OpenOcean 2013. Integrating habitat dynamics into population & ecosystem assessment using cooperative research within an IOOS framework

NORTHEAST FISHERIES SCIENCE CENTER
STUDY FLEET

MARACOOS
Ocean Information for a Changing World

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John Hoey (NOAA)
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Hank Lackner
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Lunds Fisheries
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Dave Richardson (NEFSC)
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Physical and Biological Oceanographers
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Nikitas Georgas (Stevens)
Enrique Curchitser (Rutgers)

Fisheries Management
Rick Seagraves (MAFMC)
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Human Dimensions
Steven Gray (U Hawaii)

NOAA OFFICE OF SCIENCE AND TECHNOLOGY
NATIONAL MARINE FISHERIES SERVICE

Integrating habitat dynamics into population & ecosystem dynamics

- Does our habitat paradigm cross the land-sea boundary?
  - Seascapes are not landscapes

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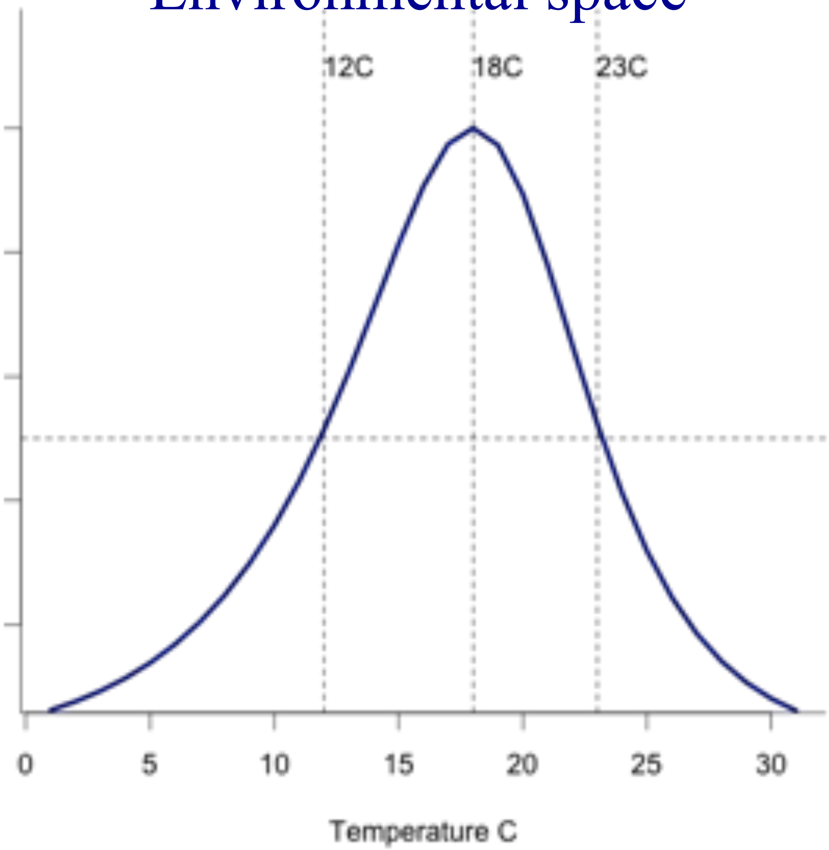
- Integrating habitat dynamics into population & ecosystem assessment & dynamics: Cooperative research in an IOOS framework

What is habitat?

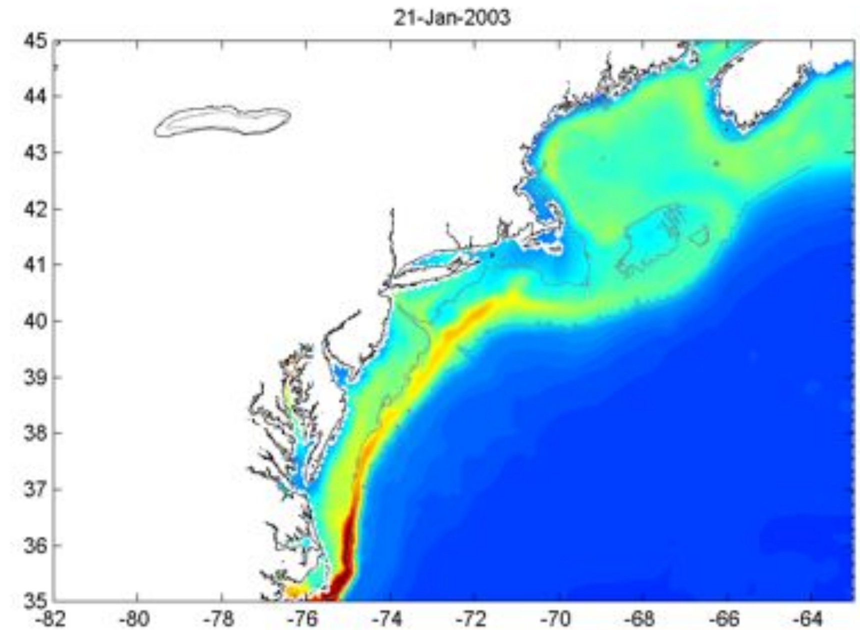
Niche theory: Hutchinson, G. E. 1957. Concluding Remarks. Cold Spring Harbor Symposia on Quantitative Biology 22:415-442.

Niche dimension
Environmental space

Effects on population growth rate r



Habitat = niche projected onto environmental varaition in space & time



Scenopoetic niche = <u>physico-chemical factors</u> affecting population growth rate
Bionomic niche = <u>biotic factors</u> affecting population growth rate

Integrating habitat dynamics into population & ecosystem dynamics

- Does our habitat paradigm cross the land-sea boundary?
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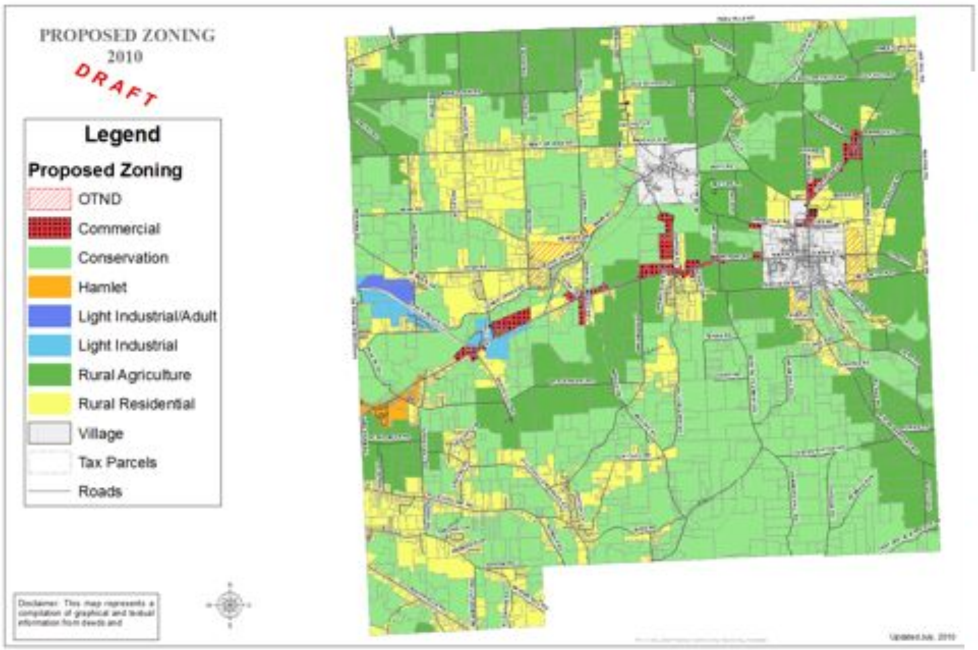
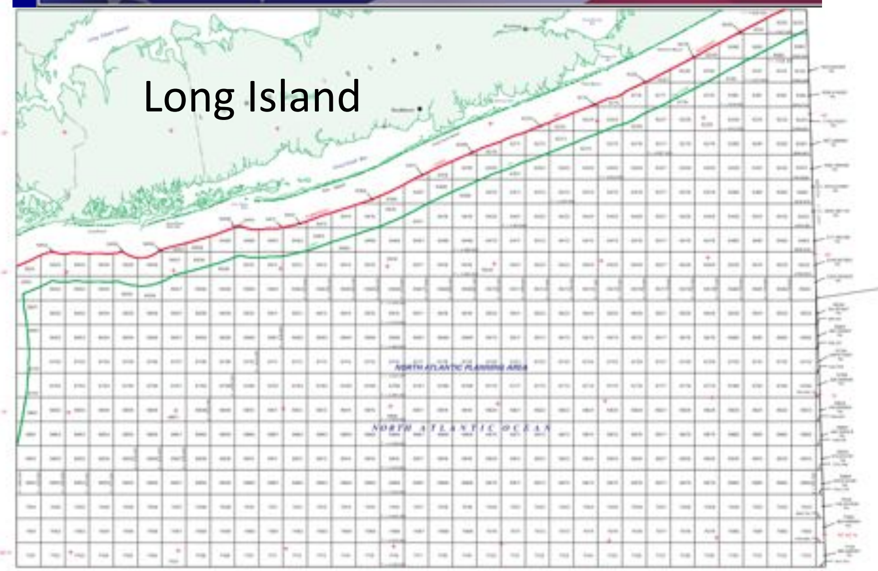
Why is it so difficult to link habitat & population dynamics in the sea?

We apply principals of landscape ecology to the sea

Landscape planning map





Block diagram of "submerged lands"

We apply principals of landscape ecology to the sea

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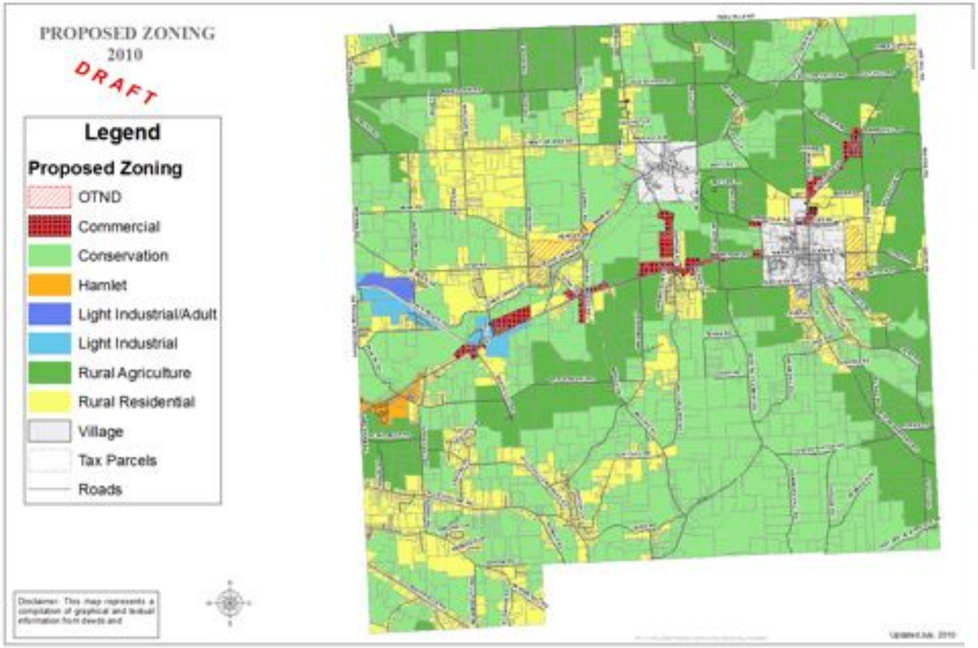

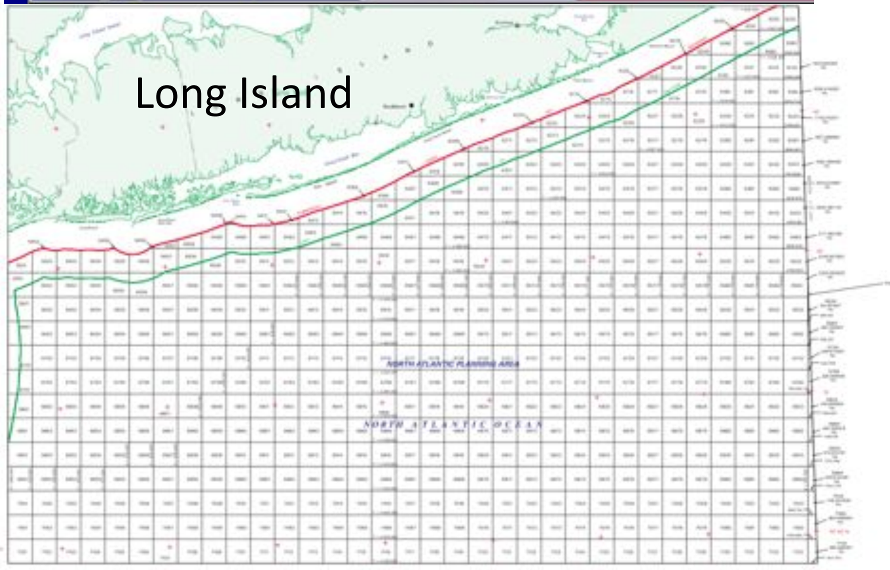

Landscape paradigm

Block diagram of "submerged lands"

- Landscape ~2 dimensional
- Habitat patches defined by sharp gradients/boundaries
- Flows of materials across landscape are slow & infrequent
- "Natural" change of landscape is slow

We apply principals of landscape ecology to the sea

Landscape planning map

"Natural landscape changes only occur in geological dimensions of time"

Troll (1950) The geographic landscape & its investigation

Landscapes are "stationary"

- Landscape ~2 dimensional
- Habitat patches are defined by sharp gradients/boundaries
- Flows of materials across landscape are slow & infrequent
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hotlink

Comparison of some physical properties of air and water?

Property	Air	Seawater	Ratio SW/AIR	Organism
Density	low	high	**850:1**	~seawater
Thickness (Viscosity)	low	high	**14:1**	
Drag (Reynolds #)	low	high	**12:1**	
Heat capacity	low	high	**4:1***	
Heat transfer by conduction	low	high	**23:1**	~seawater
"Salt" concentration	low	high	**32:1**	~seawater
% water by weight	low	high	**40:1**	~seawater
Oxygen concentration	high	low	**1:38**	
Oxygen diffusion	high	low	**1:10**	
Speed of sound	slow	fast	**4:1**	
Light penetration	high	low	**1:100-1mill**	
Electrical conductivity	low	high	**20 bill:1**	

* 3500:1 by volume

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Controls body morphology & motion

* 3500:1 by volume

Comparison of some physical properties of air and water?

Controls or masks metabolism & physiology

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Limits metabolism

* by volume 3500:1

Comparison of physical properties of air and water?
“Fish can’t overcome physics”

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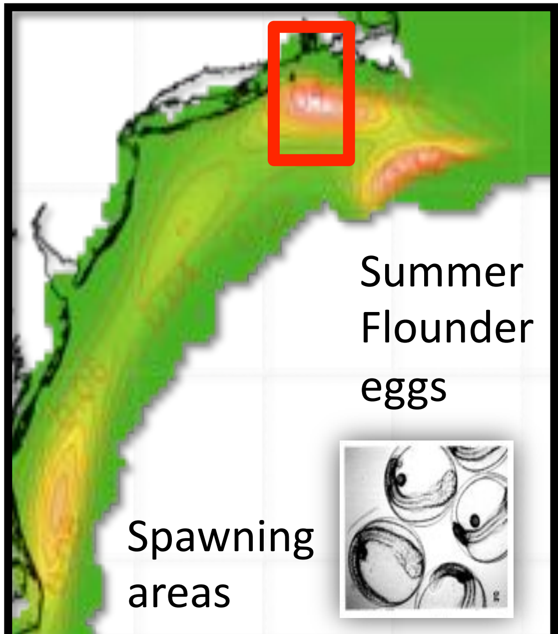
Controls dominant sensory modes
Vertical location of plant production

* 3500:1 by volume

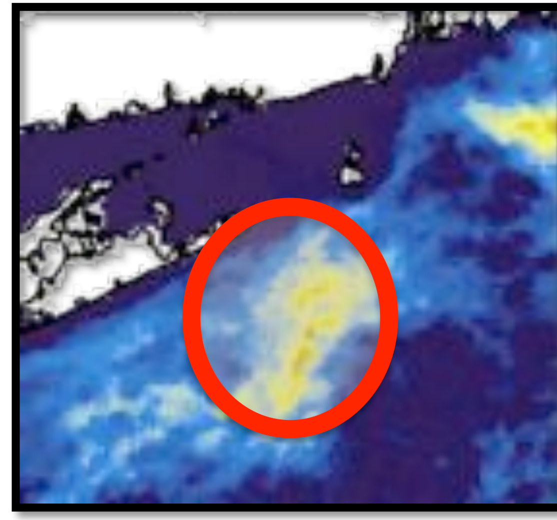
Connectivity of fundamental "habitat" forming processes

Terrestrial landscape perspective:

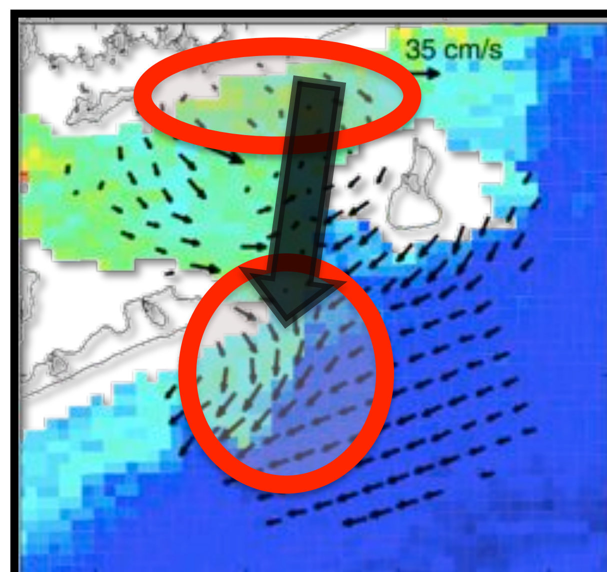


Seascape perspective material coupling

Frontal probability (from Dave Ullman)

