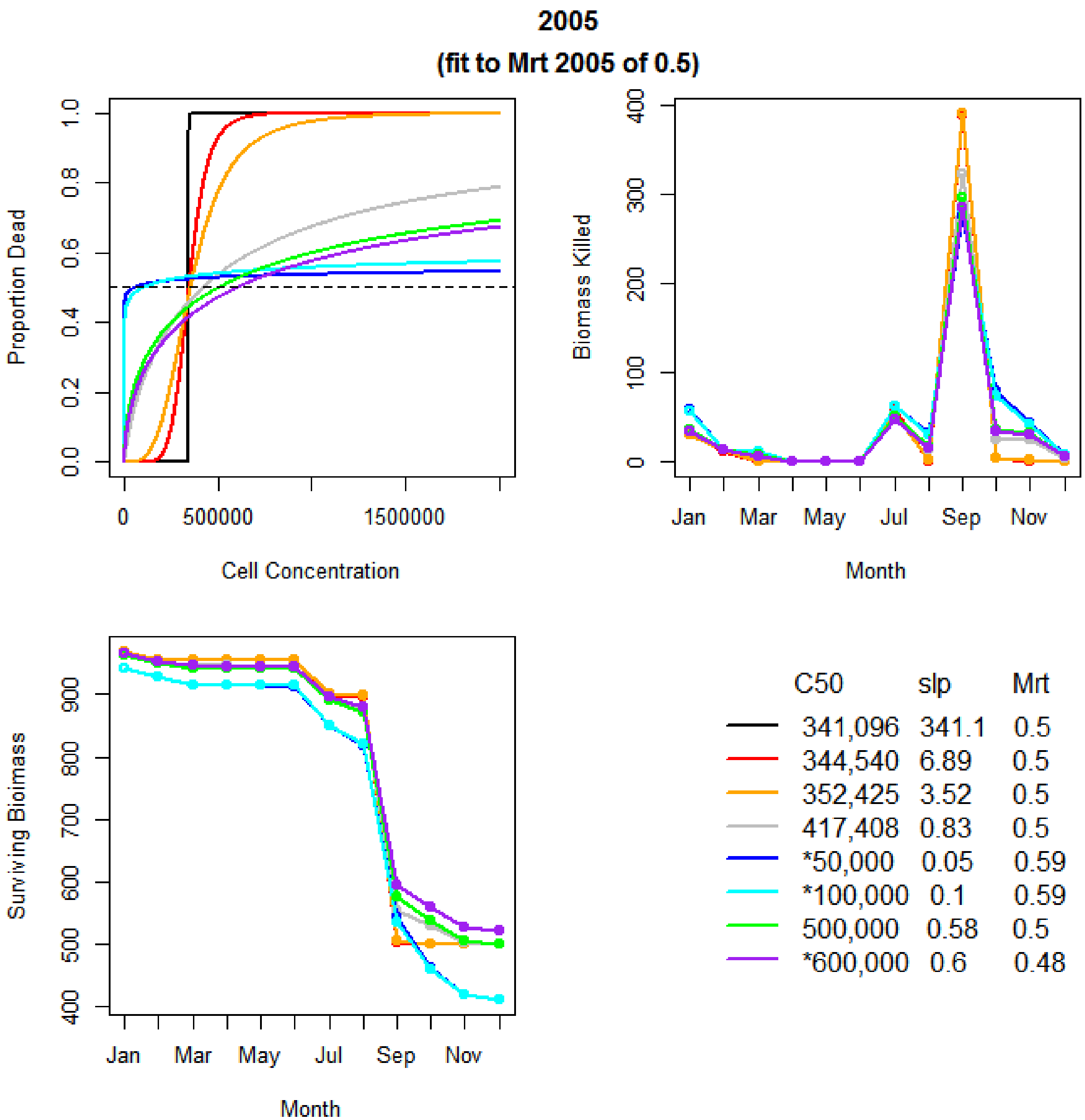
$$P_{dead} = \frac{1}{1 + \left(\frac{x}{C_{50}}\right)^{-\left(\frac{C_{50}}{a}\right)}}$$

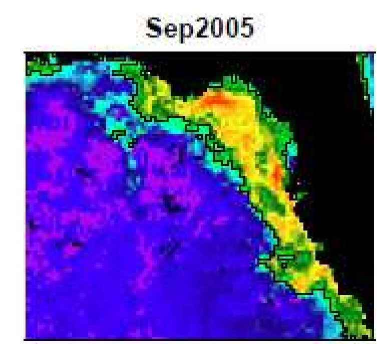
Applied in each grid cell for each month

Total killed summed over ages, cells, and months to determine mortality (prop. biomass killed) for year

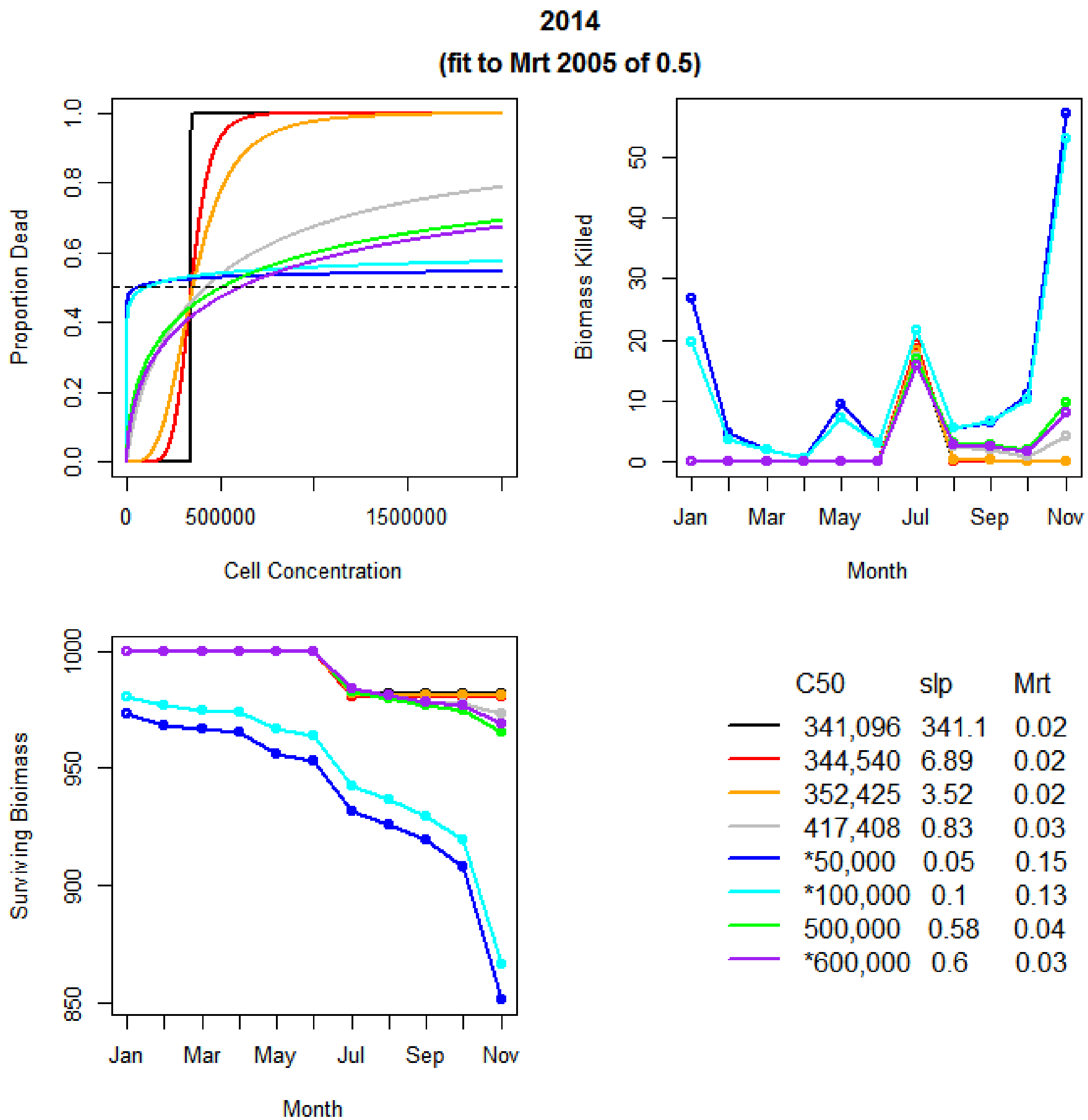
2005

- Parameters are estimated to generate mortality from assessment
- Most mortality occurred in September
- Note some curves do not produce 2005 estimate

