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Short Note

Depredation by Killer Whales (*Orcinus orca*) on a Blue Shark (*Prionace glauca*) in Northeastern Atlantic

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Killer whales (*Orcinus orca*) consume a wide variety of prey, including marine mammals, teleost fish, seabirds, sea turtles, and cephalopods (Ford, 2019). Killer whale populations throughout the world tend to exhibit dietary specialization, feeding selectively upon only a very small subset of prey species from the 200 species that they are known to predate (Heimlich-Boran, 1988; Baird et al., 1992; Ford, 2019). These ecological specializations are maintained by their feeding habits and social behavior (e.g., acoustic repertoires), which result in reproductive isolation and, ultimately, genetic divergence (Ford & Ellis, 2014). Such ecologically specialized and reproductively isolated populations of killer whales are known as ecotypes. Around the world, 11 ecotypes have been identified: three in the northeastern Pacific, five in the Southern Ocean, and three in the northeastern Atlantic (de Bruyn et al., 2013; Ford, 2019). These ecotype specializations reflect cultural traditions that have evolved over millennia in which feeding behaviors are passed from one generation to the next by social learning (Ford, 2019).

Certain ecotypes have been observed preying upon cartilaginous fishes, including sharks and rays. The Offshore killer whales of the northeastern Pacific Ocean are a fish-specialist ecotype that prey on bony fishes (i.e., Pacific halibut [*Hippoglossus stenolepis*], chinook salmon [*Oncorhynchus tshawytscha*], sculpin [Cottoidea], and opah [*Lampris guttatus*]), as well as cartilaginous fishes (i.e., blue shark [*Prionace glauca*], Pacific sleeper shark [*Somniosus pacificus*], spiny dogfish [*Squalus acanthias*], and salmon shark [*Lamna ditropis*]) (Jones, 2006; Dahlheim et al., 2008; Ford, 2019). During predatory events, teeth of the Offshore killer whale can become severely worn due to the abrasive quality of shark skin (Ford et al., 2011; Ford & Ellis, 2014), which is roughened by embedded dermal denticles that protect sharks from predators (Southall & Sims, 2003). Thus, predation observations and tooth-wear evidence for this ecotype suggest that sharks may be particularly important in their diets (de Bruyn et al., 2013). The Offshore ecotype from the northeastern Pacific appears to target shark livers, perhaps exclusively (Ford, 2019), which comprise up to one third of a shark's total mass and is rich in lipids (Lingham-Soliar, 2005), representing a nutritious food for the killer whales. Off California, for example, a great white shark was killed, and only the liver was consumed (Pyle et al., 1999).

In South Africa, Engelbrecht et al. (2019) documented two events in which killer whales of a separate ecotype preyed upon broadnose sevengill sharks (*Notorynchus cepedianus*), using a specialized feeding method in which only the liver of each shark was consumed. Other researchers in South Africa suggested the existence of a flat-toothed killer whale morphotype that occurs in offshore areas and preys upon sharks, similar to the Offshore killer whale in the North Pacific Ocean (Best et al., 2014; Engelbrecht et al., 2019). Besides the Offshore ecotype of the northeastern Pacific and the events in South Africa, records of killer whales preying on sharks are rare (Table 1). Herein, we present details of a single observation of killer whales feeding upon a blue shark captured in a pelagic longline fishery in the northeastern Atlantic Ocean.

On 18 September 2015 at 1447 h (GMT), a pelagic longline fishery was operating in the northeastern Atlantic Ocean (35.37° N, 38.57° W, a position more than 2,000 km from the European mainland). The longline and branchline (hanging from the longline) lengths were 120 km and 20 m,

Table 1. Events of killer whales (*Orcinus orca*) preying on sharks

Species	Location	Source
Prionace glauca	California (USA), Southeast Brazil, New Zealand, South Africa, Uruguay	Ternullo et al., 1993; Fertl et al., 1996; Visser, 2000b; Dahlheim et al., 2008; Best et al., 2010; Passadore et al., 2015
Sphyrna sp.	Galápagos (Ecuador)	Sorisio et al., 2006
Sphyrna lewini	Papua New Guinea	Visser & Bonoccorso, 2003
Sphyrna zygaena	New Zealand	Visser, 2005
Isurus oxyrinchus	New Zealand, South Africa, Uruguay	Visser, 2000a; Williams et al., 2009; Passadore et al., 2015
Carcharhinid shark	Golfo Dulce (Costa Rica),	Fertl et al., 1996
Carcharodon carcharias	California (USA), South Africa	Pyle et al., 1999; Best et al., 2010
Notorhynchus cepedianus	Patagonia (Argentina), South Africa	Reyes & García-Borboroglu, 2004; Engelbrecht et al., 2019
Alopias vulpinus	New Zealand	Visser, 2005
Galeorhinus galeus	New Zealand	Visser, 2000a
Cetorhinus maximus	New Zealand, California (USA)	Brown & Norris, 1956; Norris, 1958; Fertl et al., 1996
Cetorhinus maximus	Southern California (USA)	Brown & Norris, 1956; Norris, 1958
Carcharhinus galapagensis	Galápagos (Ecuador)	Fertl et al., 1996
Rhincodon typus	Gulf of California (México)	Fertl et al., 1996; O'Sullivan & Mitchell, 2000
Carcharhinus amblyrhynchos	Papua New Guinea	Visser & Bonoccorso, 2003
Somniosus pacificus	Northeastern Pacific	Ford et al., 2011
Squalus suckleyi	Not specified	Ford & Ellis, 2014
Lamna ditropis	Not specified	Ford & Ellis, 2014