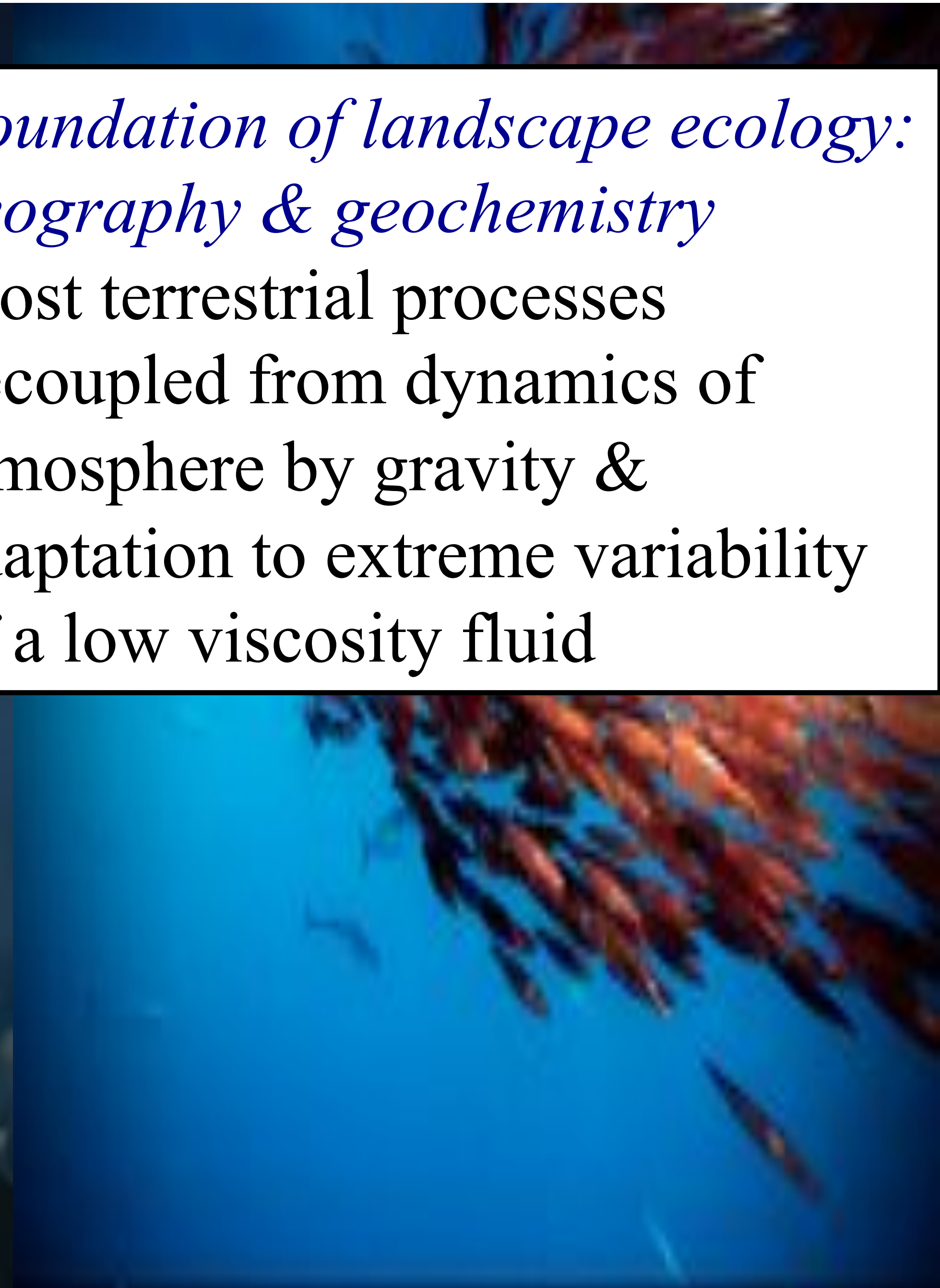


Nutrients + 1 & 2 production + advection + fronts



40 kms

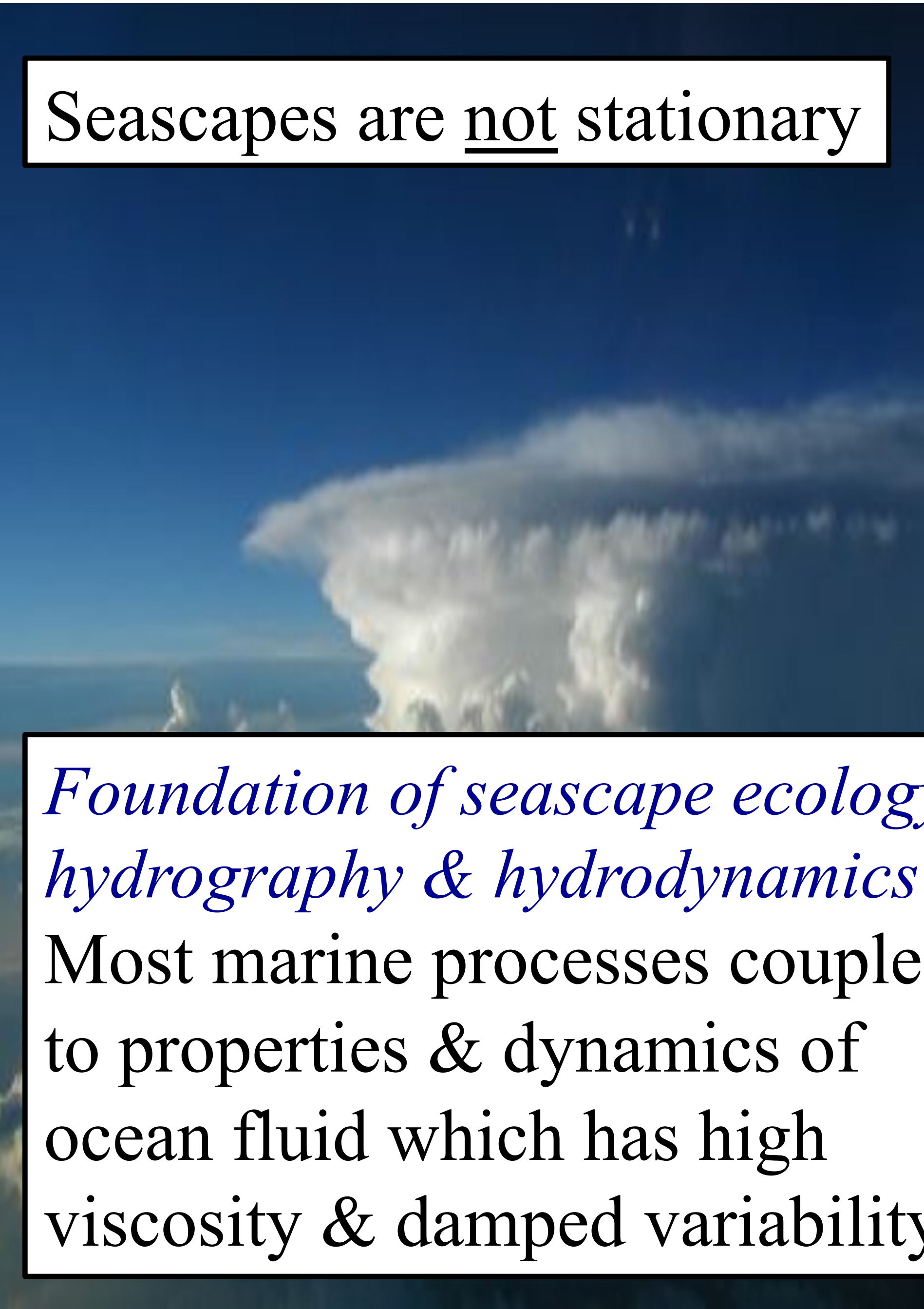
Should paradigms of seascape & landscape ecology be the same?



Foundation of landscape ecology: geography & geochemistry

Most terrestrial processes decoupled from dynamics of atmosphere by gravity & adaptation to extreme variability of a low viscosity fluid

Should paradigm of seascape & landscape ecology be the same?

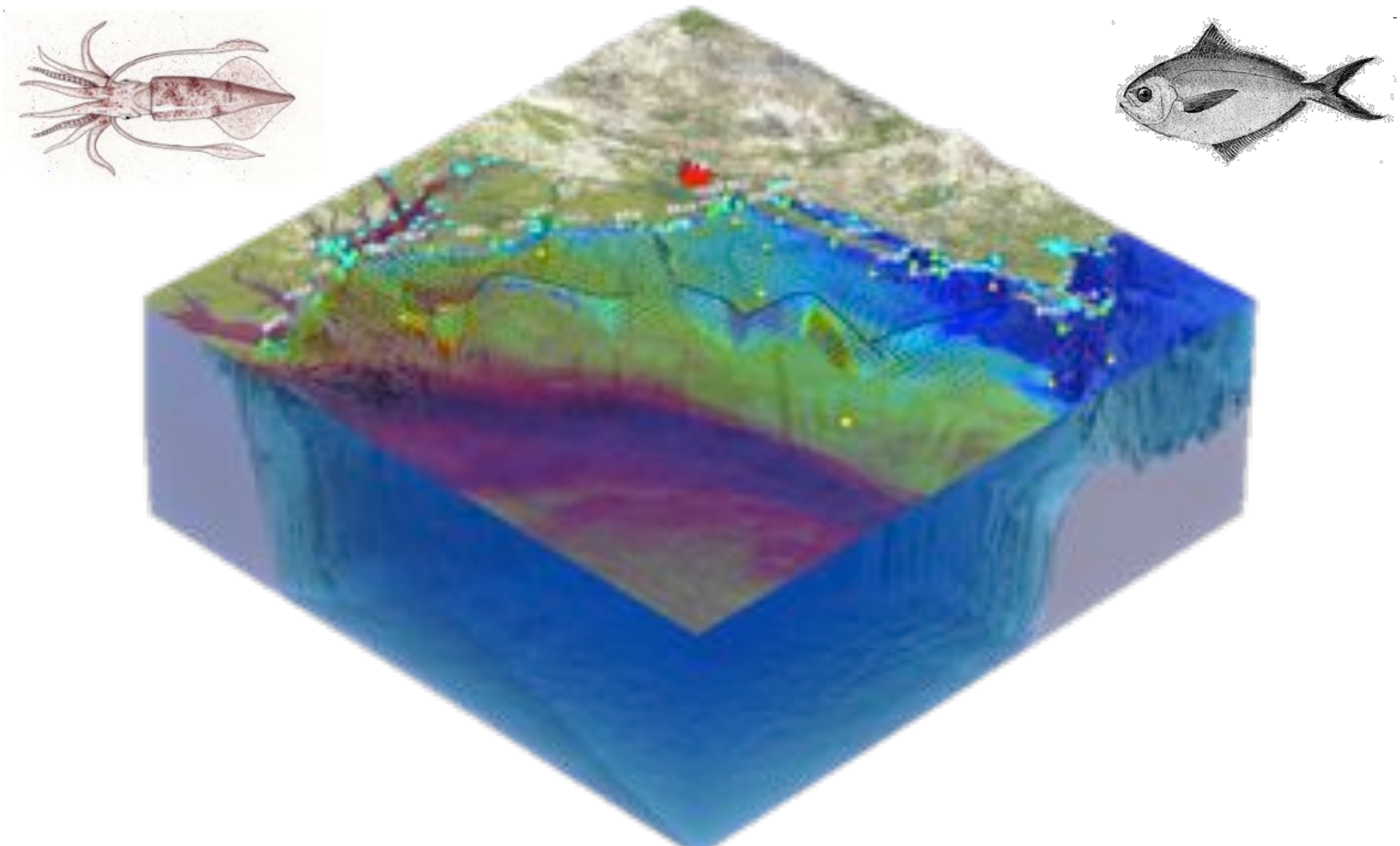


Seascapes are not stationary

Foundation of seascape ecology: hydrography & hydrodynamics

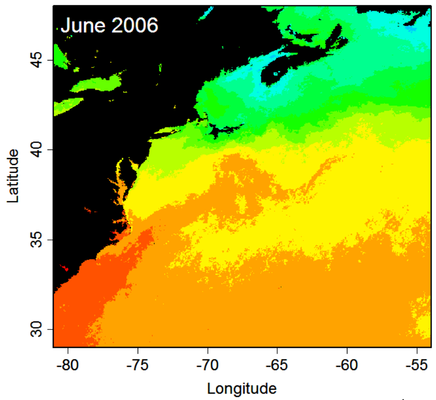
Most marine processes coupled to properties & dynamics of ocean fluid which has high viscosity & damped variability

What we need is a Hydrodynamic Information System (HIS) describing the properties & dynamics of the fluid fish live in

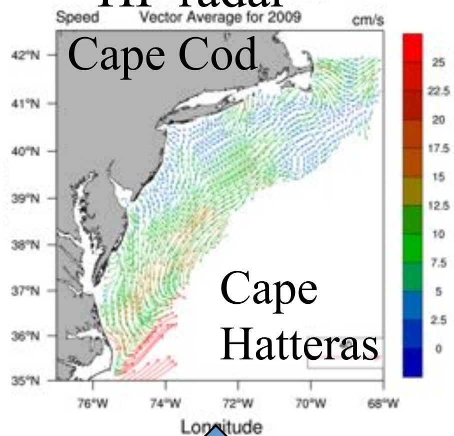


Integrated ocean observatories (IOOS) are HIS

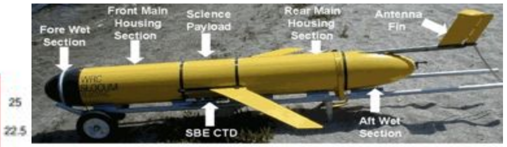
Data: Satellites

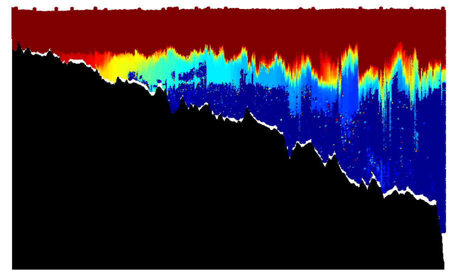


HF radar

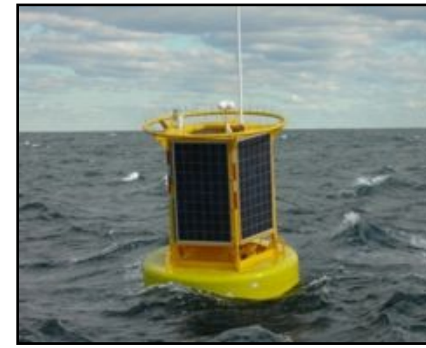


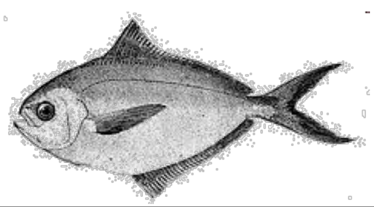
Gliders





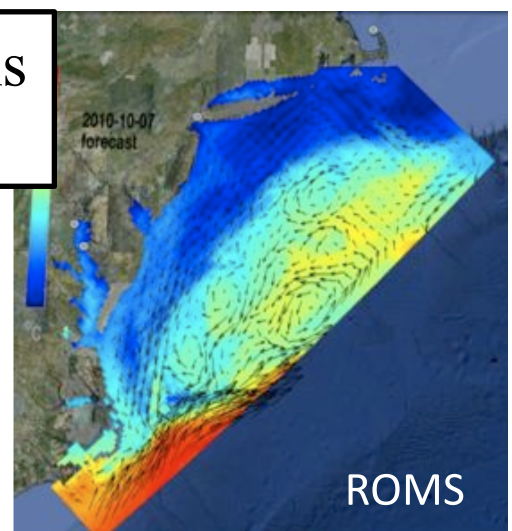
Buoys

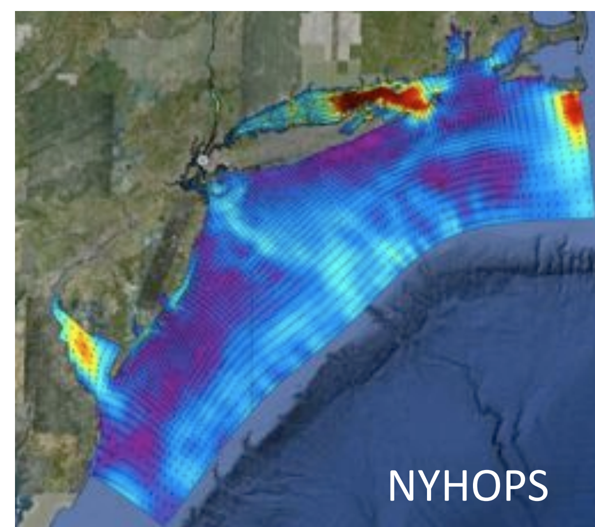




Ensemble of Assimilation Models

Describe properties & motions of the fluid fish live in





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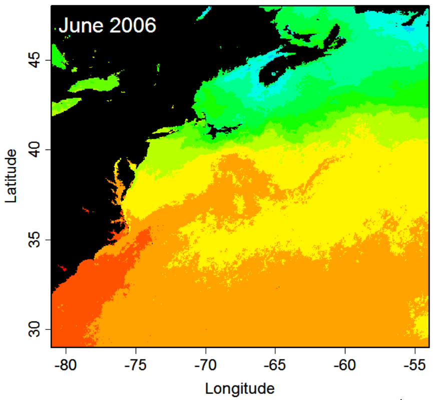
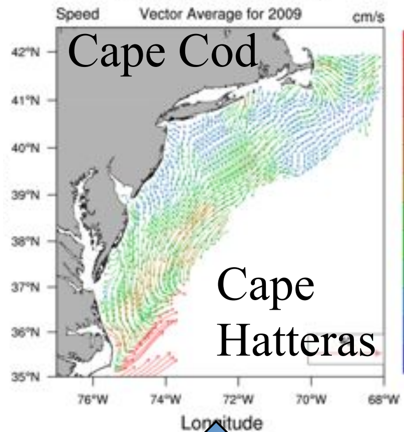
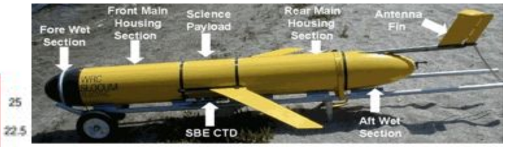
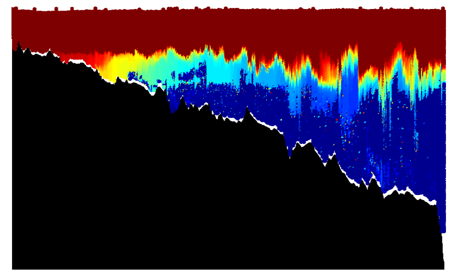
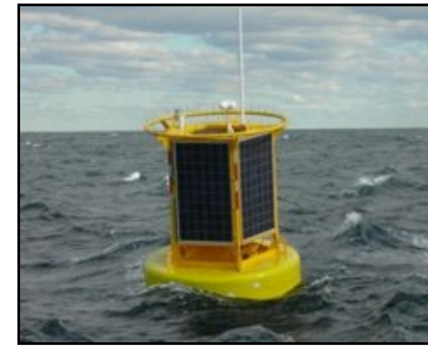
IOOS are regional ocean collaboratories built by expert stakeholder partners

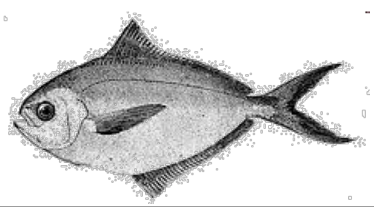












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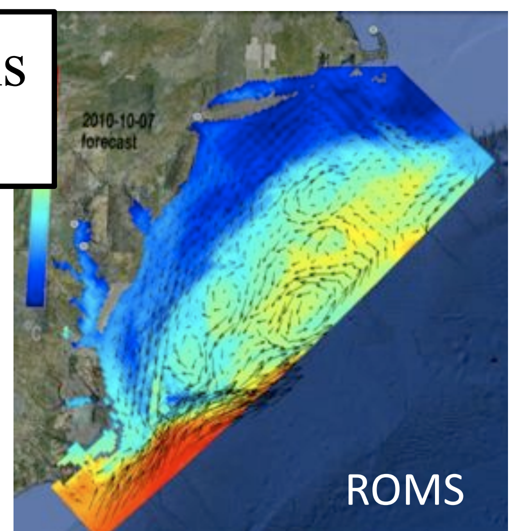
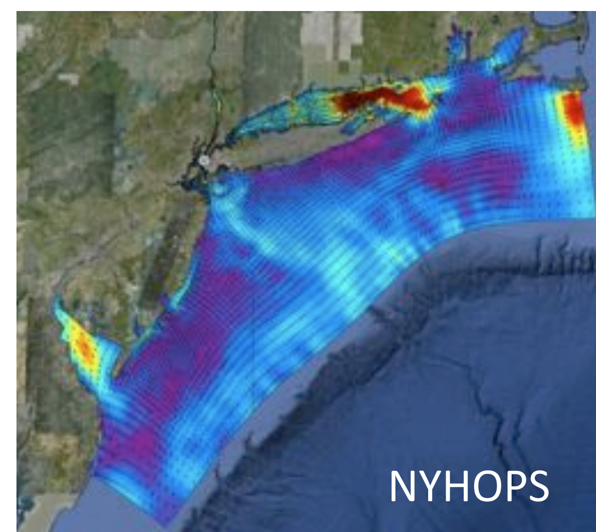




Integrating habitat dynamics into population & ecosystem dynamics

- Does our habitat paradigm cross the land-sea boundary?
  - Seascapes are not landscapes

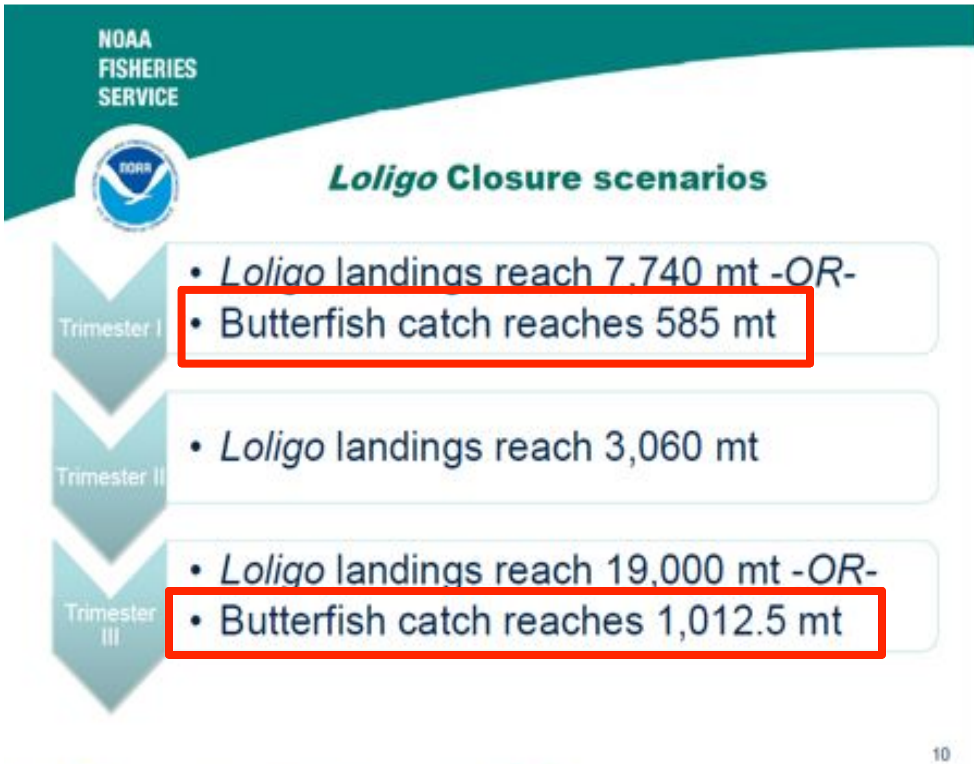
- Regional Ocean Observing Systems IOOS are Hydrodynamic Information Systems (HIS vs. GIS)
  - & partnerships of stakeholder experts with vested interest in regional ocean monitoring & forecasting from physics to fish

- Cooperative research within an IOOS framework: Integrating habitat dynamics into population & ecosystem assessment & dynamics:

Collaborative development of a seascape ecology you can use

Sometimes a management problem finds you

"Make habitat model to reduce butterfish bicatch in longfin squid fishery"



