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Predation in the Anthropocene: Harbour Seal (*Phoca vitulina*) Utilising Aquaculture Infrastructure as Refuge to Evade Foraging Killer Whales (*Orcinus orca*)

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Abstract

The rapid emergence of new marine developments (e.g., marine renewables, port infrastructure) alongside the substantial growth of existing industries has ultimately resulted in an unprecedented increase in anthropogenic structures within the marine environment over the previous century. Knowledge of whether marine species interact with, avoid, or accommodate and adapt to such structures is essential to ensure that further development of marine environments do not compromise conservation objectives of marine species. This article documents one such interaction. Herein, we describe the observation of a harbour seal (*Phoca vitulina*) seeking refuge from a group of foraging killer whales (*Orcinus orca*) within a blue (aka common) mussel (*Mytilus edulis*) farm. Aerial video footage (38 min 27 s) was collected using an unmanned aerial system during an encounter at an aquaculture site in Dury Voe, Shetland, UK. Analysis of the footage showed the killer whale group spent 73.7% of the total encounter time exhibiting predatory associated behaviours and that they were observed interacting with the mussel farm infrastructure only during "predation activity" for a total of 26 min 52 s (72.8%). The harbour seal interacted with the mussel farm infrastructure during re- and proactive anti-predator behaviour and when exhibiting fatigue for 27 min 59 s, 94.4% of the total time the seal was observed. It is clear that both marine and terrestrial predator–prey interactions are increasingly occurring in settings that are in some way defined by the Anthropocene. The implications of this are discussed, including potential entanglement risk and human-altered "landscapes of fear." As comprehension of the potential effects of human-altered risk grows, such knowledge should be taken into consideration prior to further modification of marine habitats.

Key Words: Anthropocene, manmade structure, aquaculture, killer whale, *Orcinus orca*, harbour seal, *Phoca vitulina*

Introduction

Knowledge of how predators and prey may experience and interact with anthropogenic structures within marine environments is relatively limited considering the unprecedented rates of "ocean sprawl" over the previous century (Price et al., 2016; Bishop et al., 2017; Guiden et al., 2019; Hemery et al., 2021). The rapid emergence of new marine developments (e.g., marine renewables, port infrastructure) and substantial growth of existing industries and conservation objectives (e.g., marine protected areas) have recently been termed the "blue acceleration" (Jouffray et al., 2020). Many marine species have habitats or ranges that are now increasingly overlapping with areas utilised by human activities. As a result, these species are now effectively having to either avoid or attempt to accommodate and adapt to new infrastructure and evolutionarily novel stimuli (Sol et al., 2013; DeMars & Boutin, 2018). In some cases, species may stand to benefit from such modifications (e.g., artificial structures may aggregate prey and thus provide novel foraging opportunities; Inger et al., 2009; Arnould et al., 2015; Lieber et al., 2019); whereas, in other cases, the consequences may be negative (e.g., structures may create barriers to movement; Li et al., 2021) or fatal (e.g., drowning through entanglement within an aquaculture structure; Ryan et al., 2016).

As anthropogenic structures in the marine environment increase, it is likely that the rate of encounters and interactions with such structures for most marine species will increase (Russell et al., 2014); thus, compiling a repository of documented interactions to develop an understanding of the ecological consequences of these structures is crucial (Bishop et al., 2017; Hemery et al., 2021). However, once placed into the marine environment, the anthropogenic infrastructure itself and any associated interactions with marine life are inherently difficult to monitor given that most of these structures are often submerged (sometimes at considerable depth), often located in remote locations, and are subject to severe oceanic conditions (e.g., salt water, wave action). This has meant that studies that evaluate interactions and responses of mobile marine megafauna to infrastructure(s) have tended to require novel technology or analytical techniques, consideration of incidental and/or opportunistic records, and has often required lateral thinking (e.g., Onoufriou et al., 2019; Gillespie et al., 2020). For example, inferences of megafauna behaviour and associations around infrastructure have arisen through analysis of incidental sighting records (e.g., Delefosse et al., 2018), analysis of animal-borne tag data (e.g., Russell et al., 2014; Arnould et al., 2015; Sparling et al., 2018; Onoufriou et al., 2021), analysis of passive acoustic monitoring (PAM) data (e.g., Todd et al., 2009, 2016; Macaulay et al., 2017; Malinka et al., 2018; Palmer et al., 2021), and review of time-lapse camera footage (e.g., Orr et al., 2017) and underwater Remotely Operated Vehicle (ROV) video footage (e.g., Todd et al., 2020; Mascorda Cabre et al., 2021).

