Modeling Blue Whale Movement Behavior in Relation to Environmental Conditions in the California Current from Satellite Tracking and Remote Sensing

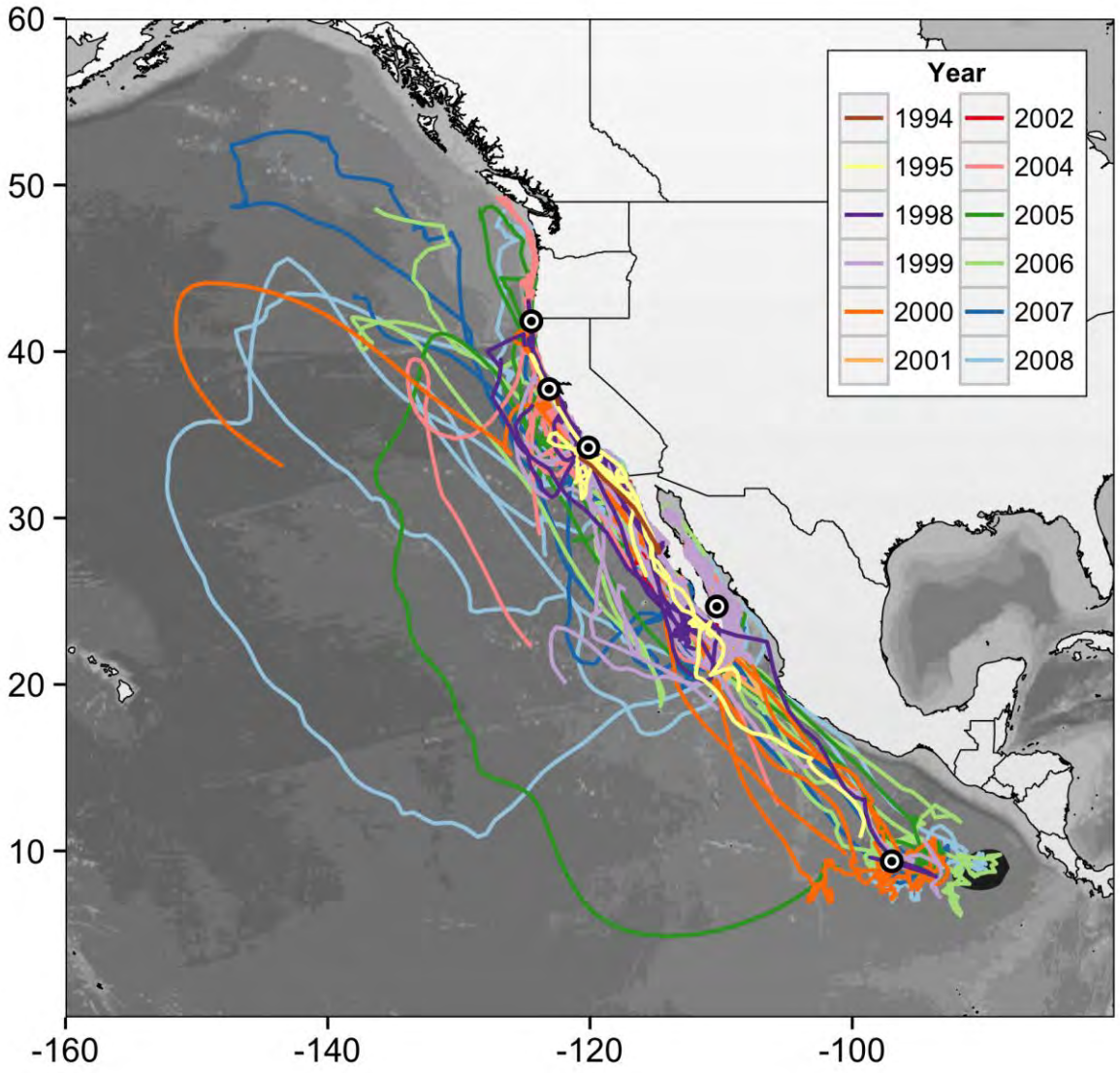
Daniel M. Palacios

Marine Mammal Institute & Fisheries and Wildlife Dept.
Oregon State University

Ladd M. Irvine, Bruce R. Mate, Elliott L. Hazen, Karin A. Forney, Elizabeth A. Becker, Monica L. DeAngelis, Steven J. Bograd and Helen Bailey

S5 (#11220): Understanding our Changing Oceans through Species Distributions and Habitat Models Based on Remotely Sensed Data
Tuesday, November 8, 2016

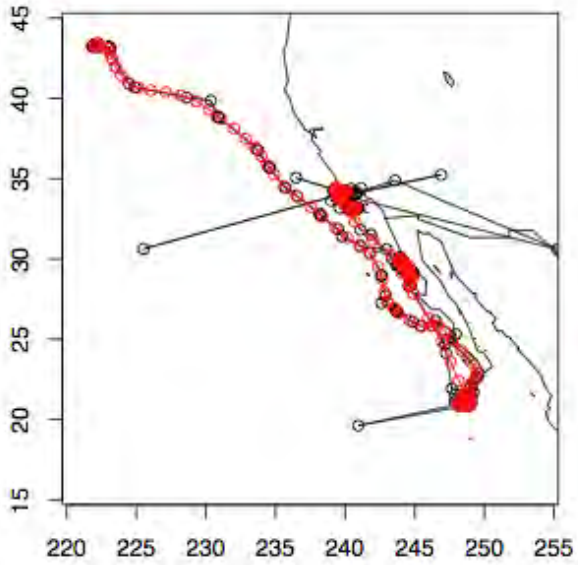
Bruce Mate's blue whale Argos tracks, 1994-2008



