

Records of Fatal Killer Whale (*Orcinus orca*) Attacks on Fin Whales (*Balaenoptera physalus*) with an Emphasis on Baja California, Mexico

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Abstract

Historically, there has been only one documented fatal killer whale (*Orcinus orca*) attack on a fin whale (*Balaenoptera physalus*)—from Baja California, Mexico (BC), in 2005. We compiled records of seven more recent fatal attacks, including four more from BC. Two male killer whales that we identified were involved, separately or together, in at least four of the five fin whale kills off BC as they traveled with their groups the length of the Baja Peninsula on both sides. They were also involved in two Bryde's whale (*Balaenoptera edeni*) kills, and we suggest that they might specialize on large whale prey. We discuss offensive and defensive strategies during these attacks and the role (or lack thereof) of adult male killer whales. One of the fin whales taken appeared to be a healthy adult, which raises questions about large whales as prey for killer whales. We also discuss the burgeoning role of citizen science in this type of research, noting that most of our data came from social media postings.

Key Words: Baja California, citizen science, fin whale, *Balaenoptera physalus*, killer whale, *Orcinus orca*, predation

Introduction

As globally distributed apex predators, killer whales (*Orcinus orca*) feed on a great diversity of marine megafauna, including mammals, fishes, seabirds, turtles, and cephalopods (Jefferson et al., 1991; Ford, 2019). When they prey on baleen whales, however, they usually target smaller species (e.g., minke whales [*Balaenoptera acutorostrata* and *Balaenoptera bonaerensis*]; Pitman & Ensor, 2003; Ford et al., 2005; Goodall et al., 2007) or the calves of larger species (Jefferson et al., 1991; Reeves et al., 2006; Pitman et al., 2007, 2015; Ford & Reeves, 2008). How much of a threat killer whales pose to healthy adults of large baleen whale species remains unresolved and controversial (e.g., Springer et al., 2003; Mizroch & Rice, 2006; Reeves et al., 2006; Mehta et al., 2007; Steiger et al., 2008). Recently, however, Totterdell et al. (2022) described, for the first time, fatal killer whale attacks on three separate pygmy blue whales (*Balaenoptera musculus brevicauda*) off Bremer, Western Australia, including one that appeared to be a healthy adult.

Killer whale attacks on fin whales (*Balaenoptera physalus*), of any age, have rarely been reported, and few of these have had recorded outcomes. Shevchenko (1975) reported that 53.4% of fin whales killed by Soviet whalers in the Southern Hemisphere had killer whale tooth rake marks on

them. He concluded that most attacks occurred in warmer waters (where killer whale prey was generally less abundant), that sick or old individuals were most likely to be targeted, and that most attacks were unsuccessful. Among the 15 (mostly anecdotal) killer whale harassments/attacks on fin whales listed by Jefferson et al. (1991), the only kill reported (from Greenland in 1908) was deemed “possibly unreliable” (pp. 173, 177).

Nearly all of the more recent accounts of fin whale attacks, published or otherwise, have come from the Gulf of California, Mexico (GoC). Vidal & Pechter (1989) reported on an apparent attack by three killer whales on two fin whales in the northern GoC in 1982, and Ford & Reeves (2008) provided accounts of two additional attacks in the GoC in 1984 and 2005; the latter one was fatal. Killer whales purportedly attacked a fin whale cow and calf off Santa Rosalia, GoC, on 28 January 2005; the calf was killed and eaten (Guerrero-Ruíz, 2013). A local newspaper account (*El Peninsular*, 31 March 2005), however, identified the whales as humpbacks (*Megaptera novaeangliae*), but the dorsal fin in the accompanying photos looked more like that of a Bryde’s whale (*Balaenoptera edeni*), and we were unable to confirm the species. Thus, to our knowledge, the only credible report to date of killer whales attacking and killing a fin whale, anywhere, is the one listed by Ford & Reeves (2008) from the GoC in October 2005.

Herein, we summarize reports of killer whale attacks on fin whales worldwide, but with a special focus on Baja California, Mexico (BC), where most of these attacks occurred. We discuss behavioral observations recorded during these attacks and the implications for large rorquals as prey for killer whales.

Methods

We reviewed published and unpublished accounts, including social media postings, of killer whale attacks on fin whales globally. A heavy reliance on “citizen science” data from social media postings meant that the account details are necessarily uneven, but we reviewed all available imagery and narratives from these events and contacted eyewitnesses, to the extent possible, to verify their authenticity.

Photo-identification studies in the GoC have identified a minimum of 192 individual killer whales, at least some of which are suspected to comprise a resident population (Guerrero-Ruíz, 2013; González-Ruelas, 2016, 2019). To learn more about the individual killer whales involved in the BC fin whale attacks, their ranging patterns, and other prey species taken, we matched photographs of animals from these events to

images from four separate killer whale photo-identification catalogs that include coverage in the region. These catalogs have different numbering systems and use their own prefixes, including “ME” numbers (Black et al., 1997), “E” numbers (Olson & Gerrodette, 2008), “MX” numbers (Guerrero-Ruíz, 2013), and “UABCS” numbers (Universidad Autónoma de Baja California Sur, Marine Mammal Research Program, unpub. photographic catalog, 1973-2008). We found that two distinctive male killer whales—E256 (aka ME87, MX87, and UABCS_Oo_M_077) and E261 (aka MX157 and UABCS_Oo_M_089)—were regularly photographed off the Baja Peninsula, which could be due in part to a photo-taking public more likely to photograph adult male killer whales than females and juveniles. These two individuals were readily identifiable, and both, separately or together, were involved in several (and possibly all) of the fin whale attacks documented off BC. Therefore, we used these two individuals as proxies for the groups they traveled with and highlighted their participation in the accounts below and in the discussion that follows.