Through such techniques, foraging around infrastructure has been inferred for a variety of marine mammal species. For example, a collation of sighting records shows presence of at least seven marine mammal species around North Sea oil and gas installations, with PAM data showing an increase in diel echolocation activity (indicating nighttime feeding) of harbour porpoises (*Phocoena phocoena*) around platforms (Todd et al., 2009; Delefosse et al., 2018). Animal-borne tracking data has evidenced movement that would indicate foraging activity of grey (*Halichoerus grypus*) and harbour (*Phoca vitulina*) seals along pipelines; of harbour seals around wind turbine bases; and of Australian fur seals (*Arctocephalus pusillus doriferus*) around pipelines, cable routes, oil/gas wells, and shipwrecks (Russell et al., 2014; Arnould et al., 2015). These examples provide evidence that human-induced changes to the marine environment may be altering foraging opportunities and natural predator–prey landscapes (Madin et al., 2016), though the consequences of this are still not well understood.

The use of aerial video footage from unmanned aerial systems (UASs), particularly from drones, to illustrate marine megafauna interactions around anthropogenic structures is still uncommon (Lieber et al., 2019), though the increase in use of these devices presents potential for an increased understanding of relationships between them (Pirotta et al., 2022). This article documents an observation of a harbour seal taking refuge from a group of foraging killer whales (*Orcinus orca*) within a blue (aka common) mussel (*Mytilus edulis*) farm. Footage collected using a UAS provides a novel opportunity to observe an anthropogenic structure being incorporated into predator–prey foraging strategies, of which similar records in the literature are scarce.

Observations

A group of killer whales was first observed from land at 0830 h UTC within Gulberwick Bay, Shetland, UK, on 6 March 2022 (Figure 1). The sighting was reported to the local cetacean sightings' Facebook page ("Shetland Orca Sightings") and to a local sightings network instant messaging group (WhatsApp "Shetland Cetacean Group'), which enabled other watchers to track and follow the group as they moved north around the coastline during the day (Figure 1).

These killer whales were photo-identified as the "27s group" through photo-identification to known individuals within a curated catalogue (Scullion et al., 2021). The group was comprised of two adult males (ID #72 and #34), two adult females (ID #27 "Vaila" and ID #73), one female/subadult male (ID #152), and two juveniles or calves (ID #150 [born 2015 or 2016] and #153 [calf of ID #73, born 2019]; Scullion et al., 2021). This group regularly moves between the Northern Isles of the UK and more northerly waters (i.e., Faroe Islands, Iceland) and has been observed previously hunting harbour porpoise in Shetland waters (N. McCaffrey, unpub. data, 2019; R. Shucksmith, unpub. data, 2019) and in Eyjafjörður, North Iceland (Scullion et al., 2021).

At 1440 h, the killer whales were reported moving into Dury Voe, a 6-km-long inlet on the east coast of mainland Shetland (60.33860, -1.124674; Figures 1 & 2). The group was observed from land moving westwards. At 1503 h, the group was seen to approach and begin to mill around the Outer Grunna Voe (within Dury Voe) blue mussel mariculture farm (operated by Blueshell Mussels Ltd) (Figure 2). The farm consists of eight pairs of 300-m-long twin-headlines, each held horizontally afloat by specifically designed mussel floats which hold the twin-headlines parallel to one another, 1.2-m apart (Figure 3). From each headline hang

Figure 1. Sighting of the 27s group of killer whales (*Orcinus orca*) around the Shetland Isles on 6 March 2022, showing their predicted track throughout the day. Sightings data are from the local sightings networks ("Shetland Orca Sightings" Facebook page and the WhatsApp "Shetland Cetacean Group").

8- to 10-m-long dropper lines, spaced 0.5 m apart, which are the site of mussel mariculture (either spat collection or mussel growth to adulthood; at this location, lines were collecting spat; M. Laurenson, pers. comm., 1 April 2022). The dropper lines form a continuous loop back to the headline, with 18 to 27 m between the seabed and the dropper lines (site depth: 28 to 25 m).

At 1502 h, a UAS (DJI Mavic 3 Cine drone; *firmware*, Version 01.00.0500) was launched from land to observe the killer whales. When the UAS arrived above the group, a harbour seal was seen within the field of view located initially between the mussel twin-headlines at the north end of the mussel farm (having not been visible from land). As the interaction progressed, both the harbour seal and killer

