Marine Geospatial Ecology Lab

"Applications of optimization algorithms & habitat models for

marine ecoregional
&
marine ecosystem-based management"

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Michael Coyne

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DUKE UNIVERSITY

Marine Ecosystem-Based Management

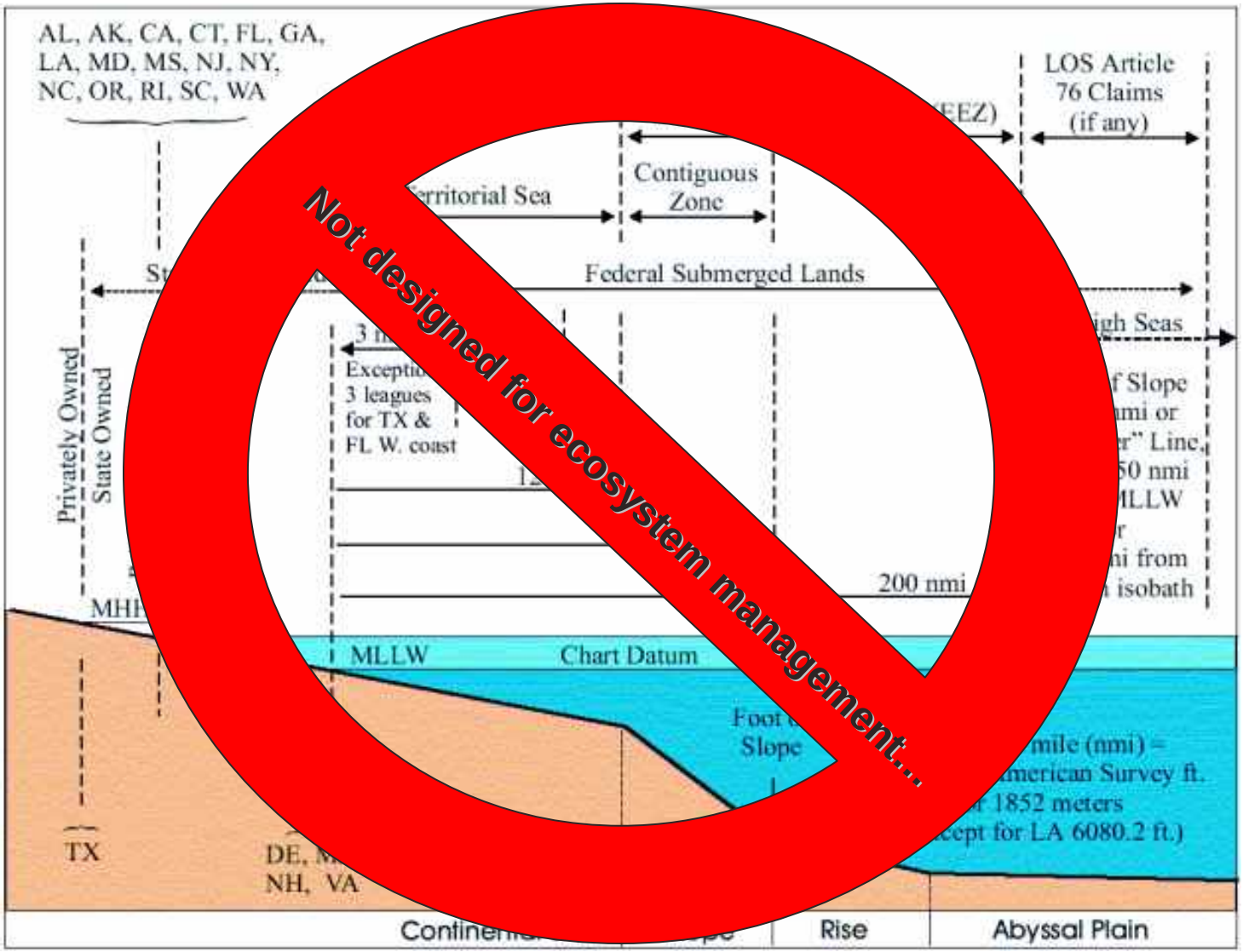
- Marine ***ecoregional planning*** is different from ***ecosystem-based management***

- Habitats (benthic & pelagic) must be ***defined by species use*** not cover maps

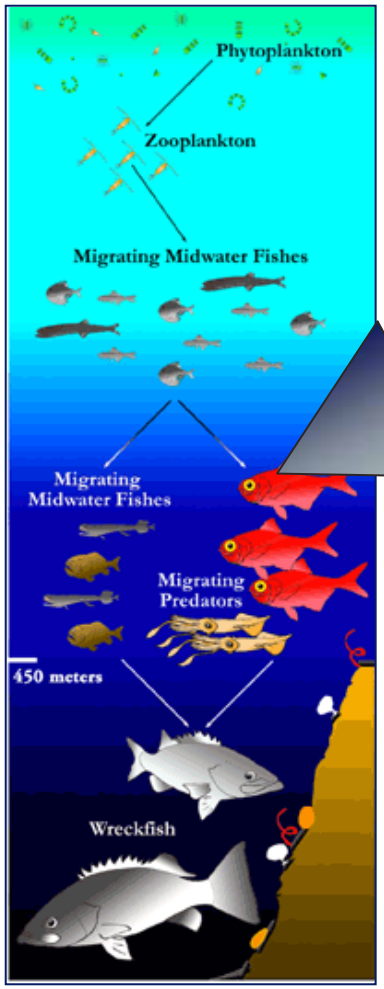
- Marine-EBM will be analyzed & implemented through ***models*** so we need to be measuring, mapping and monitoring variables that will be useful for ecosystem models and ***forecasting***.

Marine Ecosystem Management

Marine jurisdiction / management regions



Marine Ecosystem-Based Management



?

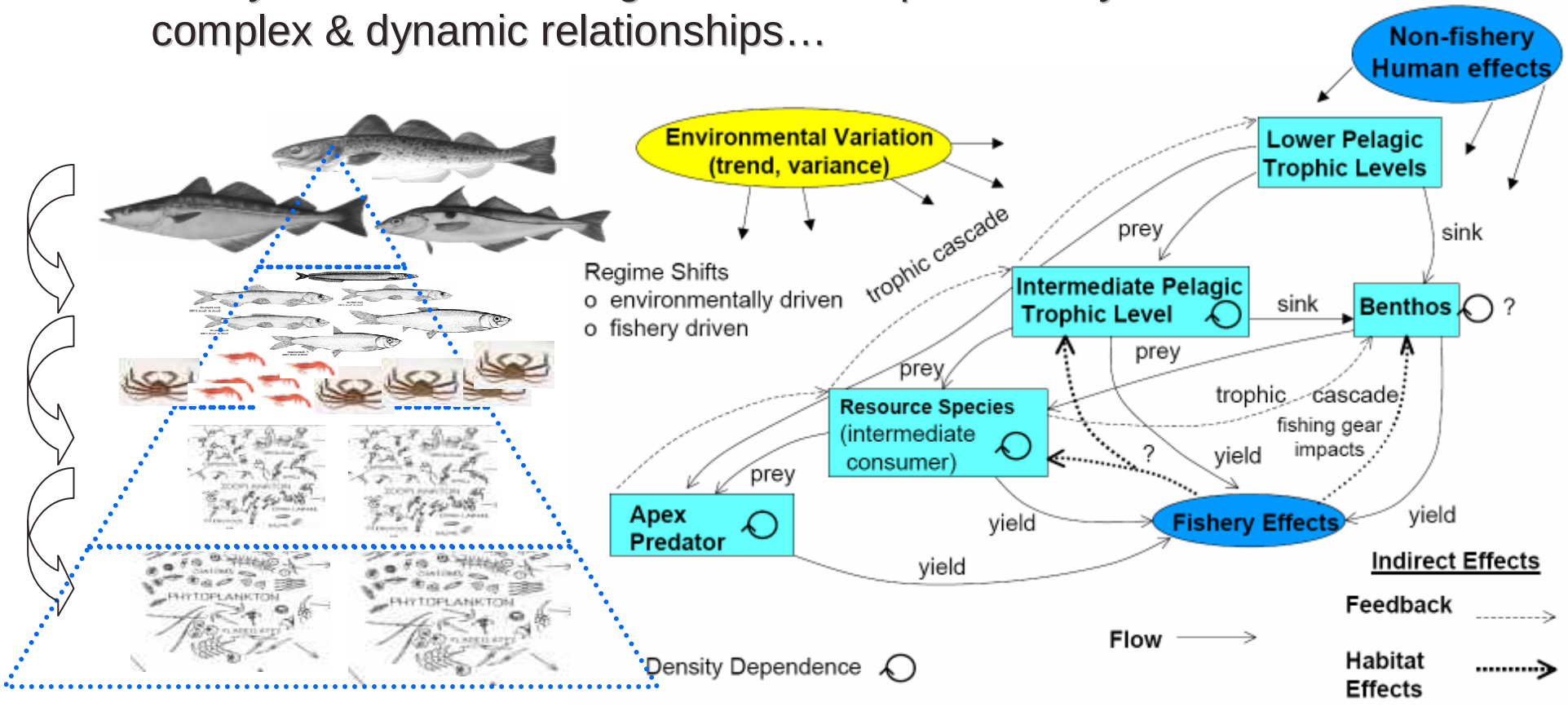
While the employment of ecoregional management is a move in the right direction…

ecoregional management
is not equivalent to
ecosystem-based management

Marine Ecoregional Managment

Geospatial tools for ecosystem-based management

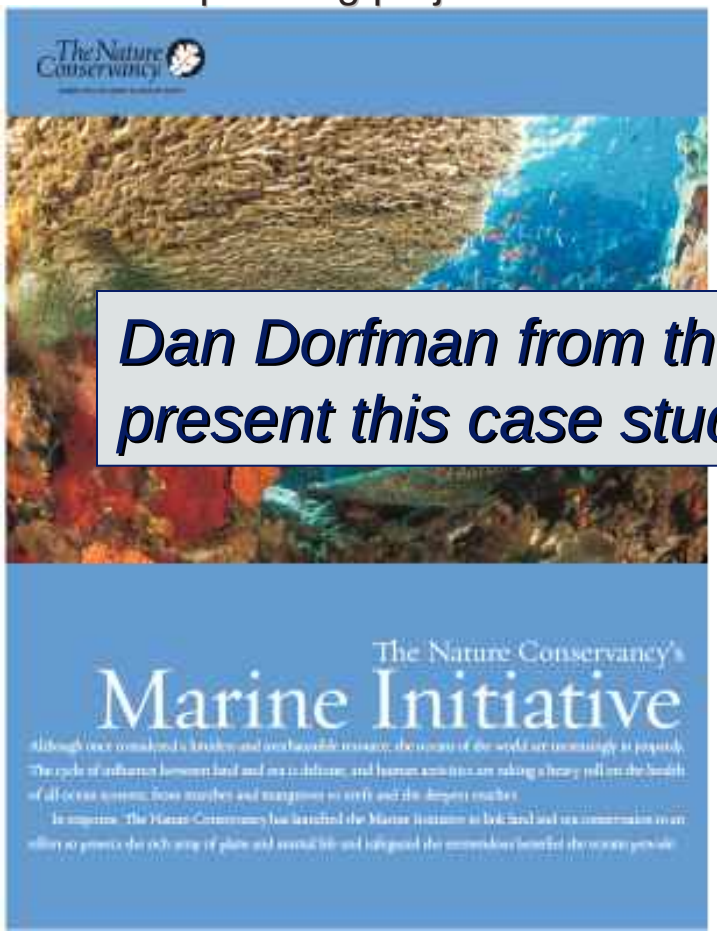
Ecosystem-based management will requires analysis of complex & dynamic relationships…

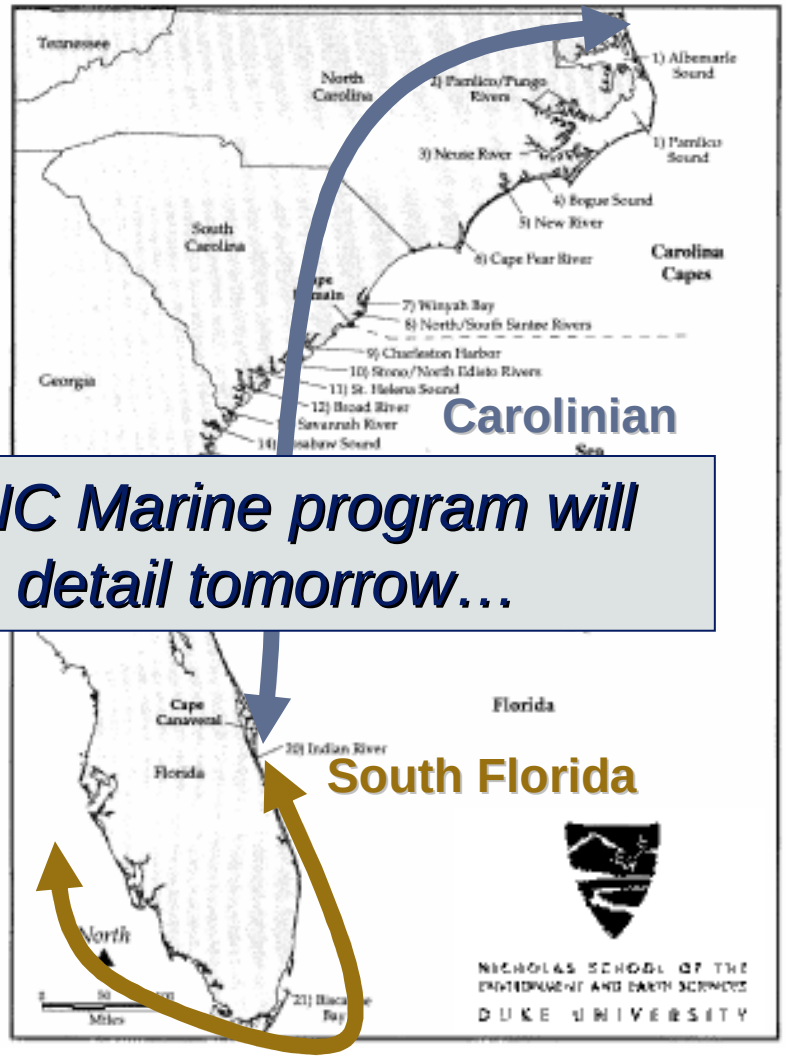


S. Murawski. 2004. The challenge of Managing Marine Resources in 5 Dimensions. Workshop on GIS Tools Supporting Ecosystem Approaches to Management . NOAA-CSC.

