

Cheap DECAF: Density Estimation for Cetaceans from Acoustic Fixed Sensors Using Separate, Non-Linked Devices

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LONG-TERM GOALS

Several of the current methods for density estimation of cetaceans using passive fixed acoustics rely on large, dense arrays of cabled hydrophones and/or auxiliary information from animal tagging projects conducted at the same time as the acoustic survey. Obtaining such data is costly, and may be impractical to the wider community interested in estimating cetacean density. Therefore, the goal of Cheap DECAF is to focus on the development of cetacean density estimation methods using sensors that are sparsely distributed and less expensive to deploy than the cabled military arrays focussed on to date.

OBJECTIVES

Recordings of fin whales (*Balaenoptera physalus*) from a sparse array of Ocean Bottom Seismometers (OBS) will be the dataset used to develop and test a variety of density estimation methods. The OBS array was deployed for 1 year (2007-2008) off the south coast of Portugal, near the Straits of Gibraltar (Fig. 1).

The specific objectives of the project are to:

1. demonstrate how cue-counting methods can be used efficiently to obtain estimates of density over long time periods and large spatial scales using directional sound sensors;
2. extend the methods to allow for uncertainty in the depth of vocalising animals;
3. develop and apply methods based on tracking moving individual animals;
4. develop and apply methods based on measuring total sound energy in relevant frequency bands;
5. obtain baseline estimates of spatial density of fin whales in the study area.

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 2012		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Cheap DECAF: Density Estimation for Cetaceans from Acoustic Fixed Sensors Using Separate, Non-Linked Devices				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Centre for Research into Ecological and Environmental Modelling (CREEM) University of St Andrews St Andrews, UK				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 6	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

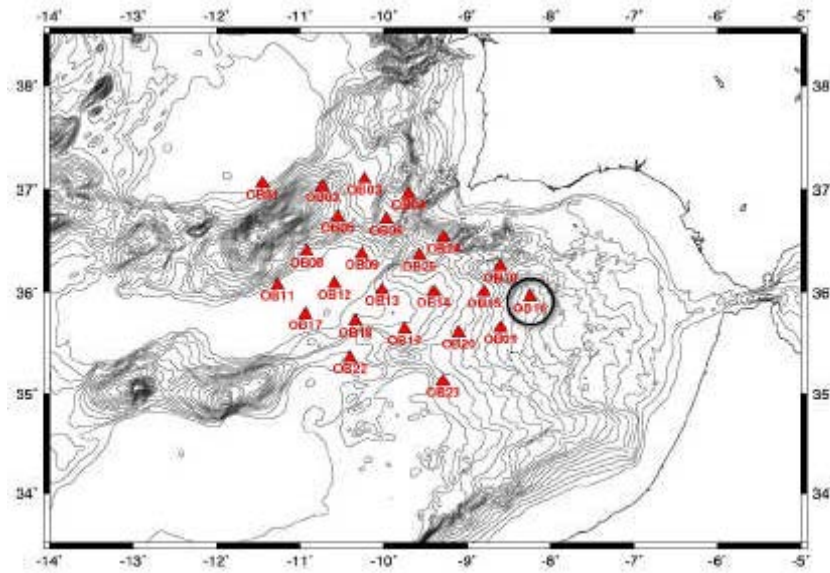


Fig. 1. Location of the array of 24 OBS sensors in the Atlantic off Portugal.

APPROACH

This project is in collaboration with Oregon State University (grant number: N00014-11-1-0606, PI: David Mellinger). The work is divided into 3 components, as follows:

Component 1: Fin whale vocalisations will be automatically detected and localised across the 1-year dataset, using existing methods. Established distance sampling methods using cue counting will be used to generate seasonal density estimates, and spatial patterns in density will be related to oceanographic features. Customised distance sampling software will be used (Thomas *et al.*, 2010). This component will also include the development of methods to account for the depth distribution of animals, which will involve a simulation exercise.

Component 2: This component will focus on estimating density where the unit of interest is the individual animal, rather than a cue, i.e., vocalisations. Methods to account for the movement of individual animals will be developed via a simulation study, building on work completed for a Master's thesis (DiTraglia, 2007).

Component 3: This component will develop a method that uses the total energy present in a species' frequency band as the statistic upon which a density estimate is made. The approach used will involve a Monte Carlo simulation and propagation modelling, to link density of animals to a given received energy level.

