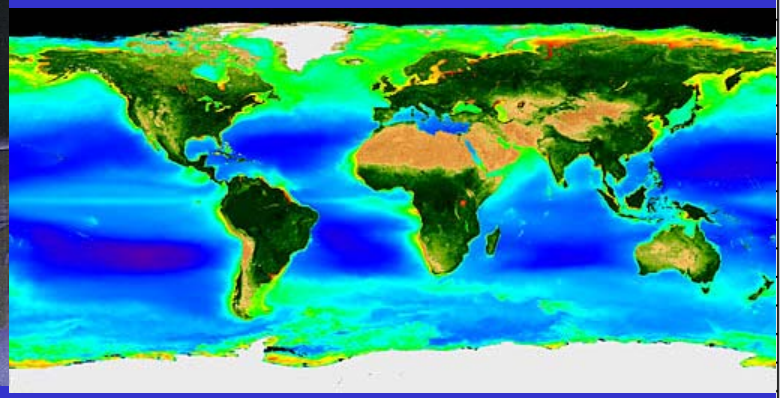
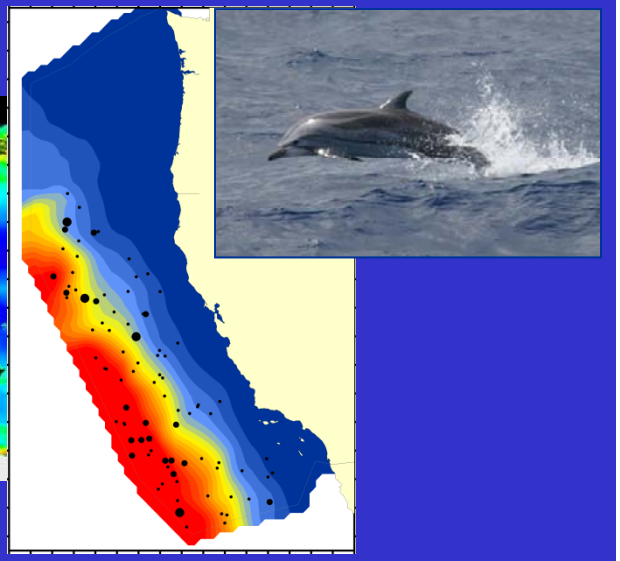
Forecasting cetacean distributions with ocean models and advanced remote-sensing products

Ecological Modeling Workshop
Marine Mammal Conference 2011
Tampa, Florida





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Outline

Background

- Habitat-based density models
- Need for increased temporal resolution

Case Study: Nowcasts and Forecasts

- Advanced RS products and ocean models
- Technical approach
- Results

Practical Considerations

- Data access and use
- Model validation

Methods of Estimating Cetacean Density

Line-transect analyses

- Low resolution (spatial and temporal)

(Barlow & Forney 2007)

Habitat-based density models

- Greater spatial resolution
- Low temporal resolution

(Barlow et al. 2009; Forney et al., in press, ESR)

Case Study: Can we improve temporal resolution?

- "NOWCASTS" based on new SST products
- "FORECASTS" based on ocean circulation models

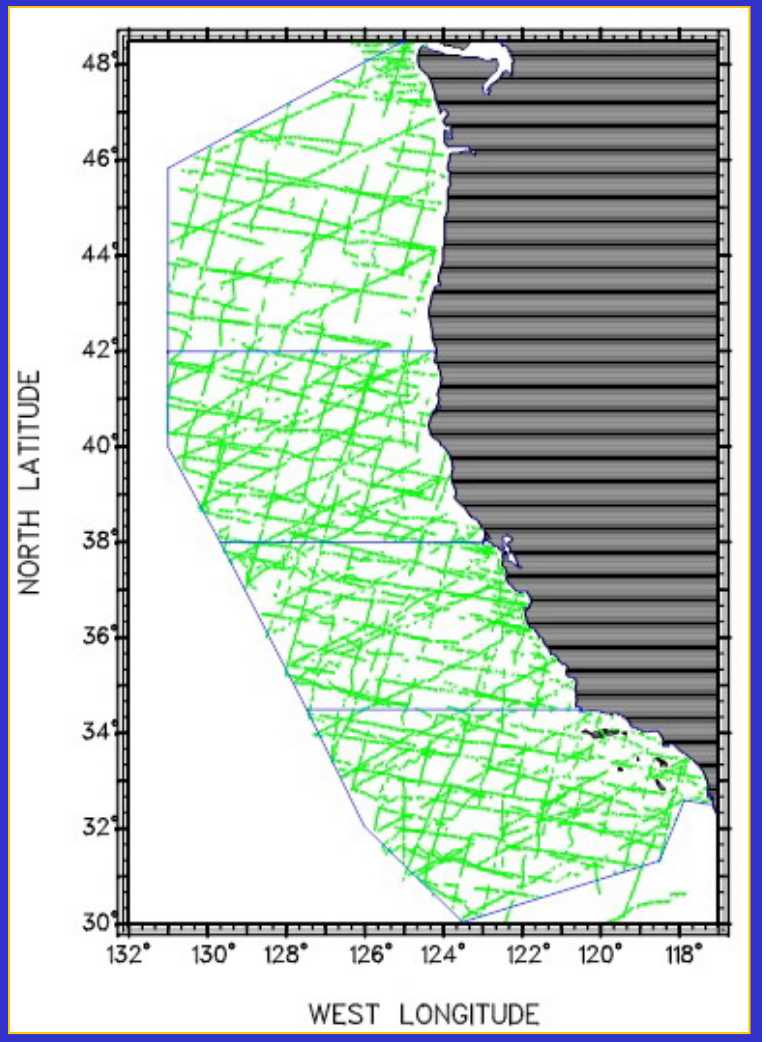
(Becker et al., in press, ESR)

SWFSC West Coast Shipboard Surveys

Cetacean surveys, summer & fall 1991, 1993, 1996, 2001, & 2005.

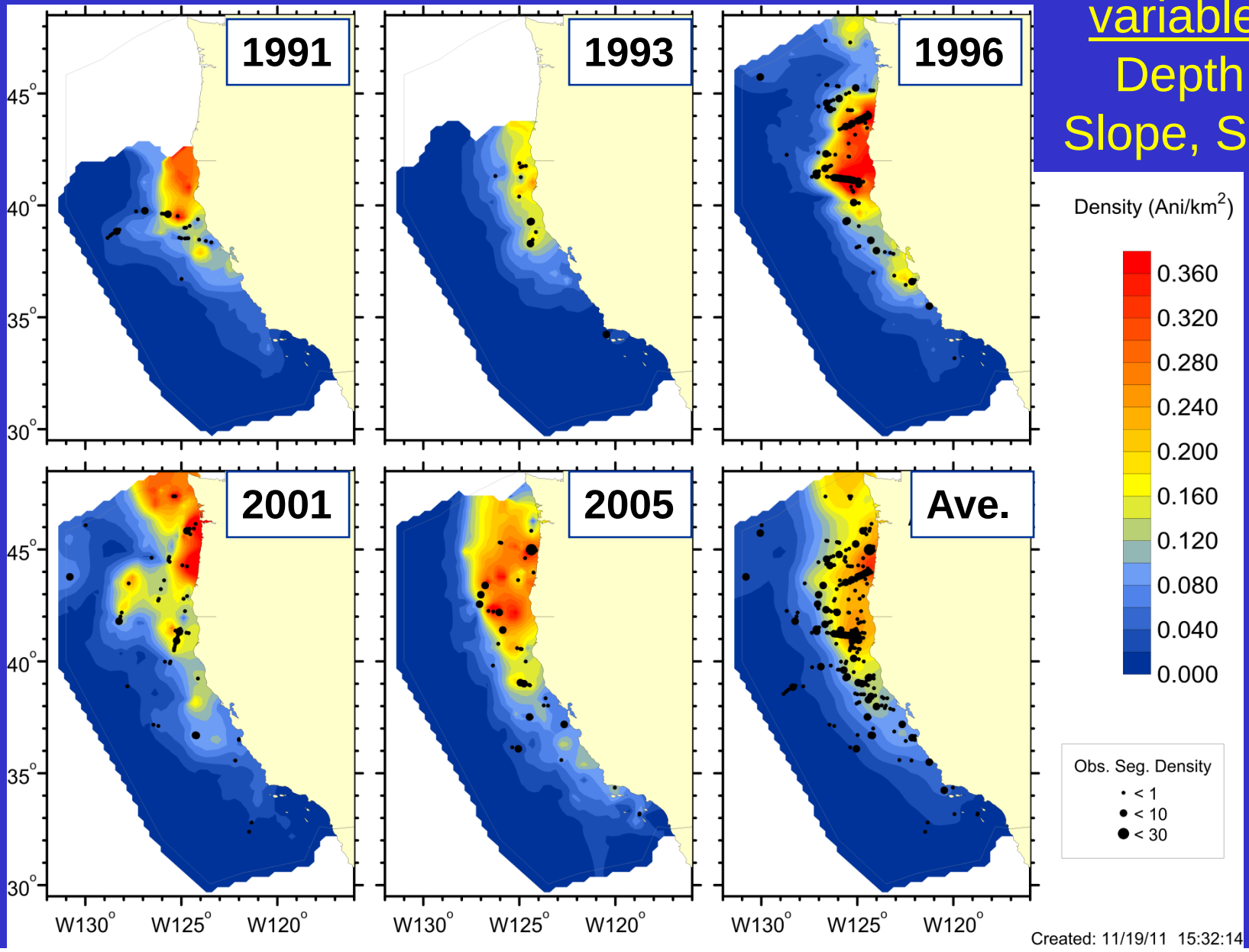
Systematic line-transect methods were used on all surveys.