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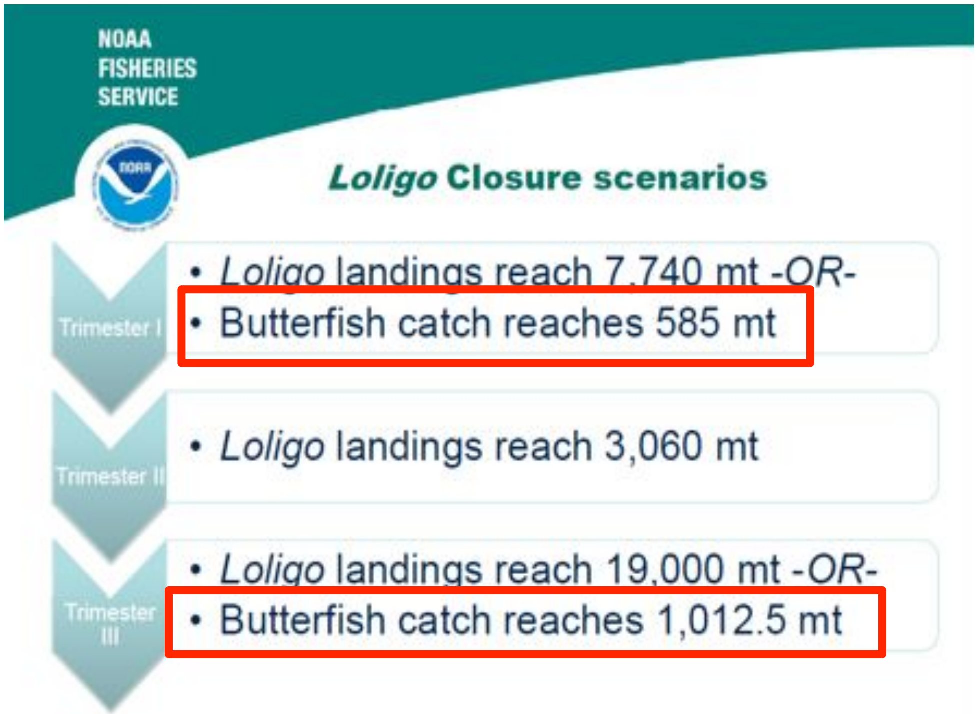

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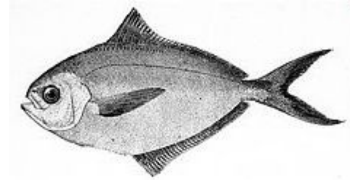
"Butterfish Smackdown"
Make competing models



Hypothesis:

Combining fishermen & scientists' knowledge within an Operational Ocean Observing System should:

(1) Increase chance of accurately capturing ecosystem dynamics & key driving processes at appropriate space-time scales

(2) enable adaptive decision making at scales matching those of the ecosystem

Scientists & Fishermen

- Bottom Temperature
- Solar elevation
- Day length
- Surface fronts
- Bottom complexity
- Bottom depth
- Mixed layer depth

+

Scientists

- Index of "upwelling"

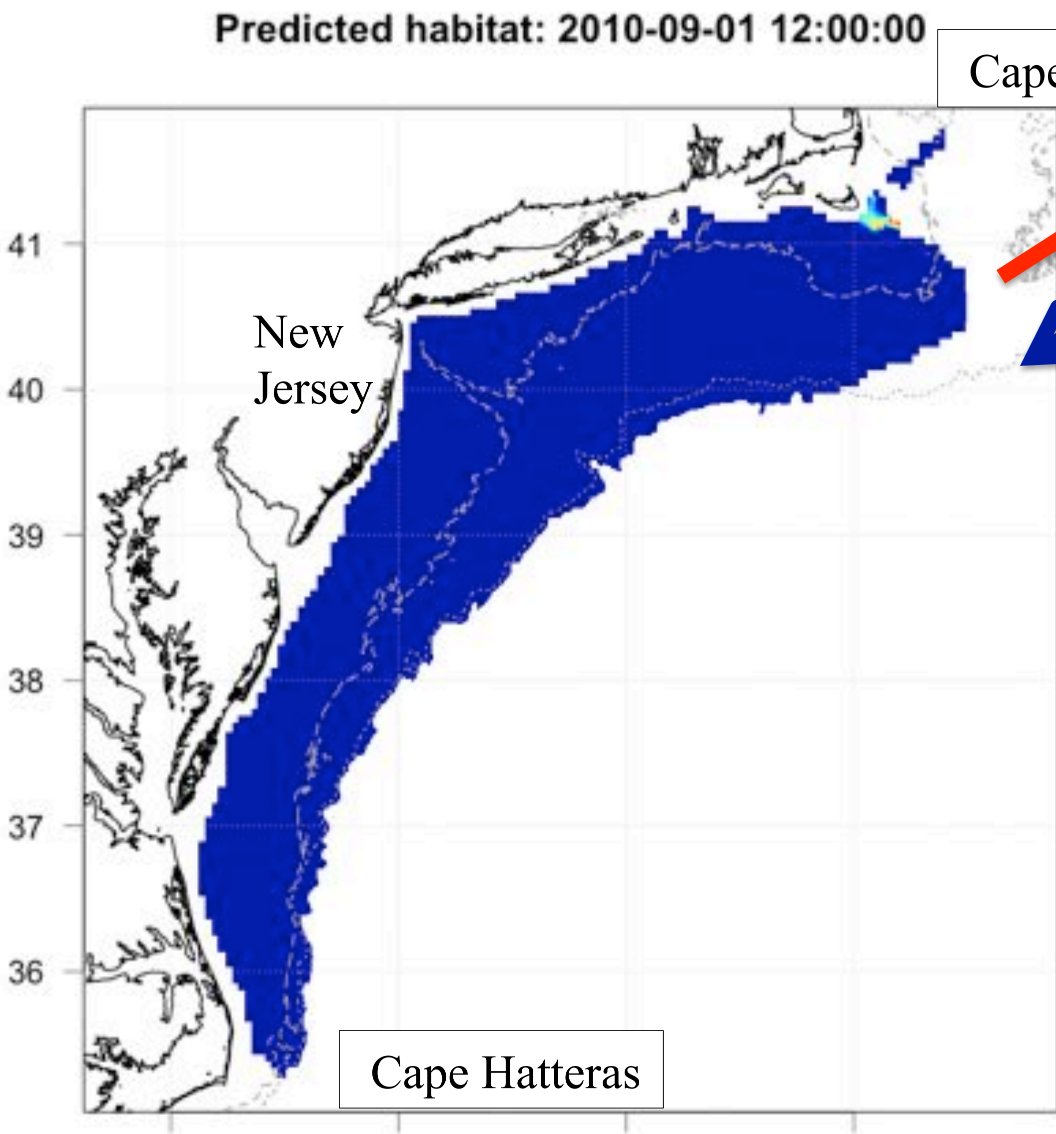
Fishermen

- Sediment grain size
- Lunar Phase
- Chlorophyll

Field evaluation of prototype operational habitat model (ver 2.0)

Model "now cast" based on IOOS observations

Catch & environmental data & analysis



F/V Karen Elizabeth

Model evaluation survey
Formal integration of fisherman knowledge

3 canyon areas
Atlantis/Veatch
Wilmington
Norfolk

Regional hotspots

X

Night

Daylight

Diel vertical migration

X

Model "now casts"

Not habitat

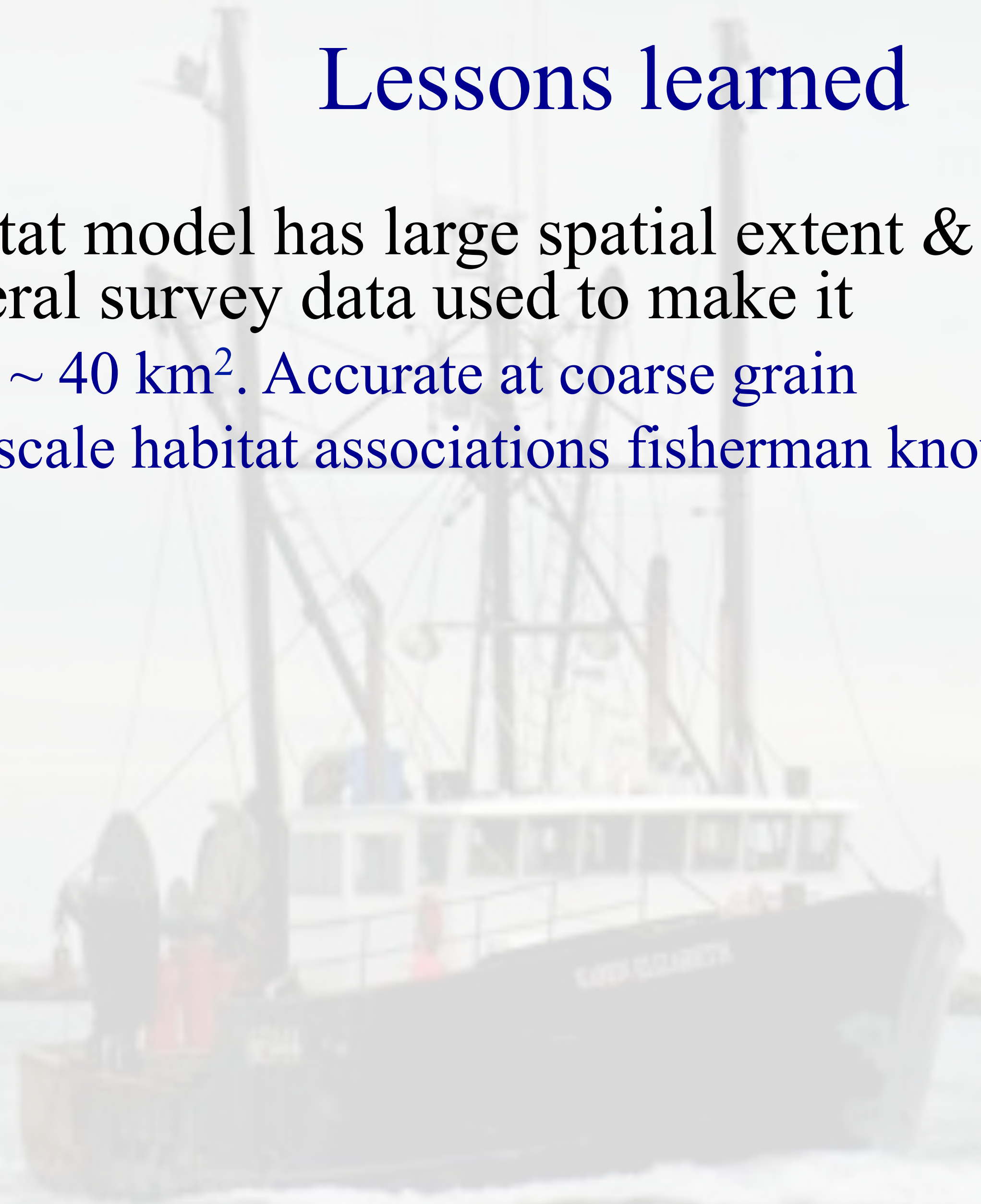
Habitat

Fisherman "now cast"

Habitat

Lessons learned

- 1) Habitat model has large spatial extent & coarse grain like the federal survey data used to make it
  - grain ~ 40 km^2. Accurate at coarse grain
  - Fine scale habitat associations fisherman know not described



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- 3) Animals concentrated in habitats under or un-sampled in assessment surveys
  - Seasonally productive inshore & offshore fringes of ecosystem where rates of mixing & nutrient enrichment high
  - Where triggers for ecological processes including migration are changing rapidly with climate change

Habitat model 3.0

Goal: Develop model to address lesson # 3

1) Quantify amount of habitat not sampled along ecosystem fringes

3) Model changes in habitat (& potential species distributions) with seasonal & inter-annual changes in climate

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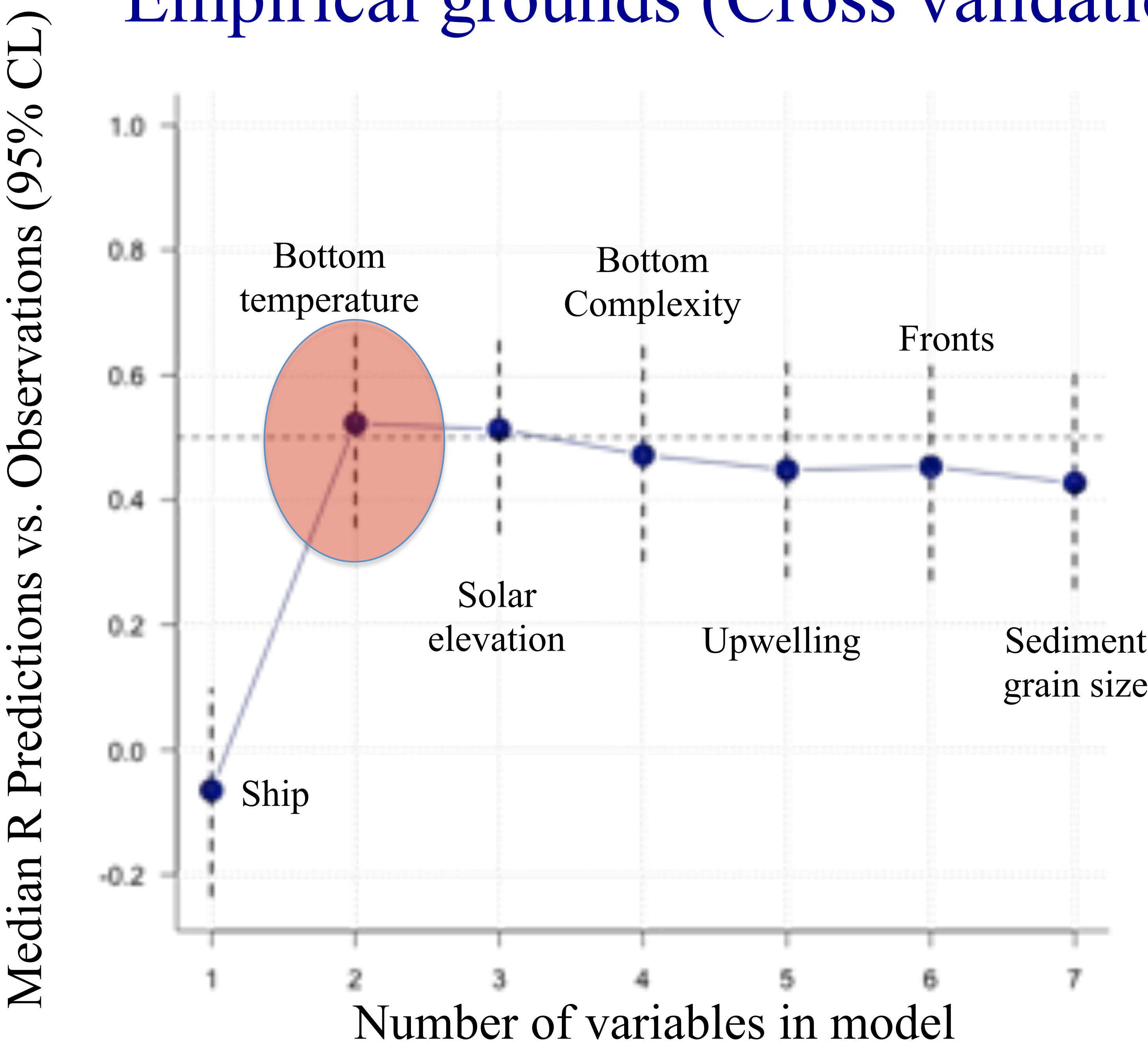
Strategy for model building:

Keep it Simple Stupid (KISS)

Defensible mechanistic & empirical grounds

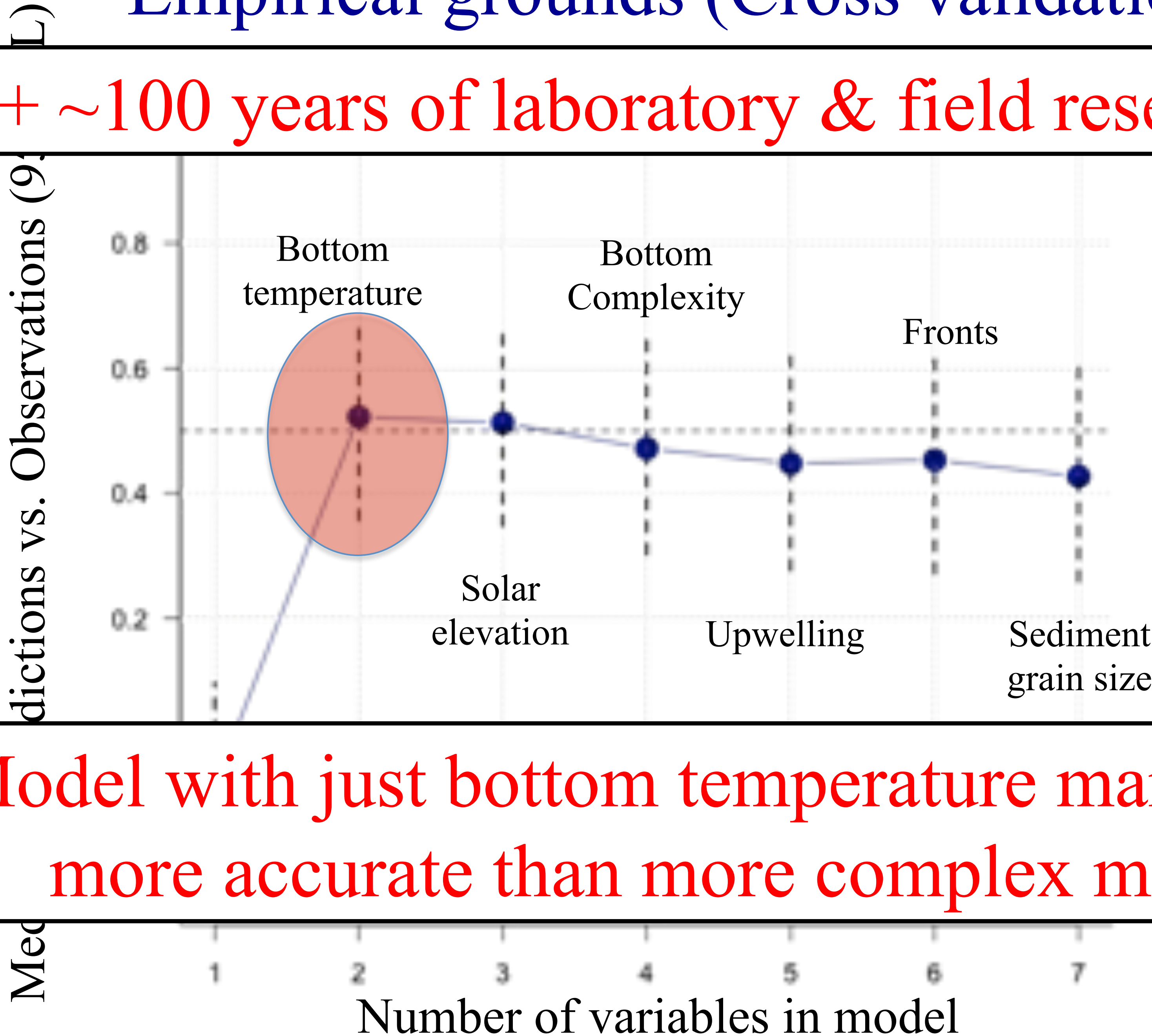
Model must be accurate

Empirical grounds (Cross validation):



Empirical grounds (Cross validation):

+ ~100 years of laboratory & field research



Model with just bottom temperature marginally more accurate than more complex model

Mechanistic grounds:

"Temperature is tyrannical in the ocean"

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“Temperature is tyrannical in the ocean”

- Thermal properties of seawater
  - Ocean is thermally benign
    - Heat capacity in ocean is 3500 x’ s higher than air by volume & ocean volume is huge. Temperature less variable & slow to change
  - Most animals are “cold blooded” ectotherms. Costs of being warm blooded high, benefits are low.
    - Heat transfer by conduction > 20x faster in ocean than air. Heat transfer by free & forced convection 40 & 190 xs faster

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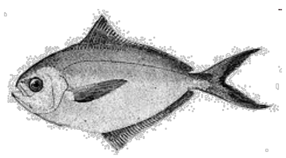
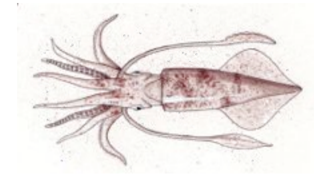
    - Heat transfer by conduction > 20x faster in ocean than air. Heat transfer by free & forced convection 40 & 190 xs faster
- Ectotherms: metabolism & <u>ALL</u> performance rates linked to metabolism are regulated by external temperature
  - + 2C Temperature ~ metabolic rate + 15%

