Combing survey and satellite data with circulation models for weekly predictions of right whale habitat suitability

Dan Pendleton

Acknowledgements

Co-authors: Andy Pershing, Nick Record, Patrick Sullivan, Bruce Monger, Steven Philips, Chris Clark, Stormy Mayo, Robert Kenney, Caroline Good, Tim Cole, Moe Brown

Funding: NASA, NOAA, NSF

New England Aquarium

Cornell University

THE UNIVERSITY OF MAINE

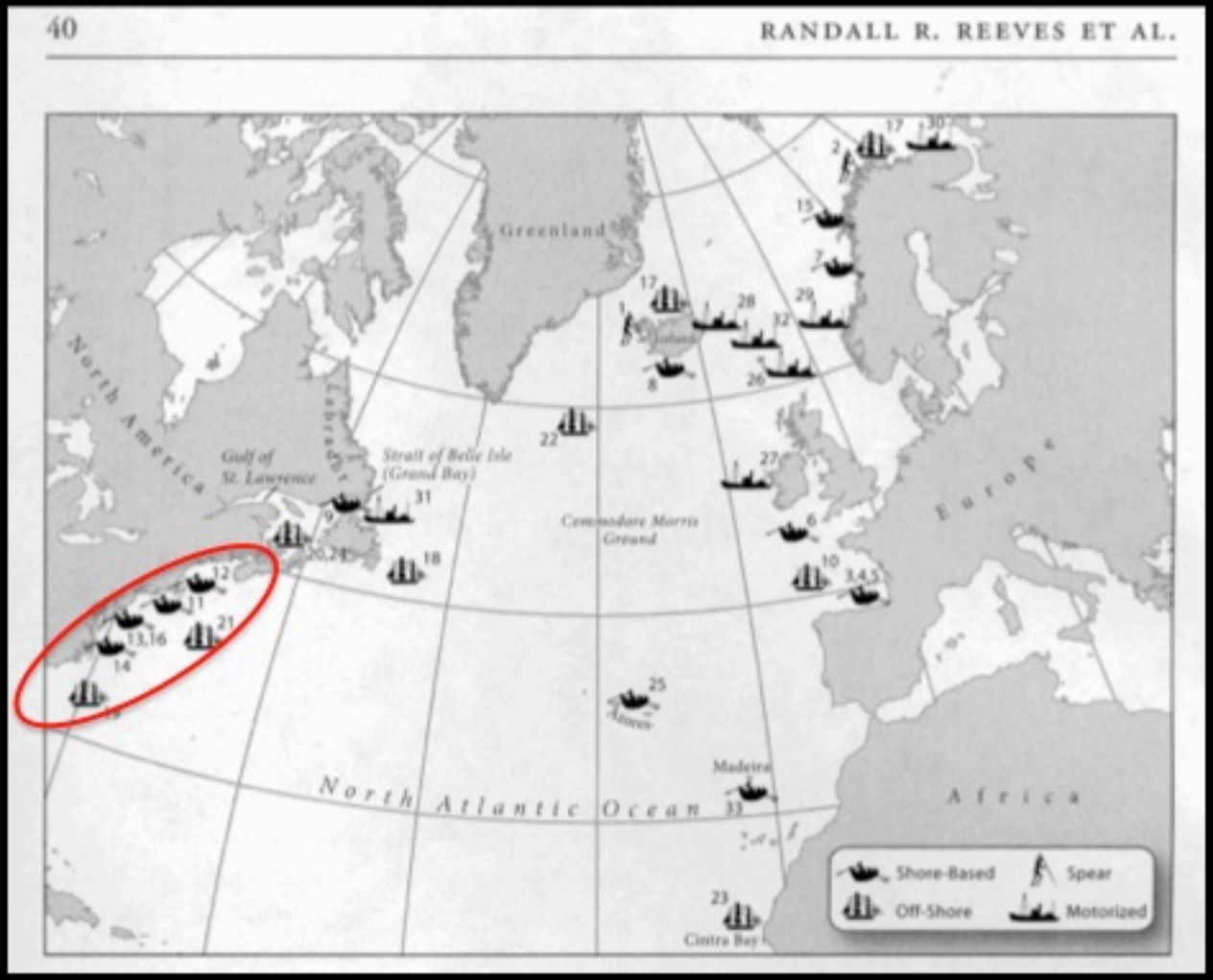
Gulf of Maine Research Institute
Science. Education. Community.

NOAA

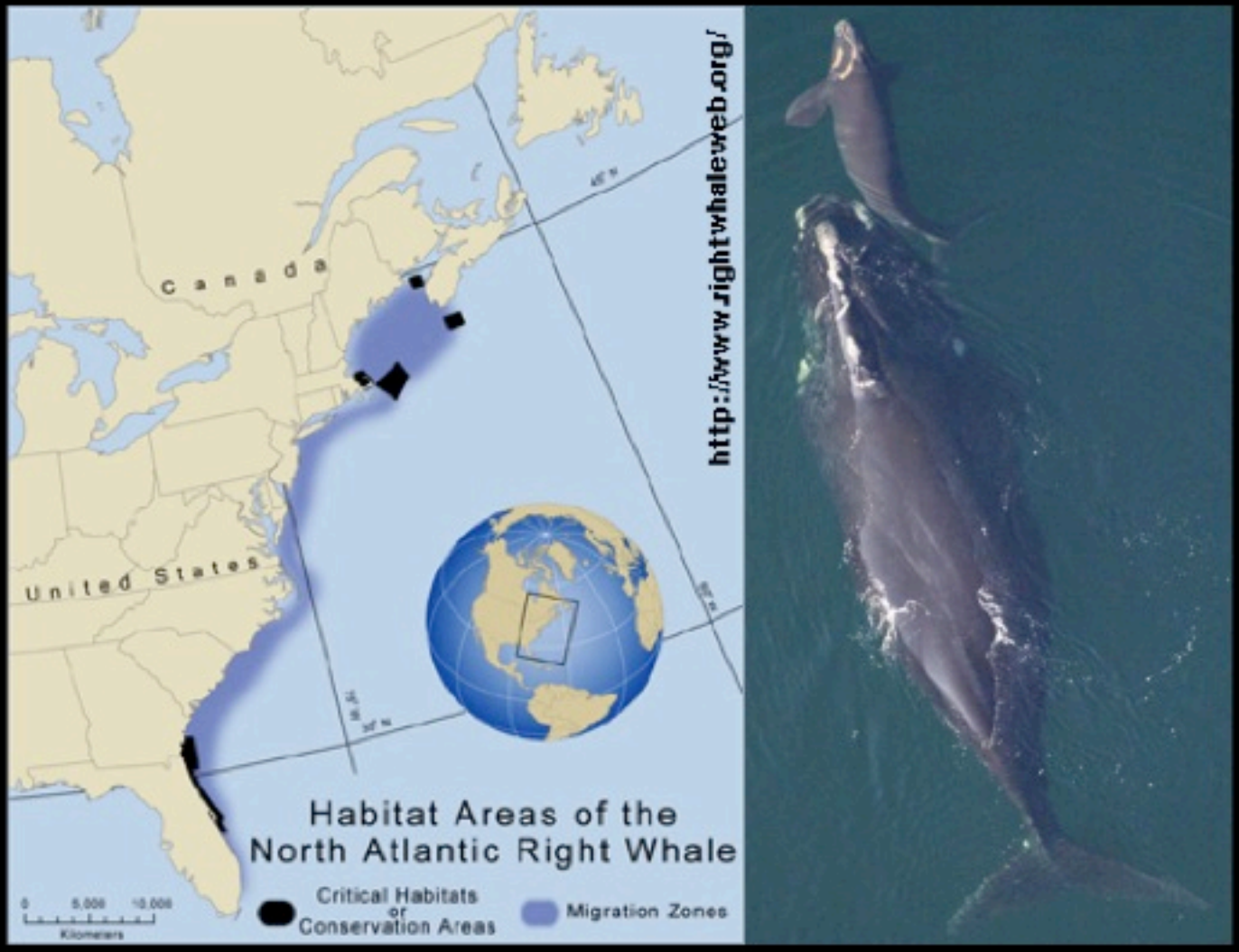
Outline

- North Atlantic right whale background
- Generation 1 copepod model (*Calanus*)
- Weekly habitat modeling in CCB & GSC
- Generation 2 copepod model (*Calanus* & *Pseudocalanus*)
- Weekly habitat modeling in CCB & MB