Marine Ecoregional Planning

The ***Nicholas School*** conducted the analysis for two recent marine ecoregional conservation planning projects





Dan Dorfman from the TNC Marine program will present this case study in detail tomorrow…

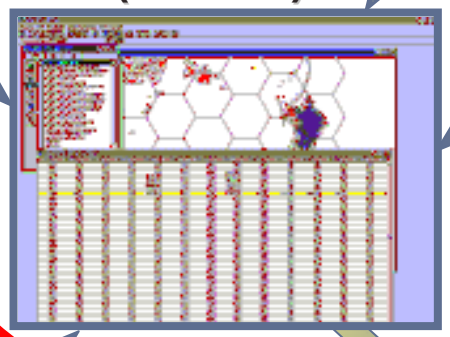
Marine ecoregional planning process:

GIS Data

Planning Units (Hexagons)

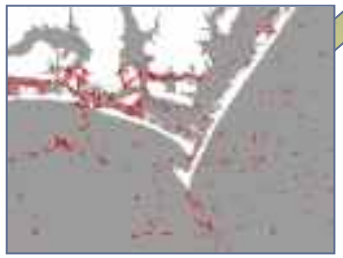
Coarse filter / fine filter targets

Optimization (MARXAN)

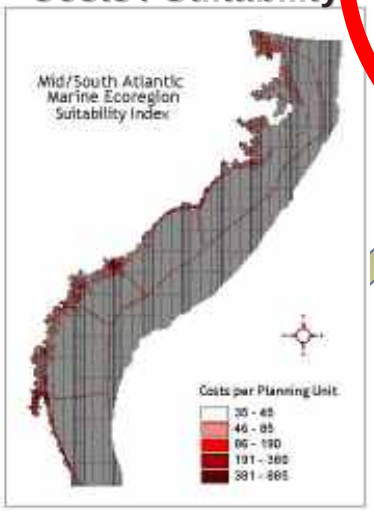


Goals: (example 30% BLM 0.5)

Surrogate data



Costs / Suitability

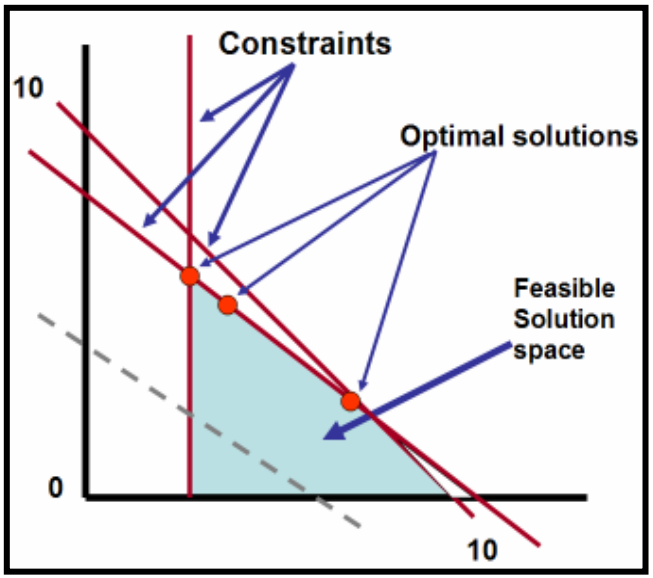


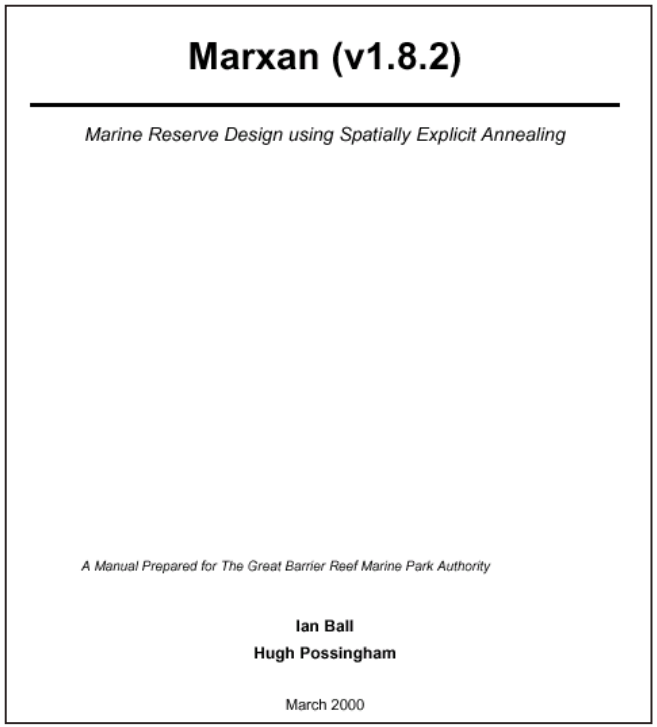
Marine ecoregional plan

Marine Ecoregional Planning Process

Optimization programs designed to be used for spatially aggregating habitat patches for optimal coverage.

These methods are run iteratively until the computer converges on an optimal solution (~1,000,000 runs)….





Marxan (v1.8.2)

Marine Reserve Design using Spatially Explicit Annealing

A Manual Prepared for The Great Barrier Reef Marine Park Authority

Ian Ball
Hugh Possingham

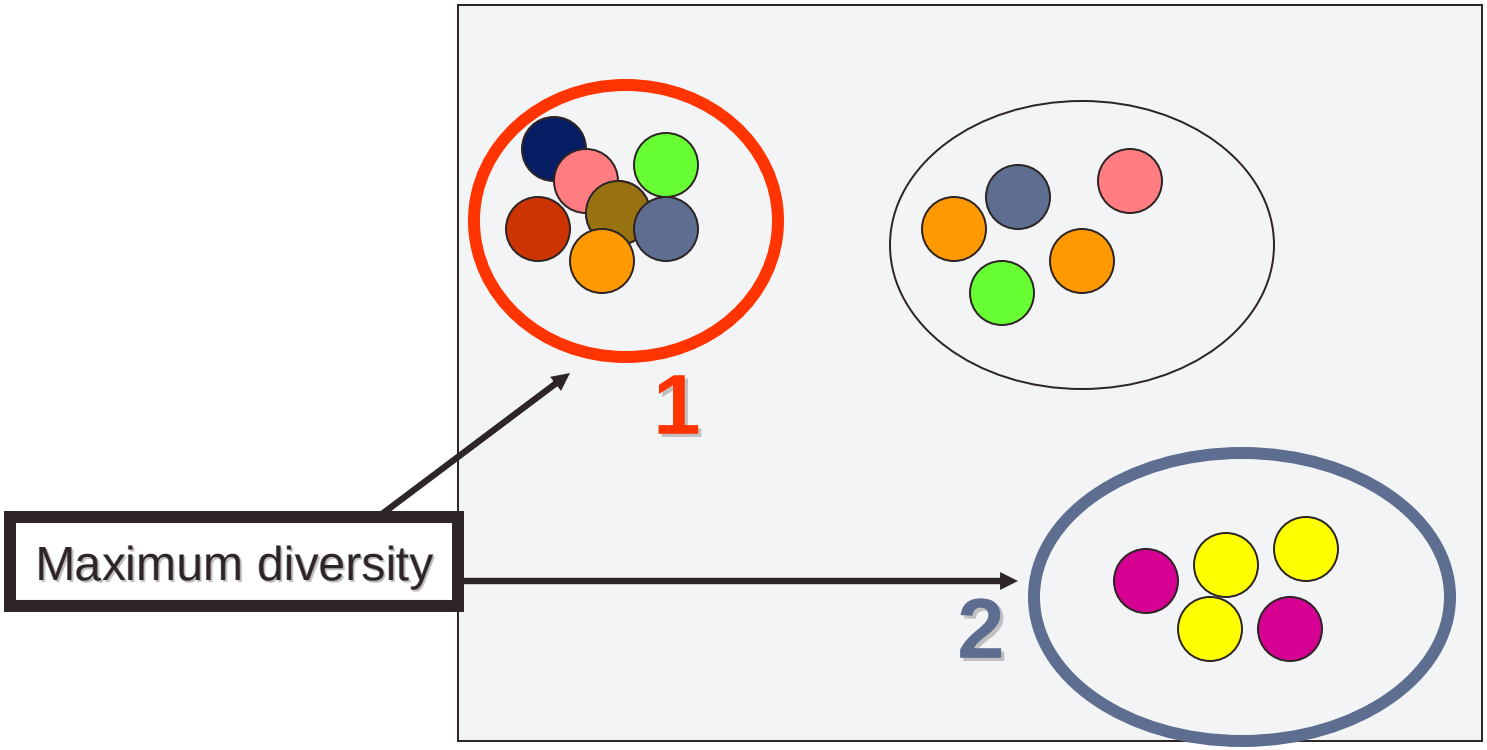
March 2000

http://www.ecology.uq.edu.au/marxan.htm

Marine Ecoregional Planning Process

This algorithm relies on the goal of ***complementarity***.

You select the site that gives you the most different species / targets…
Then the site that give you the most new (complementary) species / targets
And so on…

