

Diving and surfacing characteristics of coastal minke whales (*Balaenoptera acutorostrata*) in the Moray Firth, Scotland: Implications for visual estimates of population size

Jade L. Rogers^{1,2}, Kevin P. Robinson¹, Joanna L. Kershaw²

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¹Cetacean Research & Rescue Unit (CRRU), 48 Seatown, Gardenstown, Banff AB45 3YQ, Scotland, UK

²University of Aberdeen, School of Biological Sciences, Tillydrone Avenue, Aberdeen, Scotland, UK, AB24 2TZ

j.rogers.19@abdn.ac.uk



Introduction

The minke whale is the smallest and most abundant baleen whale in UK waters, with an estimated North Sea population size of 9,000 (Hammond *et al.*, 2017). Within the highly productive shelf waters of the outer Moray Firth, in northeast Scotland, the species is commonly sighted between June and October (Robinson *et al.*, 2009). Animal density is estimated from boat and ariel cue count surveys, using a detection function known as $g(0)$, defined as the probability of detecting an object on a survey transect line (Thomsen *et al.*, 2004). However, surfacing behaviour significantly alters the probability of an individual being detected (availability bias). This heterogeneity in surfacing behaviour can be modelled by including variables such as age class and behaviour in the detection function, to provide more accurate estimations of abundance. Parameters can be adjusted when estimating abundance in a known feeding area or in areas more commonly associated with a particular age class (e.g. Robinson *et al.*, 2023).

Methods

Dedicated boat surveys were carried out between June and September 2006 to 2023 (Beaufort sea state ≤ 4 , visibility ≥ 1 km) within a 1,980km² study area (Figure 1). During dedicated focal follows, the time was recorded from the first surface event and noted between each subsequent blow. The time between each blow and the direction of travel was used to determine the behaviour of each individual. Age class was determined based on size (adults > 6.5 m, juveniles < 6.5 m). Surfacing rate was calculated using the total number of surfacing events $- 1 /$ the duration of the focal follow (after Weir *et al.*, 2023).

Results

- Adult whales and feeding whales showed significantly higher surfacing rates than juvenile and travelling whales (one-way ANOVA: $F_{1,42} = 7.11$, $p = 0.01$ and $F_{1,44} = 7.09$, $p = 0.01$, respectively) (Figure 2).
- No correlation was found between dive duration and pre-dive or post-dive surface duration.
- Both age class and behaviour were found to significantly influence pre-dive surface duration ($Z = 2.83$, $p < 0.01$ and $Z = 2.61$, $p < 0.01$, respectively). Juvenile and travelling minke whales showed shorter pre-dive surface durations.
- Age class was found to influence post-dive surface duration ($Z = 3.07$, $p < 0.01$). Juveniles had a shorter post-dive surface duration than adults.

