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Novel evidence of interaction between killer whales (*Orcinus orca*) and juvenile white sharks (*Carcharodon carcharias*) in the Gulf of California, Mexico

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White sharks (*Carcharodon carcharias*), have only one known natural predator in the ocean, the orca or killer whale (*Orcinus orca*). While interactions between these coexisting apex predators are known to occur, killer whales are adept at subduing adult white sharks and consuming their energy-rich livers. White sharks in turn are highly responsive to the appearance of killer whales and will vacate habitual feeding aggregations *en masse* to avoid predation. To date, interactions between killer whales and juvenile white sharks (~2.5 m TL) have been reported in South Africa, while the literature reports that these interactions occur primarily with larger white sharks, which naturally have a larger liver, and potentially compete with killer whales for pinniped prey. Here we document novel repeated predations by killer whales on juvenile white sharks in the Gulf of California. Aerial videos indicate consistency in killer whales' repeated assaults and strikes on the sharks, indicating efficient ability by the mammals in attempting to induce tonic immobility in the prey and allow uninterrupted access to the liver for consumption. Once extirpated from the prey body, the target organ is shared between the members of the pods including calves. Images analysis of the killer whales involved in the attacks confirms previous observations of an existent pod possibly specialized in hunting elasmobranchs in this region.

KEYWORDS

prey-predator interactions, dietary specialization, elasmobranch, hunting technique, eastern Pacific Ocean, orca, predation

1 Introduction

Despite an extensive overlap in distributional range and trophic niche, a few observations of interactions between killer whales (*Orcinus orca*) and white sharks (*Carcharodon carcharias*) are known to occur and have been recorded in South Africa, Australia, and California (Pyle et al., 1999; Best et al., 2010; Jorgensen et al., 2019; Towner et al., 2022; Towner et al., 2023; Bowlby et al., 2023). Documented predation on white sharks, have to date, occurred in sites where juveniles, subadults and adult white sharks aggregate (Kock and Johnson, 2006; White et al., 2019; Tanaka et al., 2021; Towner et al., 2022; Towner et al., 2023; Reeves et al., 2025). However, to date there is little evidence of killer whales targeting juvenile white sharks, with the notable exception of a white shark ~2.5 m total length (TL) (subadult white sharks range from 2.5 m to 3.5 m TL) captured by a killer whale in a white shark aggregation area in Mossel Bay, South Africa (Towner et al., 2024). Toward the warmer edge of their distribution in the eastern Pacific, the white shark has been recorded at Cedros, San Benito, Guadalupe, and the Revillagigedo Islands in the Mexican Pacific, and is occasionally observed along the western coast of the Baja California Peninsula (McCosker and Lea, 1996; Compagno et al., 1997; Santana-Morales et al., 2012; Hoyos-Padilla et al., 2016; Becerril-García et al., 2020; Madigan et al., 2021). White sharks also inhabit the Gulf of California (GC), Mexico where Galván-Magaña et al. (2010) compiled 38 records of white shark captures and reliable sightings from 1964 to 2010, including the presence of juveniles and adults. Most of the records have been obtained from incidental captures during artisanal and industrial fishing activities (Santana-Morales et al., 2012). However, in the last 10 years a potential redistribution of a white shark cohort has been observed in the Northeast Pacific (White et al., 2019; Tanaka et al., 2021), attributed to oceanographic anomalies such as El Niño and the Blob (warm water mass that formed in the Gulf of Alaska and traveled the California current). This redistribution includes an increase in the record of juvenile white sharks in Isla Guadalupe (Santana-Morales et al., 2021) and an increase in the sighting of juvenile and adult white sharks in the GC (pers. comm. Omar Santana-Morales). In the latter area, sightings of killer whales are reported to be frequent year-round (Guerrero-Ruiz et al., 1998, 2007; Niño-Torres et al., 2015) and although there are no historical records of white shark predation by killer whales in the GC, researchers have recently reported predation on different species of rays: Munk's pigmy devil ray (*Mobula munkiana*), cownose ray (*Rhinoptera steindachneri*) and pelagic stingray (*Pteroplatytrygon violacea*; Higuera-Rivas et al., 2023) and three species of sharks: bull shark (*Carcharhinus leucas*; Ayres et al., 2024), whale shark (*Rhincodon typus*; Pancaldi et al., 2024), prickly shark (*Echinorhinus cookii*; Lara-Lizardi et al., 2025), and unidentified shark (O'Sullivan and Mitchell, 2000; Guerrero-Ruiz et al., 2007). Here we document the first records of interactions between killer whales and juvenile white sharks in Mexican waters.

