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Monitoring whale populations from acoustic data over large temporal and spatial scales

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Background

- Wildlife monitoring programs are costly.
  - How many are there?
  - What are their patterns/trends
  - Often required for conservation and management
- Alternative cost-efficient approaches?
- One option: “platforms of opportunity”.
- Example: Comprehensive Nuclear Test Ban Treaty Organization International Monitoring System (CTBTO IMS)

Images courtesy of Maxim Weise at FreeDigitalPhotos.net

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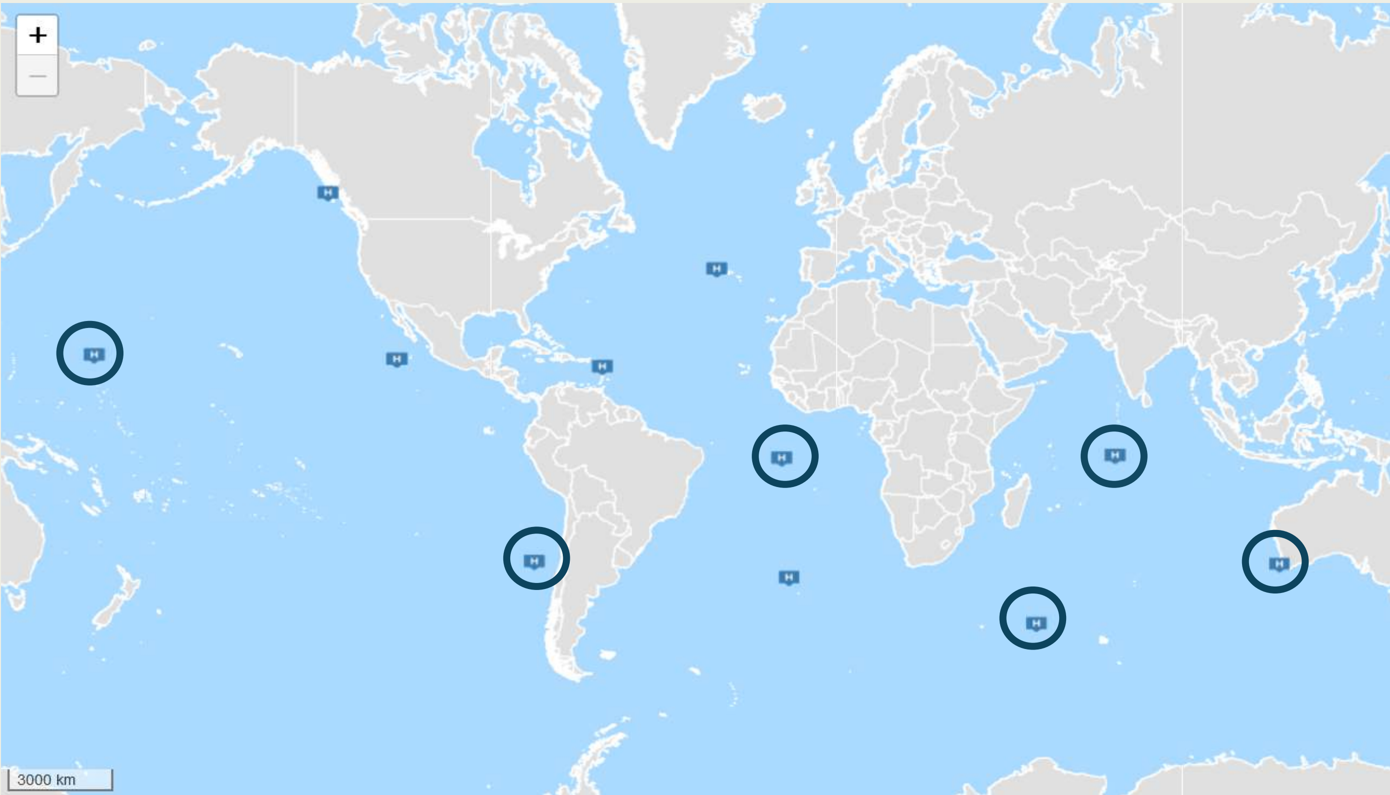
Example: Comprehensive Nuclear Test Ban Treaty Organization International Monitoring System (CTBTO IMS)