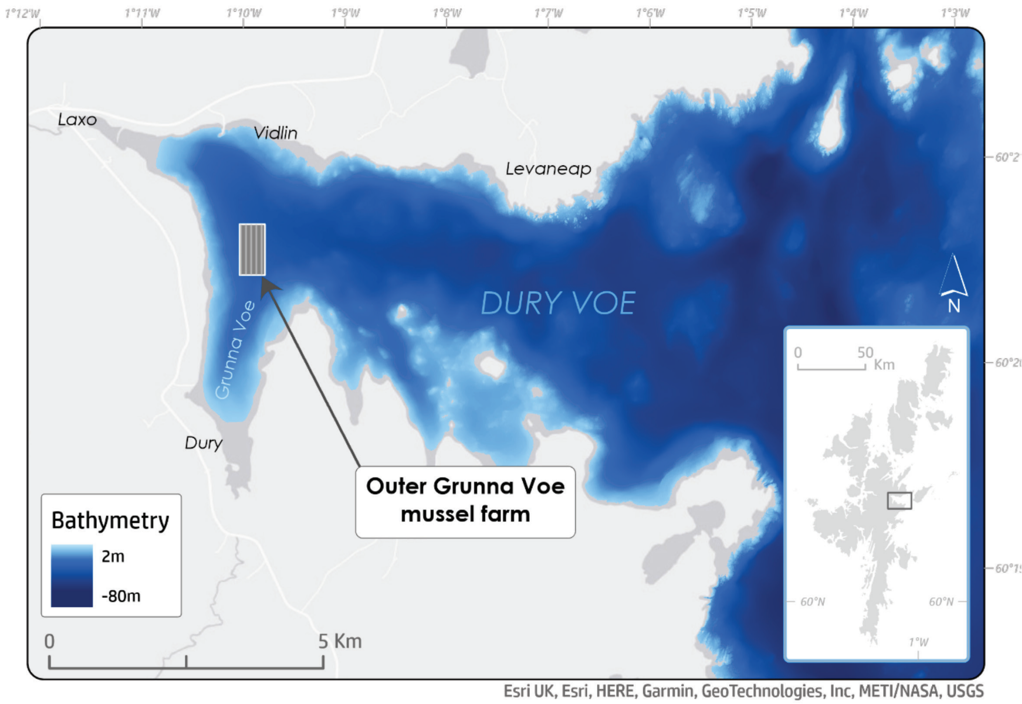

Figure 2. Map of Dury Voe, an inlet on the east coast of mainland Shetland. The position of the Outer Grunna Voe mussel farm, the site of the killer whale and harbour seal (*Phoca vitulina*) predation event, is highlighted. An inset map of Shetland (UK) highlights the location of Dury Voe (see black rectangle).

whales moved southwards within the farm footprint, with the eventual kill occurring just south of the farm.

The UAS completed two flights, capturing 38 min 27 s of aerial video footage. There was minimal time between the killer whales beginning to mill around the farm and the UAS capturing footage overhead; thus, we are confident this event was captured within the described observations. The sea conditions during the encounter were Beaufort 3 (27 km/h), and the tide was falling (low tide: 1900 h, 0.35 m).

Methods

Behavioural Categorisation

All recorded aerial video footage was viewed in detail, and the killer whale and lone harbour seal behaviours were categorised into one of several states (Figures 4 & 5). The duration spent in each behavioural state was tabulated and summed to present overall time in each state for both predator(s) and prey. This was then used to infer time spent "interacting" with infrastructure, which herein refers to the amount of time the infrastructure was in some way part of the encounter (e.g., swimming within headlines). There were a small number of occurrences during which either the killer whale group or the harbour seal was no longer within the field of view (e.g., swam out of field of view). Therefore, total time in each behavioural state represents the minimum time spent in each state rather than a definitive total time.

Killer whale behavioural state was categorised as follows:

- *Predation activity* – tracking, observing, and predation
- *Other activity* – at depth, milling, and swimming away from seal
- *Post-kill activity* – mouth nudge, tail slapping at the surface, prey in mouth, milling, and time at depth

Harbour seal behavioural state was categorised as follows:

- *Anti-predator behaviour* – action taken to reduce risk of predation (Gaynor et al., 2019)