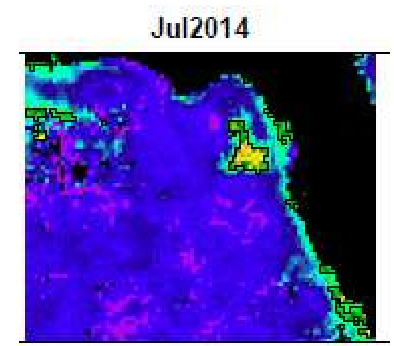




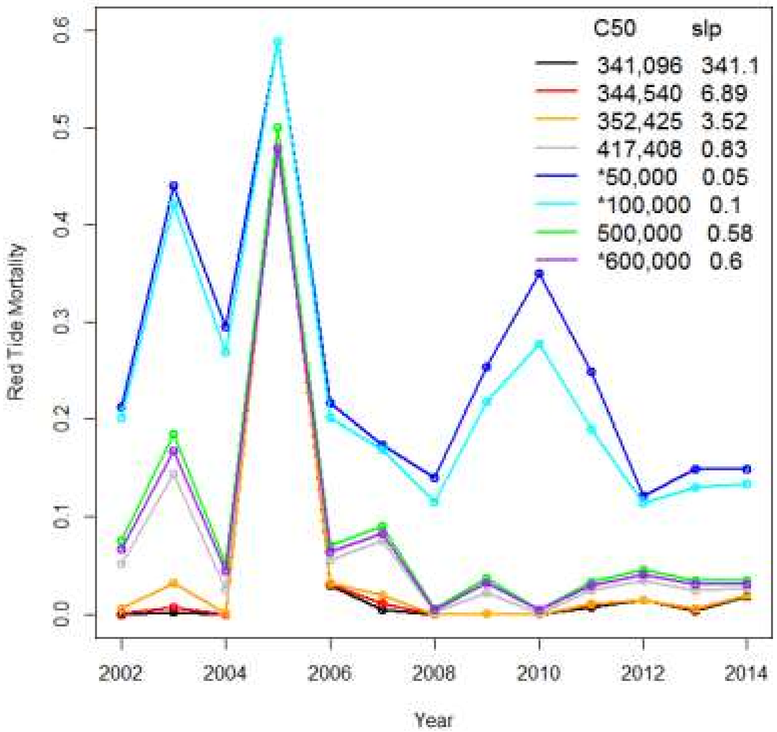
2014



- response functions estimated for 2005 are applied using maps from other years
- Most mortality occurred in July
- Note some curves do not produce 2005 estimate



Gag red tide mortality (proportion biomass killed)



	curve 1	curve 2	curve 3	curve 4	curve 5	curve 6	curve 7	curve 8
2002	0.000	0.001	0.006	0.052	0.213	0.202	0.076	0.050
2003	0.002	0.007	0.032	0.145	0.441	0.422	0.186	0.132
2004	0.000	0.000	0.001	0.026	0.296	0.269	0.052	0.029
2005	0.500	0.500	0.500	0.500	0.589	0.589	0.500	0.447
2006	0.029	0.031	0.032	0.056	0.217	0.202	0.071	0.052
2007	0.004	0.011	0.020	0.076	0.174	0.169	0.091	0.067
2008	0.000	0.000	0.000	0.002	0.140	0.116	0.006	0.003
2009	0.001	0.001	0.001	0.022	0.254	0.218	0.037	0.022
2010	0.000	0.000	0.000	0.001	0.351	0.278	0.005	0.002
2011	0.007	0.009	0.011	0.025	0.249	0.191	0.033	0.024
2012	0.014	0.014	0.015	0.035	0.122	0.114	0.046	0.033
2013	0.003	0.004	0.006	0.025	0.149	0.130	0.035	0.024
2014	0.018	0.020	0.019	0.027	0.149	0.134	0.035	0.025

- C_{50} estimates between 300,000 and 500,000
- M_{rt} 2014 = 0.018 – 0.035
- 4-7% of mortality caused in 2005

PART II:

Ecosystem modeling for single-species management:

characterizing environmental uncertainty in stock projections

Objectives

- Demonstrate that ecosystem models can be useful for single-species management
- Characterize environmental uncertainty in stock projections
  - Stochastic simulations with an Ecosim model
  - Uncertainty in predator-prey abundances
  - Uncertainty in bottom-up processes
- Predict the ecosystem Impacts of single-species management
- Ultimately, tailor the products from ecosystem models for the Council and SSC

Description of Model

- Ecopath with Ecosim and Ecospace model
- Developed from 2010-2013
- Focus on important West Florida Shelf reef fish
- Builds upon recent modeling efforts on the GoM:
  - Gulf of Mexico model (Walters *et al*. 2006) & West Florida Shelf model (Mackinson *et al*. 2001)

- Ecosystem-based Evaluation of Fisheries Policies and Tradeoffs on the West Florida Shelf (Chagaris, PhD dissertation 2013)
  - Trophic interactions and fishery harvest policies on the West Florida Shelf (Ecosim)
  - Tradeoffs in optimal harvest policies for West Florida Shelf fisheries (Ecosim policy optimization)
  - Evaluation of marine protected areas in the eastern Gulf of Mexico (Ecospace)

- Last presented to Council at joint Standing & Ecosystem SSC meeting in Tampa, March 2013

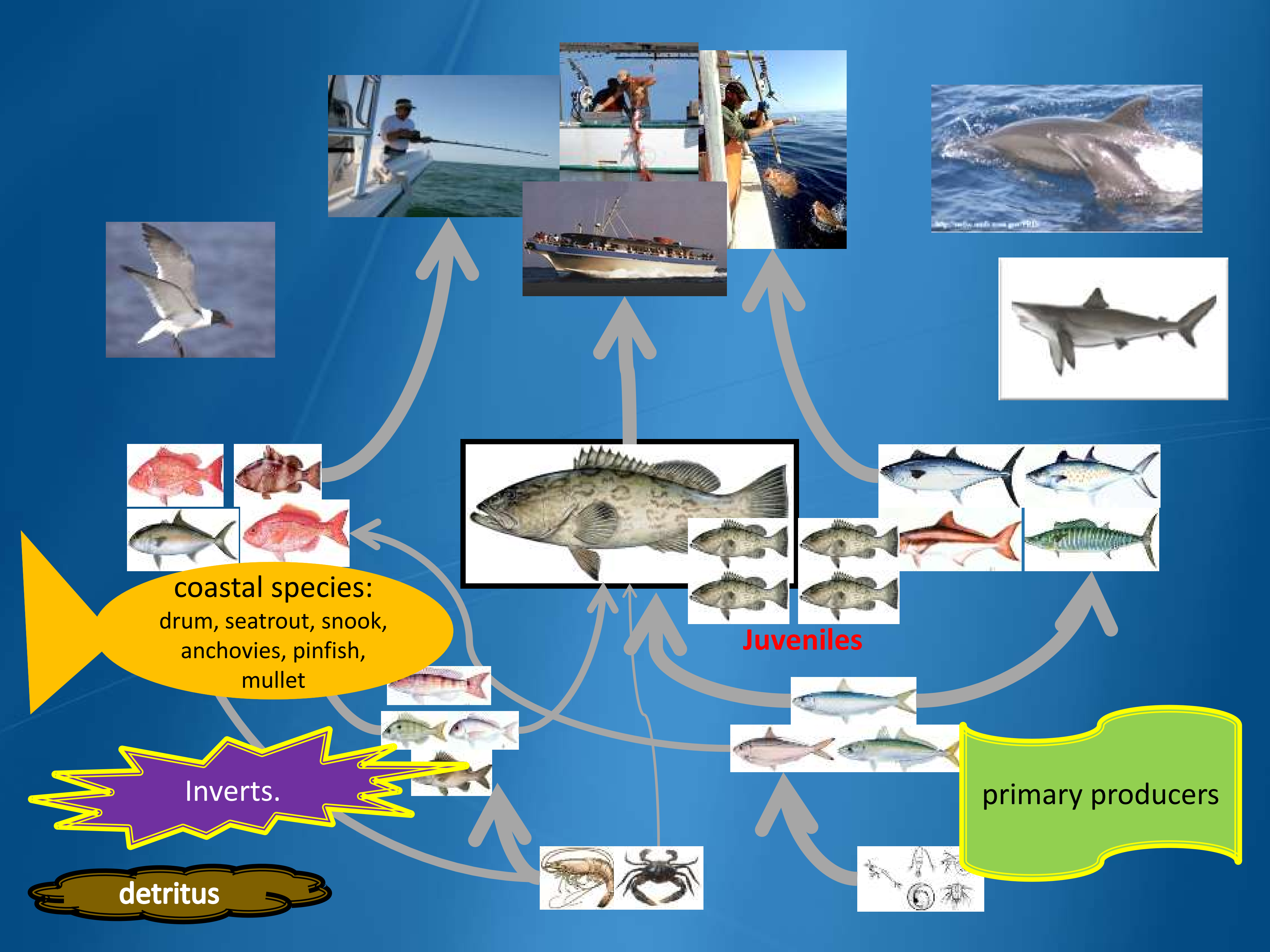
WFS Reef Fish Model

- focus on reef fish species
  - 11 managed reef fish species, 5 reef fish functional groups
  - Age stanzas to represent ontogenetic shifts in diet, habitat, fishing pressure
- Pelagic groups – competitors, potential predators
- Coastal groups – forage, potential predators/competitors with juv.

