Cetacean habitat and density modeling

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Review of NOAA Fisheries' Science on Marine Mammals & Turtles
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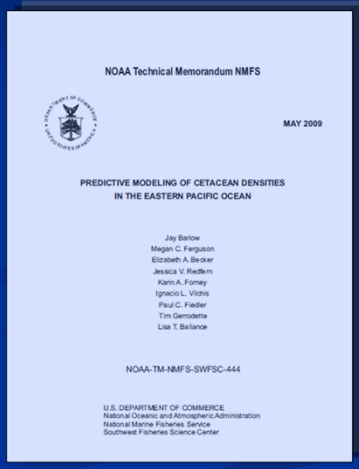
Drawing on collaborative studies by many at SWFSC:

Elizabeth Becker, Megan Ferguson, Jay Barlow, Paul Fiedler, Jessica Redfern, TJ Moore, Lisa Ballance, Tim Gerrodette, Ignacio Vilchis, Dave Foley

Peer-reviewed publications:

- Barlow et al. 2009 *(numerous projects)* *NOAA Tech Memo NMFS-SWFSC-444*
- Forney 2000, *Conservation Biology*
- Ferguson et al. 2006, Ecol. Modelling
- Redfern et al. 2006, *MEPS (modeling review)*
- Becker 2007, *PhD Diss., UC Santa Barbara*
- Redfern et al. 2008, *MEPS*
- Becker et al. 2010, *MEPS*
- Becker et al. 2012, *ESR Special Issue*
- Forney et al. 2012, *ESR Special Issue*
- Redfern et al. 2013, *Conservation Biology*
- Becker et al. 2014, *ESR Special Issue*
- Forney et al. 2015, *ESR Special Issue*


NOAA Technical Memorandum NMFS

MAY 2009

PREDICTIVE MODELING OF CETACEAN DENSITIES IN THE EASTERN PACIFIC OCEAN

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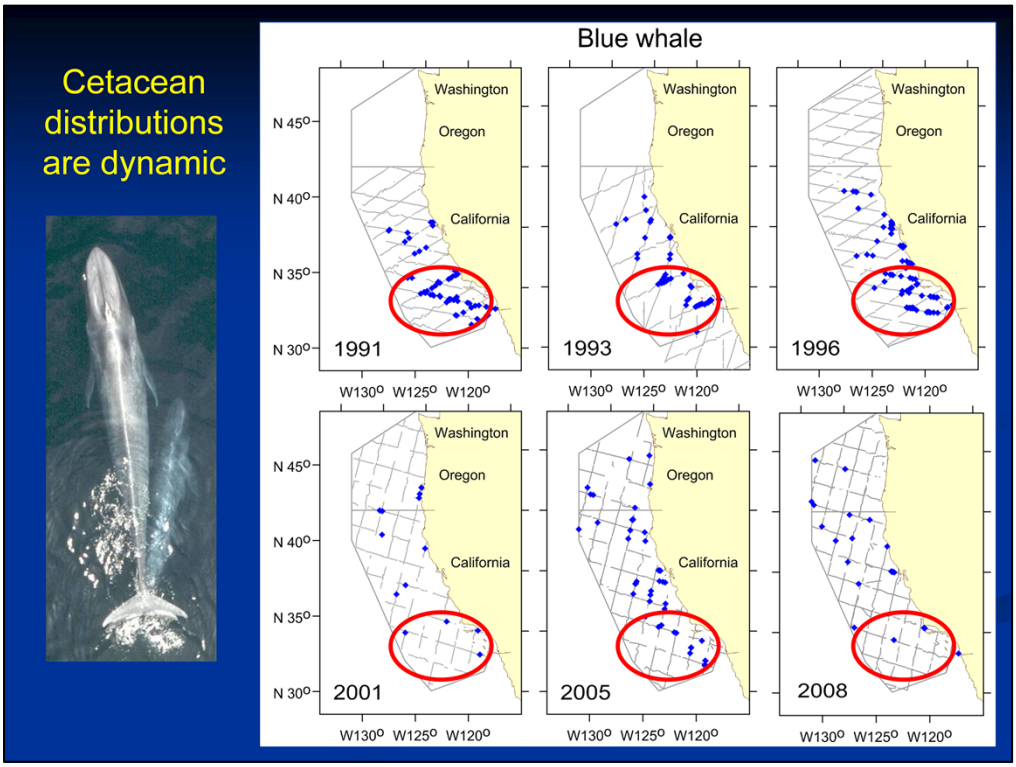
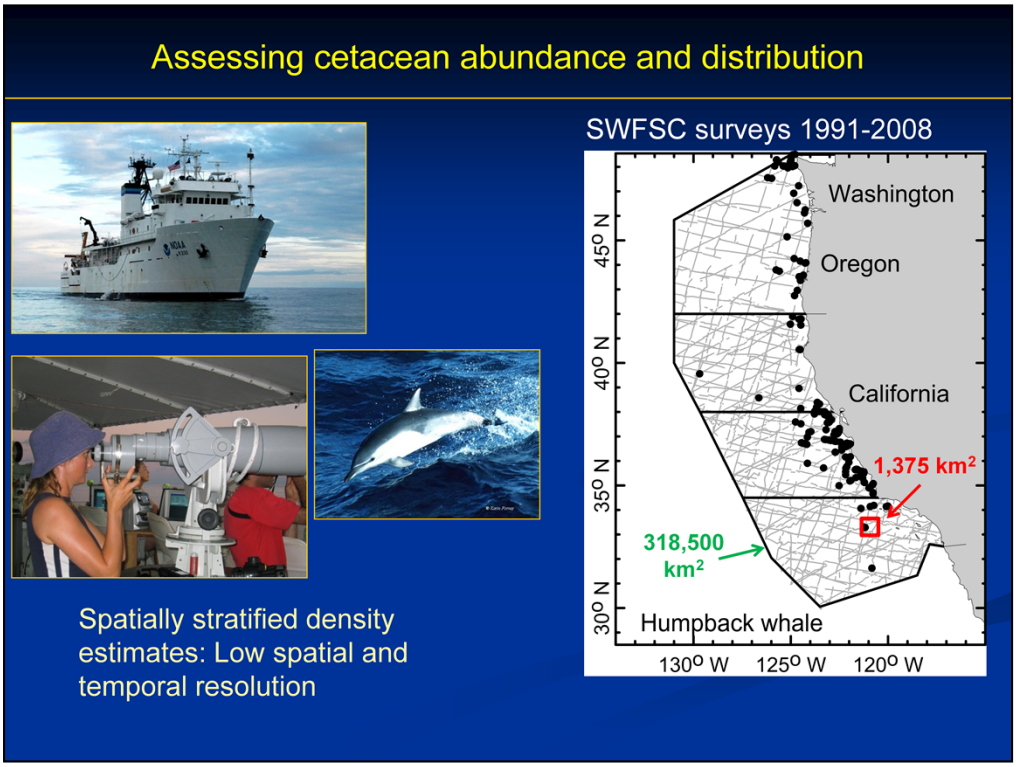
U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