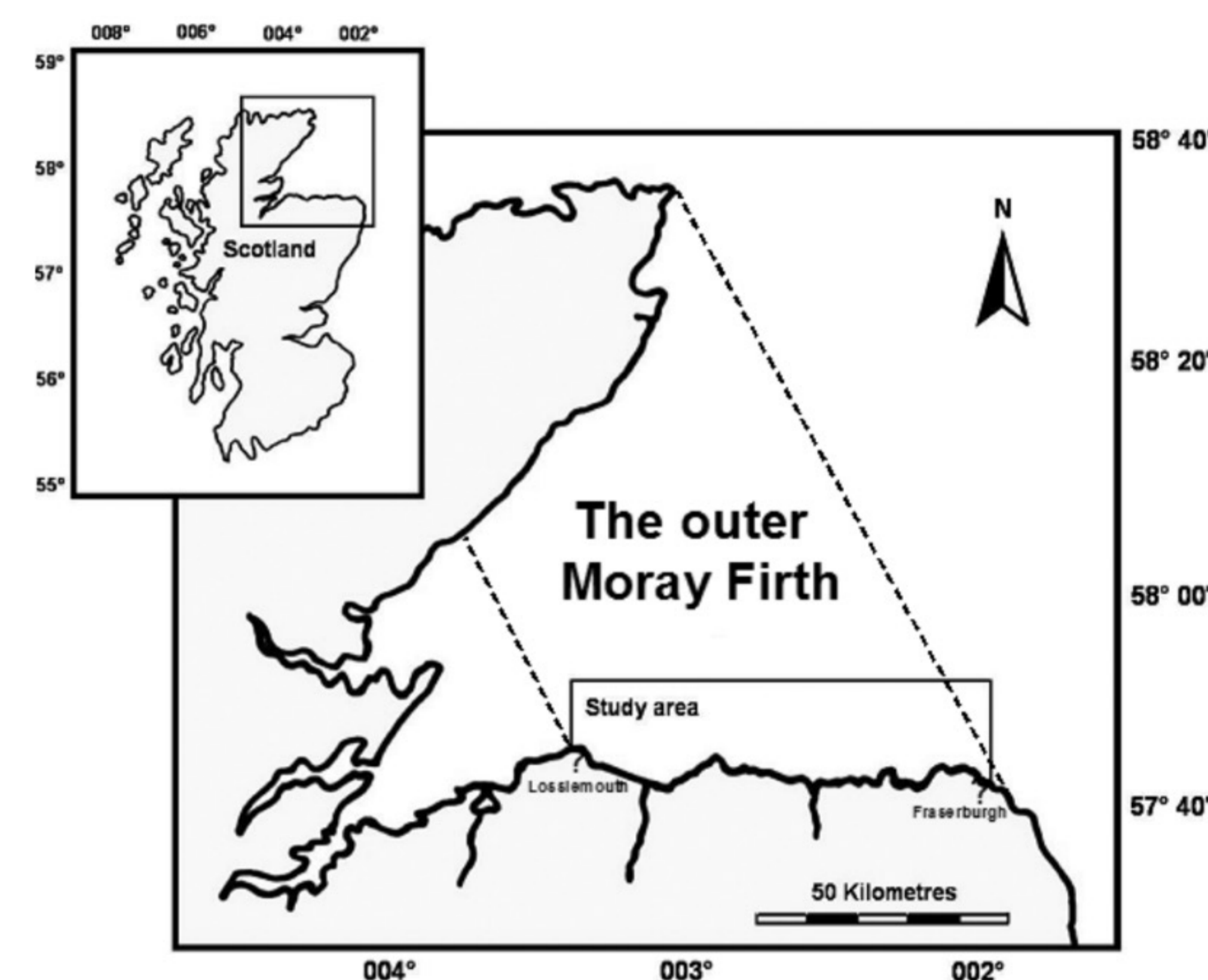


Fig. 1. The position of the outer Moray Firth study area in northeast Scotland, northwest North Sea

Discussion

Surfacing rates were found to be consistent with other studies in minke whales, thereby providing a reliable parameter to correct for availability bias (Heide-Jørgensen & Simon, 2023). Our data show little correlation between dive time and surface duration, suggesting that animals are not reaching their aerobic dive limit (ADL). Diving below the ADL would maximise time for foraging without the need for a longer recovery time. Adults frequently use more active feeding strategies, such as prey corraling, which expend higher amounts of energy (Robinson *et al.*, 2023) and so require a longer surface recovery time, reflected here in higher surfacing rates. Travelling whales perform short dives to avoid drag created by the surface turbulence (Christiansen *et al.*, 2015), expending less energy and surfacing less frequently, as shown here with lower surfacing rates. Considering variation in diving behaviour is therefore important when estimating availability bias to provide more accurate estimations of abundance.