Thermal niche model + bottom temperature hindcasts

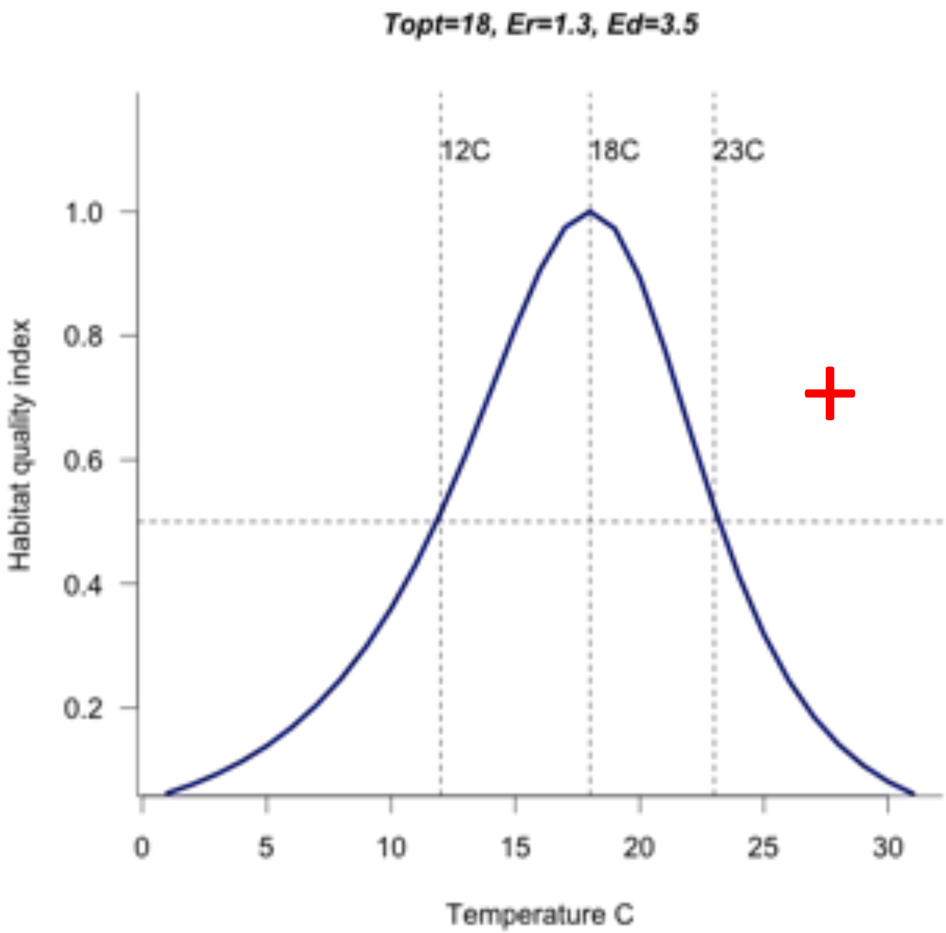
= Thermal habitat simulation





Thermal niche model with metabolic basis fit to field data

IOOS ocean model hindcast of daily average water temperature under the surface



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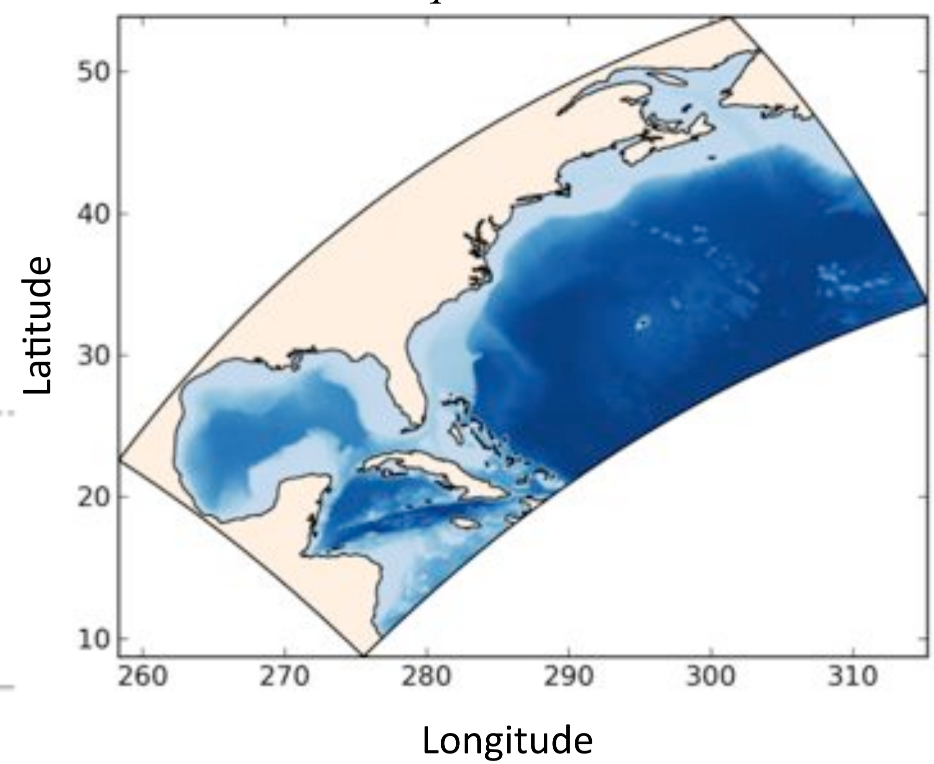
ROMS

Enrique Curchitser

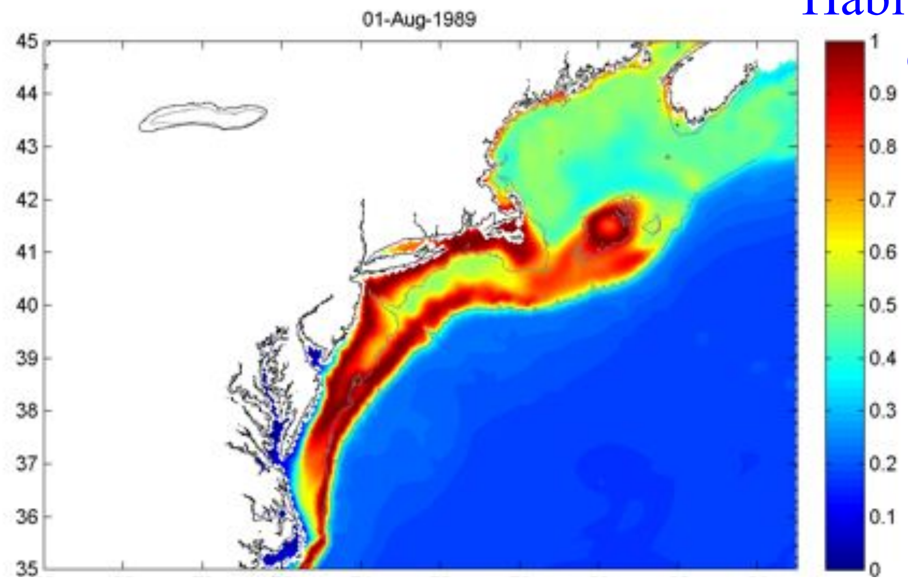


Simulated thermal habitat quality on the bottom (2d)

1989-1990

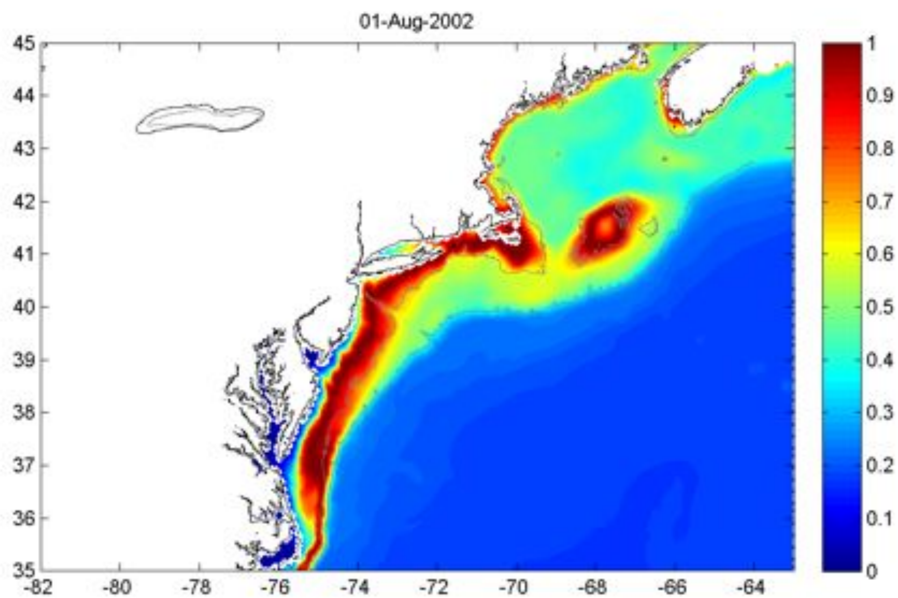
Habitat Quality

Good

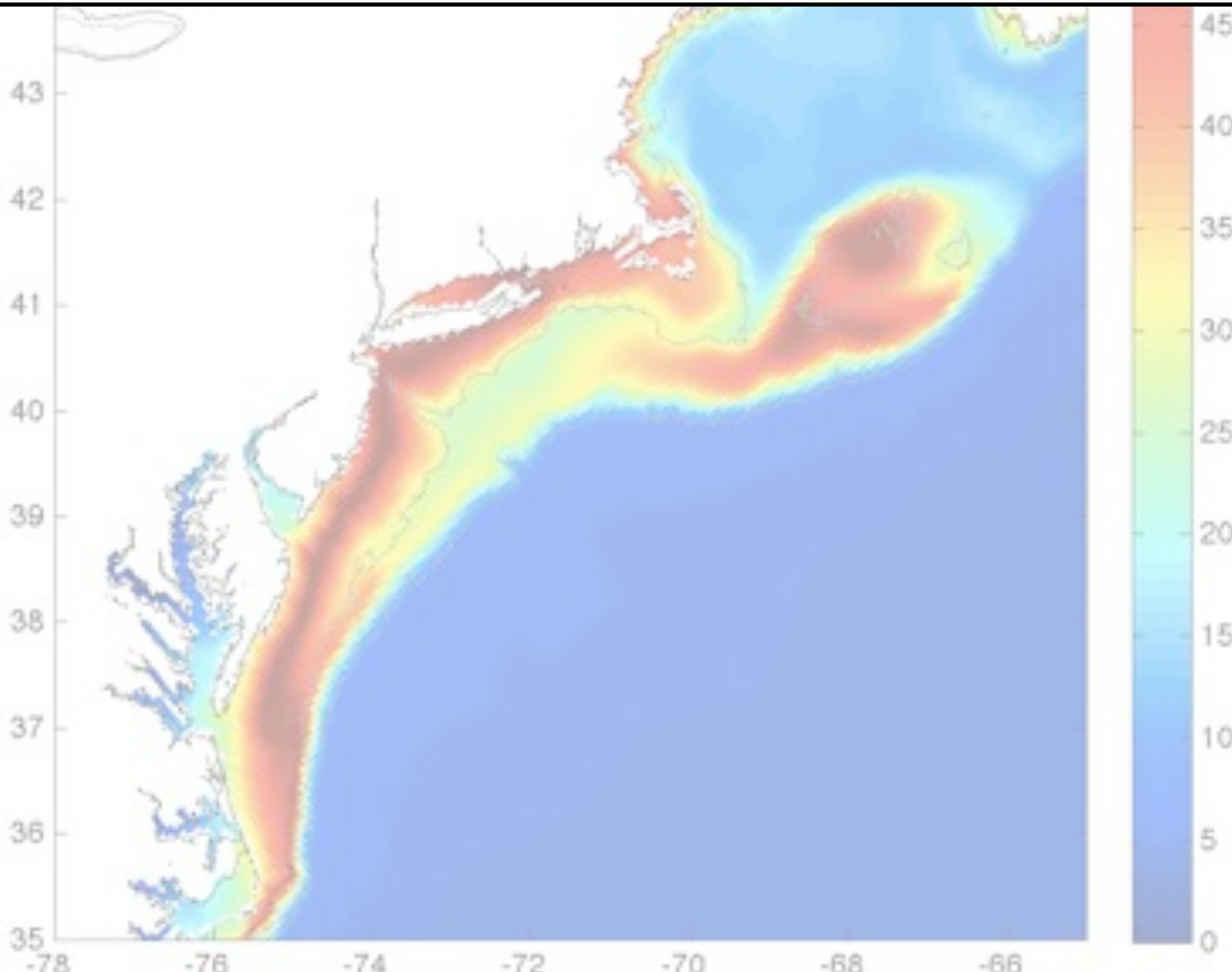


Poor

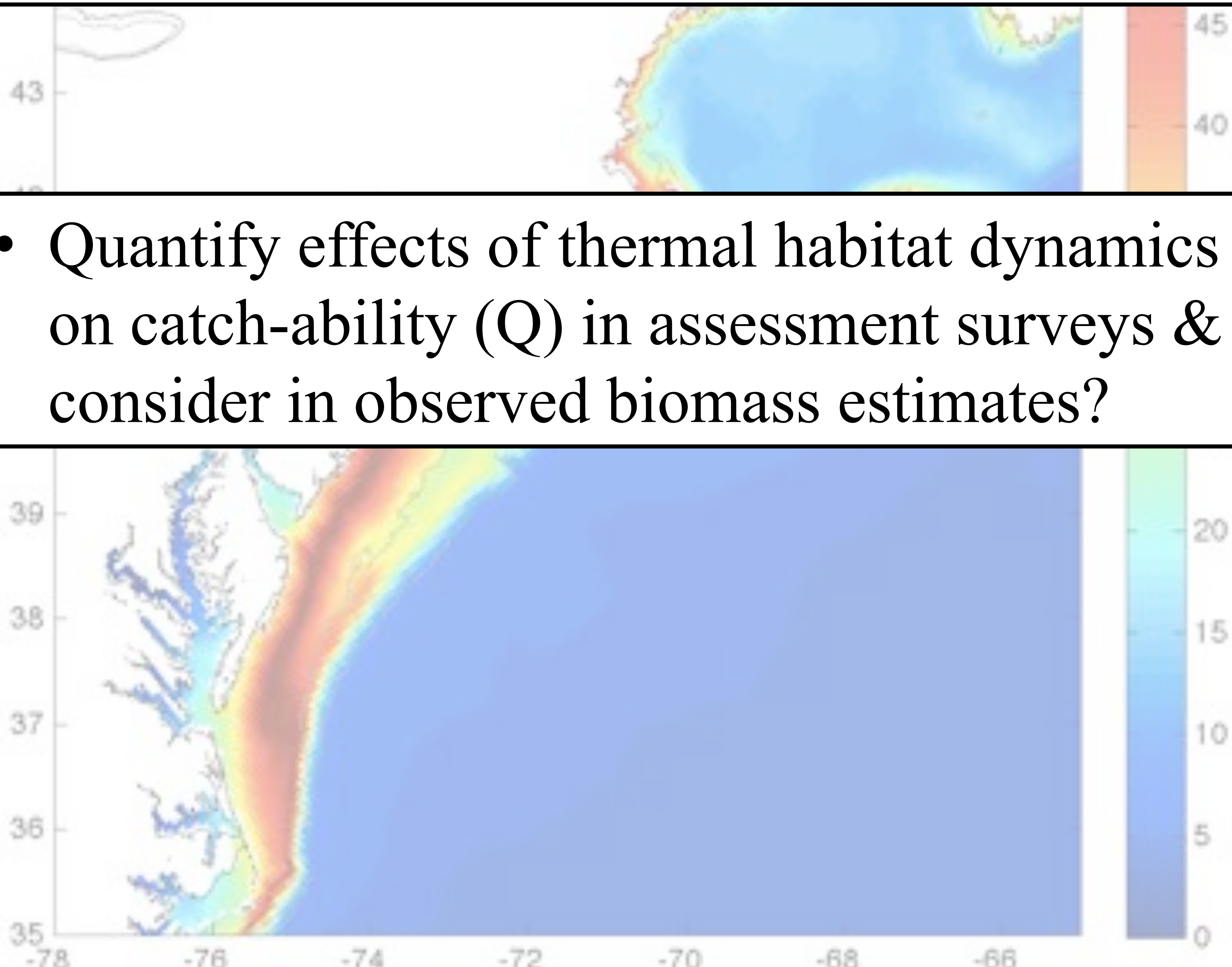
2002-2003



What can we do with model v3.0?

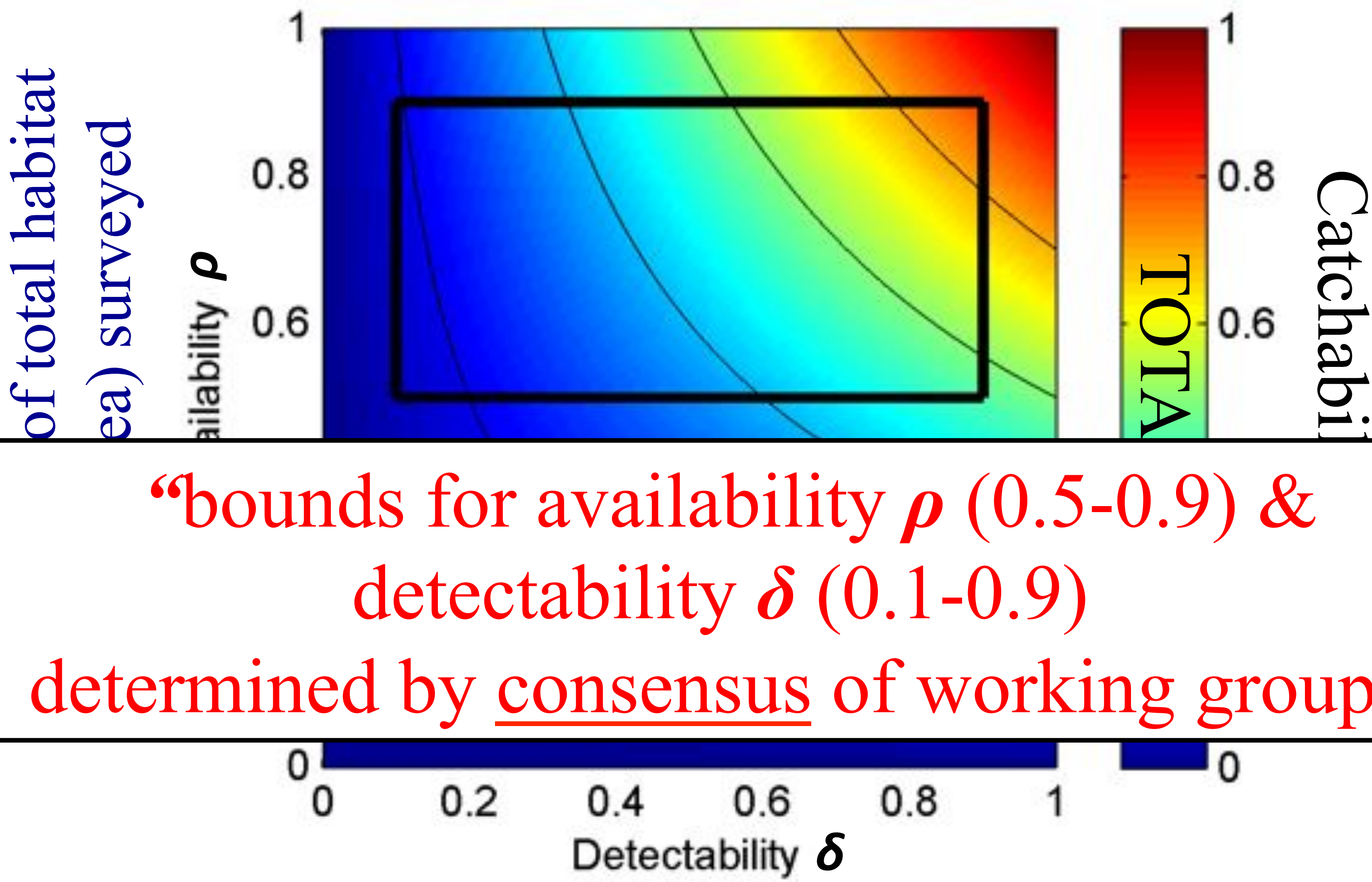


What can we do with model v3.0?



- Quantify effects of thermal habitat dynamics on catch-ability (Q) in assessment surveys & consider in observed biomass estimates?