Circles denote hydrophone stations (as opposed to land-based T-phase stations). Adapted from https://www.ctbto.org/map/

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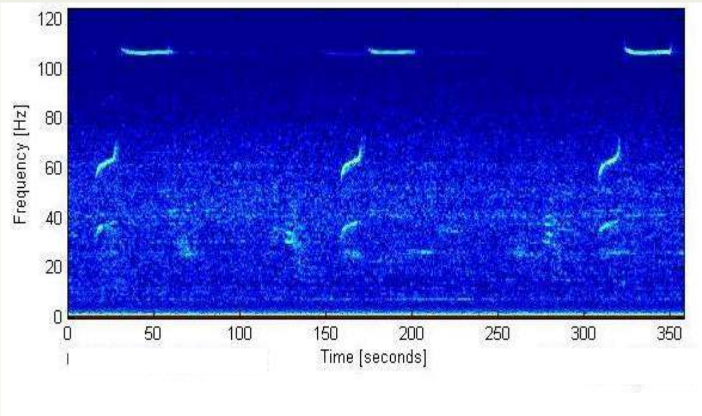
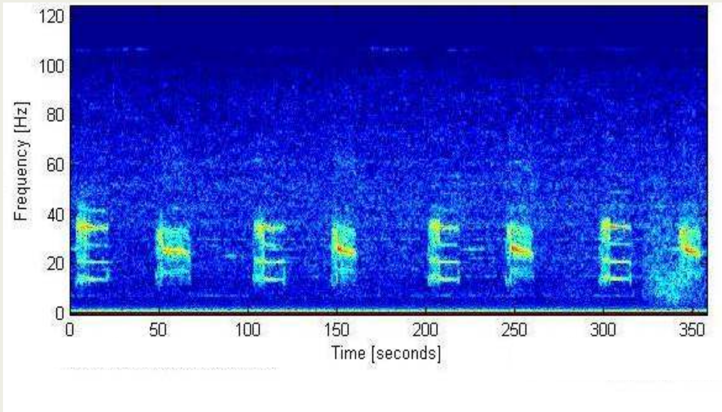
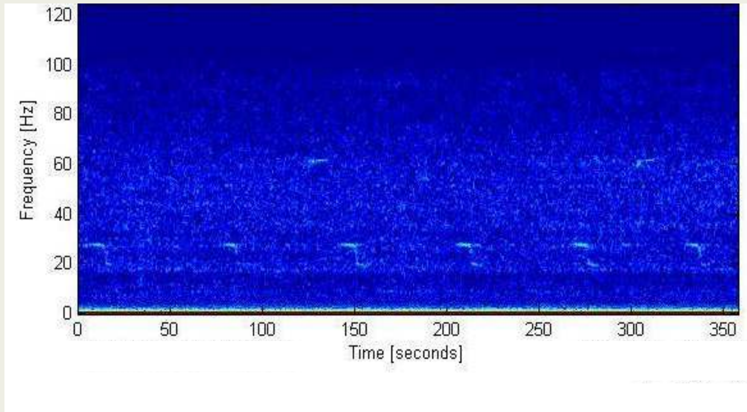
Indian Ocean baleen whale sounds (some examples)







