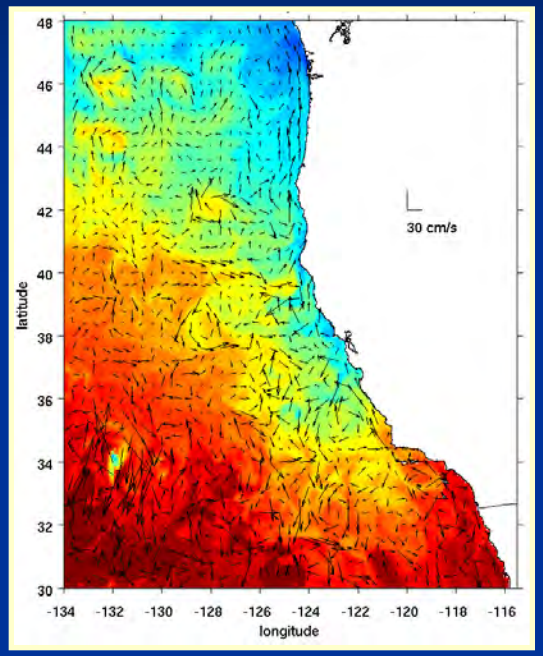
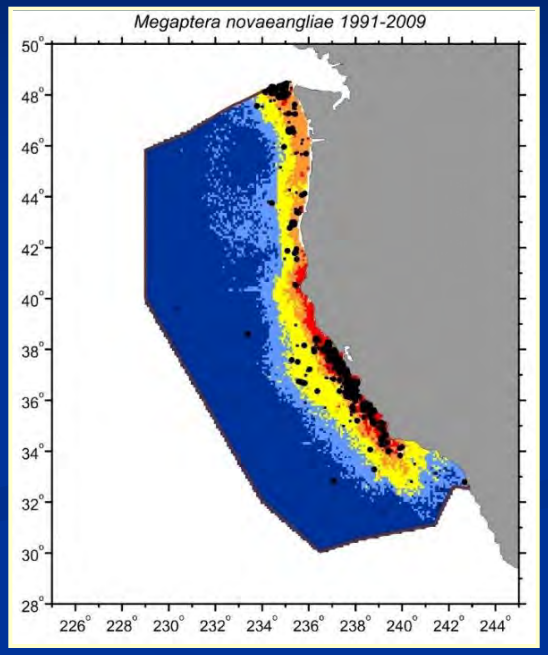
Moving towards dynamic ocean management: How well do modeled ocean products predict species distributions?



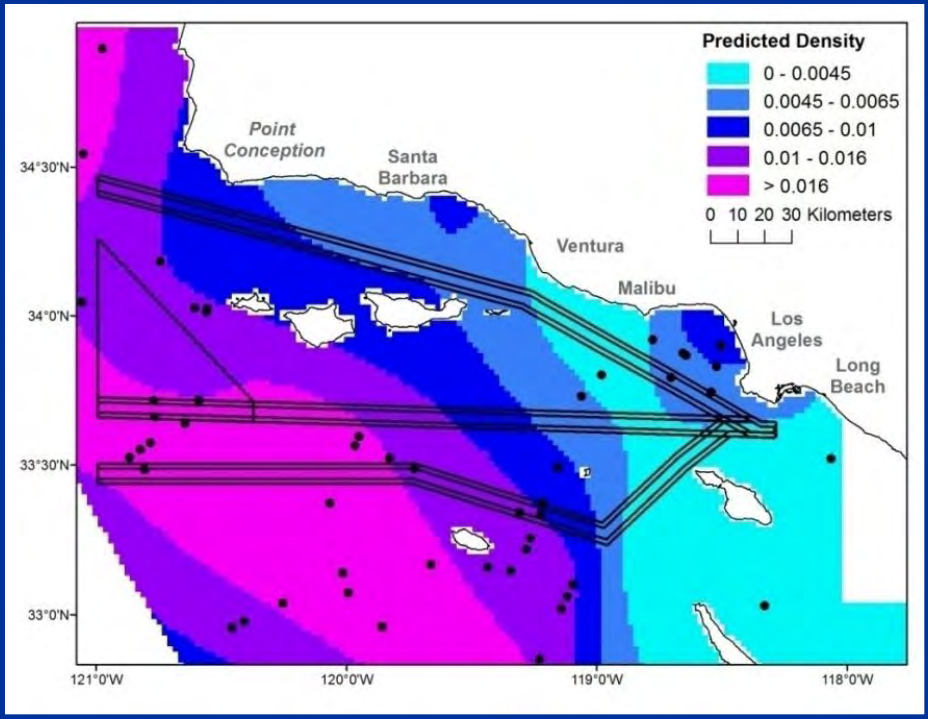


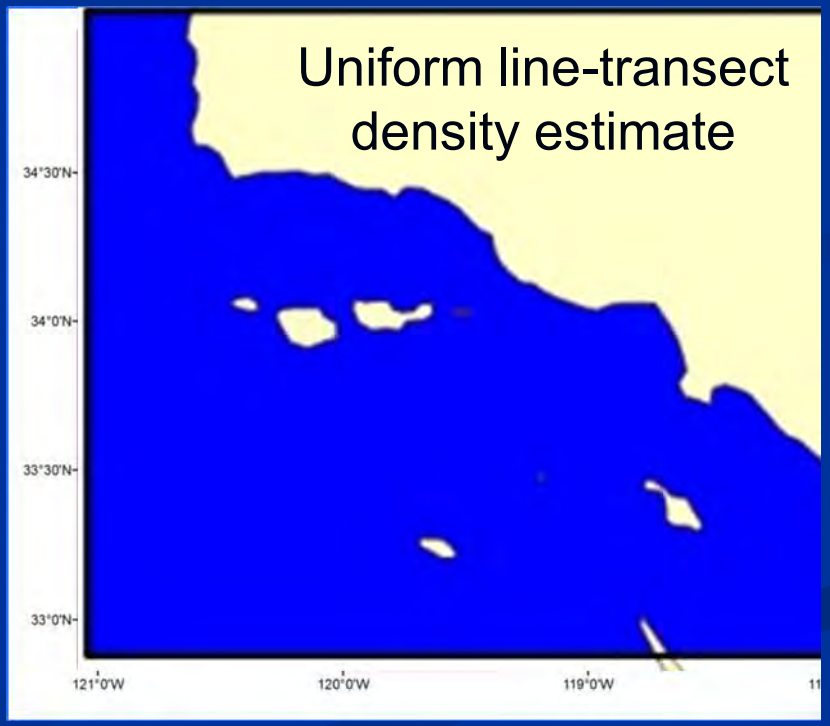
Elizabeth A. Becker, Karin A. Forney, Paul C. Fiedler, Jay Barlow, Susan J. Chivers, Christopher A. Edwards, Andrew M. Moore, and Jessica V. Redfern

PICES 25: Celebrating the Past, Imagining the Future
San Diego, CA, November 8, 2016

Species distribution models

A valuable tool for developing mitigation measures and assessing risk (e.g., ship strike risk in southern California).