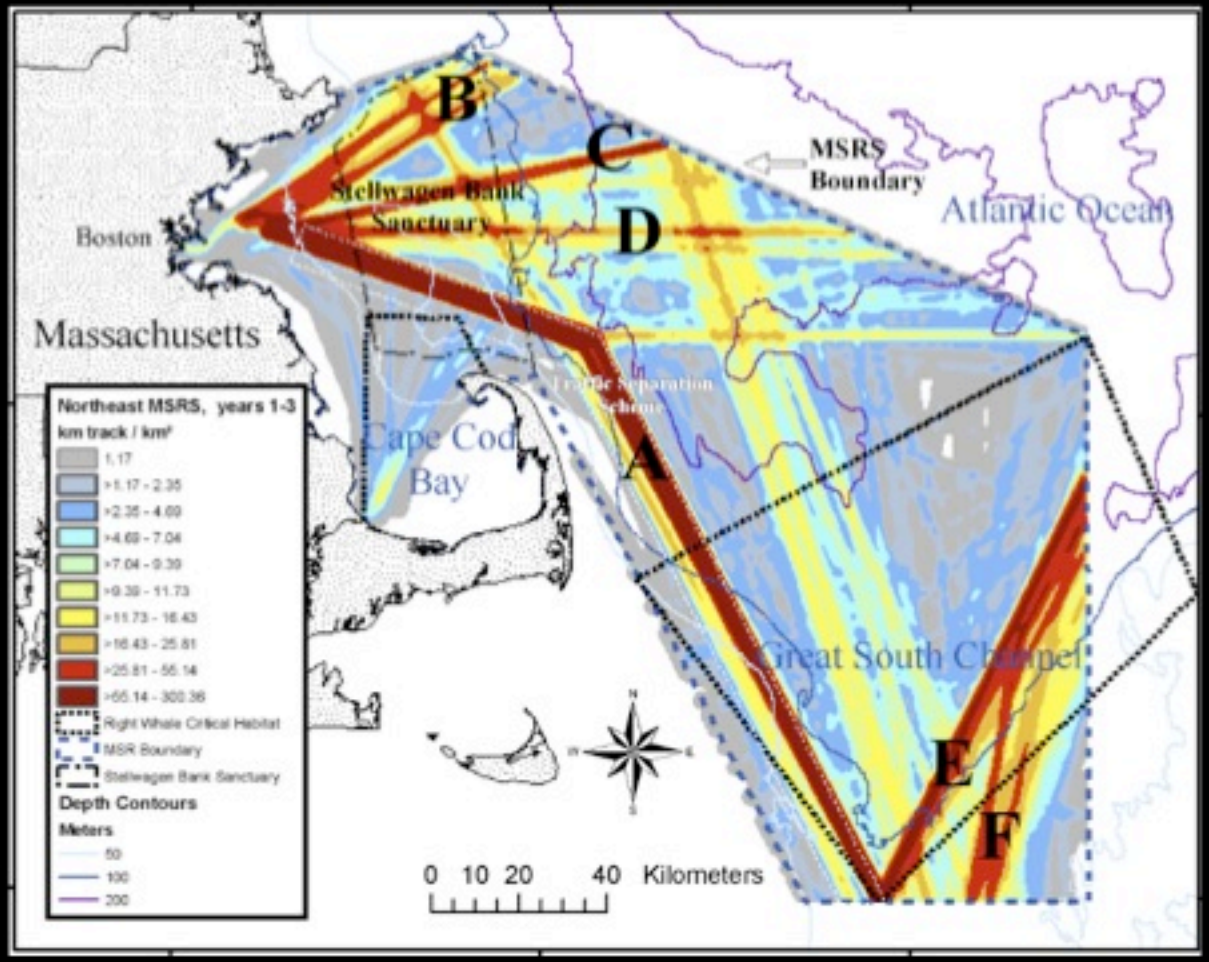
Historic distribution of North Atlantic right whale fisheries



Current distribution of NA right whales



Ship traffic: 1999-2002



Ward-Geiger et al. 2005, Coastal Management

Intense survey effort to reduce mortality

Regional scale data is useful

Vol. 378: 211–225, 2009
doi: 10.3354/meps07832

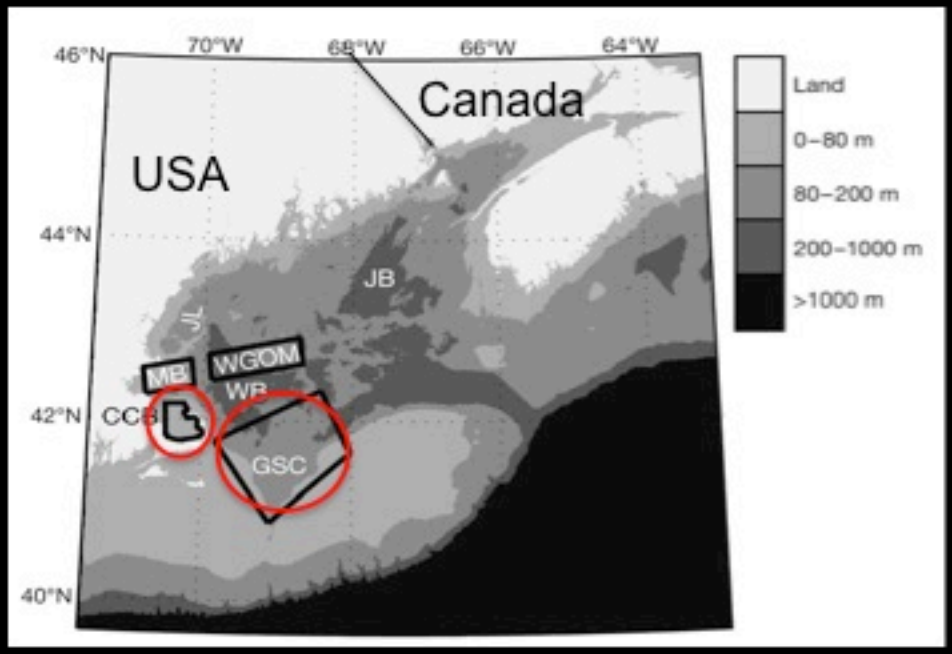
MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

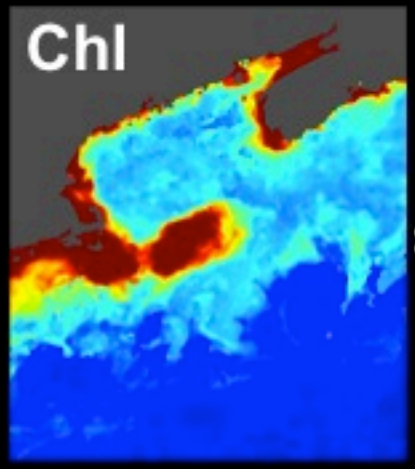
Published March 12

OPEN ACCESS

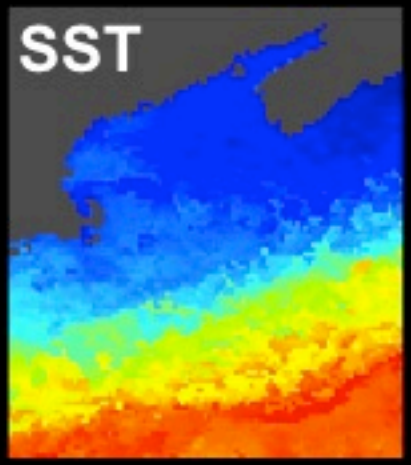
Regional-scale mean copepod concentration indicates relative abundance of North Atlantic right whales

Daniel E. Pendleton[1,2,3,*], Andrew J. Pershing[2,3], Moira W. Brown[4,7], Charles A. Mayo[4], Robert D. Kenney[5], Nicholas R. Record[2,3], Timothy V. N. Cole[6]