U.S. West Coast wide 'snapshot'



Completed transect lines

Dall's porpoise (*Phocoenoides dalli*) **densities**



Key predictor variables
Depth, Slope, SST

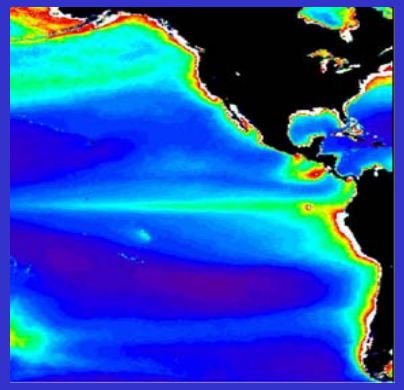
Challenge: Marine mammals are highly mobile; distributions change on seasonal, interannual and decadal time scales

Tropical species

Temperate species

Goal: Implement NOWCAST and FORECAST capability into habitat models to facilitate temporal predictions

Technical Approach



Marine Mammal Survey Data

Habitat Data

Cetacean Habitat-Based Density Models

$$Density = \frac{n \cdot s}{L \cdot 2 \cdot w}$$

Generalized Additive Models (GAMs)

Encounter Rate (n/L):

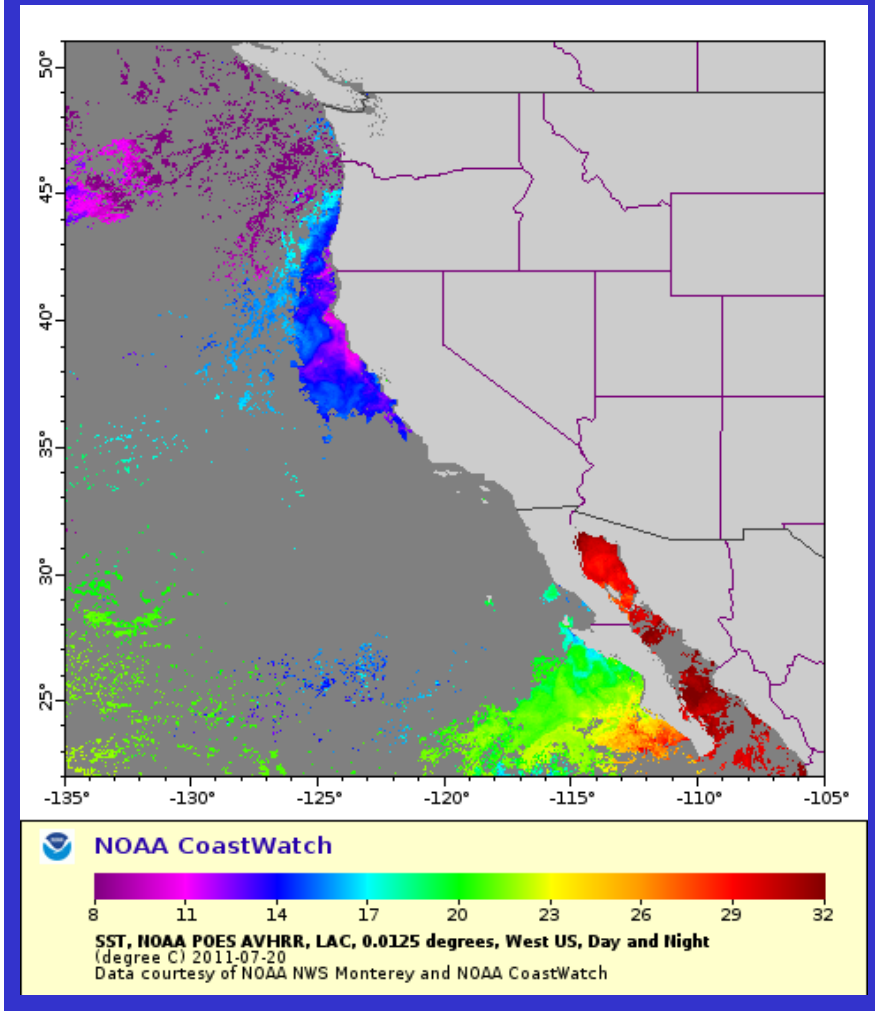
ln(n) = offset(L) + f(SST) + f(depth)....

Group Size (s):

ln(s) = f(SST) + f(depth) + ...

Nowcasts and Forecasts – Case Study

Predictions must rely on remotely sensed or modeled oceanographic data



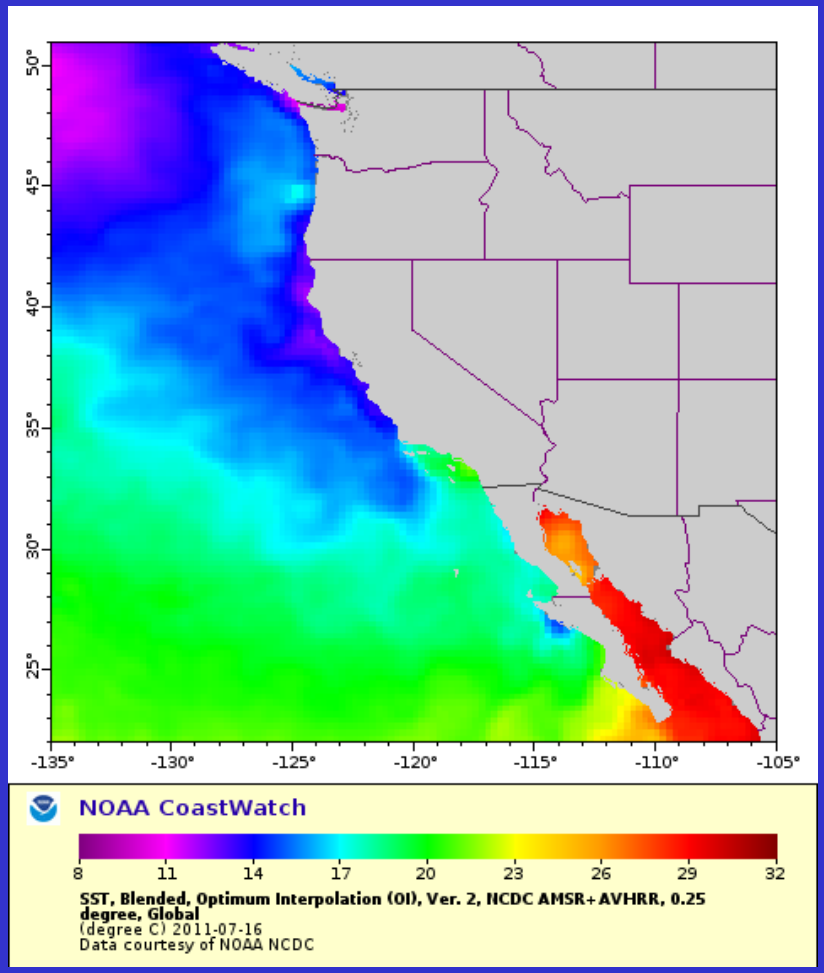
CLOUDS are a problem!

