# INTERACTIONS BETWEEN SEABIRDS AND SHARKS AT A FUR SEAL CARCASS

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**ABSTRACT**

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The transfer of nutrients and energy from carcasses to scavengers is an important ecosystem function. In marine ecosystems, mammal carcasses can represent a spatiotemporally restricted but substantial pulse in resource availability, as they are typically only briefly available to scavengers on the surface. Little is understood about how these scavengers respond to such pulses, or how inter-scavenger interactions may influence their behaviour. We describe scavenging interactions of procellariiform seabirds at a fresh and floating New Zealand Fur Seal *Arctocephalus forsteri* carcass, recently killed by a White Shark *Carcharodon carcharias*, over the continental slope of southeastern Australia. We highlight potential exclusive and facilitative interactions between the shark and various seabirds, which may play an important role in energy-transfer dynamics in surface pelagic environments. We also provide apparently novel descriptions of scavenging at a marine mammal carcass for six of the seven seabird species that attended the carcass. Further study of sea-surface scavenger behaviour, interactions, and ecology will provide valuable insights into energy-transfer dynamics in pelagic ecosystems.

**Key words:** energy transfer, food webs, scavenging, pelagic, Procellariiformes, White Shark

## INTRODUCTION

Scavenging is widespread in vertebrate predators and is an important ecosystem function (DeVault *et al.* 2003, King *et al.* 2007, Selva *et al.* 2019). The behaviour makes use of spatiotemporally restricted pulses in resource availability, whereby energy in an animal becomes available as a carcass once it dies (Fallows *et al.* 2013). Interactions among scavengers and between predators and scavengers can be complex, as certain species can exclude or facilitate others, leading to functionally diverse scavenging guilds (Naves-Alegre *et al.* 2022). Unlike predation, scavenging can occur regardless of the trophic positions of the deceased animal and associated scavengers; thus, it is an important and distinct pathway of energy transfer in ecosystems (Barton *et al.* 2013). In marine ecosystems, the carcasses of mammals (e.g., cetaceans, pinnipeds) are high-value resources for scavengers due to the large quantities of lipids and proteins they contain (e.g., Laidre *et al.* 2018). However, these animals often die and subsequently sink in remote locations, making observations of surface scavenging at sea difficult to obtain (Moore *et al.* 2020). Most scavenging of marine mammals at sea has been documented in seafloor communities (e.g., Smith *et al.* 2015, Scheer *et al.* 2022), with relatively few observations of surface scavenging of floating carcasses (e.g., Fallows *et al.* 2013, Joiris 2021). Thus, the dynamics of surface-scavenging communities and the associated energy transfer remain poorly described.

Procellariiform seabirds are a diverse and abundant group of pelagic foragers, capable capturing their own prey and/or scavenging. They use olfactory and visual cues to locate prey, and they occupy a range of trophic positions from largely zooplanktivores (e.g., prions and storm petrels) to predators of cephalopods and fish (e.g., albatross; Billerman *et al.* 2022). Their propensity to scavenge is evident in their documented attraction to and feeding behaviour around fishing vessels, where discards are available (e.g., Collet *et al.* 2018), and near vessels conducting pelagic birdwatching trips, where chum is used to attract seabirds (e.g., Friesen *et al.* 2017, Gorta *et al.* 2019). However, there are few descriptions of procellariiform seabirds scavenging marine mammal carcasses in the peer-reviewed literature, and of these limited descriptions, few describe their behaviour or interactions (e.g., Lévêque *et al.* 1996, Pyle *et al.* 1999, Joiris 2021, but see Pitman *et al.* 2007).

In contrast, feeding on marine mammal carcasses, particularly whales, has been relatively well documented across many shark species, including White Sharks *Carcharodon carcharias* (Cliff *et al.* 1989, Long & Jones 1996, Fallows *et al.* 2013, Tucker *et al.* 2019). White Sharks are generalist apex predators, capable of hunting large fish and marine mammals from the surface to mesopelagic depths (Cliff *et al.* 1989, Klimley *et al.* 1992, Huveneers *et al.* 2018, Le Croizier *et al.* 2020). They also scavenge floating marine mammal carcasses, particularly those with substantial blubber reserves (e.g., seals and whales; Klimley 1987, Fallows *et al.* 2013, Tucker *et al.* 2019). While attending marine mammal carcasses, White Sharks are rarely aggressive towards other sharks (Tucker *et al.* 2019), and their interactions with other scavengers, such as seabirds, are largely limited to observations of seemingly deliberate but non-consumptive strikes (e.g., Hammerschlag *et al.* 2012, Klimley 2023).