Components 1 and 2 are being led by the personnel involved with this project, and Component 3 is being led by Oregon State University. There is also a project management element, coordinating bi-monthly tele-conference progress meetings, and at least two face-to-face meetings, one in each project year.

WORK COMPLETED

This project began in September 2011. We have had monthly tele-conference meetings in order to get all three components underway and Danielle Harris, the named post-doc on the project, has visited Matias in Lisbon for a 2-week research visit, as per the original proposal. We are also planning an annual project meeting in Lisbon in mid-October.

Under Component 1, an exploratory analysis of the dataset has been undertaken by manually viewing spectrograms from a representative subsample of the data. The duration and frequency range of a sample of fin whale calls were measured in order to aid the development of the automatic detector. Matias has conducted extensive development of the localisation method and has also completed a validation study using airgun sounds of known location. The detection and localisation routine has been run across 12 instruments for the entire year (not all instruments could generate ranges due to equipment failure). Preliminary monthly call densities have been estimated using distance sampling. Work is continuing to quantify the performance of the current automatic detector. The results will then be refined to incorporate (1) the detections from the remaining instruments (2) environmental covariates that affect detectability (such as ambient noise) and (3) a correction for animal depth. Spatial patterns of density will then be explored.

A manuscript giving an overview of the localisation method and the results from analysing a single day of data (as a proof of concept that distance sampling can be applied to these data) has been submitted for publication (Harris *et al.*, submitted). A separate manuscript describing the localisation method in detail and the results of the validation study is currently being prepared (Matias *et al.*, in prep.).

Under Component 2, a literature review of animal movement models has been undertaken. A technical meeting has been arranged by Harris & Thomas with other colleagues at the University of St Andrews to review recent work on accounting for animal movement in distance sampling analyses, so that the planned further method development capitalises on this research.

Under Component 3, methods were investigated for eliminating, or at least lessening, noise sources from a recording so as to arrive at a better estimate of the energy present in the frequency band used by fin whales. Noise elimination methods, which are based on successive linearly-scaled power spectra (a “power spectrogram”), focused on three types of noise: (1) harmonic noise such as that from ships, which is lessened by finding spikes in the power spectrum, removing them, and interpolating across the removed frequencies; (2) impulsive noise such as that produced by seismic airguns, which is lessened by removing those spectra altogether from the power spectrogram; and (3) broadband noise, which is lessened by estimating its level at frequencies below and above the target frequency band and interpolating in between to determine how much of the extant energy is from fin whales. We also performed a literature search to estimate fin whale calling rates in the area.

RESULTS

In the preliminary analysis, data from 12 instruments were processed. The number of available days of data for each instrument ranged between 160 and 324 days (all recordings made between September 2007 and August 2008). The total number of detections (each with an associated range) was 69476. A summary of data availability and number of detections for each instrument is given in Table 1 and an example of detections in a single day around an instrument is given in Fig. 2. The detections were presumed to be fin whale calls – false detections were not checked for in this preliminary analysis.

Table 1. Number of available days of data and detections of presumed fin whale calls for each OBS instrument.

OBS ID	04	06	10	12	14	16	18	19	20	21	24	25
Data days	268	160	301	324	308	309	321	319	314	311	257	260
Detections	5054	303	8138	6722	6351	5427	8085	6323	7004	7430	1466	7173

For the distance sampling analysis, the data were truncated at 3000 m. A detection function model (a hazard rate model with no adjustment terms) was fitted to the data (Fig. 3). The average probability of detection was estimated to be 0.24. Monthly call densities ranged from 0 to 3.6 calls/10 km². hr⁻¹ (Fig. 4). A strong seasonal pattern in call density was observed, with peak densities occurring in the winter months.