2 Material and results

For each record, we recorded date, time, location, group composition (calves, juveniles, sub adults and adults), traveling mode and any record of feeding behavior. The predation events were documented with a Canon EOS-1D X Mark II DSLR camera and a Canon 100–400 mm lens from a 9 m long fiberglass boat with a 200 Hp 4-stroke outboard motor. Underwater photos and videos were obtained with a second Canon EOS-1D X Mark II camera and a Canon 11–24 mm lens inside a Nauticam underwater housing, and aerial video was recorded using DJI drones, a Phantom 4 Pro and an Inspire 2 X7. High-quality video frame shots of dorsal fins were extracted for photoidentification of individual killer whales using distinctive features, including scars and nicks (Bigg, 1987).

2.1 First record

(See [Supplementary Video 8](#)) On 15th of August 2020, at about 15:00 hours, a group of five female killer whales was sighted in the southwestern area of the GC (24°19'07.1"N 110°28'33.2"W). Comparing the size of the individuals with the size of the 9 m long fiberglass boat, it was determined to consist of four subadult females (~4 m long) and one adult female (~6 m long). The size of the shark was estimated by comparing its TL (~2 m) with that of the killer whale and the identification of the species was confirmed by the moderately stout, torpedo-shaped body, grey to bluish-grey color on the upper surface and white below, large pectoral and first dorsal fins (Klimley and Ainley, 1998). At 00:07 seconds, one of the subadult females pushes the white shark to the surface and the elasmobranch turns and avoids being hit by the orca. At 00:25 seconds, one of the five killer whales pushes the white shark from its ventral side towards the surface, at this moment the juvenile shark is already bleeding from its ventral side. The killer whale releases it and while she is breathing, another killer whale takes hold of the shark. At 00:49 seconds, a subadult female attempts to grip the shark and then performs an evasion technique known as "Tail Slapping" (Klimley and Hoyos-Padilla, 2023). The crescent shaped tail and the distinctive caudal keel of the species are visible ([Figures 1a, b](#)). At 03:14 minutes two of the subadult killer whales (referred to as KWM1 and KWM2 for the purposes of this research; see [Supplementary Figures 1–6](#)) take turns to manipulate the shark by keeping it upside down. At 03:27 minutes both killer whales descend deeper with the shark and at 03:39 minutes the other three killer whales follow the rest of the pod underwater. By 05:25 minutes of the video, the adult female killer whale (referred to as KWM3; see [Supplementary Figure 7](#)) and three of the subadults appear at the surface; the KWM1 has the two-lobed liver of the shark in her mouth ([Figure 1c](#)). The organ is then released to let KWM2 grab it. The organ is once again released by KWM2 and passed to KWM3. After that and until 7:13 minutes, four of the five identified killer whales pass the liver between each other, holding it