- Sample size
- Spatial and temporal resolution
- Mean and variance calculations

Advanced Remote Sensing Products

Global High Resolution SST (GHRSST) = Blended SST

Developed by Remote Sensing Systems, Santa Rosa, CA



- High-resolution infrared data (9km)
- Microwave (data for cloudy areas)
- Optimal interpolation
- Pixel-by-pixel error characterization

Gentemann et al. 2009, Oceanography

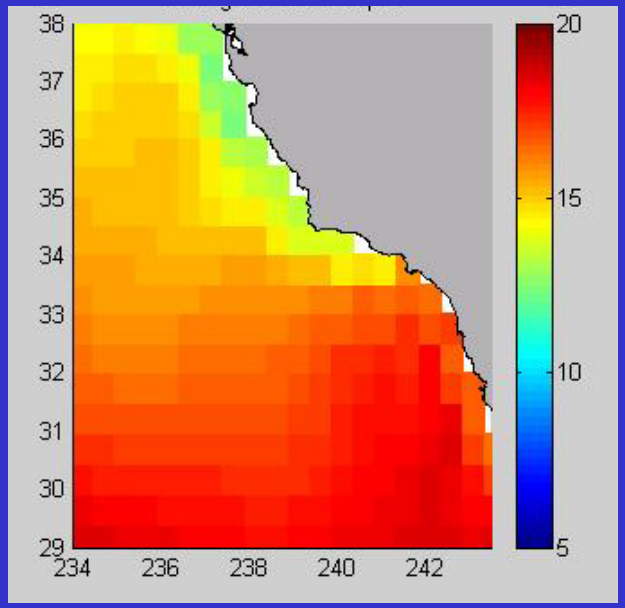
NOWCASTS

Ocean Models

Regional Ocean Modeling System (ROMS)

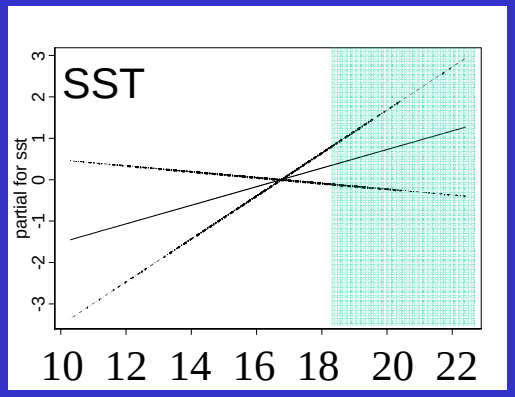
Developed for the NASA-funded FAST Project (Chavez, Chai, Chao, Barber and Foley)

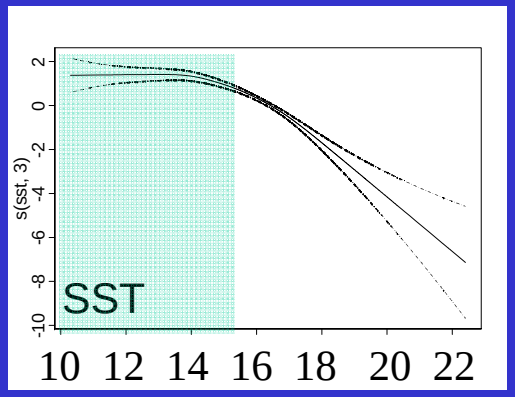
- Basin-wide Pacific 12.5 km NASA\JPL ROMS model
- Run by Yi Chao's group at JPL
- Uses forecast surface fluxes
- Monthly mean products
- Lead time = 1-9 months

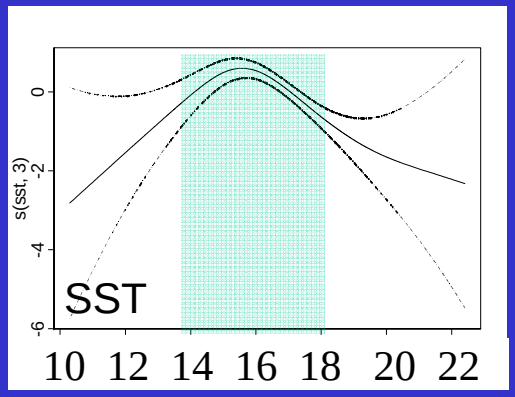


FORECASTS

Feasibility Study







Key Predictors

- **SST**
- **Depth**

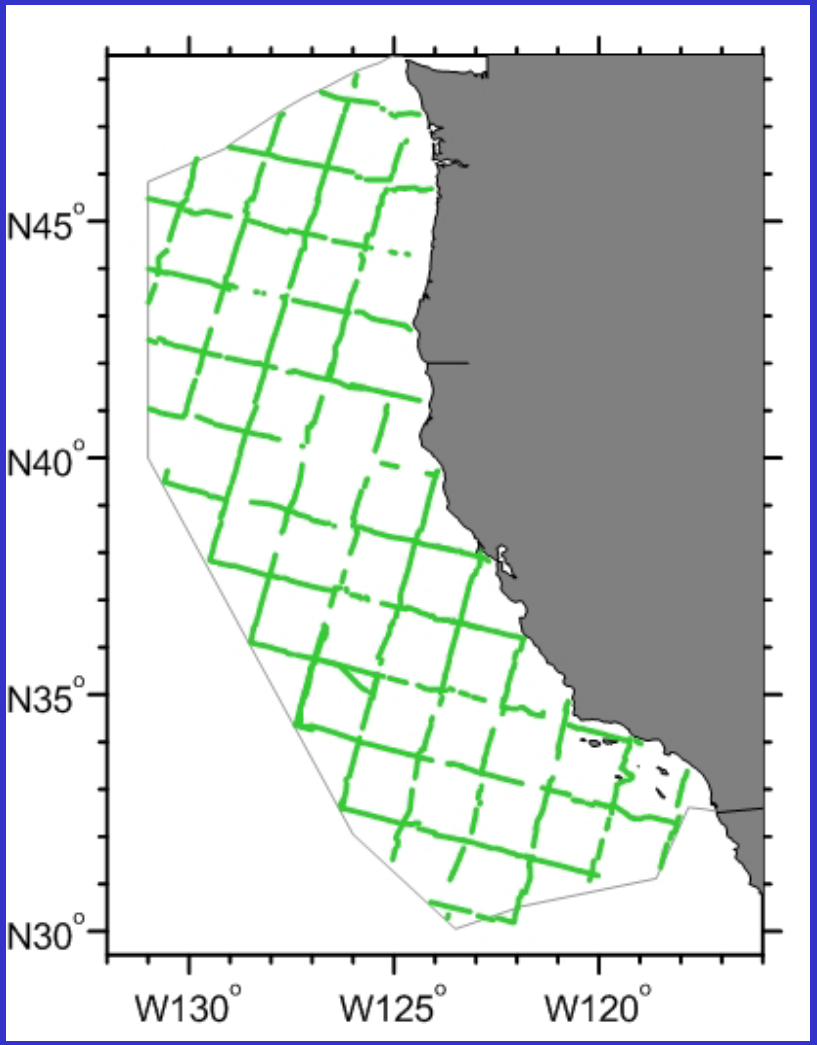
- **SST**
- **Depth**
- **Slope**

- **SST**
- **Depth**
- **Slope**

Validation

- Apply species-specific predictive habitat models to environmental conditions for 2008.
- Use survey data to assess predictive performance.