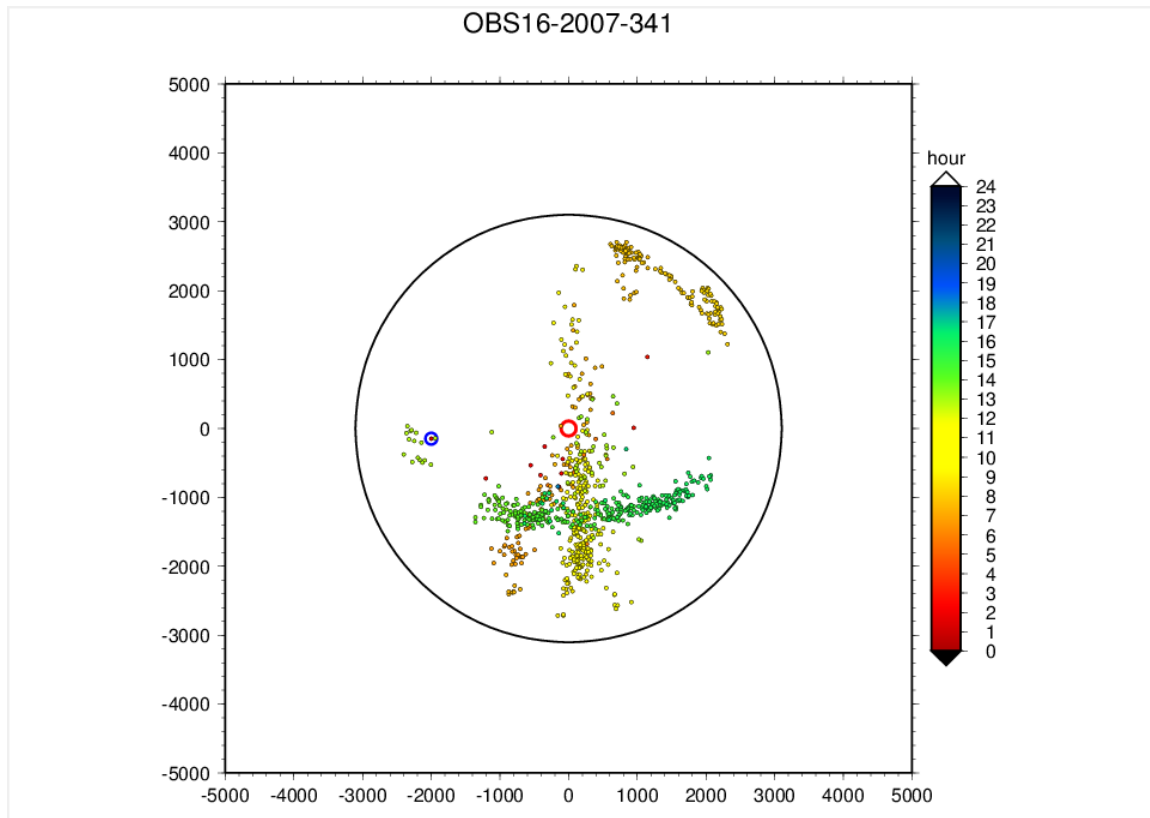


Fig. 2. All located calls plotted around OBS16 during 7th December 2007. Time of detection is colour-coded. The red circle at (0,0) marks the position of the OBS, the small blue circle shows the first detection and the large black circle denotes the critical range beyond which ranging is not possible (3119 m). All units in metres.

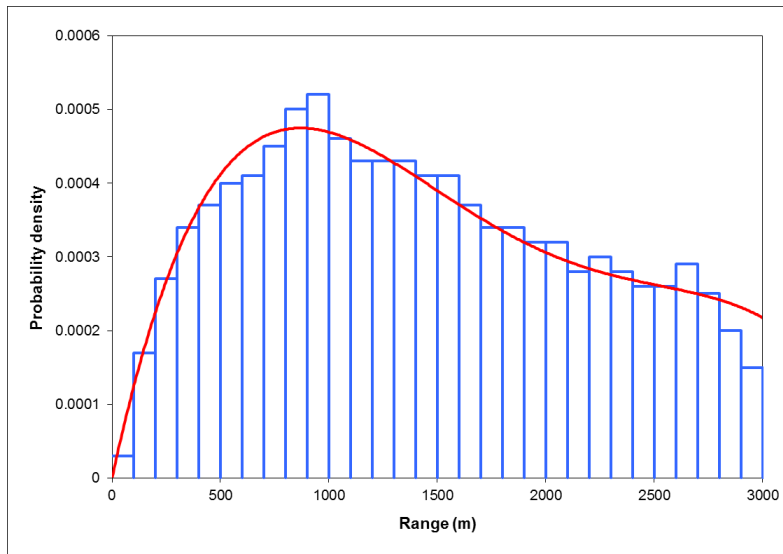


Fig. 3. The fitted detection function (plotted as a probability density function) (red line) with a histogram of the observed ranges of the detections truncated at 3000 m. The frequencies of the histogram have been scaled accordingly.

