Estimating the abundance of whales using information from sparse arrays of seabed-mounted hydrophones.

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CREEM
Talk outline

- Introduction to Passive Acoustic Monitoring
- Point transect sampling and assumptions
- Case study 1: Blue whales in the Indian Ocean
- Case study 2: Fin whales in the Atlantic Ocean
- Summary and Acknowledgments

Photo courtesy of J. Hildebrand
Visual vs. Acoustic Surveys

Visual surveys:
- Severely affected by bad weather conditions.
- Reduced ability to survey at night.
- Require the animals to surface.

Acoustic surveys:
- Equipment can continue to monitor in bad weather.
- Can be conducted 24 hours a day.
- Equipment can be deployed for long time periods.
- Animals must vocalise.
- Need to understand the vocal behaviour of the study species.
Fixed Passive Acoustic Monitoring

- Many types of PAM equipment (towed vs. fixed).
- Fixed PAM – autonomous/cabled/radio linked.
- Hydrophone arrays – dense or sparse.

What is a sparse array?

Definition for this project: An array where the hydrophones are too far apart for the same call to be detected by multiple sensors.

- Military/seismic arrays can be used as platforms of opportunity – also detect cetaceans.
Point transects – a quick recap

(1) Census – count everything
Point transects – a quick recap

(2) **Point count** – count everything in circles

\[ \hat{D} = \frac{n}{k \pi w^2} \]

\[ \hat{N} = \hat{D} \times A \]

- \( \hat{D} \) = estimated density
- \( n \) = number of detections
- \( \hat{N} \) = estimated abundance
- \( k \) = number of points
- \( A \) = study area
- \( w \) = radius of points
Point transects – a quick recap

(3) **Point transect** – count all **detected** individuals in circles

\[ \hat{D} = \frac{n}{k \pi w^2 \hat{P}_a} \]

\[ \hat{N} = \hat{D} \times A \]

\[ \hat{P}_a \] = proportion of objects detected
Point transect assumptions and PAM

- All animals at zero distance are detected.

- **True distribution of animals with respect to distance is known.**

- Only count individual/group once within each circle.

- No measurement error (distance, group size, species).

- **Survey is a snapshot – no movement of animals.**

- Distribution of objects around hydrophones is representative of entire survey area.

- Independent detections.
Case study 1: Blue whales at Diego Garcia

- Comprehensive Nuclear Test Ban Treaty data
- 2 arrays - a northern and southern site, each with 3 hydrophones
- Good data availability for 2002 and 2003 (84.5% and 91.4%, respectively).
Blue whales at Diego Garcia – a biologically interesting area

9 different blue whale songs have been recorded around the world – 3 occur around Diego Garcia

Fig. 1. Distribution of blue whale song, classified into nine regional types (numbers). See Table 1 for regional designations.

Blue whales at Diego Garcia – a rich dataset

6: Southern Ocean

7: North Indian

9: Southwest Indian (a)

9: Southwest Indian (b)
Blue whales at Diego Garcia – estimating abundance

Call density

- Detector results (adjusted for false +ve/-ve) = \( n \)
- Then estimate \( w \).
- How loud is a Sri Lankan call and how far do they travel?
- Estimate source level.
- Use propagation modelling to estimate the maximum range of detection.
- Possible to use a distribution of source levels – more biologically accurate.
- Assume all calls are detected within \( w \).
- Point count data.
Blue whales at Diego Garcia – estimating abundance

Call density
- Detector results (adjusted for false +ve/-ve) = \( n \)
- Then estimate \( w \).
- How loud is a Sri Lankan call and how far do they travel?
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- Use propagation modelling to estimate the maximum range of detection.
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Whale density
- Need average call rate of a whale.
- Hard biological question.
Case Study 2: Fin whales in the North East Atlantic

- Sparse array of 24 OBS (ocean bottom seismometers) instruments deployed 2007-2008
- Part of the NEAREST project
- Designed to investigate tsunami characteristics.
- Each OBS contains 3 seismometers and 1 hydrophone


- Fin whale calls have been detected.
- The multiple sensors per OBS allows range to a call to be calculated.
- This allows standard distance sampling to be conducted.
<table>
<thead>
<tr>
<th>Case study</th>
<th>Data</th>
<th>Research challenges</th>
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<tbody>
<tr>
<td>Blue whales in northern Indian Ocean</td>
<td>• Being treated as sparse array.</td>
<td>• Standard distance sampling not possible.</td>
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<td></td>
<td>• Investigating absolute density/abundance</td>
<td>• Assumptions of distance sampling violated due to:</td>
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<td></td>
<td></td>
<td>- Hydrophones not randomly placed</td>
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<td></td>
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<td>- Long term monitoring (rather than a “snapshot”)</td>
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<tr>
<td>Fin whales in the North East Atlantic Ocean</td>
<td>• Sparse array</td>
<td>• Long term monitoring</td>
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