Data: courtesy of the CTBTO

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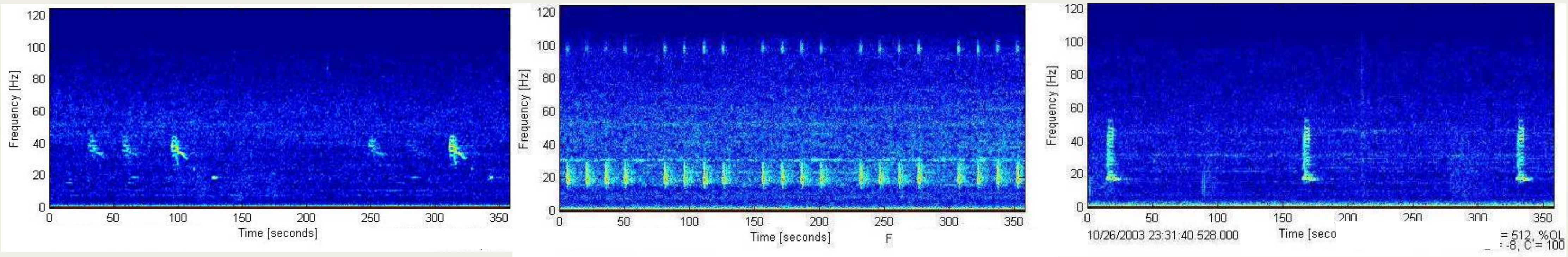

Data: courtesy of the CTBTO

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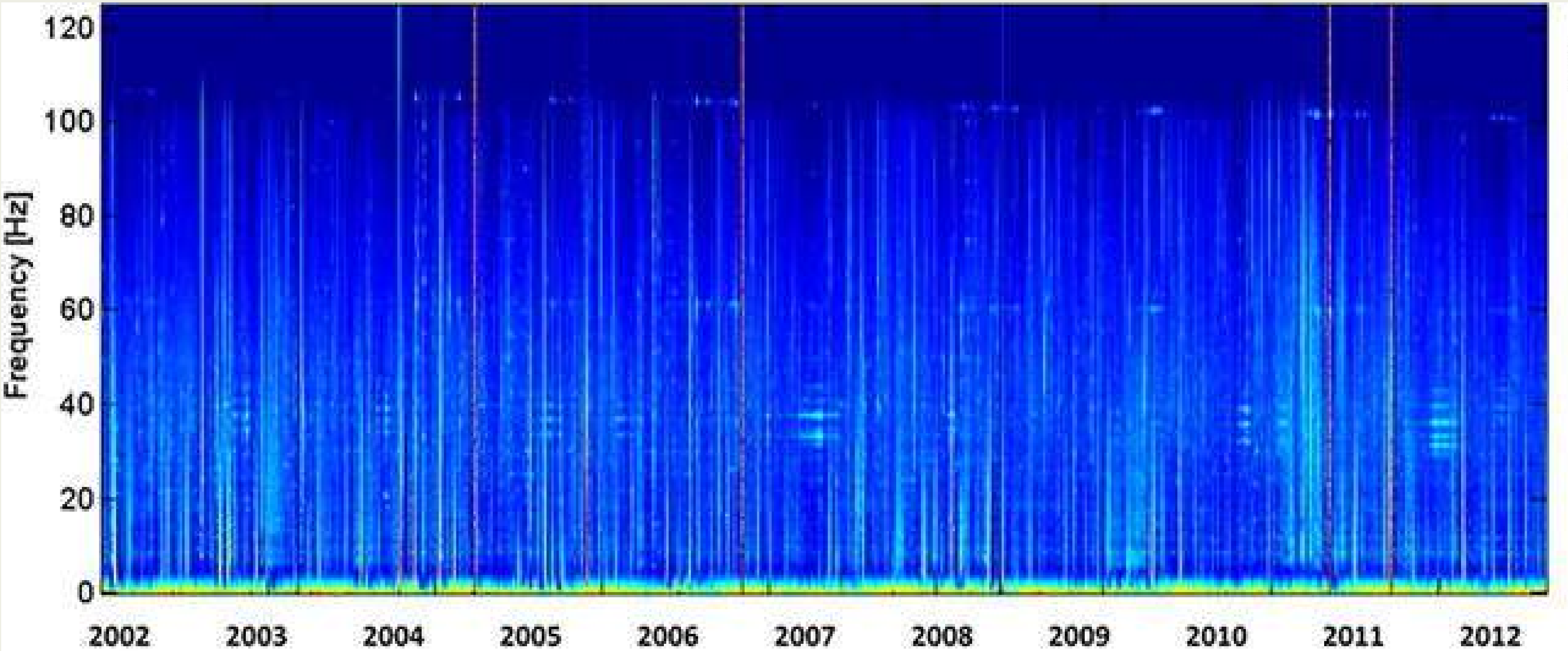
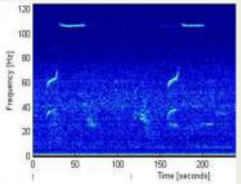
A lot of data available