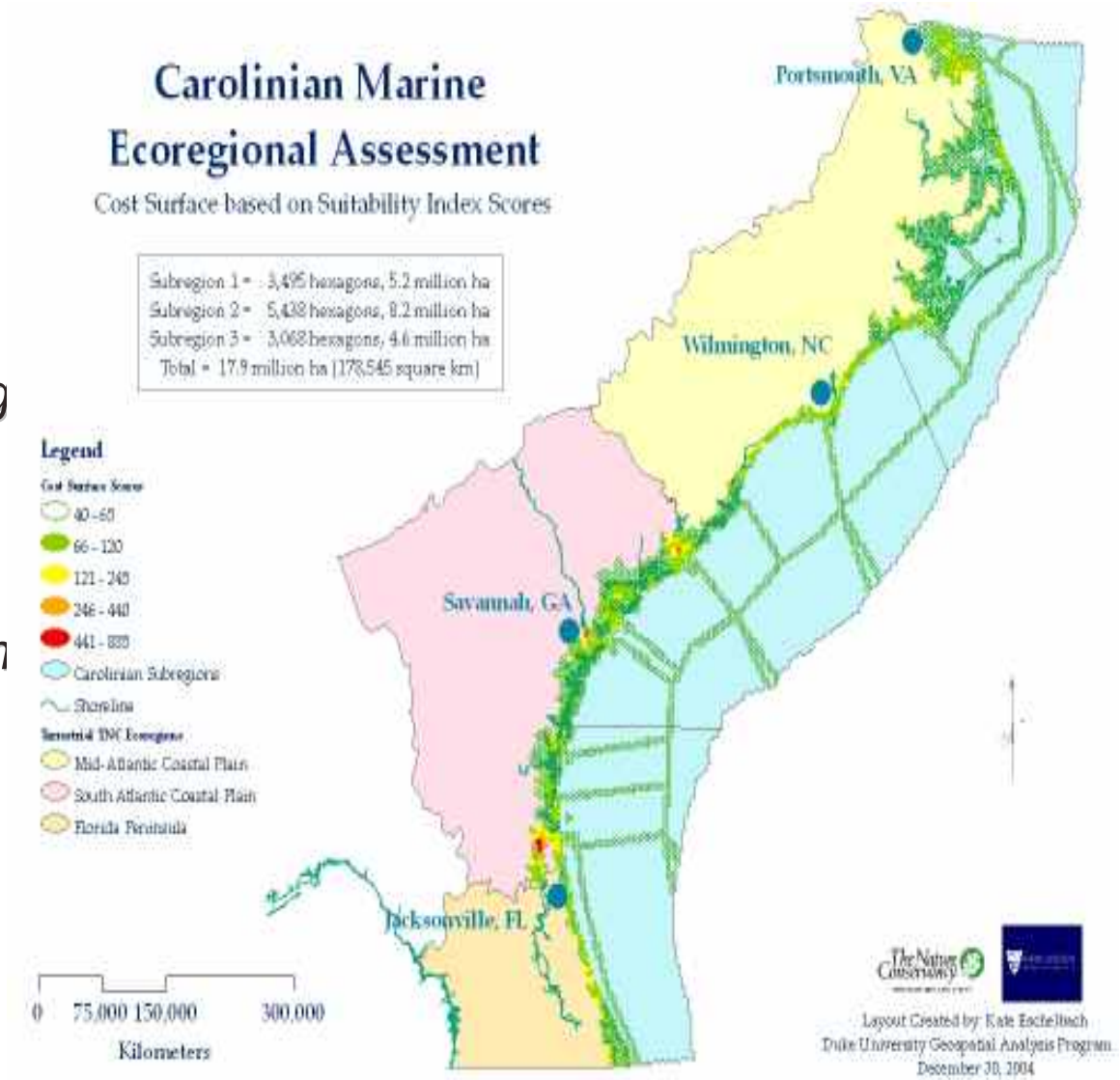


Carolinian Ecoregion: Targets

Fine and Coarse Filter Targets of the Carolinian Ecoregion				
Fine Filter Target	*Scientific Name*		*Coarse Filter Target*	*Coarse Filter Target*
American Oystercatcher	***Haematopus palliatus***		**Benthic Complexity - Deep**	**Intertidal Scrub-Shrub**
Black Crown Night Heron	***Nycticorax nycticorax***		**Benthic Complexity - Shallow**	**Irregularly Flooded Salt and Brackish Marsh**
Black Skimmer	***Rynchops niger***		**Coarse Sand Beach**	**Mixed Sand and Gravel Beach**
Common Tern	***Sterna hirundo***		**Exposed Scarp with Clay**	**Regularly Flooded Salt Marsh**
Green Heron	***Butorides virescens***		**Exposed Tidal Flat**	**Salt Marsh w/Variable Flood Regimes**
Little Blue Heron	***Egretta caerulea***		**Fine Sand Beach**	**Shellfish Habitat**
Piping Plover	***Charadrius melodus***		**Forested Wetlands**	**Sheltered Tidal Flat**
Reddish Egret	***Egretta rufescens***		**Fresh Marsh**	**Sheltered Tidal Flat with Oysters**
Wood Stork	***Mycteria americana***		**Gravel and Shell Beach**	**Submerged Aquatic Vegetation**
Yellow Crown Night Heron	***Nyctanassa violacea***		**Hardbottom - Deep**	**Tidal Fresh Marsh**
Right Whale Calving Ground	***Lissodelphis borealis***		**Hardbottom - Shallow**	
Shortnose Sturgeon Habitat	***Acipenser brevirostrum***		**Habitat Area of Particular Concern**	**Habitat Area of Particular Concern**
Sea Turtle Nesting Beaches	***C. mydas, D. coriacea, C. caretta***		**(The Point, 10-Fathom Ledge and Big Rock)**	**(Charleston Bump Complex)**
Total Fine Filter Targets	***13***		***Total Coarse Filter Targets***	***23***
			Total Number of Targets	*36*

Carolinian Ecoregion: Threats

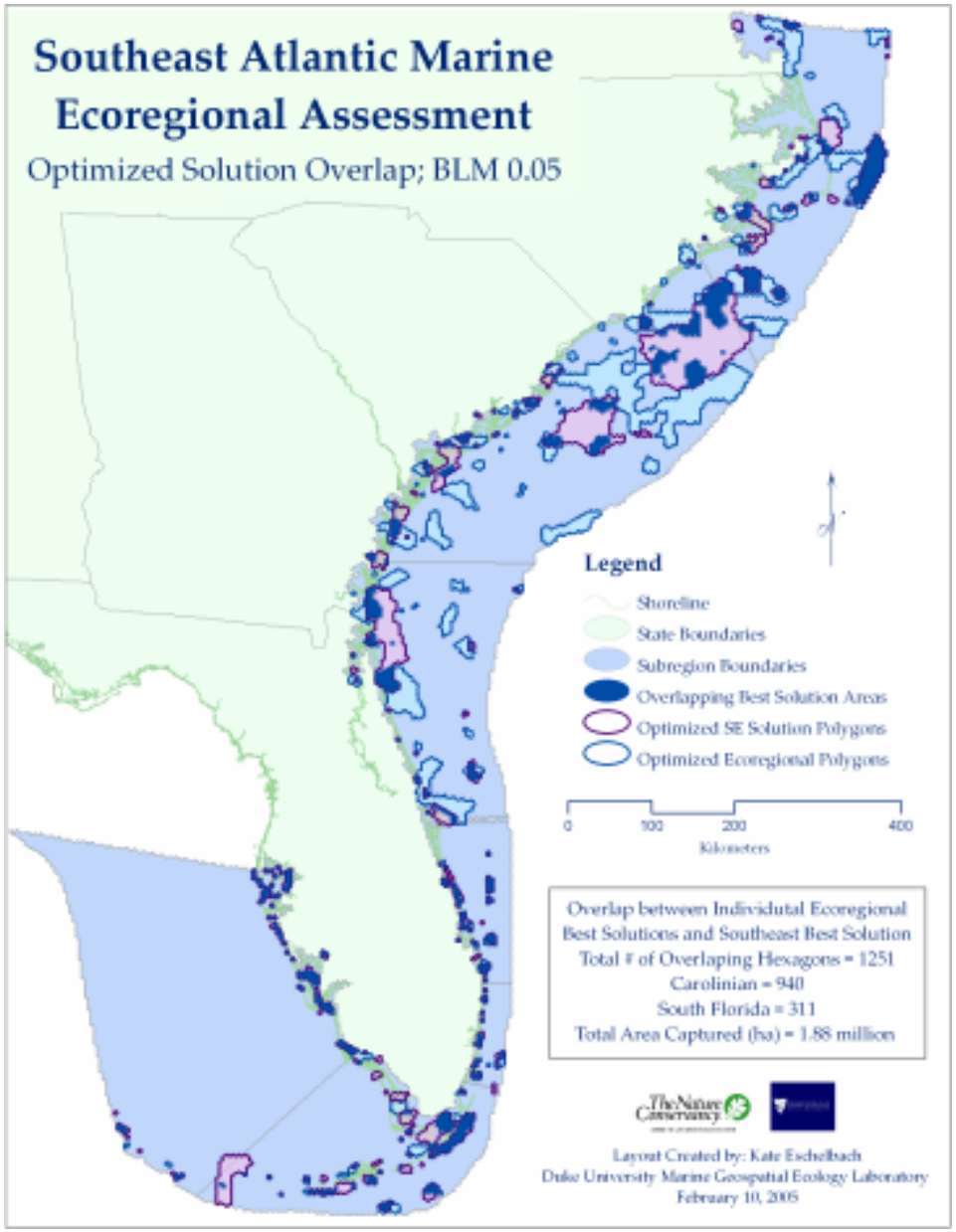
- *Anthropogenic Threats*
  - *Mean population change between 90-00*
  - *Housing Density*
  - *Road Density*
  - *Major Ports and Shipping Lanes*
  - *Hardened Shorelines*
  - *NPDES permits*
  - *Dredged Shipping Chann*
  - *Superfund Sites*
  - *Offshore Dredge Sites*

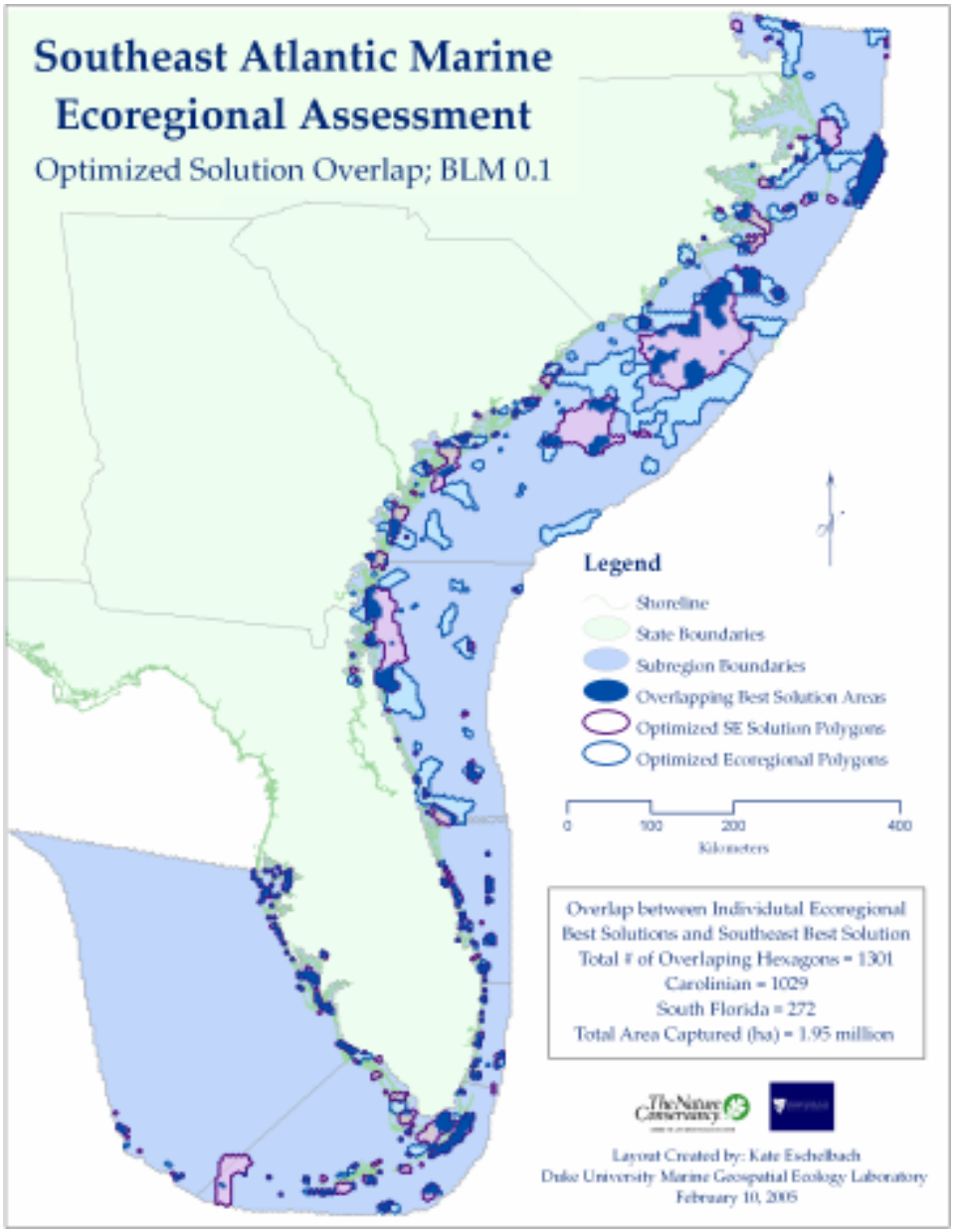


Subregion stratification

Example scenarios

Overlap - Southeast Atlantic





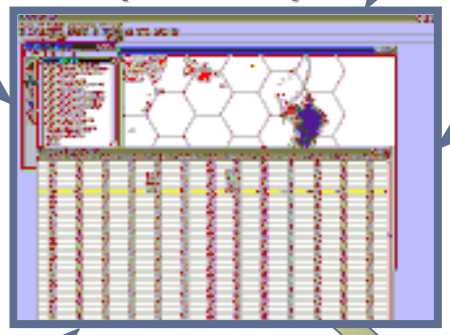
Marine ecoregional planning process:

GIS Data

Planning Units
(Hexagons)

