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

David K. Mellinger
Cooperative Institute for Marine Resources Studies
Oregon State University (OSU)
2030 SE Marine Science Dr.
Newport, OR 97365
phone: (541) 867-0372 fax: (541) 867-3907 email: David.Mellinger@oregonstate.edu

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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 (OBSs) are being 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 Strait 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 vocalizing 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.

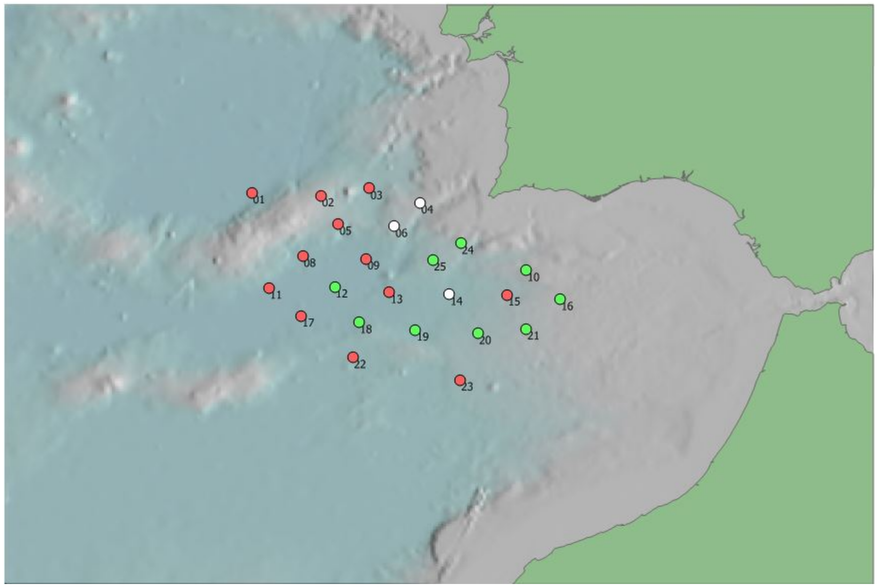

Fig. 1. Location of the array of 24 OBS sensors in the Atlantic off Portugal. Green denotes instruments that could range to detections for their entire deployment, red denotes instruments that could not range to detections and white denotes instruments that could range to detections for parts of their deployment.

APPROACH

This project is in collaboration with the University of St. Andrews (grant number: N00014-11-1-0615, PI: Len Thomas). The work is divided into 3 components:

Component 1: Fin whale vocalisations have been automatically detected and localised across the 1-year dataset, using existing methods. Established distance sampling methods using cue counting have been used to generate seasonal call density estimates, and spatial patterns in call density have been related to oceanographic features (an appropriate calling rate is required in order to generate estimates of animal density from call densities). Customised distance sampling software has been used (Thomas *et al*., 2010). This component has also included the development of methods to account for the depth distribution of animals, which involved 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 are being developed via a simulation study, building on work completed for a Master's thesis (DiTraglia, 2007).

Component 3: This component is developing 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 involves a Monte Carlo simulation and propagation modeling, to link density of animals to a given received energy level.

Components 1 and 2 are being led by the University of St. Andrews, and Component 3 is this project. There is also a project management element, coordinating bi-monthly teleconference progress meetings, and at least two face-to-face meetings, which were completed in previous years.

WORK COMPLETED

We continued to have teleconference meetings at least bi-monthly.

Under Component 3, noise-reduction methods were applied to make optimal estimates of the energy present over the year in the fin whale frequency band. Noise elimination methods, which are based on successive linearly-scaled power spectra (a "power spectrogram"), focused on two types of noise reduction: (1) harmonic noise such as that from ships, which is lessened by finding spikes in the power spectrum and removing them using a median filter; and (2) broadband noise, whether impulsive or relatively stationary, which is lessened by estimating its level at frequencies below and above the target frequency band and interpolating between them to estimate what portion of the measured energy is from fin whales (Fig. 2). In effect, this allows us to measure the amount of acoustic energy from fin whales – the received level of the singing fin whales (RL_{fin}).

