

Short Note

Observations of top predators foraging on fish in the pack ice of the southern Ross Sea

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New micro-technology with links to satellites has revolutionized the collection of information on the foraging movements of marine animals, but observations of actual foraging are still very rare. Here we describe foraging by killer whales (*Orcinus orca* (L.)), minke whales (*Balaenoptera bonaerensis* Burmeister), Adélie penguins (*Pygoscelis adeliae* (Hombron & Jacquinet)) and emperor penguins (*Aptenodytes forsteri* Gray), in all cases we believe feeding on fish, in the south-western Ross Sea, Antarctica.

Killer whales

On 23 January 2004, we observed C ecotype killer whales (Pitman & Ensor 2003), seemingly feeding, off Cape Washington and travelling within 2 m of the pack ice edge toward Campbell Glacier tongue. We followed them by helicopter as they tracked along the regular pack ice edge; ice thickness was about 2 m. The animals stopped at a small right-angle embayment in the ice formed by a large multi-year floe. Two adult (female-sized) animals emerged from under the ice floe and then spy hopped. In the meantime, an adult male arrived, remaining motionless for about 20 sec before diving under the ice. Of the two previously mentioned animals, one moved away to then return to the ice, while the other dove under the ice floe belly up. At this stage other animals gathered. A mother-calf pair emerged close to the ice emitting bubbles of air, joined soon by another female-calf pair. These eight animals were joined by four more, spy hopping around the ice floe, which then cracked in two. No penguins or seals were observed in the immediate area of the episode.

The event lasted about 5 min, in the course of which the 12 animals displayed a behaviour similar to the herding phase of the 'carousel method' (Similä & Ugarte 1996). We noted that individuals swam with the white underside of their body towards the ice floe and emitted bubbles close to the surface, in a way comparable to the cooperative feeding reported by these authors for killer whales preying on herring (*Clupea harengus*) in northern Norway.

Therefore we interpreted this behaviour as a feeding-related activity intended to encircle the (fish?) prey to prevent them from escaping to deeper waters. To date there is little direct information on the diet of the C form of the killer whale (Ainley *et al.* 2006a). It is recognized as a fish-eating species targeting toothfishes (*Dissostichus* spp.; Berzin & Vladimirov 1983), but it is thought to also eat Antarctic silverfish (*Pleuragramma antarcticum* Boulenger) (Ainley *et al.* 2006a, 2006b). A similar behaviour has been observed in a Weddell seal (*Leptonychotes weddellii* Lesson) in McMurdo Sound (Ross Island vicinity), where the seal attempted to catch fish in a crevice under the ice by expelling blasts of air (Davis *et al.* 1999). In that area, the Weddell seal feeds extensively on the Antarctic silverfish (Burns *et al.* 1998) but also the bald rock cod/notothen (*Pagothenia borchgrevinkii* Boulenger; Kim *et al.* 2005). Between 1996 and 2006 at Cape Crozier, GB and DA frequently observed groups of 10–30 type C killer whales or of 1–12 minke whales apparently foraging along the Ross Ice Shelf edge and nearby fast ice edges. In several instances, killer whales were observed near the surface with belly up. The whales were typically seen either travelling to and from the ice edges, or diving at or under the ice edge repeatedly over several hours, indicating that most foraging associated with either glacial or fast ice edges.

Other predators

On 9 January 2007, sighting from the 60 m high bluff of Cape Royds (Ross Island) at a distance of about 500 m, DA observed one minke whale, in loose pack ice, swimming just beneath the surface in a tight circle having a radius of about 30 m, its back to the centre. It then would disappear from sight for a couple of minutes, emerging again in the immediate vicinity. It did this several times throughout the day in an area called "Backdoor Bay", in McMurdo Sound.

In the same general area, from the same vantage point, DA also observed several instances of small flocks of Adélie penguins, 10–15 per flock, generating vortices by swimming round and round just beneath the surface, the

radius of each vortex being about 20 m. The flock would completely disappear but then appear in a rush, popping vigorously to the surface within the vortex centre. At times, they would then porpoise as fast as they could in one direction for about 30–40 m, whereupon they would make a right angle turn as they dove. They would appear 10 m from where they dove. They would then porpoise in the opposite direction, repeating the same manoeuvre. At the time, individuals in the population at Cape Royds were feeding only on fish, likely silverfish, as judged by the food regurgitated to chicks (Ainley *et al.* 2006a).

In most years at Cape Crozier, we have observed penguins generating vortices in waters along the face of the Ross Ice Shelf, but usually at distances at 1–2 km or more, too far to be certain about what they were doing. On one occasion (December 2002), closer observations of such vortices made from the ice edge (by GB and others) revealed groups of several hundred Adélie penguins and dozens of emperor penguins repeatedly making extended dives under the fast ice locked between the Ross Ice Shelf and the Cape Crozier Adélie penguin colony. At any given time, one to several dozen penguins would dive simultaneously, having spent 20–30 sec at the surface, and we could see that the penguins were diving towards the ice edge. We do not know how deeply they were diving but at least 10 m (potentially much deeper). The emperor penguins were observed feeding fish, probably silverfish (judging from the black guano), to their nearly-fledged chicks, which had gathered nearby.

Although, *a priori*, we cannot exclude other fish species (such as *Trematomus newnesi* Boulenger (Williams 1988) or *Pagothenia borchgrevinki*, which is found in association with ice shelves (Gutt 2002)), the predatory activity performed by the orcas and the other predators that we observed in Terra Nova Bay and off capes Royds and Crozier was also likely directed at silverfish. We have rarely found other fish species in the diet of penguins nesting at Royds or Crozier (Ainley *et al.* 2003), although we have a photograph of a penguin trying to swallow a large *Trematomus* spp. *Pleuragramma antarcticum* is a small, shoaling, herring-like species dominating, in both number and biomass, the water column fish fauna of most shelf areas of the Southern Ocean (Eastman 1993) and is recognised as a principal prey species for many predators in the Ross Sea (La Mesa *et al.* 2004, Ainley *et al.* 2006b). In particular, the coastal region of our observations is within a geographic area very important for the life cycle of silverfish, as deduced by a high abundance of larvae (Granata *et al.* 2002), and of a recently discovered large spawning ground near the Italian Mario Zucchelli Station (Vacchi *et al.* 2004). In the same area, *P. antarcticum* represents the most important prey for the Cape Washington emperor penguins at the colony (Cherel & Kooyman 1998); they are important as well in the diet of Adélie penguins at Edmonson Point (Clarke *et al.* 1998).

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