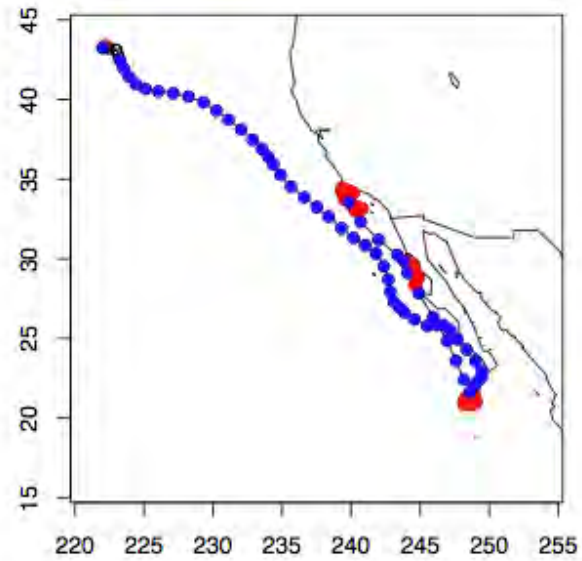
104 tracks [7-505 d]
12 tagging seasons over 16-yr period 1994-2008
No tagging in 3 yrs: 1996, 1997, 2003

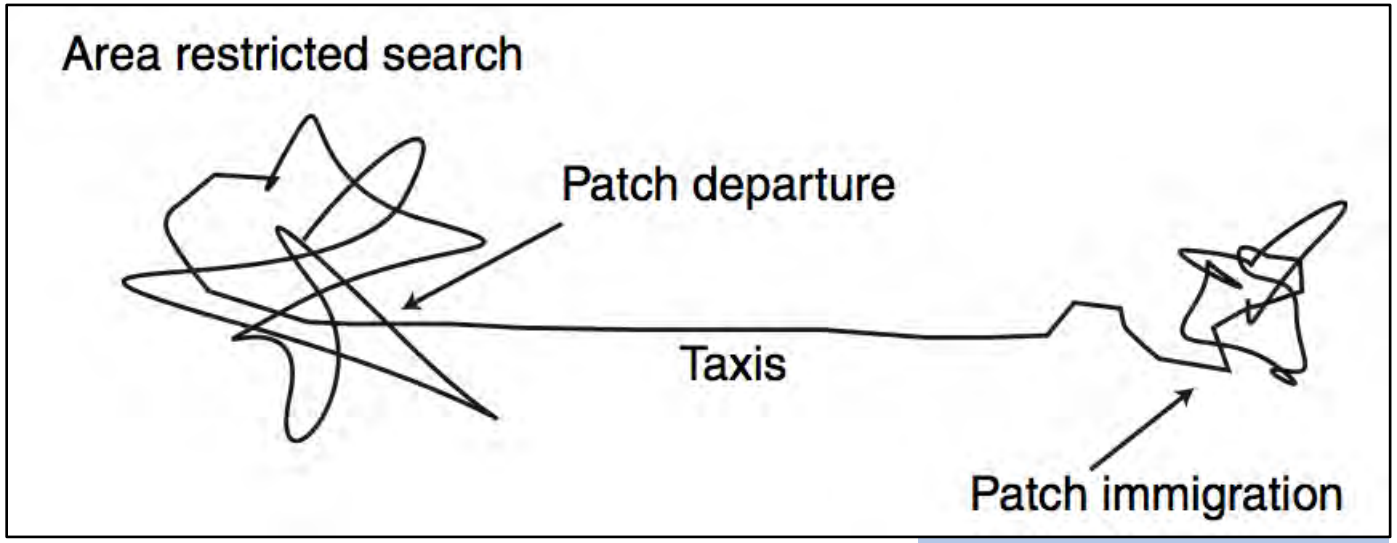
Switching state-space models

Satellite / SSM locations



Transiting, ARS





Schick *et al.*, 2008, *Ecol. Lett.*