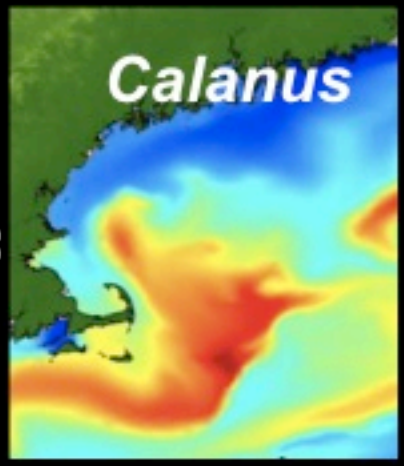


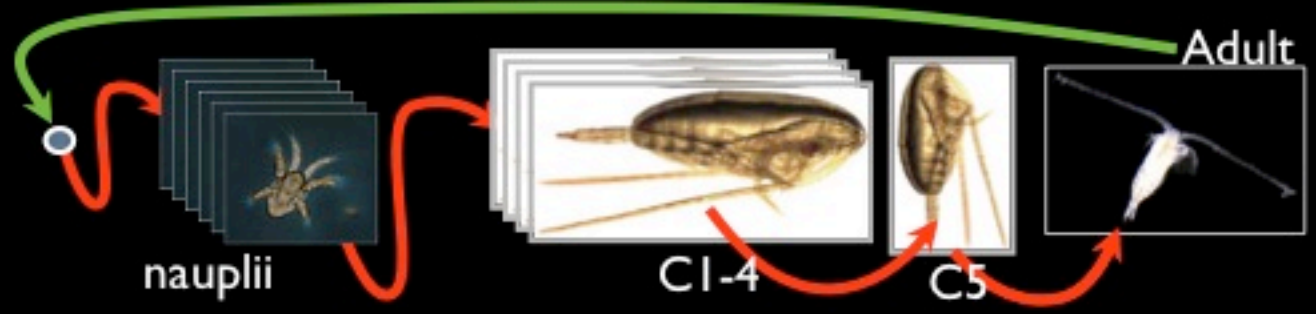

Chl

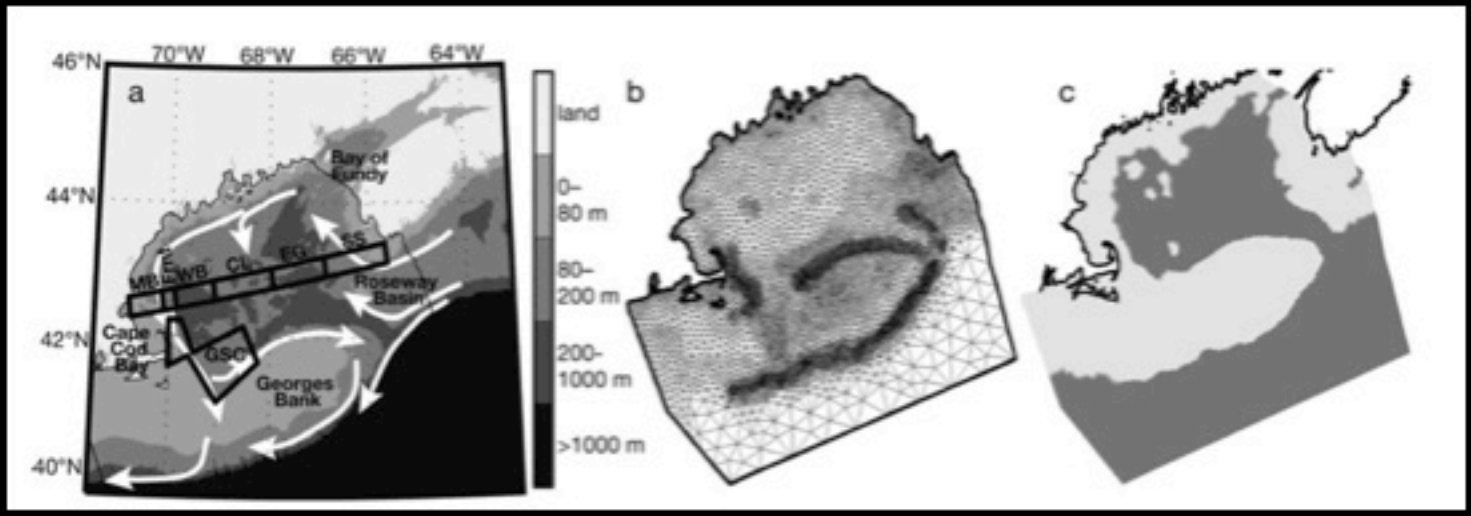
*


SST

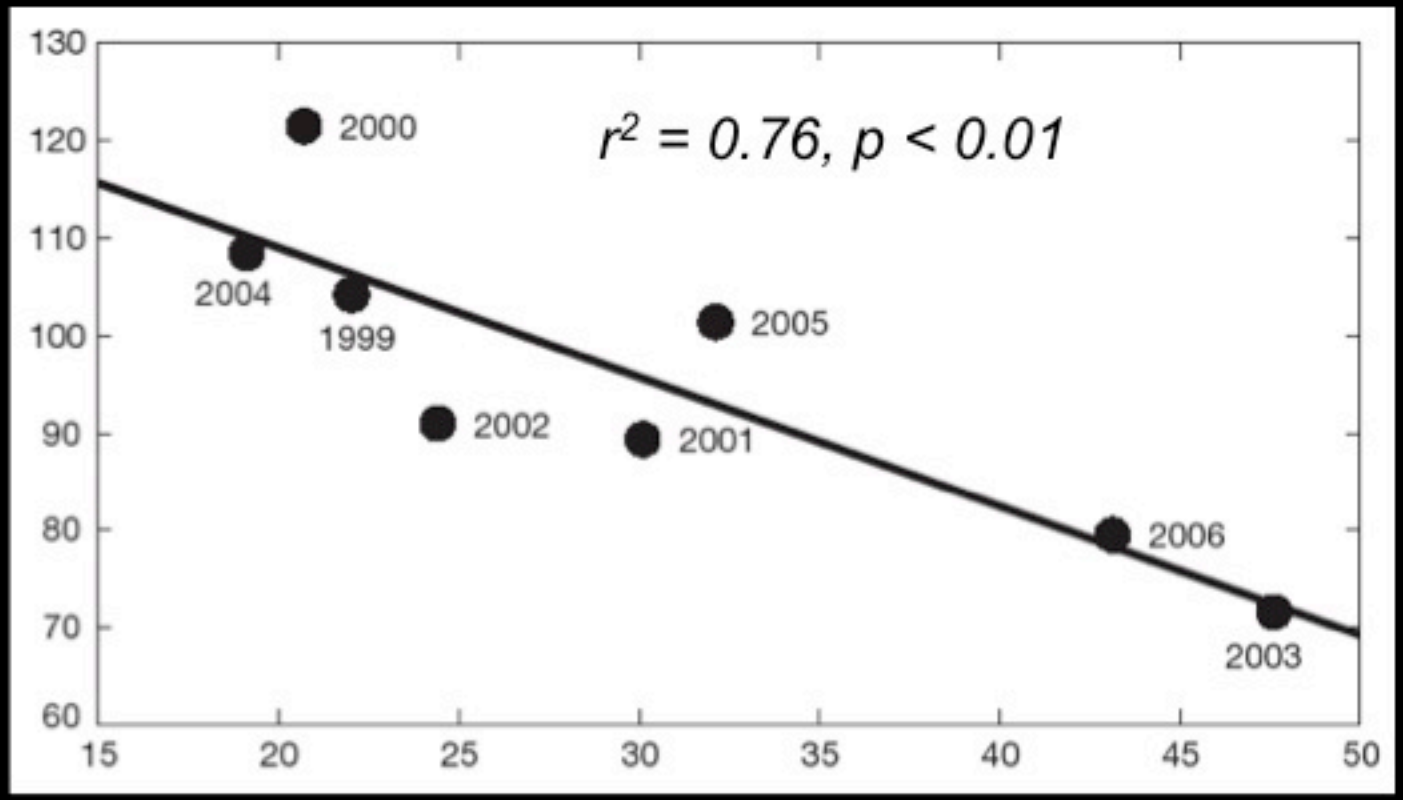
=


Calanus


Adult
nauplii
C1-4
C5


46°N
70°W
68°W
66°W
64°W
a
44°N
42°N
40°N
Bay of Fundy
MB
EWB
CL
EG
ES
Roseway Basin
Cape Cod Bay
GSC
Georges Bank
land
0–80 m
80–200 m
200–1000 m
>1000 m
b
c