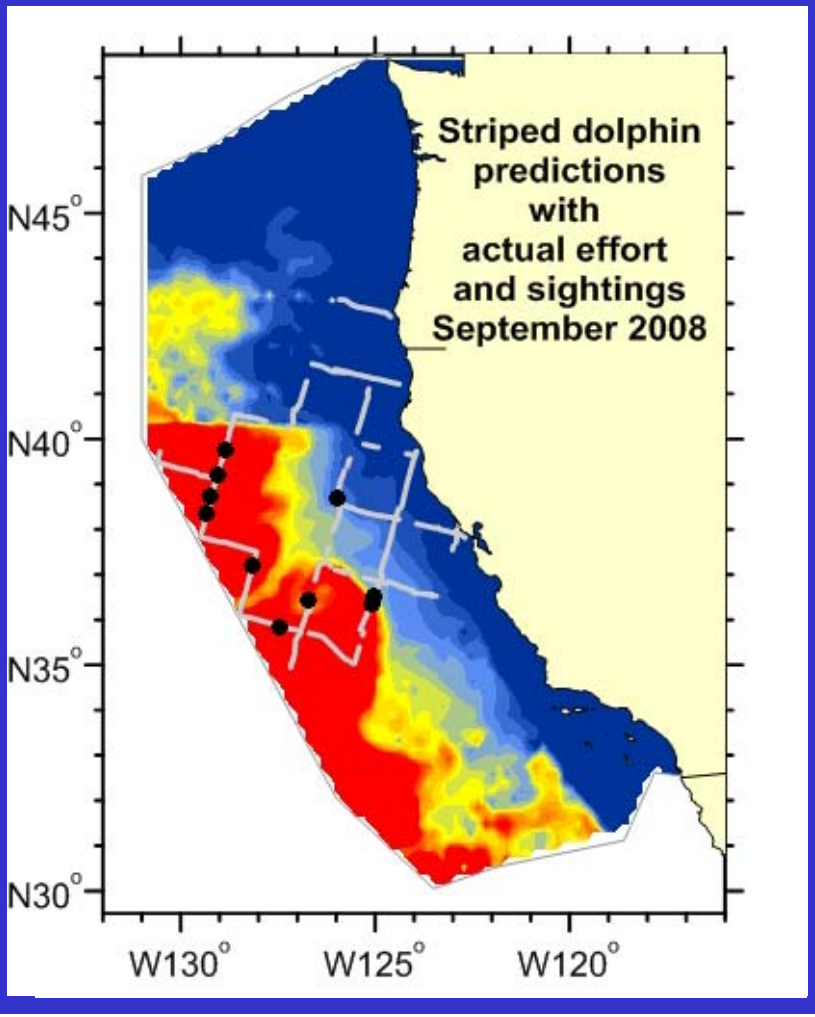
Fin whale
Balaenoptera physalus

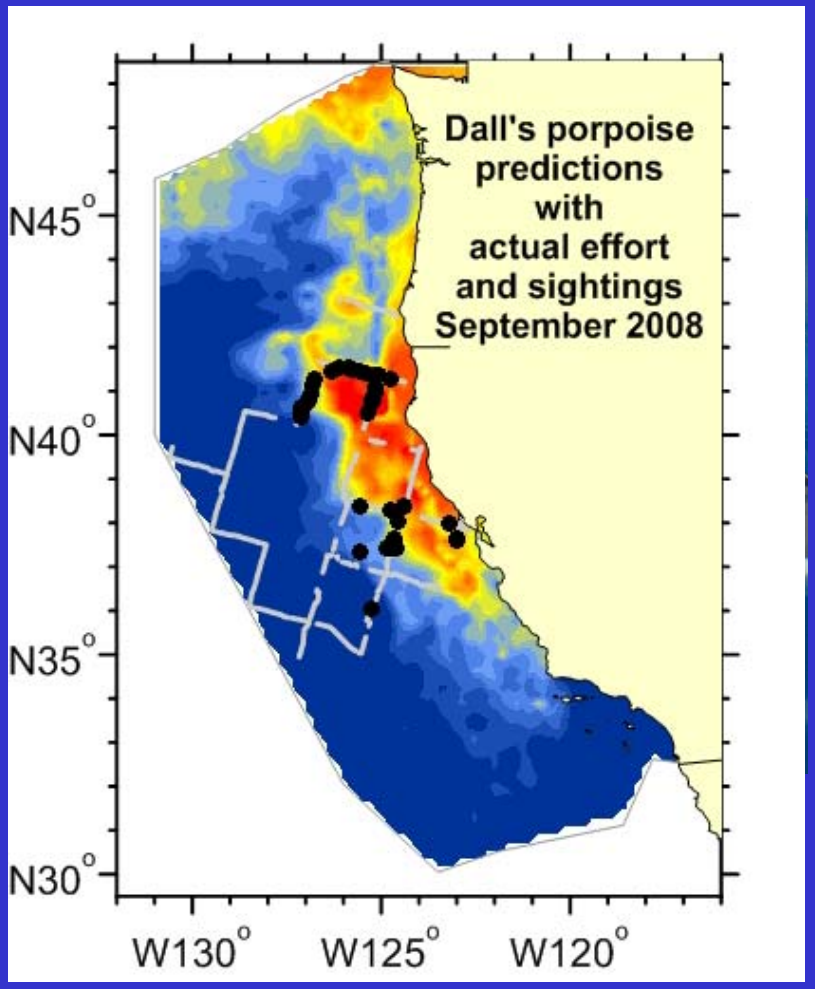


Completed transect lines 2008

Striped dolphin
Stenella coeruleoalba

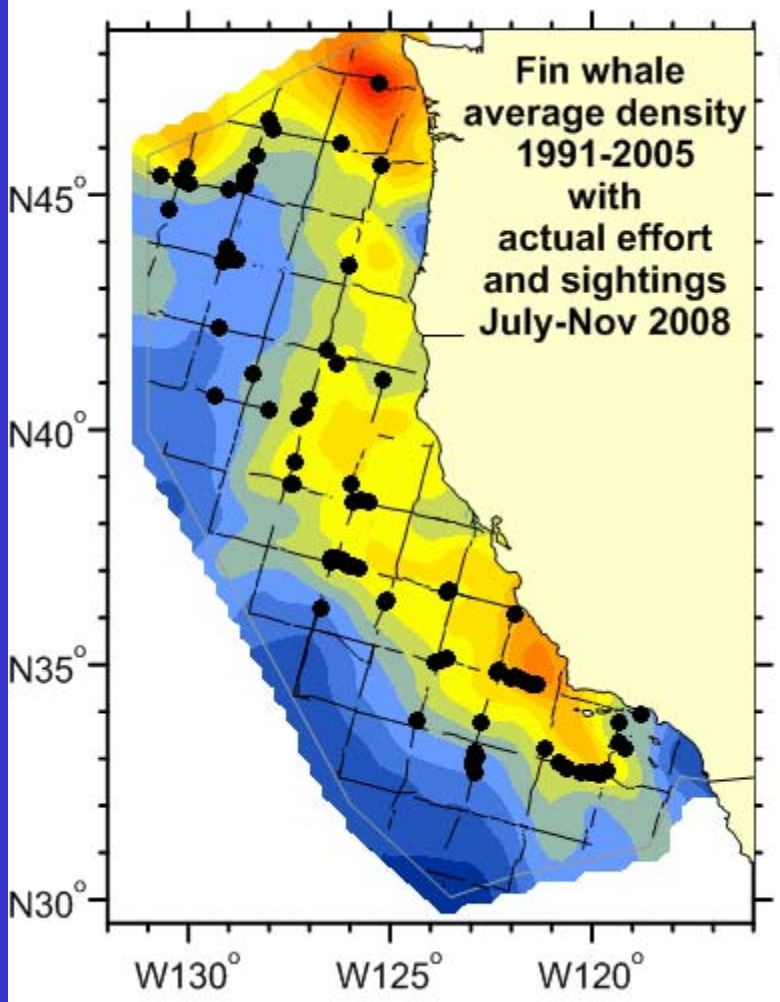
NOWCASTS
(using GHRSST 'blended SST')

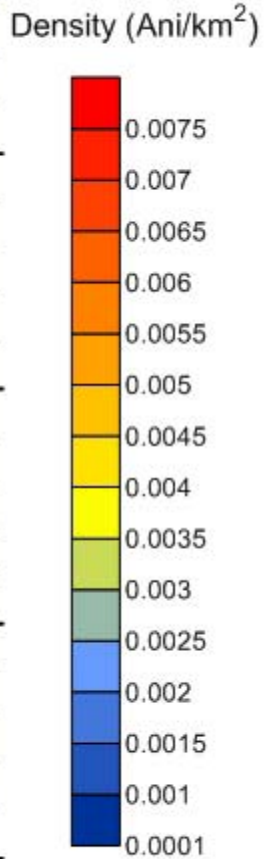




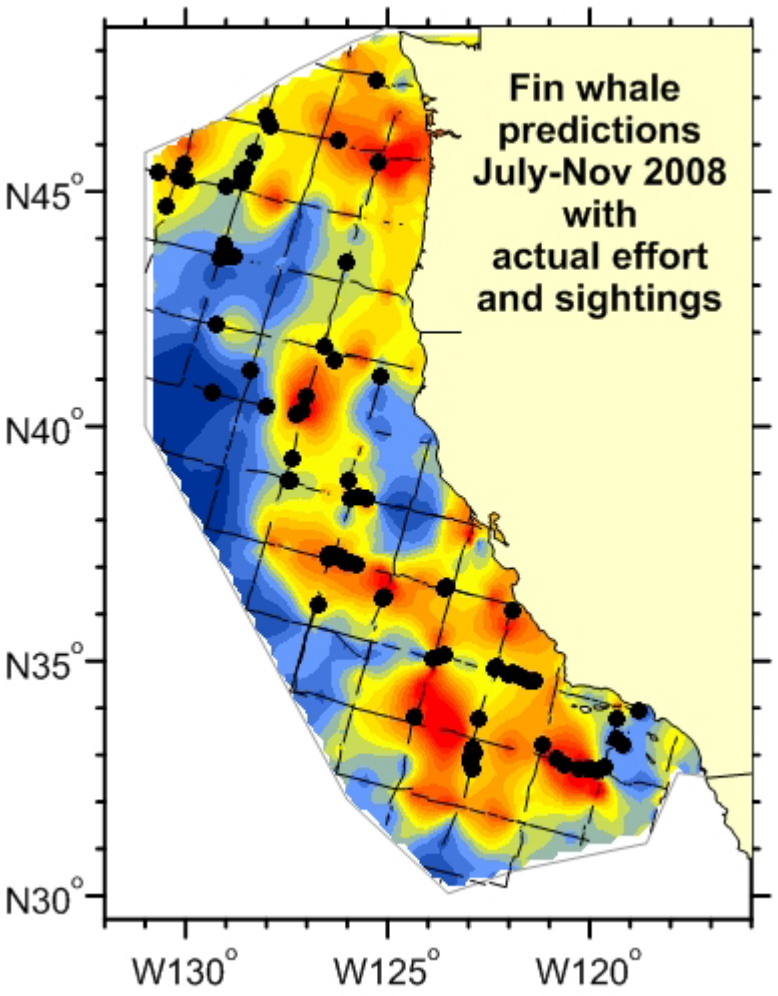
NOWCAST – Fin whale density for entire survey (July-Nov 2008)