In the following accounts, we provide details from all lethal killer whale attacks on fin whales globally that we were able to verify. For BC, we include information on all reported fin whale attacks, lethal or otherwise, and we indicate when killer whales E256 and E261 were confirmed as present. We also report observations of other prey species taken by these two individuals (Table S1; the supplemental table for this article is available on the *Aquatic Mammals* website).

Results

Attack #1 – 2 March 1982, GoC, 3 Killer Whales
Adult female or immature male killer whales chased a pair of fin whales; the attack was described as “apparently unsuccessful” (Vidal & Pechter, 1989, p. 372), but the fin whale and attackers all swam off in the same direction, and the observers never saw how the attack ended.

Attack #2 – January 1984, GoC, 7 Killer Whales
According to Ford & Reeves (2008), Attack #2 was an “[a]ttack in progress on fin whale observed from air. Killer whales circled, held flippers, and repeatedly rammed fin whale. No defensive actions seen. Observation ended after 1.5 hours due to darkness” (p. 86).

Attack #3 – 17 October 2005, GoC, 16 Killer Whales

Ford & Reeves (2008) reported the following: “Fin whale chased for 1 hour at speeds of up to 40 km/h. Fin whale slowed after fleeing for 10 km and was

attacked and killed. Killer whales fed on sinking carcass for c. 15 min, then left area” (p. 86).

Attack #4 – 30 March 2007, São Miguel Island, Azores, ~20 Killer Whales

From a whale-watching boat, one coauthor (RR) observed a group of killer whales (including adults, juveniles, and three to four calves) attack and kill a young fin whale estimated to be 10 to 12 m long. The attack was already underway when the boat arrived, and observations lasted ~30 min. The fin whale was alive initially but swimming slowly; there was a lot of splashing and blood in the water as the killer whales bit the whale’s body and dorsal fin, seemingly at will. At least one adult male killer whale was present; it was actively involved in the attack when observations began and was described as “trying to drown the fin whale” by swimming on top of its head. From the video footage, the male killer whale can be seen next to the fin whale and apparently trying to remove chunks of flesh: its head is shaking vigorously, and its dorsal fin is wobbling side-to-side. By the time the boat left, the fin whale was dead, and the carcass was beginning to sink. Only the separated dorsal fin remained floating at the surface (see below and Hancock [1965] about detached dorsal fins). The carcass appeared to be largely white because the killer whales had removed much of the skin. Similarly, Hancock (1965) reported killer whales eating the skin off two common minke whales in British Columbia, Canada. At the Azores attack, approximately two dozen Cory’s shearwaters (*Calonectris borealis*) were also present and feeding on scraps of flesh (video from this event is available at https://www.youtube.com/watch?v=LYq12Hxx_Zo).

Attack #5 – 1 November 2011, Pacific Side of Northern Baja California, 15 to 20 Killer Whales
Observations were made 2.8 km north of North Coronado Island, Mexico, by fishermen in a skiff from San Diego, California. At ~1400 h, they encountered a group of killer whales (including at least three adult males and two calves) attacking a fin whale, which they observed for over 2 h (in videos posted online, the whale was incorrectly identified as a blue whale). The fin whale, estimated to be at least 15.2 m long, swam slowly as the killer whales repeatedly attacked; it made no effort to flee. Adult female killer whales and their young stayed close to the fin whale and appeared to be the ones pressing the attack; the adult males mostly stayed on the periphery but were actively involved at times. The fin whale had flesh missing from its head and a large gaping wound in its lower jaw; there was a lot of blood in the water, most of which seemed to come from the flanks behind the

dorsal fin. The killer whales surfaced near the head, flippers, flanks, and flukes of the fin whale, ramming and biting it at and below the surface. One or more killer whales regularly swam on top of the fin whale, mostly on its rostrum, which appeared to make surfacing difficult for the fin whale. The fin whale swam directly toward the fishing boat several times during the attack, apparently for cover, and the boat moved away each time.

The killer whales displayed a variety of surface-active behaviors during the attack, including breaches and tail slaps, with one killer whale hanging vertically in the water for a few seconds with the posterior half of its body out of the water. At least 200 western gulls (*Larus occidentalis*) circled overhead during the attack, picking up scraps of flesh from the water (other bird species were likely present as well). The fin whale died near the south end of South Island. As killer whales fed on the carcass, some females and, especially, juveniles socialized around the boat, closely approaching it several times and passing directly under it. They slapped their flukes on the water multiple times, and one did an aerial summersault. At 1630 h, the boat departed to San Diego. Several videos from this encounter were posted online (e.g., www.youtube.com/watch?v=VUoYoF8z8pw). E261 was among the killer whales identified in the videos.