Published in: Jennifer L. Miksis-Olds; Sharon L. Nieukirk; Danielle V. Harris; *The Journal of the Acoustical Society of America* **144,** 3618-3626 (2018) DOI: 10.1121/1.5084269.

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Absolute density estimation from acoustic data

- Various methods available to estimate animal absolute densities or abundances

  e.g., distance sampling, spatial capture recapture, simulation-based

- These methods estimate the **probability of detection**, a key parameter for absolute density/abundance estimation

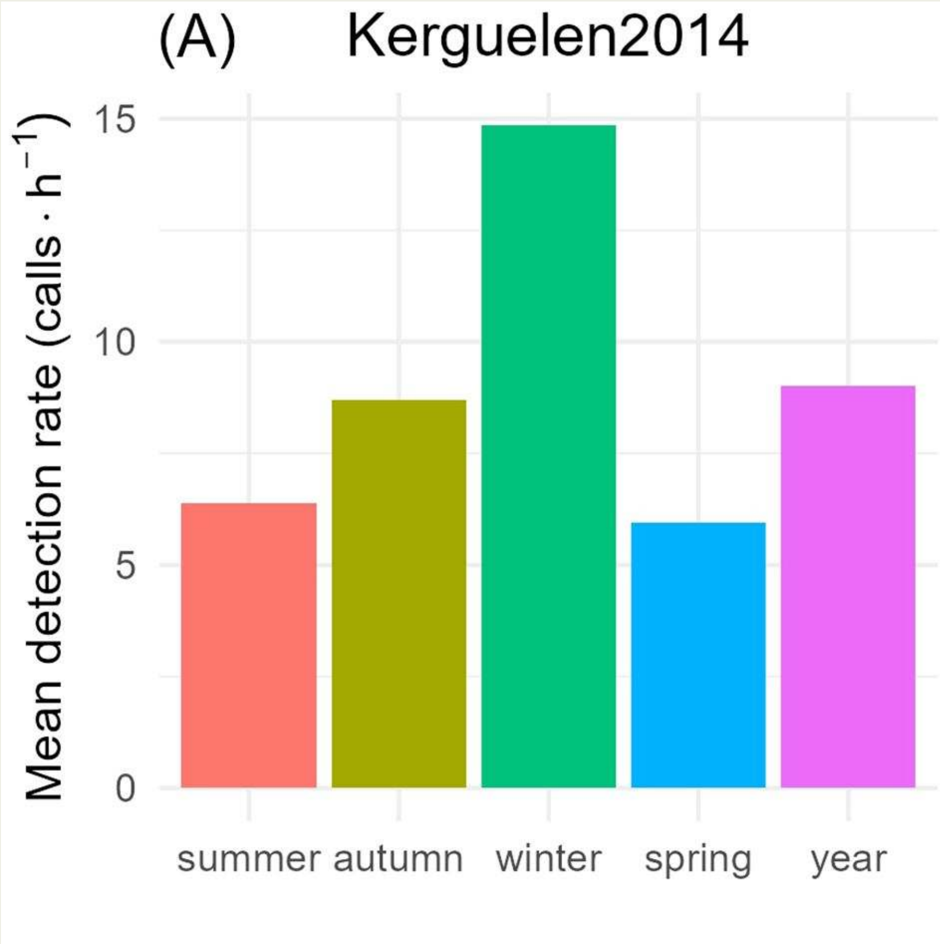
Counting calls ("cue counting")

$$\hat{D} = \frac{n(1-\hat{c})}{\pi w^2 k \hat{P} T \hat{r}}$$

$\hat{D}$ = estimated density
n = number of detections
$\hat{c}$ = false positive proportion
w = radius of points
k = number of points
$\hat{P}$ = proportion of animals detected
T = monitoring time per point
$\hat{r}$ = cue production rate