Average 91-05



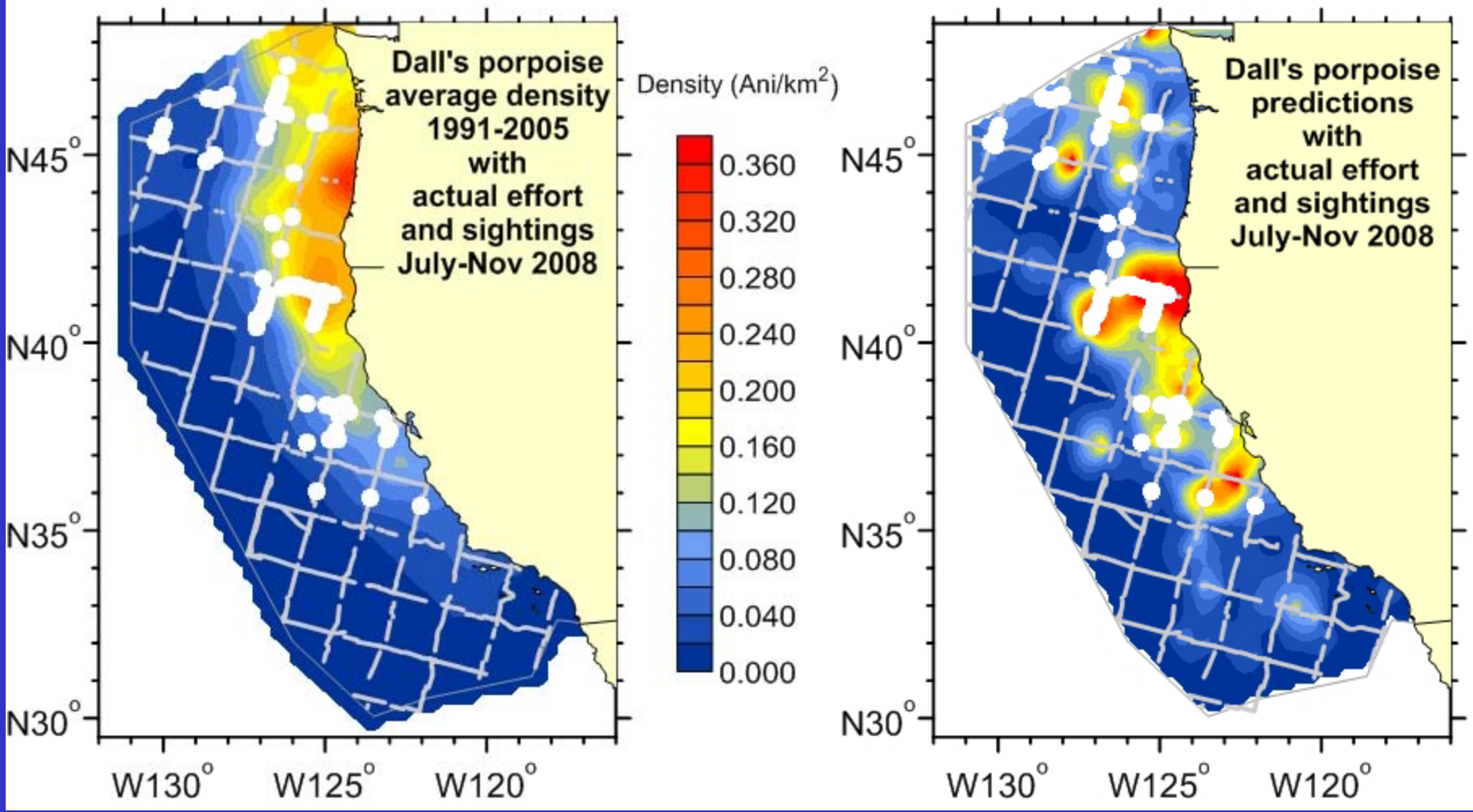


"Daily forecast"



NOWCAST – Dall's porpoise density for entire survey (July-Nov 2008)

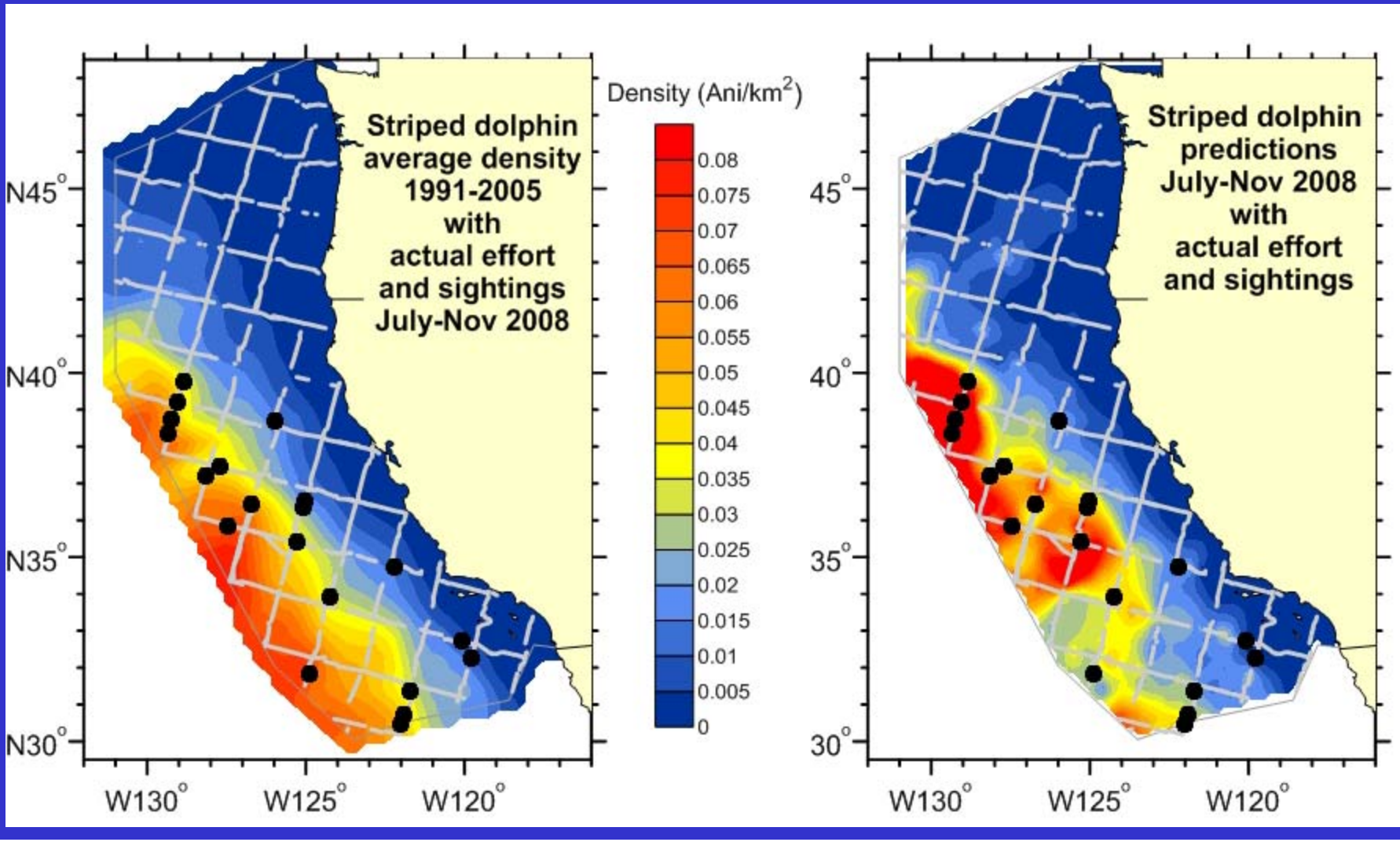
Average 91-05 **"Daily forecast"**



NOWCAST – Striped dolphin density for entire survey (July-Nov 2008)