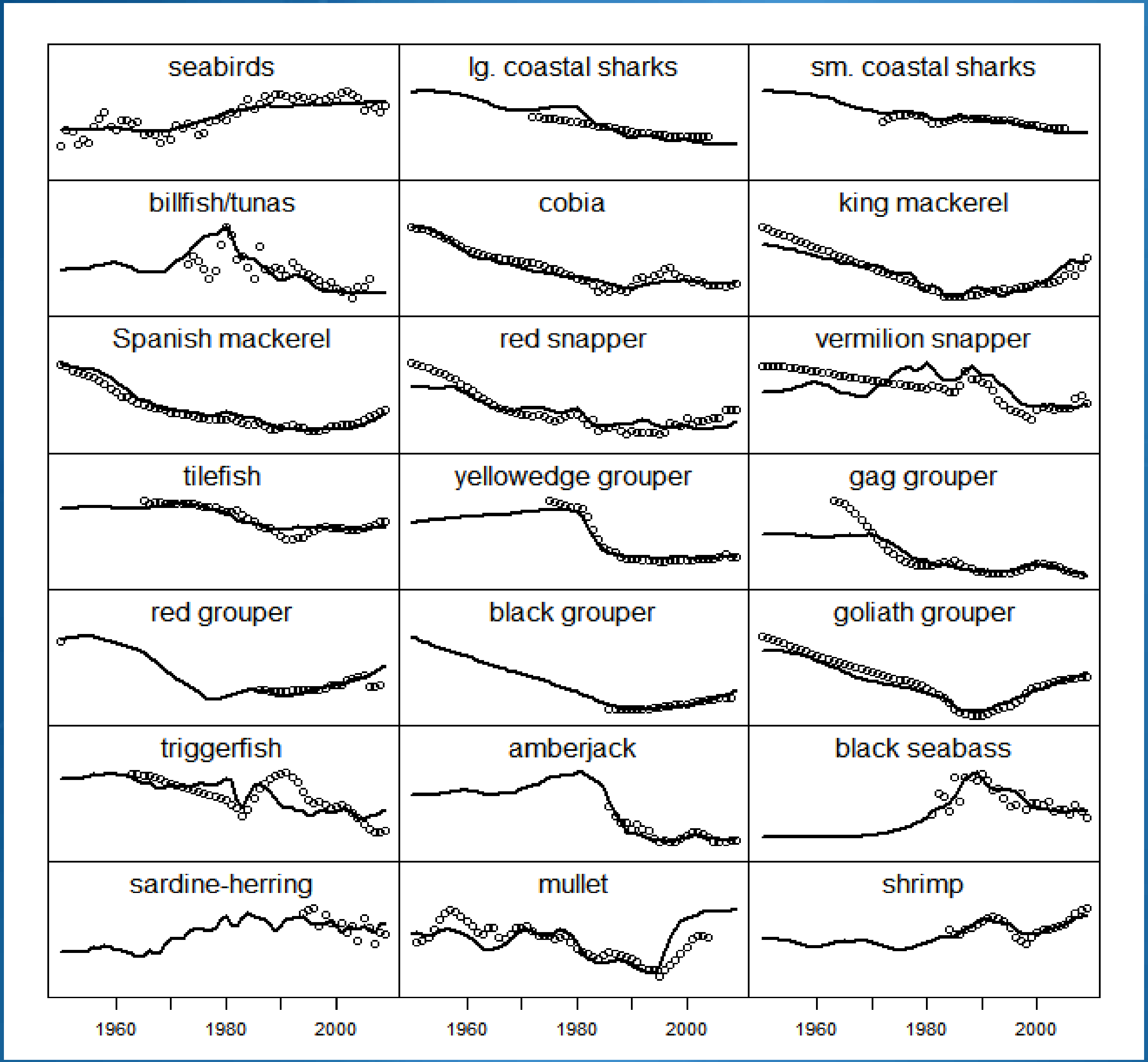
- **70 biomass pools**
  - 1 dolphin, 1 seabird group
  - 43 fish groups (11 are non-adult age stanzas)
  - 18 invertebrate groups
  - 4 primary producers
  - 3 detritus groups

Non-fish groups largely unchanged from earlier WFS model

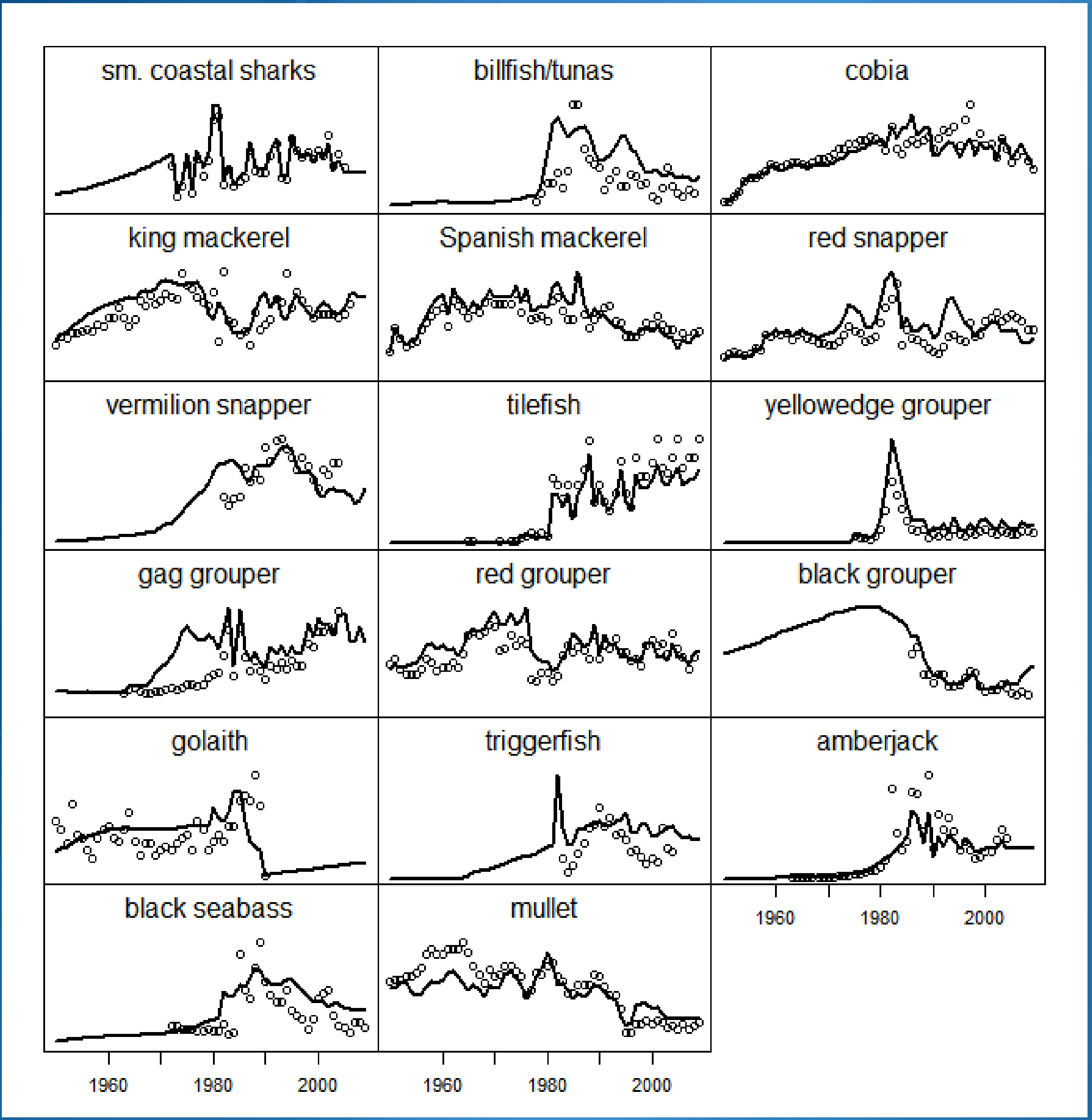
- **14 fishing 'fleets'**
  - 4 recreational: shore, private boat, charter boat, headboat
  - 10 commercial: bottom longline, handline, trawl, seines, offshore gill/trammel, fish trap, crab traps, cast nets, troll, pelagic longline
- Ecosim calibrated to timeseries from 1950-2009


coastal species:
drum, seatrout, snook, anchovies, pinfish, mullet
Juveniles
Inverts.
primary producers
detritus