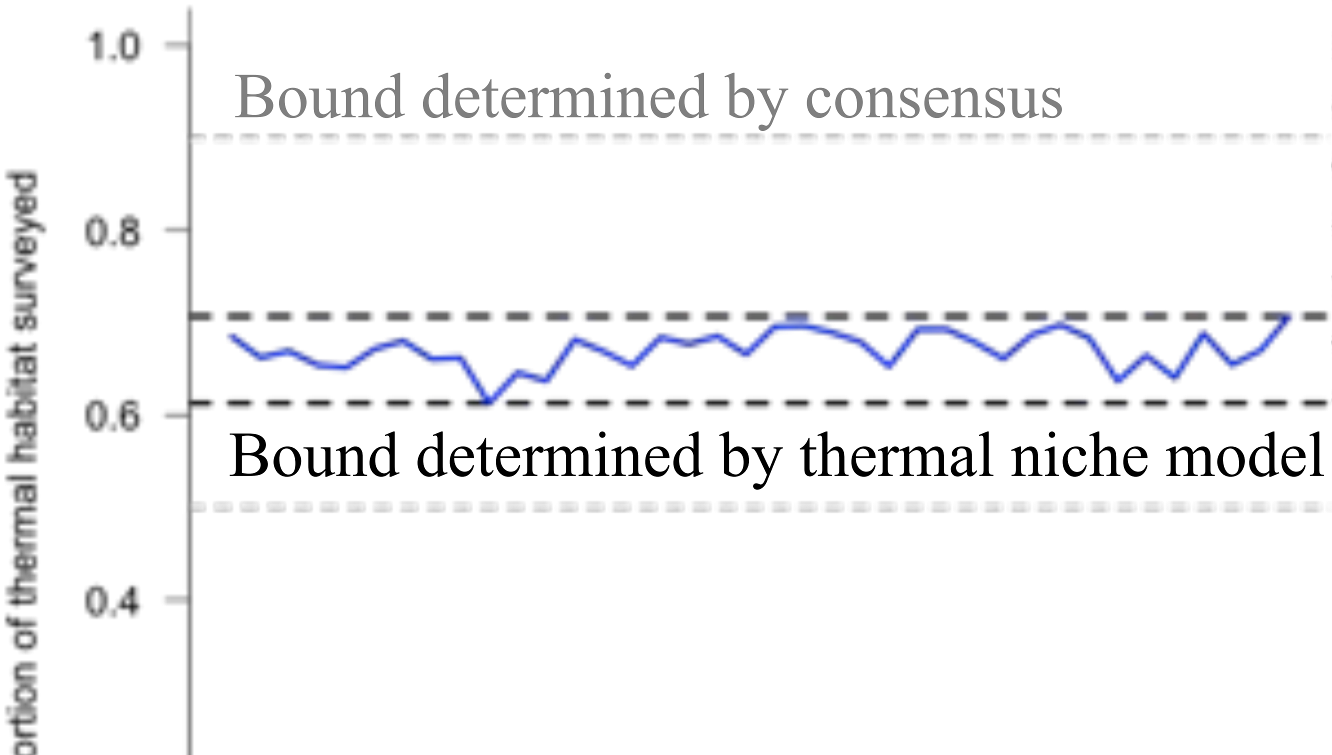
SARC 49: butterfish population biomass estimate
With no landings, catchability in survey(Q) used to scale biomass

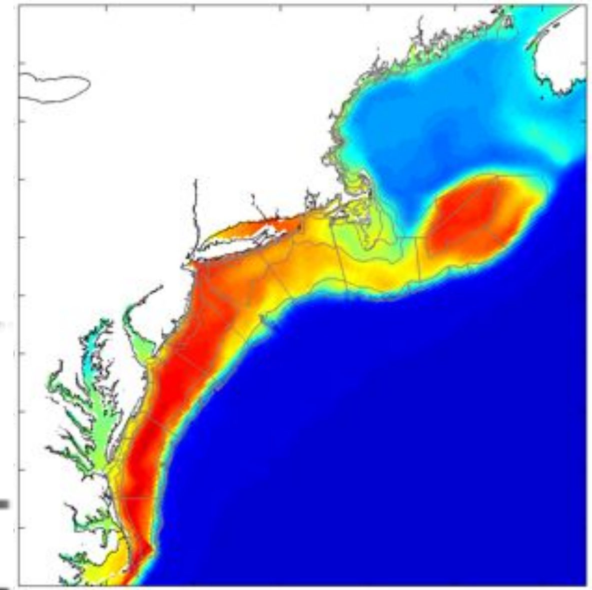


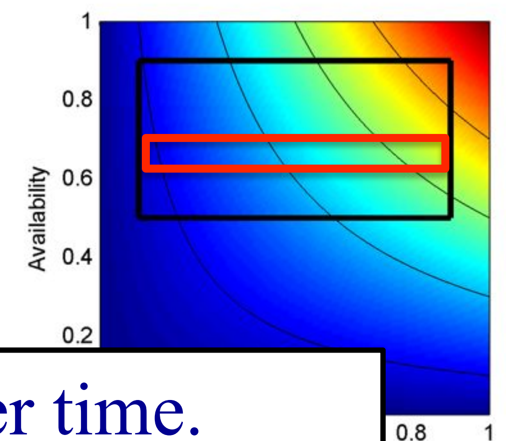
"bounds for availability ***ρ*** (0.5-0.9) & detectability ***δ*** (0.1-0.9) determined by <u>consensus</u> of working group"

Proportion of fish occupying a station caught in net

Habitat model based estimate of availability (*ρ*) of butterfish to fall NEFSC survey







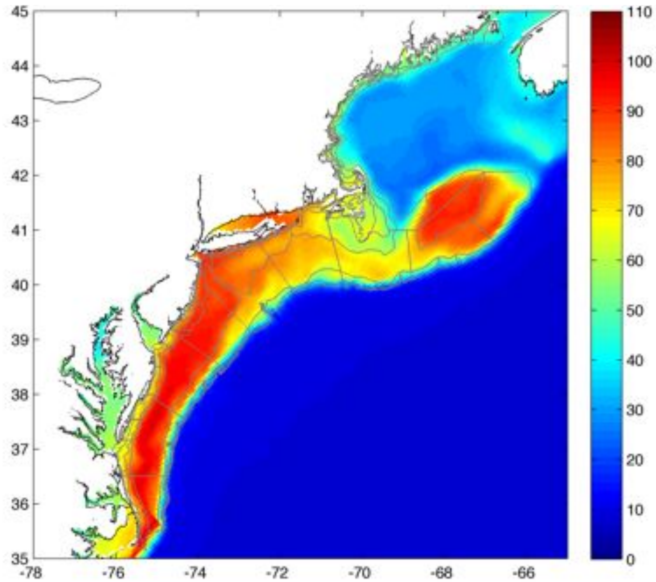
Estimate changes in availability (***ρ***) over time.

Consider effects on ***ρ*** of shifts in species distributions with temperature change associated with climate change

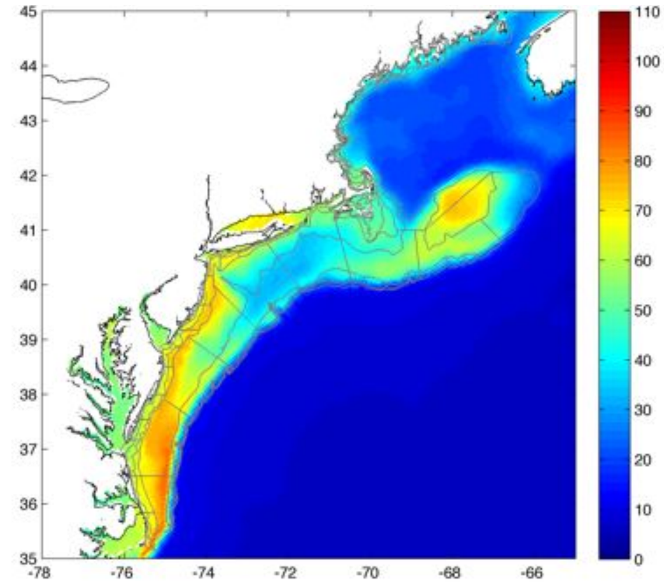
Cumulative thermal habitat suitability Fall NEFSC assessment surveys.

Restratify data for observed population biomass estimation?

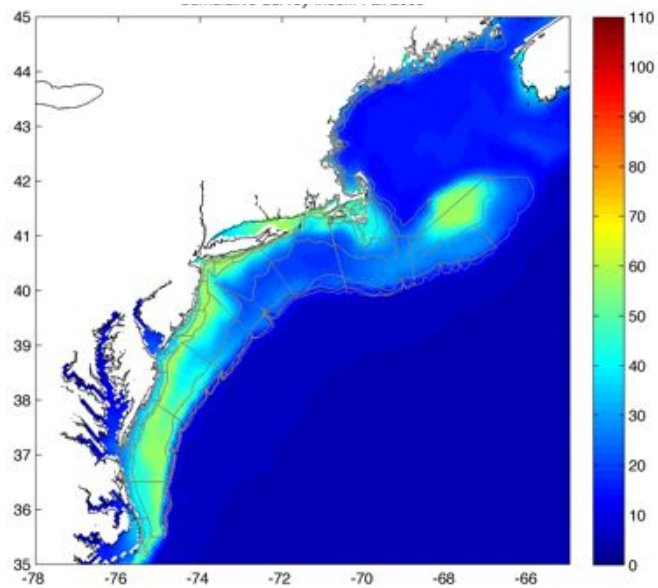
Fall 1977



Fall 1981



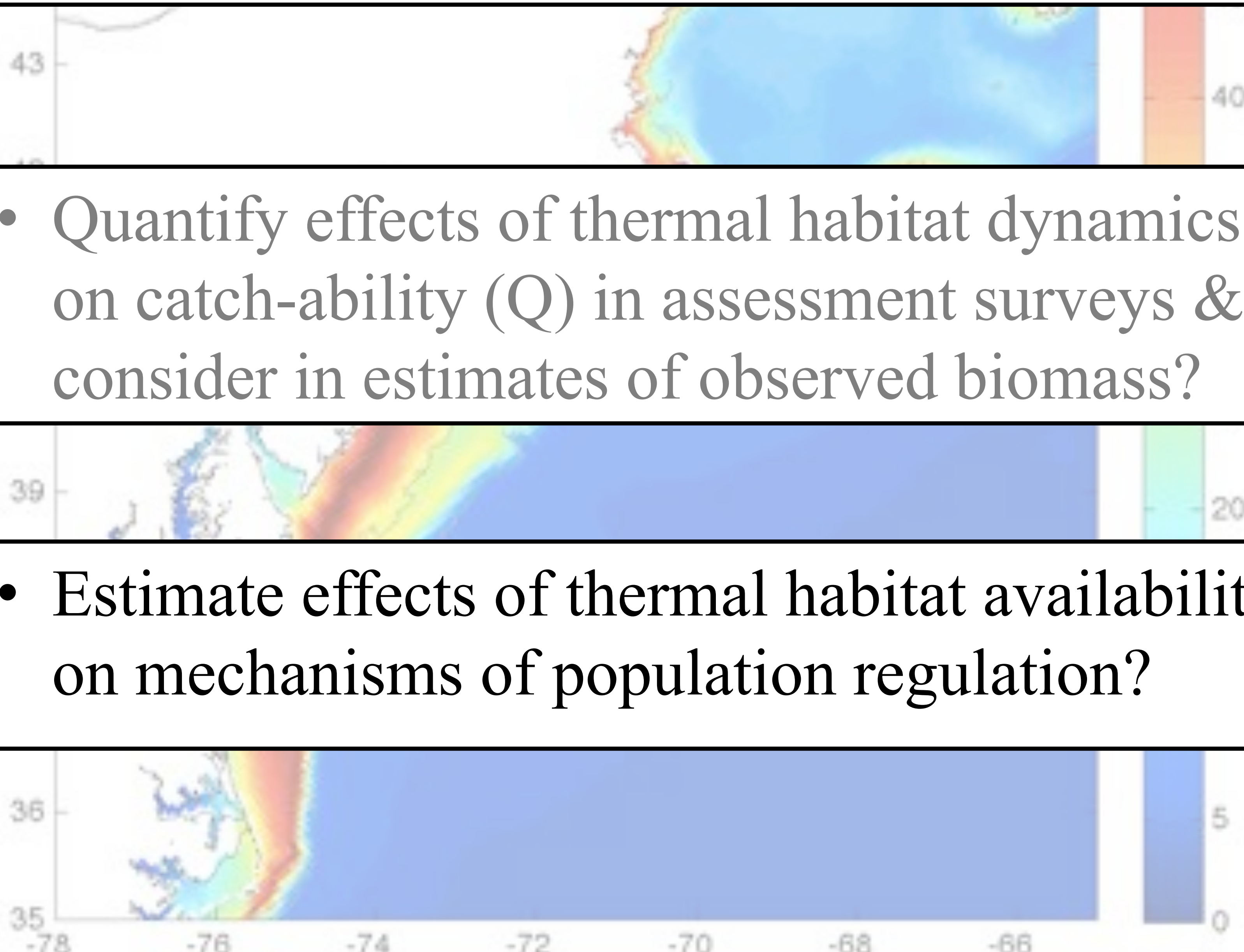
Fall 2005



What can we do with model v3.0?

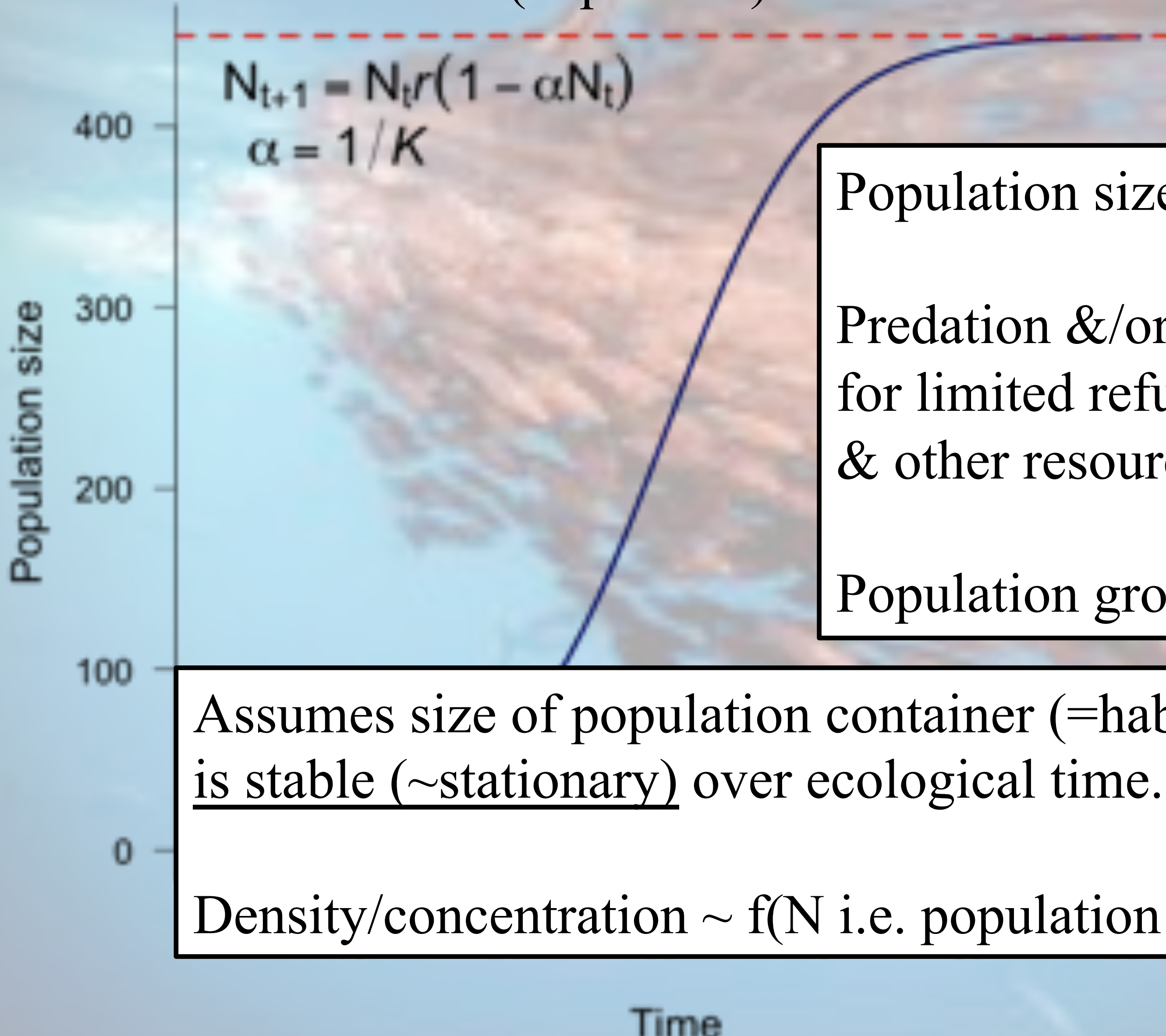
- Quantify effects of thermal habitat dynamics on catch-ability (Q) in assessment surveys & consider in estimates of observed biomass?

- Estimate effects of thermal habitat availability on mechanisms of population regulation?



Logistic population growth with density dependence

K (environmental carrying capacity) = 450 fish
α (K per fish) = 1/K = 1/450 = 0.0022



Population size increases,

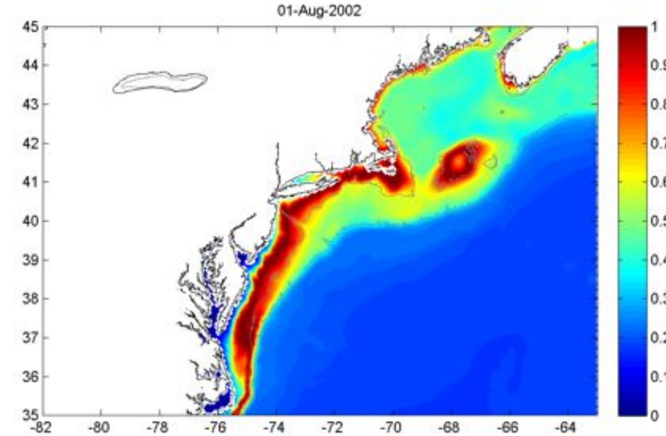
Predation &/or competition for limited refuge, food, mates & other resources increases

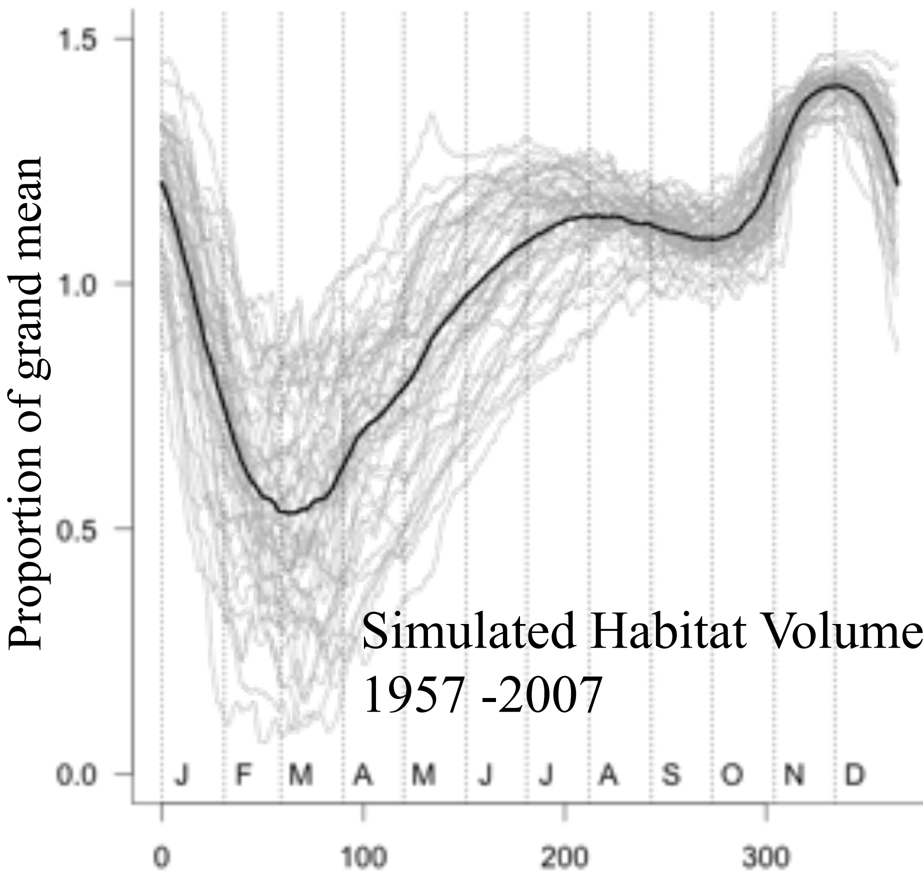
Population growth declines

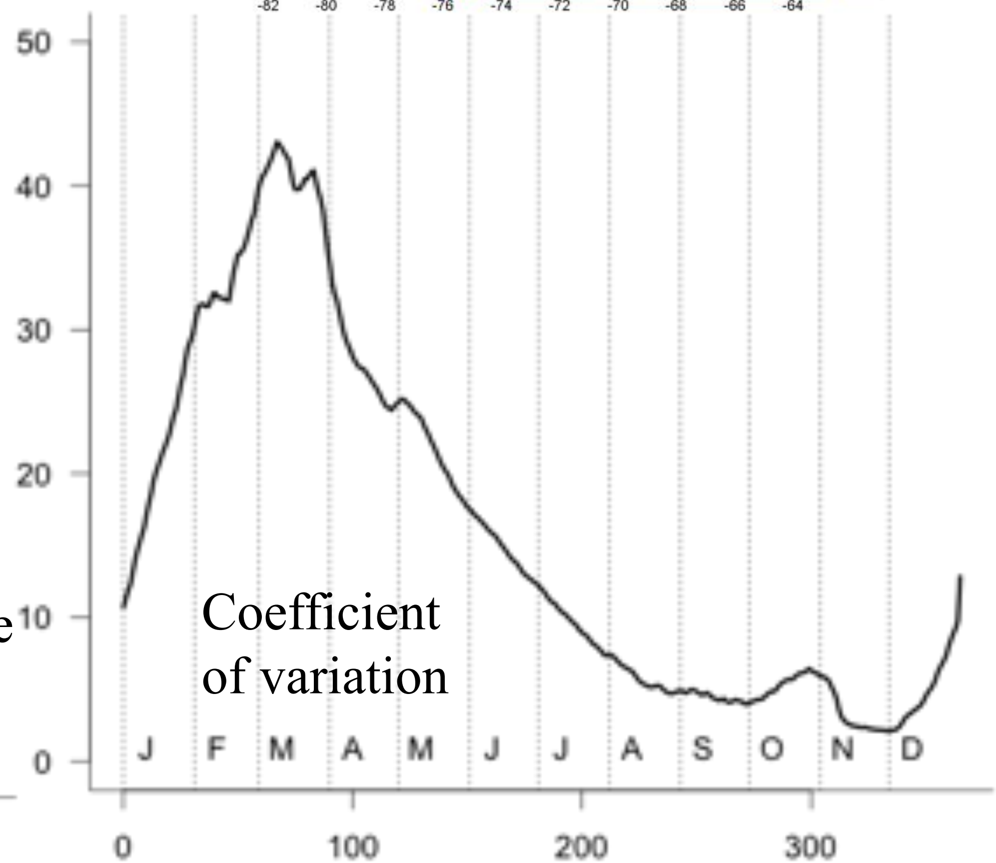
Assumes size of population container (=habitat) <u>is stable (~stationary)</u> over ecological time.