Attack #6 – 9 June 2012, GoC, 14 to 18 Killer Whales

The event was observed from a tour boat operated by The One Baja. Witness and company spokesperson, M. Correa, stated that at ~1200 h, the boat approached a group of killer whales, including two adult males, that were attacking a fin whale smaller than their 15 m vessel. When first observed, the fin whale had numerous bleeding injuries; it swam slowly the entire time and made no effort to flee, indicating that the attack had probably been underway for some time prior to the boat’s arrival. The killer whales were closely flanking it, and some were ramming it. At least one cow-calf pair stayed primarily near its head. The fin whale repeatedly circled back toward the tour boat and passed under it, while multiple killer whales were flanking it and making contact. Periodically, when the fin whale attempted to surface, a killer whale swam onto its head, which appeared to hamper its breathing. At other times, killer whales swam onto its back. The killer whales bit its back, caudal peduncle, and flippers; there was a large bite wound on its right side, and blood was coming out of its mouth. During the attack, the killer whales displayed a variety of surface-active behaviors, including breaches and tail slaps.

After about 40 min (1240 h), the fin whale approached and surfaced within 20 m of the boat. It stopped, rolled on its side, and slowly lifted its head part way out of the water. The killer whales grabbed it by the flippers, and one swam on top of its head. The fin whale sank out of sight, apparently pulled down by its flippers; it was not seen again and presumed dead. A huge slick appeared at the surface where it was pulled down, and all the killer whales in the immediate vicinity dove down into the slick and out of sight. After about 15 min, pieces of flesh started floating to the surface, and birds and California sea lions (*Zalophus californianus*) converged on the area. Some of this event was captured on video (<https://youtu.be/mWxFbOrGEPE>). Killer whales E256 and E261 were both identified in photos from this attack.

Attack #7 – 19 January 2019, GoC, 8 Killer Whales
Observations were made from the Museo de la Ballena research vessel *Narval* and lasted just over 1 h, from 1155 to 1300 h. One coauthor (AMO-G) witnessed an attack on a fin whale by a group of killer whales that included one adult male, one adult female with a calf, and at least five indeterminate aged/sexed individuals (i.e., females and/or juvenile males).

When first detected, the killer whales were causing a commotion in the water, ~600 m southeast of the vessel as it was anchored in San Luis Gonzaga Bay. Less than 1 min later, a fin whale appeared among the group, lifting most of its head out of the water as it swam rapidly away from the killer whales. It initially headed northwest, almost directly toward the vessel, but when 70 to 100 m away, it veered toward the shore. At times during the chase, two juvenile killer whales flanked the fin whale, each swimming ~1 m on either side of it. Fresh tooth rake marks on the fin whale's dorsal fin were visible in the first photographs taken, suggesting that the attack was probably already underway (for an unknown length of time) when first observed.

The fin whale continued swimming toward the shore, and, with the killer whales in close pursuit, it traveled north along a rocky shoreline for about 5 min before turning southwest toward the opposite side of the bay. At that time (1209 h), the adult male killer whale joined the attack, and the fin whale reacted immediately by vigorously slapping the water with its tail at least three times. As the fin whale approached a sandy beach near the southern end of the bay, it turned north again and followed the shoreline from 100 to 150 m offshore. After 55 min of observation (1250 h), the fin whale appeared to be fatiguing: it was swimming noticeably slower, and although it continued tail-slapping, it was less vigorous than before. When

the fin whale and pursuing killer whales reached the far end of the sandy beach, they rounded a rocky promontory and were lost from view. Five minutes later (1255 h), the fin whale was still not visible, but the killer whales were swimming offshore, out of the bay, at a much slower pace (i.e., no longer porpoising out of the water).

At ~1330 h, a launch was deployed to search for the fin whale. It was found stranded alive on the beach where it died at ~1445 h as the tide went out. A length of rope, estimated to be 1 fathom (1.8 m) long, was used to estimate the whale's length as ~21 m. It was not obviously injured, emaciated (Figures 1 & 2a), or in ill health, so it was inferred to be a healthy adult (see below). Because it stranded ventral side down, its sex could not be determined.

On the beach, the fin whale showed a series of superficial and still bleeding wounds from the attack. There were tooth rake marks on the tip of the rostrum (Figure 2a), on both lower lips (Figure 2a & b), and on the dorsal fin (Figure 2c); the right flipper, in addition to having rake marks, appeared to be recently broken (Figure 2d). There were also bite wounds on the dorsal ridge anterior to the dorsal fin (Figure 2e) and, especially, on the caudal peduncle (Figure 2f). There were no rake marks on the flukes.

When the other killer whales left, a female or juvenile male stayed behind, ~250 to 300 m offshore of the stranded fin whale, and waited for ~30 min before departing. That night, the fin whale was towed out of the bay to dispose of the carcass. Killer whale E261 was identified from the photographs.

Attack #8 – 25 March 2019, GoC, 15 to 20 Killer Whales

Clam fishermen posted cell phone footage on social media that shows at least two adult male killer whales, several females, juveniles, and calves, and multiple indeterminate ages/sexes attacking a fin whale close to their boats. We reviewed a short (5:13) video posted by fisherman R. Tambo-Montes, who reported that an attack on a large ("perhaps 16 m") fin whale was already underway when the fishermen arrived in their pangas (open fishing boats) at ~0700 h and lasted for an additional 60 to 90 min.

