

## Behavioural observations of foraging minke whales (*Balaenoptera acutorostrata*) in the outer Moray Firth, north-east Scotland

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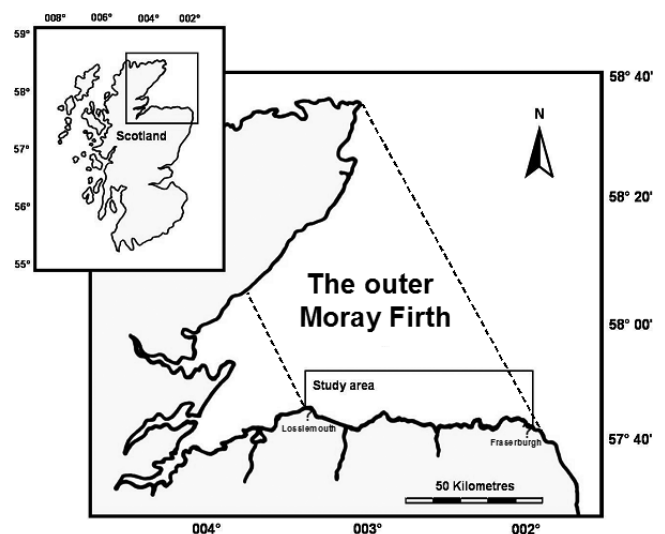
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The minke whale (*Balaenoptera acutorostrata*) is a widespread, opportunistic species showing spatial and seasonal variations in diet according to local availability of prey. Although previous research has been conducted on the foraging strategies of this small rorqual whale, in terms of prey aggregation and assimilation, relatively little has been published on the foraging association of this species with coastal seabirds. Over the past five years, minke whales occurring along the outer coastline of the southern Moray Firth in north-east Scotland during the summer and autumn months have been recorded foraging in the presence of seabirds, such as kittiwakes (*Rissa tridactyla*), herring gulls (*Larus argentatus*), guillemots (*Uria aalge*) and shearwaters, which form dense feeding rafts at the water's surface. The formation of bird rafts notably occurs independently of the presence of *B. acutorostrata*, believed instead to be the successive result of prey concentrated at the surface by predatory schooling fish from below rather than by activities of the whales themselves. In this area of the North Sea, schooling mackerel (*Scomber scombrus*) constitute the most significant component of the summer fish biomass and are believed to perform the role of compacting targeted sandeel (*Ammodytes* spp.) prey into concentrated bait balls almost exclusively. The resulting ball of prey is consequently available to the foraging whale, which can be seen opportunistically utilizing successive bird rafts rather than expending unnecessary energy corralling the *Ammodytes* prey by traditional, active entrapment methods. The role of the mackerel in increasing both the rate and density of sandeel ball formation (as indicated by the presence and activity of associated bird rafts) is therefore thought to be very significant in this inshore Scottish location. Changes in oceanographic variables such as water temperature have been directly correlated with the migration of *S. scombrus*. The observed inter-annual variability in *B. acutorostrata* distribution in the outer Moray Firth may subsequently be related to the respective distribution and abundance of these migratory, pelagic fish species.

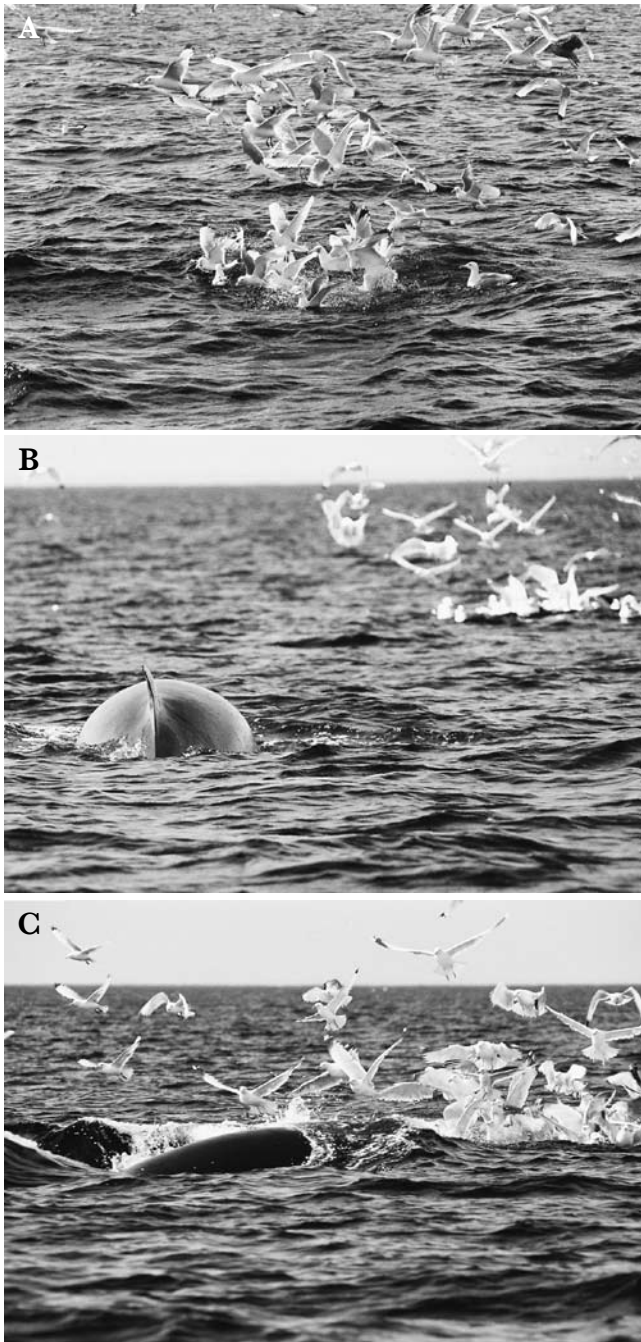
The cosmopolitan minke whale (*Balaenoptera acutorostrata* Lacépède) is an opportunistic species showing spatial and seasonal variations in diet according to local availability of prey. With its broad menu and flexible feeding habits, the species utilizes a range of strategies when foraging (Hoelzel et al., 1989; Wells et al., 1999). One method, known as bird-associated foraging, however, appears to be particularly prevalent in Scottish waters. Here, the whales exploit concentrations of small fish compacted together at the water's surface by flocks of feeding seabirds from above and by schooling predatory fish below. Whilst several studies have noted this behaviour (e.g. Gill et al., 2000; Robinson & Tetley, 2005), few have investigated the processes behind such a foraging strategy. This communication highlights the bird-associated feeding methods utilized by coastal minke whales in north-east Scotland, both from a behavioural ecology perspective and with respect to the importance of the outer Moray Firth as a summer feeding ground for these and other essential marine fauna.

