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Direct evidence for gray seal (*Halichoerus grypus*) predation and scavenging on harbor porpoises (*Phocoena phocoena*)

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Predator-prey interactions play a crucial role in community and ecosystem dynamics. Documenting these interactions and understanding the mechanisms and drivers of prey selection are therefore important to predicting the potential effects of environmental changes (*e.g.,* prey availability). For large and elusive marine top predators, however, this can be challenging. Although marine mammals are generally described as top predators in marine ecosystems, most species are also at risk of predation from species such as killer whales (*Orcinus orca*), sharks (Selachii), polar bears (*Ursus maritimus*), and leopard seals (*Hydrurga leptonyx*) (*e.g.,* Weller 2009 for a review). The frequency of predation on marine mammal populations is highly variable among species and contexts (*e.g.,* Corkeron *et al.* 1987, Baird and Dill 1995, Heithaus and Dill 2002).

The harbor porpoise (*Phocoena phocoena*) is a small odontocete (1.3–1.9 m in length, 50–70 kg in weight for adults, depending on subspecies, population, and sex) that has been documented as prey for killer whales (Ford *et al.* 1998) and great white sharks (*Carcharodon carcharias*) (Arnold 1972). In some locations, they are killed, but not consumed, by common bottlenose dolphins (*Tursiops truncatus*) (*e.g.*, Ross and Wilson 1996). More recently, Haelters *et al.* (2012) deduced that gray seals likely were responsible for fatal lesions and mutilation of two harbor porpoise carcasses examined along the coast of Belgium. Missing portions of skin and blubber on both porpoises suggested that seals had fed on the carcasses. If confirmed, gray seal

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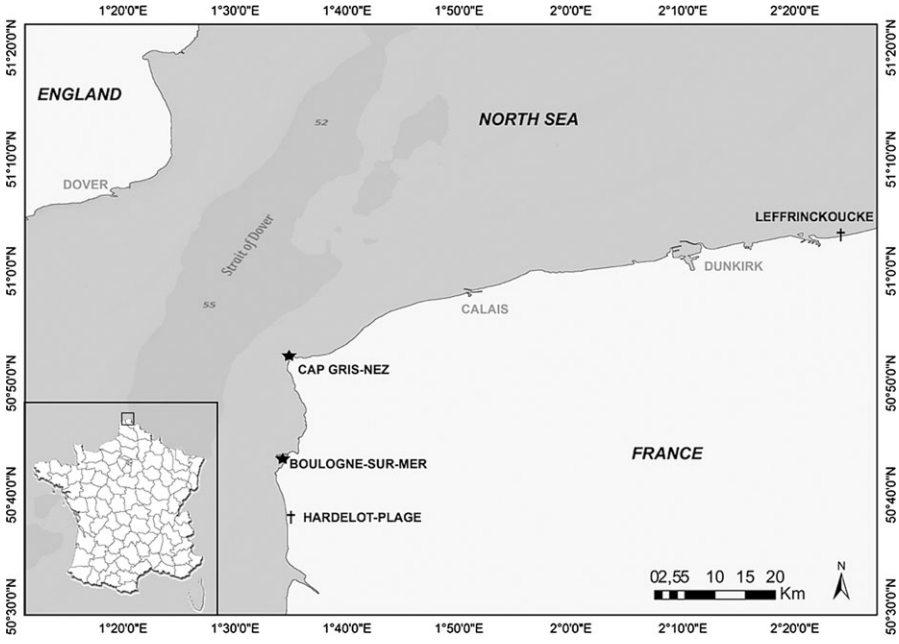

Figure 1. Study area with stars showing locations where predation and scavenging of harbor porpoise by gray seals have occurred and crosses indicate sites of dead stranding animals.

(*Halichoerus grypus*) consumption of harbor porpoises—whether predation or scavenging—might reflect a change in gray seal feeding habits in the southern North Sea (Haelters *et al.* 2012), where these two species co-occur (Kiszka *et al.* 2004, Vincent *et al.* 2005, Härkönen *et al.* 2007, Hammond *et al.* 2013). In fact, porpoise predation by gray seals might be a more widespread phenomenon. Since 2003, dozens of cases of dead porpoise stranded along the Dutch coast may have been killed or scavenged by gray seals every year, based on post mortem examinations and predator identification criteria proposed by Haelters *et al.* in 2012.[2]

Here, we provide direct observations of gray seal predation and scavenging on harbor porpoises in the Strait of Dover (eastern English Channel), off the coast of France in the eastern English Channel (Fig. 1). Two observations were made from the cliffs (up to 45 m above sea level) of Cap Gris-Nez, while the third was made inside the fishing harbor of Boulogne-sur-Mer (50°43.41′N, 1°36.03′E; Fig. 1). We also describe possible predation or scavenging based on external body observations made on two harbor porpoises freshly stranded in January and March 2012 on the northern French coast.