When the footage starts, the fin whale was swimming slowly (estimated 3 to 5.5 km/h) and was surrounded by killer whales that were in tight formation and apparently attacking at will. Some killer whales struck the fin whale with open mouths, while others swam on top of it. It had a large open wound estimated to be 1 m deep on the dorsal ridge immediately behind the dorsal fin, and it seemed unable to swim away. At times, the fin whale appeared to seek cover from the fishing boats. The adult female and younger killer



Figure 1. The ecology of fear? An apparently healthy adult fin whale (*Balaenoptera physalus*; estimated length 21 m) that live-stranded in the northern Gulf of California, Mexico, while being pursued by killer whales (*Orcinus orca*). It later died when the tide went out (Attack #7; Table S1). (Photo credit: A. Ortega-Gonzalez)

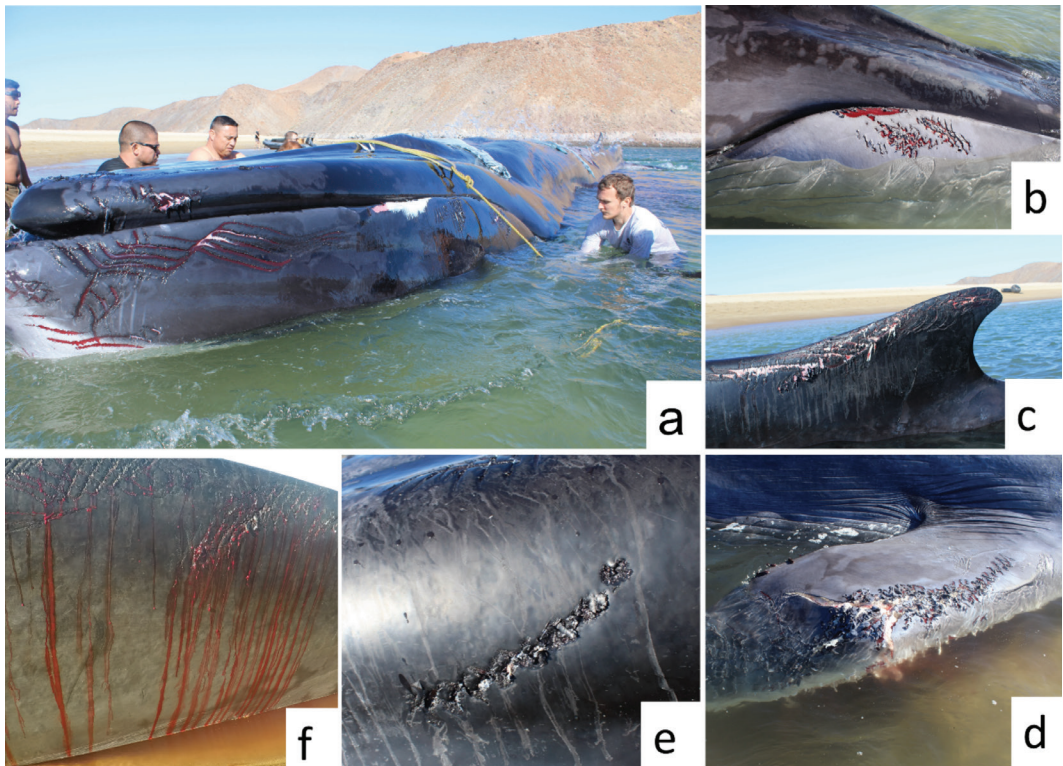


Figure 2. Details of the wounds on the same fin whale as in Figure 1, showing (a) fresh (bleeding) killer whale tooth rake marks on the rostrum and left bottom lip, (b) fresh rake marks on bottom right lip, (c) rake marks on leading edge of dorsal fin, (d) rake marks and damage to the right flipper, (e) a bite on the dorsal ridge in front of the dorsal fin, and (f) multiple, fresh rake marks along the top of the caudal peduncle. (Photos provided by A. Ortega-Gonzalez)

whale appeared to be most actively involved in the attack; throughout the video, they flanked the fin whale more closely than a nearby adult male, which followed on the fin whale's right side. The killer whales were clustered around the head, flippers, and peduncle, and some appeared to be feeding on the fin whale near the peduncle wound. Several killer whales broke away and briefly approached the cameraman's panga, as did the other adult male present, who stayed away from the attacking killer whales.

Periodically, individuals next to the fin whale vigorously shook their heads back and forth, apparently trying to remove flesh. At least one killer whale swam briefly on its side, and some were tail-slapping. Right after the whale took a breath at around minute 3:14 of the video, a killer whale that appeared to be an adult female swam on top of the fin whale's head for about 45 s. It seemed like the killer whale was trying to prevent the fin whale from surfacing and breathing. The fin whale exhaled underwater, surfaced with no blow, then successfully surfaced and respired. The fin whale made three more blows, then a killer whale appeared to lay across the fin whale's head for over 35 s and was still on the fin whale's head when the video ended. The fin whale slapped the water with its flukes a few times, but this action seemed to be more as a reflex than a defensive measure; it appeared to have trouble breathing.

The fishermen reported that the fin whale was killed. They also stated that most observations of killer whale attacks on fin whales and minke whales occur during the winter months. Video of the attack was posted online (<https://www.facebook.com/rigobertonicolas.tambomontes/videos/2326243250773406>). One of the killer whales present was identified as E261.