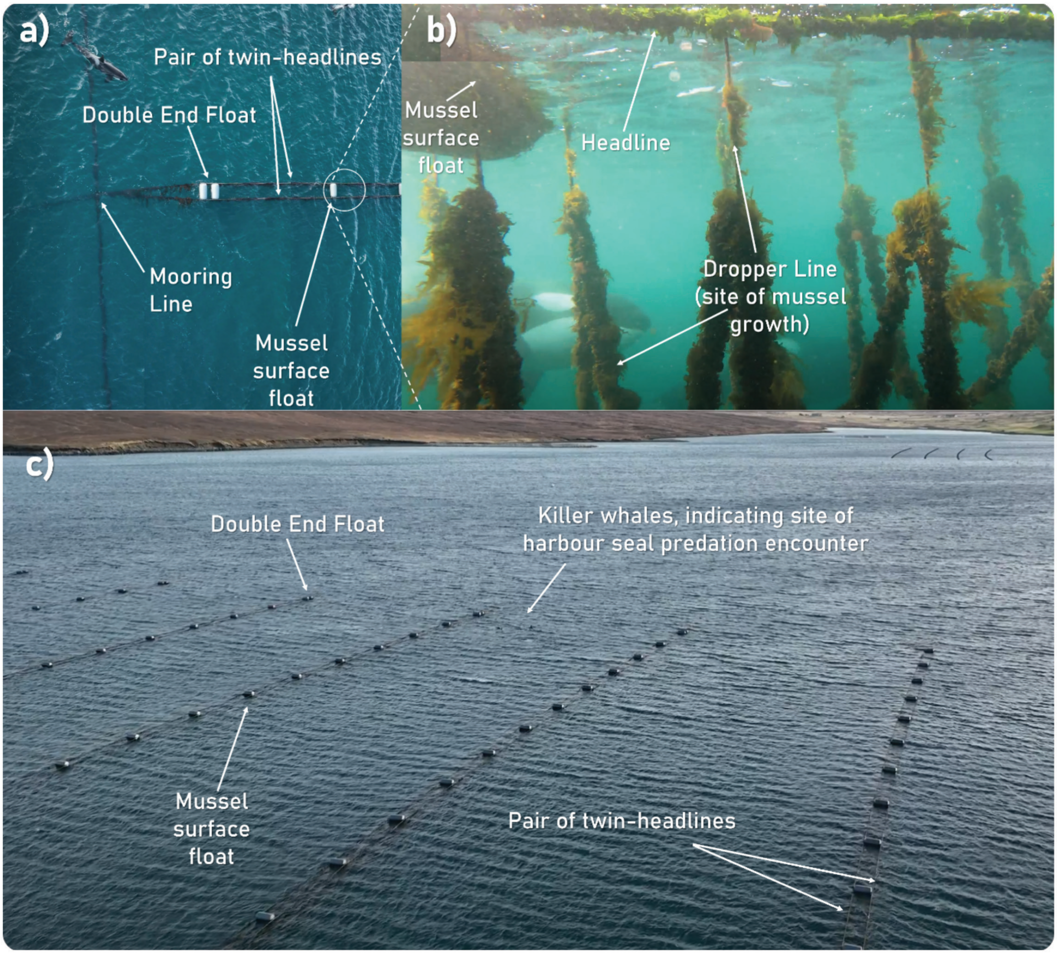

Figure 3. (a) Diagram of mussel farm orientation; (b) example of how a mussel farm with dropper lines is set up underwater; and (c) aerial view of the mussel farm, including the indicative site of predation activity described in the article.

- *Reactive* – porpoising or swimming within and along longlines and in open water
- *Proactive* – vigilance (head up, looking around)

- *Fatigue* – head or body resting on longline, stationary, and logging
- *Immobile* – captured in killer whale mouth or floating (presumed stunned or dead)

Note: It is possible that some behavioural observations may represent more than one behavioral state (e.g., when the harbour seal is logging or stationary within longlines, it is categorised as fatigue, though it may be fatigue *and* proactive anti-predator behaviour [i.e., attempting to hide]). Observations were categorised based on the most apparent behaviour, though during interpretation, this complexity should be kept in mind.

Video examples of each behavioural state are available to view in the "Supplemental Material" section of the *Aquatic Mammals* website (https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=10&Itemid=147). The video plays three times slower than real time to aid in behavioural identification and observation of activity.

Results

Of the 38 min 27 s of aerial video footage captured and analysed of the encounter, killer whales were recorded in 36 min 54 s and the harbour seal in 29 min 43 s. One or more of the killer whales exhibited behaviour associated with predation prior to the kill for a total of 27 min 13 s, which proportionally equates to 73.7% of killer whale group time in this behavioural state (Table 1 & Figure 4; supplementary video). This represents a minimum estimate of predator time spent in foraging effort as it does not include time when the UAS was not recording (i.e., activity before UAS arrived on scene, activity between video clips, activity during UAS battery change). Additionally, there was 6 min 30 s (17.6%) of observed killer whale post-kill behaviour recorded (e.g., at least two different killer whales were observed carrying parts of the seal carcass in their mouth) and 3 min 11 s (8.6%) of "other" activity (Table 1 & Figure 4; supplementary video). The killer whale group was observed interacting with the mussel farm infrastructure only during the "predation activity," totalling 26 min 52 s (72.8%) of killer whale observation time (Table 1).