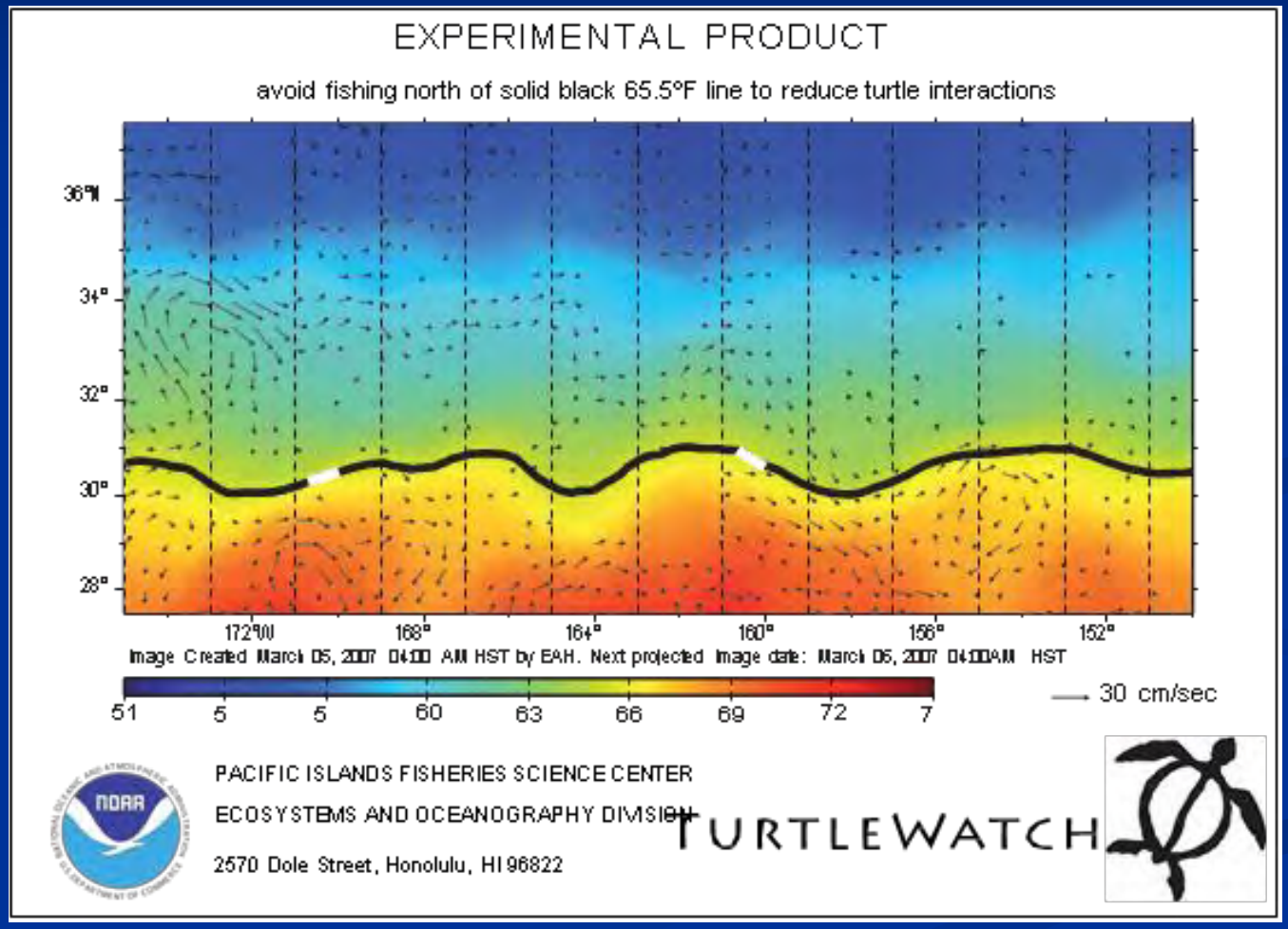


Redfern et al. 2013, Conservation Biology

Dynamic ocean management (DOM)

Guides policies based on predicted species distributions

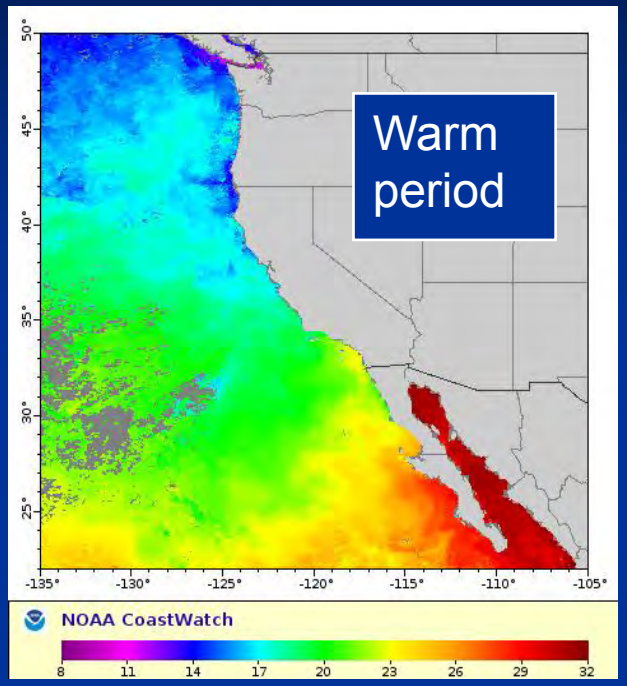
(e.g., Hobday et al. 2014; Lewison et al. 2015; Maxwell et al. 2015)