Attack #9 – 5 May 2019, GoC, 9 Killer Whales

S. Velazquez viewed the attack from a small aircraft for ~40 min. At least one adult male killer whale was present. The attack was purportedly not fatal, but blood was visible in the water. There were no photos or video taken.

Attack #10 – 23 October 2019, off Morro Bay, California, 5 Killer Whales

While underway on a fisheries research vessel, one coauthor (RP) observed a group of killer whales—one adult male and four indeterminates—attacking a fin whale; the encounter lasted 24 min, from 1125 to 1149 h. The killer whales were first observed surfacing in a large slick on the water where birds (minimum 25 gulls [*Larus* spp.] and one northern fulmar [*Fulmarus glacialis*]) were picking at the surface. The fin whale was still alive when first observed but was badly wounded. It had fresh rake marks on the upper and lower lips and on the splash guard of



Figure 3. A “likely fatal” attack on a fin whale off Morro Bay, California (Attack #10; Table S1); killer whales have removed a section of the upper lip, and there are tooth rake marks on the lower lip. (Photo credit: R. Pace)

the blowhole, and a large section of flesh had been ripped from the rear edge of the rostrum on the right side (Figure 3). The rake marks on the lower lip appeared to be concentrated near the arch toward the back of the lip. As the boat left, it passed by a ~2-m-long section of flesh floating at the surface that presumably came from the fin whale. Throughout the observation, the fin whale did not attempt to flee from the killer whales or resist the assault, and the coauthor (RP) concluded that the attack was “likely fatal.” Although these individual animals had not previously been identified off California or Mexico, four of these individuals were subsequently photographed in Monterey Bay (with three other unmatched whales) on 25 August 2021 when they killed a Risso’s dolphin (*Grampus griseus*) and were subsequently given California Killer Whale Project photo-ID catalog numbers CA292, CA293, CA294, and CA295 (Schulman-Janiger & Black, unpub., January 2022).

Attack #11 – 17 July 2020, GoC, 8 Killer Whales

One coauthor (HR-N) observed a killer whale attack from the BC mainland using binoculars and was able to positively identify the prey as a fin whale. He watched for ~40 min until sundown. At one time, the killer whales had managed to stop the fin whale; it began moving again but at a slower speed. It was not possible to determine if the attack was fatal. No photos or video were taken.

Attack #12 – 22 April 2021, Puerto Williams, Chile, 7 Killer Whales

One coauthor (DC) videotaped much of the event, and from the videos, the killer whales included one adult male, one small juvenile, and approximately four to five adult females/large juveniles. The footage comprised 11 short segments, 24 to 98 s in length:

1. The video began with killer whales chasing a fin whale, at moderately high speed, roughly 50 m from the shoreline in a Chilean fjord; two abandoned and dilapidated metal piers are visible along the shoreline.
2. Footage showed the fin whale with its head up against the pilings of the second pier and, moving beside the fin whale, what appeared to be an adult female killer whale (with nick in top of dorsal fin), which seemed to lead the attack throughout the video. Although stationary, the fin whale raised and lowered its flukes as if swimming slowly.
3. Two or three adult female killer whales focused their attentions on the left side of the caudal peduncle of the fin whale or possibly its flukes. The fin whale was parallel to the shore with its right side closest to it and was still raising and lowering its flukes as if slowly swimming.
4. Two females were perpendicular to the left side of the caudal peduncle, just in front of the fluke. It was not clear if they were biting the fluke or the peduncle, but blood was coming to the surface. The fin whale continued to raise its flukes out of the water.
5. At least five killer whales were present, comprising two or three adult females, maybe two large juveniles, and a smaller juvenile. The attacking killer whales all seemed focused on a single location on the peduncle. Presumably an open wound was present that each killer whale in turn was targeting. One at a time, they positioned themselves perpendicular to the left side of the peduncle. Then, they swam in and bit the fin whale, evidenced by more blood flowing to the surface. The attacking killer whale shook its head vigorously, which caused its dorsal fin to wobble as it tore off flesh and swam away.
6. The fin whale was thrashing its flukes vigorously as three or four killer whales continued taking turns attacking the left side of the peduncle (and possibly the flukes). The fin whale’s head was wedged into a jumble of metal pier debris, leaving only its posterior body exposed to attack (Figure 4).
7. The fin whale was pumping its flukes as if trying to wedge further into the debris as, one at a time, three to four killer whales continued attacking the left side of the peduncle.
8. At this time, the lead female killer whale placed her head at the front of the fin whale’s flukes and appeared to be pushing the fin whale backward, away from the pilings into which it was wedged; the killer whale’s flukes kicked furiously in this effort. The fin whale was eased out a bit from the pilings and seemed to be kicking its flukes to wedge itself back in.
9. From this new perspective, the fin whale can be seen to be only about 10 m from shore and perhaps aground with its right side to the shoreline; this may be why all the attacks were on the left side. Four adult female/large juvenile killer whales were present at this point.