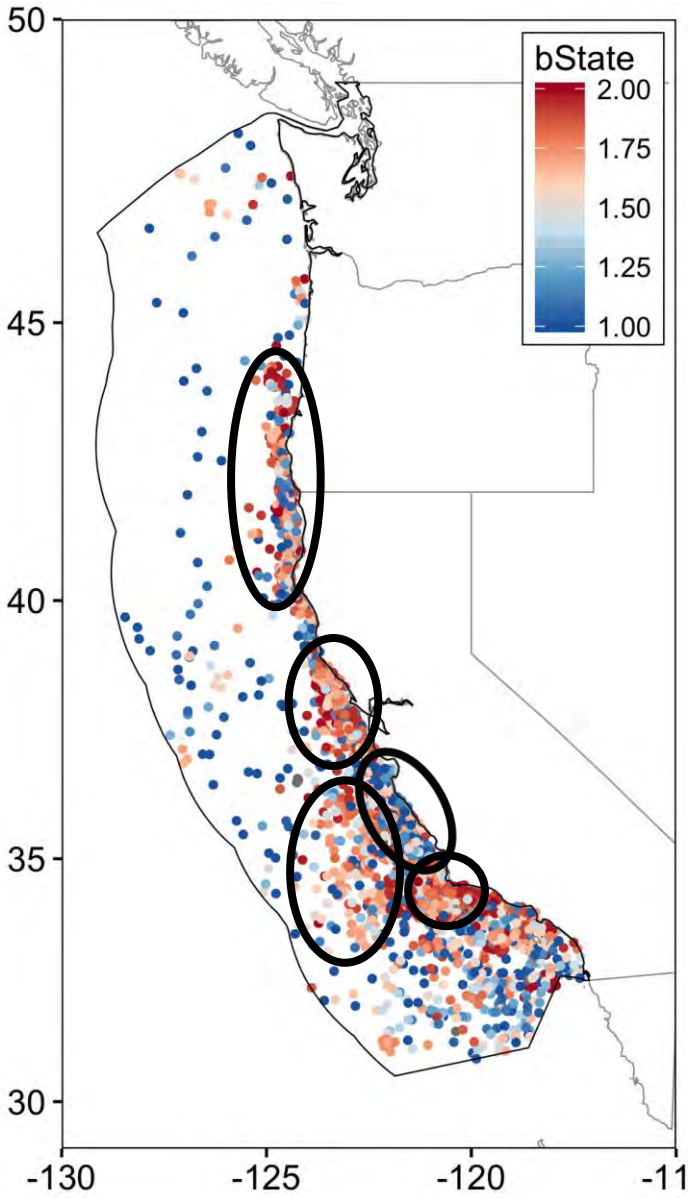
Data gridding for US EEZ

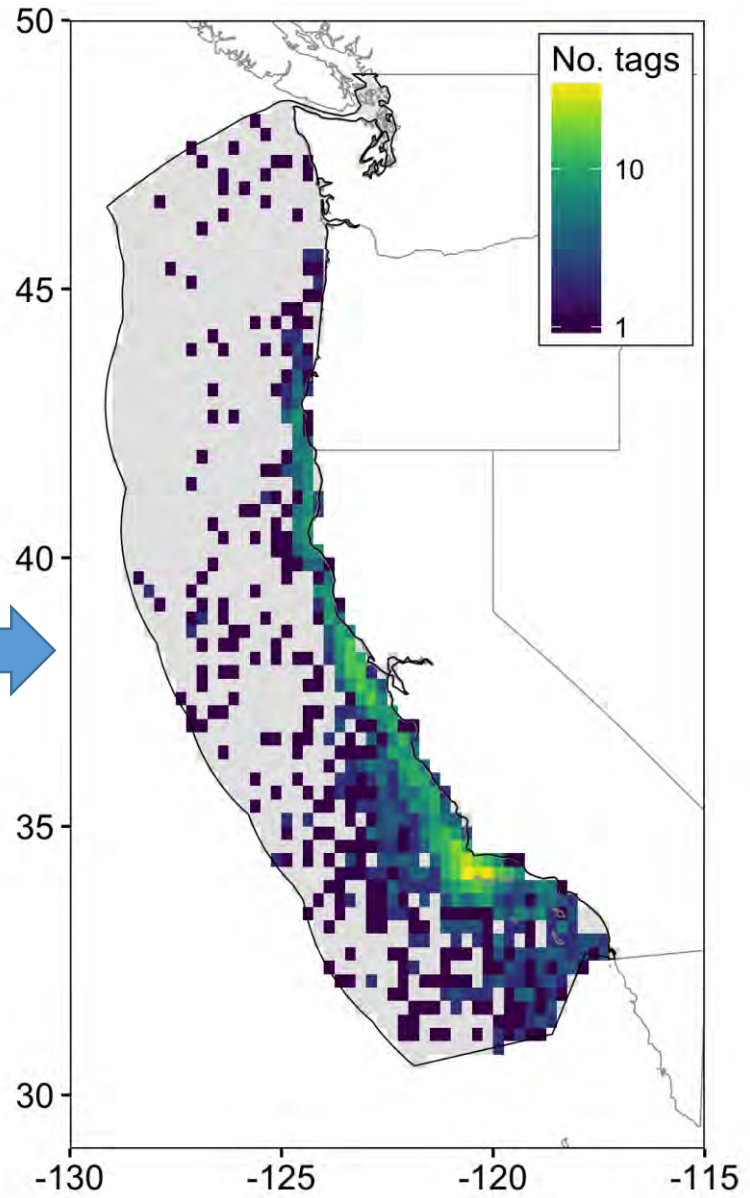
<u>1999-2008</u>
Tracks: 64 whales
Locs: 3,334 w/ bState

<u>Grid: 0.25 x 0.25 deg cells</u>
Cells in EEZ: 1,395
Cells occupied: 538 (39%)

Mean locs/cell: 6.2 [1-189]
Mean tags/cell: 3.2 [1-35]