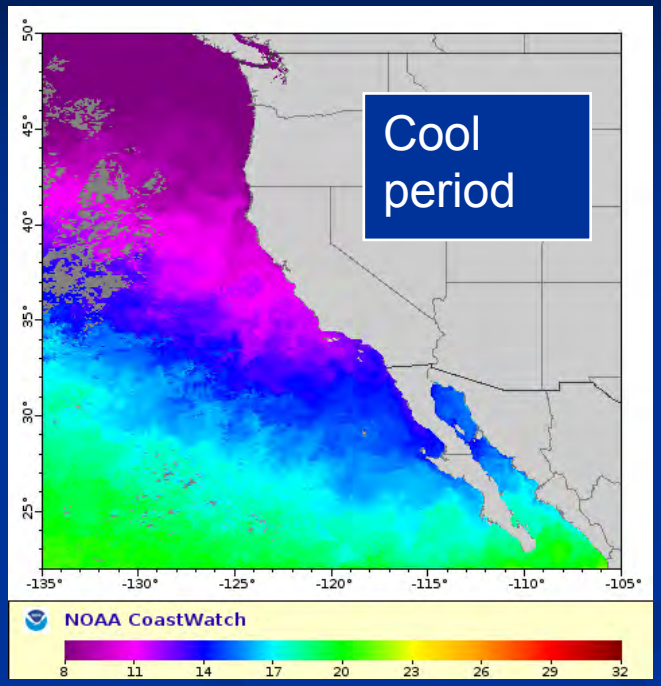


Howell et al. 2008, 2015

Dynamic California Current

Oceanic variability at multiple temporal scales.





For some species…

… Nowcast possible using remotely sensed SST data

… Forecast possible using 3-4 month SST projection from regional ocean modeling system (ROMS).

Becker et al. 2012, Endangered Species Research

Objective

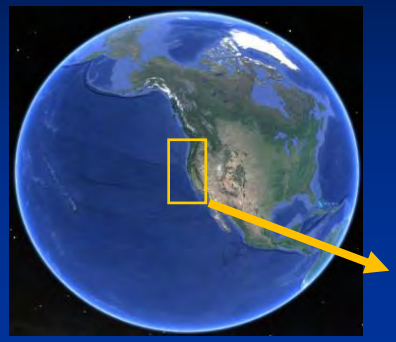
Evaluate the performance of a broader suite of ROMS outputs to predict dynamic cetacean distributions

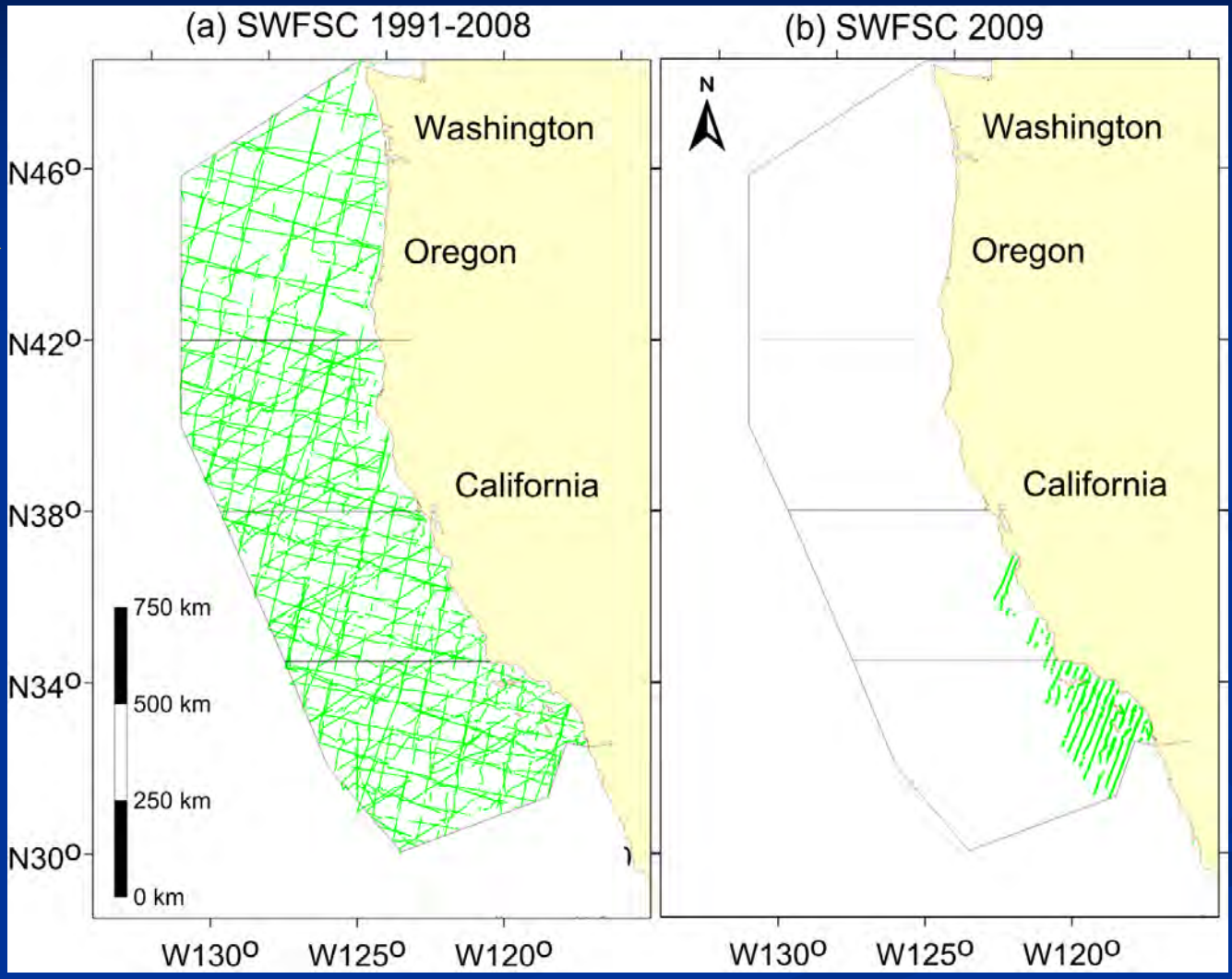
Compare to traditional models developed using "measured data" (satellite and *in situ*)

- Blue whale
- Humpback whale
- Fin whale
- Bottlenose dolphin (offshore ecotype)
- Short-beaked common dolphin
- Risso's dolphin
- Northern right whale dolphin
- Pacific white-sided dolphin
- Dall's porpoise
- Striped dolphin
- Long-beaked common dolphin

California Current Ecosystem Study Area

SWFSC systematic ship surveys: Summer/Fall 1991 - 2009





Includes a total of 72,454 on-effort km

Habitat variables

Measured Data (in situ or remotely sensed)	Regional Ocean Modeling System (ROMS) Output*
Sea surface temperature (SST)	Sea surface temperature (SST)
SD (SST) ~ proxy for fronts	SD (SST) ~ proxy for fronts
Salinity	Salinity
Mixed layer depth	Mixed layer depth
Chlorophyll	Sea surface height (SSH)
	SD (SSH)
	Potential energy anomaly (measure of stratification)
Bathymetric variables in both model types: depth, slope, aspect	