The first observation was made by an experienced observer using an optical telescope on 16 February 2013 from the cliffs of Cap Gris-Nez (50°52.88′N, 1°34.41′E; Fig. 1) during seabird and marine mammal land-based surveys. An adult gray seal (presumed male based on relative body size and head morphology; Jefferson *et al.*

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2008) was seen approximately 2 km from shore, using its fore flippers to handle a harbor porpoise, which appeared to be dead. Over a 15 min period, the gray seal, apparently feeding, removed blubber and skin strips from the carcass. It was unclear if the seal had killed the porpoise or was scavenging the carcass.

The second observation, also made from the cliffs of the Cap Gris-Nez during land-based seabird and marine mammal surveys, occurred on 19 April 2013. A solitary juvenile harbor porpoise was observed swimming slowly approximately 10 m from shore for 3 min before an adult gray seal (presumed adult male) attacked the porpoise. The attack was sudden and came from underneath the porpoise. The seal was able to grab the porpoise on the right side of its head in front of the right eye (Fig. 2a–f). The porpoise was released by the seal for a few seconds, but a second attack was made, again on the porpoise's right side. Approximately 6 min after the first attack, the seal drifted out of site while still handling the porpoise.

The third observation was made opportunistically by an experienced marine mammal observer inside the fishing harbor of Boulogne-sur-Mer at 1850 local time on 16 March 2013. An adult male gray seal was observed ripping off and eating a large piece of blubber and skin from a dead and putrefied harbor porpoise, stranded in a very shallow area. The decomposition state of the animal suggested that it had been dead for approximately 5–6 d (Peltier *et al.* 2012).

On 21 January and 9 March 2012, we examined two stranded harbor porpoises (fresh) along the coast of northern France. The first individual, a 110 cm juvenile female with a body mass of 24.5 kg was found at Hardelot-Plage (Fig. 1). Its dorsal blubber thickness of 21 mm suggested the animal was in good nutritional condition prior to death (Lockyer 1995). The second animal, a 114 cm, 20.3 kg juvenile female, was found in Leffrinckoucke (Fig. 1). Its dorsal blubber thickness of 20 mm was also consistent with good nutritional condition. Both porpoises appeared to have been attacked or fed upon by a gray seal; they showed similar external traumatic lesions to those observed on two porpoises found washed ashore in Belgium in 2011 (Haelters *et al.* 2012). They had several deep lesions through skin and blubber on the ventral

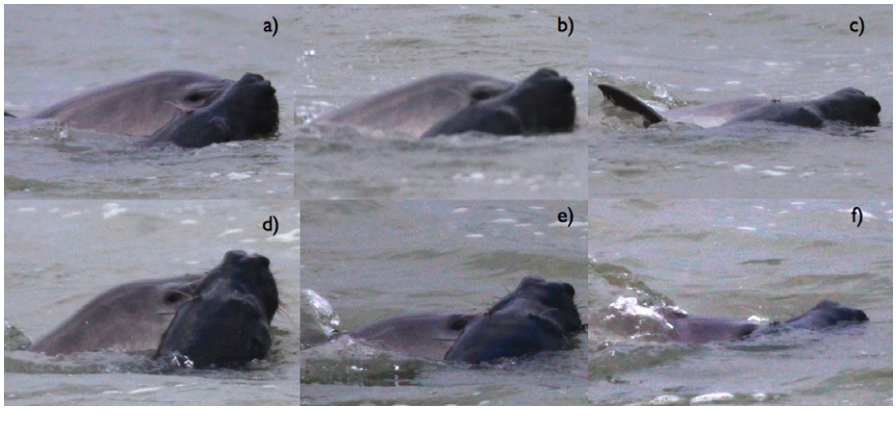

Figure 2. Pictures (a–c) show the sequence of the first attack of the gray seal on a harbor porpoise and the sequence (d–f) illustrate the second attack. Photos (a) and (d) show the gray seal coming from below the animal and biting it directly on the right face of the head. Photos (c) and (f) show a gray seal trying to drown a porpoise. Photo credit: L. Scalabre.

and lateral right side of the head and on the posterior edges of the mouth. Several hemorrhagic cuts around the neck were observed in the blubber suggesting that the lesions occurred prior to death. The second individual had extensive external lesions with a large piece of skin and blubber missing from the left side of the animal (Fig. 3).