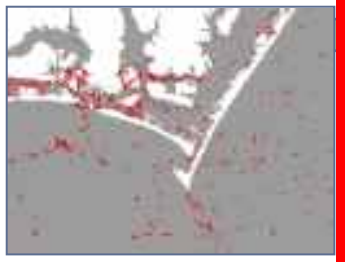
Coarse filter / fine filter targets

Optimization
(MARXAN)

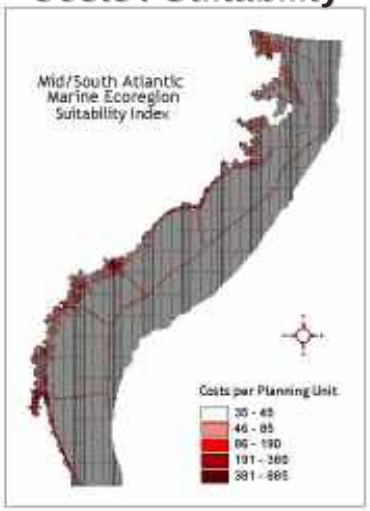


Goals:
(example 30%
BLM 0.5)

Surrogate data



Costs / Suitability

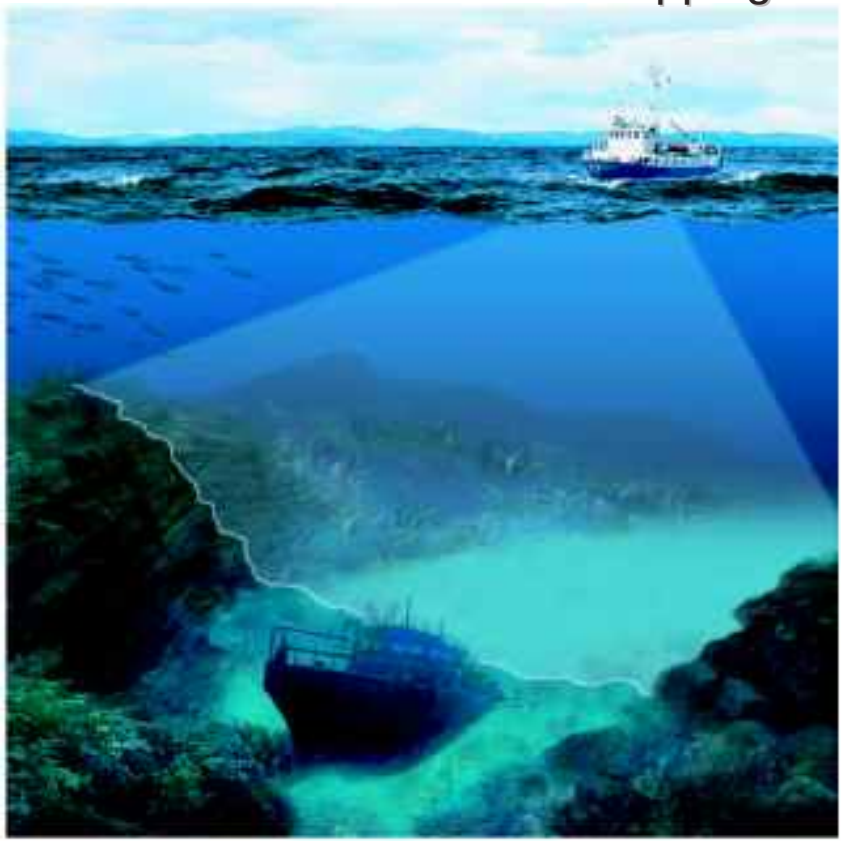


Marine
ecoregional plan

“Habitats”

Marine Ecoregional Planning Process

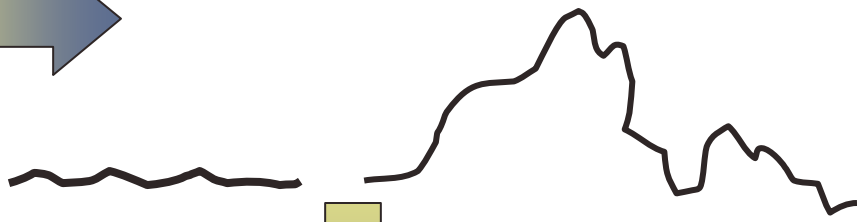
Side-scan / mulit-beam mapping



Source: NAP 2003. A Geospatial Framework for the Coastal Zone National Needs for Coastal Mapping and Charting

Potential habitat mapping

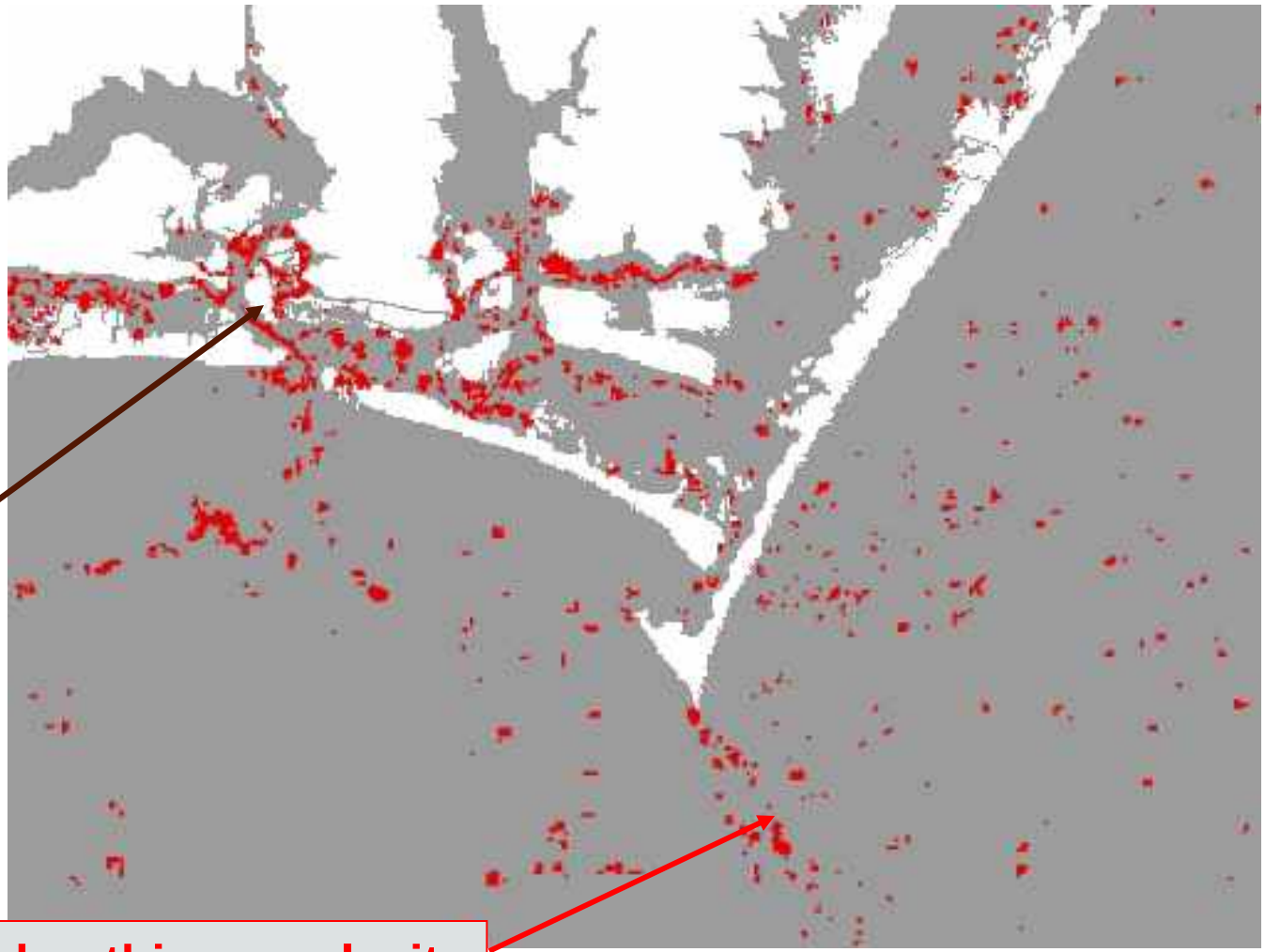
Index of bottom complexity (rugosity)



Low relief high relief

Marine Ecoregional Planning Process

Bottom Complexity
(threshold)

