Estimating Blainville’s beaked whale density at AUTEC using passive acoustic data


16-07-2009
Introduction
  Background
  The beaked whale case study

Methods

Application
  Number of detected clicks - \( n_c \)
  Click production rate - \( r \)
  Proportion of true positives - \( c \)
  Detection function - \( P \)
  Density estimate - \( D \)

Preliminary look at ambient noise influence on detection function

Conclusions and future work
The problem

- Estimating the abundance of natural populations is fundamental for adequate management

- "How many are there?" - Despite the simplest question one can ask about a population, the answer is not simple

- Most common approach for cetaceans is distance sampling (using boats or planes)

- But there are several complicated issues associated with visual sighting based methods

The use of hydrophones has been suggested as an alternative to collect useful data.
AUTEC

The Atlantic Undersea Test and Evaluation Center (AUTEC, in the Bahamas) has

- 93 bottom mounted hydrophones (only 82 active in this data set)
- depths of $\sim 2$ km and separated by about $\sim 4$ km
- covering an area of $\sim 1536$ km$^2$
- recording sound continuously
- automatic detection and classification to get cetacean detections
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Beaked whales

Here we consider Blainville’s beaked whales (BBW):

- deep long dives, with short periods at the surface
- great number of echolocation clicks during the deeper part of dives
- very hard to detect visually

Data kindly provided by Robin Baird (many thanks!)
Population Density: number of animals per unit area

\[ D = \frac{N}{A} \]

- **D** - density
- **N** - number of animals
- **A** - area

If we can not count all the animals in the covered area:

\[ D = \frac{n}{aP} \]

- **n** - number of detected animals
- **a** - covered area
- **P** - detection probability
Formulation II

Animal density ($D$) can be estimated$^1$ based on the $n_c$ clicks detected over time interval $T$ over $K$ hydrophones by (cue counting approach)

$$
\hat{D} = \frac{n_c \hat{c}}{K \pi \hat{P} w^2 T \hat{r}}
$$

 onde

- $\hat{r}$ - click production rate
- $\hat{c}$ - proportion of sounds classified as BBW that were really BBW
- $w$ - maximum distance at which it is possible to detect a click
- $\hat{P}$ - detection probability of a click in a circle with radius $w$ around the hydrophone

$^1$ $\hat{\theta}$ represents an estimator of $\theta$
Intuitive approach

\[ D = \frac{n_c c}{k\pi w^2 P Tr} \]

sounds that were really BBW

\((\text{effective detection area}) \times (\text{clicks produced by an animal during time period } T)\)

Note that:

- \(n_c \times c\) represents the number of true BBW sounds
- \(K \times \pi \times w^2 \times P = K \times \pi \times \rho^2\) it is the effective area of detection
- \(T \times r\) it is the number of clicks produced by an animal in the time period \(T\)
Number of detected clicks

Data: \(\approx 6\) days of data (from the 26th April till 2nd May 2005) - Previously analyzed by Moretti et al. 2006

- counts over 4961 minutes
- \(n_c = 2940521\) sounds considered to be BBW clicks (pooled over the 82 hydrophones)
- hydrophone as the sampling unit (CV 5.5%)
Available data for estimating $r$

5 whales, 21 dives, many thousand clicks
Results

Weighted average of the number of clicks per second per full deep dive cycle (weighed by time).

\[ r = 0.41 \text{ clicks per second (CV 9.8\%)} \]
Sampling

Not possible to get c directly, sampling approach was used. Given the 6 day data set:

- sample of 30 small time periods (10 minutes each)
- systematically spaced over the 6 day data set (with a random start)
- for each period, and for each hydrophone and minute, manual evaluation of which detected sounds were really BBW or not
Results

\( c \) estimated by the weighted mean of the proportion of true positives (weights: total number of clicks per period).

- (during sampled periods) 160302 sounds detected and originally considered to be BBW
- 78450 (∼50%) identified as being for sure from BBW
- ∼6% of all clicks in a ”mixed” group (BBW + other)

\[ \hat{c} : 0.549 \ (CV=1.99\%) \ or \ 0.489 \ (CV=2.29\%) \]

(depending on considering ”mixed” clicks to be all or none from BBW)
Proposed approach to estimate $P$

Estimate a detection function: detection probability as a function of relevant covariates.

- DTag’s over 4 whales (for a total of 13 deep dives)
- For each click produced by the animal, record of its detection (or failure to do so) in surrounding hydrophones
- “Logistic regression” to estimate the detection function
Distances from clicks to hydrophones

Example: distances to produced clicks and detected by hydrophone

T.A. Marques, J. Ward, L. Thomas, N. DiMarzio, P.L. Tyack, I
Estimating Blainville’s beaked whale density at AUTEC
Fitted model

\[ P (\text{detecting a click is a function of}): \]

- Distance
- Orientation (relative)
- Pitch (relative)

Integrate out variables by simulations

\[ P = \text{mean click detection probability, in a 8 km radius, is 0.032 (CV 15.9%).} \]
Density estimate

Combining all this information, the estimated BBW density is:

25.3 (17.3-36.9) or 22.5 (15.4-32.9) BBW per 1000 km$^2$, depending on the proportion of true positives

Moretti et al. 2006: 34.7 or 25.4 BW per 1000 km$^2$
Ambient noise

- Characterizing the ambient noise at AUTEC ("sprinkles")
- Adding ambient noise to hydrophone data from DTag events
- Small data subset: 1 Dtag, 4 hydrophones (all AHRP uni-directional)
- 4 levels of noise added, resulting in an ambient noise criteria (ANC)
- Re-run detector and classifier to get detections associated with DTag data
- New model for the detection function, now including ANC
Ambient noise II

▶ Unexpected increase in detections with moderate levels of noise
▶ Strange pattern for hydrophone 73

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Table 1: Overall probability of detection (pooled across distances and angles) of clicks as a function of ambient noise level, per hydrophone

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Ambient noise III

Preliminary look at ambient noise influence on detection function
Conclusions and future work

Ambient noise IV

- Get a new density estimate, accounting for ambient noise
- Get ANC within 5 minute periods over the 6 day data set
- Each click in each period gets the detection probability of detection conditional on the observed ANC and with other covariates integrated out

Proof-of-concept $\rightarrow$ AHRP uni-directional hydrophones only
Conclusions

- results consistent with other estimates in the area
- easily extendable to other species (and to terrestrial environments)
- but estimating detection function required DTag’s, which are not available in the supermarket
- need the right (i.e. for the survey period considered) detection function, click rate and true positive proportion
- process can be optimized at several levels
Future work

- more independent dive data for modeling the detection function
- incorporate ambient noise in the detection function and contrast results (work in progress)
- better sound classification (ambiguity / mixed groups)
- testing under different scenarios
- DECAF: other approaches to estimate the detection function from passive acoustic data (e.g. SECR, sonar equation, sound propagation models, etc)