Modeled *Calanus* predicts right whale arrival date

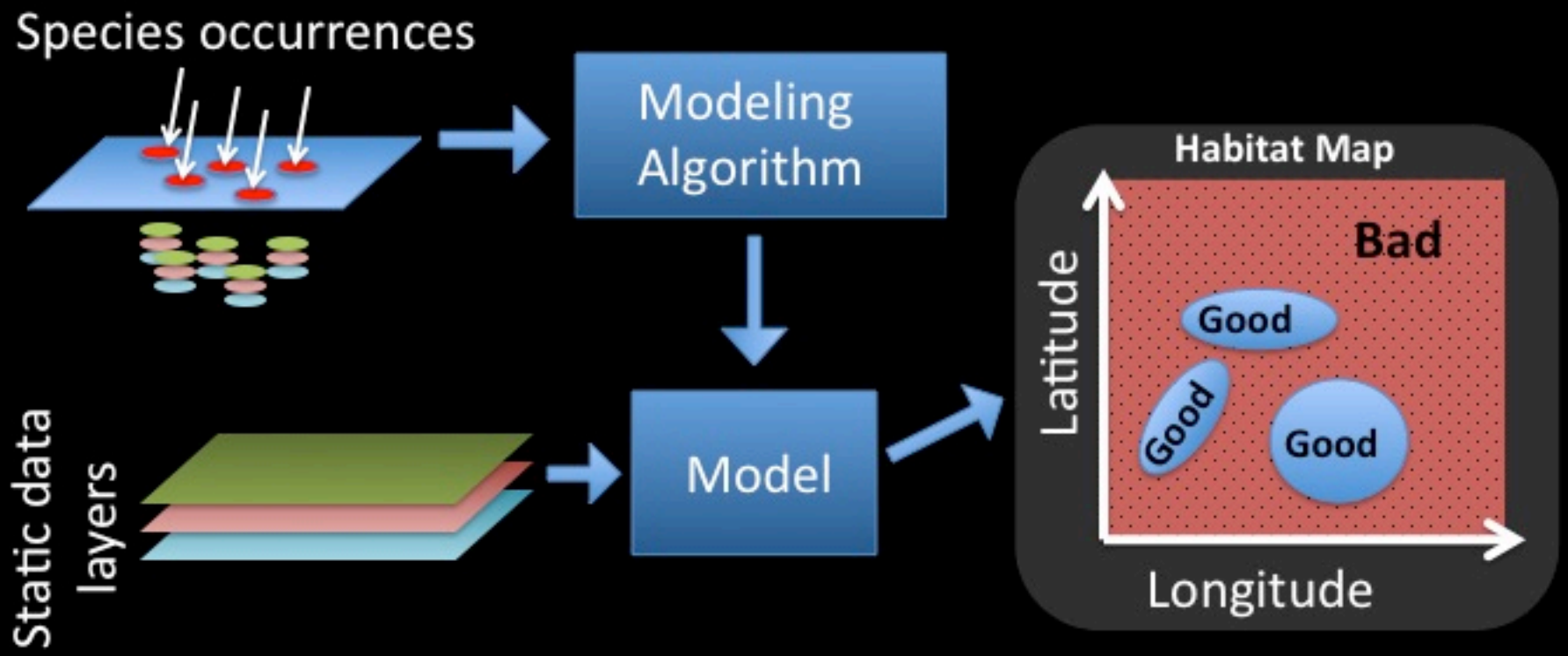


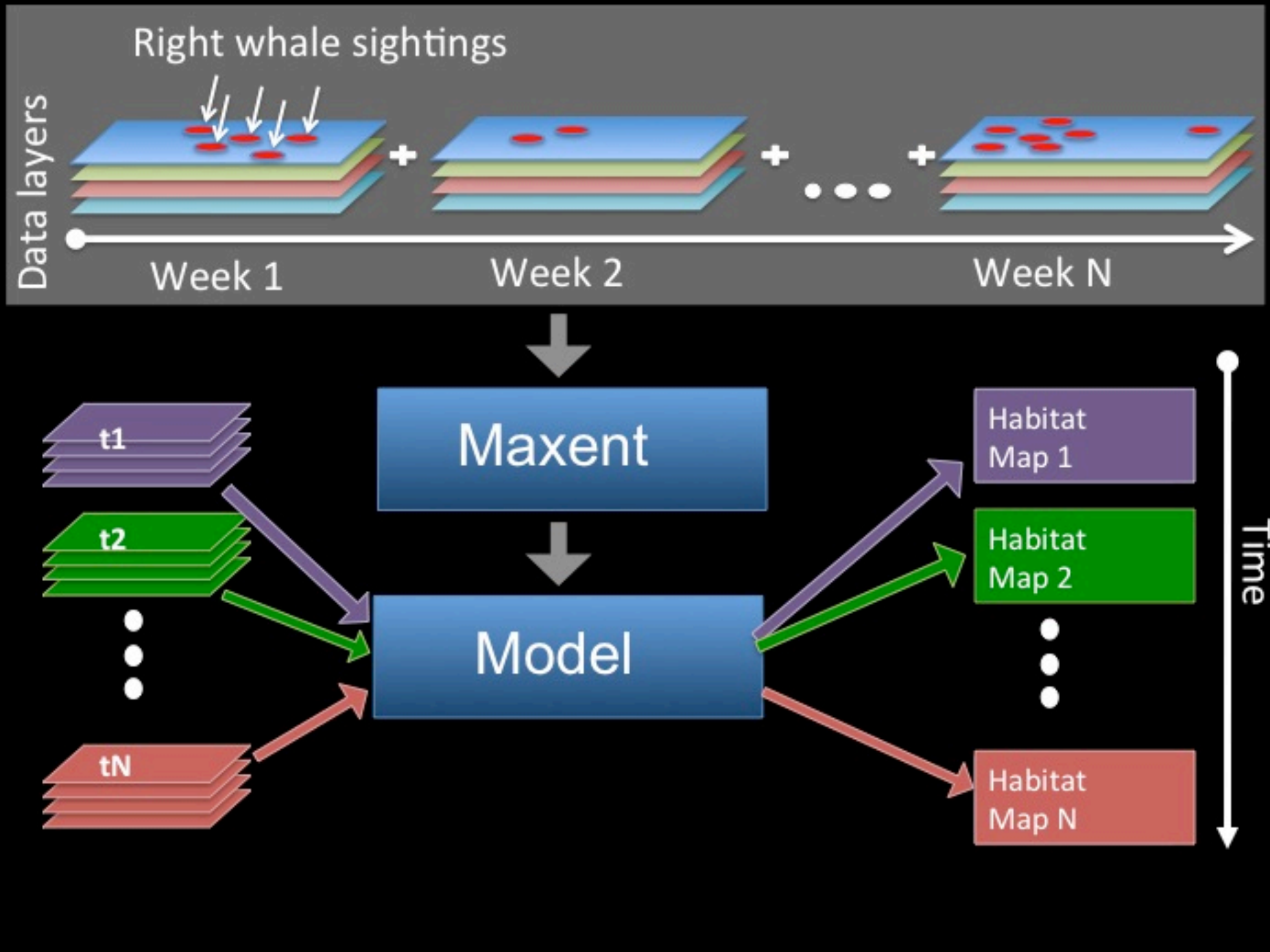
Pershing et al. 2009 MEPS
Also, Pendleton et al. 2009 MEPS

Can ENMs aid short term right whale conservation efforts?

- Issue warnings to vessel operators and members of the fishing community
- Identify areas likely to host aggregations of right whales in the next week
- Direct survey effort
- Find new habitat

Standard (time invariant) ENM



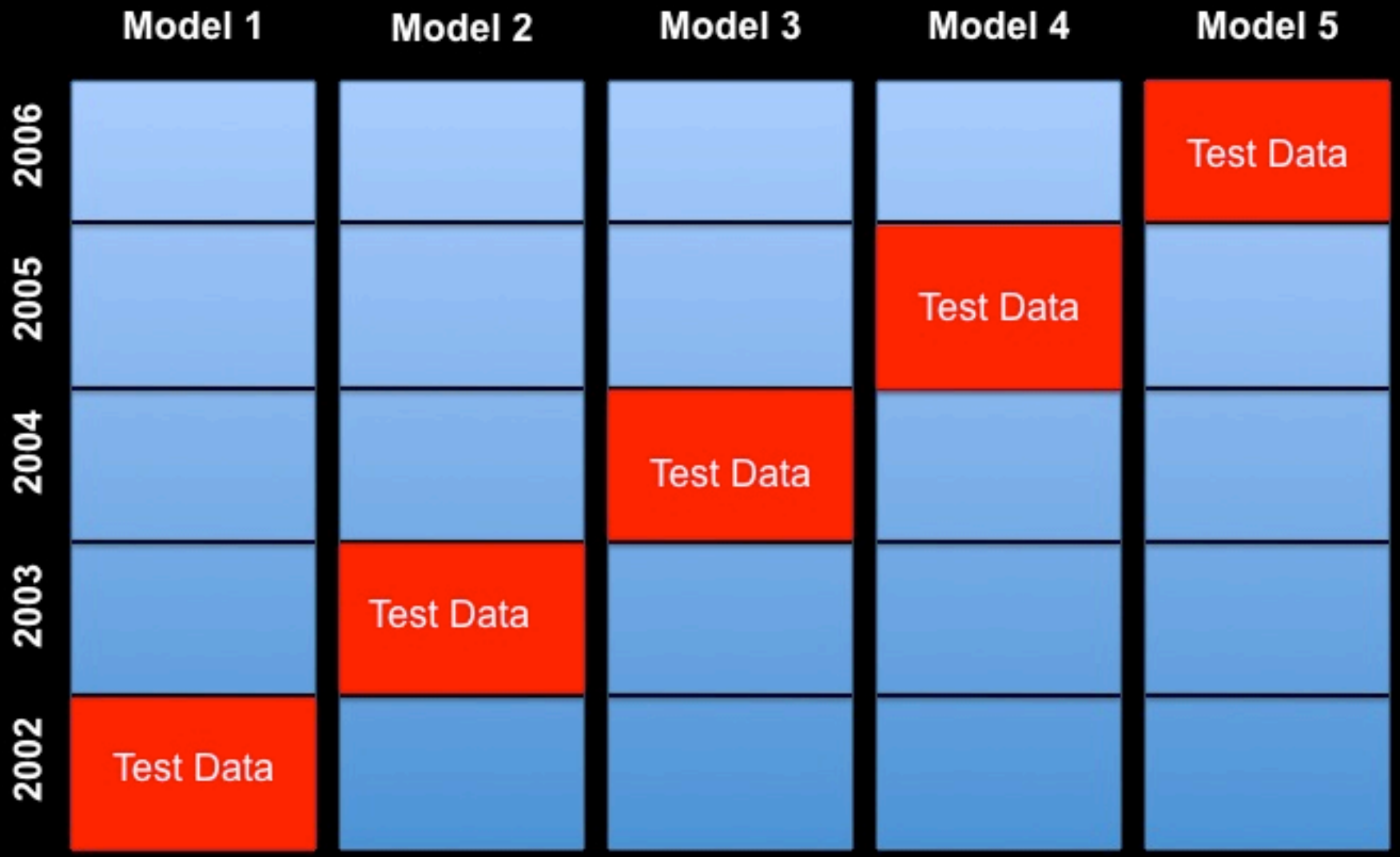

Right whale sightings
Data layers
Week 1
Week 2
Week N
Maxent
Model
t1
t2
tN
Habitat Map 1
Habitat Map 2
Habitat Map N
Time

Hypotheses

- *H1*: Prey is an important predictor of the distribution of right whales

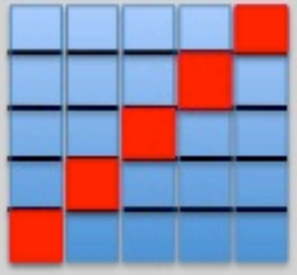
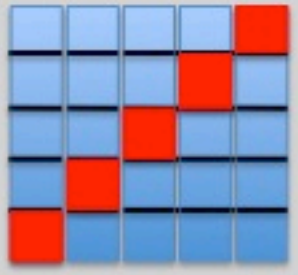
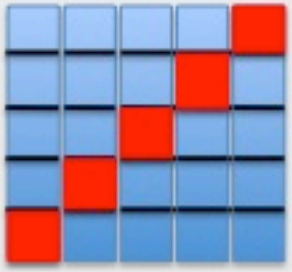
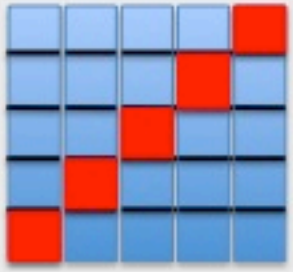
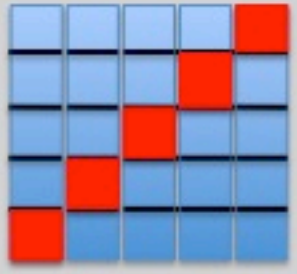
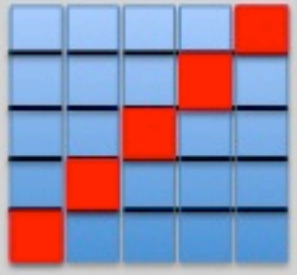
- *H2*: Right whale environmental preferences are dynamic

