Passive Acoustic Distance Sampling

Tiago A. Marques
(Len Thomas & Danielle Harris)

Distance sampling surveys
of marine mammal density and abundance:
from introductory ideas to latest developments
I am possibly the best marine mammal for visual surveys 😊!
Visual methods are...

• Dependent on day light
• Dependent on weather
• Temporally restricted (hard to automate recordings, so depends heavily on humans)
• Far from ideal for animals that spend most of their time submerged
But since (most) marine mammals produce (“easily” identifiable) species specific sounds, and these can be identified often further away that visual detections can occur, passive acoustic density estimation has seen huge developments in the last decade.

Here we focus on distance sampling developments, but a range of other applications for passive acoustic data, including major developments in spatially explicit capture recapture methods, have also been developed.
Estimating animal population density using passive acoustics

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Passive acoustic distance sampling

Actually, nothing new there, people have been doing it for many many years with birds!
A key aspect of those forest studies always has been that the focus of the survey, the object of interest, were the animals themselves

Therefore key constraints were animal movement and double counting of animals
Fixed PAM vs. Towed PAM

Line transects

Point transects

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ESTIMATES OF SPERM WHALE ABUNDANCE IN THE NORTHEASTERN TEMPERATE PACIFIC FROM A COMBINED ACOUSTIC AND VISUAL SURVEY

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Figure 1. Diagram showing the tow cable, depressor weight, and horizontal hydrophone array used for the acoustic survey (not to scale). The lower 30 m of the tow cable was fared to reduce drag and cable strum. A nylon rope was used to stabilize the last 30 m at the tail of the array.
Sperm whale distribution and seasonal density in the Faroe Shetland Channel


Figure 2. (A) Angle, relative to boat, of the click of two sperm whales as the vessel passed by; (B) reconstruction of one whale’s position to estimate perpendicular distance.

Figure 3. Histogram of perpendicular distances to all located sperm whales.

Sperm whale abundance estimates from acoustic surveys of the Ionian Sea and Straits of Sicily in 2003

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The use of passive acoustics distance sampling for marine mammals greatly leveraged on switching the focus from animals to cues (here the individual sounds).

So was that something new from acoustics?

... not really 😊!
Cue counting: using whale blows to estimate whale abundance (needs a blow rate production)

Minke whale abundance estimation from the NASS 1987 and 2001 aerial cue–counting surveys taking appropriate account of distance estimation errors

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ABSTRACT

We estimate the abundance of minke whales (Balaenoptera acutorostrata) from the Icelandic coastal shelf aerial surveys carried out as part of the 1987 and 2001 North Atlantic Sightings Surveys (NASS). In the case of the 1987 survey, the probability of detecting animals at distance zero (g(0)) is very close to 1 but there is substantial random measurement error in estimating distances. To estimate abundance from these data, we use methods which assume g(0)=1 but which include a distance measurement error model. In the case of the 2001 survey, measurement errors were sufficiently small to be negligible, and we use double platform methods which estimate g(0) and assume no measurement error to estimate abundance. From the 1987 survey, we estimate abundance to be 24,532 animals, with 95% CI (19,399; 44,916). From the 2001 NASS survey data, minke whale abundance is estimated to be 43,633 animals, with 95% CI (30,148; 63,149).

Estimating cetacean population density using fixed passive acoustic sensors: An example with Blainville’s beaked whales

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Methods are developed for estimating the size/density of cetacean populations using data from a set of fixed passive acoustic sensors. The methods convert the number of detected acoustic cues into animal density by accounting for (i) the probability of detecting cues, (ii) the rate at which animals produce cues, and (iii) the proportion of false positive detections. Additional information is often required for estimation of these quantities, for example, from an acoustic tag applied to a sample of animals. Methods are illustrated with a case study: estimation of Blainville’s beaked whale density over a 6 day period in spring 2005, using an 82 hydrophone wide-baseline array located in the Tongue of the Ocean, Bahamas. To estimate the required quantities, additional data are used from digital acoustic tags, attached to five whales over 21 deep dives, where cues recorded on some of the dives are associated with those received on the fixed hydrophones. Estimated density was 25.3 or 22.5 animals/1000 km², depending on assumptions about false positive detections, with 95% confidence intervals 17.3–36.9 and 15.4–32.9. These methods are potentially applicable to a wide variety of marine and terrestrial species that are hard to survey using conventional visual methods. © 2009 Acoustical Society of America. [DOI: 10.1121/1.3089590]

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song unit, echolocation click, etc. Considering Eq. (2), an estimate of density \( \hat{D} \) from the \( n_c \) detected cues over a time period \( T \) (and additional information detailed below) can be obtained by

\[
\hat{D} = \frac{n_c(1 - \hat{c})}{K \pi w^2 \hat{P} T \hat{P}}
\]

where \( w \) is the distance away from the hydrophones beyond which cues are assumed to not be detected, \( \hat{P} \) is the estimated average probability of detecting a cue made within distance \( w \), \( \hat{P} \) is the estimated cue production rate, \( \hat{c} \) is the estimated proportion of false positive detections, and \( K \) is the number of replicate sensors used.