Here, we describe an observation of procellariiform seabirds and a White Shark feeding on a New Zealand Fur Seal *Arctocephalus forsteri* carcass in pelagic waters of the Tasman Sea, over the continental slope off southeastern Australia. We describe the community that attended the carcass, as well as their observed feeding behaviour and interactions. Our observations expand on current understanding of surface pelagic foraging interactions and feeding behaviours, as well as on current knowledge of trophic, food-web, and energy-transfer dynamics in pelagic ecosystems more broadly.

## METHODS

On 17 September 2022 at 10h23, the floating carcass of an adult New Zealand Fur Seal was encountered 42 km east of Eden, New South Wales (NSW), Australia (37°04′48″S, 150°23′24″E; ~1 300 m water depth), on a pelagic birdwatching trip (Gorta 2022). We observed the carcass, seabirds, and shark for 108 minutes, with the aid of binoculars and digital cameras. Conditions were clear and sunny, with light to moderate northwesterly winds, 1.5–2.0 m of swell, and a sea-surface temperature of 18 °C (from the on-board thermometer). The combination of wind and a southward-moving surface current caused us to drift south-southeast at 1.4 m/s over ground (from the GPS track of the vessel, a 38-foot Randell).

## RESULTS

The seal carcass was first located from a distance due to a small but visible group of circling seabirds. On our approach, the carcass was tossed back and forth by something below the surface (Fig. A1A in Appendix 1, available online). A White Shark whose length was visually approximated at 3.5 m was observed next to and below the boat soon after we arrived at the carcass, which we observed from as close as 5 m (Fig. A1B, Fig. A2). The fresh condition of the carcass and the extent of blood leaching into the water from its opened upper breast indicated that it had been recently killed by the shark (Fig. A1B). This opening was widened during the observation period as the shark fed, from the ventral surface of the thorax to the upper belly (Fig. A1B, A1C). Internal organs, muscle, and blubber were exposed from the opening (Fig. A1C). The shark was observed feeding on the carcass five times, grabbing the seal in its jaws and thrashing it about to tear off chunks of meat (Fig. A1A, S1D). During this process, loose pieces of meat were freed from the carcass and the lighter pieces (e.g., blubber) floated on the surface, on which some seabirds fed (Fig. A1B, A1C). We did not observe any diving behaviour from foraging seabirds. The water was visibly smooth, caused by fatty oils from the carcass that formed a slick extending approximately 100 m from the carcass (Fig. A1A–A1C).

Seven procellariiform seabird species, comprising at least 41 individuals, were present for all or part of our observations of the carcass (Table 1). Grey-faced Petrel *Pterodroma gouldi*, Providence Petrel *Pterodroma solandri*, and Fairy Prion *Pachyptila turtur* were all observed feeding, gathering free-floating seal meat (likely blubber) while sitting on the water (Table 1, Fig. A3A). These petrels would otherwise arc and glide, circling around the carcass before alighting on the water to feed or flying off (Table 1, Fig. A3B). Other observed feeding behaviours (Table 1) included dipping (e.g., Fairy Prion, which would gather food items by quick, shallow ‘dipping’ fly-bys) and pattering (e.g., White-faced Storm Petrel *Pelagodroma marina*, which would hover with feet extended and touching the surface). Foraging was observed immediately around the carcass and along the oil slick extending from it. Shy Albatross *Thalassarche cauta*, Buller’s Albatross *T. bulleri*, and Northern Giant Petrel *Macronectes halli* were observed investigating the carcass while in flight on multiple occasions (Table 1, Fig. A3C). At times, they alighted approximately 50 m from the carcass along the slick, but they were not recorded actively feeding.