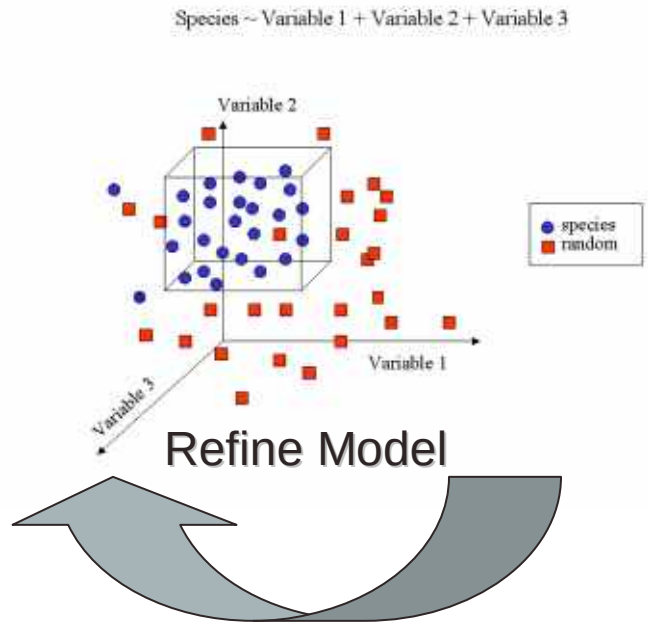


Marine Habitat modeling: Benthic

Geographic Space

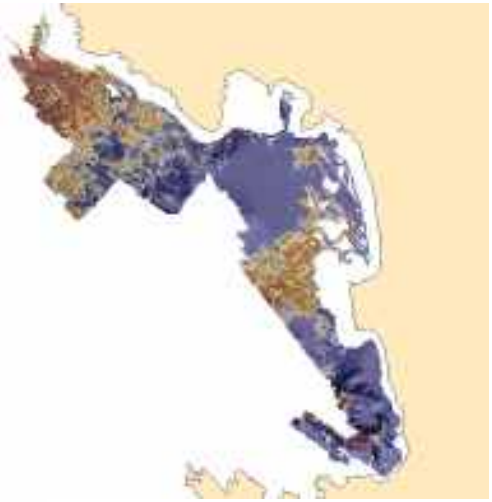
Sample Data

Statistical Data Space



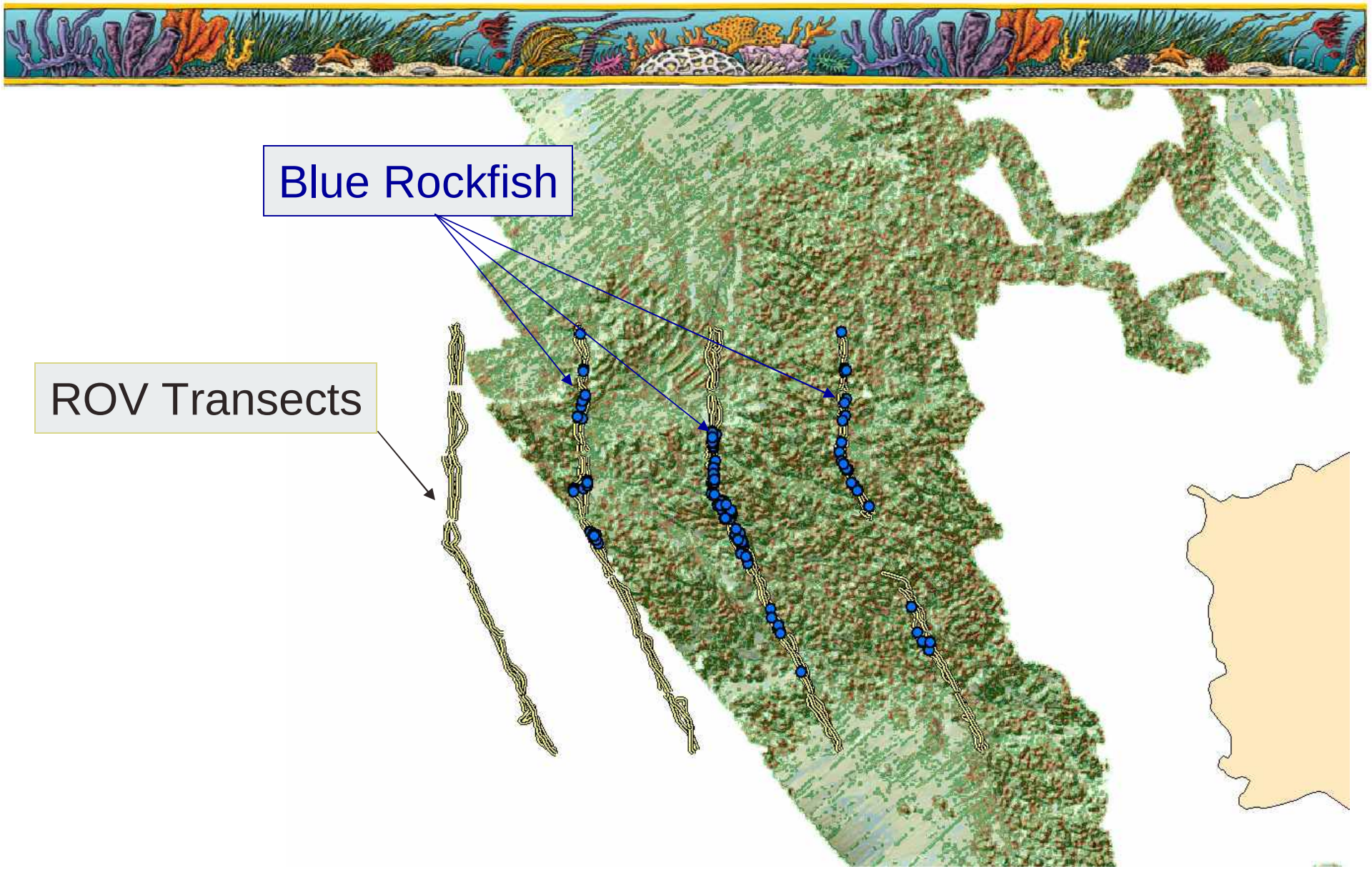
Refine Model

Geographic Space

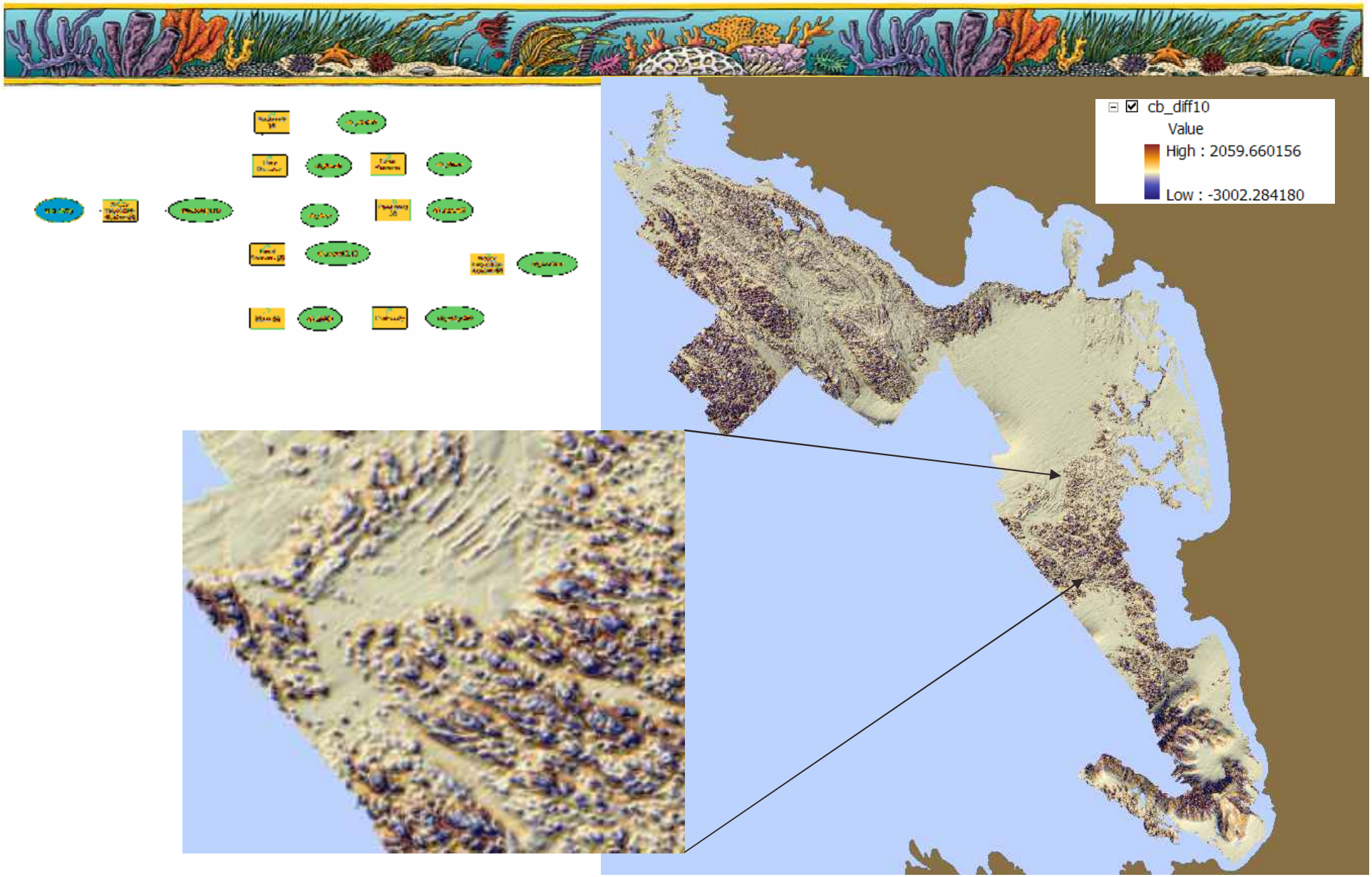


Model Habitat

Carmel Bay

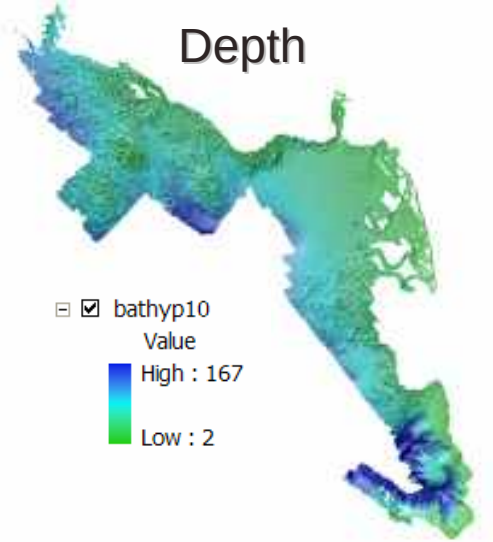


Benthic complexity: rugosity & relief

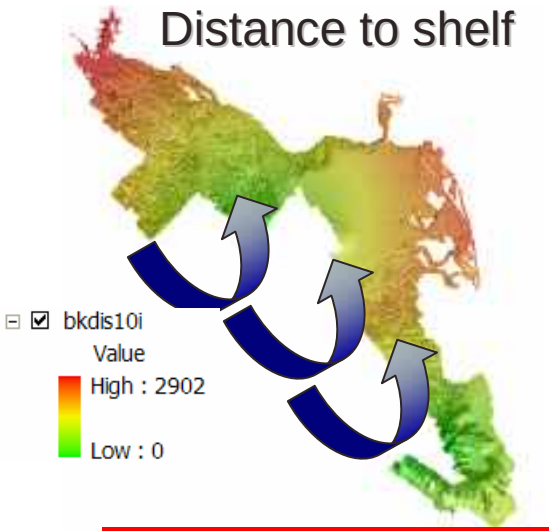


Benthic habitat affinity models

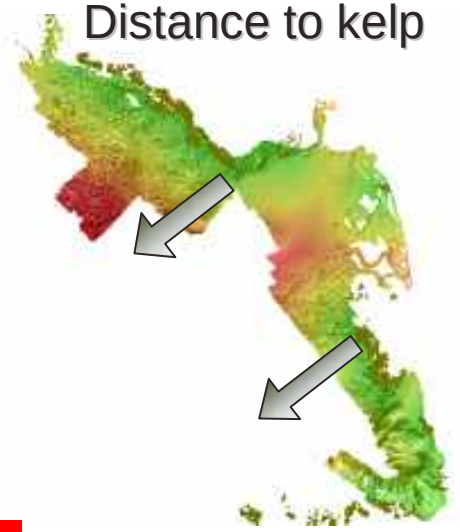
Depth



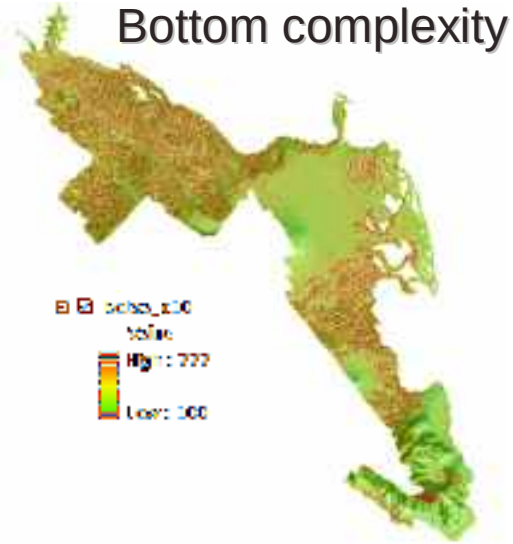
Distance to shelf



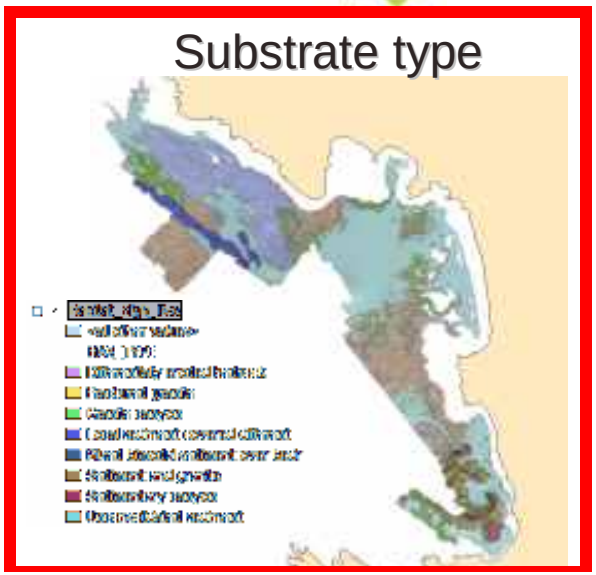
Distance to kelp



Bottom complexity



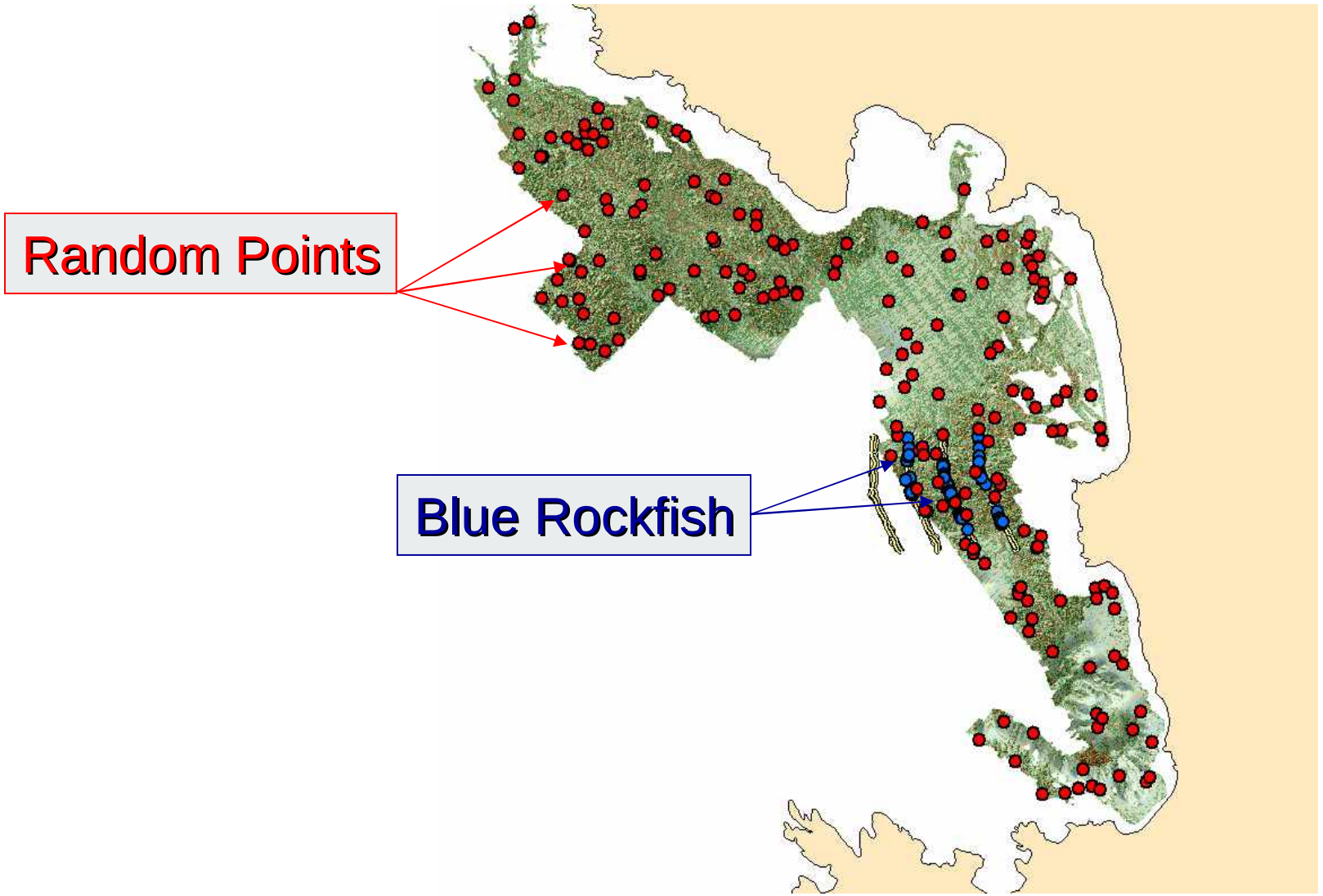
Substrate type



Bottom type not "habitat"