Figure 4. A 14.2-m fin whale became wedged into some dilapidated pier pilings after being attacked by killer whales off Puerto Williams, Chile, in April 2021. The whale became dislodged and was killed by the attackers (Attack #12). (Photo credit: D. Chevally)

10. The fin whale seemed to have wedged itself further into the pilings again as three killer whales lined up perpendicular to the left side of the peduncle. At times, it was not clear if the killer whales were interested only in feeding or if they were also trying to push/pull the fin whale out into open water.
11. The fin whale was finally in open water—apparently the killer whale dragged or pushed it out from the debris. There was a violent attack on the front end of the fin whale, and blood was coming out of its mouth when it surfaced. As it swam parallel to the shoreline in very shallow water, four or five killer whales continued to attack it vigorously. The photographer scanned out to show, for the first time during the attack, a single adult male killer whale swimming by itself, 50 m or so offshore from the fin whale.

The footage ends with the fin whale slowly swimming in a kelp bed with several killer whales moving along beside it and seemingly attacking at will. The whale eventually died and stranded on a nearby beach. It measured 14.2 m. (Some of the video footage from this attack is available at <https://youtu.be/DllmL1Peu3c>.)

Discussion

Large Whale Specialists off Baja California?

Seven of the 10 fin whale attacks since 2005 that we documented globally, including five of the only eight known fatal (or “likely fatal”) attacks, occurred in the waters off BC (Figure 5; Table S1).

The two male killer whales that were regularly identified in fin whale attacks off Mexico (E256 and E261) were both long-term residents in BC waters: E256 was photographed during at least 17 different killer whale encounters spanning a 28-y period (1984 to 2012), and E261 was identified during at least 20 encounters over a 21-y period (1997 to 2019; Figure 5; Table S1). Their plotted sighting locations also indicate that, rather than being resident within the GoC, both occurred up and down both coasts of the entire BC peninsula—ranges that encompassed all the fin whale attacks reported off Mexico (Figure 5). Furthermore, E256 and E261 were collectively involved in most, if not all, the BC attacks, including at least four of the nine attacks reported here (no photographs were available for the other five) and at least four of the five fatal attacks (no photographs were available for the fifth; Figure 5; Table S1). E261 was present during fin whale kills #5 (2011), #6 (2012), #7 (2019), and #8 (2019); E256 and E261 were both present during kill #6 (Table S1). In addition, E256 was among a group of 12 killer whales that were feeding on an unidentified large whale kill on 9 March 2008, 20 km south of Loreto, GoC (Table S1, Record #22). At that time, a large, freshly detached dorsal fin with bleeding rake marks was found floating on the water, and, based on photos taken, it appeared to be from a fin whale (although possibly a Bryde’s). Just prior to the encounter, several fin whales and at least one humpback were seen “fleeing” from the immediate area where the killer whales were feeding (F. Wilson, pers. comm., 11 February 2021).

In addition to fin whales, killer whales have been reported attacking and killing Bryde’s whales in the GoC on at least three occasions: in 1988 (Silber

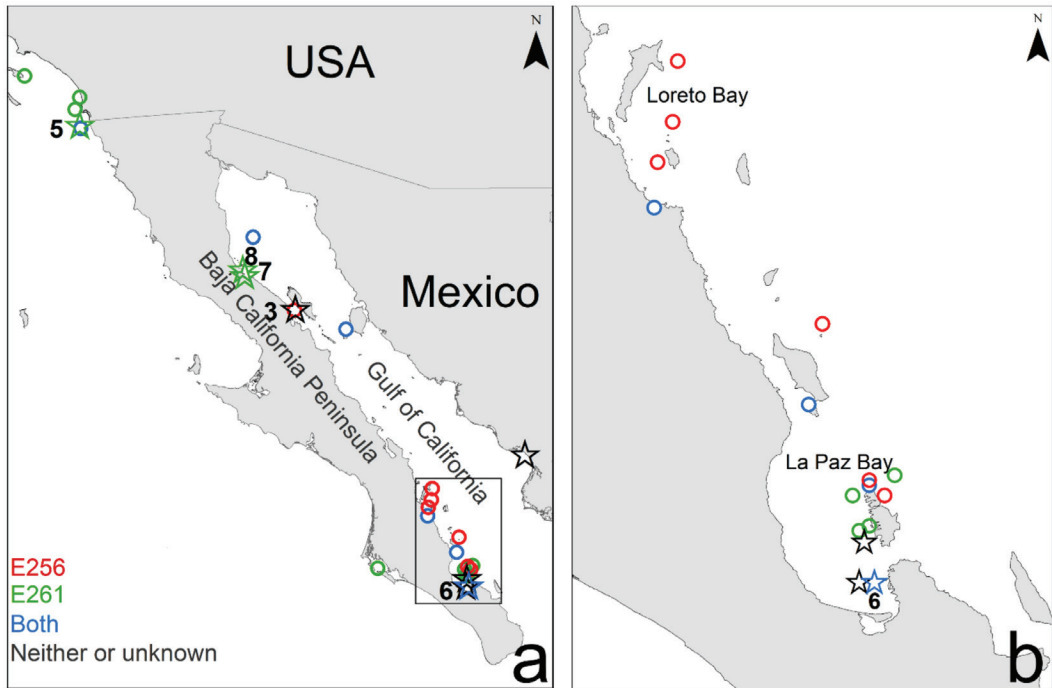


Figure 5. (a) Shown are the locations of eight killer whale attacks on fin whales off Baja California, Mexico (stars), and 21 additional sightings of male killer whales E256 or E261 when no fin whale attack was reported (circles); colors indicate which of the two killer whales was present. Numbered stars indicate lethal attacks; unnumbered stars were unsuccessful or had unknown outcomes. An additional attack (#2; Table S1) had no location other than “Gulf of California” and is not included; and (b) enlarged inset shows details of events in region from La Paz Bay to Loreto Bay.

et al., 1990), 1998 (Guerrero-Ruíz, 2013), and 2000 (Ford & Reeves, 2008). The latter was documented in a video by one coauthor (MF) (<https://www.youtube.com/watch?v=4puJppvtzP8&feature=em-comments>). The first attack was observed from an airplane and not photographed, but E256 and E261 were both photographed at the other two events (Table S1, Record #s 6 & 8).