## DISCUSSION

The floating carcass of a New Zealand Fur Seal offered a rare opportunity to observe the foraging behaviours of and interactions among seabirds and a shark in a surface pelagic environment. A top-order marine predator (one White Shark) and several avian predators (seven species of procellariiform seabirds) fed, scavenged, or showed interest in the carcass. Foraging and interactive behaviour among scavengers expands our understanding of the potentially

**TABLE 1**
**The seven procellariiform seabird species recorded interacting with the New Zealand Fur Seal *Arctocephalus forsteri* carcass, estimated counts of the individuals present, and a summary of their observed feeding behaviour**

| Species | Count | Feeding behaviour |
|---|---|---|
| Northern Giant Petrel *Macronectes halli* | 2 | Did not feed, investigative flights over the carcass, alighted on water 50–100 m away. |
| Fairy Prion *Pachyptila turtur* | 3 | Investigative short flights around the carcass and sitting on the water often for prolonged periods of time near the carcass or in the slick. Picked food off the surface while sitting and by dipping: shallow dips of the head when in flight low over the water to pick up food from the surface. |
| White-faced Storm Petrel *Pelagodroma marina* | 1 | Fluttering on the surface, picking up food items with feet against the water and wings beating. |
| Grey-faced Petrel *Pterodroma gouldi* | 4 | Investigative arcing and soaring over the carcass. Fed by alighting on the water briefly to pick up food from the surface before taking off again. |
| Providence Petrel *Pterodroma solandri* | 10 | Investigative arcing and soaring over the carcass. Fed by alighting on the water briefly to pick up food from the surface before taking off again. |
| Buller’s Albatross *Thalassarche bulleri* | 1 | Did not feed, investigative flights over the carcass, and alighted on water 50–100 m away. |
| Shy Albatross *Thalassarche cauta* | 20 | Did not feed, investigative flights over the carcass, and alighted on water 50–100 m away. |

important but poorly known processes involved in surface pelagic energy-transfer dynamics, and we highlight previously undescribed foraging behaviour by some procellariiform seabirds.

White Sharks play an important predatory and scavenging role across their distribution, often feeding on marine mammal carcasses (Klimley 1987, Fallows *et al.* 2013, Tucker *et al.* 2019). They will preferentially target lipid-rich blubber on these carcasses, consistent with our observation of the wide opening in the seal carcass that had the skin and blubber removed, exposing the muscle and internal organs (Pratt *et al.* 1982, Curtis *et al.* 2006). As the shark opened the carcass and shredded blubber and tissue by biting and thrashing, oils, other bodily fluids, and small pieces of blubber and tissue were released from the carcass into the water. Surface disturbance caused by the shark's feeding activity, as well as the release of flesh, fluids, oil, and the scent of the carcass, likely attracted the seabirds, which in turn provided a visual foraging cue for other seabirds.

Seven procellariiform seabird species of varying size and diet interacted with the seal carcass. Small White-faced Storm Petrels and Fairy Prions actively fed on floating pieces of the carcass, alongside medium-sized Grey-faced and Providence petrels. The larger procellariiforms—multiple albatross species and Northern Giant Petrel—flew in and around the carcass and alighted on the water nearby, but they did not feed during our observations. Albatross and giant petrels typically alight on the water to scavenge on surface material (Billerman *et al.* 2022) but may have avoided scavenging alongside the shark due their perception of the shark as a threat (e.g., Johnson *et al.* 2006, Meyer *et al.* 2010, Hammerschlag *et al.* 2012). This is consistent with observations of large seabirds such as Brown Pelicans *Pelecanus occidentalis* at the Farallon Islands, California, USA, which will show interest but not land on the water around shark-seal predation events (P. Pyle pers. comm.) and can be subject to non-consumptive strikes from White Sharks (Klimley 2023). In our observations, the larger procellariiform species waited nearby, frequently performing investigative flights over the carcass and potentially over the shark. Internal organs and flesh, relatively low in lipids compared to the blubber layer, are often rejected by sharks but are attractive to seabirds (Fallows *et al.* 2013, NZBO 2013). White Sharks can also leave kills for extended periods (Klimley & Curtis 2006), thus it may have been worthwhile for the larger seabirds to wait for the shark to leave. The smaller seabirds appeared less wary of the shark as a potential predator, often landing on the surface to feed near the carcass before taking flight again—they are likely not prey for White Sharks due to their small size and limited energy value. As such, we posit that the White Shark facilitated scavenging by smaller seabirds while inhibiting larger seabirds that perceived it as a threat (i.e., exclusion via fear; Brown & Kotler 2007). This represents a potential risk-reward energy trade-off driven by accidental predation risk and/or fear. The shark also facilitated seabird scavenging by tearing open the carcass and freeing small pieces, making resources available that would otherwise have been inaccessible. This complements our current understanding of marine surface-scavenger ecology (e.g., Thiebot & Weimerskirch 2013, Collet *et al.* 2018) but is dependent on further observation and study to quantify.