Density/concentration ~ f(N i.e. population number)

Seasonal dynamics in availability of thermal habitat



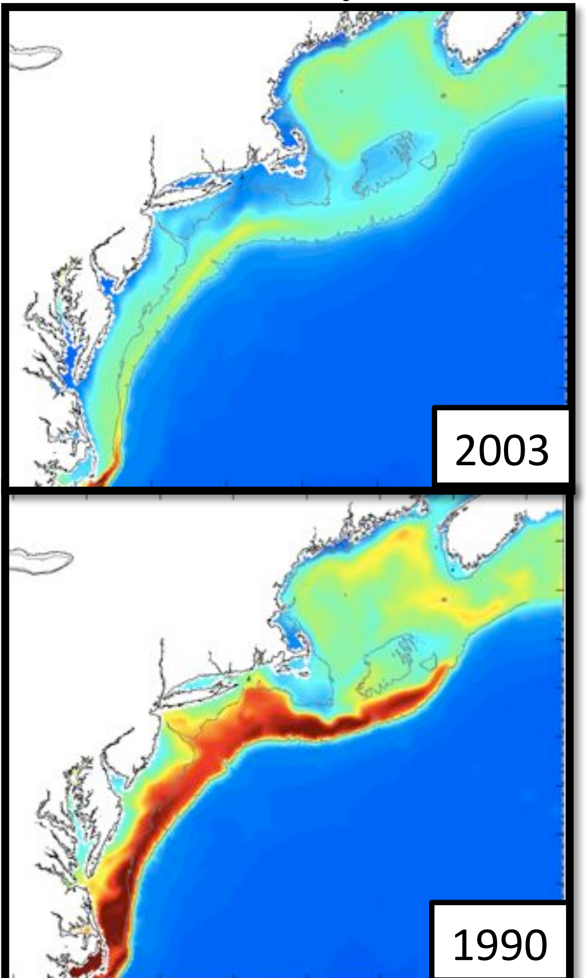


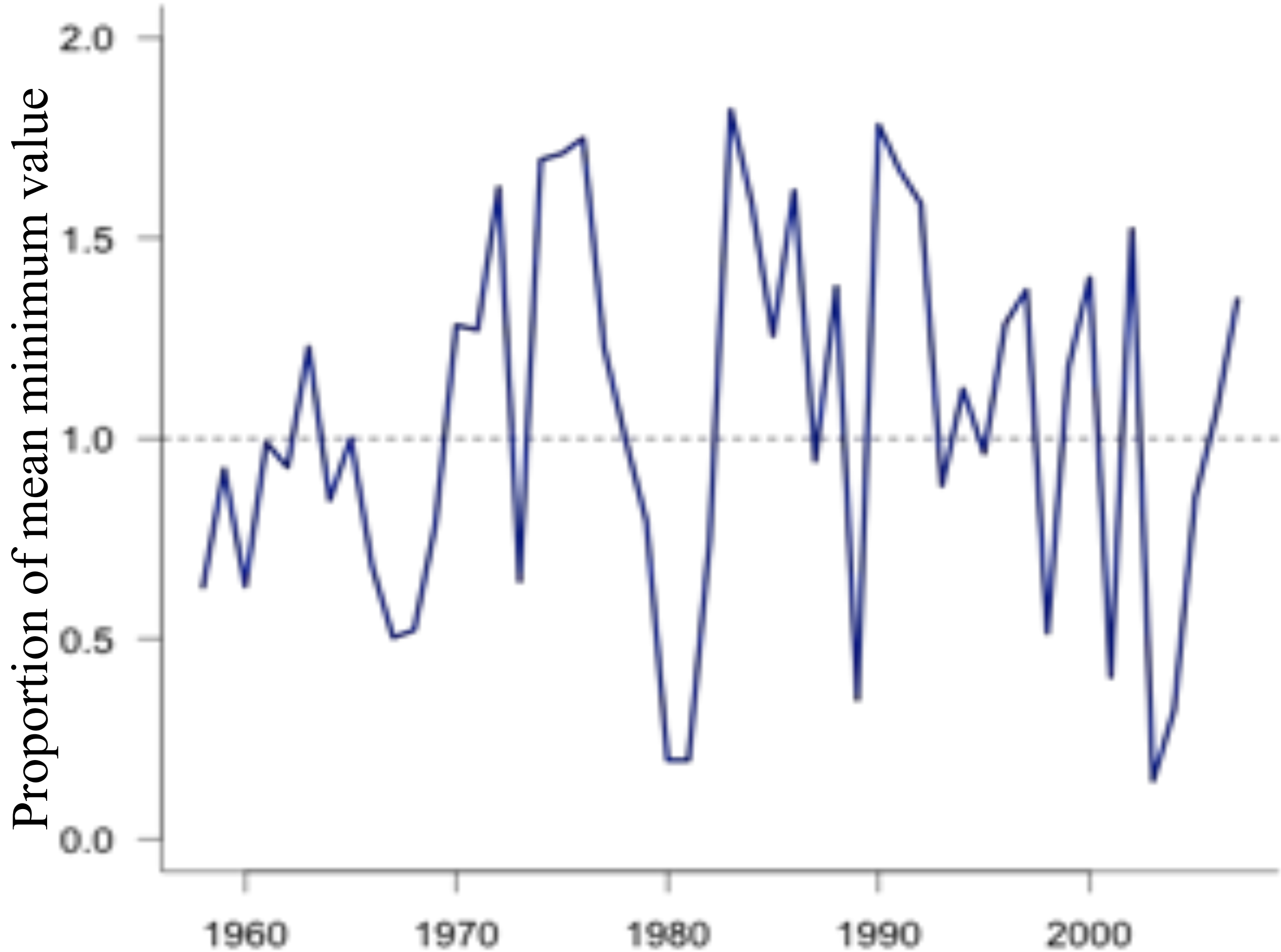


Day of the year

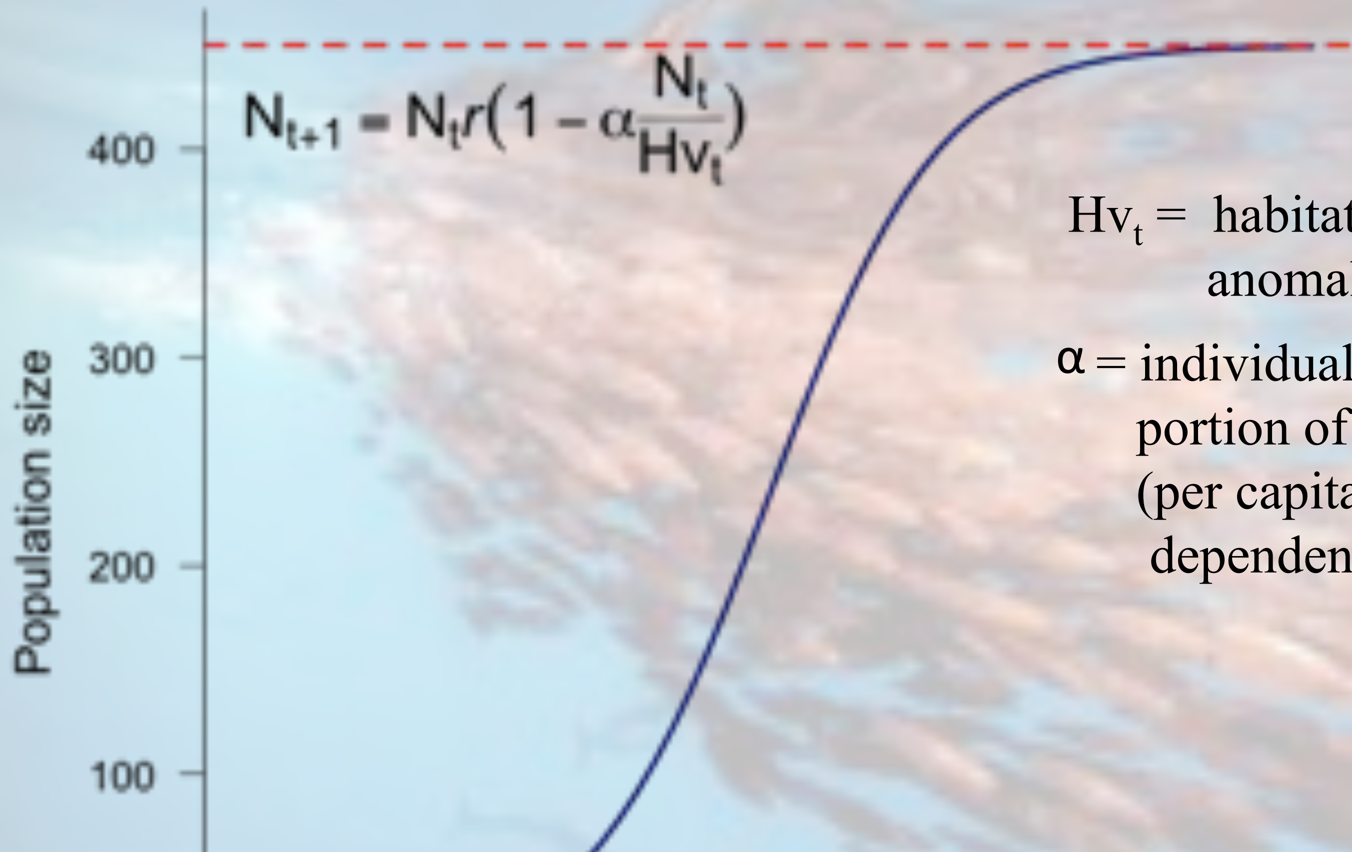
An index of annual minimum habitat volume hV_t

Late February/March





Simple population model that puts density in density dependence (i.e. # individuals in a habitat volume)



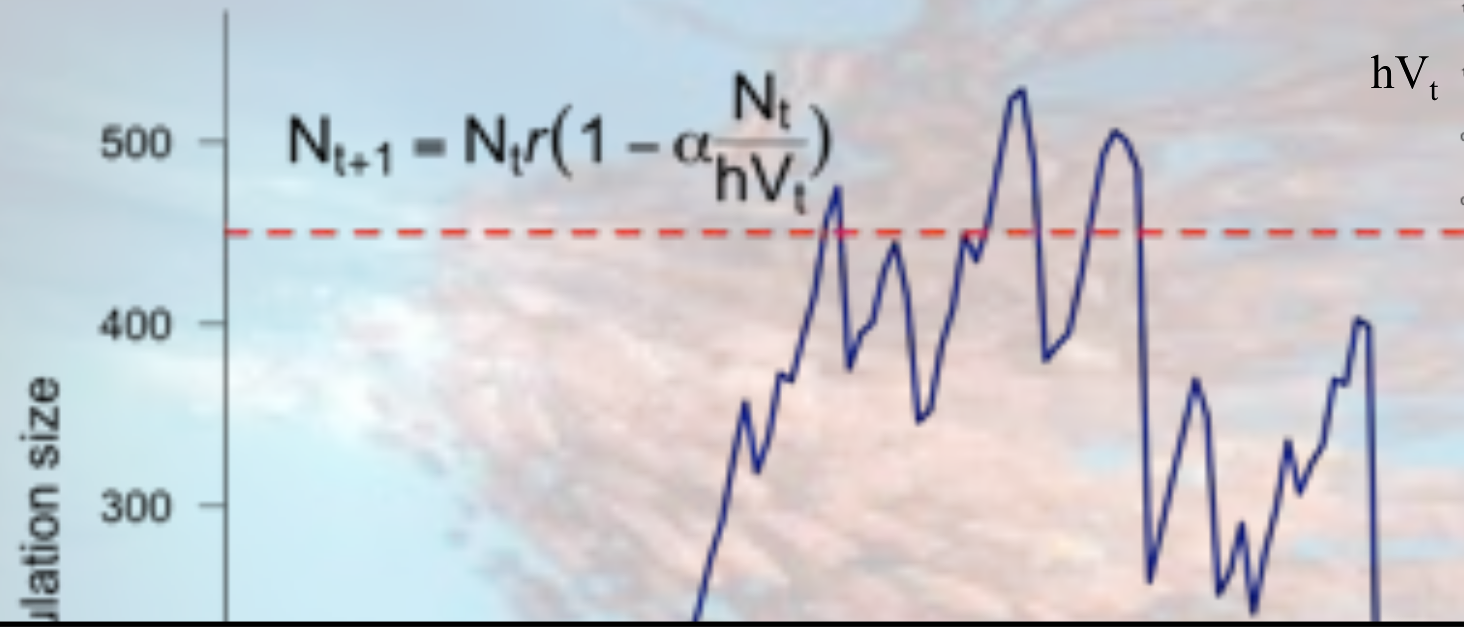
Hv_t = habitat volume anomaly

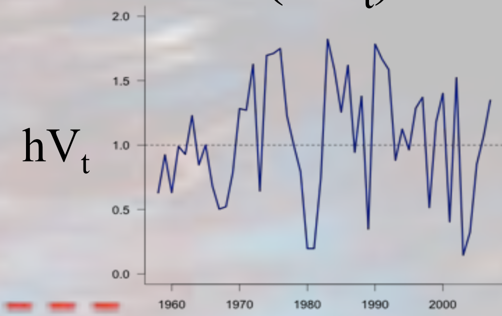
α = individual animals portion of carrying capacity (per capita density dependent effect)

Assume size of population container (~habitat) is <u>not stable</u> over ecological time.

Density/concentration ~ f(population size/habitat volume)

Simulation of population model integrating habitat volume (hV_t)



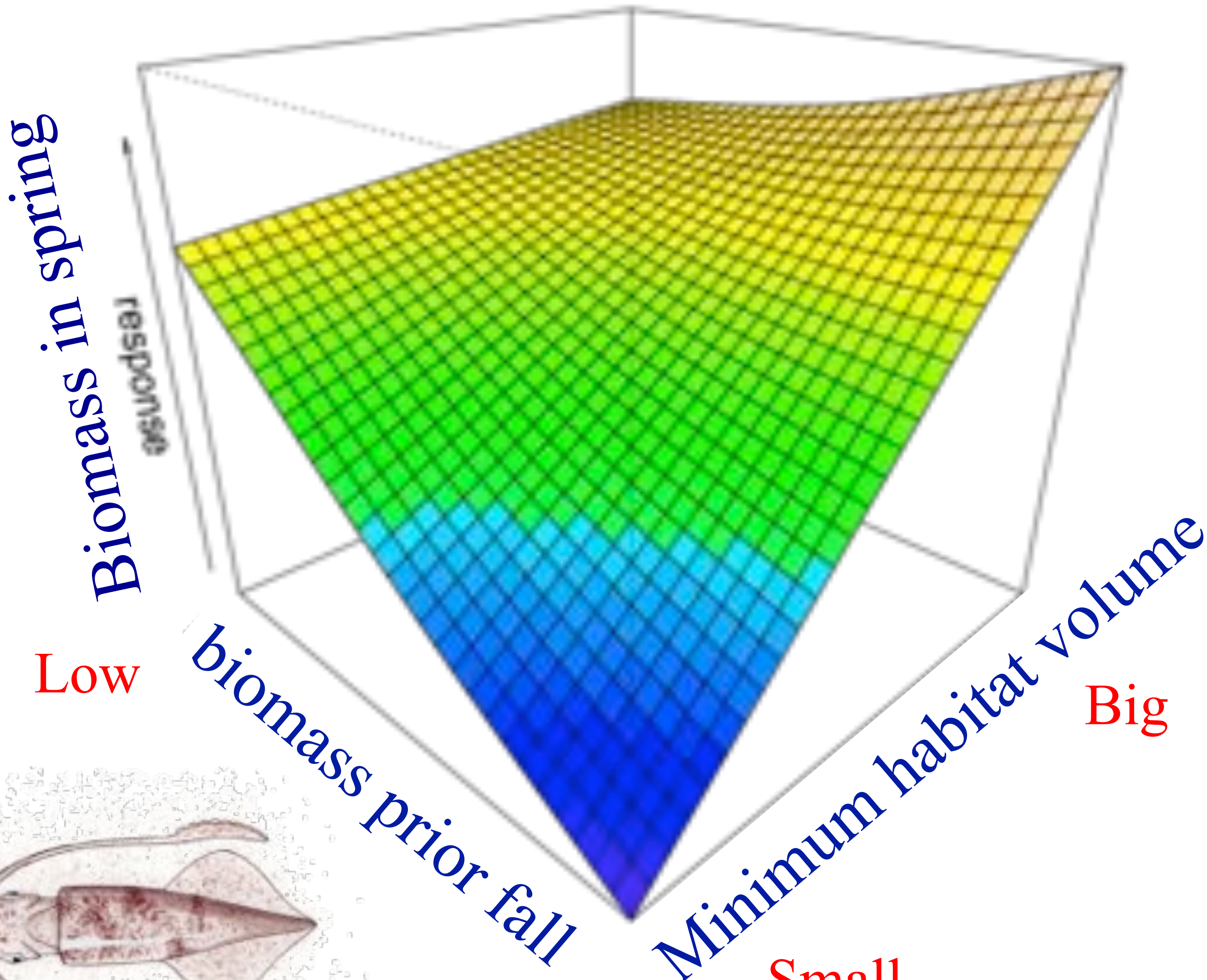


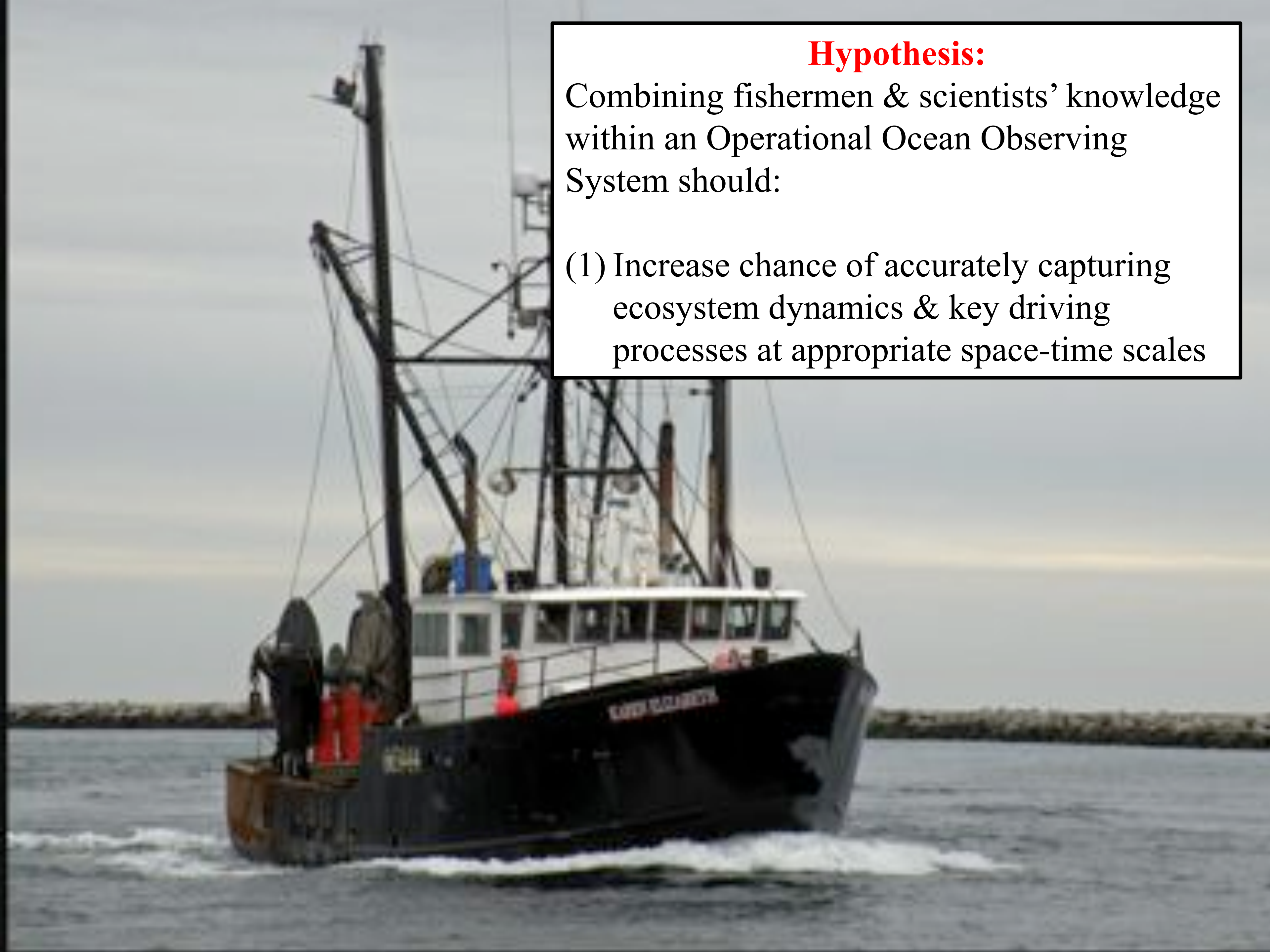
Hypothesis:

- Dynamic changes in habitat availability in the ocean can modulate mechanisms of density dependence

- Can partially decouple mechanisms of population regulation from population number (e.g. encounter rates with predators including fisherman?)