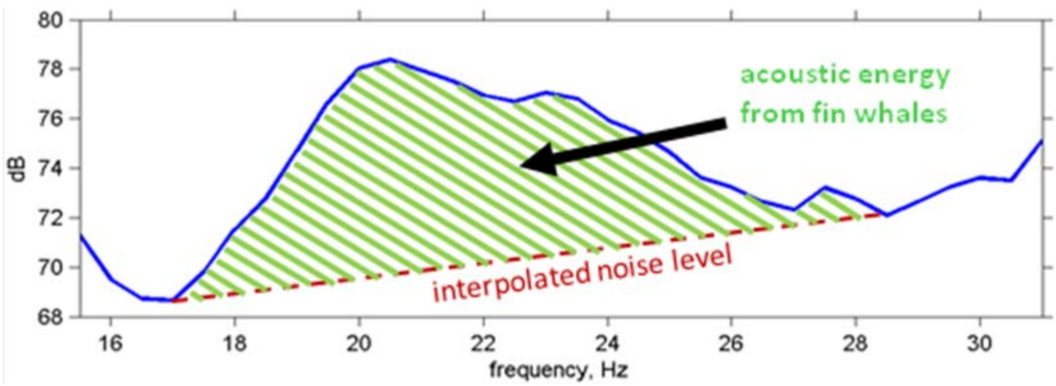

Fig. 2. A spectrum containing the fin whale energy band (18-25 Hz) showing how interpolation is done to estimate the background noise level.

Once these noise sources were removed, the received level could be measured at each hydrophone over the course of the year-long deployment. This required substantial computation, which was completed.

The other major computational task was to run acoustic propagation models to estimate the propagation loss from points in and near the hydrophone array to each hydrophone. This was done for radials around each instrument site by student Elizabeth Küsel.

The calling rates of singing fin whale were estimated by measurement of the pulse periods of 13 singing whales (mean: 13.4 s) and information on sequence length, inter-sequence interval, and bout length from the literature to estimate the fraction of the time that fin whales call. A distribution of fin whale source levels was also estimated using a survey of literature.

These data were all combined using a Monte Carlo method that simulated a range of singing fin whale densities and estimated, for each one, what the received level (RL) at each hydrophone would be. This is effectively a density-to-RL function (Fig. 3).

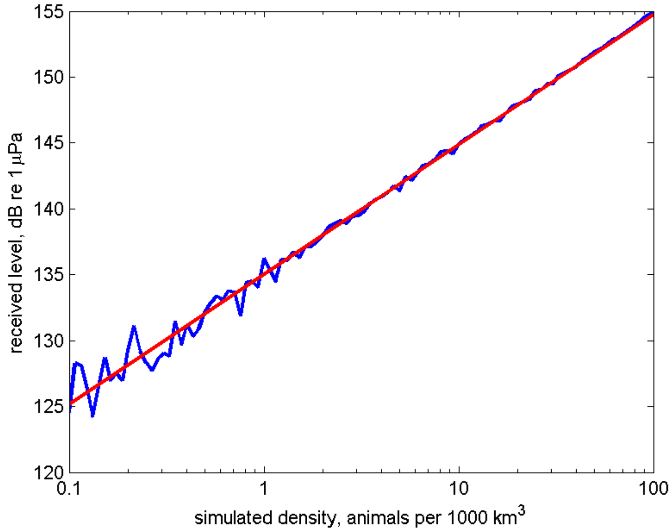

Fig. 3. The output of the Monte Carlo model: modeled received level (RL_{fin}) as a function of simulated density for one hydrophone location, with red showing the least-squares best-fit line. This function was inverted to allow converting measured RL_{fin} values to densities.

We inverted this function to obtain a RL_{fin}-to-density function, which was then used with the measured RL_{fin} values from the hydrophone data to estimate the density of singing fin whales at each hydrophone over the course of the year. To prevent a single loud whale near a hydrophone from resulting in an incorrectly large density estimate, RL_{fin} estimates were averaged over 5 day intervals. This was repeated for all 24 hydrophones. Spatial interpolation was used to estimate fin whale density in between the hydrophone locations, and the result plotted as a density image. This was repeated every 5 days throughout the year, and a video was produced showing fin whale density over the course of the year.