The work I will be presenting has been conducted by a team of SWFSC scientists, working together on two modeling projects funded by SERDP and NASA, respectively. Some key publications are shown here.

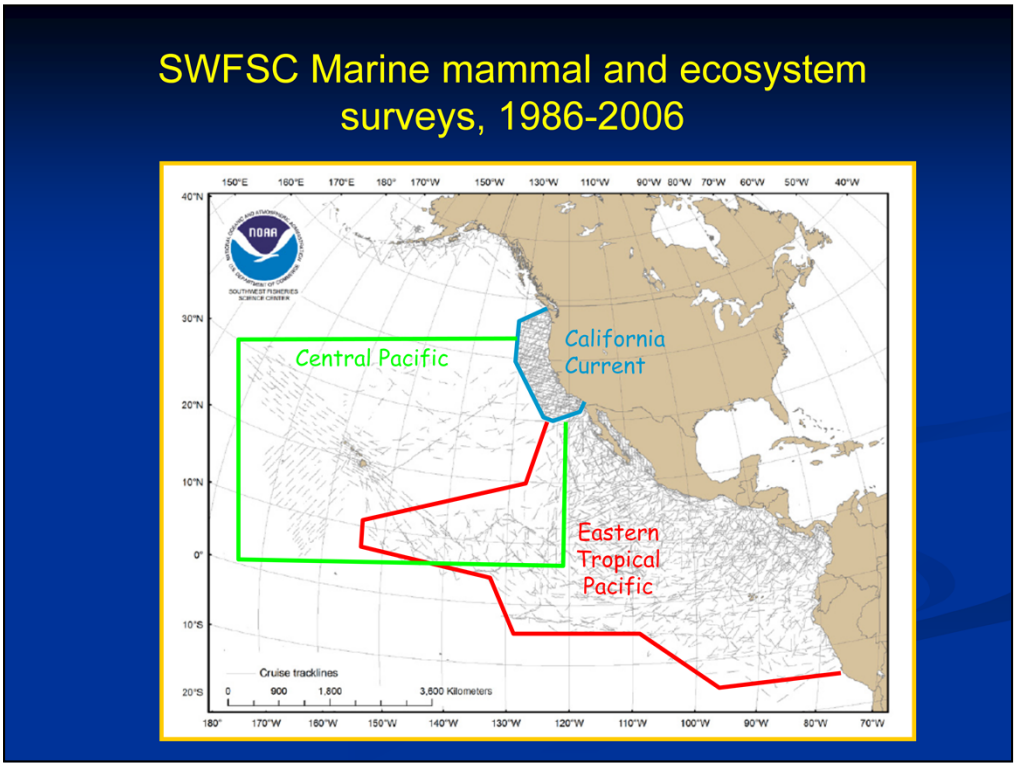


Why do we need habitat models of cetacean density?