* UCSC Ocean Modeling and Data Assimilation Group (*Moore et al. 2011, Progress in Oceanography*)

Species-specific GAM frameworks

$$Density = n \cdot s \ / A_E$$

for species with small and less variable group size
(all large whales & Dall's porpoise)

n*s: $ln(n) = offset(A) + f(SST) + f(depth)....$

n*s ~ Tweedie

for species with often very large and highly variable group size
(all delphinids)

n: $ln(n) = offset(A) + f(SST) + f(depth)....$

s: $ln(s) = f(lat,lon)$

n: Tweedie

s: log-normal
with spatial model

GAMs include segment-specific parameters, based on viewing conditions

$$A = 2*L*ESW*g(0)$$

A = area effectively searched

L = length of effort segment

ESW = effective strip width, given sea state, visibility, swell anomaly

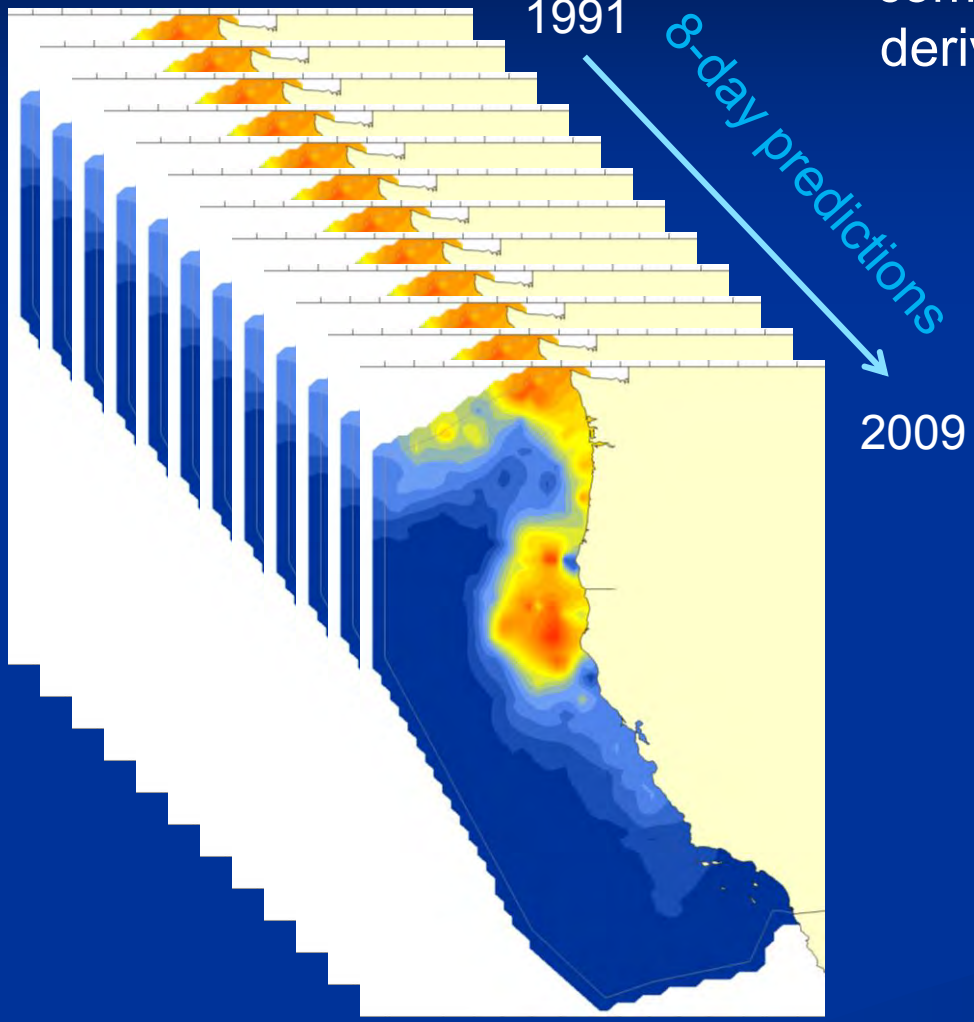
g(0) = probability of detection on the transect line, given sea state

Segment specific ESW: Barlow et al. 2011

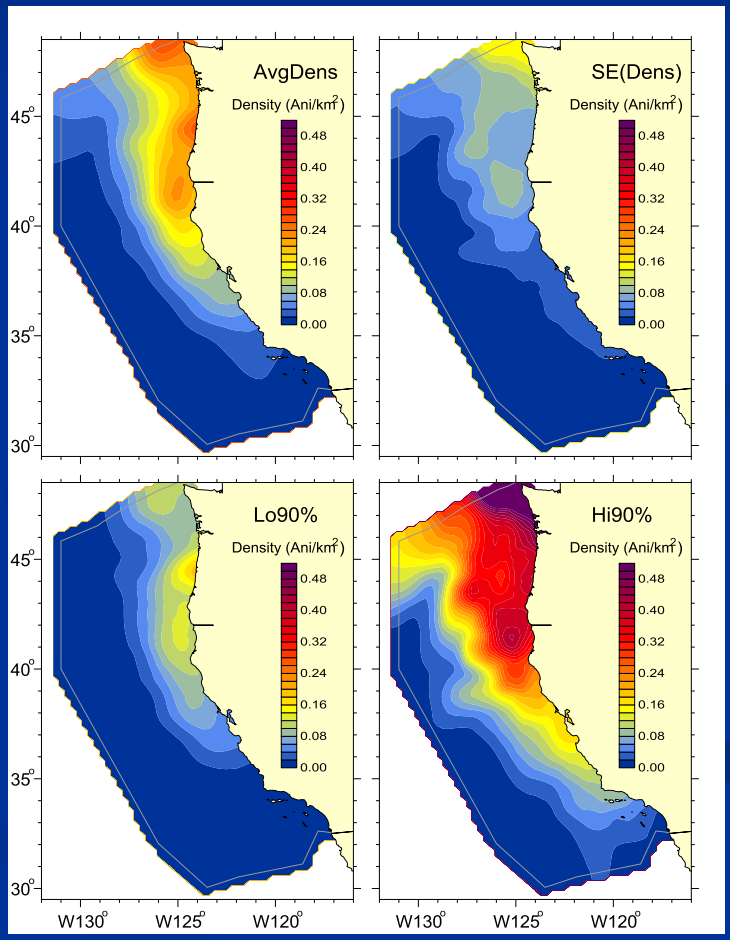
Segment-specific g(0): Barlow 2015

Accounts for actual viewing conditions (e.g. sea state, visibility)