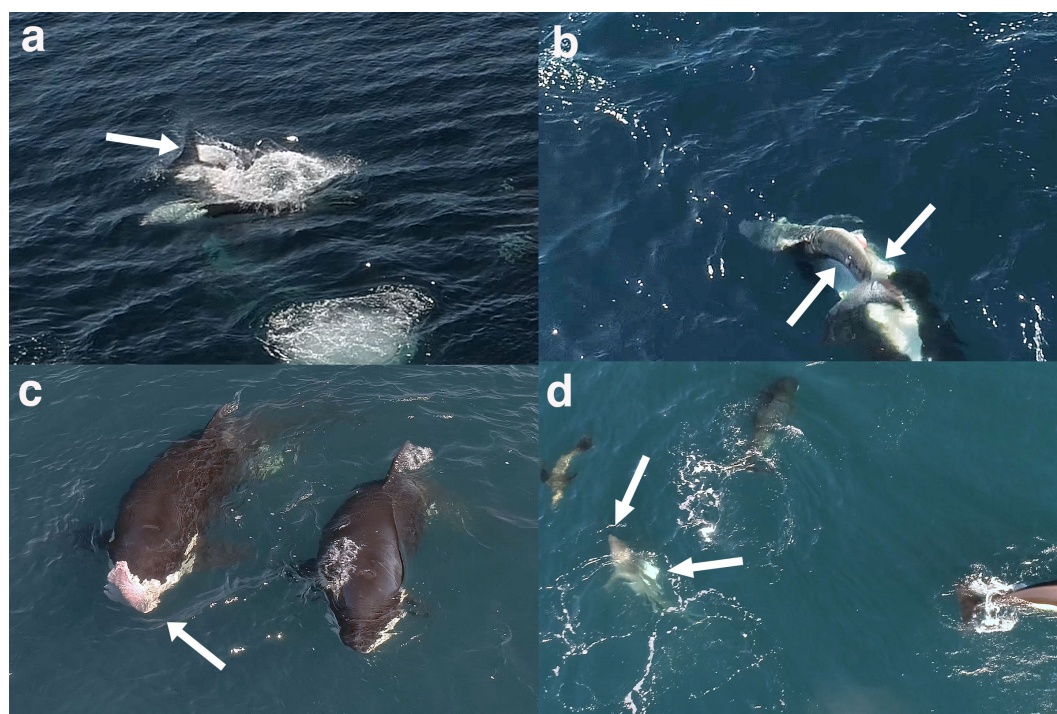


FIGURE 1

Sequence of the killer whales attacking the first juvenile white sharks (*Carcharodon carcharias*) on 15th of August 2020. Identifying features of the species are visible (denoted by white arrows): (a) The crescent-shaped tail. (b) The distinctive caudal peduncle and keels, large triangular first and small second dorsal fins are visible. (c) The two-lobed liver is being hold by the orca. (d) The moderately stout, torpedo-shaped body is visible, and the partially exposed liver is seen on the right side of the second shark attacked. Photos credit: Jesús Erick Higuera Rivas.

with their snouts, and then submerge into the water. Since the beginning of the video timeline, a California sea lion (*Zalophus californianus*) seems interested in getting part of the liver, but the orcas discourage its attempts by repeatedly exhaling bubbles. At 07:14 minutes, the killer whales appear again at the surface attacking another juvenile white shark of ~2 m TL. The alive shark is attacked several times by the killer whales until 10:51 minutes when the shark's liver is observed partially exposed from the elasmobranch's body (Figure 1d) hanging on the right side. At 11:04 minutes the motionless shark begins to sink, allowing the researchers to distinguish the distinctive characteristics of the species such as the keel, and the crescent-shaped tail. Later, pieces of pink color tissue are observed floating at the surface.

2.2 Second record

(See [Supplementary Video 9](#)) On 3rd of August 2022, at 14:56 hours approximately five killer whales, (one adult male, one adult female, two subadults and one calf) are sighted assaulting a juvenile white shark (~2 m TL) in the location where the previous predation event was recorded. The video starts with an adult female reaching the surface, then diving down followed by the other four killer whales. After the 00:30 seconds of the video, the ventral part of the white shark's body is observed. At 1:22 minutes the adult female surfaces to breathe with the shark visible in her mouth while it is held below the surface with its mouth open and its pectoral fins