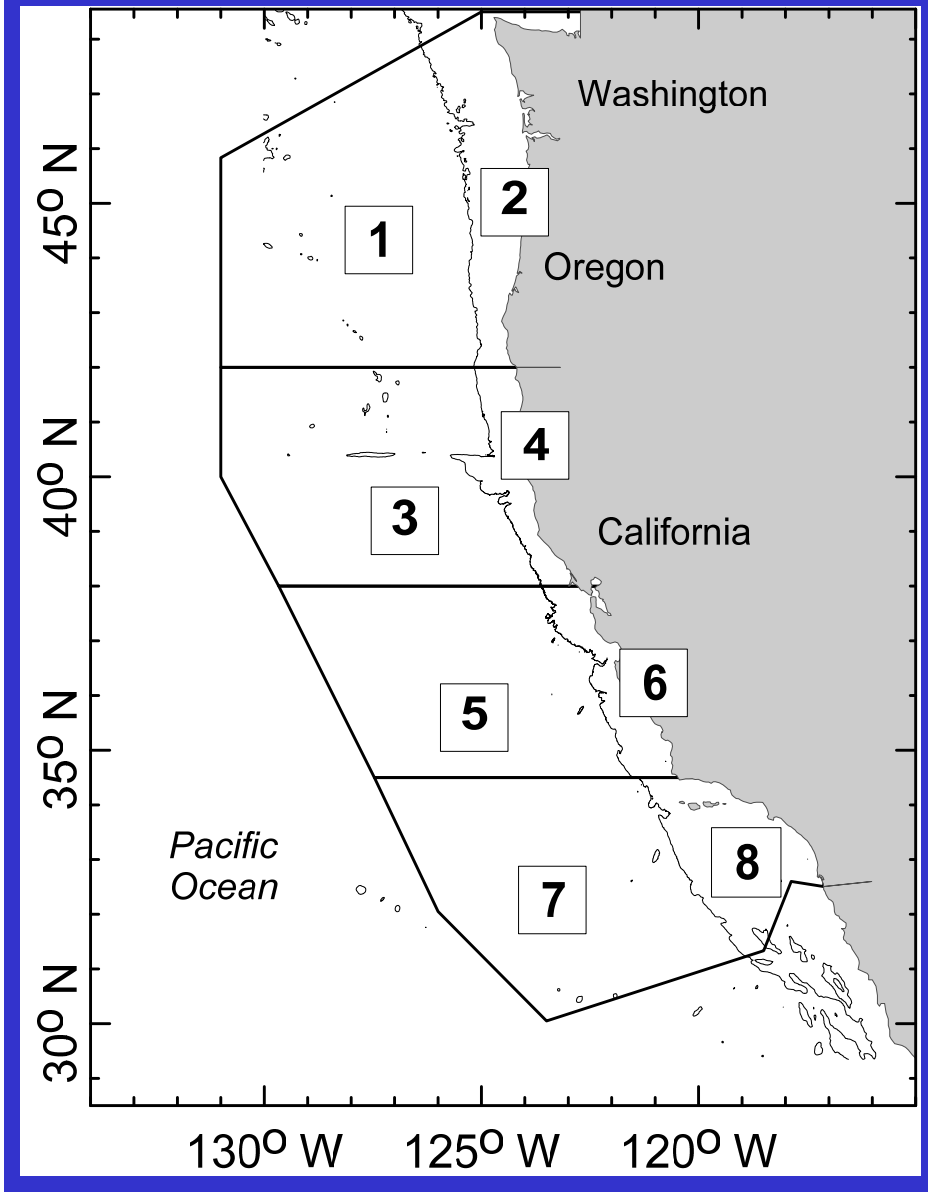
Average 91-05

"Daily forecast"



Spearman rank correlation

Do models capture geographic patterns observed in 2008?



Striped dolphin	**r**
1991-2005 Avg	0.850
Nowcast	0.875

Dall's porpoise	**r**
1991-2005 Avg	0.778
Nowcast	0.766

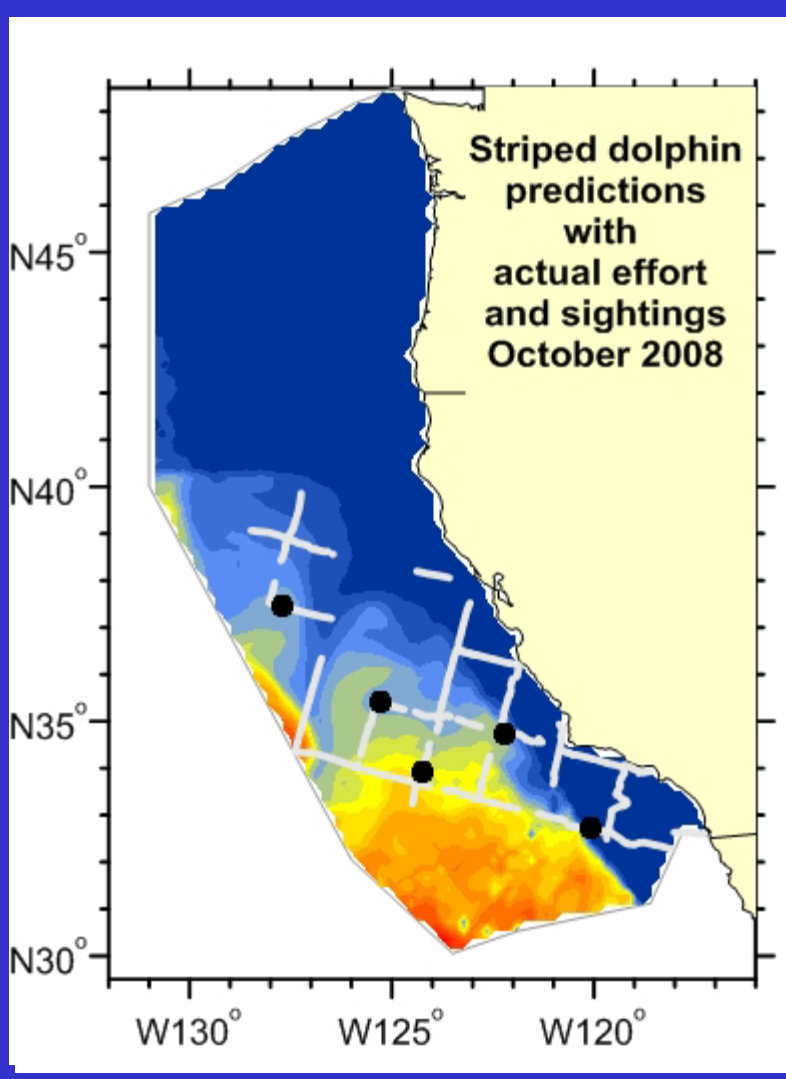
Fin whale	**r**
1991-2005 Avg	0.810
Nowcast	0.905

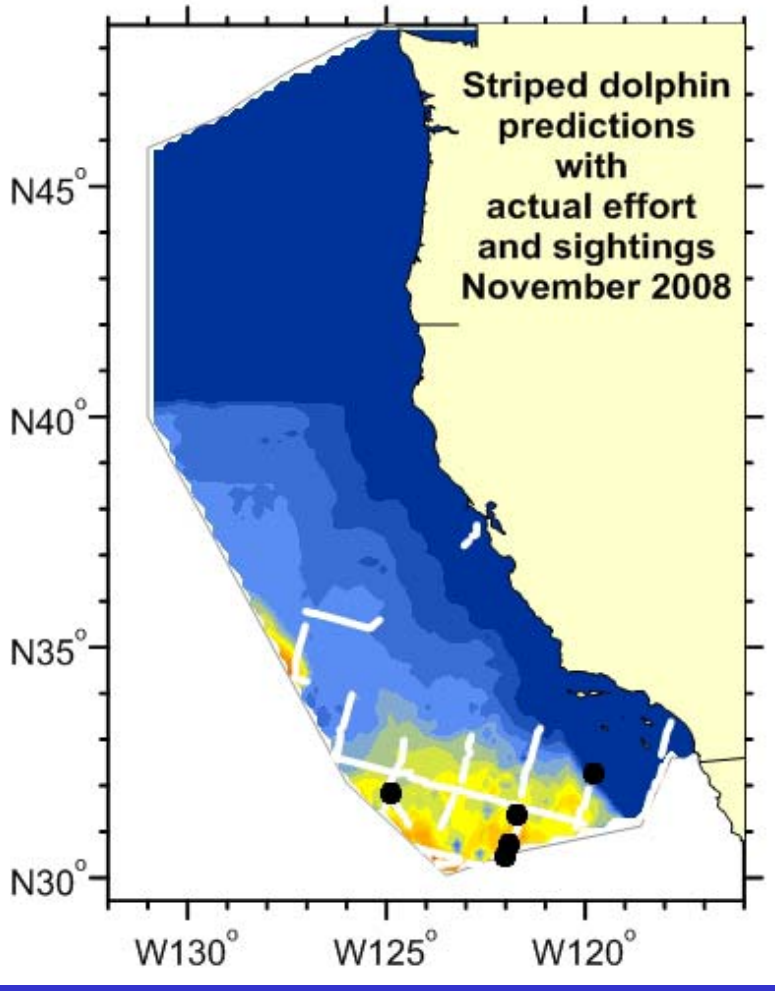
r_{crit} = 0.643

Yes, for both model types.

