



Original investigation

Humpback whale (*Megaptera novaeangliae*) and killer whale (*Orcinus orca*) feeding aggregations for foraging on herring (*Clupea harengus*) in Northern Norway

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ABSTRACT

Aggregations of predators on food patches have been documented for both terrestrial and marine animals. Here, we documented for the first time, and investigated, non-predatory aggregations occurring between humpback whales (*Megaptera novaeangliae*) and killer whales (*Orcinus orca*) while feeding on wintering Norwegian spring spawning herring (*Clupea harengus*) in Andfjord, northern Norway. Observational data were collected during 109 opportunistic surveys through three seasons 2013–2016. Killer whales were observed feeding on 59 occasions, with one to three humpback whales involved in 47 of these feeding events (79.7%), and there was an increased probability of finding feeding humpback whales when feeding killer whales also were observed. With killer whales identified as the initiating species in 94.4% of the feeding aggregations for which the first species was known, and with humpback whales joining and feeding on the fish ball afterwards, we suggest that humpback whales may benefit more from these aggregations than the opposite.

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Introduction

The ocean is a dynamic environment where irregularly allocated resources define the distribution of organisms. Food patches, defined as dense concentrations of homogenous resources, often promote spatial and temporal aggregations of predators through two main facilitative mechanisms. First, a concentration of foragers on food patches may subsequently enhance discovery of unpredictable prey by neighbors in search of food, a passive process called local enhancement (Bruno et al., 2003; Grunbaum and Veit, 2003; Poysa, 1992; Silverman et al., 2004). Second, predators may actively associate with hetero-specifics if easier prey capture and increased foraging efficiency are provided (Bearzi, 2006; Berec, 2010; Goyert et al., 2014; Lett et al., 2014). Higher predator densities may also encourage schooling behavior of fish prey, promoting possible mutual benefits among foragers (Lett et al., 2014; Similä and Ugarte, 1993). Predator interactions remain advantageous as

long as prey density outweighs competition, and otherwise become negative (competitive) when resources diminish (Poysa, 1992).

Mixed-species feeding aggregations in the marine environment have been reported in many species including seabirds, pinnipeds, cetaceans and fish (e.g. Au and Pitman, 1988; Bearzi et al., 2006; Brager, 1998; Camphuysen and Webb, 1999; Goyert et al., 2014; Pitman and Ballance, 1992; Vaughn et al., 2007). As a common factor of all studies, some species appear to act as catalysts, initiating the feeding process, with other species arriving at a later stage when prey have been found or concentrated and predation eased, and are called opportunists (Camphuysen and Webb, 1999).

Off the coast of northern Norway, killer whales (*Orcinus orca*) occur throughout the year with a peak of observations during October–January when the Norwegian spring spawning (NSS) herring (*Clupea harengus*) over-winters in coastal waters (Similä et al., 1996). From 1986 through 2005, when herring wintered in the Tysfjord – Vestfjord system, studies highlighted killer whales as efficient herring predators with specialized feeding techniques including carousel feeding (Similä, 1997b; Similä and Ugarte, 1993). In carousel feeding, killer whales herd the fish into a tight ball close to the surface and capture individual herring after debilitating them with underwater tail slaps (Domenici et al., 2000; Similä, 1997a; Similä and Ugarte, 1993; Simon et al., 2006). Killer

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whales were shown to adjust group size in relation to herring school size (Nøttestad et al., 2002), but feeding aggregations with other cetacean predators were never reported over the course of these long-term studies.

Humpback whales (*Megaptera novaeangliae*) use the Norwegian Sea as a migration corridor between their summer feeding areas, mainly located around Jan Mayen and Bear Island, and their low latitude breeding ground (Øien, 2007). Since 2010, the wintering ground of the NSS herring has been located in offshore and coastal waters between 69°N and 73°N (Huse et al., 2010; Norges Sildesalgslag, 2010) where humpback whales, never before observed on the former herring wintering ground, have been present in large numbers and observed feeding on the same herring schools as killer whales (personal unpublished observations). Although adult humpback whales have previously been observed opportunistically feeding alongside another cetacean species, the Indo-Pacific bottlenose dolphin (*Tursiops aduncus*; Stockin and Burgess, 2005), interactions between humpback and killer whales reported to date have often been agonistic, and almost exclusively involved predation (killer whales towards humpback whales) or defense (e.g., humpbacks being attacked by killer whales or defending other prey species; see Pitman et al. (2017) for a review). This paper reports on the first observations of feeding aggregations formed by killer whales and humpback whales.

We investigated the scope of feeding aggregations formed by humpback and killer whales on the wintering ground of the NSS herring, and further examined if one of the species could be identified as initiating the feeding events. More specifically, using observations collected over three winter seasons (December–February 2013–2016), we tested if observing

feeding humpback whales was related to the occurrence of feeding killer whales, thus suggesting that in these mixed-species feeding aggregations killer whales act as catalysts while humpbacks are opportunists. Possible mechanisms involved in the formation of these feeding aggregations and potential competition are discussed. To our knowledge, this is the first report on humpback whales and killer whales feeding on common prey patches, therefore providing a valuable contribution to our current understanding of humpback whale–killer whale interactions.