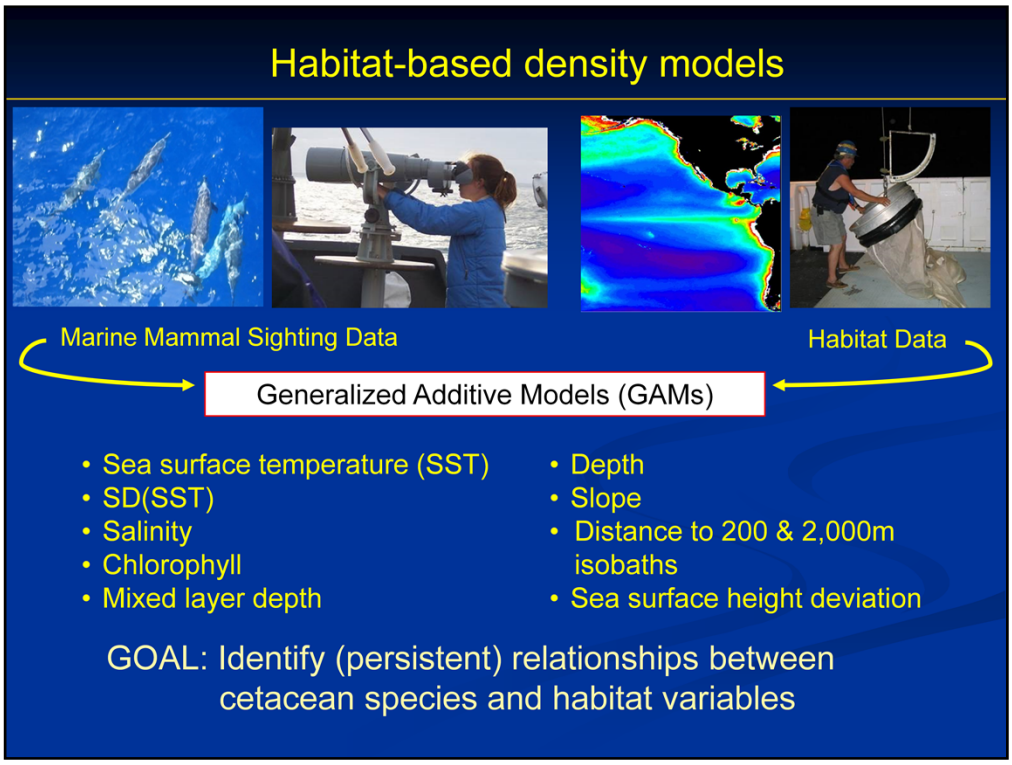
- Cetacean distributions are dynamic
- Movement in and out of our California Current Ecosystem (CCE) study area can confound abundance estimation and the detection of trends, as with these blue whale results. Estimated abundance off the U.S. West Coast was much greater during the 1990s than during the 2000s, but this appears to have been caused by changes in distribution of blue whales during summer/fall (not a true change in population size)
- Habitat-based models can help us understand these changes and place animal distribution / density into an ecosystem context.



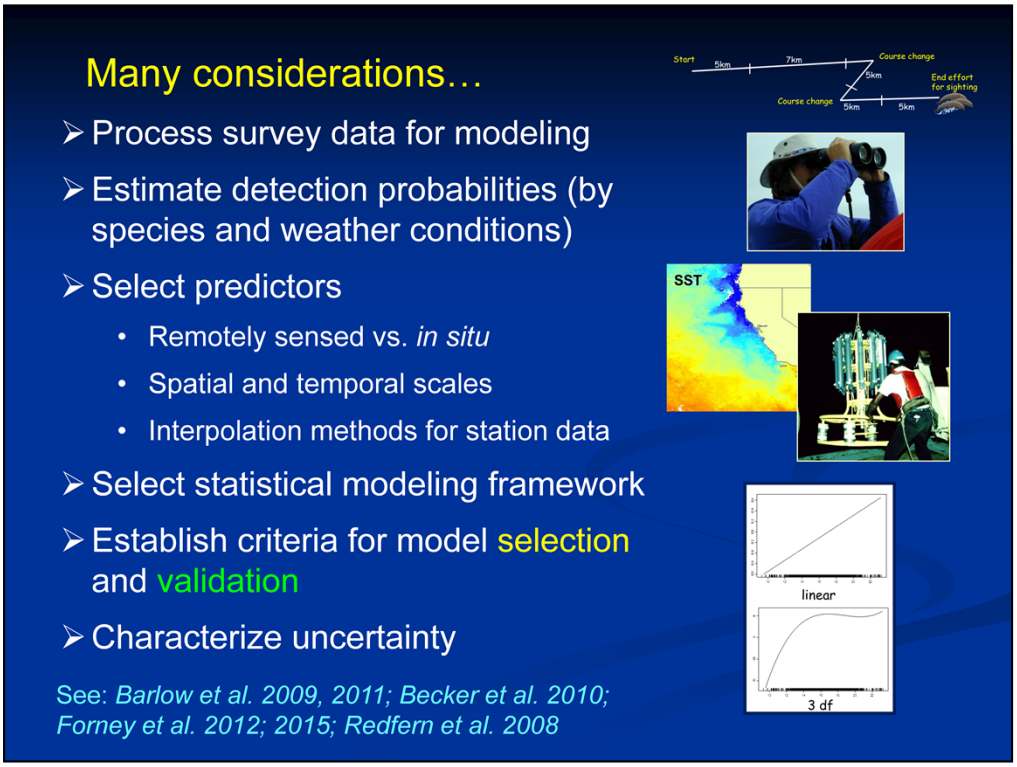
To illustrate further, the map shows our survey coverage for 1991-2008, with humpback whale sightings. For abundance estimation, we stratified into four geographic strata because of habitat differences and heterogeneity in survey coverage. The individual strata, however, are still too large to reliably assess impacts in smaller areas, such as shown (hypothetically) in red. Habitat-based density models allow us to further resolve spatial patterns at finer scales.