EEZ area: 825,549 km^2
Occupied: 321,964 km^2

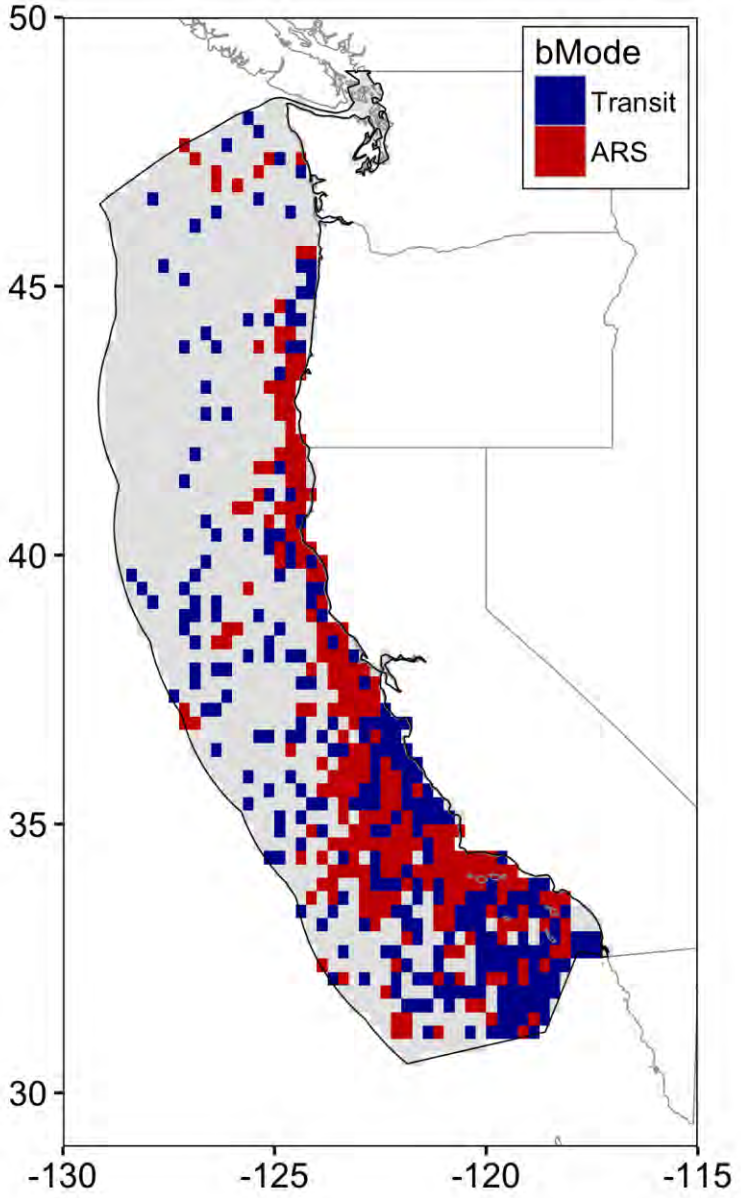




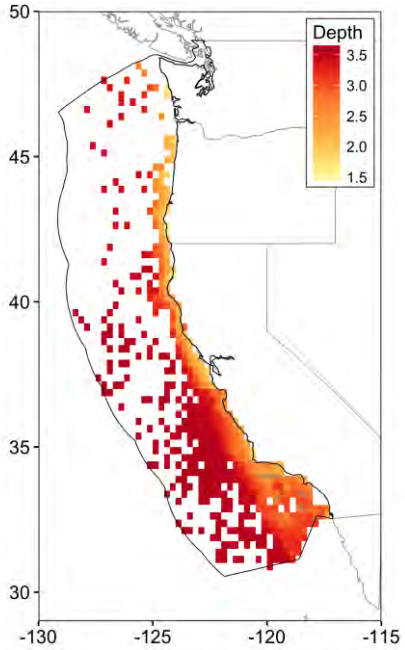
Response variable

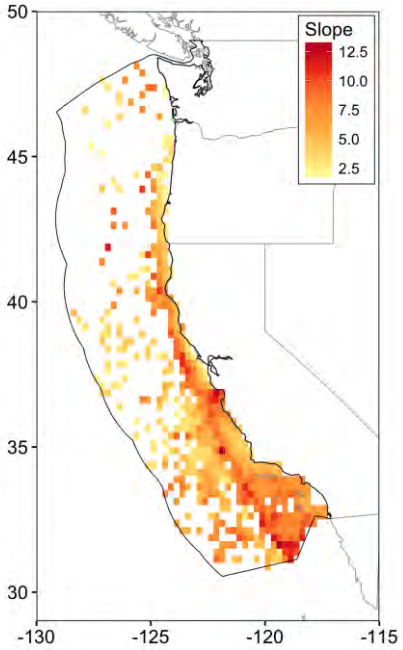
Mean behavioral state → Behavioral mode
Cells occupied: 538
ARS presence: 263 cells (0.49 prevalence)
Transit (ARS absence): 275 cells

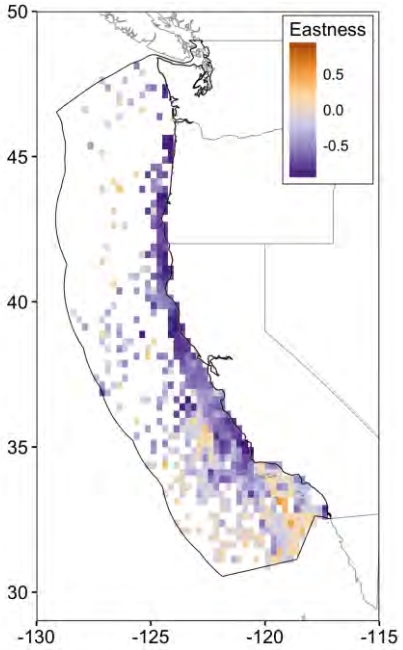
"Given that a cell is occupied, how likely is to be used for ARS behavior?"