Model Calibration: Fits to Abundance



Model Calibration: Fits to Catch



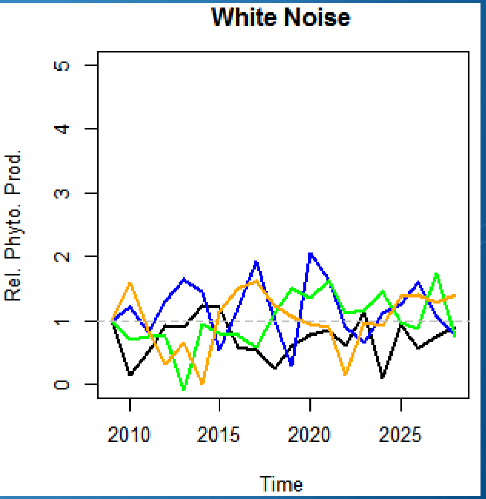
Stock Projections in SEDAR 2009 update assessment

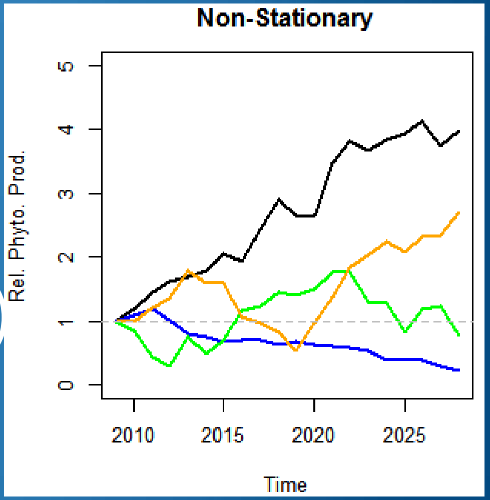
- Projections considered six fixed F management scenarios.
  - Scenario 1: F = FCURRENT
  - Scenario 2: F = FMAX
  - Scenario 3: F = 90% of FMAX
  - Scenario 4: F = 75% of FMAX
  - Scenario 5: F that rebuilds stock to SSBMSY by 2019
  - Scenario 6: F that rebuilds stock to SSBOY by 2019

- The decision table considered ten fixed landing management scenarios.
  - 0.5 to 5.0 million pounds gutted weight, in increments of 0.5 mp gw
  - 500 bootstrap iterations with random recruitment from historical period
  - Probability of overfishing based on number of iterations where F exceeded Fmax

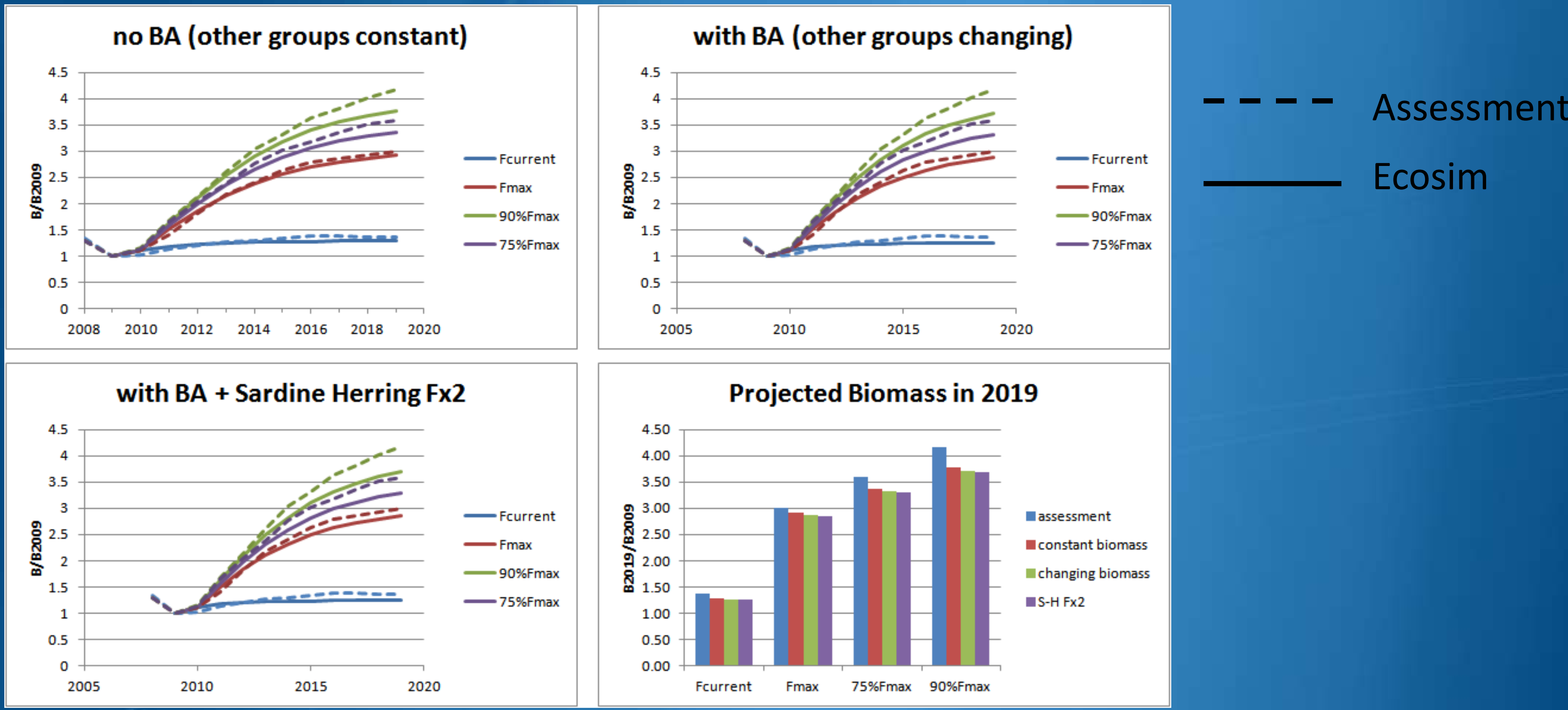
Stock Projections in Ecosim

- Deterministic (no uncertainty)
  - Prescribe a single or set of policy options or environmental scenarios
- Monte-Carlo simulations
  - Conducts Ecosim scenario with randomly chosen starting (Ecopath) values
  - If combination of parameters results in unbalanced model, the draw is rejected and another is made
  - 100 simulations per projection with random biomass
- MultiSim simulations
  - automates loading of environmental forcing fxns
  - 100 simulations per projection with random phytoplankton forcing time series
  - 'white noise' and non-stationary
- From stochastic simulations the probability of overfished (B < MSST) or overfishing (F > MFMT) can be determined for each projection scenario