FORECAST – Striped dolphin density

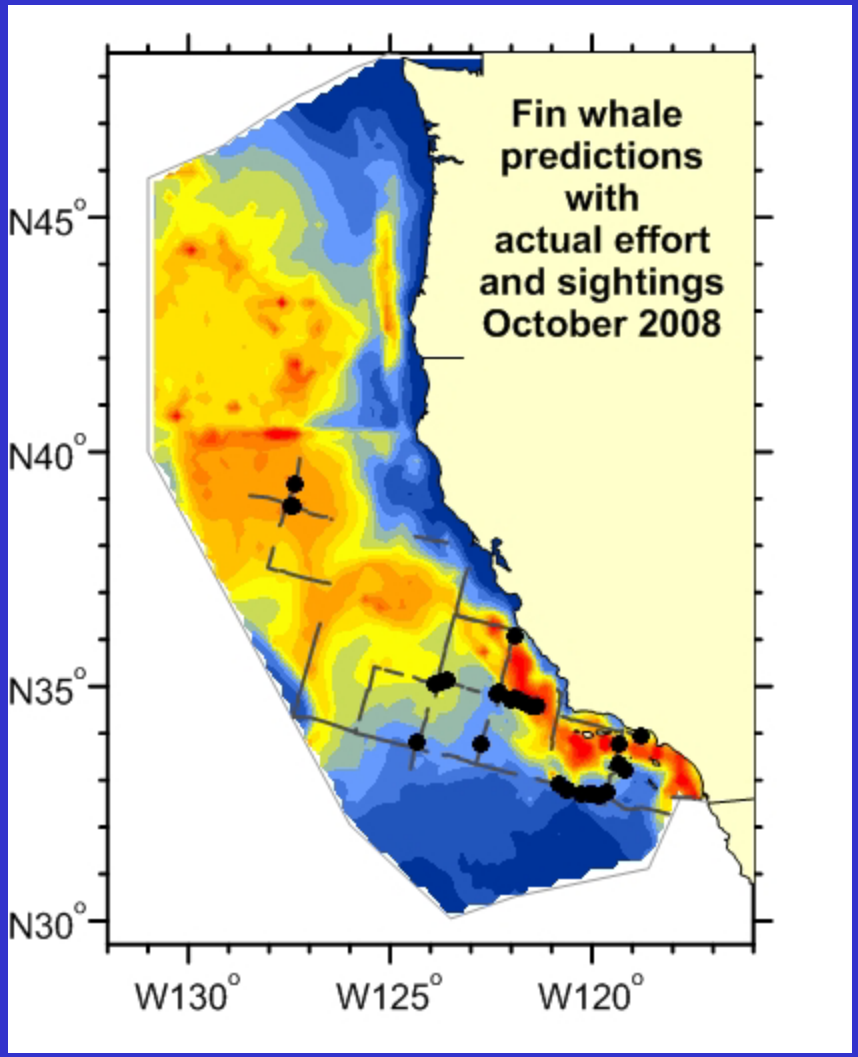
ROMS: July 2008 predictions for Oct/Nov 2008