Cross validation



Experimental Design

H1

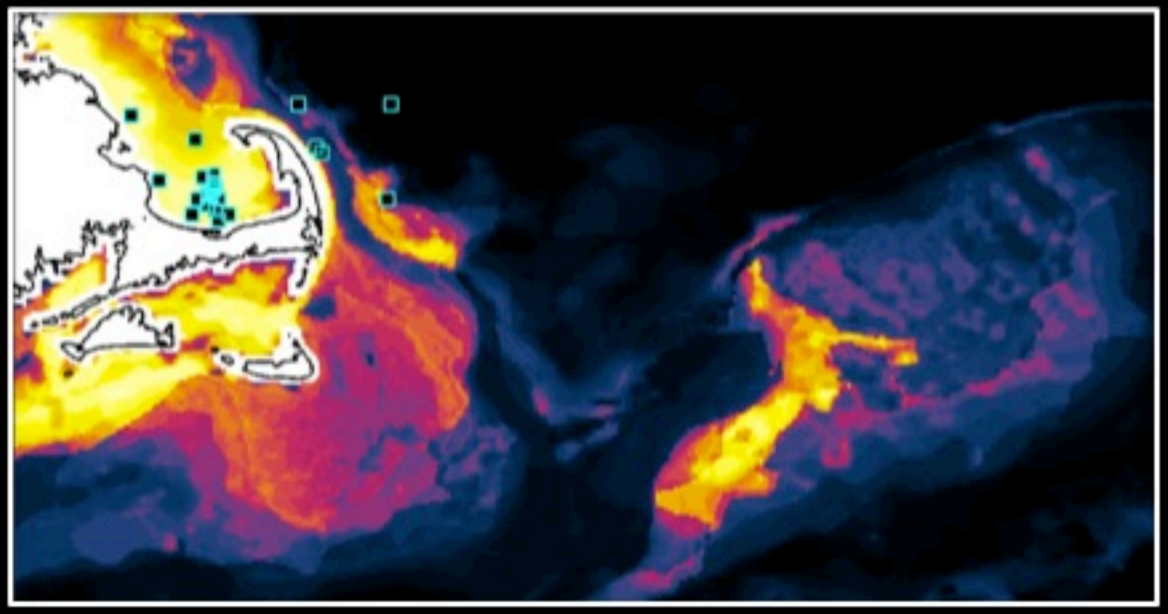
	With *Calanus*	Without *Calanus*
Winter+Spring		
Winter		
Spring		