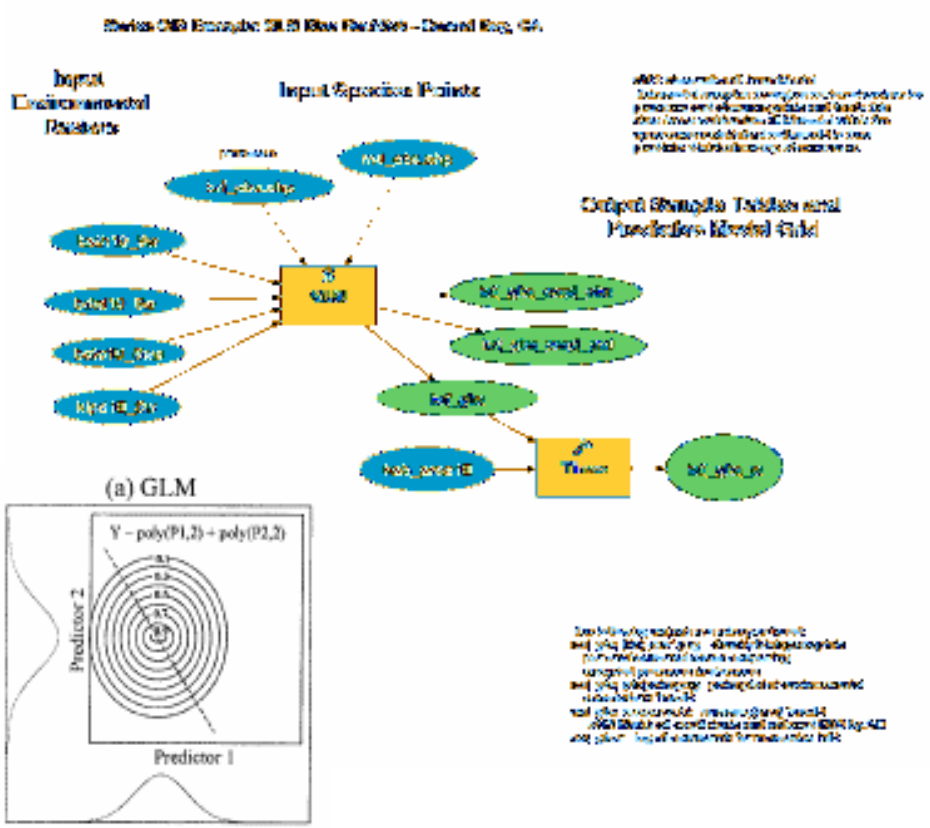
Carmel Bay, CA

Carmel Bay

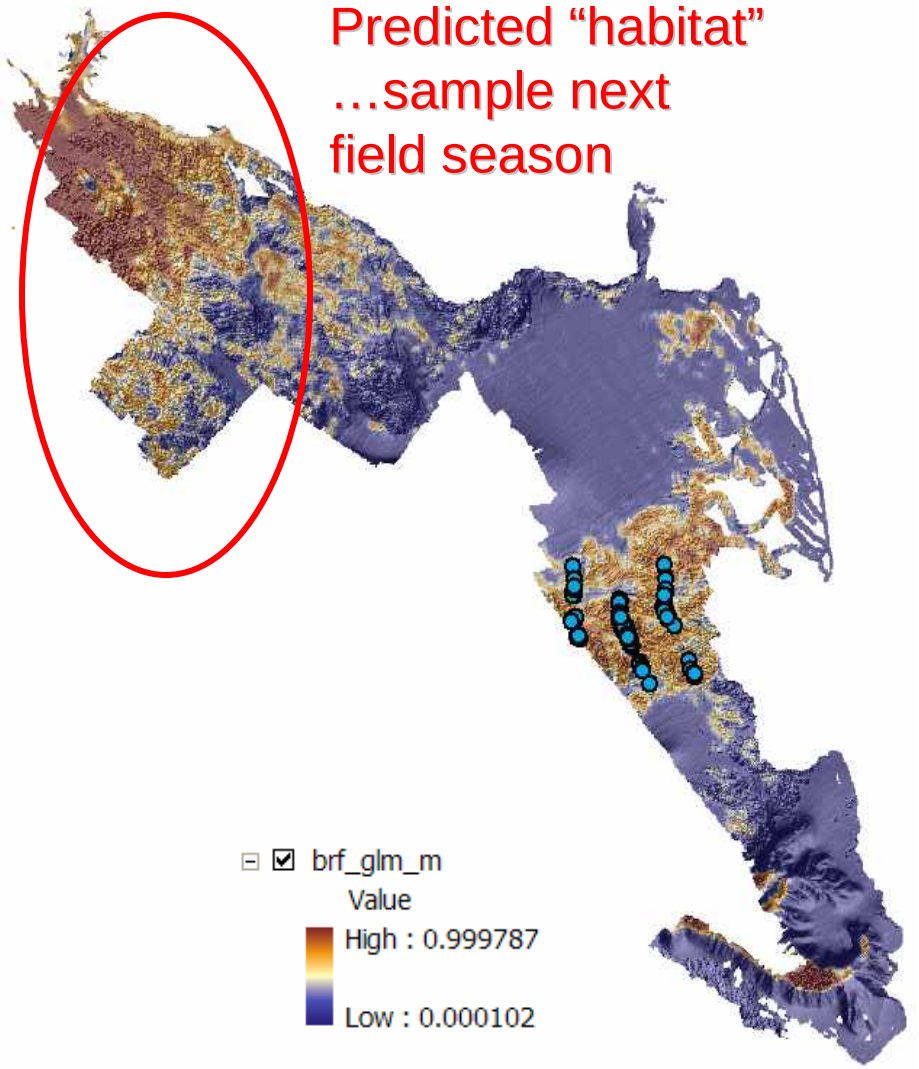


Carmel Bay: Blue Rock Fish

Predicted Rockfish habitat area



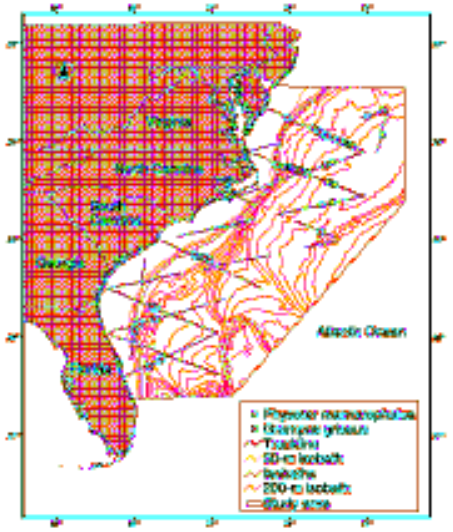
Predicted "habitat" …sample next field season