visible (Figures 2a–c). Between 1:35 and 2:46 minutes, the adult female, a subadult killer whale, and the calf surface to breathe and then dive down and approach the rest of the group holding the shark. At 02:48 minutes, one of the subadult killer whales holds the shark near the left pectoral fin. From Figure 2b it is possible to observe the characteristic black tips on the underside of the white shark's pectorals, another key identifying feature of *C. carcharias*. The shark is visibly bleeding from the gills, and its liver is exposed (Figure 2d). At 03:43 minutes the females and calf surface to breathe, pieces of the shark's liver tissues are visible in the mouths of the females. The male orca and calf are then seen feeding on liver tissue at the surface between 04:31 and 4:50 minutes. At 5:08 several birds, such as boobies (*Sula nebouxii*), gulls (*Larus heermanni*), pelicans (*Pelecanus occidentalis*) and frigates (*Fregata magnificens*) are also observed feeding on pieces of the shark's tissues. The group of mammals then heads north leading to the end of the predation event.

3 Discussion

The ecotype of killer whales observed in the GC is not clear; some killer whales have been observed hunting both cetaceans (Guerrero-Ruiz et al., 2007) and chelonians (Esquivel et al., 1993; Sarti et al., 1994), which is consistent with the transient ecotype found off the northwest coast of North America. Other killer whales have been observed hunting elasmobranchs (Guerrero-Ruiz et al.,

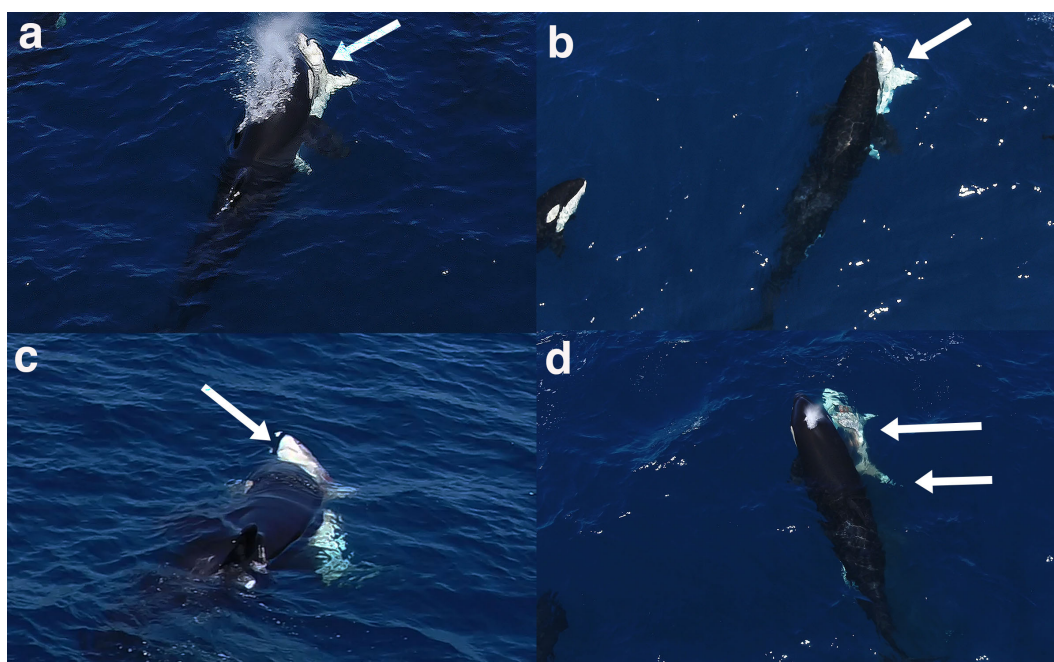


FIGURE 2

Sequence of the killer whales attacking a juvenile white shark (*Carcharodon carcharias*) on 3rd of August 2022. Identifying features of the species are visible (denoted by white arrows): (a) Large gill slits. (b) Large pectoral fins, black tip on the underside of the white shark's pectoral, moderately stout, dark grey to bluish-grey color on the upper surface and white below. (c) Shape of curvature of the upper and lower jaws. (d) A partially exposed liver is seen on the left ventral side of the shark, as well as the upper lobe of the caudal fin. Photos credit: Marco Villegas Martínez.