CCE grid predictions: 10km spatial resolution



Predict on 8-day non-overlapping composites covering survey periods and derive averages and variance estimates



Model comparison

Four model types:

- Full suite of measured data*
- Full suite of ROMS output
- Constrained ROMS output
- Constrained measured data*

} Restricted to variables available from both data sources

Performance assessed using:

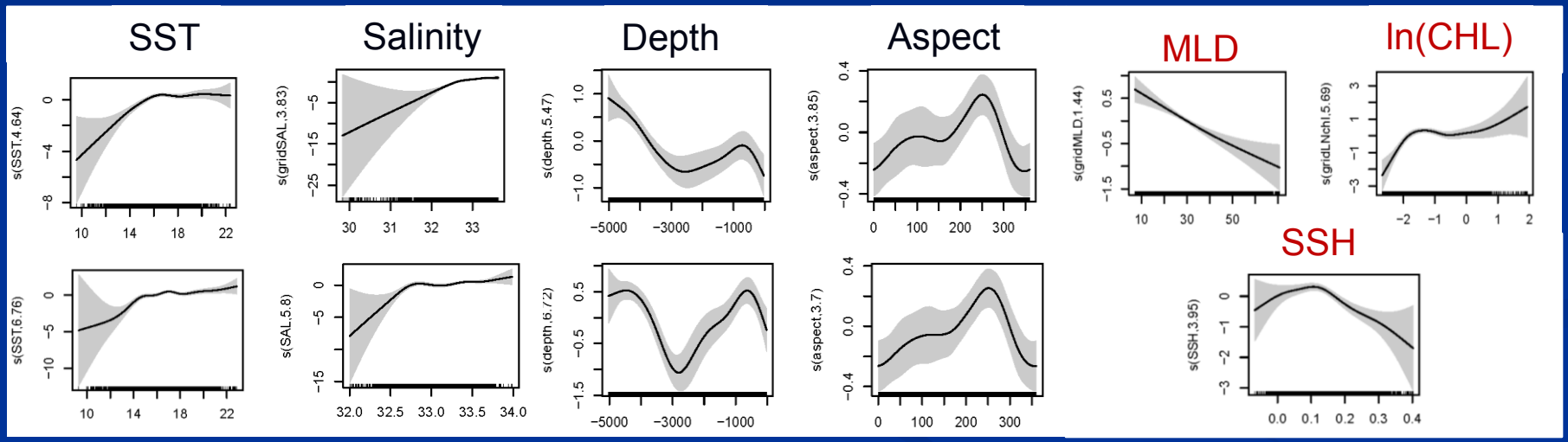
- Explained deviance
- Root mean squared error (RMSE)
- Observed/predicted density ratios
- Inspection of observed/predicted distributions
- Comparison to line-transect estimates

* Similar measured data models have received extensive validation in previous studies:

- *Barlow et al. 2009*
- *Becker et al. 2010*
- *Forney et al. 2012*
- *Becker et al. 2012*
- *Redfern et al. 2013*
- *Becker et al. 2014*

Model predictors: measured data vs. ROMS

Delphinus delphis:



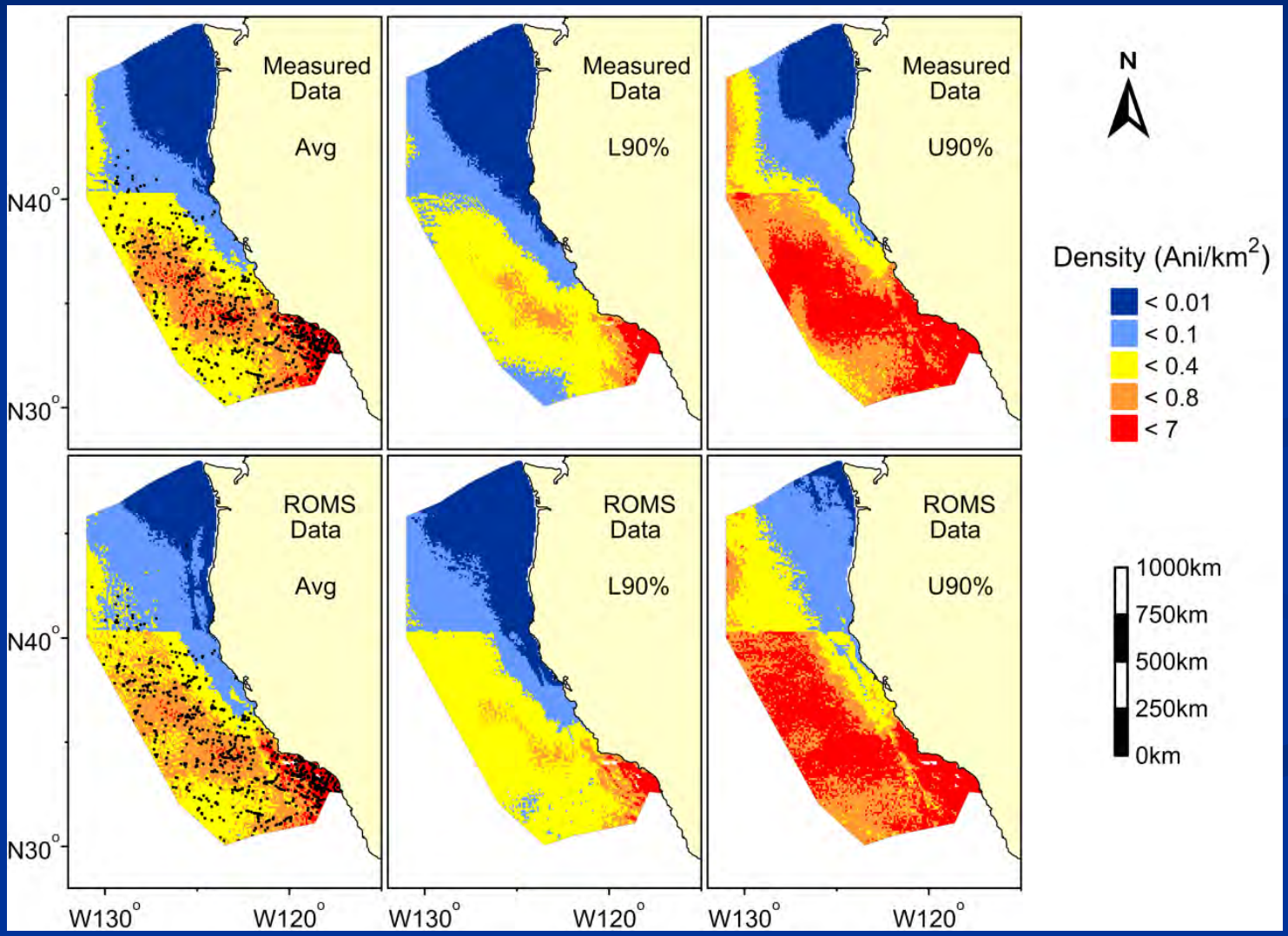
Performance metrics were similar for both model types.