Marine Habitat modeling: Pelagic

Typical Marine Mammal Habitat Modeling Approach

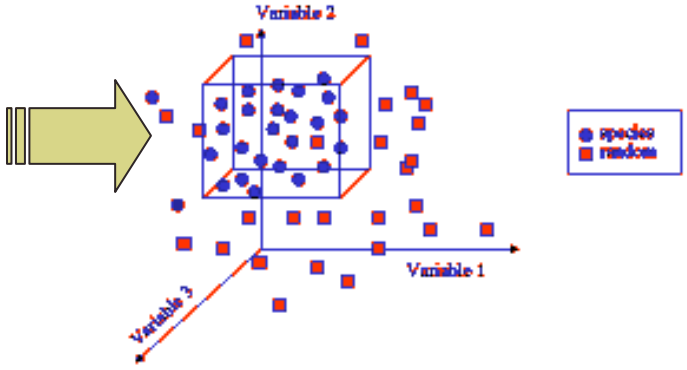
Geographic Space



Sample Data

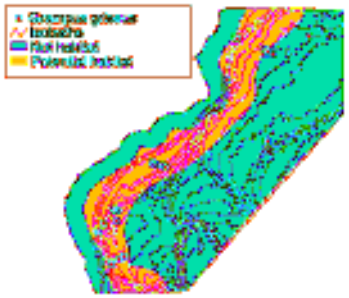
Statistical Applications Data Space

Species ~ Variable 1 + Variable 2 + Variable 3



Redefine Model

Geographic Space



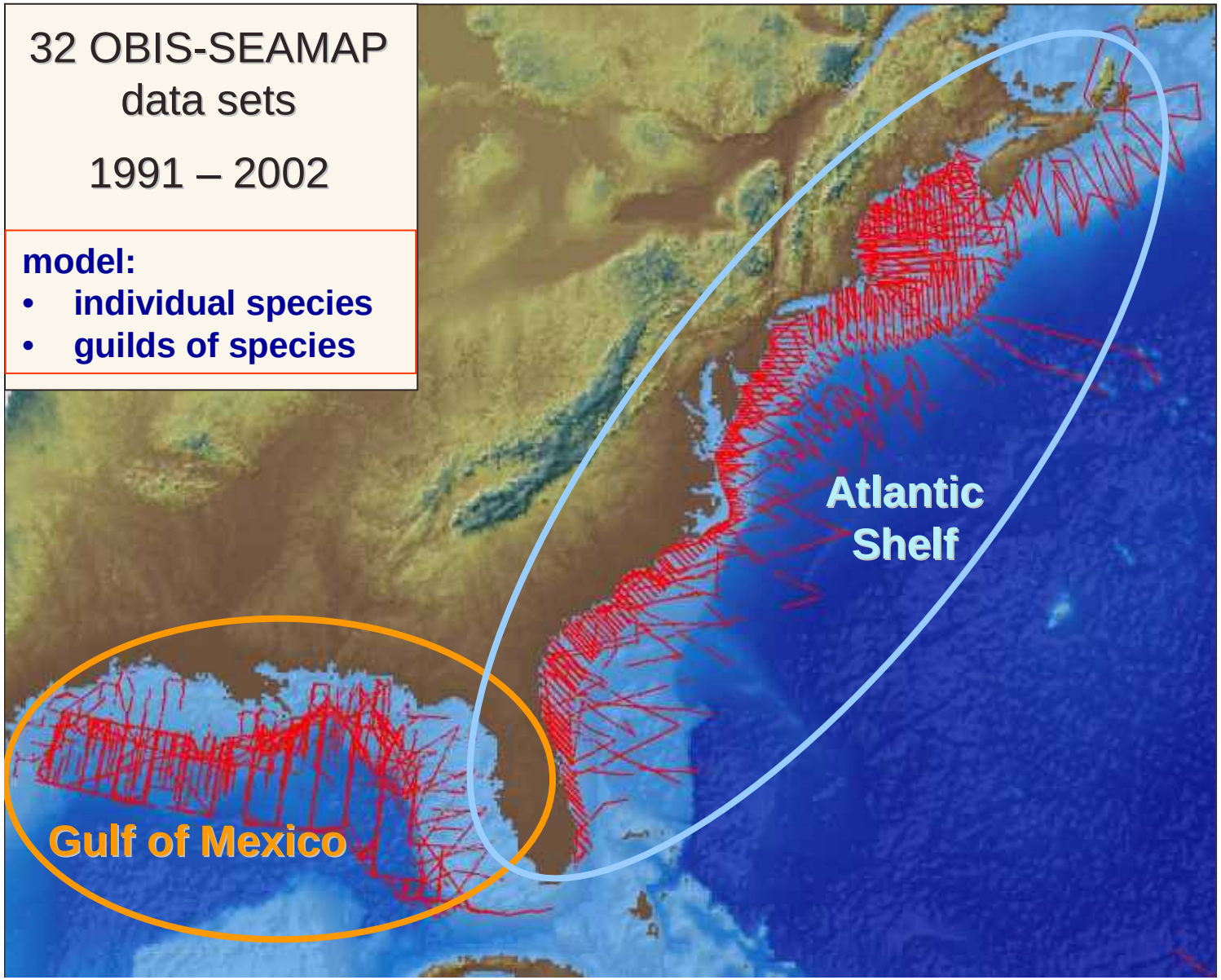
Model Habitat

Pelagic habitat affinity models

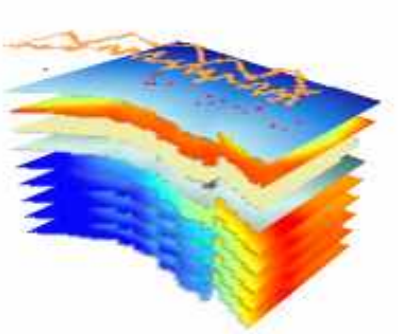
32 OBIS-SEAMAP data sets

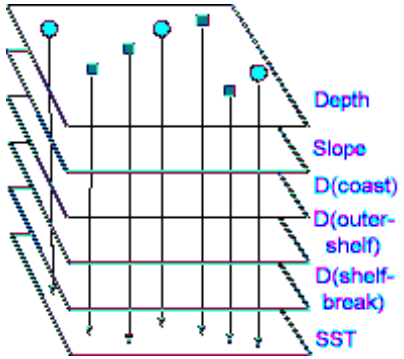
1991 – 2002

model:
- **individual species**
- **guilds of species**

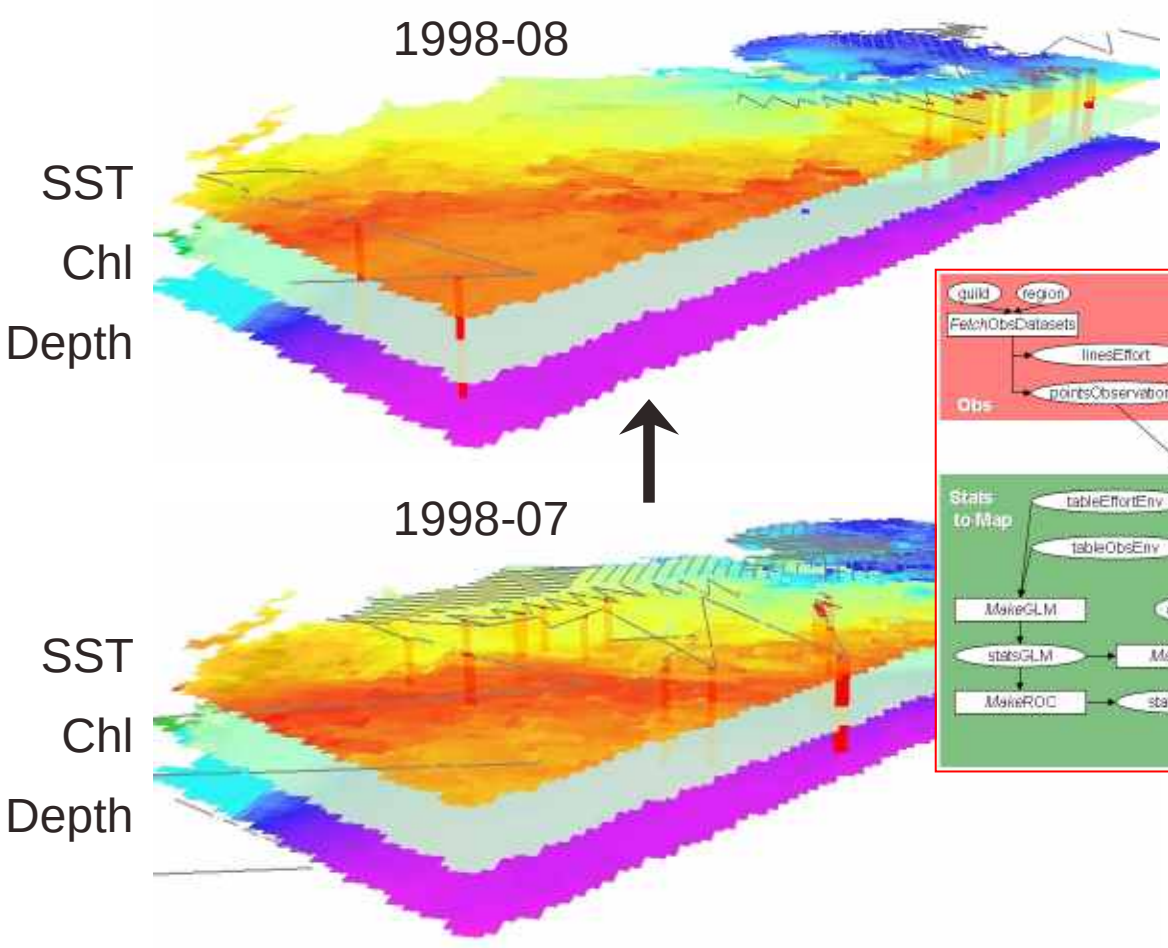


Temporal sampling

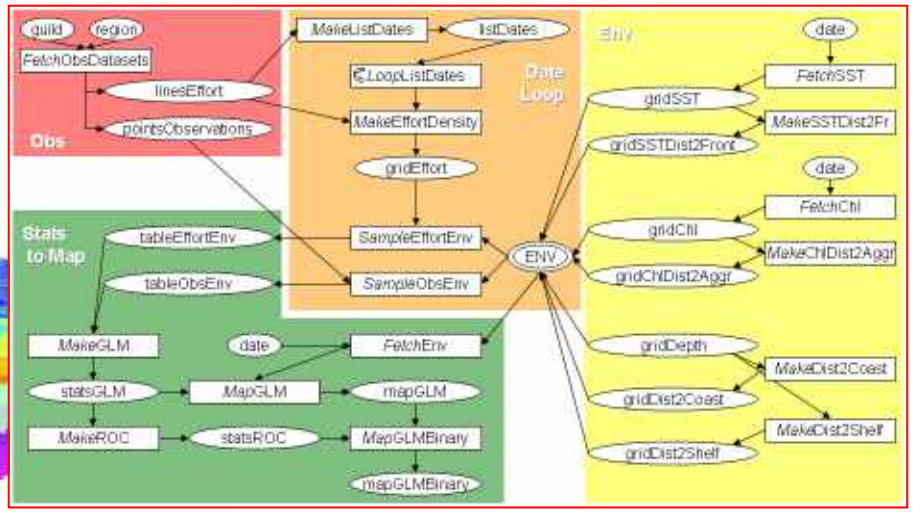




SAMPLING THROUGH TIME AND LAYERS



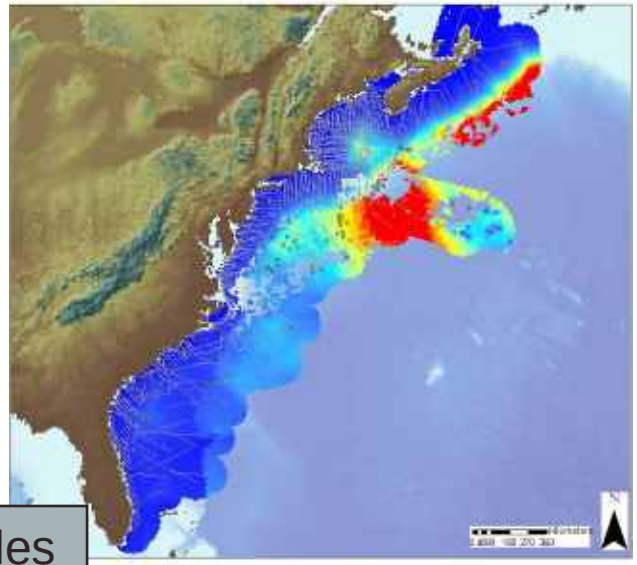
workflow



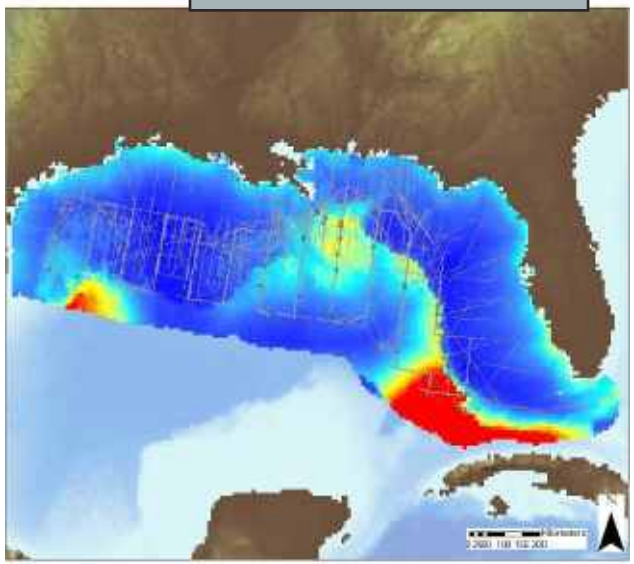
e.g. Beaked whales in
Northeast, monthly timestep

Pelagic habitat models

MULTIVARIATE MODELS



Beaked Whales



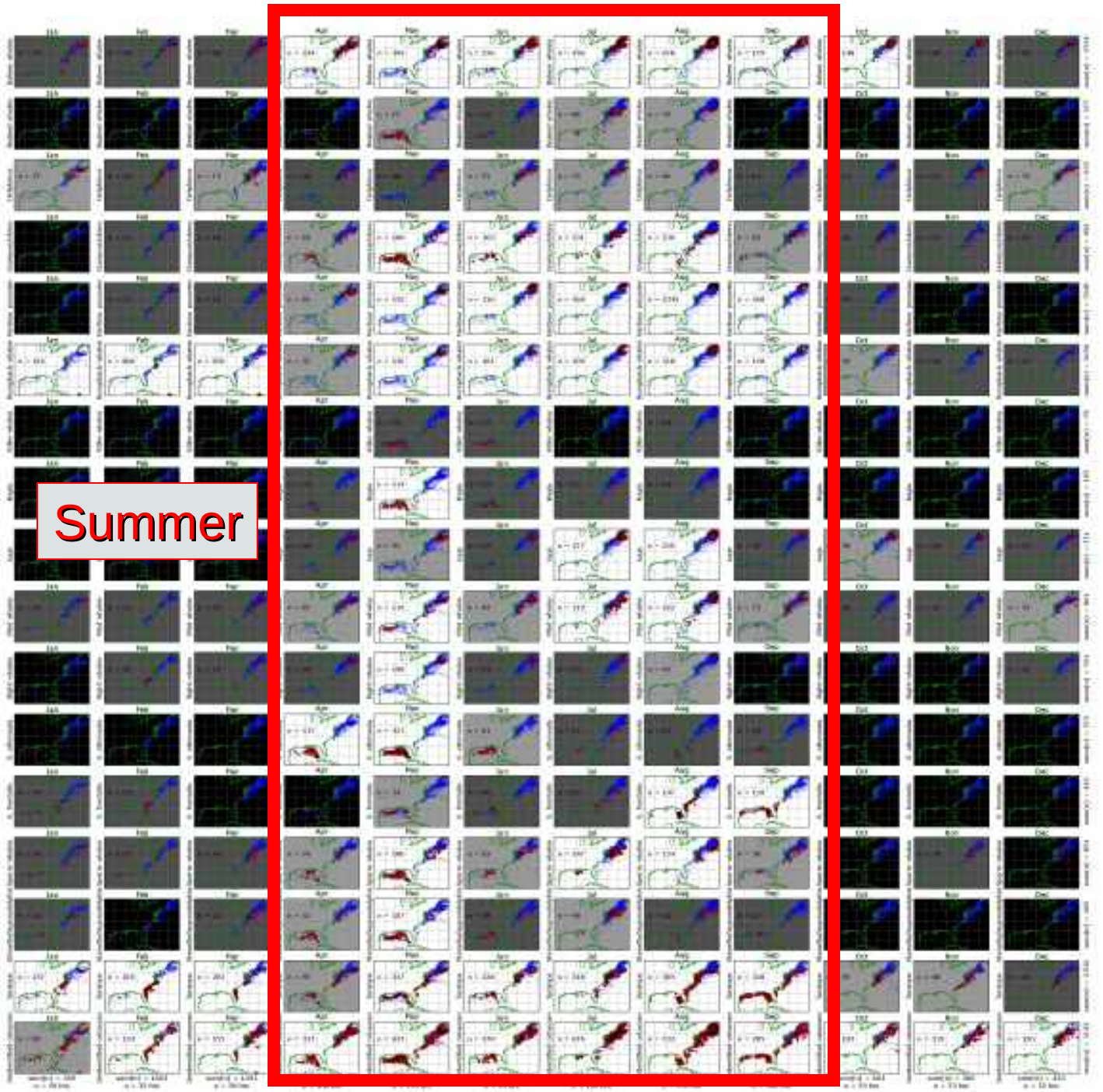
Forecast for a specific 8 day time period