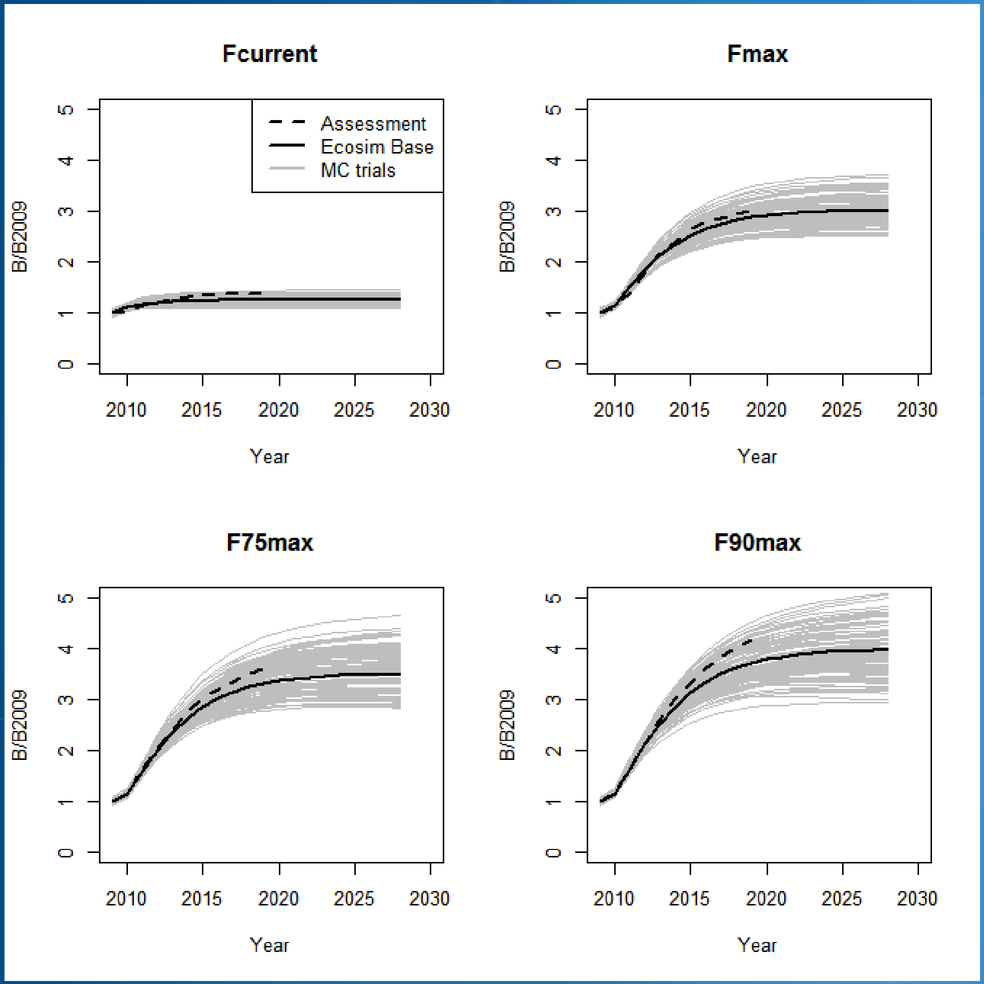


Deterministic Projections



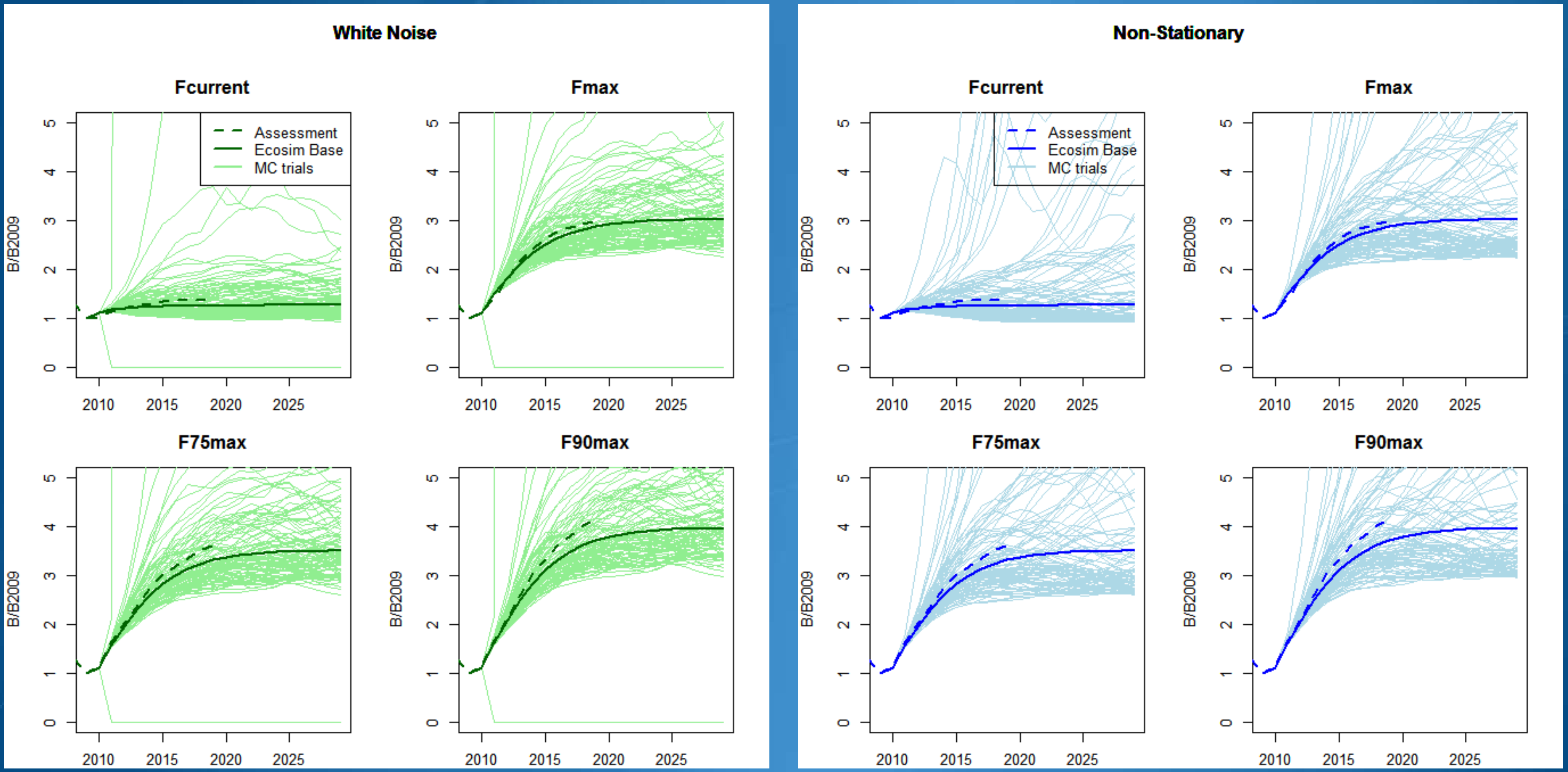
- Projections are similar to those from single species model (2009 update assessment)
  - Differences likely caused by vulnerability settings and trophic interactions
- Projected changes in other groups has little impact on gag
  - Predation is poorly defined
  - Competition effects are low at small stock sizes

Gag projections using Monte-Carlo Simulations



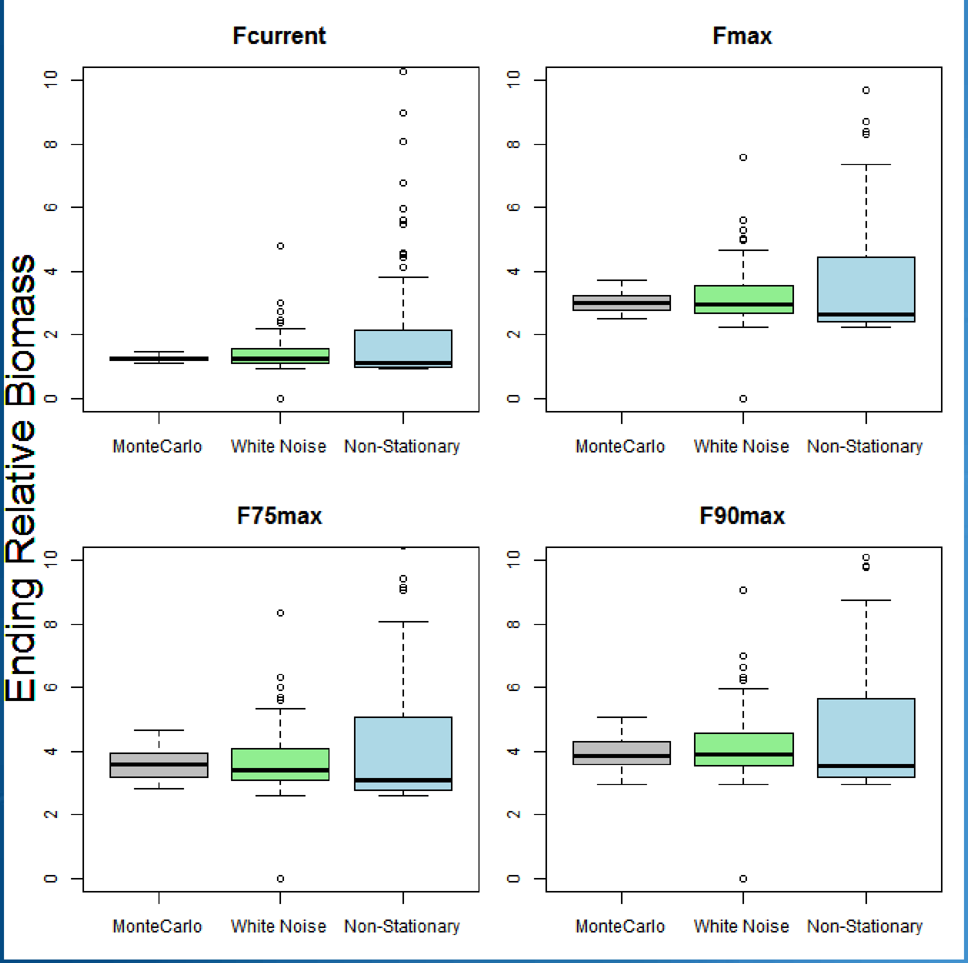
- Random draws of Ecopath starting biomass
- Draws from within uniform distribution with a specified CV
- Requires mass balance
- Represents the uncertainty associated with predator and prey abundances in projection start year