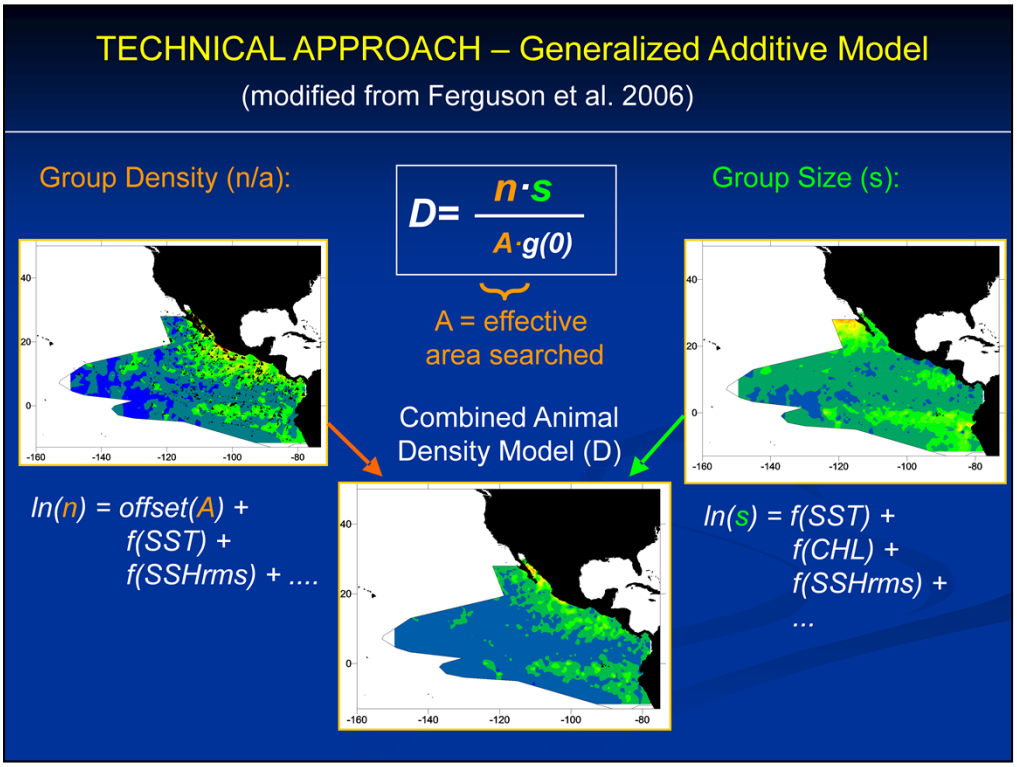
The foundation of our models is this extensive survey data set, covering broad areas of the eastern Pacific Ocean. We have developed models for the three regions shown here, but I will focus on the California Current Ecosystem today.