The harbour seal was recorded in 29 min 43 s of aerial video footage of which 14 min 50 s (49.9%) was categorised as reactive anti-predator behaviour, 9 min 50 s (33.1%) as proactive anti-predator behaviour, 4 min 53 s (16.4%) as fatigue, and 0 min 10 s (0.5%) as immobile (Figure 5 & Table 2; supplementary video). The harbour seal was observed interacting with the mussel farm infrastructure during re- and proactive anti-predator behaviours and when exhibiting fatigue, totalling 27 min 59 s or 94.4% of seal observation time (Table 2).

During the final observed predation activity, the harbour seal was body slammed in open water by one of the killer whales, followed quickly by a tail slap from another killer whale (see supplementary video). The seal was then observed floating in open water, presumed stunned or dead. Following the kill, great black-backed gulls (*Larus marinus*) and other unidentified gull species were observed hovering over the water.

Table 1. The total time and proportion of the encounter that the killer whale (*Orcinus orca*) group spent in each behavioural state during a predation event on a harbour seal (*Phoca vitulina*) around mussel farm infrastructure. Also shown is the total time and proportion of the encounter in which the killer whale group was interacting with the farm infrastructure.

Killer whale group				
Behavioural category	Sub-behavioural state	Interacting with infrastructure?	Time spent exhibiting behaviour (mm:ss)	Proportion of time spent in this behavioural type (%)
Predation activity	Tracking: Parallel swimming along headlines	✓	15:52	43.03
	Tracking: In open water		00:10	0.45
	Tracking: Turn to follow seal	✓	00:30	1.34
	Observing: Head on	✓	09:46	26.48
	Observing: Spyhop	✓	00:44	1.99
	Predation: Attempted capture		00:01	0.06
	Predation: Chase		00:04	0.18
	Predation: Body slam		00:04	0.17
	Predation: Tail slap (of seal)		00:02	0.08
	Total		27:13	73.76
Other activity	Time spent at depth		01:56	5.24
	Milling		01:02	2.79
	Swimming away from prey		00:13	0.60
	Total		03:11	8.63
Post-kill activity	Post kill: Mouth nudge (of seal)		00:01	0.06
	Post kill: Tail slapping at surface		00:02	0.08
	Post kill: Prey in mouth		00:55	2.50
	Post kill: Milling, circling		04:43	12.80
	Post kill: Time spent at depth		00:49	2.20
	Total		06:30	17.63
Total	Total observation involving interaction with mussel farm infrastructure		26:52	72.83
	Total observation		36:54	100.00

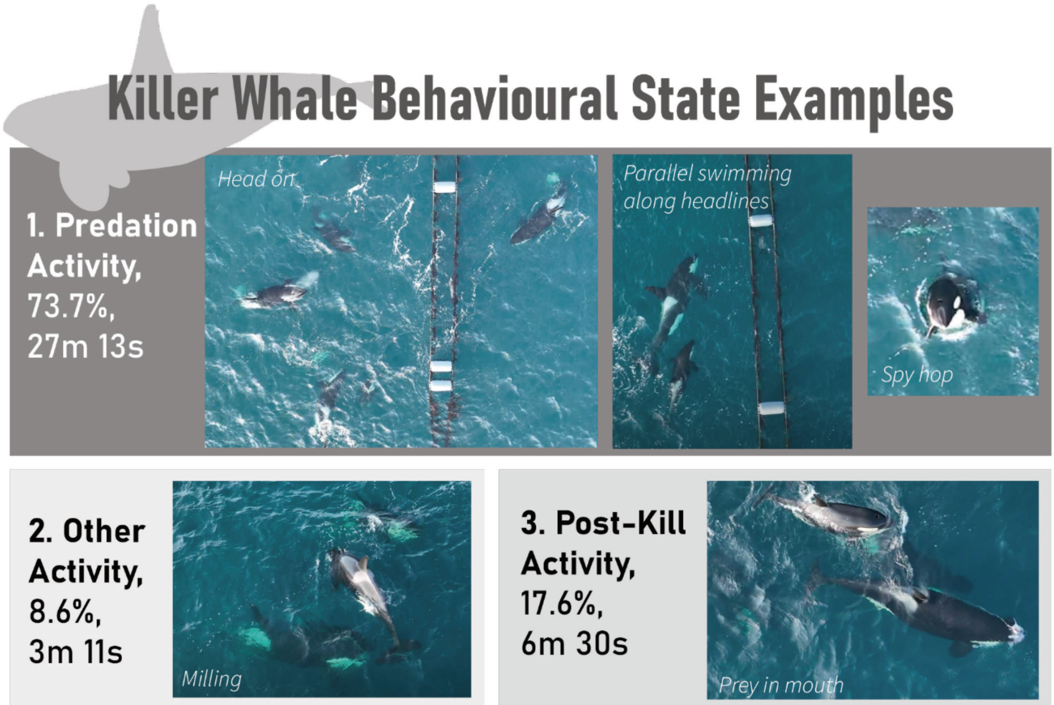

Figure 4. Example imagery of the three different states that killer whale group behaviour was categorised into during a predation event on a harbour seal around mussel farm infrastructure. Also described is the total time spent in that behavioural state, with the percentage value representing the proportion of the total encounter that the killer whales spent in that behavioural state (m = minutes; s = seconds).

