CHARACTERISING FEEDING GROUND HABITAT OF BALEEN WHALES IN EAST ANTARCTICA: A PLANNED ANALYSIS

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Scope

One of the central aims of the CCAMLR-IWC workshop held in Hobart, Tasmania, in August last year was to develop a framework to extend Southern Ocean ecosystem modelling efforts to include predator-prey interactions, with krill the central node. Models of these interactions would further inform sustainable CCAMLR krill catch limits while being mindful of potential impact on higher predators, such a baleen whales. Analysis of potential impacts will require, at the very least, both predictive and explanatory models of whale distributions. To date there has been scant quantitative research into the environmental drivers of whale distribution off East Antarctica that could be used to extend or augment existing Southern Ocean ecosystem models. One of the direct recommendations of this workshop was to start exploring and analysing existing data from multidisciplinary broad-scale surveys to model whale feeding habitat. The Australian Antarctic Division holds whale sightings, krill, oceanographic and other environmental data from broad-scale multidisciplinary voyages off East Antarctica (30-150°E) known as the BROKE and BROKE-West voyages; so there is now an opportunity to begin to build models to explain whale distribution as a function of the underlying biotic and abiotic environment. The species this analysis will focus on are humpback, blue, fin, sei, Antarctic minke and southern right whales.

This short note outlines some sources of data, methods and potential offshoots from a planned analysis of baleen whale distribution in east Antarctica. We welcome any suggestions or feedback.

Data

The first BROKE (Baseline Research on Oceanography, Krill and the Environment) survey, conducted in the austral summer of 1996, aimed to provide a quasi-synoptic description the ecosystem and oceanographic features in an area of 873,000km^2 adjacent to the coast of east Antarctica, between 80° and 150°E (see Nicol *et al.* (2000) for further details and for details of whale distributions see Thiele *et al.* (2000). The second survey , BROKE-West, conducted in the austral summer of 2006, had identical aims, but focussed on the coastline further west, between 30° and 80°E and covered an area of 1,300,000km^2 (the results of this voyage are currently in the final stages of preparation for publication as a Special Issue of Deep-Sea Research - Nicol and Meiners *in prep*). These surveys consisted of north-south oriented transects, extending between130nm and 412nm from the coastline. During both BROKE surveys, data collected included acoustic detections of Antarctic krill, details of circulation and water masses, primary production, composition of pelagic communities (fish, squid and zooplankton) and sighting surveys of birds and acoustic and sighting surveys of cetaceans. We also have access to remotely sensed sea ice and primary productivity data..

Analyses

By definition, these analyses will be multivariate; and, by necessity, they will be spatial. However, there may be little reward in directly modelling whale distribution as a function of a suite of environmental covariates, given such variables may themselves be descriptors for krill distribution, a likely driver of whale habitat. There will, therefore, be a multi-pronged approach modelling a) krill-environment, b) krill-whale and c) whale-environment interactions. The strength of modelling whale distribution with data from BROKE and BROKE-West surveys lies in the accompanying hydroacoustics data which describes krill distribution in high resolution detail (albeit in 2 dimensions). It is also likely that relationships between whale and krill distribution and various environmental covariates will be highly nonlinear, will have non-Gaussian errors and will be subject to process lags. There are many statistical techniques that could be used to model these non-Gaussian and non-linear relationships: such as generalized linear models (in particular nonlinear regression) and generalized additive models (with classification and regression trees or multivariate adaptive regressions splines, etc, to aid in model-selection). In the first instance we will explore explanatory models, which seek causal links between whale abundance and distribution, krill abundance and distribution and the nominated suite of environmental covariates, as opposed to a parsimonious predictive model. Parameter estimates from explanatory models are much more easily fed into ecosystem level models than their often caveat-laden predictive counterparts. Explanatory models also allow testing of ecological/biological meaningful hypotheses about the drivers of whale distribution, which will be of interest to the greater cetacean research community.

Off-shoot analyses

There are a number of secondary analyses that would benefit from the establishment of relationships between whale, krill and environmental covariates in the Southern Ocean. Recently, there have been abundance estimates presented to IWC-SC which are based on the use of spatial models for abundance estimation (e.g., Bravington and Hedley (2009: SC/61/IA14)). This model-based approach uses the relationships (either predictive or explanatory) between animal distribution and abundance to extrapolate over entire survey areas, usually resulting in total abundance estimates that are often more precise than their design-based equivalents (methodology detailed in Hedley and Buckland (2004)). In a similar vein, this information can also be used to produce more optimal and efficient survey designs (e.g., Hedley *et al.* (2007: SC/59/IA3)), where track design is set out in order to target more effort to areas with higher variability (due either to a lack of information or from inherent variance).

References

Bravington, M. V. and Hedley, S. L. (2009). Antarctic minke whale abundance estimates from the second and third circumpolar IDCR/SOWER surveys using the SPLINTR model. Paper SC/61/IA14, presented to the IWC Scientific Committee, June 2009 (unpublished),

Hedley, S. L., Bravington, M. V. and Peel, D. (2007). Design of future SOWER cruises. Paper SC/59/IA3, presented to the IWC Scientific Committee, June 2007 (unpublished), 11 pp.

Hedley, S. L. and Buckland, S. T. (2004). Spatial models for line transect sampling. *Journal of Agricultural Biological and Environmental Statistics* **9**, 181-199.

Nicol, S. and Meiners, K. BROKE-West, a large ecosystem survey of the South West Indian Ocean sector of the Southern Ocean (CCAMLR Division 58.4.2). *Deep-Sea Research II* **To appearin late 2009**.

Nicol, S., Pauly, T., Bindoff, N. L., Wright, S., Thiele, D., Hosie, G. W., Strutton, P. G. and Woehler, E. (2000). Ocean circulation off east Antarctica affects ecosystem structure and sea-ice extent. *Nature* **406**, 504-507.

Thiele, D., Chester, E. T. and Gill, P. C. (2000). Cetacean distribution off Eastern Antarctica (80-150 degrees E) during the Austral summer of 1995/1996. *Deep-Sea Research Part II-Topical Studies in Oceanography* **47**, 2543-2572.