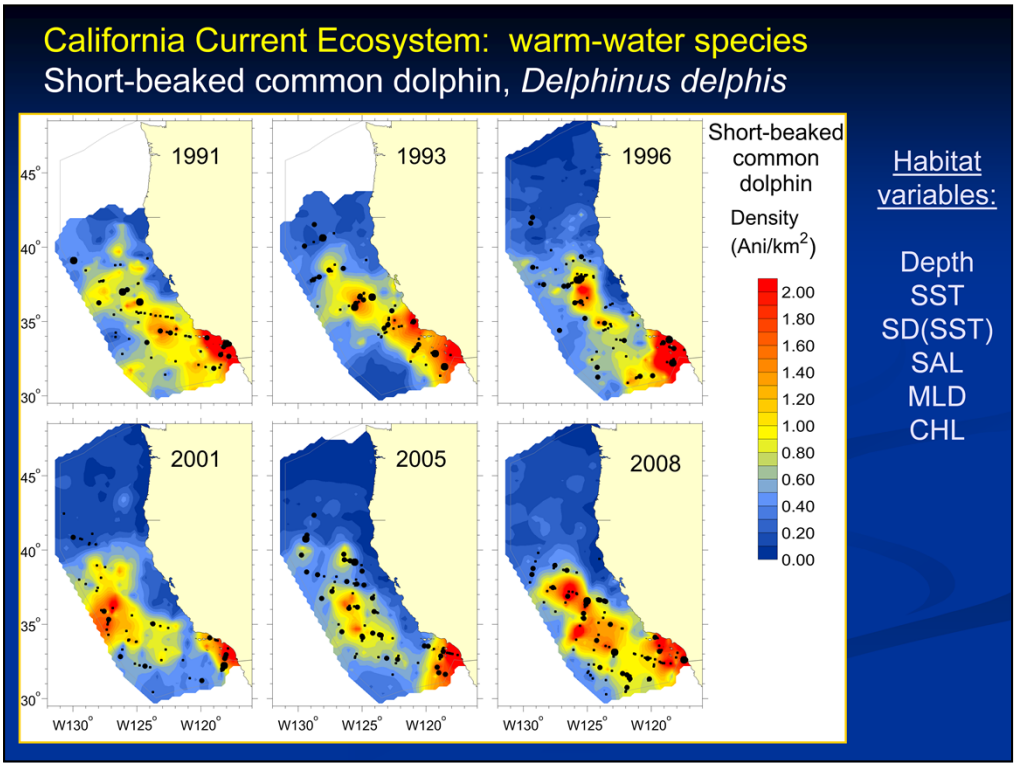
The general approach for developing habitat-based density models involves combining the marine mammal sighting data with habitat data derived from in-situ and remotely sensed sources. After considering several methods, we decided to use GAMS to develop these models.



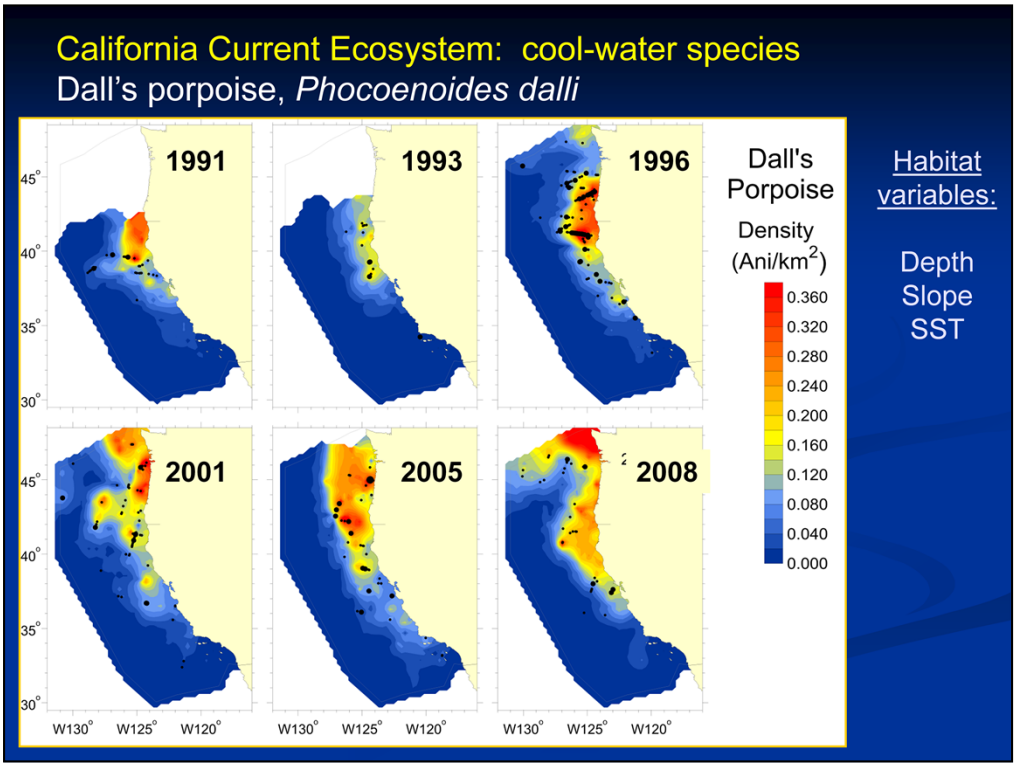
In addition to the modeling method, we considered and evaluated many other analytical choices (details can be found in the references shown at the bottom of this slide). In particular, the model validation step is critical for establishing robust models, and uncertainty estimation is very important for management.