Gag Projections using random primary production scenarios



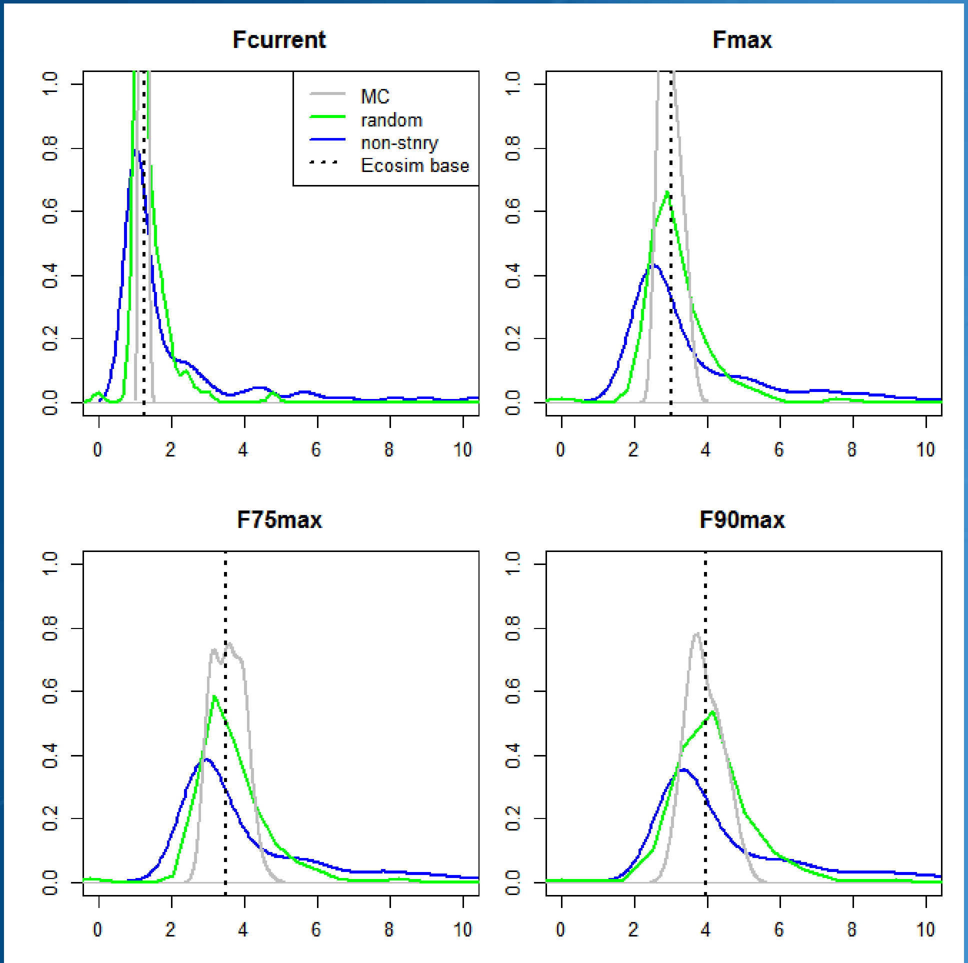
- Scenarios generated externally and loaded into Ecosim as forcing on phytoplankton production
- White noise represents random, inter-annual variability
- Non-stationary random processes may occur due to climate change

Uncertainty Comparison



- Uncertainty due to predator/prey abundances and random variation in PP is about equal
- Non-stationary PP scenarios lead to largest uncertainty in projected biomass

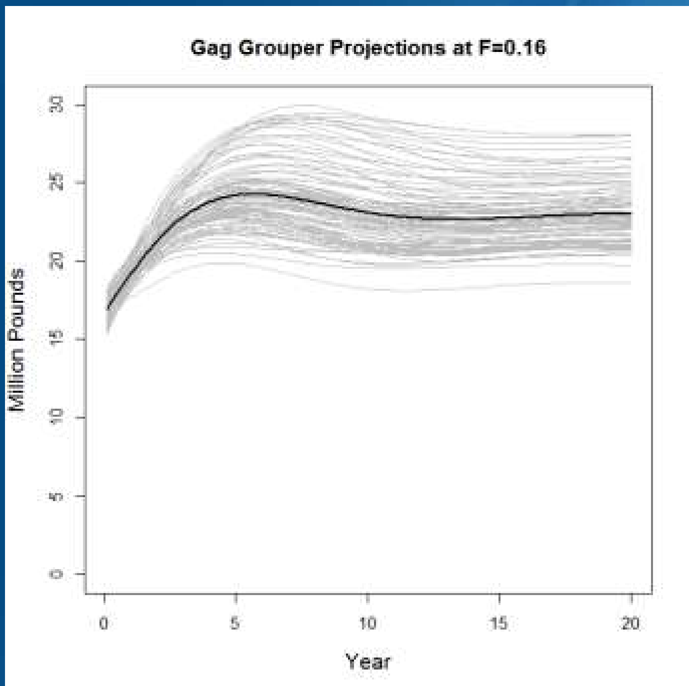
Uncertainty Comparison

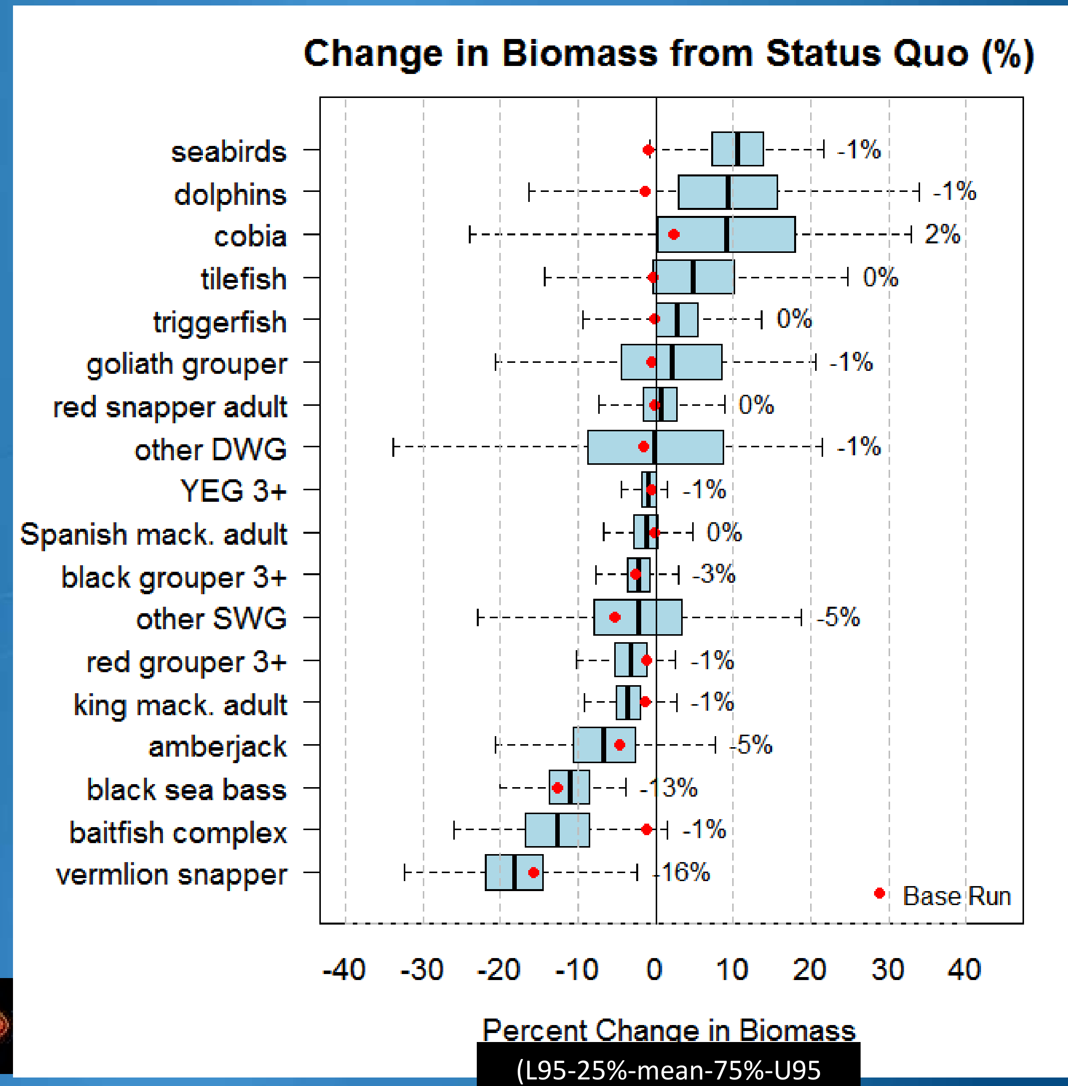


- Uncertainty due to predator/prey abundances and random variation in PP is about equal
- Non-stationary PP scenarios lead to largest uncertainty in projected biomass
  - Mode shifts left with long tail at larger values

Ecosystem Impacts

Rebuilding Gag, F = .16





- Year 10 biomass ≈ 23 mp
- Projected biomass from single species model is 22-30 mp under F of .14-.19
- Potential for impact on vermilion snapper, black sea bass, and GAJ
- Modest impacts on other species

What else can these models do?