Short-beaked common dolphin

Average density | Lower 90% CI | Upper 90% CI

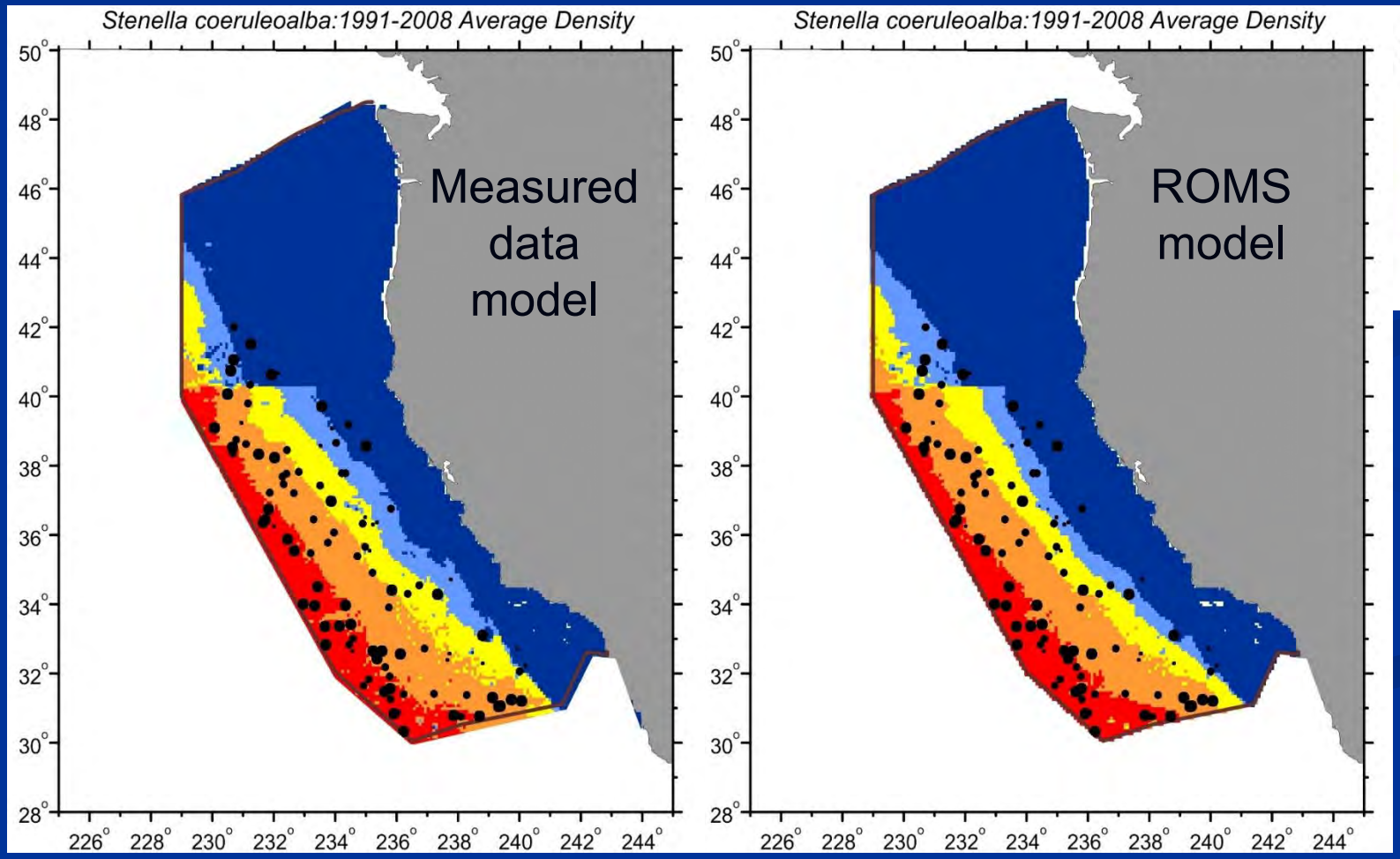
Measured data

ROMS



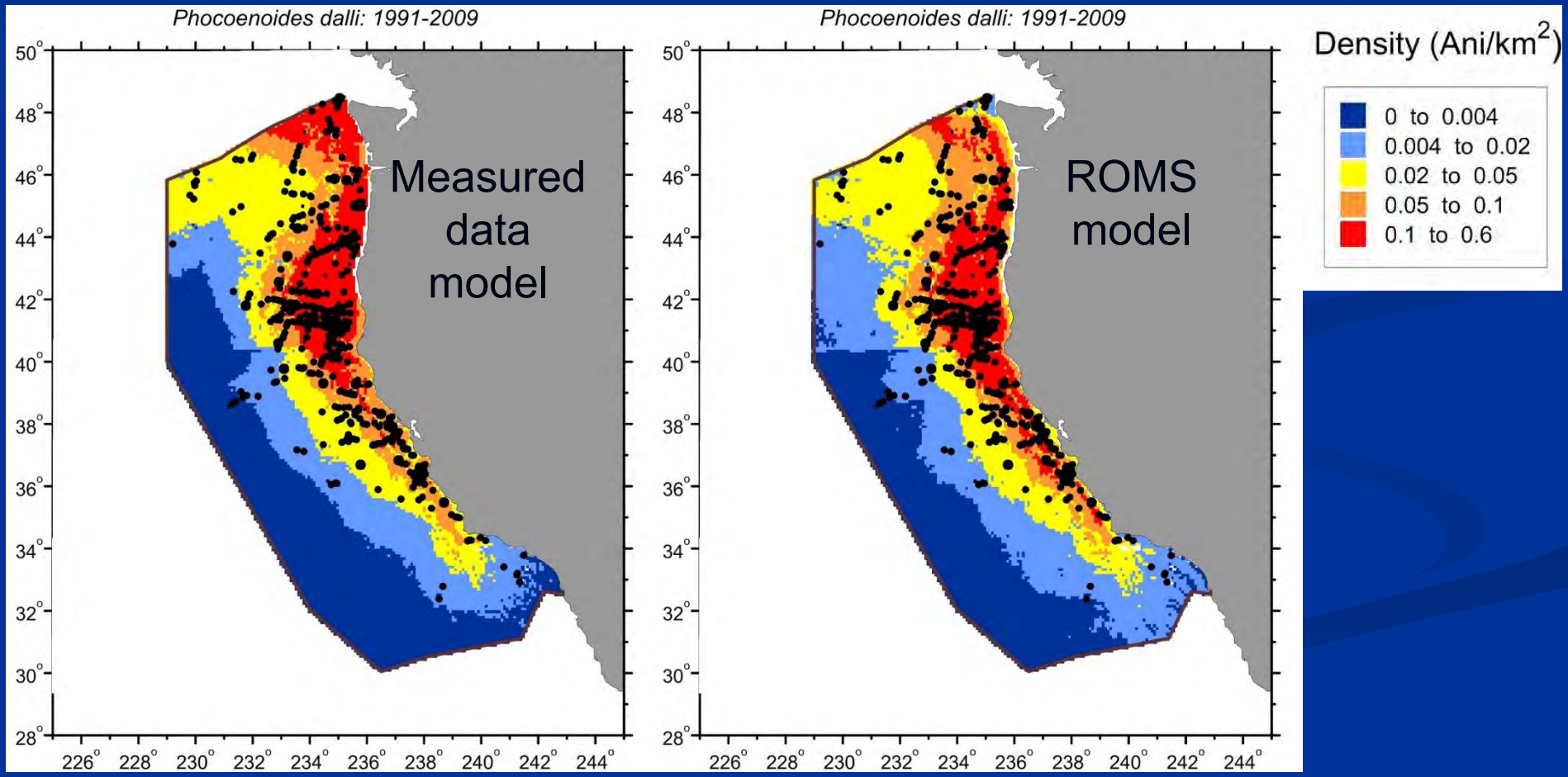
METRIC	MD	ROMS