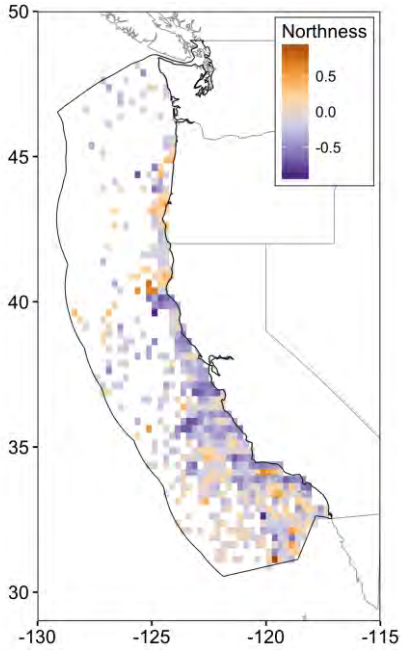


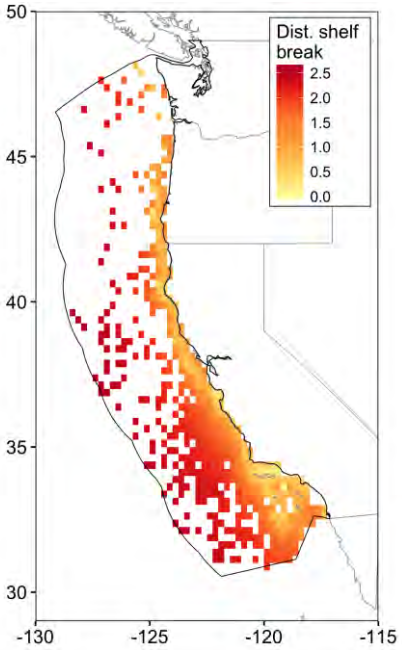
Bathymetric predictors



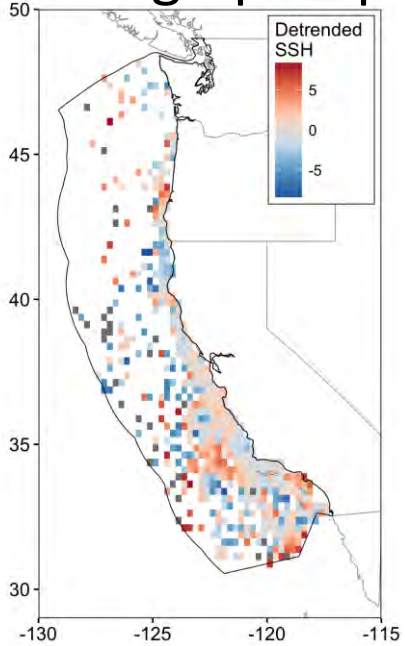


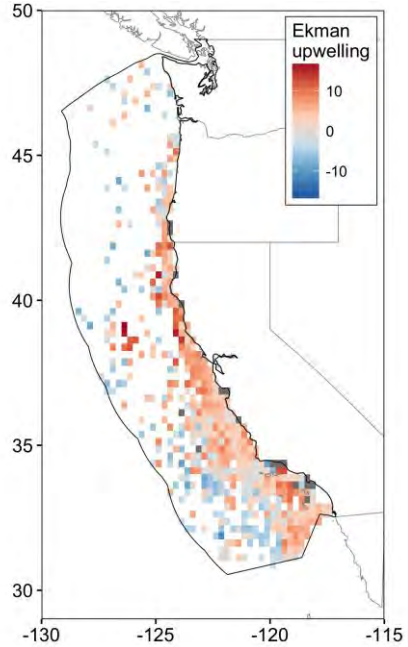


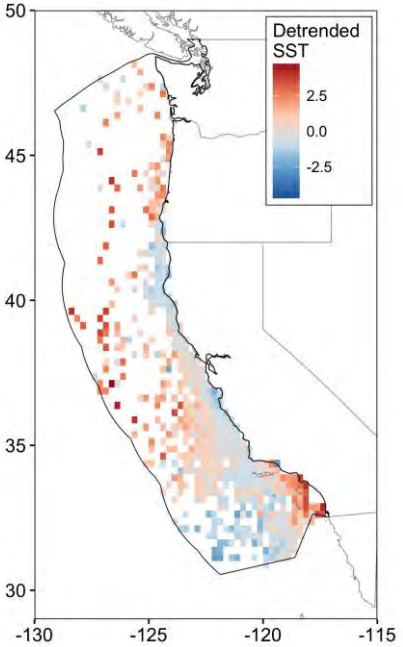


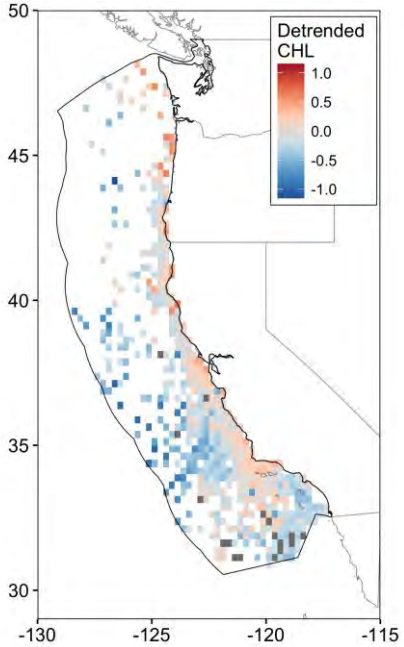


Oceanographic predictors









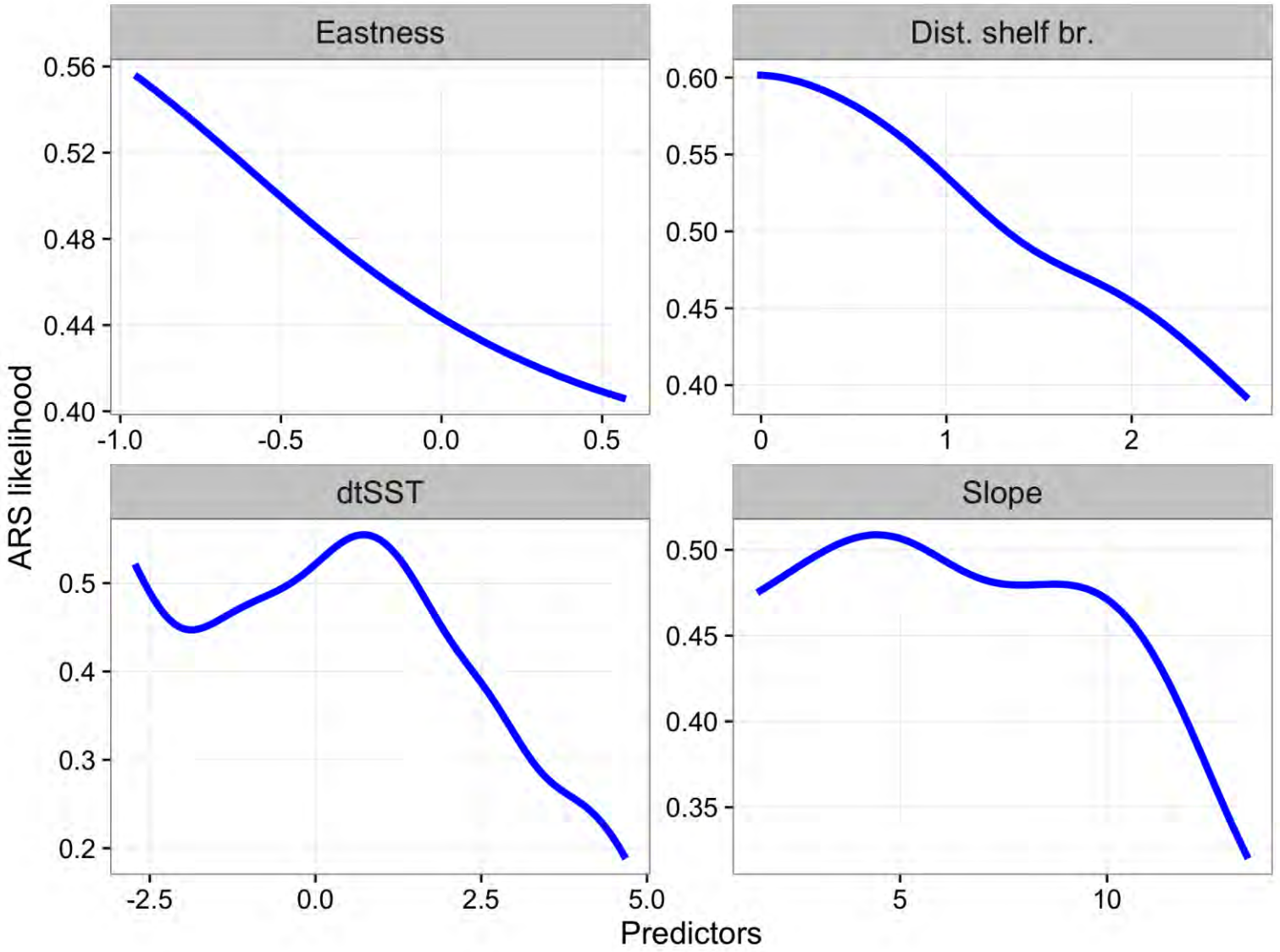
<u>Transformations</u>

- Depth: log10
- Slope: square-root
- Distance to shelf: log10
- CHL: log10
- WEKM: square-root, separately for -/+ values
- Detrend SSH, SST, tCHL w.r.t. latitude

Habitat modeling

- Model: Behavior ~ *f*(Environment)
- Response: presence/absence of ARS (binary)
- Predictors: environmental proxies of krill aggregation
- Method: Nonparametric multiplicative regression in HyperNiche (McCune 2004, 2009)