Material and methods

Study area

Observations were made around the northern tip of Andøya, centered on Andenes (69°19'N, 16°08'E), Vesterålen, northern Norway (Fig. 1). The NSS herring stock, which has occupied diverse wintering areas over the last decades, started over-wintering in both coastal and offshore waters between 69 and 73°N in 2002 (Huse et al., 2010). Andfjord, a fjord running to the east of Andøya and open in the north towards the Norwegian Sea, has been part of the current wintering ground of the NSS herring. All the feeding events presented in this study occurred in near-shore waters where depths were all less than 250 m and commonly less than 100 m.

Data collection

Observations during the winter seasons 2013–2014 and 2014–2015 were collected during whale watching trips operated from Andenes on board a 36-foot-long rigid hull inflatable boat.

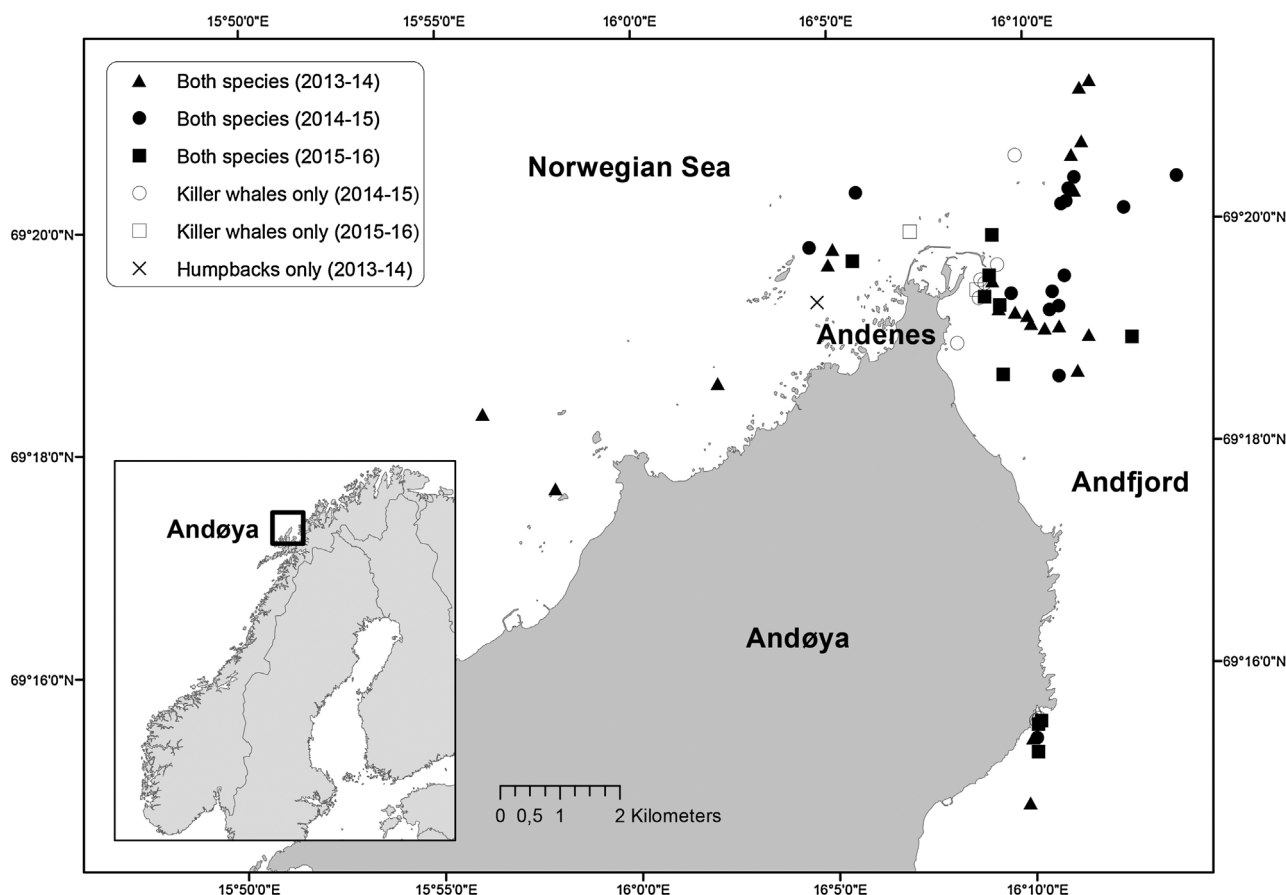


Fig. 1. The map shows the study area where all the field trips were conducted during the three seasons. Each symbol represents the exact location, based on GPS coordinates, of feeding events involving humpback and/or killer whales.

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