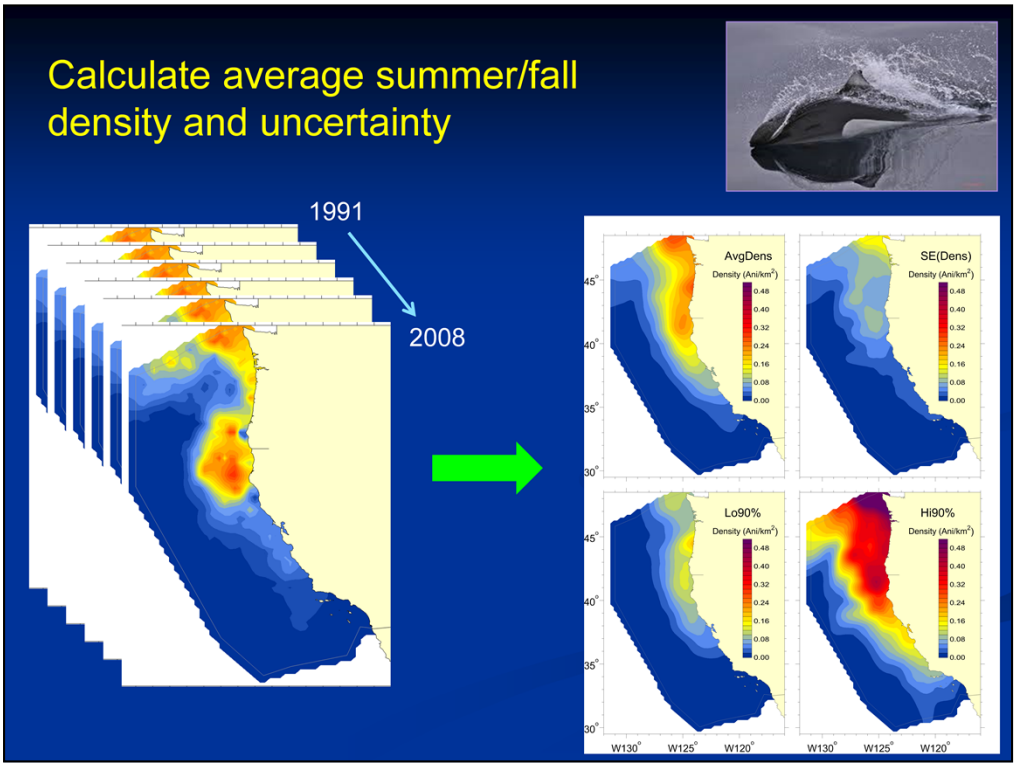
The technical approach varied slightly by species and region, but generally involved building separate models for encounters of animal groups and mean group size. The area effectively searched (based on transect segment length and detection distances for different species and viewing conditions) is included as an offset. These two models are then combined within a line-transect framework to estimate animal density at each location within the study area.



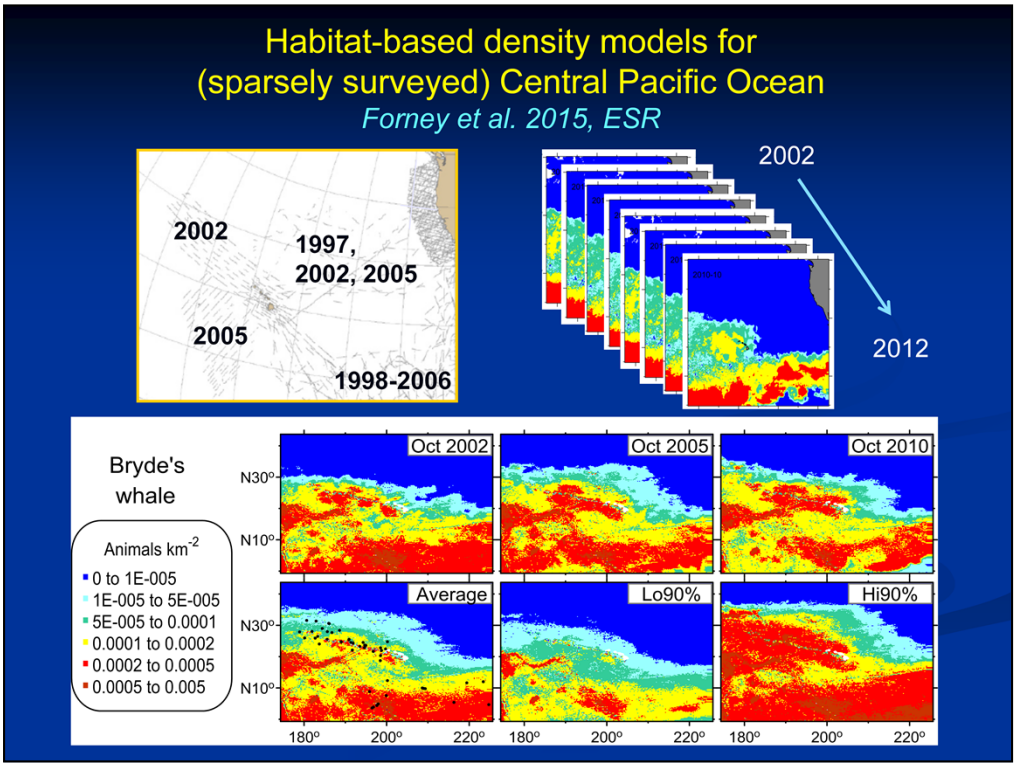
This shows an example of yearly predictions from a habitat-based density model for a warm-water species within the CCE for our 1991-2008 surveys. Warm colors indicate areas with high density and blue shades represent low density. Sightings are shown with black dots. We see that the habitat-based model captures interannual variability in the distribution of this species.