Our observations provide the first direct evidence of a gray seal preying upon a harbor porpoise and evidence that gray seals had killed two dead-stranded porpoises. These observations add to growing evidence from Belgium and the Dutch coast that gray seals are preying upon harbor porpoises, as hypothesized by Haelters *et al.* (2012). Seals, however, may be more likely to target young individuals, as suggested by at least two of our observations as well as data from the two stranded porpoises. While past studies suggested that seals might target porpoises that are in poor condition (Haelters *et al.* 2012), our data suggest predation occurred on individuals that were not nutritionally stressed.

Observation #2 suggests that gray seals may use an ambush (or sit-and-wait) technique to attack harbor porpoises that also is used to target other prey (*e.g.,* Thompson *et al.* 1991). However, hunting techniques used by gray seals to capture and handle porpoises remain unclear because behavioral observations were collected at a distance and the sample size is still small. Nevertheless, the handling of porpoises using pectoral flippers while extracting skin and blubber strips was similar to reports of gray seals handling other large prey (*e.g.*, fish; Bonner 1989). In addition, attempts to submerge the porpoise as documented during observation #2 and evidence for bilateral hyphema and severe congestion of the respiratory system associated with lung edema described by Haelters *et al.* (2012) suggest that gray seals might kill porpoises by asphyxiation. This method is similar to that used by killer whales on young gray whales (*Eschrichtius robustus*, see Weller 2009).

Our observations also show that gray seals scavenge harbor porpoises. Marine mammals are regularly scavenged by a diversity of predators, primarily sharks,

Figure 3. External view of the left lateral side of a harbor porpoise stranded on 9 March 2012, showing the disappearance of a large strip of skin and blubber. Photo credit: OCEAMM.

whereas scavenging by other marine mammals has been confirmed for polar bears and killer whales on cetaceans (Whitehead and Reeves 2005, Weller 2009) and on one occasion by a gray seal on a harbor porpoise off the Dutch coast (Camphuysen and Siemensma 2011). Seals appear to target skin and blubber and were not observed consuming muscle. Such selective consumption of marine mammal carcasses is also observed in polar bears (Stirling and Archibald 1977) and killer whales (Williams *et al*. 2004). Fat tissue has the highest energy content and is more easily digested, making it unsurprising that we observed gray seal scavenging on even highly decomposed harbor porpoise carcasses.

Increasing abundances of both gray seals and harbor porpoises in the eastern English Channel and southern North Sea (Reijnders *et al.* 1995, Camphuysen 2004, Hammond *et al.* 2013) may explain increased observations of seal-porpoise interactions. Indeed, gray seals were almost extinct in the southern North Sea from the end of the 16th to the mid-20th century due to hunting. However, populations have grown tremendously since the 1980s (Reijnders *et al.* 1995, Härkönen *et al.* 2007), including those considered to be peripheral, such as along the French coast of the English Channel (Vincent *et al.* 2005, Härkönen *et al.* 2007). During the same period, the abundance of harbor porpoises has been increasing since the 1990s in the southern part of the North Sea (Camphuysen 2004, Hammond *et al.* 2013), including the French coast of the English Channel (Kiszka *et al.* 2004; OCEAMM, unpublished data). For decades, however, harbor porpoises and gray seals in the northern North Sea have co-occurred at high levels of abundance, whereas predation and scavenging has never been recorded. Observations such as those reported here and elsewhere had not been reported before 2011, despite intense observation efforts since the 1990s (including sighting and stranding networks; *e.g.,* Kiszka *et al.* 2004, Haelters *et al.* 2012). Therefore, it is possible that gray seal predation on, and scavenging of, harbor porpoises in the Strait of Dover and adjacent southern North Sea waters is increasing in frequency. It is also likely that changes in gray seal prey abundance have contributed to seals expanding their diets and exploring new foraging grounds, such as the southern North Sea. The decline in populations of high-energy prey (such as the lesser sandeel, *Ammodytes marinus*; Furness 2002) in the northern North Sea may explain the use of other foraging grounds and other high-energy prey (*i.e.*, harbor porpoises) in the southern North Sea. However, further studies are needed to test this hypothesis. Although only recently recognized, interactions between gray seals and harbor porpoises in the southern North Sea and eastern English Channel warrant further investigation to determine the frequency of interactions, the importance of porpoises to seals as food, and whether seal predation represents a significant mortality source for porpoises.

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