Figure 5. Example imagery of the four different states that harbour seal behaviour was categorised into during a predation event on a harbour seal around mussel farm infrastructure. Also described is the total time spent in that behavioural state, with the percentage value representing the proportion of the total encounter that the harbour seal spent in that behavioural state (m = minutes; s = seconds).

Table 2. The total time and proportion of the encounter that the harbour seal spent in each behavioural state during a killer whale predation event around mussel farm infrastructure. Also shown is the total time and proportion of the encounter in which the harbour seal was interacting with the farm infrastructure.

Harbour seal				
Behavioural category	Sub-behavioural state	Interacting with infrastructure?	Time spent exhibiting behaviour (mm:ss)	Proportion of time spent in this behavioural type (%)
Anti-predator behaviour: Reactive	Porpoising: Open water		00:02	0.09
	Porpoising: In headlines	✓	01:02	3.48
	Swimming: In headlines	✓	11:42	39.36
	Swimming: Open water		01:27	4.86
	Swimming: Chase		00:01	0.06
	Turning	✓	00:37	2.06
	Total		14:50	49.91
Anti-predator behaviour: Proactive	Vigilance (e.g., head up): In headlines	✓	09:50	33.12
	Total		09:50	33.12
Fatigue	Head on headline	✓	00:19	1.05
	Body resting on headline	✓	00:53	2.97
	Logging within headlines	✓	03:09	10.60
	Stationary within headlines	✓	00:27	1.80
	Total		04:53	16.42
Immobile	Captured (seal escapes)		00:01	0.07
	Floating (dead or stunned)		00:09	0.49
	Total		00:10	0.56
Total	Total observation involving interaction with mussel farm infrastructure		27:59	94.43
	Total observation		29:38	100.00

Discussion

Herein, we use the unique perspective provided by a UAS (drone) to share, to the best of our knowledge, a previously undocumented predator–prey interaction (between a killer whale group and a harbour seal) within anthropogenic infrastructure (a shellfish [blue mussel] farm). This observation presents a new opportunity for discussion and understanding of how two marine apex predators may be "living with" marine infrastructure.

Marine Mammal Interactions with Shellfish Aquaculture

Cetacean interactions with mariculture sites tend to be dependent on culture methods and the species involved (Díaz López & Methion, 2017), with marine mammal interactions with finfish aquaculture frequently described (e.g., Ribeiro et al., 2007; Northridge et al., 2013; Bonizzoni et al., 2014; Frau et al., 2021). Comparatively less frequently reported are marine mammal interactions with shellfish aquaculture, though records of both positive and negative interactions do exist.

Mussel farm infrastructure has been found to impede collaborative hunting and coordinated feeding strategies of dusky dolphins (*Lagenorhynchus obscurus*) hunting for schooling fish (Lloyd, 2003; Pearson et al., 2012). Further, avoidance and displacement has been reported around some shellfish farm sites (Würsig & Gailey, 2002; Ribeiro et al., 2007; Visser, 2007; Becker et al., 2011; Callier et al., 2018)—for example, bottlenose dolphins (*Tursiops* sp.) in Shark Bay, Western Australia, decreased their overall use of areas with pearl oyster (*Pinctada fucata*) farms, also exhibiting apparent reluctance to swim through farm infrastructure, with some adult females swimming all the way around the sites to avoid swimming through them (Watson-Capps & Mann, 2005). Similar reluctance to enter the boundaries of green-lipped mussel (*Perna* *canaliculus*) farms has been reported in dusky dolphins in New Zealand (Markowitz et al., 2004).

In contrast, there is also evidence in the literature of co-occurrence and, in some cases, apparent attraction of marine mammals to shellfish aquaculture sites. Mussel farm workers in Iceland report cetaceans swimming through or within 50 m of farms, noting sightings of harbour porpoises, killer whales, long-finned pilot whales (*Globicephala melas*), minke whales (*Balaenoptera acutorostrata*), humpback whales (*Megaptera novaeangliae*), and white-beaked dolphins (*Lagenorhynchus albirostris*) (Young, 2015). There have also been occasional observations of Chilean dolphins (*Cephalorhynchus eutropia*) inside the perimeter of shellfish farms (Heinrich et al., 2019) and an observed increase in bottlenose dolphin (*Tursiops truncatus*) occurrence around and close to Mediterranean mussel (*Mytilus galloprovincialis*) farms in Galicia in northwest Spain (Díaz López & Methion, 2017). Positive attraction to farms may be due to the large aggregations of fish species around sites, with shellfish farms acting as fish aggregating devices, which can then provide high densities of high-quality prey for dolphins and other fish-eating species (Díaz López & Methion, 2017; Callier et al., 2018; Mascorda Cabre et al., 2021). Concurrent sightings of marine mammals proximal to marine farms may also be in part due to the optimal conditions required for mariculture production mirroring the environmental parameters preferred by marine mammals (Heinrich et al., 2019).