Empirical support for 'winter habitat squeeze" hypothesis
Longfin squid population biomass estimates





Hypothesis:

Combining fishermen & scientists' knowledge within an Operational Ocean Observing System should:

(1) Increase chance of accurately capturing ecosystem dynamics & key driving processes at appropriate space-time scales

Integrating habitat dynamics into population & ecosystem dynamics

- Does our habitat paradigm cross the land-sea boundary?
  - Seascapes are not landscapes
    - fluid properties & processes are paramount
    - seabed features important as predation refuges, surfaces for accumulation of organic matter etc. but within context of properties of the fluid

Integrating habitat dynamics into population & ecosystem dynamics

- Does our habitat paradigm cross the land-sea boundary?
  - Seascapes are not landscapes

- Regional Ocean Observing Systems IOOS are Hydrodynamic Information Systems
  - & Neutral ground facilitating interdisciplinary collaboration among government, academic, industry stakeholder experts in science informing regional ecosystem assessment & management

Integrating habitat dynamics into population & ecosystem dynamics

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- Regional Ocean Observing Systems IOOS are Hydrodynamic Information Systems
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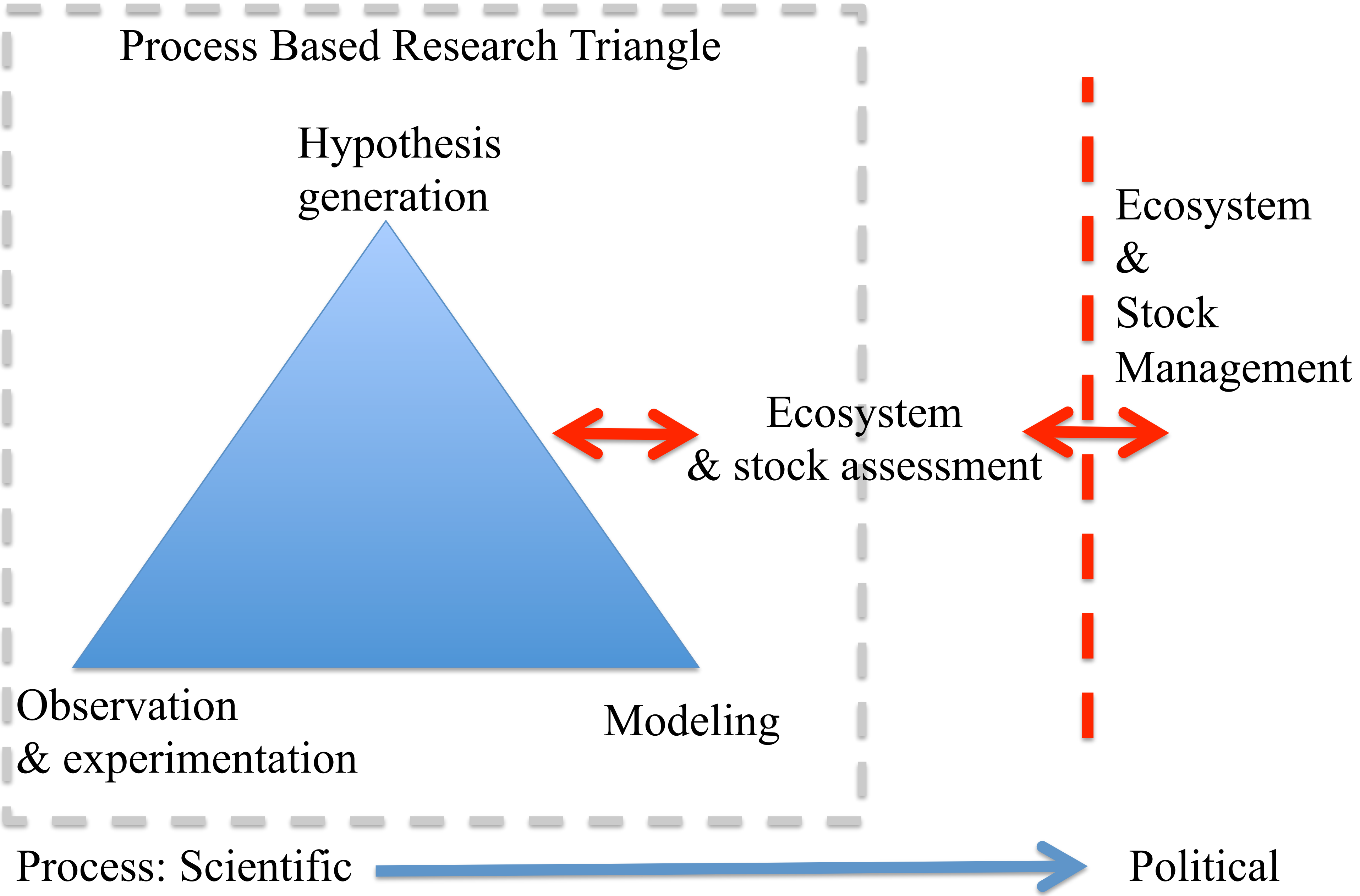
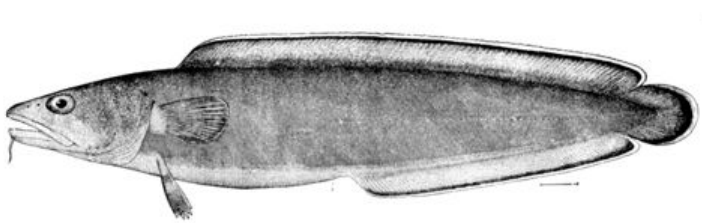
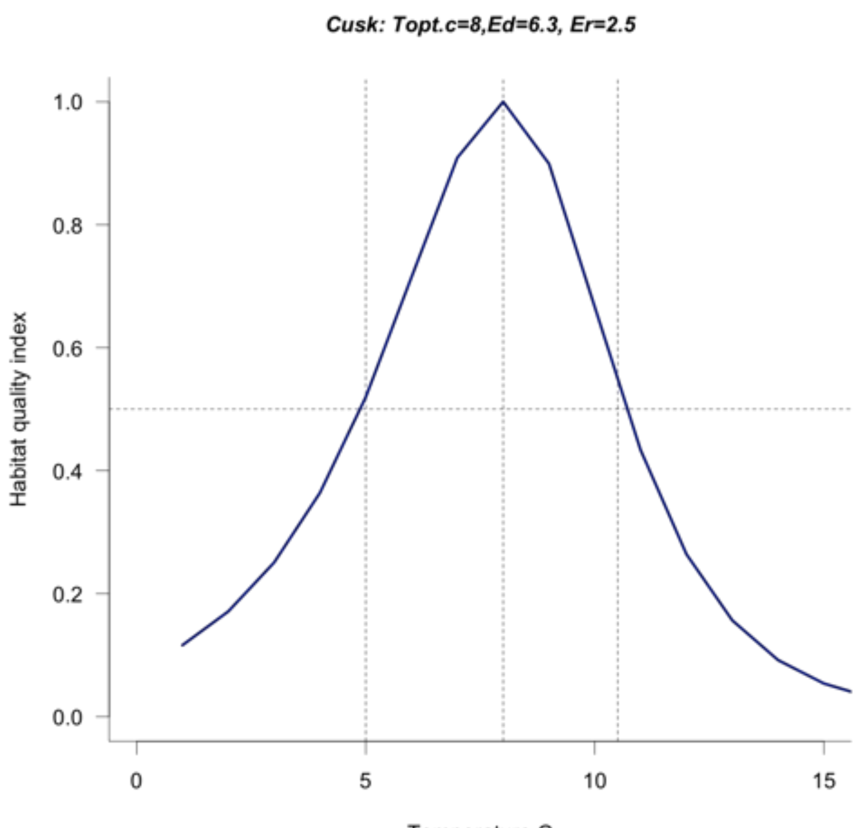
- Integrating habitat into population & ecosystem requires focusing on dynamic properties of habitat/seascape

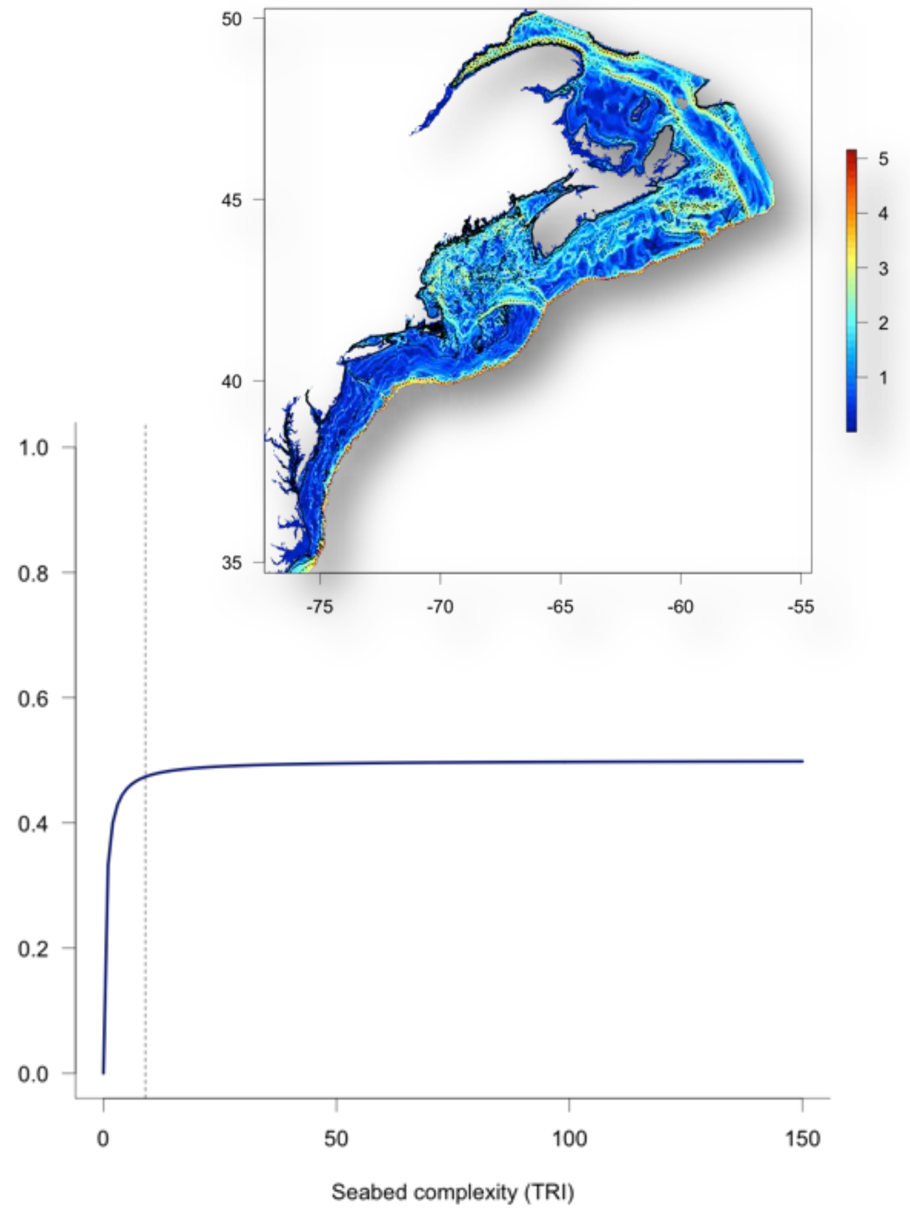
Where we are working



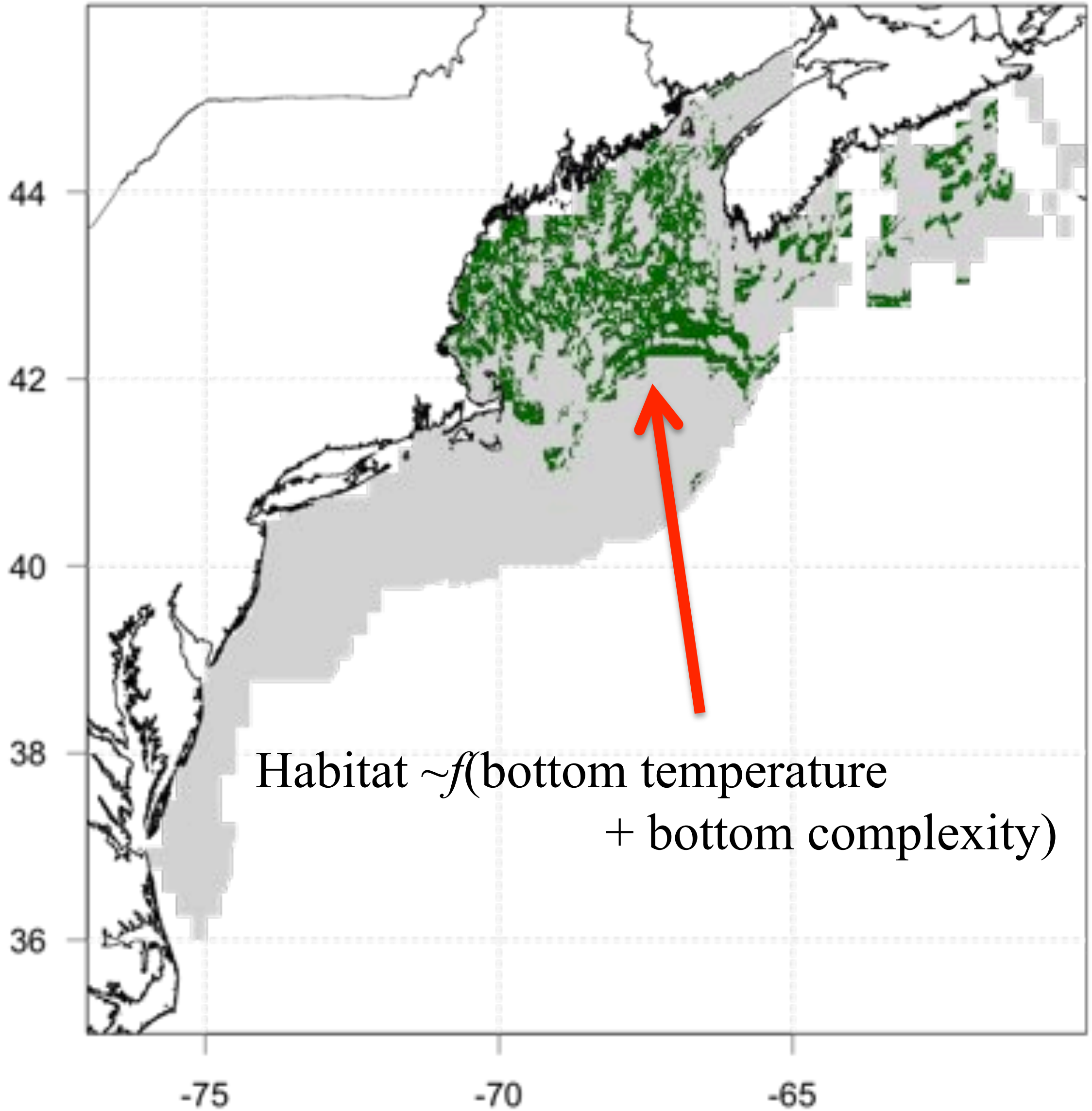
Lets get complicated:
Integrating water column features with seabed characteristics