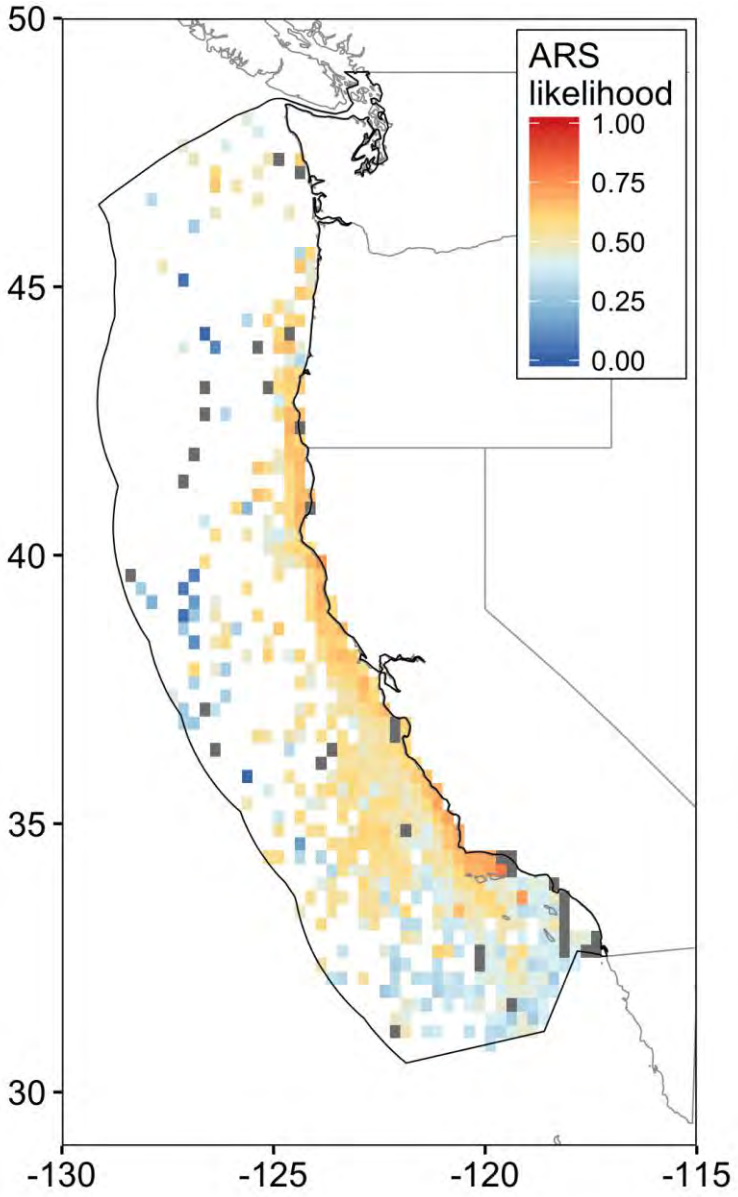
Habitat modeling

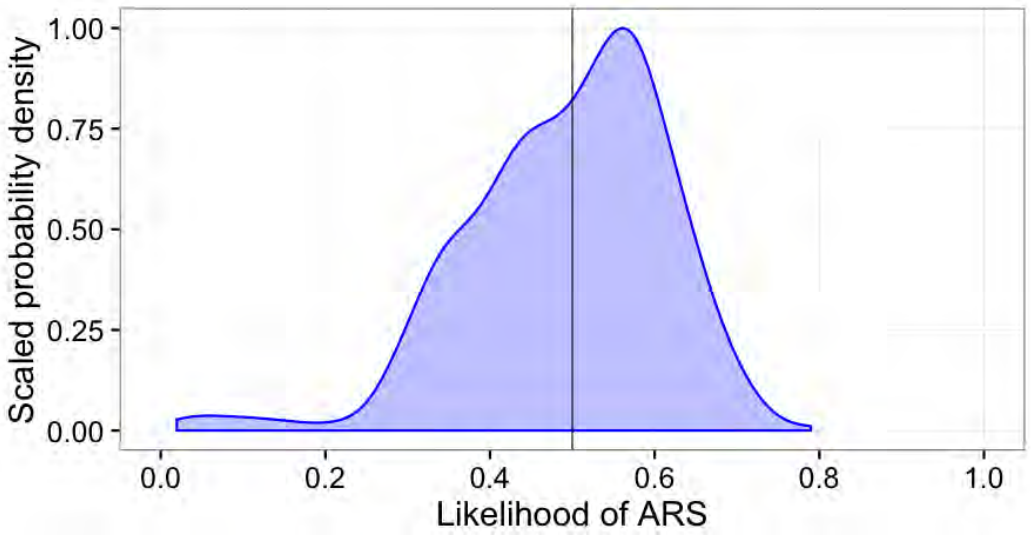


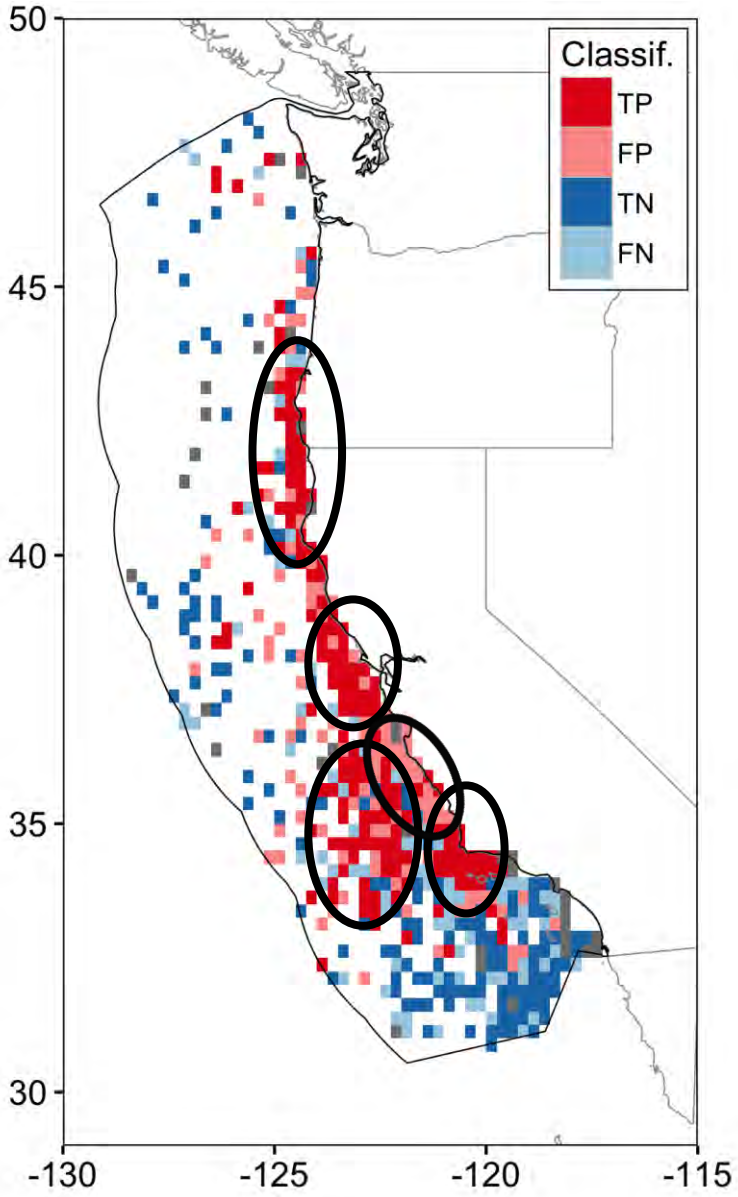
bMode ~ eastness x *slope* x *distShel* x *dtSST*
logB = 8.2, aveB = 1.04, n = 490

