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


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

Density (Animals/km²)

- 0.360
- 0.320
- 0.280
- 0.240
- 0.200
- 0.160
- 0.120
- 0.080
- 0.040
- 0.000

Obs. Seg. Density:
- < 1
- < 10
- < 30

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

**Goal:** Implement **NOWCAST** and **FORECAST** capability into habitat models to facilitate temporal predictions.
Technical Approach

Cetacean Habitat-Based Density Models

\[ \text{Density} = \frac{n \cdot s}{L \cdot 2 \cdot w} \]

- **Encounter Rate (n/L):**
  \[ \ln(n) = \text{offset}(L) + f(\text{SST}) + f(\text{depth}) + \ldots \]

- **Group Size (s):**
  \[ \ln(s) = f(\text{SST}) + f(\text{depth}) + \ldots \]

Marine Mammal Survey Data

Habitat Data

Generalized Additive Models (GAMs)
Predictions must rely on remotely sensed or modeled oceanographic data

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

CLOUDS are a problem!
Advanced Remote Sensing Products

Global High Resolution SST (GHRSSST) = 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
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
Feasibility Study

Key Predictors

- SST
- Depth
- SST
- Depth
- SST
- Depth
- SST
- Depth
- SST
- Depth

Striped dolphin

Dall’s porpoise

Fin whale
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
NOWCASTS
(using GHRSSST ‘blended SST’)

Striped dolphin
*Stenella coeruleoalba*

Striped dolphin predictions with actual effort and sightings September 2008

Dall’s porpoise predictions with actual effort and sightings September 2008
NOWCAST – Fin whale density for entire survey (July-Nov 2008)

Average 91-05

Fin whale average density 1991-2005 with actual effort and sightings July-Nov 2008

Density (Ani/km²)

“Daily forecast”

Fin whale predictions July-Nov 2008 with actual effort and sightings
NOWCAST – Dall’s porpoise density for entire survey (July-Nov 2008)

**Average 91-05**

Dall's porpoise average density 1991-2005 with actual effort and sightings July-Nov 2008

**“Daily forecast”**

Dall's porpoise predictions with actual effort and sightings July-Nov 2008
NOWCAST – Striped dolphin density for entire survey (July-Nov 2008)

Average 91-05

“Daily forecast”

Striped dolphin average density 1991-2005 with actual effort and sightings July-Nov 2008

Striped dolphin predictions July-Nov 2008 with actual effort and sightings
Spearman rank correlation

Do models capture geographic patterns observed in 2008?

<table>
<thead>
<tr>
<th>Species</th>
<th></th>
<th>1991-2005 Avg</th>
<th>Nowcast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Striped dolphin</td>
<td>$r$</td>
<td>0.850</td>
<td>0.875</td>
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<tr>
<td>Dall’s porpoise</td>
<td>$r$</td>
<td>0.778</td>
<td>0.766</td>
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<tr>
<td>Fin whale</td>
<td>$r$</td>
<td>0.810</td>
<td>0.905</td>
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</table>

$r_{crit} = 0.643$

Yes, for both model types.
FORECAST – Striped dolphin density
ROMS: July 2008 predictions for Oct/Nov 2008

Striped dolphin predictions with actual effort and sightings
October 2008

Striped dolphin predictions with actual effort and sightings
November 2008
FORECAST – Fin whale density
ROMS: July 2008 predictions for Oct/Nov 2008

Fin whale predictions with actual effort and sightings October 2008

Fin whale predictions with actual effort and sightings November 2008
FORECAST – Dall’s porpoise density
ROMS: July 2008 predictions for Oct/Nov 2008

Dall's porpoise predictions with actual effort and sightings October 2008

Dall's porpoise predictions with actual effort and sightings November 2008
### "Relative Density" (ER*GS) Comparisons

#### October 2008

<table>
<thead>
<tr>
<th>Species</th>
<th>Relative Density</th>
<th>Ratio (survey/predicted)</th>
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<tr>
<td></td>
<td>Survey</td>
<td>Average</td>
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<tr>
<td>Striped dolphin</td>
<td>0.0180</td>
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<td>Dall’s porpoise</td>
<td>0.0043</td>
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<td>Fin whale</td>
<td>0.0205</td>
<td>0.0074</td>
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#### November 2008

<table>
<thead>
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<th>Species</th>
<th>Relative Density</th>
<th>Ratio (survey/predicted)</th>
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<tbody>
<tr>
<td></td>
<td>Survey</td>
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<td>Striped dolphin</td>
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<td>0</td>
<td>0.0223</td>
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<tr>
<td>Fin whale</td>
<td>0.0133</td>
<td>0.0109</td>
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</tbody>
</table>
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
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)