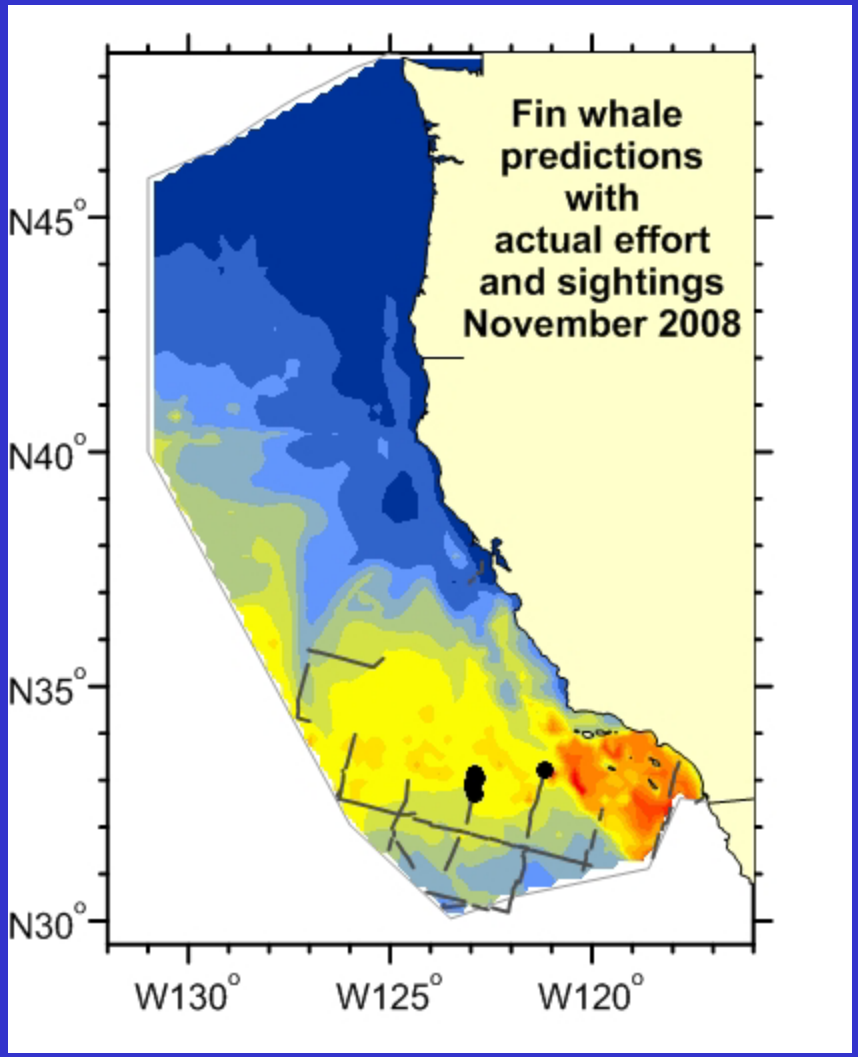




FORECAST – Fin whale density

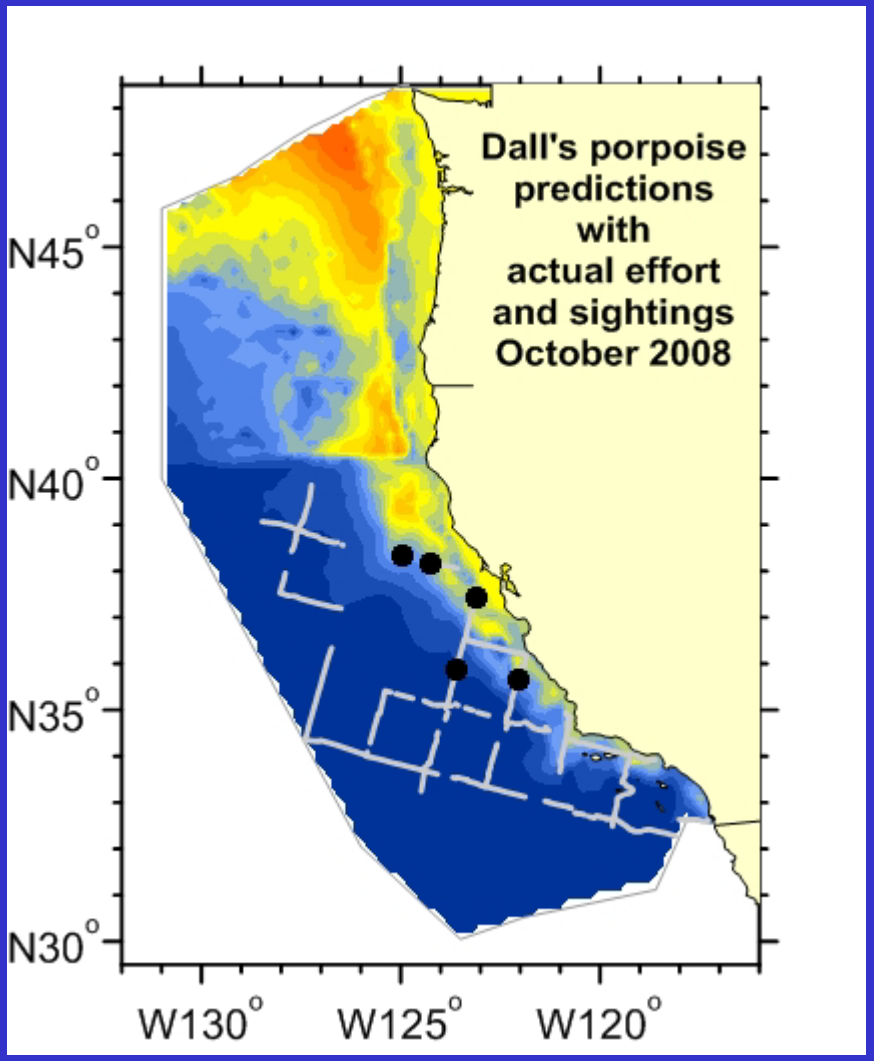
ROMS: July 2008 predictions for Oct/Nov 2008

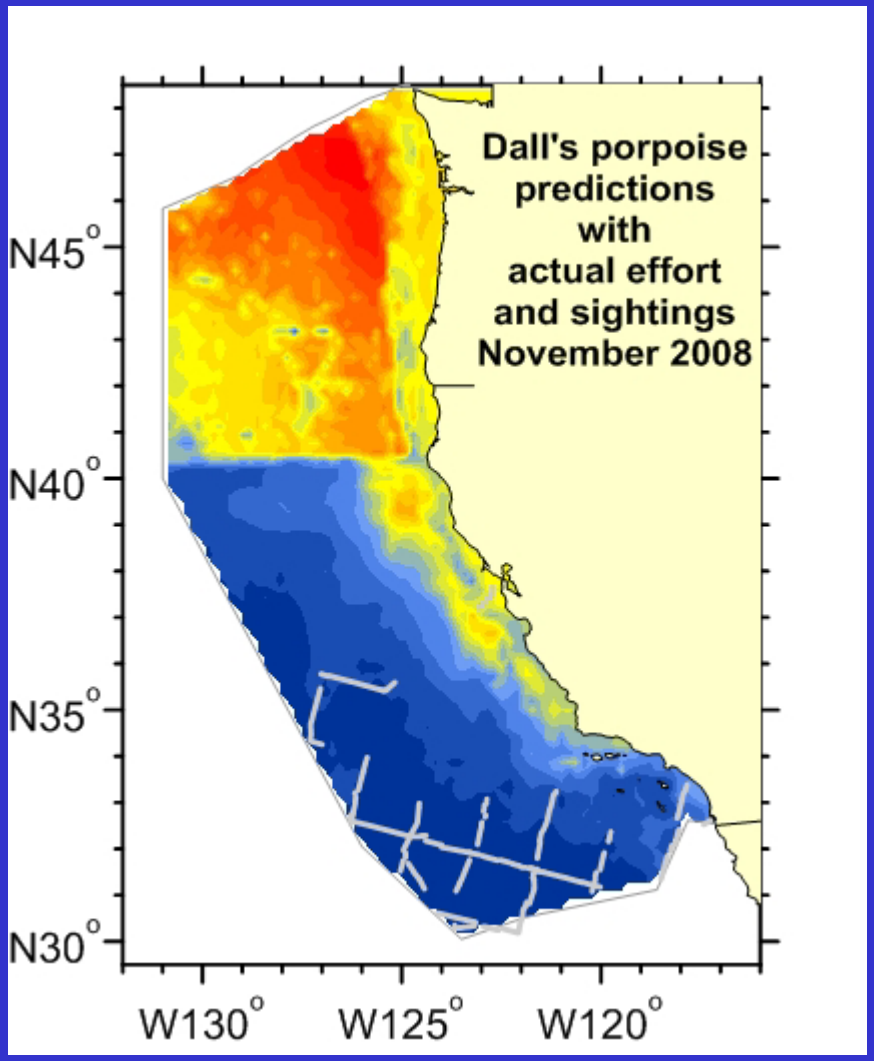




FORECAST – Dall's porpoise density

ROMS: July 2008 predictions for Oct/Nov 2008





“Relative Density” (ER*GS) Comparisons

October 2008

Species	Relative Density			Ratio (survey/predicted)	
	Survey	Average	Forecast	Average	Forecast
Striped dolphin	0.0180	0.0672	0.0385	0.27	**0.47**
Dall’s porpoise	0.0043	0.0241	0.0189	0.18	**0.23**
Fin whale	0.0205	0.0074	0.0115	2.77	**1.78**

November 2008

Species	Relative Density			Ratio (survey/predicted)	
	Survey	Average	Forecast	Average	Forecast
Striped dolphin	0.0217	0.0493	0.0410	0.44	**0.53**
Dall’s porpoise	0	0.0223	0.0118	-	-
Fin whale	0.0133	0.0109	0.0134	1.33	**0.99**

Conclusions

- Results are promising for the three species tested:
  - NOWCASTS possible on time scales of days to weeks
  - FORECASTS possible on time scales of 3-4 months

Next steps

- Expand to other cetacean species
- Include additional satellite-derived variables:
  - Sea surface salinity: Aquarius launched in June 2011
  - CHL, SSH,…
  - Thermocline depth: Derived from SST and SSH
- Include additional ROMS forecast products:
  - CHL, Thermocline depth, Salinity, maybe plankton

Practical Considerations

Satellite Data Products

Recommended website for US west coast:

http://coastwatch.pfeg.noaa.gov/coastwatch/CWBrowser.jsp

Coastwatch:

- Multiple data formats (grid, contour, vector, etc.)
- Multiple data sets (SST, chl, winds, PP, etc.)
- Hindcasts available for most products
- Data access: available via OPeNDAP server (site provides examples of Matlab and R code)
- Links to other browsers for all the world's oceans

Practical Considerations

Why ROMS?

- Used successfully in relevant project (FAST)
- Data products of interest:

  SST, chlorophyll, salinity, mixed layer depth
- Location = study-area specific (Pacific)
- Hindcasts available for most products
- Data access: available via OPeNDAP server for select months off the west coast
- NASA/JPL made data available (we did not fund the modelers!)

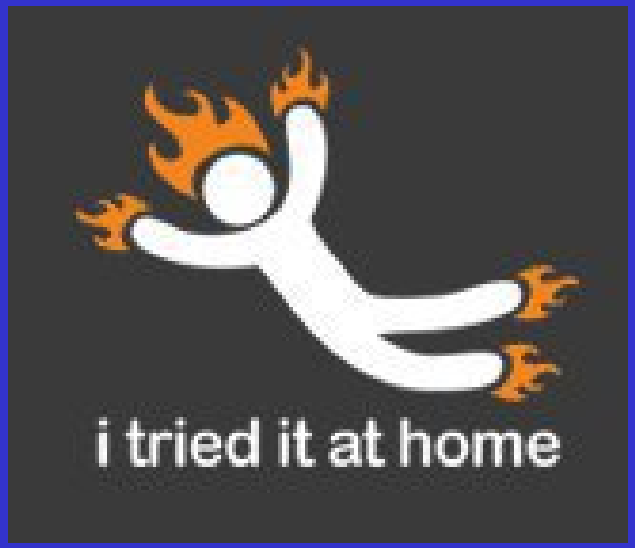
Practical Considerations

ROMS

HOWEVER, requires fairly sophisticated technical and programming knowledge

AND

suggest always having an oceanographer handy!



Practical Considerations

Interdisciplinary Studies

Collaboration/Partnering is KEY!!!

Why you might want to involve an oceanographer

1. **Identifying relevant parameters**
2. **Choosing the best data set**
3. **Getting the data**
4. **Interpreting the results**

Acknowledgements

- Marine mammal observers, oceanographers, chief scientists, cruise leaders, officers and crew of surveys
- Lisa Ballance and Paul Fiedler (Southwest Fisheries Science Center)
- Yi Chao (JPL)
- Megan Ferguson (NOAA/NMML)

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