Killer whales have also attacked blue whales off both coasts of BC as documented by Tappy (1979) and by two more-recent social media postings cited by Totterdell et al. (2022): (1) on or about 23 September 2013, “no less than 25 killer whales” attacked a blue whale off San Quintin, western BC (<https://www.youtube.com/watch?v=zdB1pATdT6Y>); based on the number of killer whales present and the intensity of the attack, we suspect that it was likely fatal; and (2) on 21 July 2016, an estimated 20 to 25 killer whales attacked a blue whale near Isla Espíritu Santo, GoC (<https://www.facebook.com/650995745057910/videos/667511220073029>). According to witnesses, the attack was fatal. Due to poor image quality, we were unable to identify any individual killer whales from either attack, but both attacks occurred within the at-sea ranges

of E256 and E261 (Figure 5) and during the years when at least E261 was known to be attacking fin whales off BC. Although E256 was also reported feeding on bottlenose dolphins (*Tursiops truncatus*) and manta rays (*Mobula* sp.; Guerrero-Ruíz, 2013; Table S1, Record #s 14 & 15), large rorquals (e.g., fin, Bryde’s, and possibly blue whales) were the most common prey reported for both E256 and E261, indicating that they could be large whale prey specialists. To assess the impact of killer whale predation on rorqual populations off BC, more needs to be known about the species, age/size classes, and numbers of whales taken there.

Offensive and Defensive Strategies

Based on a review of behavioral responses to killer whale attacks, Ford & Reeves (2008) categorized baleen whales as either “fight species” or “flight species,” and more recent field observations support these categorizations. Fight species include the gray whale (*Eschrichtius robustus*), right whales (*Eubalaena* spp.), bowhead whale (*Balaena mysticetus*), and humpback whale. These are bulky, slow swimmers that use their enormous size and flailing, oversized appendages to aggressively ward off

attackers. They tend to breed in coastal waters and often form defensive groupings when under attack (Ford & Reeves, 2008; Pitman et al., 2015). When attacked, fight species—especially mothers with calves—often seek refuge in shallow, nearshore waters as has been reported for bowhead whales (Ferguson et al., 2012; Shpak & Paramonov, 2018), southern right whales (*Eubalaena australis*; Ford & Reeves, 2008), gray whales (Barrett-Lennard et al., 2011), and humpback whales (Pitman et al., 2015). That this is an effective defense strategy is evidenced by the fact that killer whales usually break off their attack immediately once a fight species moves into shallow water (Ford & Reeves, 2008; Pitman et al., 2015).

By contrast, flight species, comprising the eight recognized *Balaenoptera* species, including fin whales, use speed and endurance to escape killer whales and usually head for open water if attacked. Once flight species are slowed down or stopped, however, they appear to have no additional defenses (Ford et al., 2005; Ford & Reeves, 2008; this study). They breed in largely unknown, offshore areas, and, unlike fight species, they do not form defensive groupings when attacked. If chased into shallow waters, flight species are often either captured and killed or strand on a beach. If they strand, they usually either die or, sometimes, assisted by a rising tide, they later swim off, in which case they might escape or be killed by their waiting attackers (Hancock, 1965; Jefferson et al., 1991; Ford et al., 2005; Goodall et al., 2007; Ford & Reeves, 2008). When *Balaenoptera* whales are attacked and strand, it is not known if they do so intentionally to avoid their predators or if killer whales deliberately attempt to drive them ashore (Ford et al., 2005; Goodall et al., 2007). Conversely, we know of no cases of fight species stranding while being attacked by killer whales (see Ford & Reeves, 2008). In general, killer whales appear to gain offensive advantage by driving fight species away from shallow water and driving flight species into shallow water.

The details from Attack #7 provide additional insight into how killer whales attack large *Balaenoptera* whales and how these flight species respond in turn. When these species are attacked and beach themselves, they sometimes show few or no visible wounds from their attackers (e.g., Ford et al., 2005; Goodall et al., 2007). For example, although the fin whale in Attack #7 was attacked almost continuously during a high-speed chase for a minimum of 65 min, when it stranded, it appeared to have only superficial rake marks on its rostrum, lips, flippers, dorsal ridge, dorsal fin, and caudal peduncle (Figures 1 & 2). These relatively minor wounds are perhaps an indication of how difficult it can be for biting killer whales to