Scavenging behaviour of procellariiform seabirds on marine mammal carcasses is poorly documented (see Lévêque *et al.* 1996, Pitman *et al.* 2007, Joiris 2021). We found no prior reports in the peer-reviewed literature of scavenging on marine mammals by any of the seabird species we observed interacting with the carcass, except the Northern Giant Petrel, for which bird and mammal carcasses form a substantial part of their diet at breeding colonies and at sea (Marchant *et al.* 1991, NZBO 2013, Billerman *et al.* 2022). Around the Farallon Islands, seabirds including Western Gull *Larus occidentalis*, California Gull *L. californicus*, and two procellariiforms—Northern Fulmar *Fulmarus glacialis* and Sooty Shearwater *Ardenna grisea*—have been observed scavenging on marine mammal carcasses, mostly those of Northern Elephant Seal *Mirounga angustirostris* (Klimley *et al.* 1992, Pyle *et al.* 1999). The fulmars often scavenge floating blubber and organs (P. Pyle pers. comm.; Hobson & Welch 1992), similar to the small- and medium-sized seabirds we observed. In the grey literature, where scavenging observations may be more commonly described (Tucker *et al.* 2019), we found evidence of marine mammal scavenging in closely related procellariiforms. For example, several species of albatross have been observed scavenging around whale carcasses, often relying on scraps produced by other predators (Elliot 1898, Milburn 2007, Frediani *et al.* 2020). Furthermore, on 27 October 2007 off the coast of Wollongong, NSW, a large aggregation of Cape Petrels *Daption capense*, Wilson's Storm Petrels *Oceanites oceanicus*, Northern Giant Petrels, Southern Giant Petrels *M. giganteus*, and Wandering Albatross *Diomedea exulans* was observed to scavenge around a large whale carcass (Milburn 2007). The birds were not feeding directly on the carcass, but rather focusing on loose pieces of the carcass and oil in the associated slick (B. Whylie pers. comm.). Storm petrels often feed on oil slicks (e.g., Verheyden & Jouventin 1994), including around marine mammal carcasses (e.g., Lévêque *et al.* 1996, Milburn 2007). All species we observed at the seal carcass have been observed feeding on chum on pelagic birdwatching trips (e.g., Gorta *et al.* 2019, Billerman *et al*. 2022), a behaviour that directly imitates scavenging. Procellariiforms scavenging marine mammals is probably not a rare occurrence, but rather rarely reported due to accessibility challenges in observing such behaviour and the rarity of floating carcasses. Thus, it is important that observations of these interactions and behaviours are documented when encountered.

## CONCLUSIONS

Marine mammal carcasses can provide a substantial but spatiotemporally limited resource pulse for marine surface scavengers, facilitating energy transfers across trophic levels. Interspecific interactions between procellariiform seabirds and sharks may also influence energy-transfer dynamics, through the facilitation of foraging for some species and potential exclusion from carcasses driven by avoidance for others. We provide apparently novel observations of scavenging on marine mammals for six seabird species. While we have some understanding of facilitation and exclusion in some scavenging guilds (e.g., Naves-Alegre *et al.* 2022), greater understanding of these interactions and their consequences will more holistically inform energy-transfer dynamics and ecosystem function, especially in surface pelagic communities. Opportunistic observations of seabirds, especially by skilled birdwatchers (see Viola *et al.* 2022) can offer important insights into these processes. Further documentation and study of the at-sea scavenging ecology of procellariiform seabirds will inform our understanding of their behavioural and foraging ecology and of the interspecific interaction dynamics of surface-scavenging communities.

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