RESULTS

Fin whale density was estimated across the area of the hydrophone array over the course of the year and a video was produced. This video, and the methods used to measure RL_{fin}, calculate the RL_{fin}-to-density function, and so on, will be be presented at the fall 2014 meeting of the Acoustical Society of America (Mellinger et al. 2014). Figure 4 shows a frame from this video.

A paper about this work is also in preparation for submission to J. Acoust. Soc. Am.

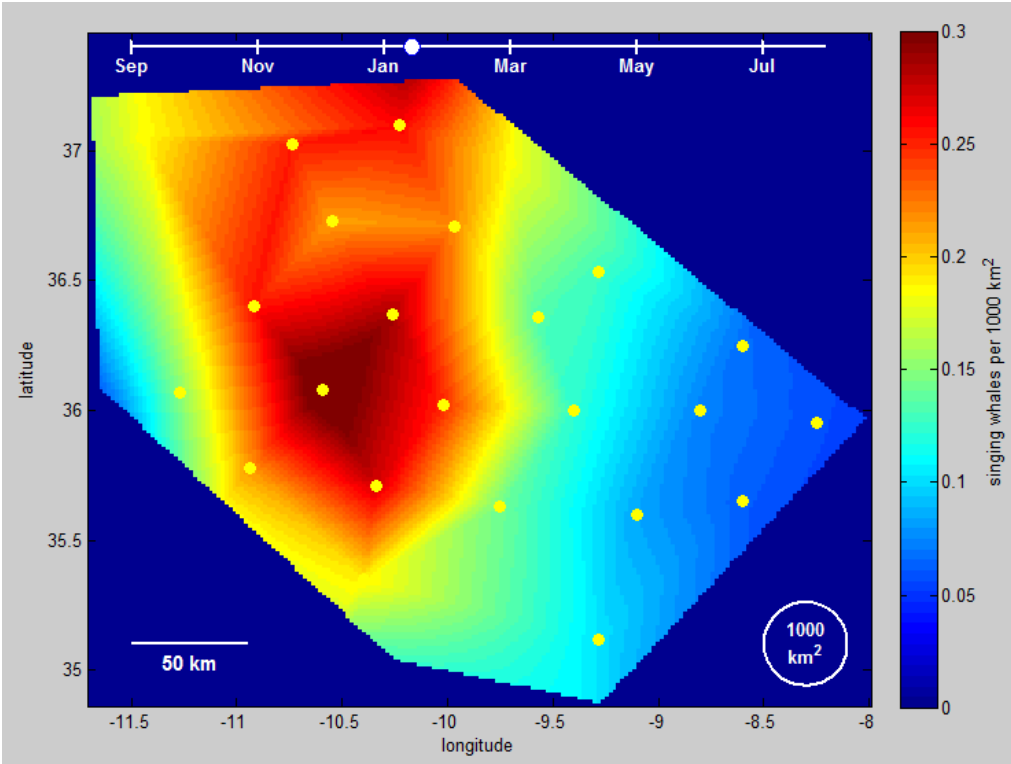

Fig. 4. A frame from the video that shows singing fin whale density throughout the year for the study location off Portugal. Yellow spots are hydrophone locations.

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 commuity. 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 should increase our capability to monitor cetacean density in geographic areas of interest, including those where naval operations are conducted. Since there have been a large number of OBS array deployments, it is our hope that this method can be applied widely to better understand the distribution, seasonality, and population density of this endangered species.

RELATED PROJECTS

Cheap DECAF (Grant number: N00014-11-1-0615, PI: Len Thomas, University of St. Andrews).

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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

Mellinger, D.K. 2013. Conditioning for marine bioacoustic signal detection and classification. Proc. Meetings Acoust. 19:010017 (8 pp.), doi:10.1121/1.4800996.