An update to the methods in Endangered Species Research 2011 paper "Estimating North Pacific right whale *Eubalaena japonica* density using passive acoustic cue counting"

Tiago A. Marques *,[1,2], Lisa Munger[3],Len Thomas[1], Sean Wiggins[3], John A. Hildebrand[3]

CREEM Technical Report 2012-1

[1]Centre for Research into Ecological and Environmental Modelling, The Observatory, Buchanan Gardens, University of St Andrews, St Andrews KY16 9LZ, UK

[2]Centro de Estatística e Aplicações da Universidade de Lisboa, Bloco C6, Piso 4, Campo Grande, 1749-016 Lisboa, Portugal

[3]Scripps Institution of Oceanography, University of California San Diego, 9500 Gilman Drive, La Jolla, California 92093-0205, USA

*tiago@mcs.st-and.ac.uk

1 Introduction

The purpose of this small report is to clear up an inconsistency in the paper Marques *et al.* (2011). This paper gives an example of how conventional distance sampling methods can be used to estimate animal density from passive acoustics, using the standard software Distance (Thomas *et al.*, 2010). The example is that of North Pacific right whales in the Bering Sea. In typical applications, distances are recorded to all detected objects of interest (right whales calls in the example) out to some maximum distance from the sensor. This was done in the right whale example, but in addition some very close calls were not used in the analysis (because distances could not be obtained) – an additional complication known in the distance sampling literature as "left truncation". This complication can be easily dealt with in the Distance software. However, the method given in the *Methods* section of Marques *et al.* (2011) is different from that implemented by Distance – although it leads to exactly the same density estimate. Here, we detail both approaches. A key quantity reported in the *Results* section of the paper, the average probability of detection p, was taken from the Distance output, and hence is not consistent with the *Methods* section of the paper. We show how the reported p was obtained. We empasize that none of the results are incorrect, and that the density estimate is unaffected by the inconsistency.

2 Details

Marques *et al.* (2011) present an estimate of right whale density obtained via conventional distance sampling. Under conventional distance sampling, one of the required multipliers to convert the number of detected objects of interest (right whale calls in Marques *et al.* (2011)) to animal density is p, the probability of detection. This corresponds to the mean probability of detection of animals in the covered area, and its standard expression is

$$p = \int_0^w g(r)\pi(r)dr \qquad (1)$$

where $g(r)$ represents the detection function, i.e., the probability of detecting an object given it is at distance r from the transect, $\pi(r)$ represents the distribution of animals, detected or not, as a function of distance r, and w represents a (right) truncation distance beyond which no objects are detected. The covered area is therefore $a = \pi w^2$.

Marques *et al.* (2011) used left truncation at w_l, which led to the need to introduce a slightly different formulation for p. The meaning of p is still the same, i.e., the mean probability of detection of animals in the covered area, but the covered area is now different, namely $a_1 = \pi w^2 - \pi w_l^2$. Hence the expression for p is given by the second equation in Marques *et al.* (2011), i.e.

$$p_1 = \int_{w_l}^w g(r)\pi_1(r)dr \qquad (2)$$

where we use $\pi_1(r)$ instead of their $\pi(r)$ because we will need to make a subtle distinction, as we show below.

An inconsistency arises because in their results, Marques *et al.* (2011) present $\hat{p} = 0.29$, but this does not correspond to the result of evaluating equation 2. This value corresponds to the method implemented in software Distance (Thomas *et al.*, 2010), which is based directly on equation 1. Of course, with left truncation, one needs a small tweak to use that expression, which is to consider by assumption that $g(r) = 0$ for $r < w_l$, i.e.

$$p_2 = \int_0^w g(r)\pi_2(r)dx = \int_0^{w_l} g(r)\pi_2(r) + \int_{w_l}^w g(r)\pi_2(r) = 0 + \int_{w_l}^w g(r)\pi_2(r)dr \tag{3}$$

and therefore one needs to consider that the corresponding covered area is the area of the circle up to w, i.e. $a_2 = a = \pi w^2$. Note that $\pi_1(r)$ and $\pi_2(r)$ in equations 2 and 3 are slightly different, because they are probability density functions with the same shape but different supports, i.e. $\pi_1(r) \propto \pi_2(r)$ but $\pi_1(r) \neq \pi_2(r)$. So while Marques *et al.* (2011) report density as

$$D = \frac{n(1-c)}{a_1 p_1 T_k r} \tag{4}$$

density was actually estimated in Distance considering

$$D = \frac{n(1-c)}{a_2 p_2 T_k r}. \tag{5}$$

While both approaches lead to the same numerical result (as $a_1 \times p_1 = a_2 \times p_2$), the methods described and the results presented in Marques *et al.* (2011) are therefore inconsistent.

References

Marques, T. A., Munger, L., Thomas, L., Wiggins, S., and Hildebrand, J. A. (2011). Estimating North Pacific right whale (*Eubalaena japonica*) density using passive acoustic cue counting. *Endangered Species Research*, **13**, 163–172.

Thomas, L., Buckland, S. T., Rexstad, E. A., Laake, J. L., Strindberg, S., Hedley, S. L., Bishop, J. R., Marques, T. A., and Burnham, K. P. (2010). Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology*, **47**, 5–14.