respectively. The main target species were swordfish (*Xiphias gladius*) and pelagic sharks, and the hooks were baited with mackerel (*Scomber scombrus*) and squid (*Illex argentinus*). From the fishing vessel, two killer whales were observed following the longline while it was being hauled back onto the vessel. One was a juvenile, and the other one was likely an adult female or an immature male given the size of the dorsal fin (too small for an adult male). The two whales then approached and attacked a hooked blue shark. During this attack, the blue shark thrashed such that its caudal fin flipped above the water surface. This interaction occurred approximately 50 m from the side of the vessel for a duration of approximately 5 min. Once the shark's carcass was hauled up onto the vessel, it was observed that the liver and digestive system were gone, as well as the pectoral fins, though the rest of the body was intact. This event was recorded opportunistically by video camera from the longline fishing vessel (video footage available in the "Supplemental Material" section on the *Aquatic Mammals* website: https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=10&Itemid=147).

These killer whales likely belonged to one of two ecotypes that have been identified in the North Atlantic, although further information is needed to confirm this (de Bruyn et al., 2013; Ford, 2019; Jourdain et al., 2019). Type 1 is primarily a fish-feeding ecotype, preying upon herring and mackerel around Iceland, Norway, and Scotland, but there are group-specific variations in the proportions of prey items taken, including high trophic level prey (Foote et al., 2009; Jourdain et al., 2017, 2019). Tooth wear in this ecotype has been observed by researchers, but they did not infer that this was due to shark predation (Foote et al., 2009). In offshore regions of the northeastern Atlantic, this ecotype is more commonly observed around vessels fishing for mackerel (Luque et al., 2006; Nøttestad et al., 2014). The Eastern stock of the Atlantic bluefin tuna (*Thunnus thynnus*) has been suggested as a third major fish-prey resource for North Atlantic killer whales (Foote et al., 2011; Esteban et al., 2016a). Tuna, and possibly other higher trophic level prey, could also be part of the diet of killer whales around the Canary Islands as suggested by dietary markers and contaminant loads from biopsy samples (Esteban et al., 2016b). Yet it is inconclusive if this orca community that feeds on tuna is another ecotype or belongs to Type 1 since no movement between the two locations has been documented (Jourdain et al., 2019). Type 2, partly sympatric with Type 1, is a marine mammal

specialist ecotype, preying on both pinnipeds and cetaceans (Ford, 2019). This ecotype exhibits little isotopic variation, consistent with a highly specialized diet primarily of baleen whales (Foote et al., 2009). Based upon our current understanding of these two ecotypes of the North Atlantic, we suggest that the killer whales involved in this shark depredation event most likely belong to the fish-eating, tooth-worn Type 1.

In this short note, because it was a single event involving depredation (i.e., acquired learned behaviors in which marine mammals obtain food collected by humans; Hamer et al., 2012), we cannot suggest that these killer whales regularly prey on sharks. These individuals could have learned to take and consume fish caught by humans that may not be part of their typical diet (Ford, 2019). However, the fact that these killer whales targeted the liver, which is a highly selective feeding behavior that is likely learned, suggests that these individuals have fed upon sharks before (Engelbrecht et al., 2019).

In many different locations around the world (i.e., Pacific, Atlantic, and Southern Oceans, and the Mediterranean and Bering Seas), killer whales have learned to remove fish, primarily tuna and swordfish, caught on longline fishing gear as it is being hauled in (Dalla Rosa & Secchi, 2007; Passadore et al., 2015; Ford, 2019). Evidence suggests that these depredations can be very selective (Ford, 2019). In a pelagic longline fishery in the southwestern Atlantic Ocean, only 10 of 57 fish species caught were depredated by killer whales. Of these, swordfish appears to be a preferred target of depredation (it constituted 43.9% of the sets with depredation; Passadore et al., 2015). Depredation events by killer whales on sharks (i.e., school shark [*Galeorhinus galeus*], shortfin mako [*Isurus oxyrinchus*], and blue shark) are rare with only three prior studies in New Zealand, South Africa, and Uruguayan waters (Visser, 2000a; Williams et al., 2009; Passadore et al., 2015). As this is the first report of shark depredation by killer whales in the North Atlantic, further studies are needed to determine if killer whales prey frequently on sharks in the North Atlantic Ocean.

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