Review paper about acoustic density estimation methods: Marques, T.A., L. Thomas, S. Martin, D. Mellinger, J. Ward, D. Moretti, D. Harris and P. Tyack. 2013. Estimating animal population density using passive acoustics. Biological Reviews 88: 287-309

Why is detection probability important?



de Castro FR, Harris DV, Buchan SJ, Balcazar N and Miller BS (2024) Beyond counting calls: estimating detection probability for Antarctic blue whales reveals biological trends in seasonal calling. *Front. Mar. Sci.* 11:1406678. doi: 10.3389/fmars.2024.1406678

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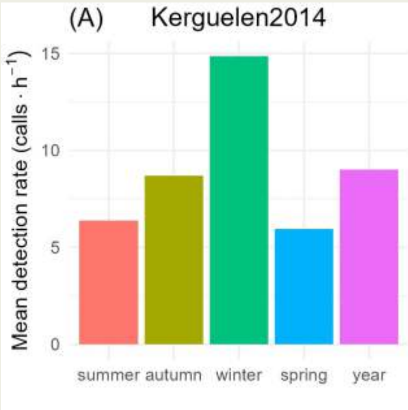

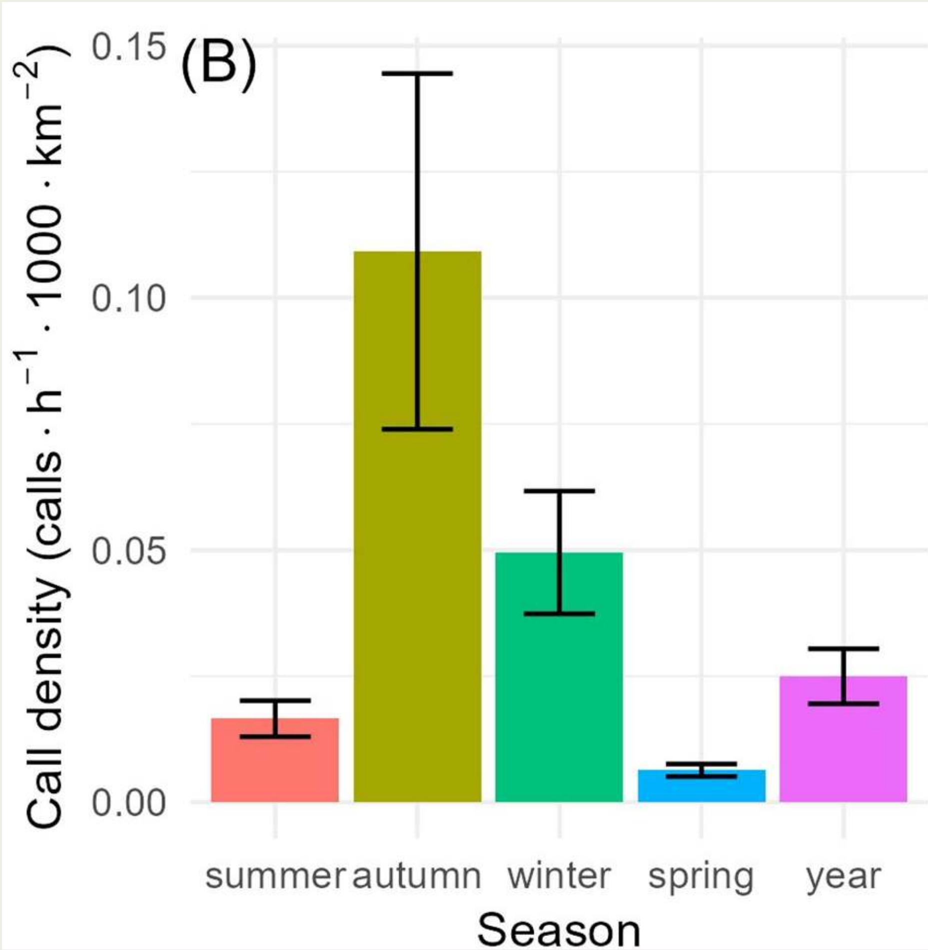

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Monte Carlo simulation-based approaches using CTBTO data