Observations were recorded from June to October 2000 to 2005 inclusive during dedicated boat surveys of an 880 km<sup>2</sup> area of the southern outer Moray Firth coastline lying between the coastal ports of Lossiemouth and Fraserburgh (Figure 1). The observations were made as part of a longer term study on the fine-scale distribution and ecology of *B. acutorostrata* in the outer southern Moray Firth by Robinson and colleagues. During 136 encounters with foraging minke whales, bird-associated feeding was recorded in 76% of all cases. Thirteen species of seabird were identified in bird feeding rafts, including: kittiwakes (*Rissa tridactyla* L.), gulls (*Larus canus* L.; *L. argentatus* Pontoppidan; *L. marinus* L.; *L. fuscus* L.), gannets (*Morus bassanus* L.), auks (*Uria aalge* Pontoppidan; *Alca torda* L.),

shearwaters (*Puffinus puffinus* Brunnich; *P. griseus* Gmelin; *Fulmarus glacialis* L.) and terns (*Sterna hirundo* L.; *S. paradisaea* Pontoppidan). Bird rafts were seen to form independently of the presence of *B. acutorostrata*, the whales appearing to be attracted to these feeding



**Figure 1.** Map of the Moray Firth in north-east Scotland showing the position of the 880 km<sup>2</sup> study area along the southern coastline of the outer firth between the coastal ports of Lossiemouth and Fraserburgh.



**Figure 2.** Illustrating the bird-associated foraging sequence of *Balaenoptera acutorostrata* in the Moray Firth: (A) a bird raft forms independently of the presence of the whales; (B) a foraging minke makes its approach towards the feeding raft frenzy; and (C) the whale lunges itself through the water column beneath the bird raft engulfing the aggregated bait ball below.

areas by the perceptible frenzy of congregating birds (Figure 2). The formation of these bird rafts was thought to be the result of successive prey concentration at the surface by schooling predatory fish below rather than activity by the whales themselves when nearby. However, whales exploiting this ephemeral, opportunistic food source appeared to expend less energy than those employing traditional, lunge-feeding prey entrapment manoeuvres.

In conclusion, minke whales in the outer Moray Firth principally employ low-energy, bird-associated feeding methods during the productive summer months. Diving birds, such as auks and shearwaters, are thought to play an essential role in the creation of bait balls at the water's surface. However, schooling mackerel (*Scomber scombrus* L.), forming the most considerable component of the summer fish biomass in this North Sea area (ICES, 2005), are believed to be the most important ingredient in the aggregation of targeted sandeel (*Ammodytes* spp.) prey into a protective ball. As such, the role of predatory mackerel in increasing both the rate and density of bait-ball formation (as indicated by the presence and activity of associated bird rafts) is thought to be highly significant in this north-east coastal location. Changes in oceanographic variables such as surface sea temperature have been directly correlated with the migration of *S. scombrus* in the North Sea (Reid et al., 1997). The inter-annual variability observed by Tetley (2004) in the fine-scale distribution of minke whales in the outer southern Moray Firth may therefore subsequently be accounted for by the respective distribution of this migratory, pelagic fish species.

It is recommended that future studies of bird-associated feeding in *B. acutorostrata* examine the dive time intervals of foraging whales as a direct behavioural measure of energy expenditure. This may be particularly significant with respect to varying conspecifics such as the proportions and numbers of seabirds in rafts, relative abundance of *S. scombrus* and the respective influence of environmental variables, as these factors may affect the short-term productivity and/or long-term stability of this dynamic, coastal ecosystem.

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