Submergence times and abundance estimation of blue whales off Sri Lanka

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ABSTRACT:
Very little is known about the blue whale populations in the waters of Sri Lanka. A first attempt at estimating their relative abundances using DISTANCE sampling methods is currently underway in the waters off the southern coast of the island. Surfacing behavior was quantified from focal follows of individual blue whales between January and March 2011. Estimates of submergence times will be used for generating more precise abundance estimates. Individuals were followed from a 32-foot vessel to observe surfacing patterns and breathing behaviour in the presence and absence of whalewatching boats. Time at first surface, length of surface interval, number of blows and final dive time were collected. The data gathered was analysed using a hidden Markov model (HMM) to identify whether dive duration was uniform or whether dives could be classified using surface interval and submergence time. The preliminary results show that the whales performed two types of dives; 'regular' and 'deep' dives with Inter Breath Intervals (IBI) of 22.0s (SD=4.7) and 635.6s (SD=405.4) respectively. Blue Whales off southern Sri Lanka spend 75% of their time performing 'regular' dives. Accordingly; we estimated that their mean IBI was approximately 173s. These preliminary results obtained using HMM may provide a more accurate correction factor than that obtained from the raw data. This may refine estimates of whale density and abundance for the area.

INTRODUCTION:
A first attempt at estimating abundance of blue whales (*Balaenoptera musculus*) in southern Sri Lankan waters using DISTANCE sampling methods is currently underway. This and other methods of abundance estimation rely heavily on cue counting. Knowledge of dive times is important to estimate the amount of time a whale spends submerged and undetectable for counting as it allows for more accurate abundance estimations.

The lack of dedicated, long-term studies on cetaceans inhabiting the territorial waters of Sri Lanka is well noted. Sri Lanka lies in the heart of the Indian Ocean whale sanctuary (area north of 55^{o}S) established in 1979 by the International Whaling Commission. Accordingly, it was intended to serve as a focal point for marine mammal research and conservation. However, apart from two comprehensive surveys around its coastline that documented presence and prevalence of marine mammal species (Alling et al., 1991), and a few short term projects (Ilangakoon, 2006; Ilangakoon and Perera, 2009; Leatherwood and Reeves, 1989; Broker and Ilangakoon, 2008), little research has been undertaken. To date, research on blue whales within this and the Exclusive Economic Zones of other Arabian Sea countries has been minimal (Baldwin et al., 1999; Small and Small, 1991).

With the end of the civil war in Sri Lanka, development is occurring at a fast pace and an unregulated whalewatching industry targeting blue whales has developed in the absence of baseline information. The rapid growth of this industry is the result of the high encounter rates and influx of tourists throughout the northeast monsoon season (December – April). As the continental shelf on the southern coast is narrowest and steepest along this portion of the coastline, accessibility to the whales is high. Moreover, the study site overlaps with one of the heaviest shipping channels in the world (Kaluza et al., 2010). As a result of this constant activity, the collection of control data (in the absence of whalewatching boats) is difficult and this preliminary analysis uses data collected in the presence of whalewatching boats.

METHODS:

Data on blue whale surfacing intervals was systematically recorded between January and March 2011 off southern Sri Lanka. Data was collected from individual focal follows. The time of the first surfacing, the number of blows while at the surface and the final dive time were recorded. Time series of Inter-Breath Intervals (IBI) were estimated as the time between two surfacings in a follow.

To model the surfacing pattern of blue whales in Sri Lanka, a hidden Markov model (HMM) was used to analyse the time series data (individual follows of IBI), using the msm package in R 2.12 (R Development Core Team 2010). In a HMM, non-observable (hidden) states can be identified from time series of observed behavioural data, and the density distribution (mean and SD) and transition probability between states in continuous time can be estimated. For blue whales in Sri Lanka, the hidden states were dive types, which were defined by the density distribution of IBI. The number of states and their initial density distributions (required by the msm package) were given from visual inspection of density histograms of the IBI data. We assumed the IBI to be the mixture of two normal distributions and that transitions between all dive types were possible (initial transition probabilities=1). The maximum likelihood of the density distribution of the two states (dive types) and the transition probability matrix was estimated from the observed time series data of IBI.

From the transition probability matrix of the fitted model it was possible to estimate the expected total length of stay in each state (dive type), from which the relative proportions that blue whales spend in each dive type could be calculated.

RESULTS:

Respiration data from a total of ten blue whales was collected during four days between January 18 and March 12 2011, off Weligama, Sri Lanka. All data was collected in the presence of vessels due to the difficulty of gathering control data in this area of heavy ship and whalewatching activity. For the HMM analysis, six follows and a total of 133 IBI were used, giving an average of 22 IBI per follow (SD=14.5).

The preliminary data showed that the blue whales in Sri Lanka engaged in two distinct dive types, regular and deep dives. The HMM estimated the mean IBI of a regular dive to be 22.0s (95%CI=21.03-22.91) with a standard deviation of 4.7s (95%CI=3.93-5.54) while deep dives had a mean of 635.6s (95%CI=438.01-833.13) and a standard deviation of 405.4s (95%CI=294.04-558.96). The relative proportion of time that the whales spent in each of these dive states was 75% (95%CI=57.9-87.1) and 25% (95%CI=12.9-42.1) respectively.

The transition probability between the two dive types per minute was also calculated. Accordingly, the probability that a blue whale performing a regular dive will remain in a regular dive in the following minute is 83% (95%CI=72.9-90.6). The probability that a blue whale will change from a regular dive to a deep dive in the next minute is 17% (95%CI=9.4-27.1). If a blue whale was performing a deep dive the probability that it would change to a regular dive in the next minute was 51% (95%CI=26.4-78.3) while it would remain in a deep dive only 49% (95%CI=21.7-73.6).

Mean IBI based on the relative proportion of dives and the mean estimate from the HMM is 173.2s. However, if this is estimated using the raw data the mean IBI decreases to 103.8s.

DISCUSSION:

Since blue whales appear to spend a larger proportion of their time performing regular dives than deep dives it is possible to anticipate that at any given time 75% of the population will be performing regular dives, surfacing only every 22s, while 25% will be performing deep dives from which they will only surface every 636s.

The mean IBI estimated from the HMM was 173s while that based on the raw data was much shorter. This means by using the latter, one would expect to see blue whales every 104s so the correction factor of missed animals would be larger, which would bias the abundance estimate for the given area. The application of the HMM to the dataset accounts for this and returns a conservative estimate that can be used to refine estimates of whale density in the area.

The preliminary results based on this small data set provide an opportunity to estimate the proportion of time the blue whales off southern Sri Lanka spend at the surface and how much time they are invisible to ensure more accurate estimates of abundance. The probability of sighting blue whales from vessels is relatively lower than from aircrafts. However, since these measurements were all made from boats they will be particularly valuable for correcting vessel-based surveys.

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