Environmental factors affecting the fine-scale distribution of minke whales (*Balaenoptera acutorostrata*) in a dynamic coastal ecosystem

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Introduction

Marine environments and habitats are often heterogeneous over spatial and temporal scales leading to the patchy distribution of their communities (Yen *et al*, 2004). Studies have demonstrated that changes in the concentration of cetaceans are primarily related to the distribution of their prey (Baumgartner, 1997), however, prey items such as fish, squid and crustacean species are all affected by a range of biotic and abiotic factors themselves. The aim of the present study was to investigate the fine-scale distribution of minke whales (*Balaenoptera acutorostrata* Lacépède) with respect to fixed (physiographic) and non-fixed (oceanographic) environmental variables (EV's) in an inshore coastal habitat in NE Scotland: to determine how the interactions of EV's within this study area may affect availability of the whales primary prey species, the sandeel (*Ammodytes marinus*). The minke whale (photo, right) is the smallest and most abundant of the baleen or mysticete whales in Scottish waters and a significant component of the marine ecosystem. As such, this small rorqual is considered to be of high conservation priority and, indeed, a critical indicator of ecosystem health and change within this region.

Photo: Kevin Robinson.

Methods

Dedicated shipboard line-transect surveys were carried out by the CRRU in the outer southern Moray Firth (N 57º40', W 3º30') (**Fig. 1**) between May and October 2000 to 2005. Four evenly placed transect routes were used – each divided into 4 sub-routes – to ensure systematic coverage of the 860 square km study area lying between the coastal ports of Lossiemouth and Fraserburgh. The GPS positions of recorded animals were subsequently plotted for comparison with underlying fixed (e.g. sediment type / geomorphology) and non-fixed (e.g. temperature and productivity) EV's using GIS applications and remote sensing techniques. GIS modelling of topographic relief (depth, slope, aspect and composition) was determined from bathymetric and sediment-type data, whilst sea surface temperature (SST) and chlorophyll-a concentrations were obtained from AVHRR and SeaWiFS satellite imagery, and expressed using ArcView v.3.3 (HCL Technologies, New Delhi).

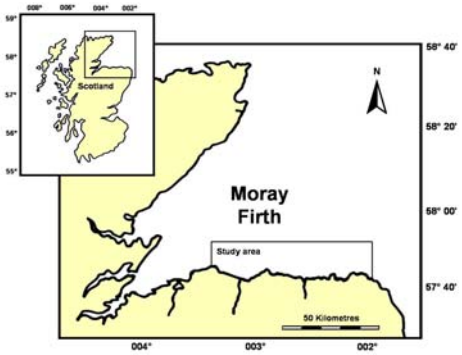


Fig. 1. Map showing the location of the Moray Firth in NE Scotland and the position of the study area along the southern coastline of the outer Moray Firth.

Results

Throughout the study period, 121 encounters with *B. acutorostrata* were recorded. Areas of highest encounter frequency were found to be characterised by features of shallow depths (from 10-14 metres), steep slopes (70-74degrees) and sandy gravel sediment types. Two oceanographic features were further identified in this area which were shown to influence the distribution of minkes: (i) a warm water plume extending out from the inner Firth; and (ii) a cold water runoff, known as the Dooley Current, running into and across the mouth of the Moray Firth embayment. Chlorophyll-a concentrations appeared to be highest in the study area when the sea surface temperature was warmer, and subsequently *B. acutorostrata* encounter frequencies were significantly higher during periods when the warm water plume was most dominant (**Fig. 2**).

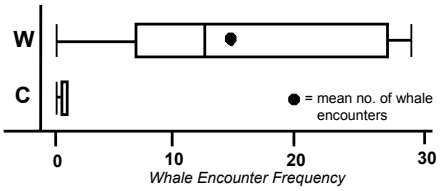


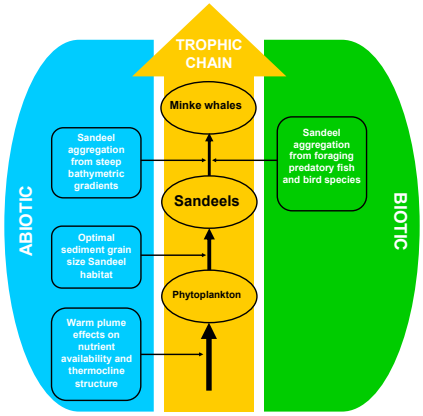
Fig. 2. Box plot showing the differences in *B. acutorostrata* encounter frequency when either the cold water current (C) or the warm water plume feature (W) was most dominant. A Mann-Whitney U test showed there was a significant difference in encounter frequency between these two periods (W=24.5, *p*=0.0167).

Discussion

From strandings records for *B. acutorostrata*, the sandeel (*Ammodytes spp.*) is known to comprise the largest component of the stomach contents in Scottish waters (Pierce *et al.*, 2004). It is hypothesised, therefore, that the environmental factors most highly correlated with *B.acutorostrata* encounter positions are those which preferentially support the optimal conditions and habitat for *Ammodytes* spp. itself. Environmental factors supporting high levels of phytoplankton could subsequently be used to indicate where and when the sandeel prey will be most abundant to foraging minke whales, and in doing so, thereby suggest those areas of highest whale encounter probability.

Whilst a number of modelling techniques have already been applied to predict the future abundance (Tjelmeland & Bogstad, 1998) and distribution (Macleod *et al.*, 2004) of cetacean species such as *B. acutorostrata* in European waters, the present findings may, however, indicate an inherent flaw in the design of these models. Firstly, current ecosystem models of abundance consider only the relationships between the trophic consumers within such a system. Yet it is apparent from studies of the feeding ecology of minke whales in the outer Moray Firth by Robinson *et al.* (unpublished data) that *B.acutorostrata* further relies on the presence of non-prey related species (such as schooling mackerel and feeding birds) to aggregate their target prey. Secondly, the distribution models only consider fixed EV's, such as bathymetry and sediment type for example, with no reference to non-fixed oceanographic variables such as SST and productivity. In this respect, when trying to understand and predict the spatio-temporal variations observed in the fine-scale distribution of *B. acutorostrata* – particularly within a dynamic coastal ecosystem such as the heterogeneous Moray Firth environment – a more detailed model accounting for both biotic *and* abiotic factors (such as that shown in **Fig. 3**) may need to be considered.

Fig. 3. Proposed model for ecosystem structure (including abiotic & biotic factors) for minke whales, sandeels and phytoplankton in inshore NE Scottish coastal waters.



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