- Approach:
  - Based on the **passive sonar equation**
  - ≈ how well sound travels through water and is detected by a sensor
  - Simulations use
    - bearings to automatically detected calls,
    - sound propagation models,
    - noise level measurements and
    - assumed source level distribution of the target calls to estimate *P*.
- Considerations:
  - Numerous parameter inputs
  - Assumptions about animal distribution (V. Tretiakov, student internship)

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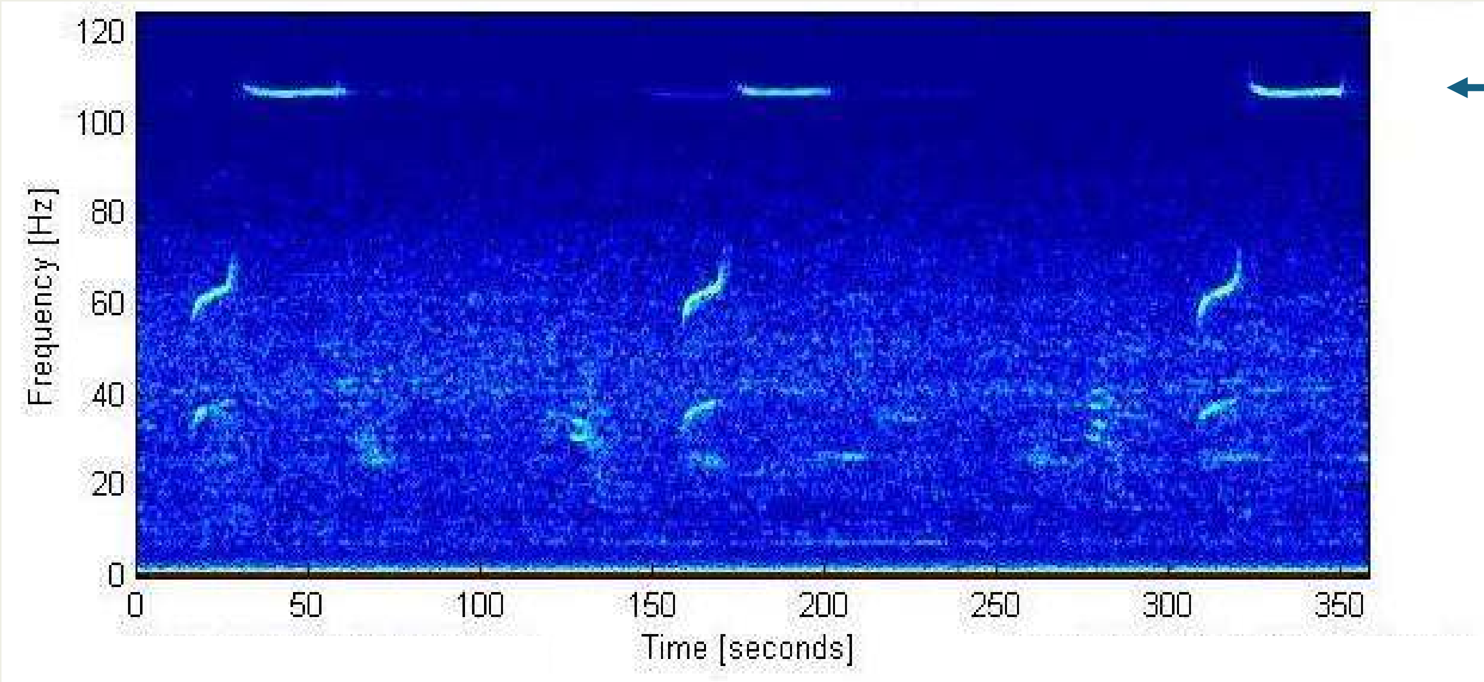
Monte Carlo simulation-based approaches using CTBTO data