Predictors	Tolerance	Sensitivity
Eastness	0.41	0.14
Dist. shelf br.	0.42	0.24
dtSST	0.59	0.62
Slope	1.66	0.25

Model predictions





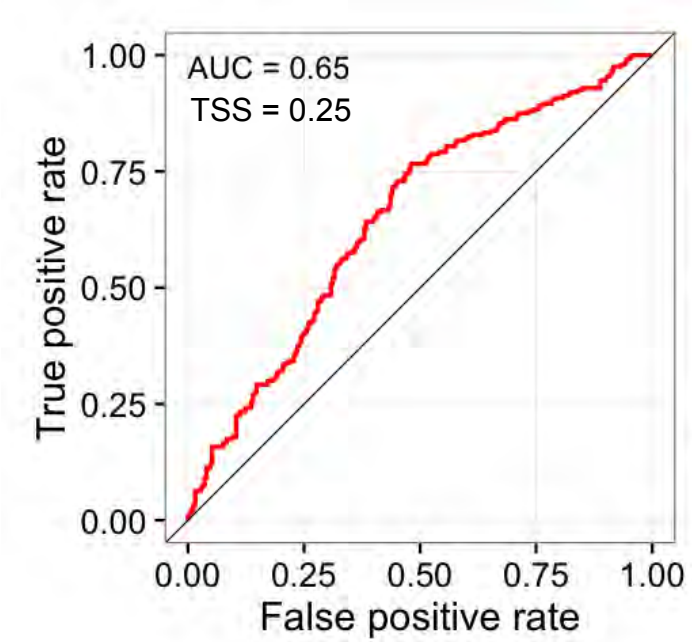


Binary classification statistics

(n = 490; cutoff = 0.5)

	Predictions		
Observations	Absent	Present	Classification error
Absent	147	103	0.41 1-Specificity (FPR)
Present	81	159	0.66 Sensitivity (TPR)

Observed prevalence = 0.49
Predicted prevalence = 0.53



Conclusions

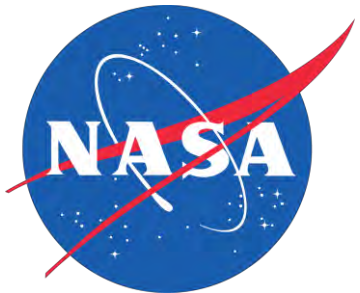
- Behavioral states from 1 loc/day captured the large-scale process of blue whale movement in the CCE during the feeding season
- Spatial and temporal resolution of predictor variables obtained from remote sensing captured relevant oceanographic processes at this scale
- Seasonal binning reduced statistical issues with tagging bias and track autocorrelation but likely led to smearing/smoothing and loss of variability and ‘degrees of freedom’

Conclusions

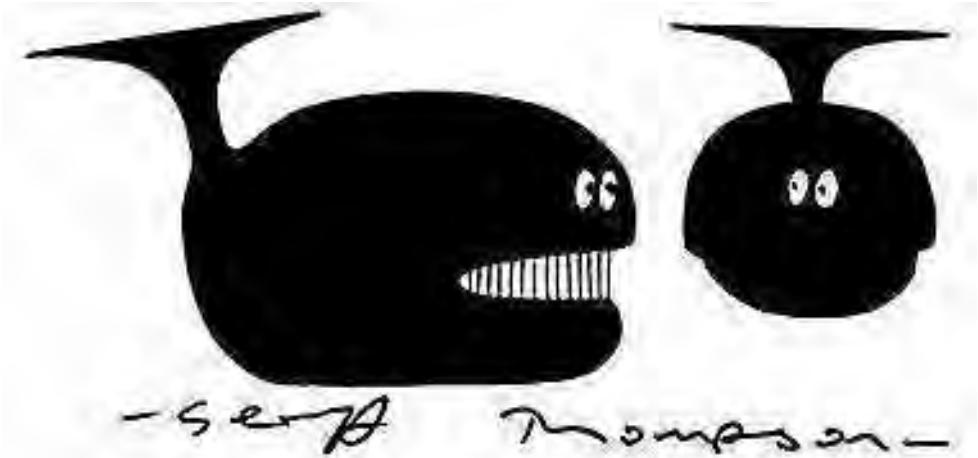
- ARS likelihood was most intense and extensive on the shelf over westward facing slopes, suggesting blue whale behavior responds to terrain, probably through krill aggregation
- Oceanographic conditions associated with highest ARS likelihood corresponded with negative temperature anomalies associated with coastal upwelling centers, as well as with slightly positive temperature anomalies associated with offshore waters
- Responses indicate that blue whales optimize foraging behavior along environmental gradients

Acknowledgments

- Field crews, research, and administrative staff at the MMI
- Satellite data are produced and distributed by NASA, NOAA CoastWatch, and AVISO
- NMFS Permits 841, 369- 1440, and 369-1757
- Tagging of Pacific Pelagics program, the Office of Naval Research, the National Science Foundation, the Alfred P. Sloan Foundation, the Moore Foundation, the Packard Foundation, the National Geographic Society
- Contributions from private donors to the OSU Endowed Marine Mammal Institute
- Interagency NASA Climate and Biological Response Program (Grant No. NNX11AP71G)
- U.S. Navy Pacific Fleet Commander for additional funding
- NAVFAC Pacific & HDR for project/contract management



Thanks!



"Let's move in for the krill."