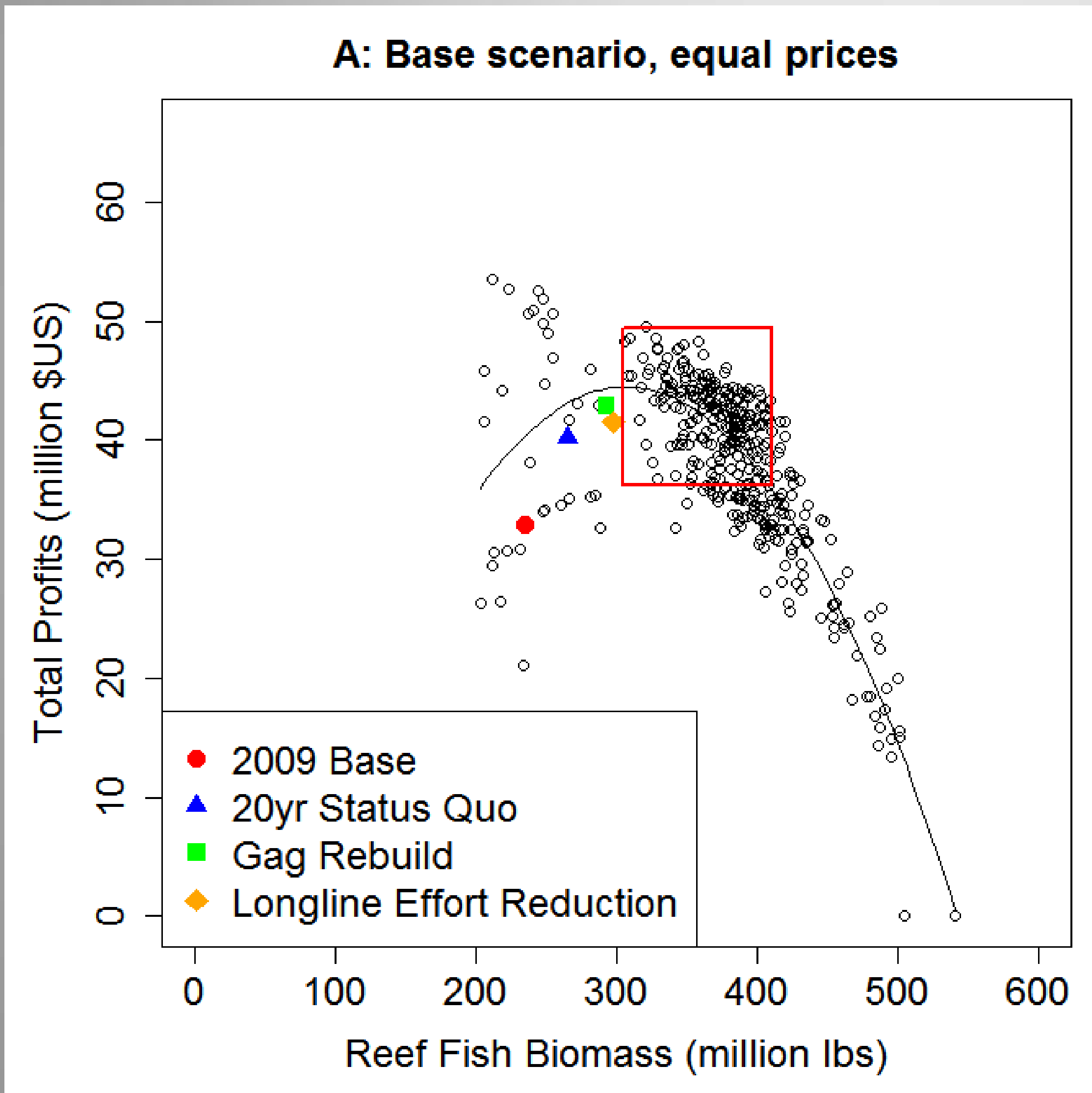
- Estimate time- and age-specific M
- Identify tradeoffs among conflicting management objectives , e.g. conservation vs. profits
  - ‘balanced’ policies exist where total reef fish biomass is appx 50% higher and total profits are 30% higher (than 2009)
- Plan and evaluate spatial policy options
  - Existing MPAs are too small for significant biomass gains
  - “Win-Win” scenarios, those with higher biomass and catch, required between 15-30% of the total area to be closed
- Link to hydrodynamic oceanographic models and satellite data – a work in progress…
  - More realistic predictions about spatial policy options
  - Predict impacts of episodic mortality events that are limited in space (oil spills, red tides)

Ecospace linked to spatial-dynamic data

- From oceanographic models or satellites
- Chl-a from satellites
- Surface and bottom temperature from HYCOM

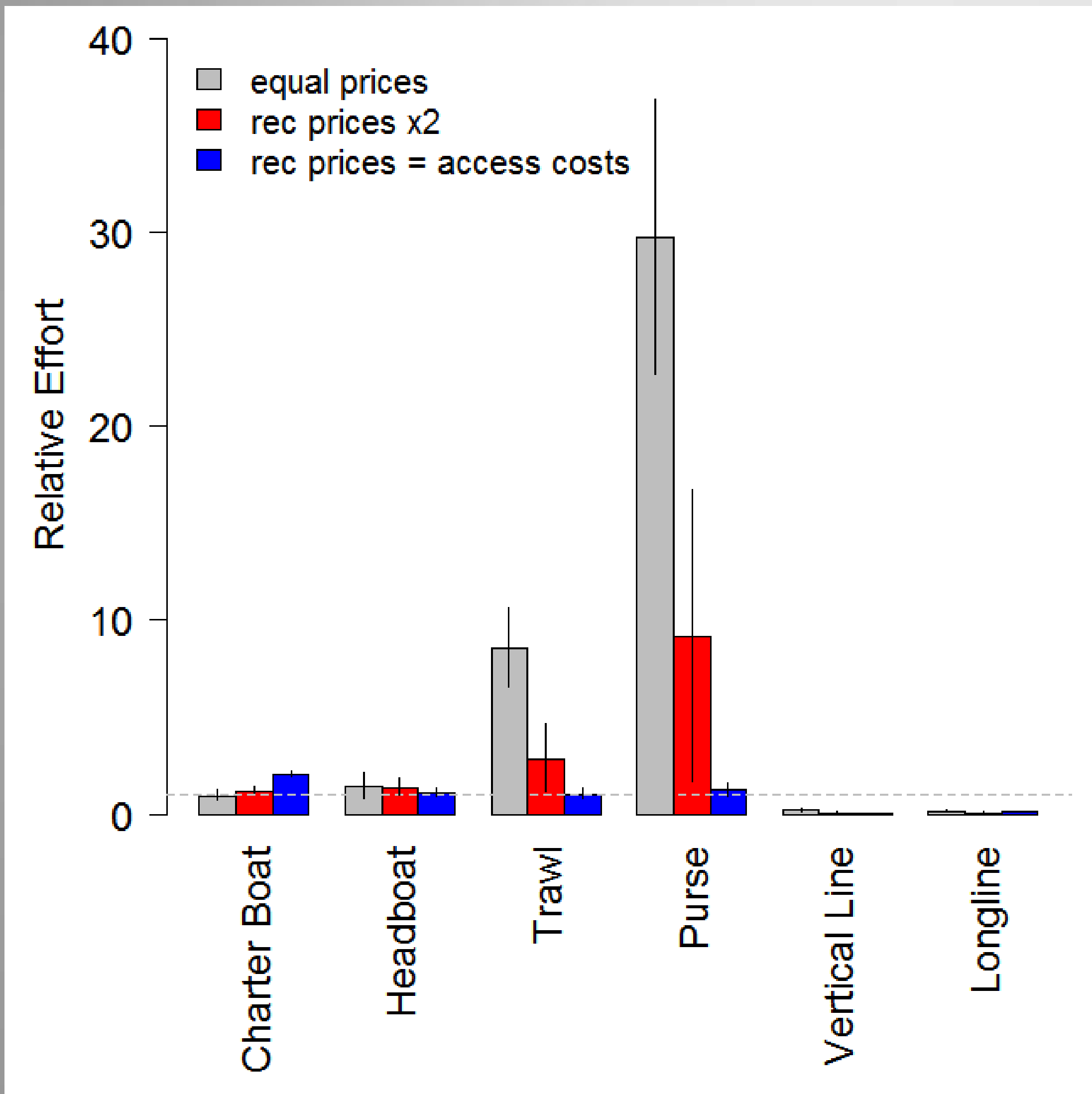
Questions?