Case study: Indian Ocean Sri Lankan blue whale song units (**2024** data)



2002 data

Data: courtesy of the CTBTO

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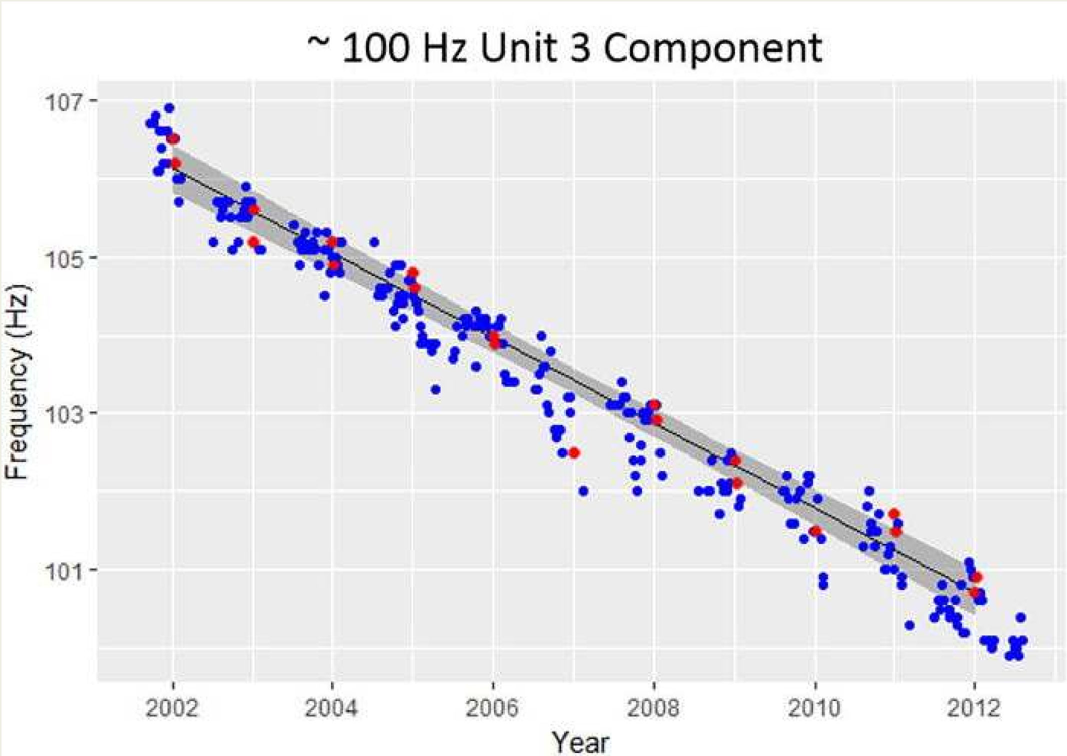
Monte Carlo simulation-based approaches using CTBTO data

Results: automated detection of calls



Continued decline from 2017 onwards investigated (Black & Harris, in prep).

Results informing automatic detector development.