Temporal Modeling

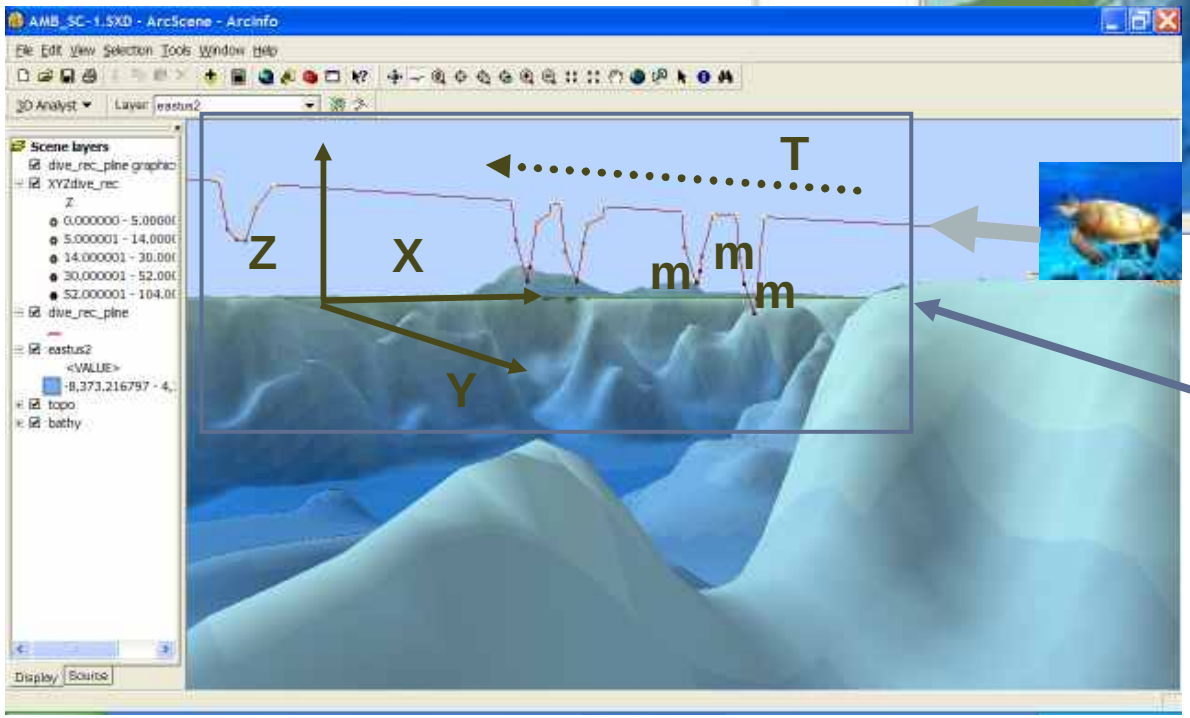
17 Guilds (rows)

12 Months (cols)

Observations
Effort



Geospatial tools for M-EBM will need to be ***multi-dimensional***…

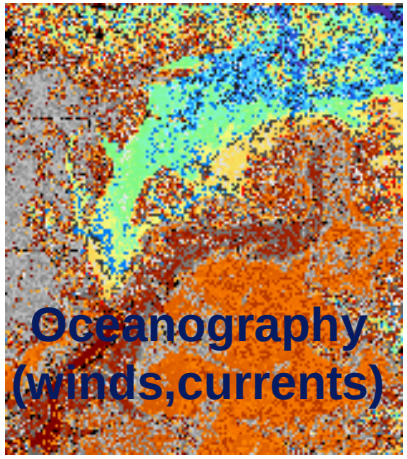


Dive Profiles:
~4D Data (X,Y,Z,T m…m)

Geospatial tools for M-EBM will need to model ***time lags***…

Spatio-Temporal Models

At large spatial scales:



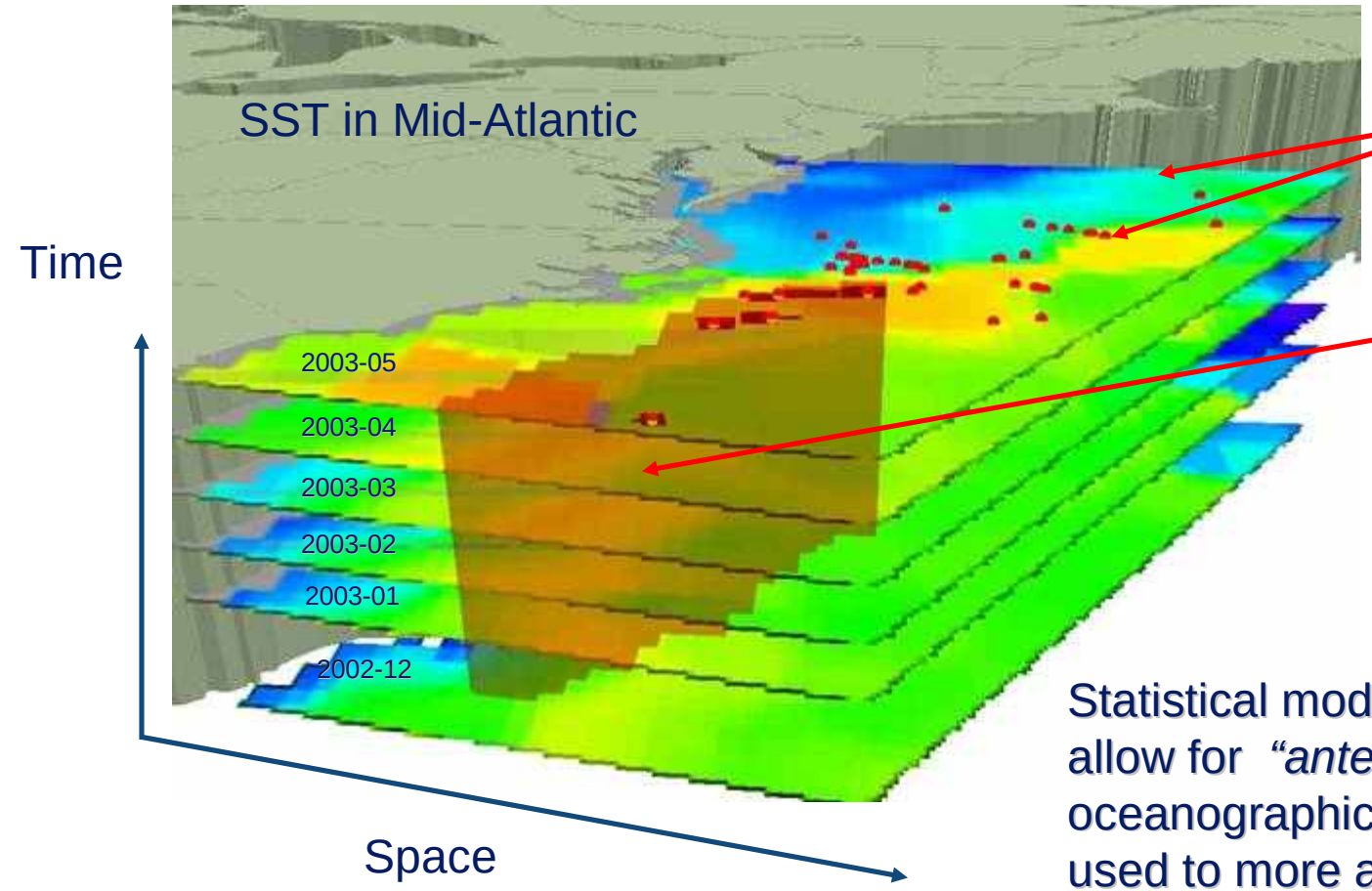
Temporal lags

At finer spatial scales:

Bathymetric and water temperature gradients → Prey availability → Marine mammal distribution

Geospatial tools for M-EBM will need to model ***events***…

Spatio-Temporal Models

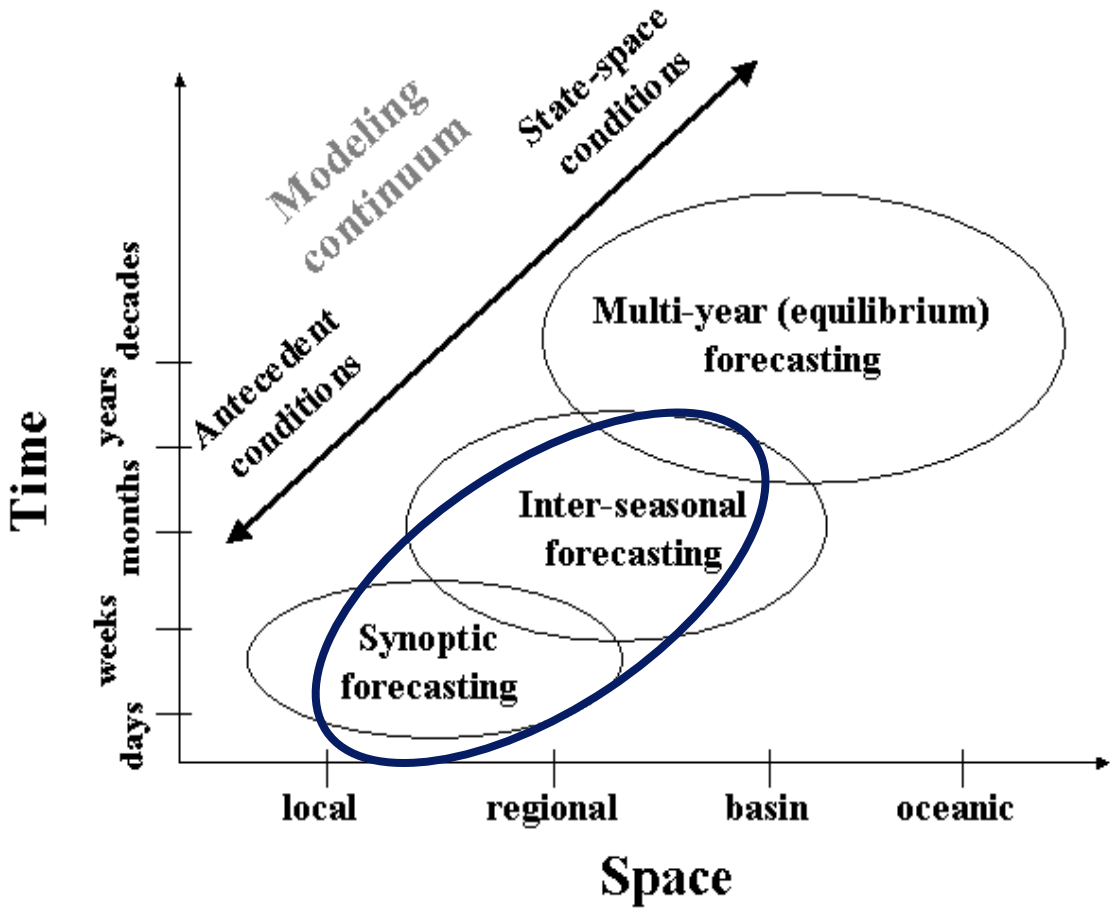


Marine mammal distribution

"Persistent" SST Event

Statistical modeling approach will allow for *"antecedent"* oceanographic conditions to be used to more accurately predict potential habitat.

Geospatial tools for M-EBM will need to ***forecast***…



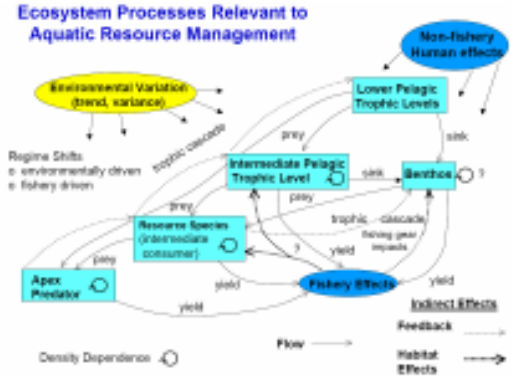
The emerging management applications are at these finer temporal scales…

Marine Ecosystem-Based Management

- Marine ***ecoregional planning*** is different from ***ecosystem-based management***

- Habitats (benthic & pelagic) must be ***defined by species use*** not cover maps

- Marine-EBM will be analyzed & implemented through ***models*** so we need to be measuring, mapping and monitoring variables that will be useful for ecosystem models and ***forecasting***.



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Questions?