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Unusual Left-Handed Surface Feeding with Bubble Production in Fin Whales (*Balaenoptera physalus*)

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The use of exhaled bubbles by foraging cetaceans to corral, encircle, or startle prey may constitute tool use (Mann & Patterson, 2013). Humpback whales (*Megaptera novaeangliae*) are well known to form closed rings of bubbles to encircle and concentrate prey for more efficient feeding—both alone and in cooperative groups (Jurasz & Jurasz, 1970; Hain et al., 1982; Friedlaender et al., 2011). Similar behaviour has been documented in Bryde's whales (*Balaenoptera brydei*; Kot et al., 2014), but the extent to which bubbles are used for prey manipulation is less understood for other rorqual species, including blue (*Balaenoptera musculus*), fin (*Balaenoptera physalus*), and minke (*Balaenoptera acutorostrata*) whales (Kot et al., 2014).

Bubbles have been associated with feeding in fin whales (Kot et al., 2014). Citing Brodie's 1993 study, Kot et al. (2014) considered that fin whales may produce bubbles incidentally either from jaw cavitation or actively from the nares. The latter is more likely because Brodie's (1993) study reported a synovial joint-crack or "pseudocavitation" (p. 2547), which produces bubbles within tissues that are not emitted into the environment. When feeding, fin whales are understood to be strongly "right-handed," favouring right-lateral lunges (RLLs; Katona et al., 1983; Kot et al., 2014). RLL is defined as "forward trajectory feeding where the whale rotates at a shallow angle from the sea surface, with its right side directed towards the sea-bed" (Kot et al., 2014, p. 1351).

Herein, left-lateral lunge-feeding (LLF) coupled with the emission of long bubble-streams is described. This behaviour occurred approximately 20 times by solitary and paired whales (n = 3) and was photographed over a 3-h period (1200 to 1615 h) on 11 December, and again on 14 December 2010, during winter fin whale surveys in Clonea Bay, County Waterford, Ireland (N 52.0913°, W -7.4849° and N 52.0998°, W -7.4513°, respectively). Navigation charts indicate a gravel benthos with mean depths of 20 and 60 m, respectively, at these locations.

Fin whales are typically considered a pelagic species, although they sporadically occur in shallow coastal waters of the Celtic Sea during autumn and winter to feed on shoals of spawning herring and sprat (Whooley et al., 2011; Harma et al., 2012; Ryan et al., 2014). The prey type could not be verified during observations in this study, but previous research suggests that sprat and herring are the most likely prey (Ryan et al., 2014). Photo-identification and biopsy sampling were the priority research activities, so only two examples of this behavior were photographed (Figure 1). This includes the presence of continuous bubble-streams over 20 to 100 m, followed by surface LLF feeding (Figures 1 & 2). The actual emission of bubbles was occurring out of sight underwater. LLFs generally marked the terminus of about 200-m diameter, clockwise-arced manoeuvres (Figure 2). Surface signatures of these straight or curved streams of exhaled air were observed as continuous rows of audible, marble-sized bubbles. Complete circles were not observed. Both photo-identification and molecular sexing results confirmed that the whales photographed in Figure 1 were different individuals of both sexes (Ryan, 2012).

The observed bubble-streams were much longer than those described for fin whales by Kot et al. (2014) and may have been used to manipulate prey (e.g., Sharpe & Dill, 1997) from below and behind to facilitate capture. Manoeuvrability in rorquals is scaled to body size (Segre et al., 2022), which may account for the different strategies among rorquals (Friedlaender et al., 2011). Humpback whales typically return to the bubble net to engulf prey (Hain et al., 1982; Friedlaender et al., 2011). Fin whales, however, were always observed lunge-feeding ahead of (and heading away from) bubble-streams with a rapid approach and longer streams of bubbles. Clupeids can be corralled by a closed net of bubbles but will rapidly flee from open walls of bubbles (Sharpe & Dill, 1997). Therefore, herring and sprat may be concentrated ahead and above a fin whale when

Figure 1. (A) Fin whales (*Balaenoptera physalus*) on 11 and 14 December 2010 in shallow coastal waters of County Waterford, Ireland; images show long, right-curved bubble-streams preceding a left-lateral surface lunge-feeding; and (B) fin whale doing a more typical right-lateral lunge in the absence of bubble-streams. (*Photographer:* Conor Ryan)

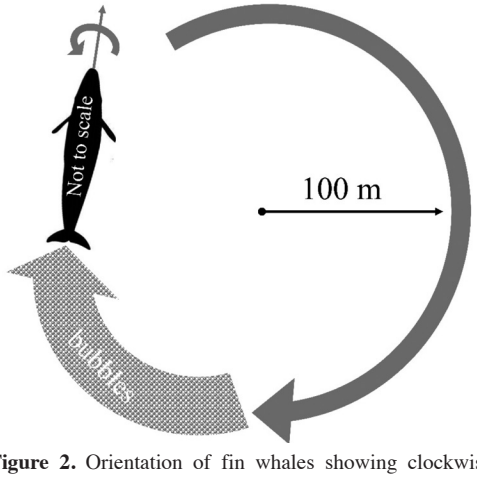

Figure 2. Orientation of fin whales showing clockwise swim direction (thick grey lines) and counter-clockwise roll direction (thin grey line) during feeding events associated with bubble-streams (patterned line)

rapidly pursued from below and behind using a bubble-stream (Figure 1).

While not quantitatively analysed herein, the qualitative evidence of regular and perhaps exclusive LLF in combination with bubbles contrasts with findings of previous studies that showed a strong preference for RLL feeding in fin whales: 81.1% (N = 212, Atlantic), 97.4% (N = 304, Gulf of California), and 100% (N = 185, Gulf of St. Lawrence) (Tershy & Wiley, 1992; Kot et al., 2014). These observations lend support to the hypothesis that asymmetrical pigmentation in fin whales may have evolved for prey-herding (Katona et al., 1983) rather than preserving countershading during RLL feeding (Mitchell, 1972). The combination of bubble-streams and exposing white pigment would increase visibility to prey and enhance the prey flight response (Sharpe & Dill, 1997; Nøttestad et al., 2002), which has been documented in killer whales (*Orcinus orca*) (Similä & Ugarte, 1993; Nøttestad et al., 2002).

Forage fish endurance—for example, the ability to escape predators—is dependent on body size (He & Wardle, 1998). Consequently, the more rapid pursuit of prey by fin whales compared with humpback whales, as an example, may result in fine-scale prey size selection. As such, the diversity of lunge-feeding strategies in rorquals raises interesting questions about the maintenance of niche partitioning. In conclusion, these observations suggest that fin whales are not strictly right-handed and may use white jaw pigment in combination with bubbles to herd prey. Quantitative research is warranted to better understand this behaviour in fin whales, as well as the response of their prey, as a potential mechanism for niche partitioning.

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