Expl.Dev.	2.34	5.01
RMSE	0.086	0.086
Obs/Pred Ratio	1.100	1.023

Striped dolphin



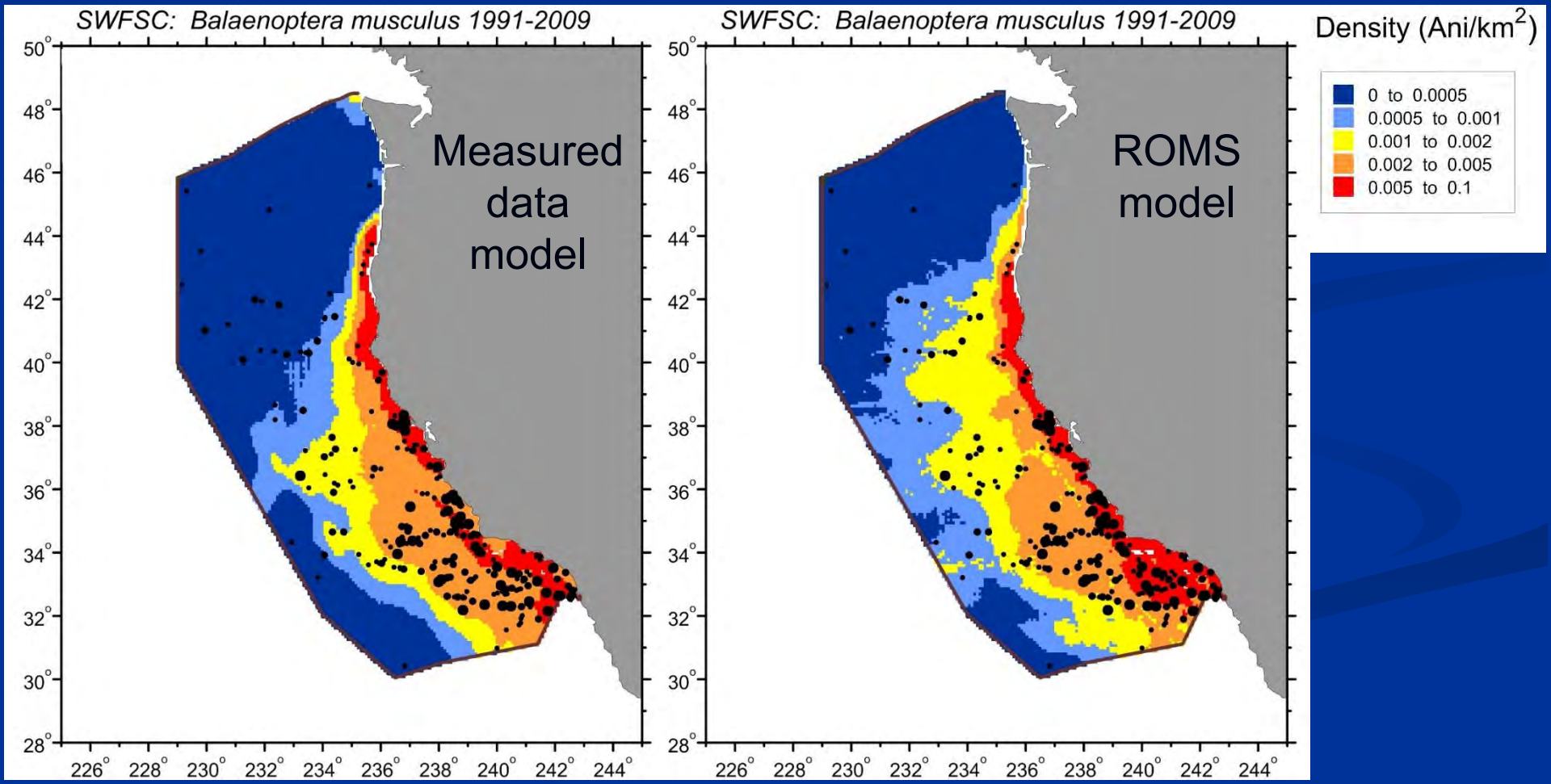
METRIC	MD	ROMS
Expl.Dev.	37.0	36.0
RMSE	1.041	1.043
Obs/Pred Ratio	0.939	0.944