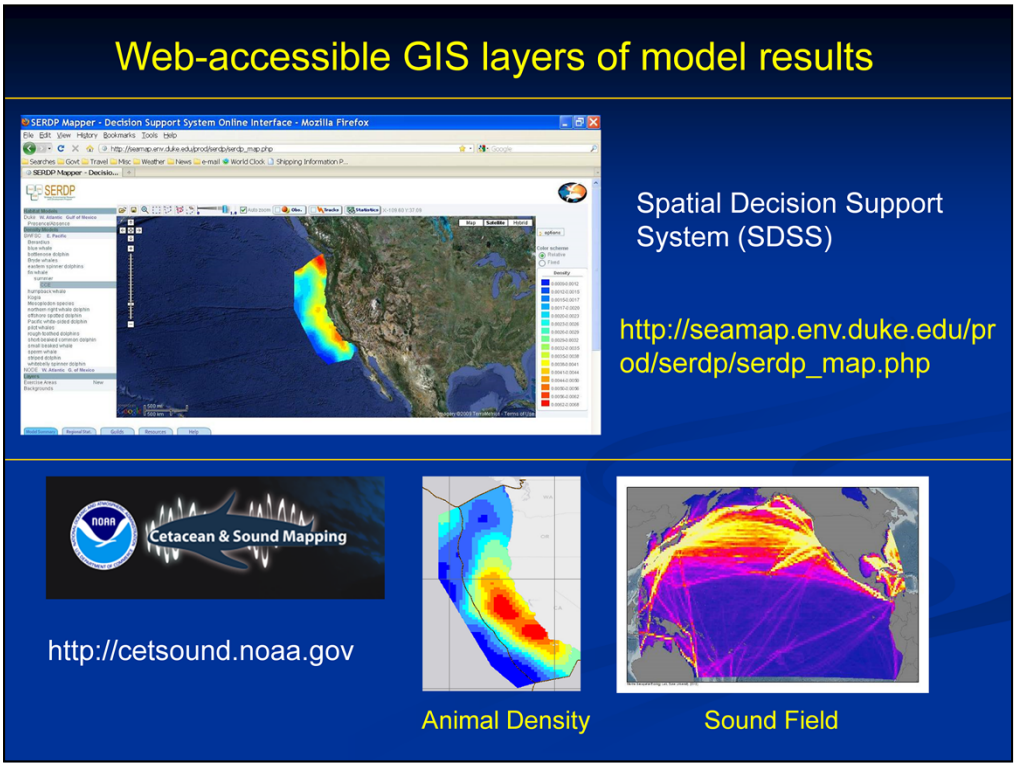
Similar plot for a cool-water species, Dall's porpoise. This is a species for which our annual line-transect densities are quite variable. This appears to be caused by differences in the amount and distribution of (cool-water) porpoise habitat.



Interannual habitat differences were found to be a much greater source of variation in density than statistical uncertainty (parameter estimates or model structure). For this reason, the uncertainty in multi-year average densities is estimated from the annual density surfaces. Average, standard error, and 90% confidence limits are provided for each density map.



The habitat-based density modeling framework also allowed us to estimate cetacean density for 9 species within the sparsely surveyed region of the Central North Pacific, where the U.S. Navy has a need to assess impacts of their training activities. These models are spatially coarser because of the much larger study area, but allow us to combine data across surveys to estimate average densities and uncertainty therein. In this case, uncertainty was estimated using model-averaging and a jackknife procedure, because there is much less interannual variation within the central North Pacific.



Our model results have been made available for download as GIS layers at two different web sites, including the national NOAA Cetacean and Sound Mapping Project, which compiled the best available information on cetacean occurrence and densities for all US EEZs. Habitat-based densities, such as those provided by our models, represented the highest-quality information within this national database.