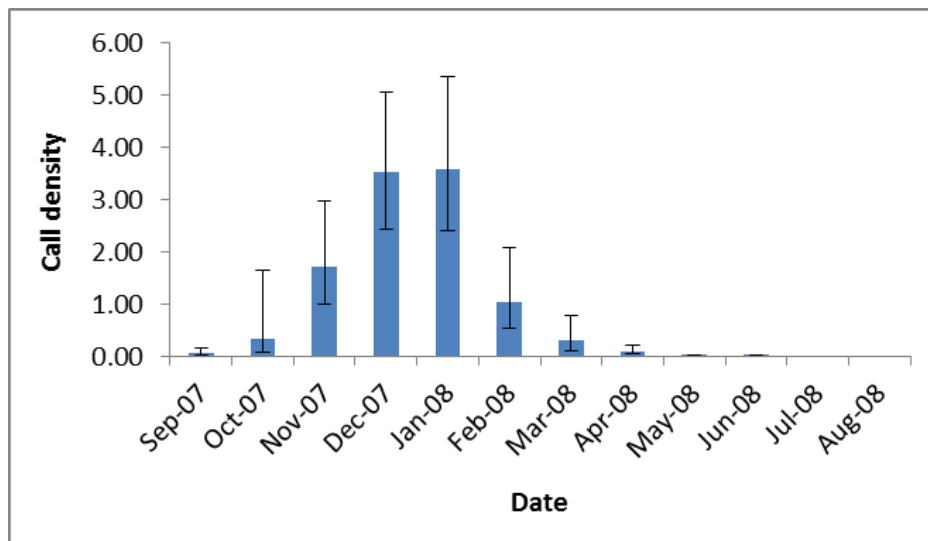


Fig. 4. Preliminary monthly call densities with 95% confidence intervals displayed. Units are calls/10 km². hr⁻¹.

For Component 3, code is being developed for the noise-reduction methods described above, and tests are being made of their efficacy. The best estimate of fin whale calling rates in the geographic area of interest off Portugal is a distribution with a mode of 18 s (Hatch and Clark, 2004).

IMPACT/APPLICATIONS

The main aim of Cheap DECAF is to make density estimation of cetaceans less costly and, therefore, more accessible to the wider scientific community. The methods developed here will be applicable to re-deployable arrays of both sea-bed mounted instruments (such as the OBS array) and surface buoys, so will hopefully increase our capability to monitor cetacean density in geographic areas of interest, including those where naval operations are conducted.

RELATED PROJECTS

Cheap DECAF (Grant number: N00014-1-11-0606, PI: David Mellinger, Oregon State University)

DECAF: Density Estimation for Cetaceans from passive Acoustic Fixed sensors – this 3-year project was funded by the National Oceanographic Partnership Program (ending February 2011) and explored many aspects of animal density estimation using acoustic data, illustrated by a range of case studies.

"The way they move" – a research project at the University of St Andrews developing algorithms for fitting state-space models to terrestrial animal tag data; the current project is leveraging many of the findings from this project.

REFERENCES

- DiTraglia, F.J. 2007. Models of Random Wildlife Movement with an Application to Distance Sampling. MMaths Statistics thesis, University of St Andrews.
- Harris, D., Matias, L., Thomas, L. & Harwood, J. (submitted) Estimating fin whale density in the north-east Atlantic using an array of ocean bottom seismometers.
- Hatch, L.T., and C.W. Clark. 2004. Acoustic differentiation between fin whales in both the North Atlantic and North Pacific Oceans, and integration with genetic estimates of divergence. Document number SC/56/SD8, Intl. Whal. Commn., Cambridge 37 pp.
- Matias, L., Geissler, W. *et al.* (in prep) Fin whale tracking using 4 component single-station recordings at the sea-floor.
- Thomas, L., S.T. Buckland, E.A. Rexstad, J.L. Laake, S. Strindberg, S.L. Hedley, J.R.B. Bishop, T.A. Marques and K.P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. *J. Appl. Ecol.* 47:5-14.

PUBLICATIONS

Harris, D., Matias, L., Thomas, L. & Harwood, J. (submitted) Estimating fin whale density in the north-east Atlantic using an array of ocean bottom seismometers.