In accordance with the observation documented herein, killer whales have been observed swimming within or close to mussel farm sites on at least one previous occasion in Shetland waters (N. McCaffrey, unpub. data, 2021; Figure 6) and are occasionally observed in the line of sight of mussel farms in Icelandic waters (Young, 2015). Further reports of spatial overlap in the published literature are scarce, though avoidance of shellfish sites has previously been reported for New Zealand killer whales (Visser, 2007). Indeed, a manmade structure very similar to a mussel farm, known as a "hukilau" (a series of weighted vertical lines hanging in the water from a long surface line), has been used successfully on two occasions to corral entrapped killer whales (Jourdain et al., 2021) and to crowd schools of spinner dolphins (*Stenella longirostris*; Norris & Dohl, 1980) due to an apparent unwillingness to pass through the lines.

There are no reports of harbour seals using shellfish infrastructure as refuge from predation in the published literature, though previous tagging data have shown that harbour seals do forage and dive around mussel farms (Vincent et al., 2010), with seals known to feed on mussels occasionally (Roycroft et al., 2004). Given the high proportion (94.43%) of time the harbour seal spent exhibiting anti-predator behaviour or fatigue within the farm infrastructure, we expect that the seal was using the structure to evade predation rather than for foraging itself during the described encounter.

A more strategic investigation into the frequency and type of sightings of marine mammals

Figure 6. Two members of the 27s killer whale group swimming parallel to mussel farm headlines; this photo was taken at a mussel aquaculture site in Muckle Roe, Shetland, on 10 April 2021 (N. McCaffrey, unpub. data., 2021).

around Scottish shellfish farms, including behaviours exhibited, would be beneficial to place this sighting into a wider context.

Implications for Entanglement Risk

Co-occurrence of marine farms and marine megafauna increases the potential for conflict or associated risks (e.g., entanglement; Würsig & Gailey, 2002). For shellfish farms, entanglement risk may vary by species and may be dependent on species being cultured and the type of structures deployed by farms. For example, dropper lines that loop back to the surface (continuous loop systems) may pose more of an entanglement risk than multiple individual dropper lines that terminate above the seabed. Previously, mussel spat collecting ropes have been identified as having the greatest risk of entanglement potential to cetaceans (in comparison to adult grow-out ropes) as adult grow-out ropes tend to be thicker, heavier, and under tighter anchor and tension (Young, 2015). However, it is possible that tensioned anchor lines may cut into the skin and flesh of panicked animals (Price et al., 2016). Where risks are found to exist, gear modifications towards low-risk designs and marine spatial planning measures that consider risk reduction should be encouraged (Young, 2015; Price et al., 2016).

During the majority of the described observations, both species were in close proximity to the farm infrastructure, with the harbour seal swimming between dropper lines and under headlines, and the killer whale group and the harbour seal swimming under and over the end mooring lines (as seen in Figure 3a). Similarly, bottlenose dolphins swim over pearl oyster farm lines (Watson-Capps & Mann, 2005) while dusky dolphins swim between lanes of mussel farm ropes and floats (Markowitz et al., 2004). Such close proximity increases the risk and likelihood of entanglement, and, unfortunately, there are a number of previous fatal entanglement cases observed and reported within mussel farm infrastructure (Young, 2015). Previous fatal records include two cases of spat catching line being caught around a Bryde's whale's (*Balaenoptera edeni*) jaws and body in New Zealand (Lloyd, 2003; Young, 2015), a juvenile humpback whale entangled in weighted single dropper spat collector lines, and a harbour porpoise with fins entangled in single dropper spat collecting lines, with the latter two both occurring in Icelandic waters (Young, 2015). There have also been unconfirmed reports of the entanglement of a Southern right whale (*Eubalaena australis*) in shellfish aquaculture gear in Argentina and of a gray whale (*Eschrichtius robustus*) in Californian waters in the United States (Price et al., 2016). Other cases were successfully disentangled and released following human intervention, including a humpback whale calf entangled in mussel spat collecting rope off Western Australia (Groom & Coughran, 2012; Young, 2015) and a North Pacific right whale (*Eubalaena japonica*) found with four thick mussel grow-out ropes wrapped around its caudal peduncle and fluke off South Korea (Young, 2015). A minke whale is also reported to have been seen entangled in gear in an Icelandic mussel farm, but it managed to free itself (Young, 2015).