2007; Higuera-Rivas et al., 2023; Ayres et al., 2024; Pancaldi et al., 2024; Lara-Lizardi et al., 2025), coinciding with a range of known ecotypes such as the offshore ecotype (Heimlich-Boran, 1988; Baird and Dill, 1995; Ford et al., 1998; Dahlheim et al., 2008) and the New Zealand coastal ecotype (Visser, 1999, 2000; Visser and Cooper, 2020), as well as a number of undescribed ecotypes, including those from the Galápagos Islands (Sonnino Sorisio et al., 2006) and from Papua New Guinea (Visser and Bonaccorso, 2003). Although as a species *O. orca* displays a generalist foraging behavior, local groups or ecotypes of killer whales typically specialize on a small range of available prey (Ford et al., 1998). In the Northeastern Pacific three sympatric ecotypes of *O. orca* have been described (Residents, Transients and Offshore) which have morphological, social, ecological, feeding, acoustic, geographic distribution and genetic differences (Bigg, 1982; Ford et al., 2000; Morin et al., 2023). An additional overlapping ecotype has also been recognized in the Eastern Tropical Pacific. This ecotype refers to generalist feeders also known to prey on elasmobranchs (Vargas-Bravo et al., 2020).

Predatory behavior of killer whales on sharks has been recorded in detail in the GC, both in bull sharks (Ayres et al., 2024) and whale sharks (Pancaldi et al., 2024). In South Africa, killer whales have been observed using a special hunting technique that involves causing a large tear in the pectoral girdle of sevengill sharks (*Notorynchus cepedianus*) to access the liver and feed exclusively on this organ (Engelbrecht et al., 2019). They have also been observed hunting and targeting the liver of juvenile great white

sharks (Towner et al., 2023, 2024). Our evidence undoubtedly shows consistency in the repeated assaults and strikes, indicating efficient maneuvering ability by the killer whales in attempting to turn the shark upside down (Figures 1a, b), likely to induce tonic immobility and allow uninterrupted access to the organs for consumption (Pancaldi et al., 2024). According to Engelbrecht et al. (2019), the lack of bite marks or injuries anywhere other than the pectoral fins shows a novel and specialized technique of accessing the liver of the shark with minimal handling of each individual. To efficiently hunt potential prey in multiple regions around the world, killer whales use specialized techniques adapted to the target. In the GC, Higuera-Rivas et al. (2023) found that killer whales hunt Munk's pigmy devil rays by targeting those closest to the edge of the school and grasping them by the wingtip and then repositioning the rays to hold them by the head. When preying on pelagic stingrays, killer whales tail-slap them forcefully several times to stun them and thus avoid being stung by the defensive spine. In two of the three predation events recorded during the present study, killer whales inverted the white sharks, possibly inducing tonic immobility, potentially to avoid bites. The posterior bite force from a 2.5 m white shark can be 3131 N (Wroe et al., 2008) and can severely injure the predator, thwarting the attack. Animal hypnosis or tonic immobility is an induced method to achieve a temporary cataleptic-like condition that can occur from less than one minute to several hours (Gallup, 1974; Páez et al., 2023). During tonic immobility the elasmobranch is in an 'unnatural' orientation, which