End-user applications of SWFSC habitat-based density models

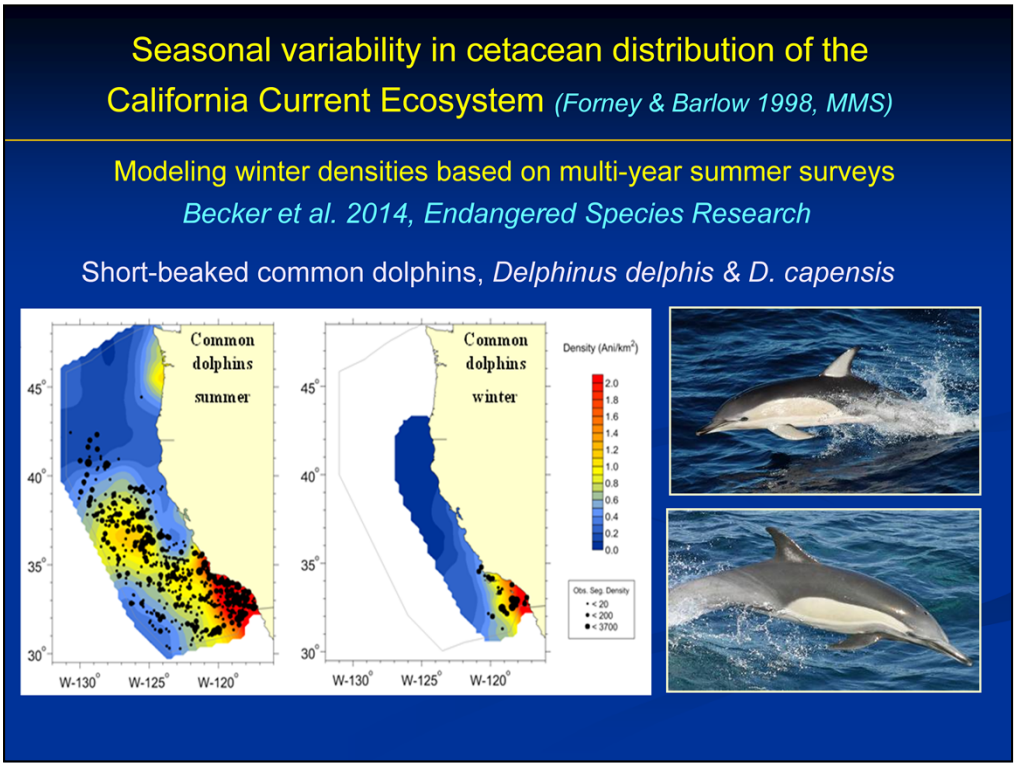
1. Fine-scale distribution, density, and abundance data for EIR preparation (U.S. Navy, marine renewable energy projects, seismic surveys, etc.)
2. Examining overlap between cetaceans and U.S. West Coast fisheries *(Saez et al. 2013; Feist et al. 2015)*

Summer/fall models – what about winter/spring?

We are aware of several projects/management applications that have used these layers.

In particular, the layers have been used in Environmental Impact Report preparation for a variety of projects, and there have been two publications that examined overlap between cetaceans and fisheries.

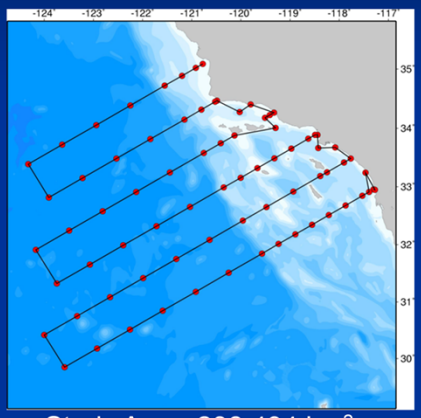
However, one caveat is that these models are only for summer/fall and there is also a need for information for winter/spring.



To address this need we have taken two approaches. The first was a paper published last year that examined whether the interannual variation in summer/fall conditions can be used to approximate winter/spring patterns using habitat-based density models. We used a winter/spring aerial survey data set within 100-150 km of the coast to evaluate performance of these models for 4 species. Initial results were encouraging, such as the common dolphin model shown here that correctly captured the seasonal southward shift in distribution. However, summer habitat conditions did not fully capture the full range of winter-spring conditions, particularly for temperate species, so more work remains to be done.

Work in Progress: SWFSC/SIO Collaboration

Develop habitat-based density models for southern California waters using both SWFSC & CalCOFI line-transect survey data



Study Area: 238,494 km^2

- SWFSC surveys conducted 1991-2014 (Coast-wide)
- CalCOFI surveys conducted quarterly, 2004-2015
- Use Bayesian hierarchical framework
- Expected to improve winter/spring estimates of cetacean density and distribution

*California Cooperative Oceanic Fisheries Investigation

Our most recent project (ongoing) is addressing seasonality off Southern California, in collaboration with SIO researchers who have collected marine mammal line-transect data during quarterly CalCOFI surveys in this region since 2004. We will use a Hierarchical Bayesian framework to combine these data into species-specific winter/spring density models.

Acknowledgements

Special thanks to:

- Marine mammal observers, cruise leaders, cruise coordinators, officers, and crew of 1991-2014 ship surveys.
- Roy Mendelssohn, SWFSC/ERD

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- NASA
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Many thanks to all the essential, talented people who made the surveys possible, and to the funders of all our modeling work.