Passive Acoustics as a Tool for Density Estimation of Delphinids: Great Potential and Great Limitations

Shannon Rankin  Jay Barlow  Julie Oswald  Tina Yack
NOAA Southwest Fisheries Science Center, La Jolla, CA
Requirements for Passive Acoustics Density Estimation:

- Detection
- Localization
- Species Recognition
- Group Size Estimation
SWFSC Line-Transect Surveys:
Towed Hydrophone Detection of Dolphins
8 Years of Visual/Acoustic Surveys

2,413 dolphin schools
20 species

All surveys in closing mode EXCEPT STARLITE 2007
Goal: Incorporate Acoustics into Line-Transect Surveys

► ‘Pilot Study’
  ▪ 7 Closing Mode Surveys (~ 4.5 months each)
  ▪ 1 Passing Mode Survey (14 days)
  ▪ Localization Experiment

► Specify methods for Line-Transect Analysis
  ▪ Acoustic Detection function by species
  ▪ Determine and quantify co-variates, etc

► Identify and Outline Needs (missing data, etc)

► Incorporate Passive Acoustics for Future LT Surveys*
  ▪ Level of Incorporation will depend on limitations & needs

* 2010 ETP Survey
Detection
Different species make different sounds

Whistles:
- Frequency-modulated
- 1 - 25 kHz
- sounds travel far

Clicks:
- Amplitude-modulated
- 6 - >100 kHz
- sounds do not travel as far
Detection Distance varies by Species

<table>
<thead>
<tr>
<th>Species</th>
<th>Sample Size</th>
<th>Detection Distance Maximum (nmi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Striped dolphins</td>
<td>131</td>
<td>10.0</td>
</tr>
<tr>
<td>Pilot whales</td>
<td>47</td>
<td>8.5</td>
</tr>
<tr>
<td>Bottlenosed dolphins</td>
<td>52</td>
<td>6.0</td>
</tr>
<tr>
<td>Spinner dolphins</td>
<td>34</td>
<td>6.0</td>
</tr>
<tr>
<td>Spotted dolphins</td>
<td>68</td>
<td>6.0</td>
</tr>
<tr>
<td>False killer whales</td>
<td>12</td>
<td>6.0</td>
</tr>
<tr>
<td>Common dolphins</td>
<td>112</td>
<td>6.0</td>
</tr>
<tr>
<td>Rough-toothed dolphins</td>
<td>28</td>
<td>4.5</td>
</tr>
<tr>
<td>Dusky dolphins</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>Killer whales</td>
<td>19</td>
<td>2.3</td>
</tr>
<tr>
<td>Risso's dolphins</td>
<td>24</td>
<td>2.3</td>
</tr>
<tr>
<td>White-sided dolphins</td>
<td>4</td>
<td>2.0</td>
</tr>
<tr>
<td>Fraser's dolphins</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Pygmy killer whales</td>
<td>2</td>
<td>1.8</td>
</tr>
<tr>
<td>Baird's beaked whales</td>
<td>2</td>
<td>1.7</td>
</tr>
<tr>
<td>Northern right whale dolphin</td>
<td>5</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Rate of Detection varies by Species

<table>
<thead>
<tr>
<th>Species</th>
<th>Sample Size</th>
<th>% Vocal</th>
</tr>
</thead>
<tbody>
<tr>
<td>False killer whales</td>
<td>19</td>
<td>100.0%</td>
</tr>
<tr>
<td>Rough-toothed dolphins</td>
<td>31</td>
<td>96.8%</td>
</tr>
<tr>
<td>Spotted and Spinner dolphins (mixed)</td>
<td>75</td>
<td>94.7%</td>
</tr>
<tr>
<td>Common dolphins</td>
<td>157</td>
<td>85.4%</td>
</tr>
<tr>
<td>Spotted dolphins</td>
<td>95</td>
<td>85.3%</td>
</tr>
<tr>
<td>Bottlenosed dolphins</td>
<td>75</td>
<td>82.7%</td>
</tr>
<tr>
<td>Spinner dolphins</td>
<td>46</td>
<td>80.4%</td>
</tr>
<tr>
<td>Striped dolphins</td>
<td>186</td>
<td>80.1%</td>
</tr>
<tr>
<td>Pilot whales</td>
<td>76</td>
<td>72.4%</td>
</tr>
<tr>
<td>Dusky dolphins</td>
<td>5</td>
<td>60.0%</td>
</tr>
<tr>
<td>Risso's dolphins</td>
<td>58</td>
<td>48.3%</td>
</tr>
<tr>
<td>White-sided dolphins</td>
<td>9</td>
<td>44.4%</td>
</tr>
<tr>
<td>Killer whales</td>
<td>49</td>
<td>42.9%</td>
</tr>
<tr>
<td>Northern right whale dolphins</td>
<td>20</td>
<td>35.0%</td>
</tr>
<tr>
<td>Pygmy killer whale</td>
<td>6</td>
<td>33.3%</td>
</tr>
<tr>
<td>Baird's beaked whales</td>
<td>7</td>
<td>28.6%</td>
</tr>
<tr>
<td>Overall*</td>
<td>1189</td>
<td>73.3%</td>
</tr>
</tbody>
</table>

Detection rate varies from 100% to < 30%
What affects our detection rate?