has the effect of altering the usual course of its sensorimotor and emotional interchanges with its environment (Chertok, 1968), making it easier to be manipulated. Prey handling and inducing tonic immobility may be more easily achieved in smaller white sharks compared with larger individuals, thereby also reducing risk of bite injury (Towner et al., 2022). In this case, we observed direct consumption of the liver, as it was observed to be shared among three of the killer whales (Figures 1c, d). Our reports display an indicative of highly selective feeding by these killer whales, as they held the white sharks upside down for several minutes until they grabbed their pectoral fins and then removed and consumed the sharks' livers, discarding the rest of the carcasses. Furthermore, we demonstrate that the female killer whales photo-identified and referred to as KWM1, KWM2 (see Supplementary Figure 6) were observed in 2018 hunting Munk's pygmy devil rays and pelagic rays (Higuera-Rivas et al., 2023), while KWM3 (see Supplementary Figure 7) was observed hunting bull sharks between 2022 and 2023 (Ayres et al., 2024). This clearly indicates that these killer whales are related to each other or belong to the same group, renamed by these authors as the "Moctezuma pod" (after the adult male), and is consistent with the analysis by Pancaldi et al., 2024, which demonstrates that this group of killer whales of the GC exhibits adapted hunting techniques depending on the type of elasmobranch they intend to consume. Distinctive nurseries for juvenile white sharks in the eastern Pacific have been identified, which are generally segregated from adult aggregating sites (Klimley, 1985; Oñate-González et al., 2017; Tamburin et al., 2019). However, recent ocean warming has been attributed to range shifts and novel occurrences of juvenile white sharks (Santana-Morales et al., 2021; Tanaka et al., 2021). For instance, a poleward shift in juvenile white shark distribution from southern to central California has been documented in relation to the increased frequency of El Niño events and marine heat waves (Tanaka et al., 2021). The central California region is a key area where white sharks and killer whales interact (Jorgensen et al., 2019). Similarly, the redistribution of the white shark population attributed to such oceanographic anomalies could potentially also lead to increase juvenile white shark occurrences in the GC potentially making them available as a prey source for the killer whales that occur there year-round.

This is the second record of killer whales targeting juvenile white sharks in the world (Towner et al., 2024) and the first in Mexican waters that we are aware of. Adult white sharks exhibit a memory and previous knowledge about killer whales, which enables them to activate an avoidance mechanism through behavioral risk effects; a 'fear'-induced mass exodus from aggregations sites (Jorgensen et al., 2019; Towner et al., 2022). This response may preclude repeated successful predation on adult white sharks by killer whales. Considering the naturally small regional population sizes of white sharks (Kanive et al., 2021), this predator evasion mechanism likely prevents significant population depletion through predation. Furthermore, given their natal philopatry (Jorgensen

et al., 2010), and a reproductive cycle greater than 12 months (Mollet et al., 2000), female white sharks would likely continue to pup in the same locations, unaware of any recent killer whale predation activity. As a result, juvenile white sharks could be more susceptible to consistent exploitation in juvenile aggregation sites.

In this study we observed repeated predation on juvenile white sharks at the same location and nearly the same calendar date, two years apart. Taken together, this suggests that juvenile white sharks may be becoming, or already are, a regular seasonal prey target for these mammals. Since no photographic identification images were taken of the killer whales in the second report, it is unknown whether they are related or associated with the pod from the first report. While *C. carcharias* already faces several threats, such as bycatch and climate change, its natural predation by killer whales might represent a significant additional pressure on the white shark populations, as seen in South Africa, where entire coastal displacements and subsequent ecological changes have heated scientific debates (Bowlby et al., 2023; Gennari et al., 2024; Bowlby et al., 2024). Future studies should 1) continue to monitor the shifting ranges and aggregation sites of juvenile white sharks driven by ocean warming, 2) test whether behavioral risk effects occur in juvenile white sharks, and 3) determine whether attacks on white sharks by killer whales represent an emerging pattern and, if not, establish the frequency of these events, as additional observations could make population-level inferences.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Author contributions

JH-R: Writing – review & editing, Investigation, Writing – original draft, Visualization, Conceptualization, Methodology. FP: Writing – review & editing, Writing – original draft, Methodology. SJ: Writing – review & editing, Writing – original draft. EH-P: Writing – review & editing, Writing – original draft.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fmars.2025.1667683/full#supplementary-material>

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