H2

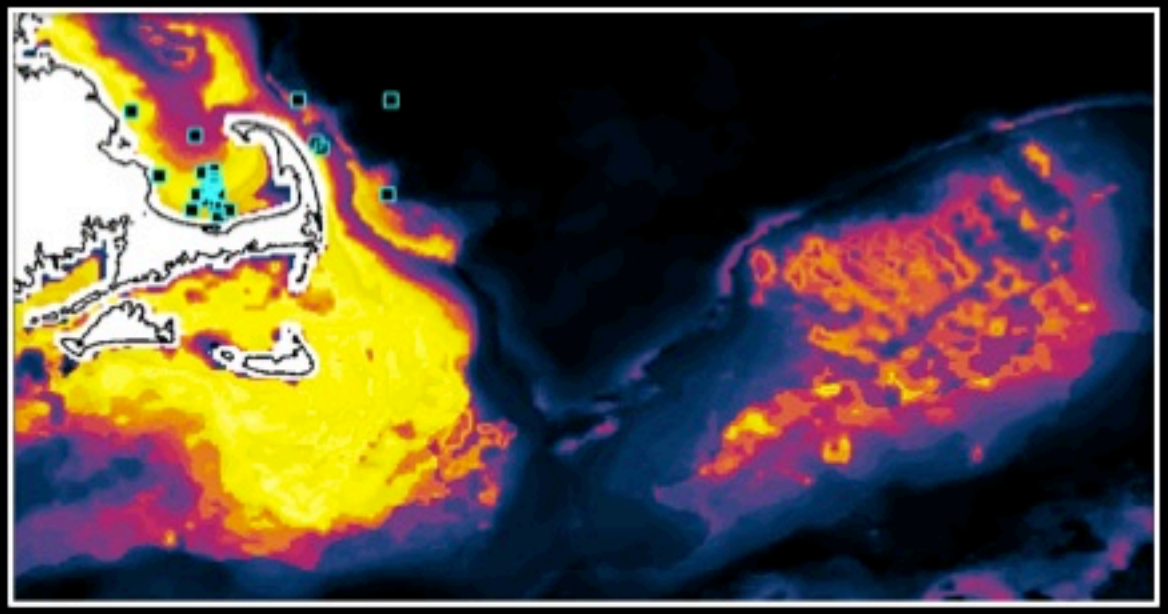
Test year = 2005

March 22 – March 29

with *Calanus*



without *Calanus*



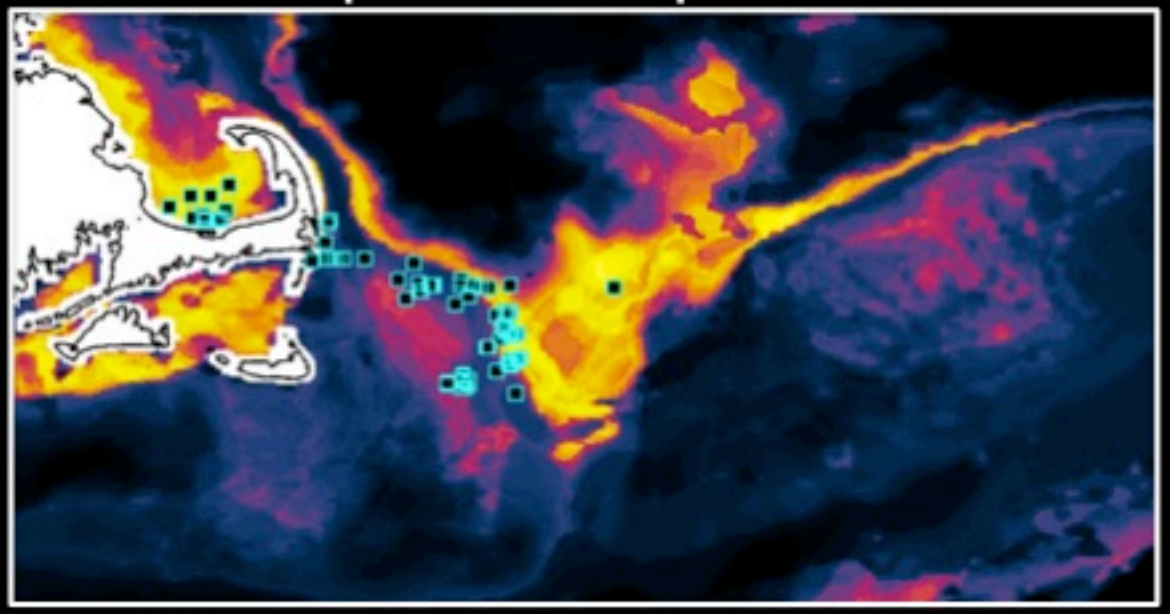
1 = high suitability

0 = low suitability

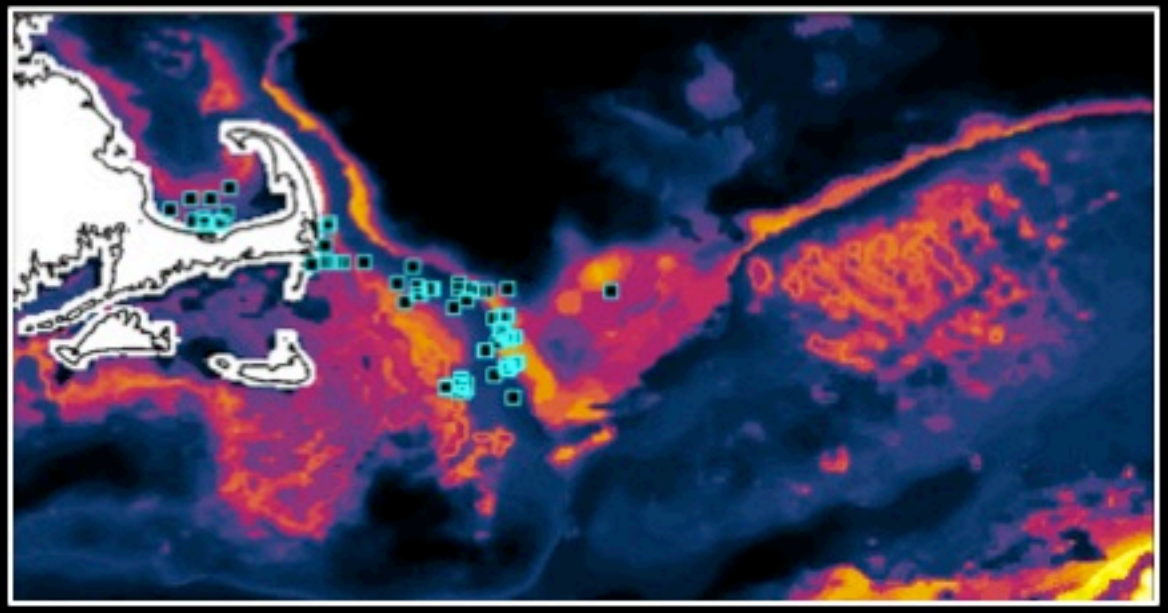
Test year = 2005

April 15 – April 22

with *Calanus*



without *Calanus*



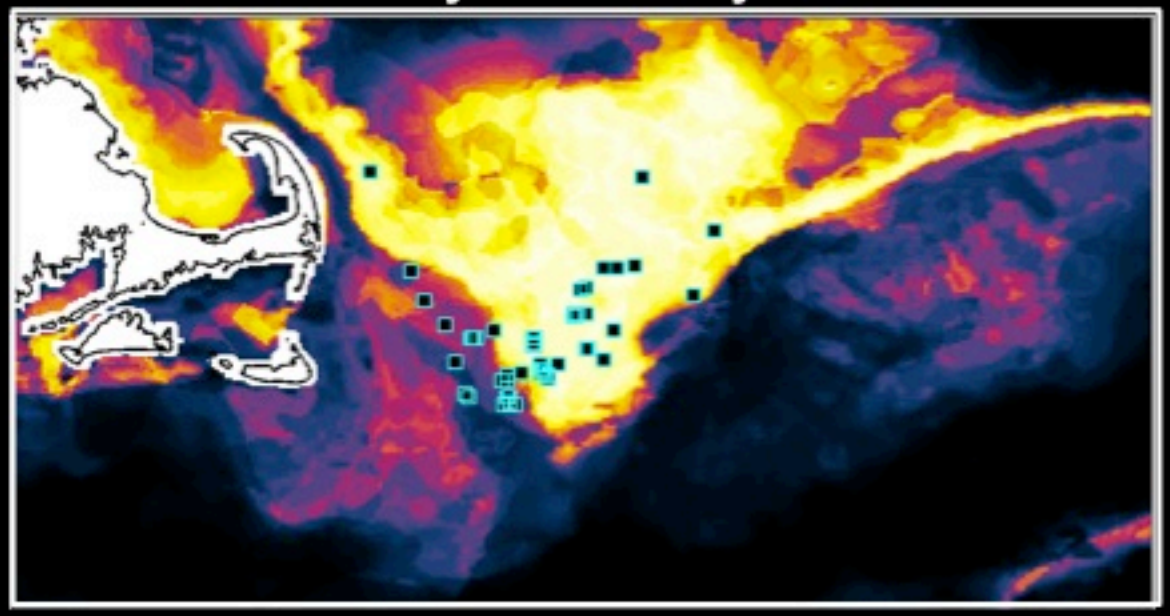
1 = high suitability

0 = high suitability

Test year = 2005

May 1 – May 8

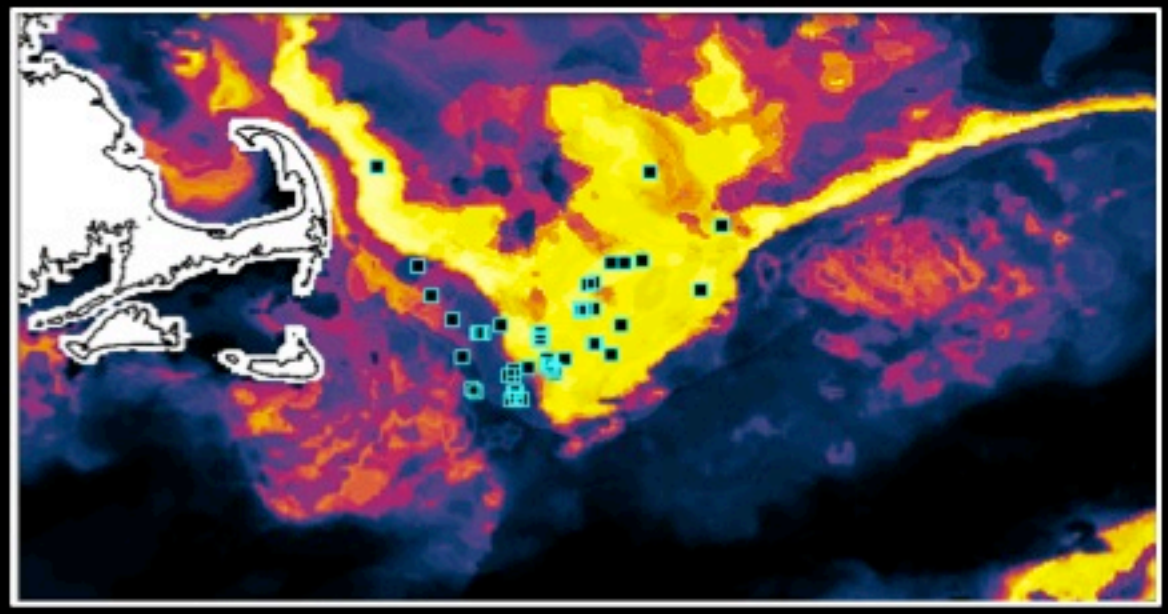
with *Calanus*



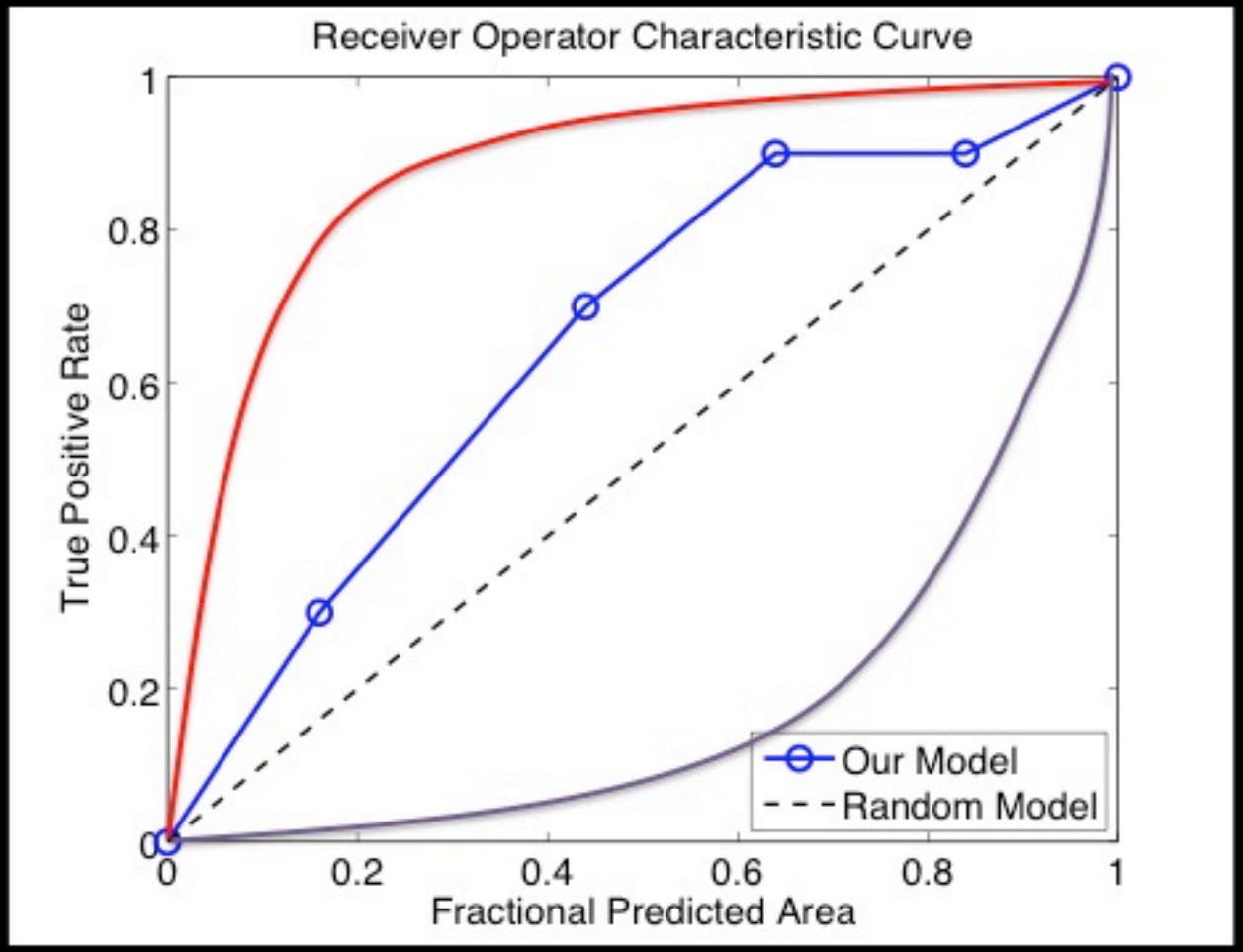
1 = high suitability

0 = high suitability

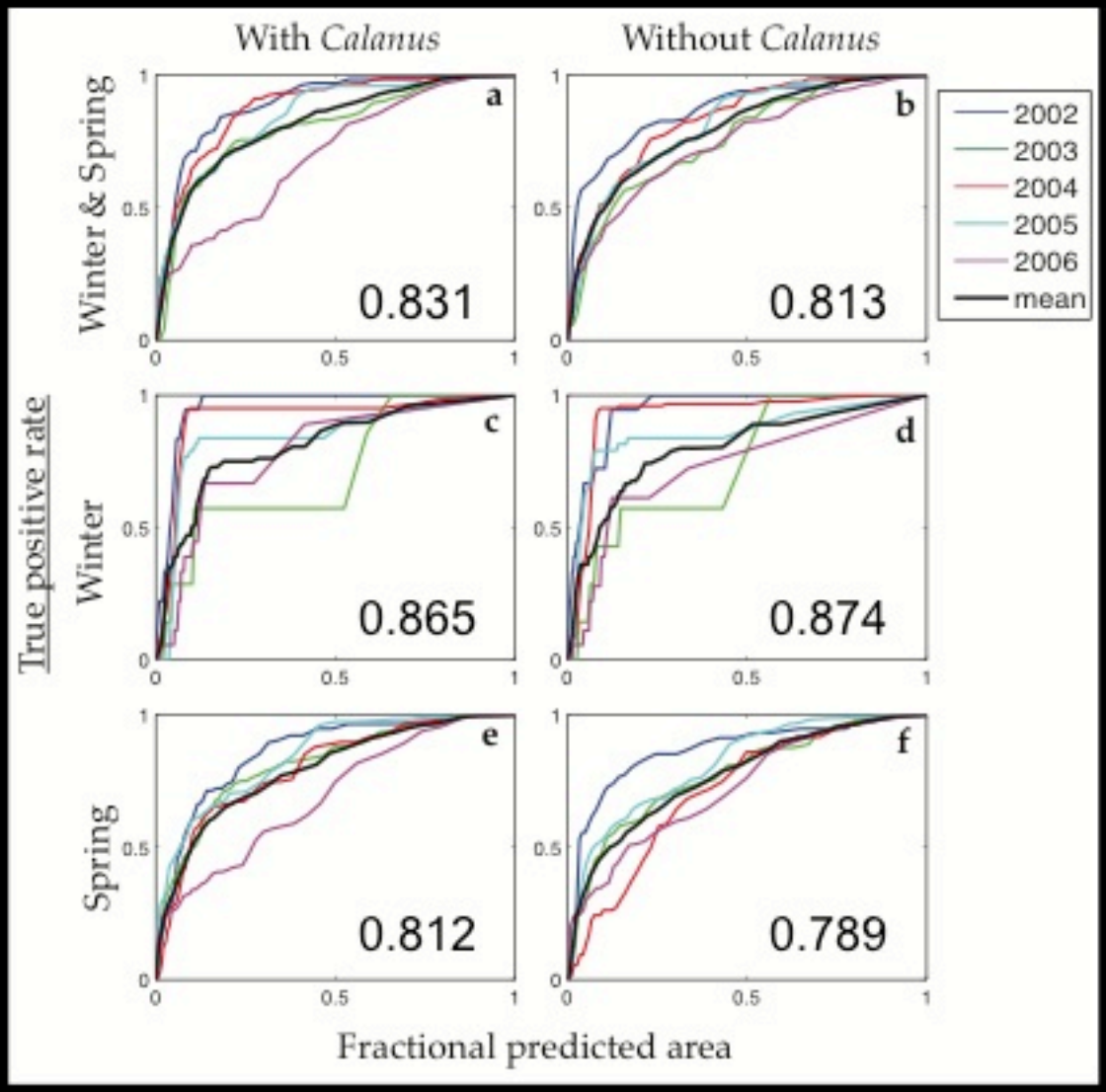
without *Calanus*



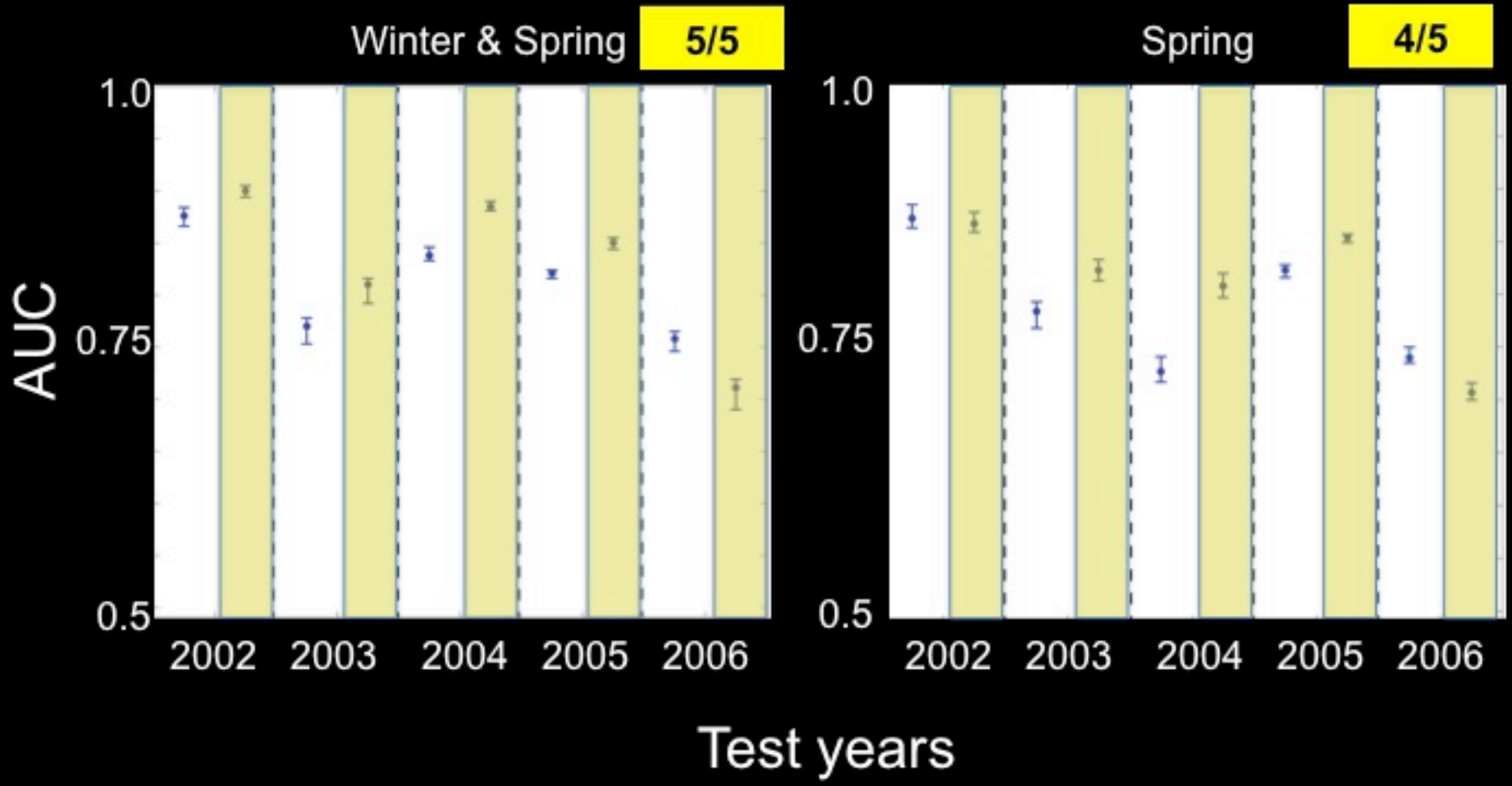
Interpreting ROC



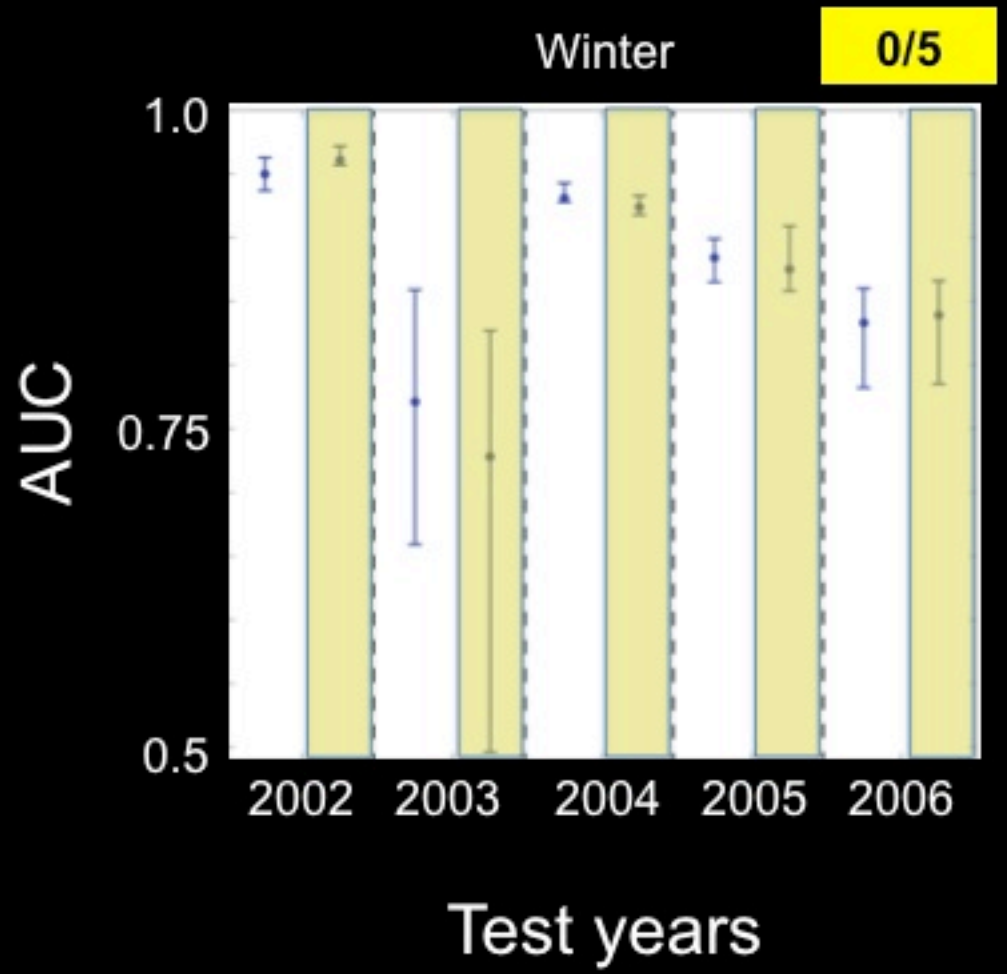
Predictive capacity measured by ROC

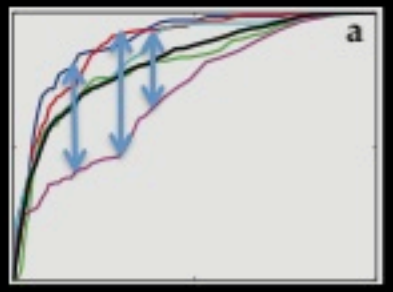


Significance of modeled *Calanus*

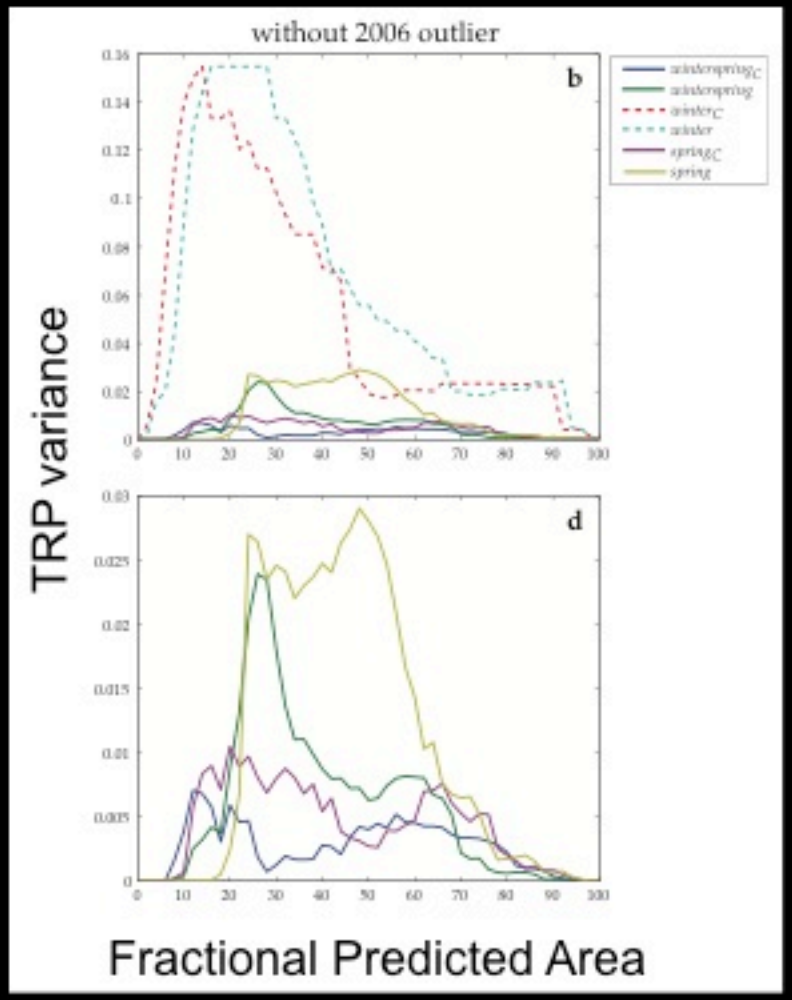


Significance of modeled *Calanus*