<table>
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<th>Tag</th>
<th>Date</th>
<th>Number of Dives</th>
<th>Dives for ( g(y) )</th>
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<td>3</td>
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<tr>
<td>Md248b</td>
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<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>
Each click produced by a tagged whale was detected, or not, in the surrounding hydrophones.

We don’t know the distances to detected clicks, but we can model the detection probability and get a detection probability!
Exactly the same detection function concept, just estimated with a different type of data (detected vs. non detected, i.e. a logistic regression)

Why not straightforward distance sampling?

Because distances could not be directly obtained from the detected sounds.

Well... not often... but sometimes they can!
From echolocation clicks to animal density—Acoustic sampling of harbor porpoises with static dataloggers

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Basin-scale distribution of harbour porpoises in the Baltic Sea provides basis for effective conservation actions

FIG. 3. (Color online) Spectrograms of a single right whale call received on two easternmost ARPs (site C and D), with overlaid normal mode arrivals of synthetic call based on range estimates, given above each call. Figure adapted with permission from Wiggins et al. (2004) in Canadian Acoustics.
Estimating North Pacific right whale *Eubalaena japonica* density using passive acoustic cue counting

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Big No No’s!

3 sensors...

Cue rate from another time and another place

Fig. 1. Bering Sea, with location of sensors (C, M2, and M4) shown. Land masses are light gray. The eastern Bering Sea shelf is outlined with a thick black line including the 200 m depth contour along its western edge. Bathymetry data were taken from Amante & Eakins (2009)

Fig. 2. Distances to detected right whale calls and fitted model: (a) shows the detection function (as a function of distance, for 3 values of the noise covariate, namely the 10, 50, and 90% quantile of the observed distribution) and (b) corresponds to the probability density function (PDF) of detection distances, and goodness-of-fit could be judged based on this plot. Vertical dashed lines represent the left and right truncation distances

Implications for right whale management

This study presents the first abundance estimate for North Pacific right whales based on acoustic data, and is strikingly similar to the numbers recently estimated by other authors (Wade et al. 2011) using mark-recapture techniques for photographic and genetic data.
Applying distance sampling to fin whale calls recorded by single seismic instruments in the northeast Atlantic

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Automated methods were developed to detect fin whale calls recorded by an array of ocean bottom seismometers (OBSs) deployed off the Portuguese coast between 2007 and 2008. Using recordings collected on a single day in January 2008, a standard seismological method for estimating earthquake location from single instruments, the three-component analysis, was used to estimate the relative azimuth, incidence angle, and horizontal range between each OBS and detected calls. A validation study using airgun shots, performed prior to the call analysis, indicated that the accuracy of the three-component analysis was satisfactory for this preliminary study. Point transect sampling using cue counts, a form of distance sampling, was then used to estimate the average probability of detecting a call via the array during the chosen day. This is a key step to estimating density or abundance of animals using passive acoustic data. The average probability of detection was estimated to be 0.313 (standard error: 0.033). However, fin whale density could not be estimated due to a lack of an appropriate estimate of cue (i.e., vocalization) rate. This study demonstrates the potential for using a sparse array of widely spaced, independently operating acoustic sensors, such as OBSs, for estimating cetacean density. ©2013 Acoustical Society of America. [http://dx.doi.org/10.1121/1.4821207]

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Gliders and drifters – not as fast as a line transect, not as slow as a point transect

Investigating the potential of a wave glider for cetacean density estimation – a Scottish study

Danielle Harris and Doug Gillespie

ongoing work related to methods development
Abundance estimation for Mesoplodon beaked whale species using drifting acoustic recorders. (147)

Part of session: Hearing and Passive Acoustic Monitoring

Room 112

Talks
Take Home Messages

Passive acoustics can have significant advantages over visual based methods, especially for deep divers.

Passive acoustic monitoring of marine mammals is now routinely applied, but density estimates still not routinely implemented.

Distance sampling is a go-to method if distances to sounds can be obtained (or detection function estimated any other way – experiments and sound propagation models).

Both towed systems and bottom mounted systems being routinely used, but drifting buoys and gliders likely to catch up soon.

Key issue (for cue based methods) is lack of knowledge about cue rate production – if you are interested on this come talk to me about ACCURATE.