To the best of our knowledge, there is no evidence within the published literature of killer whale entanglement in shellfish aquaculture gear. The observed 27s killer whale group is known on at least two previous occasions to have interacted with lines in the water, with (1) a video showing a member of the 27s group interacting with a creel buoy line which then momentarily got stuck on its dorsal fin (Shucksmith, 2022), and (2) an incidence of a fatal entanglement in rope of a 5-year-old juvenile from the group found dead on Papa Westray, Orkney Isles, in 2021 (#151; Scottish Marine Animal Strandings Scheme [SMASS], 2021; Scullion et al., 2021). These observations coupled with those described in this article show multiple incidences of this particular group interacting with manmade structures or objects in the water—behaviours which, if persistent, may increase the group's vulnerability to entanglement and other negative consequences. Further observations and publishing of such anecdotal reports are encouraged to more fully understand the type and frequency of interactions between marine mammals and manmade structures, as well as any associated potential implications.

Predator–Prey Interactions in Anthropogenic Landscapes

Killer whales in Shetland waters routinely patrol sites searching for potential prey—for example, frequenting seal haunts (Weir, 2002). Indeed, in patrolling mussel lines and structures known to aggregate prey species, such as common eider ducks (*Somateria mollissima*), cormorants (*Phalacrocorax carbo*), or seals (Weir, 2002; Roycroft et al., 2004; Booth & Ellis, 2006; Smith, 2006; Callier et al., 2018), killer whales may now be taking advantage of the novel predation opportunities that anthropogenic structures provide. The prey aggregating characteristics of infrastructure may provide a predictable prey resource for apex predators, such as killer whales, which then essentially acts as an ecological trap for seals and other prey species (Fleming & Bateman, 2018). Such structures may change the effectiveness of predator–prey strategies and alter the playing field of predator–prey dynamics (Gaynor et al., 2019;

Guiden et al., 2019). For example, predator hunting efficiency may be increased through reduced search costs, through prey escape routes being physically blocked by infrastructure, or through the evolution and adaptation of novel foraging techniques (Fleming & Bateman, 2018; Gaynor et al., 2019). Anthropogenic structures and human-introduced noise may also mask sounds or cues that predators or prey would normally tune into, thus affecting predation success.

In contrast, manmade infrastructure may provide prey refugia when predators are initially detected or, as is the case herein, during an active hunt (Madin et al., 2016; Williams et al., 2020). Infrastructure may physically impede predators from entering (Visser, 2007), or it may obstruct and hinder feeding strategies (Würsig & Gailey, 2002; Pearson et al., 2012). Indeed, of the 83.02% of total time that the harbour seal dedicated to anti-predator behaviour, 78.01% of the time was from within the mussel farm infrastructure, compared to only 5.01% of the time spent exhibiting anti-predator behaviour in open water (Figure 5 & Table 2). Considering harbour seals are undergoing regional declines in some UK subpopulations, including marked declines in Shetland waters (Thompson et al., 2019), the impact of anthropogenic structures on seals' perceived "landscape of fear" (i.e., an animal's perception of spatial variation in predation risk; Gaynor et al., 2019), along with the impact of anthropogenic structures on seals' actual spatial variation in predation risk, warrants further analysis. Similar terrestrial research documents anthropogenic alteration as having provided predators easier access to traditional prey refugia (DeMars & Boutin, 2018) and human-active sites providing prey refuge from traffic-averse predators (Berger, 2007; Muhly et al., 2011).

It is clear that both marine and terrestrial predator–prey interactions are occurring in settings differing from historical conditions and are instead defined in some way by the Anthropocene (Inger et al., 2009; Bishop et al., 2017; Guiden et al., 2019; Lieber et al., 2019; Hemery et al., 2021). As such, human-altered risk is ultimately reshaping evolutionary pathways within the oceans (Madin et al., 2016). Traditionally, this has not been considered within marine spatial planning discussions, perhaps due to a paucity in understanding of the wider ecological effects. As comprehension of the potential effects of human-altered risk grows, such knowledge should be taken into consideration prior to further modification of marine habitats. Furthermore, it is important to evaluate the consequences of the predicted increase in anthropogenic infrastructure and activity across multiple parallel industries (e.g., finfish and shellfish aquaculture, shipping, tourism, marine renewables) on human-altered risk and predator–prey landscapes and interactions, as these effects may ultimately lead to interacting cumulative impacts to marine megafauna.

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