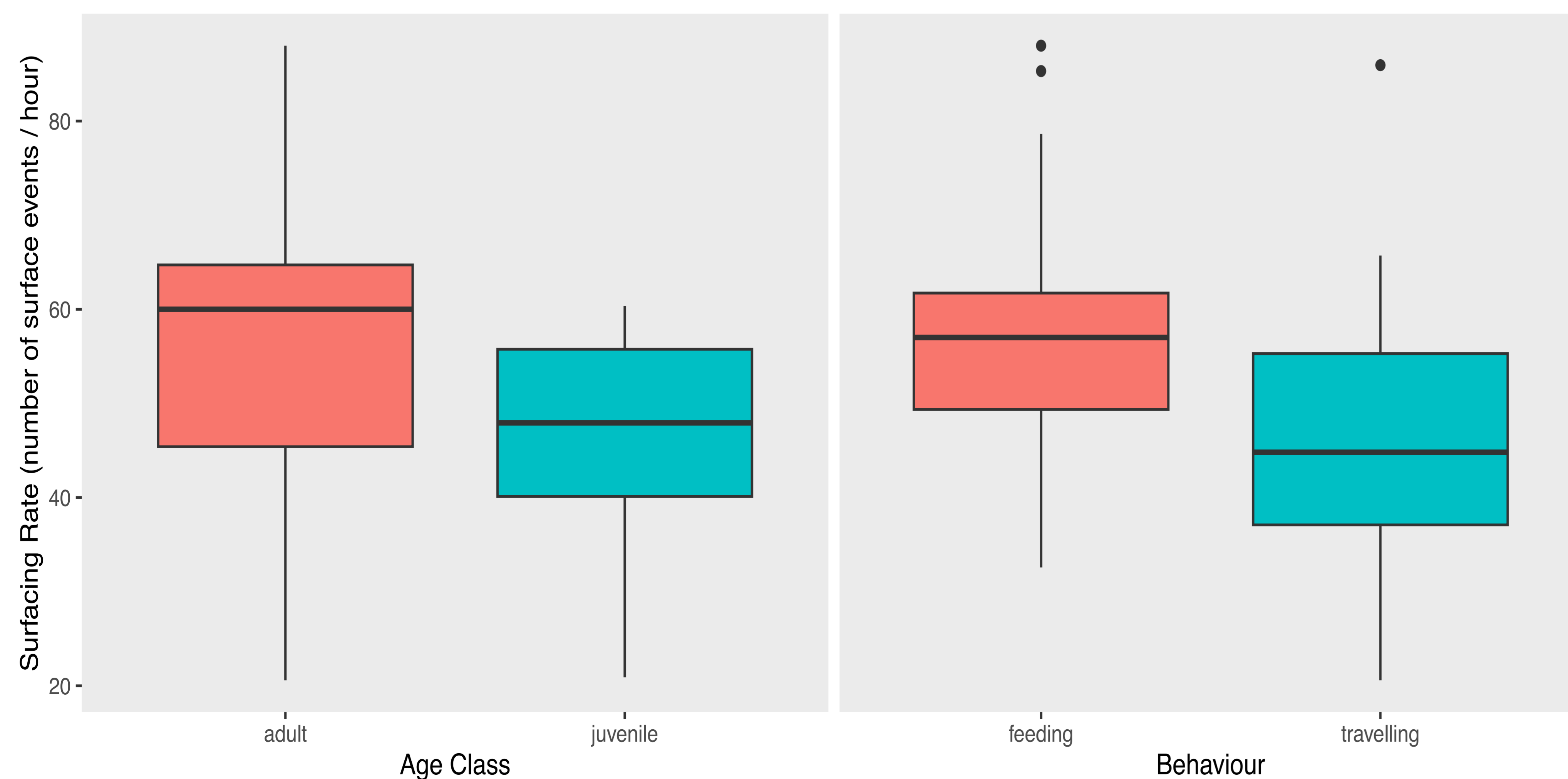


Fig. 2. A comparison of the number of surfacing events/hour for adult vs juvenile and feeding vs travelling minke whales.



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References



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