PRELIMINARY ANALYSIS
Random Forest Analysis

What variables explain dolphin schools missed by acoustics team?

Weather
- Beaufort
- Visibility
- Fog/Rain

Oceanography
- Thermocline Temperature
- Thermocline Depth
- Mixed Layer Depth
- Chlorophyll Maximum
- Distance to Shore

Sighting Information
- Species Name
- Group Size Estimate
- Presence of Mixed Species
- Same Day Detection of Orcas

* CART analysis w/ bootstrap (1000+ iterations)
Random Forest Analysis

What variables explain dolphin schools missed by acoustics team?

Analysis to Come:
- For Each Species
- Add more oceo data, redo for all cruises
- Add geographic variables (lat/long)
- Time of Day
- ???
Detection

- Must examine species independently (high variability)
  - Acoustic Detection Distance
  - Rate of Acoustic Detection

- How do I account for variability in acoustic detection?
  - Accounting for group size
  - Accounting for rare features (orcas)
  - Accounting for measurable features (oceo)
Localization Study
Localization Study

Error high ahead of ship (angles < 20°)
Localization Study

As angles increase, convergence allows for localization. The *BEST* location as group passes the beam.
Beam Distance

Low # detections near vessel:
1. Cannot measure zero distance
2. Observer detections?
3. Avoidance?

Detection peaks indicate heaping

Histogram of d0007.df$beam.distance

Passing mode acoustic detections from 2000-2007
1. Cannot measure ‘zero’

Histogram of 1st Angle of Detection

![Histogram of 1st Angle of Detection](image)
2. Observer Detection?

IF this is true → should be reflected in Passing Mode Surveys

Acoustic LOCATE Animals at beam of ship

Visual LOCATE Animals ahead of the ship
2. Observer Detections?

Visual Estimated Perpendicular Distance (all visual detections)

Acoustic Beam Distance (all acoustic detections)
3. Ship Avoidance?

Acoustic LOCATE Animals at beam of ship

Visual LOCATE Animals ahead of the ship
3. Ship Avoidance?

Passing Mode Survey:
Detections by BOTH
Visual & Acoustics
Localization

using a towed hydrophone array

- Animals detected ahead of ship, but angle estimation poor
- Localization requires detection past 40°, best past 90°
- Fundamental differences between estimated perpendicular distance and true perpendicular distance
- Possible ship avoidance (decreased detection near trackline)
- Cannot measure beam distance of zero (on trackline)
- Accurate distance measurement necessary to prevent ‘heaping’
Acoustic Detection Function

… Just for fun,

where *can* we go from here?
Detection Functions: combined species 2007

Estimated Strip Width: 4.56
Density: 0.011
Density CV: 0.175
Encounter Rate: 0.10
Encounter Rate CV: 0.16

Estimated Strip Width: 4.06 km
Density: 0.012
Density CV: 0.124
Encounter Rate: 0.10
Encounter Rate CV: 0.11

Estimated Strip Width: 4.16
Density: 0.012
Density CV: 0.111
Encounter Rate
Encounter Rate CV

* Half normal cosine
Detection Functions: 
*Steno bredanensis*  2007

### Visual
- Estimated Strip Width: 2.13
- Density: 0.001
- Density CV: 0.287
- Encounter Rate: 0.01
- Encounter Rate CV: 0.25

### Acoustics
- Estimated Strip Width: 2.66
- Density: 0.002
- Density CV: 0.219
- Encounter Rate: 0.01
- Encounter Rate CV: 0.19

### Combined
- Estimated Strip Width: 2.49
- Density: 0.002
- Density CV: 0.176
- Encounter Rate: 
- Encounter Rate CV:

* Half normal cosine
Discussion

Problems with Detection:

• Variation in Rate of Detection
• Variation in Detection Distance
• Detection varies with
  • Group Size
  • Measurable variables (oceo)
  • Rare occurrences (orcas)
• Localization
  • Cannot measure zero
  • Possible avoidance near ship
• Beam Distance vs. Estimated Perpendicular Distance
• Closing vs. Passing Mode
  • Complicates angle estimation & localization
SWFSC, NOAA

US Navy, Office of Naval Research


Observers, Acousticians, cruise leaders, survey coordinators, captain, officers and crew on shipboard surveys.

Eric Archer, Jessica Redfern, Paul Fiedler, Yvonne Barkley, Liz Zele, Al Jackson, Jim Carretta, Dave Mellinger