Dall's porpoise

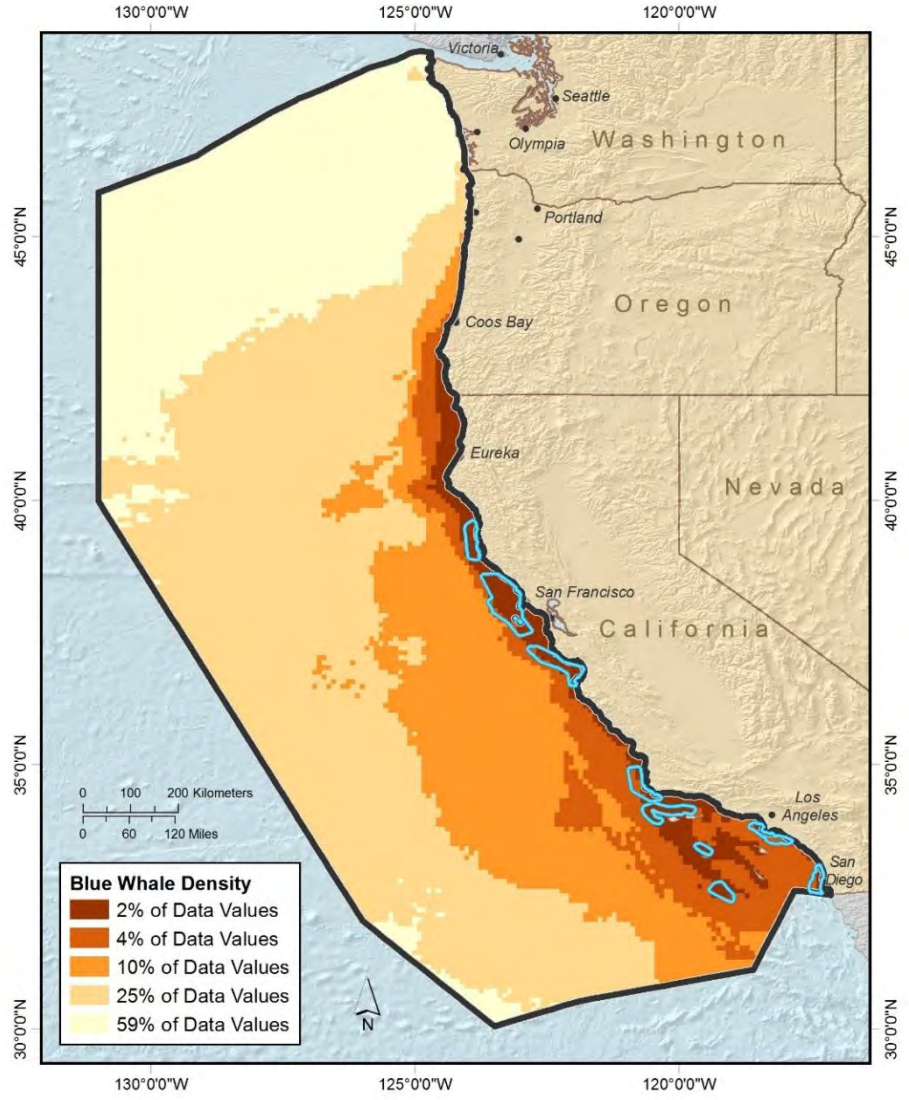


METRIC	MD	ROMS
Expl.Dev.	16.3	17.3
RMSE	0.258	0.257
Obs/Pred Ratio	0.953	0.953

Blue whale



Additional model validation



Blue whale ROMS model

Highest density predictions match well* with BIAs identified for blue whale based on small boat surveys.

(*Calambokidis et al. 2015, Aquatic Mammals*)

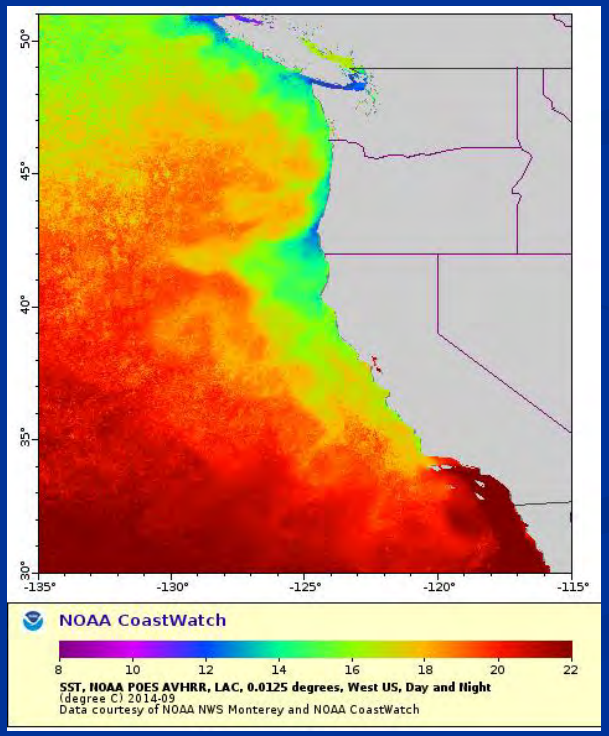
*All BIAs are located within the highest 10% of predicted density values

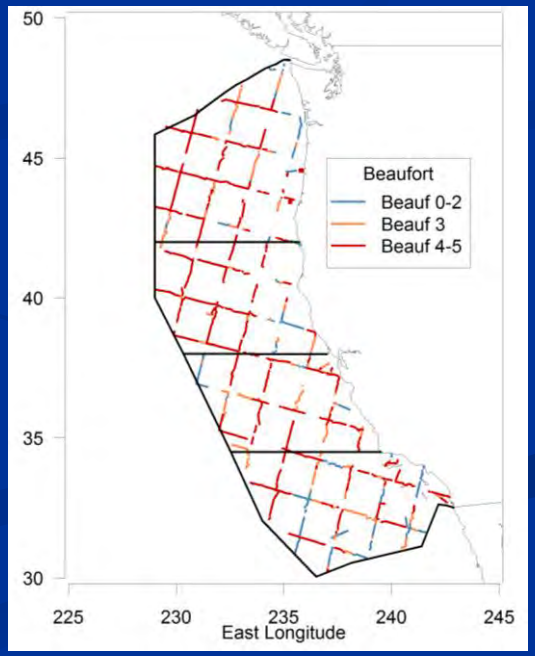
Conclusions

- ROMS and measured data models were similar for 9 out of 11 species, despite some predictor differences.
- Spatial scale matters!
- Foundation for Dynamic Ocean Management, and possibly climate change assessments.

Next steps

Additional validation on survey data from 2014, which was an anomalously warm year!





Barlow, in prep.

Acknowledgements

- Marine mammal observers, cruise leaders, cruise coordinators, officers, and crew of 1991-2009 ship surveys.
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