Model response to Inter-annual environmental variability



Inter-annual variability

Spring withOUT *Calanus*

Winter+Sping withOUT *Calanus*

Spring with *Calanus*

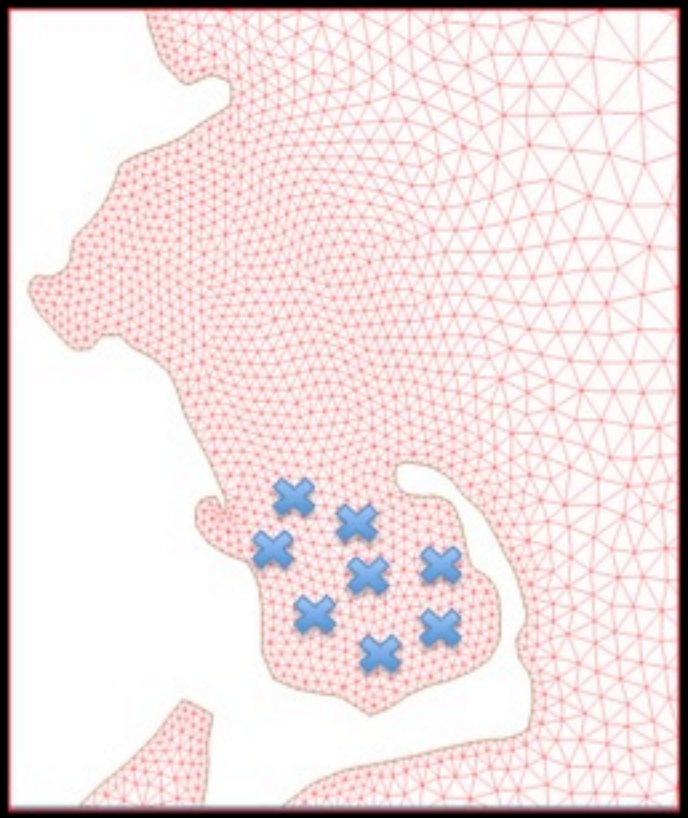
Winter+Spring with *Calanus*

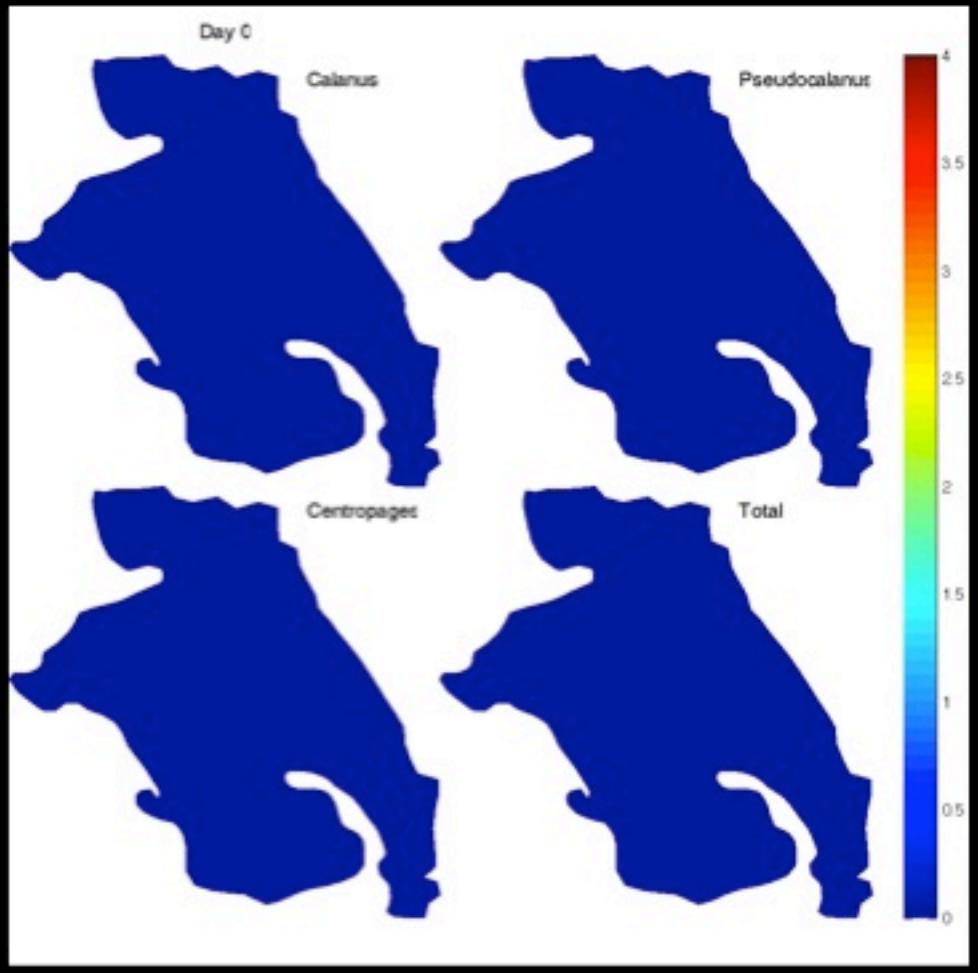
Influence of predictor variables

Model ID		A1	A2	B1	B2	C1	C2
Test Year		Winter+Spring w/*Calanus*	Winter+Spring wo/*Calanus*	Winter w/*Calanus*	Winter wo/*Calanus*	Spring w/*Calanus*	Spring wo/*Calanus*
2002	*Calanus*	**35.3**	na	10.8	na	**45.1**	na
	Bathymetry	32.5	**42.6**	20.7	23.2	34.3	**54.3**
	Chlorophyll a	19.6	33.7	26.9	33.8	12.1	24.0
	Sea Surface Temperature	12.6	23.7	**41.7**	**43.0**	8.4	21.7
2003	*Calanus*	**37.6**	na	17.6	na	**44.4**	na
	Bathymetry	28.5	**44.4**	21.1	28.2	35.6	**57.3**
	Chlorophyll	18.5	29.0	26.2	30.3	11.2	21.7
	Sea Surface Temperature	15.4	26.6	**35.1**	**41.6**	8.8	21.0
2004	*Calanus*	**36.9**	na	18.7	na	35.7	na
	Bathymetry	31.8	**48.4**	22.7	26.3	**38.6**	**56.7**
	Chlorophyll	18.0	27.7	24.6	30.0	14.2	22.9
	Sea Surface Temperature	13.4	23.9	**34.0**	**43.7**	11.4	20.4
2005	*Calanus*	**33.2**	na	15.4	na	**42.5**	na
	Bathymetry	31.6	**45.0**	20.6	26.7	39.0	**60.6**
	Chlorophyll	19.2	35.0	24.3	27.9	11.4	21.4
	Sea Surface Temperature	16.0	25.0	**39.6**	**45.3**	7.1	18.1
2006	*Calanus*	**40.9**	na	16.9	na	**46.3**	na
	Bathymetry	31.0	**47.7**	22.9	26.5	34.9	**61.4**
	Chlorophyll	15.8	27.8	22.6	31.4	11.6	20.7
	Sea Surface Temperature	12.3	24.4	**37.6**	**42.1**	7.10	17.9

Copepod models embedded in high resolution circulation model

FVCOM





Prediction into 2009

Conclusions

- Weekly estimates of habitat suitability can be made with reasonable accuracy
- Modeled *Calanus* provides significant improvement
- Transition between critical habitats observable
- Temporal rather than spatial management in CCB
- Continued Zpltn and right whale surveys are critical
- Assimilating whale survey could be the next step