gain purchase on a large, fast-moving whale with a hydrodynamic body shape. Tooth rake marks were most prevalent along the relatively accessible dorsal ridge behind the fin whale's dorsal fin (Figure 2f), and the whale's repeated tail slaps during the chase may have been in response to killer whales targeting that area. There were no rake marks on the fin whale's flukes: the fleeing whale's massive tail may have been pumping up and down too rapidly for killer whales to safely approach (Silber et al., 1990; but see Tarpy, 1979). Regarding the bites on the lips (Figures 2a, 2b, & 3), numerous accounts of orca attacks report killer whales feeding on the lips and tongue of their prey (Jefferson et al., 1991; Reeves et al., 2006), and it could be that the lips are targeted in an attempt to force the mouth open to access the tongue—the part of large whales on which killer whales prefer to feed (e.g., Silber et al., 1990; Jefferson et al., 1991; Whitehead & Reeves, 2005; Alava et al., 2013; Pitman et al., 2015; Totterdell et al., 2022).

The Role of Male Killer Whales in Attacks

The series of attacks described above also provides additional information about the behavior of adult male killer whales during attacks on large whales. In at least two of the attacks (#s 5 & 12), different observers reported that adult females and juveniles pressed the attack, while adult males mainly stayed on the periphery. This same behavior, with adult males standing by during an attack and later joining in to feed just before or after the kill, has been reported during attacks on other large whales, including bowhead whales (Finley, 1990), Bryde's whales (Silber et al., 1990), sperm whales (*Physeter macrocephalus*; Pitman et al., 2001), gray whales (Melnikov & Zagrebina, 2005), and blue whales (Totterdell et al., 2022). The reason for this behavioral asymmetry is not clear. Killer whales are strongly sexually dimorphic: adult males have a much larger body size and greatly enlarged dorsal fin and flippers relative to adult females. Although these sexually selected traits presumably contribute to reproductive success in male killer whales, they could also make them less effective and more vulnerable during attacks on large whales by reducing their speed, agility, and endurance (Reeves et al., 2006). During long chases, for example, adult male killer whales often lag far behind the females and juveniles (RLP, pers. obs., 2001). It has been suggested that at least some of the increased foraging costs for adult males is offset by maternal provisioning (e.g., Foster et al., 2012; Weiss et al., 2023) and perhaps also by a reduced level of male engagement during attacks.

Large Rorquals as Prey of Killer Whales

Debate remains about whether killer whales are capable of preying on healthy adults of the largest rorqual species (e.g., Springer et al., 2003; Mizroch & Rice, 2006; Reeves et al., 2006; Mehta et al., 2007). Totterdell et al. (2022) recently reported killer whales killing and eating an apparently healthy adult pygmy blue whale off Western Australia, and it appears that killer whales off BC can also take on healthy adult fin whales. Aguilar & García-Vernet (2015) reported that the average total body length for adult fin whales in the Northern Hemisphere is 22.5 and 21 m for females and males, respectively, and Pike & MacAskie (1969) found that fin whales taken by whalers in British Columbia, Canada, reached physical maturity at 20.8 and 19.8 m for females and males, respectively. We estimated that the unsexed individual in Attack #7 was 21 m long; and because it showed no signs of gross trauma or pathology and was not obviously emaciated (e.g., Figures 1 & 2a), it appeared to be a healthy adult. However, without a detailed necropsy, it is not possible to know if it might have had a pre-existing, debilitating condition. In the future, drone technology should allow for accurate measurements of large whales taken by killer whales to better determine the length and body condition of targeted individuals (Durban et al., 2016).

The GoC fin whale population is relatively small (estimated effective population size: 360 individuals; Rivera-León et al., 2019). It appears to be resident in the Gulf and genetically isolated, making it vulnerable to negative impacts from genetic drift, anthropogenic mortality, and habitat change (Bérubé et al., 2002; Jiménez López et al., 2019; Bernot-Simon et al., 2021). To this list of risk factors must now be added the regular (and possibly increasing) threat of killer whale predation.

Citizen Science

Starting around 2005, reports of attacks on fin whales off BC appear to have increased markedly (Table S1), but it is unknown whether this is due to an increase in the number of attacks or just the number being reported. Recently, there have also been increased reports of killer whales attacking blue and humpback whales off Western Australia, and it was suggested that as the populations of large whales continue to recover from large-scale commercial whaling during the 20th century, killer whale populations that formerly preyed upon them might also be recovering and once again starting to hunt them (Pitman et al., 2015; Totterdell et al., 2022). It is also possible, however, that other factors such as expanded research effort, the growth of whale-watching tourism, and the rise of social media have led to more of these attacks being observed and reported. For example, of the attacks

on ten fin whales reported globally since 2005 (Table S1), at least six were initially reported on social media, and none of them were recorded as part of a dedicated research program. Furthermore, these events were witnessed during a time when digital cameras, smartphones, and social media had all come into widespread usage, allowing recreational boaters, nature tourists, and fishermen to record their memorable whale encounters and post them on the Internet. As this article further demonstrates, the intersection of citizen science and social media is an increasingly important source of field observations for whale biologists (Pirota et al., 2020; Pirota & Harcourt, 2021; Natoli et al., 2022; Totterdell et al., 2022).

Note: A supplemental table for this article is available in the “Supplemental Material” section of the *Aquatic Mammals* website: https://www.aquatic-mammalsjournal.org/index.php?option=com_content&view=article&id=10&Itemid=147.

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