Tradeoff Frontier Between Reef Fish Conservation and Total Profits



- convex shape indicates that 'balanced' policies exist where both values are high
  - 300-400 mp biomass
  - 30-50% increase in profits
- 2009 (base) condition is suboptimal in both biomass and profits
- Rebuilding plans move system closer to the curve

But, we found the optimal policy is sensitive to assumptions about market prices



- Lower optimal efforts in forage fisheries when recreational value is higher
- Charter boat & headboat fleets not drastically changed
- Commercial VL and LL fisheries drastically reduced in all scenarios

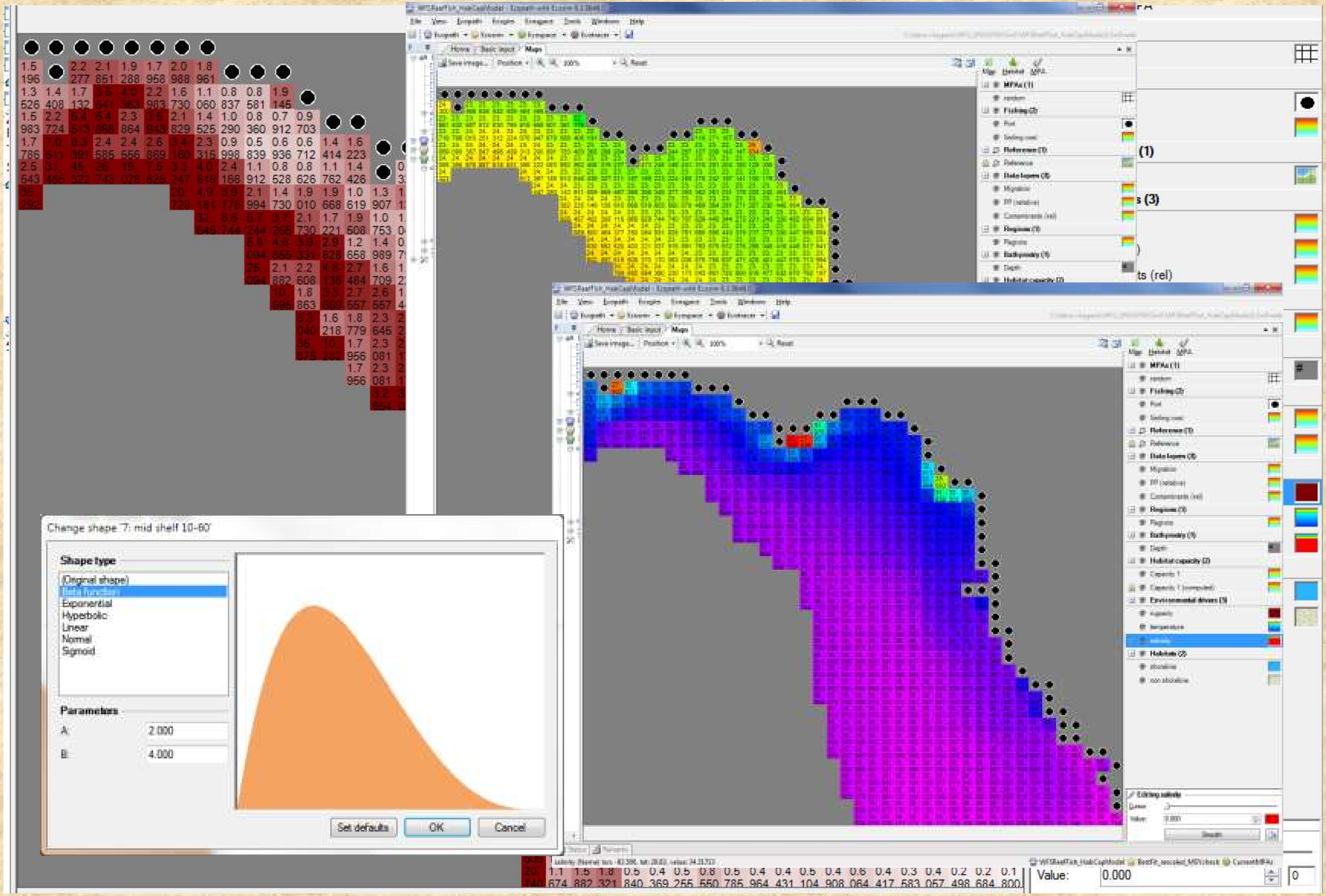
Conclusions from Optimization

- A tradeoff exists between economic and conservation management objectives
  - Total reef fish biomass appx. 50% higher
  - Total profits appx. 30% higher
- The policies along the tradeoff are different depending on relative value of each fishery
- In no scenarios were forage fisheries (shrimp trawl and purse seine) drastically reduced
  - Optimal efforts of forage fisheries declined when value of a recreationally caught fish was increased
- Optimization and tradeoff frontiers could be useful for ranking policies and helping to maximize performance in a multi-species/multi-fleet fishery

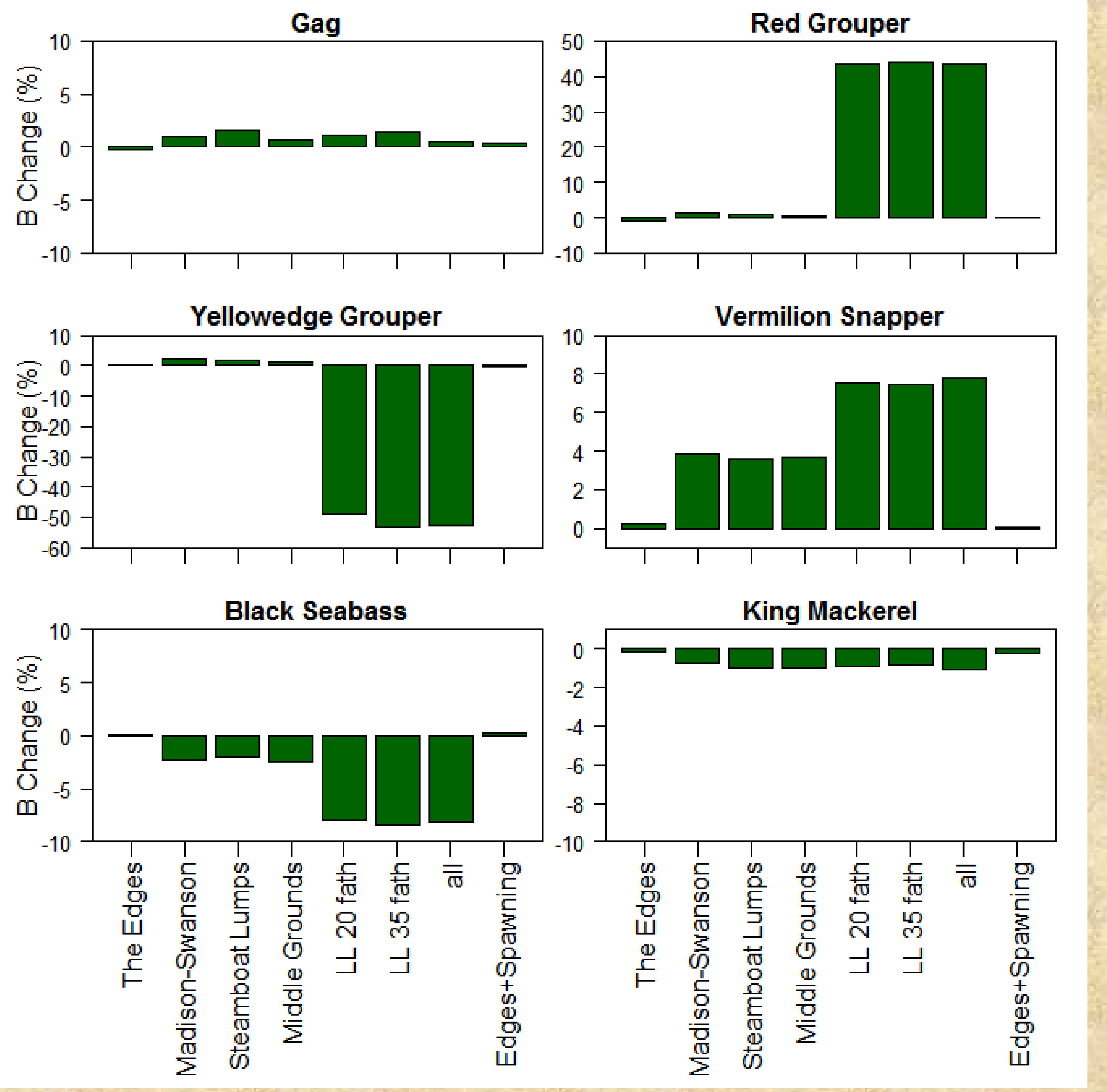
Ecospace Model Description

- Replicates Ecosim trophic-dynamics over spatial grid
- Represents dispersal, migration, and ontogenetic habitat shifts of biomass among those cells
- Fishing effort distributed based on profitability of fishing in a given cell (biomass, market price, and sailing costs)
- Multistanza age cohorts divided into large number of identical "packets" (Individual Based Model)
- Foraging area in each cell is determined using <u>habitat capacity model</u> that defines species relationships with habitat layers
  - Rugosity (USGS), SST and Chl-a (MODIS satellite), salinity (HYCOM model)
  - determines relative foraging size of each cell ("capacity") per group
- Fish then move towards areas with more foraging habitat resulting in predicted spatial distribution patterns

Habitat Capacity Model – habitat layers



Evaluating Existing MPAs



- Small reserves had little positive impact on species biomass
- Ecospace could be under representing reproductive value of some sites
  - Not accounting for migration, spawning seasonality, larval transport and survival
- Longline closures benefitted red grouper; negative effect on deep water species (tilefish, YEG)

Ecosystem Modeling for Single-Species Management

Stock Assessment	• Provide input to assessment models (M, Rec.) • Ecological hypothesis testing • Stock projections and uncertainty
Council APs & SSCs	• Rank policy options, MPAs • Simulate mgmt across multiple sectors, tradeoffs • Account for environmental uncertainty (*p**)
Fishery Management Plans	• "Environmental Consequences" • "Cumulative Impacts"