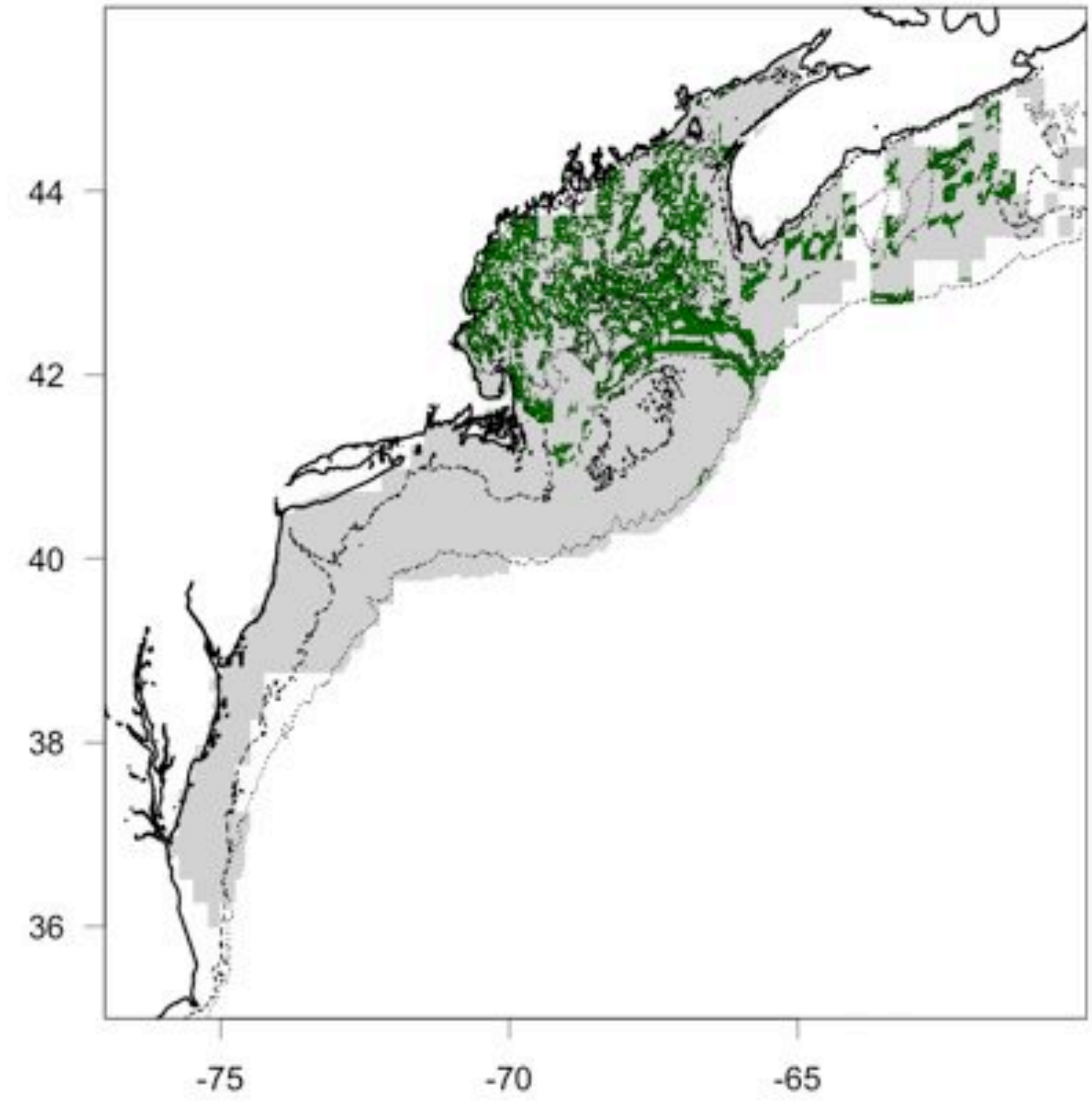


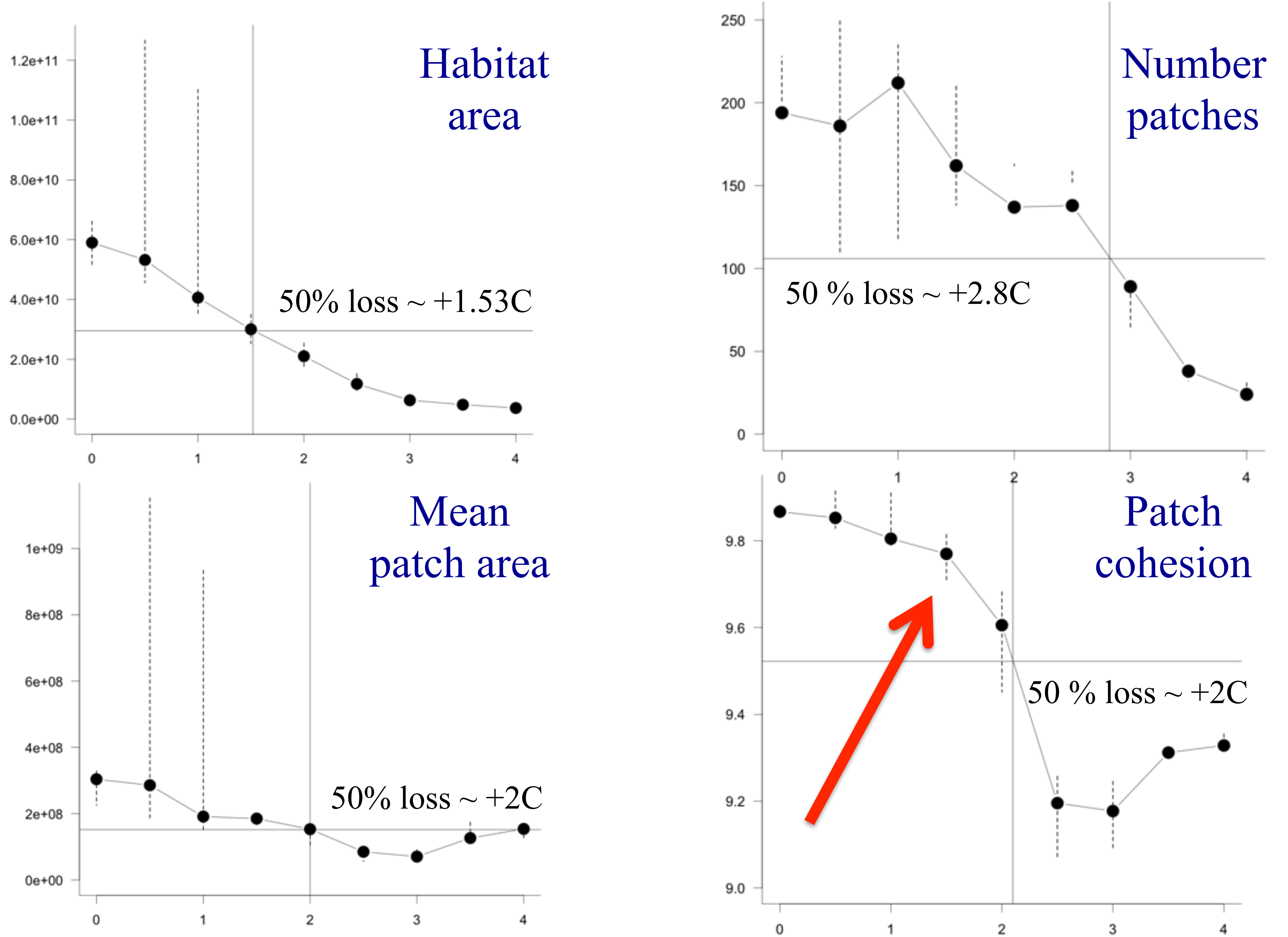


Add 0.1C increments to November/December bottom temperature c



Potential habitat NovDec

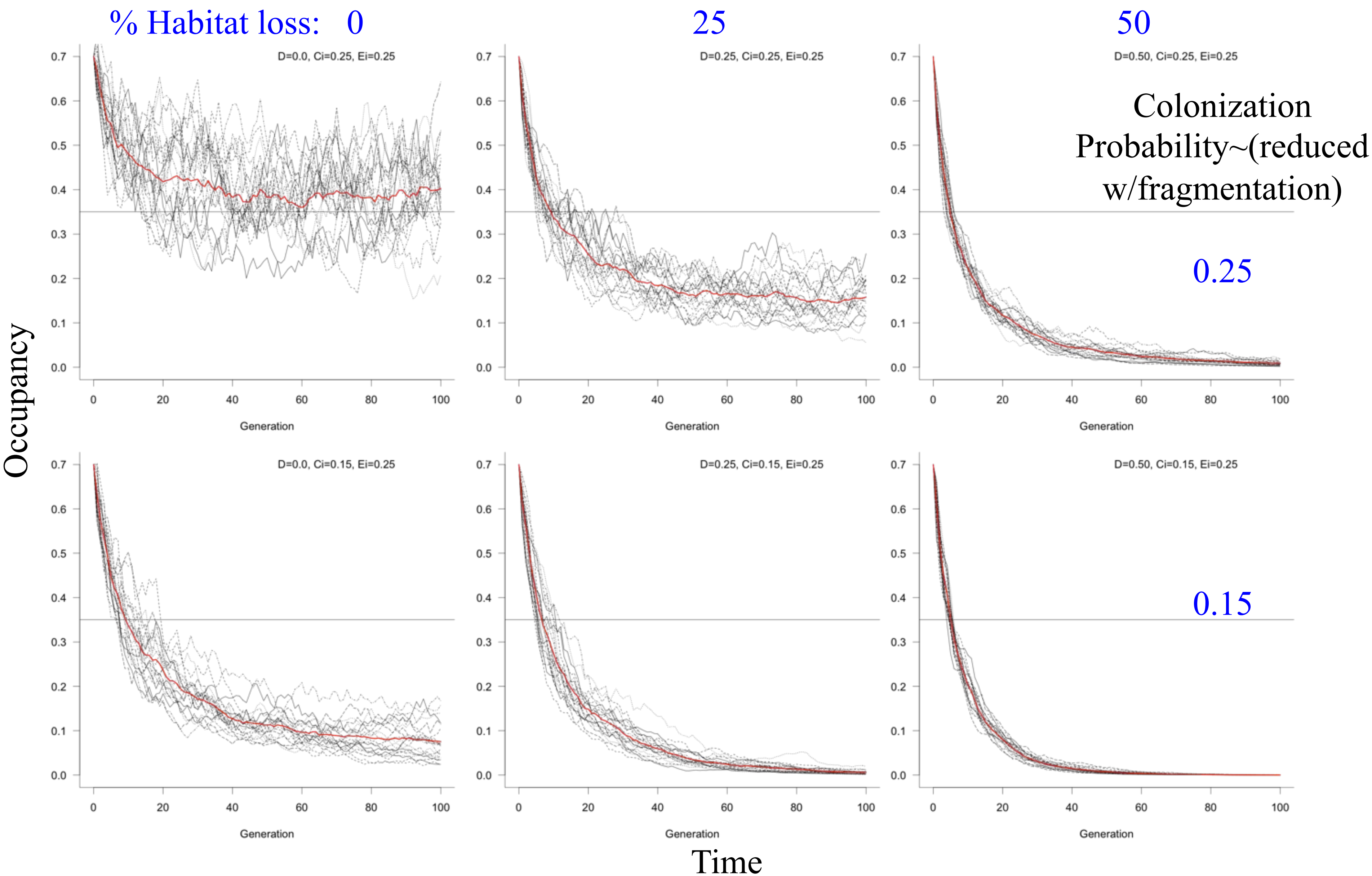




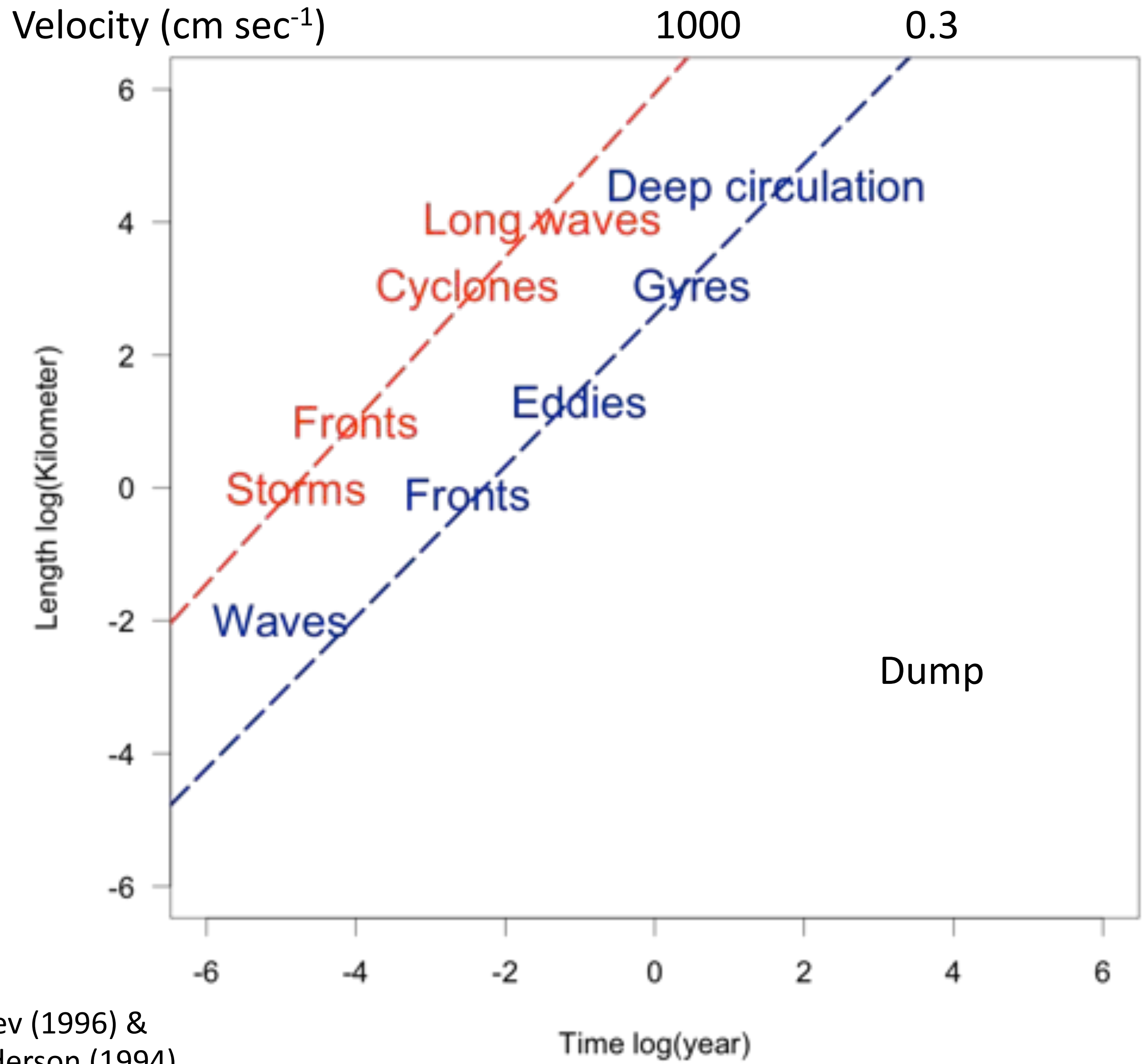
^{o}C above NovDec bottom temperature climatology

Stochastic metapopulations: with habitat loss & fragmentation

Lande model



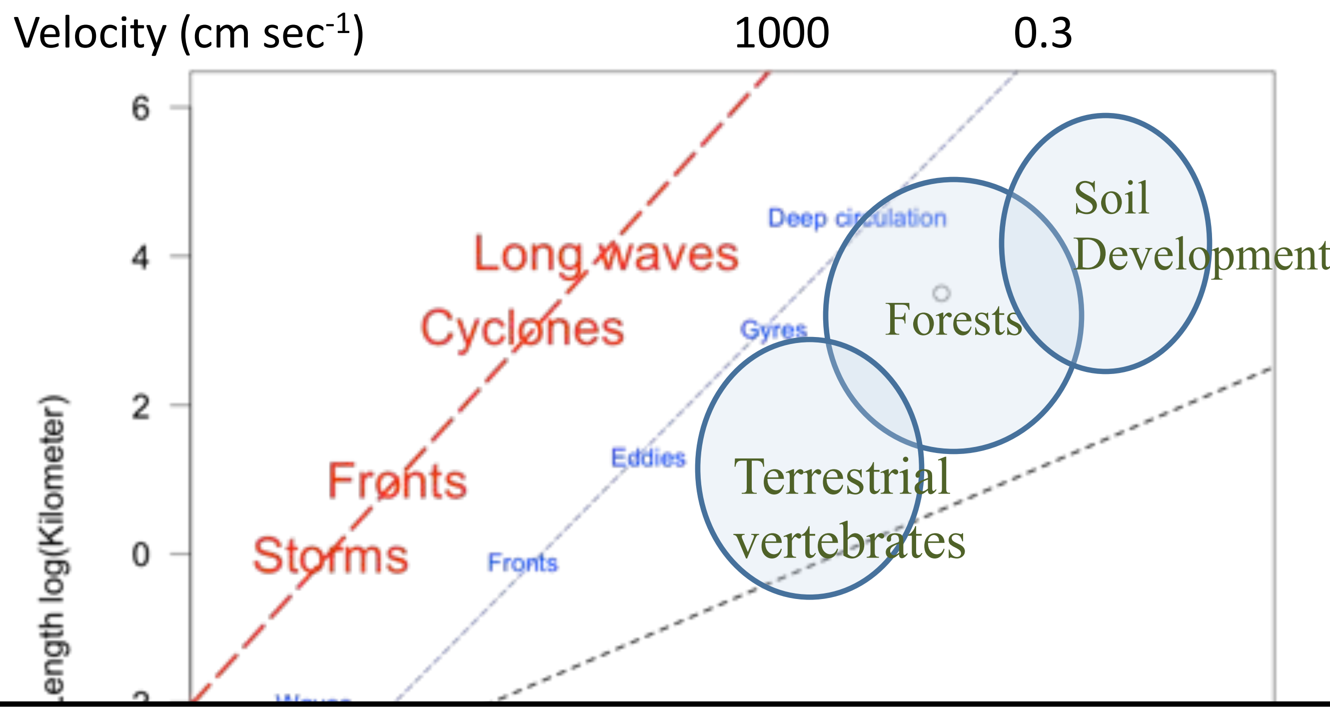
Velocities (length-time scales) of turbulence in the Atmosphere & Ocean



From Mamayev (1996) &
Steele & Henderson (1994)

Does the landscape paradigm to work in the Sea?

Length-time scales of atmosphere & ocean



Terrestrial organisms: partially decoupled from dynamics of atmosphere & many of its properties by gravity & adaptation to extreme environmental variability

Tightly coupled to biogeochemical processes

From Mamayev (1996) &
Steele & Henderson (1994)

Does the landscape paradigm to work in the Sea?
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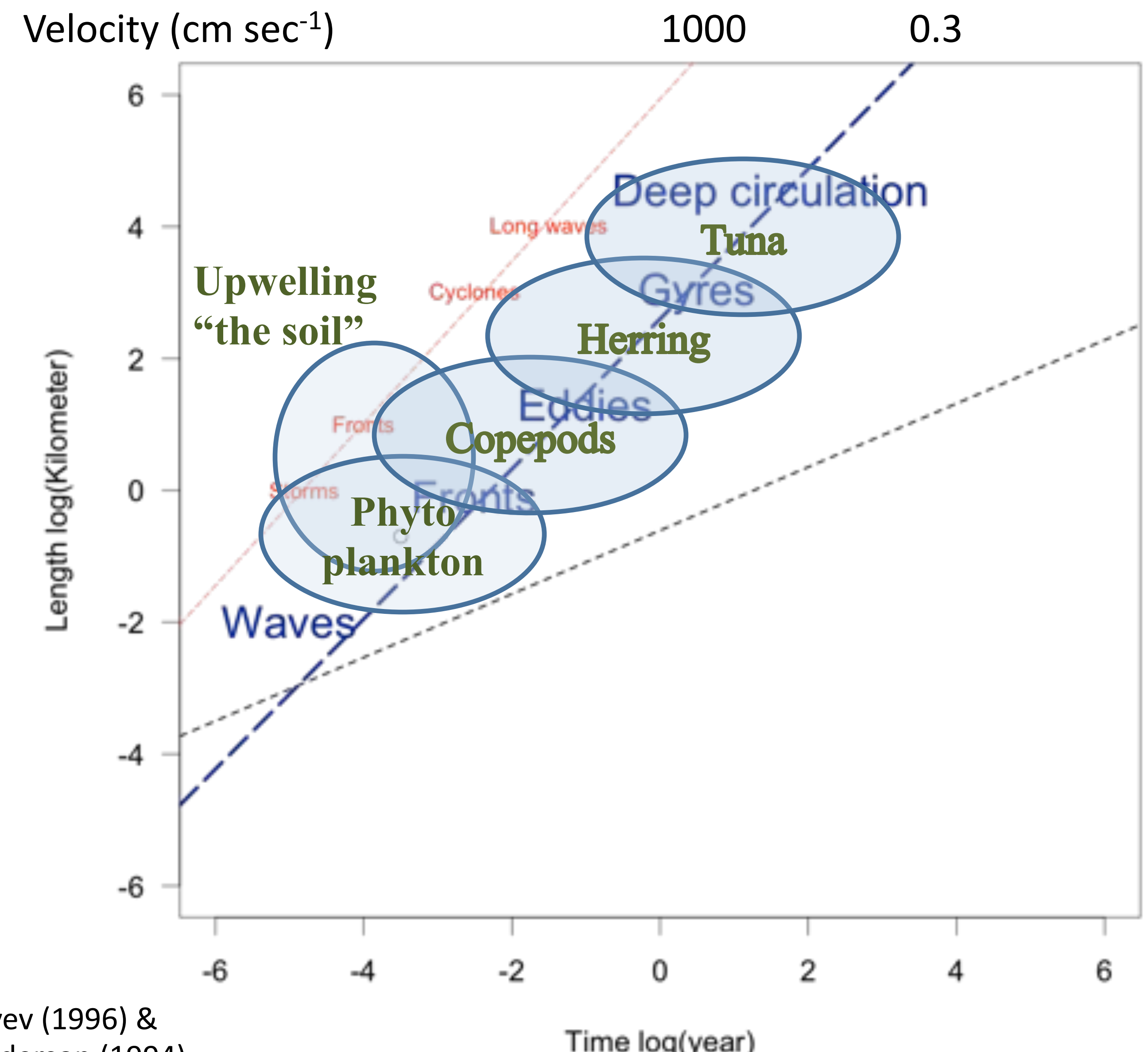

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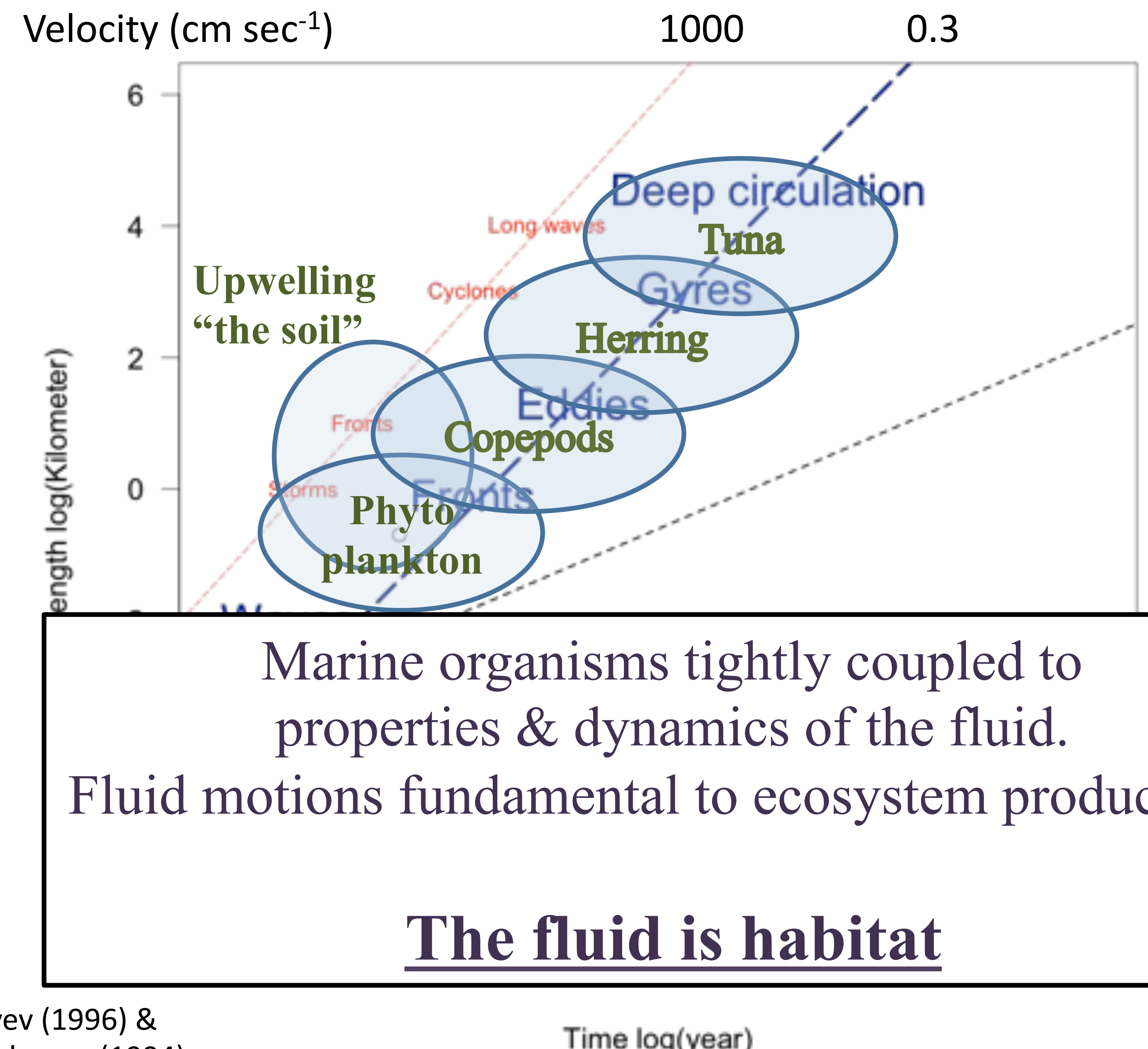

Marine organisms tightly coupled to properties & dynamics of the fluid.
Fluid motions fundamental to ecosystem productivity

The fluid is habitat

From Mamayev (1996) &
Steele & Henderson (1994)