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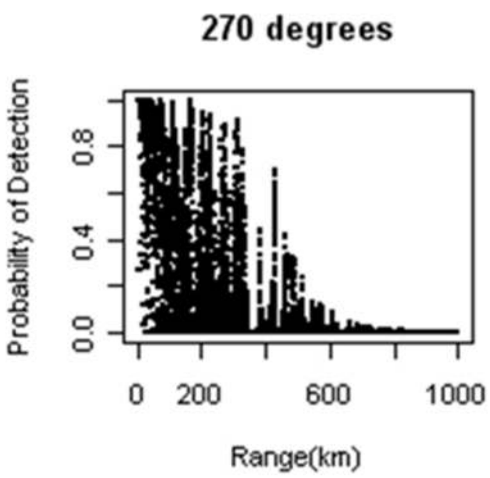
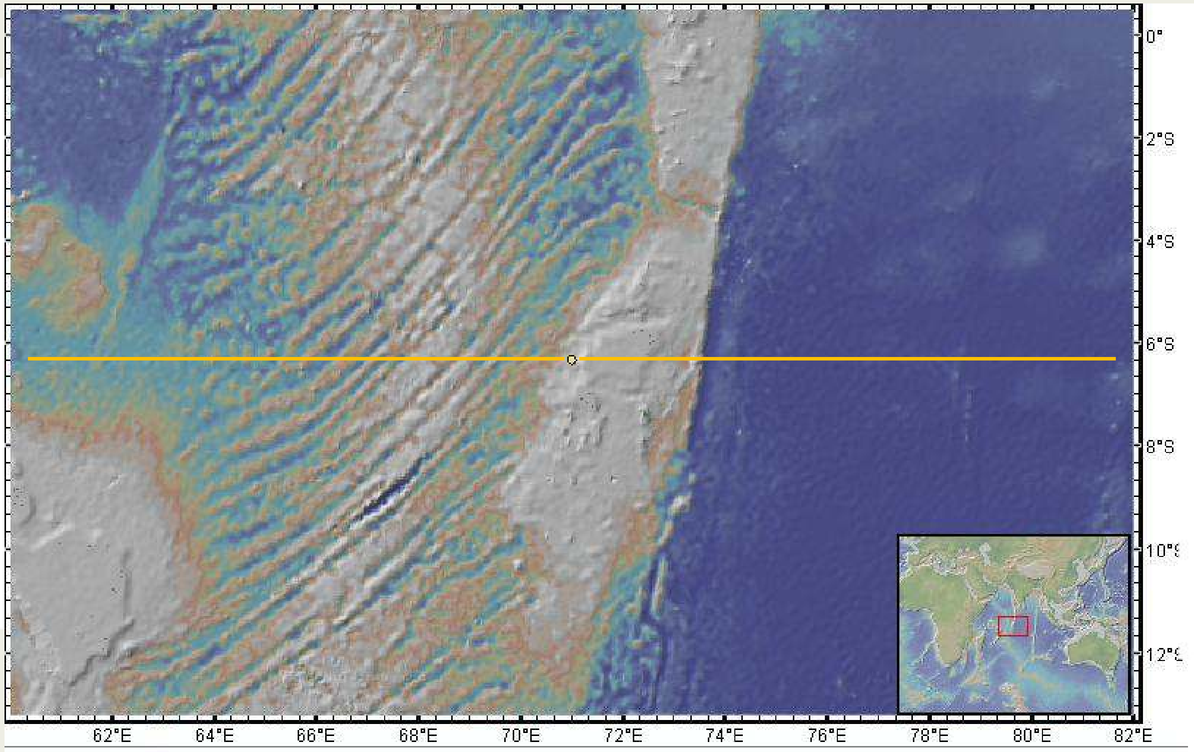
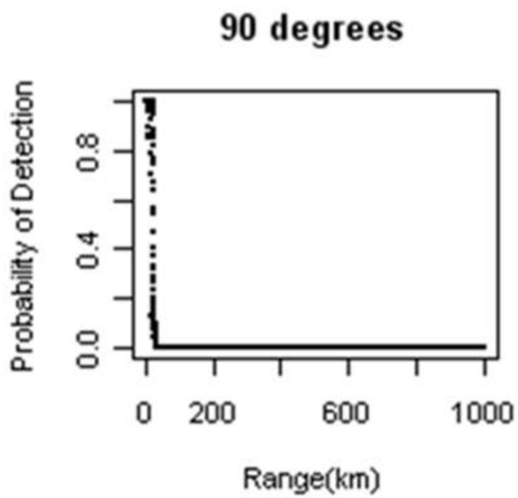
Monte Carlo simulation-based approaches using CTBTO data

Results: P is spatially variable due to extreme bathymetry (updated results in Harris et al., in press)







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Conclusions

- Example of maximising use of available data (over large spatial and temporal scales).
- Density estimation methods can help to standardise acoustic datasets collected across different sites/years.
- There are many studies with sparsely distributed instruments.

Adapted from https://www.ctbto.org/map/

Thank you!

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