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EDITED BY
Jodie L. Rummer,
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Universiti Malaya, Malaysia
Ram Kumar,
Central University of Bihar, India

*CORRESPONDENCE
Frida Lara-Lizardi
✉ frida@orgcas.org

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First record of orcas (*Orcinus orca*) preying on a prickly shark (*Echinorhinus cookei*) in the Gulf of California: insights into shark ecology

Frida Lara-Lizardi[1,2]*, María Fernanda Gómez[1] and Andrea Quintero-Perez[3]

[1]ORGCAS, La Paz, Mexico, [2]MigraMar, Bodega Bay, CA, United States, [3]Universidad Autónoma de Baja California Sur, La Paz, Mexico

The first documented instance of predation on a prickly shark (*Echinorhinus cookei*) by orcas (*Orcinus orca*) in the shallow waters of the southwestern Gulf of California, particularly around Cerralvo Island, is presented. The observation was made possible through a combination of local ecological knowledge and citizen science efforts, demonstrating the value of community involvement in marine research. Both the vulnerability of prickly sharks to industrial fishing and the deep- water sharks limited ecological knowledge in the Gulf of California emphasize the significance of this sighting. The findings underscore the necessity for ongoing research and conservation efforts, highlighting the importance of the integration of the local ecological knowledge and citizen science to protect this species' habitat in the Gulf of California and beyond.

KEYWORDS

***Echinorhinus cookei*, *Orcinus orca* predation, ecology, Eastern Tropical Pacific, local ecological knowledge, citizen science**

Introduction

The prickly shark, *Echinorhinus cookei*, is locally known by artisanal fishermen as "*malaya*" in Cerralvo Island in the Southwestern Gulf of California. It is a deep-sea benthopelagic elasmobranch species found in depths between 11 and 1,100 meters (1). They participate in evening upward migrations facilitated by its positive buoyancy, possibly as an adaptive strategy for easier vertical migration or as a hunting tactic to attack prey from below (2). Males typically reach sexual maturity around 12 years, while females reach maturity at approximately 18 years (3). Females are aplacental viviparous and exhibit high fecundity, with some records indicating a single specimen carrying up to 114 pups (4).

The orca, *Orcinus orca*, is the largest member of the dolphin family (Delphinidae). These highly intelligent and social marine mammals are characterized by their distinctive black and white coloration, robust bodies, and large dorsal fins (5). They are apex predators, feeding on a diverse diet that includes fish, squid, and marine mammals (6). They are found in all the world's oceans, inhabiting both polar and tropical areas, and exhibiting complex social structures and behaviors (7). Orcas are known for their sophisticated hunting techniques and coordinated behavior patterns, and as a result have become one of the most widely studied and recognizable marine species (8).

The Gulf of California is renowned for its high biodiversity and unique oceanographic conditions which supports a wide array of marine species, like prickly sharks and killer whales. Cerralvo Island is a prominent landmass characterized by rugged terrain surrounded by diverse marine habitats. Upwelling and oceanic currents in the vicinity of Cerralvo Island contribute to the high productivity of the region, and in turn supports thriving marine ecosystems (9). However, this region is subject to intensive industrial fishing activities, particularly shrimp trawling, which poses significant threats to the integrity of deep-sea habitats. The late maturity of prickly sharks compared to bony fishes, makes this group less resilient to anthropogenic activities (10). The presence of prickly sharks in demersal areas targeted by fishing activities raises concerns about the species' vulnerability to incidental capture in fishing gear (10).

The IUCN Red List designates the prickly shark as "Data Deficient," showing critical gaps in understanding its population dynamics, distribution, and ecological status (11). The limited encounters with prickly sharks in the Mexican Pacific, including a few within the Gulf of California, prompt further inquiry into the species' ecological dynamics and geographic range (12). Thorough surveys, research, and monitoring initiatives must be carried out to guarantee effective conservation strategies for deep sea shark species, such as prickly sharks. Additionally, collaboration among scientists, policy makers, and local communities is essential to gather necessary data and implement protective measures (13).

In Mexico and around the world, Local Ecological Knowledge (LEK) and citizen science have played important roles in filling the information gaps in shark ecology. Shaff et al. (13) employed LEK from shark fishermen in Islas Marias, a group of islands in the Mexican Pacific, to identify declines in shark abundance over the past decade and reported observations of 15 species of sharks. A study by Calatayud-Pavía et al. (14) used citizen science from a shark tourism operator and determined that the main environmental drivers influencing pelagic shark presence was sea surface temperature, wind speed and the La Niña and El Niño-Southern Oscilation (ENSO) events. Another study in the Mexican Caribbean by Blanco-Parra et al. (36) utilized citizen science from dive centers and interviews with experienced scuba divers and found trends of elasmobranchs to be decreasing and identified 24 elasmobranch species. The inclusion of LEK and citizen science initiatives has proven invaluable in supplementing traditional scientific approaches and expanding our understanding of marine ecosystems.

Here, we provide new insights into the interactions between prickly sharks and orcas. This observation represents the first documented predation event of Orcas on Prickly Sharks, contributing to the limited understanding of both Orca predatory ecology and the natural history of the Prickly Shark. Notably, we present a groundbreaking observation of an entire prickly shark being preyed by a pod of orcas in the shallow waters near Cerralvo Island, in the southwestern Gulf of California. This unprecedented sighting challenges prevailing assumptions regarding the habitat preferences of prickly sharks and calls attention to the importance of interdisciplinary collaboration in marine research. By combining scientific expertise with insights from local communities and citizen scientists, we highlight the ecological significance of this observation.

Methods

Cerralvo Island, also known as Jacques Cousteau Island (24"12′N, 109"48′W), is a volcanic island located in the southwestern region of the Gulf of California. It is separated from the peninsula by a 13 km canal with a depth of up to 500 m on the western side of the island and depths of up to 1,600 m on the eastern side (9). It lies close to the mouth of the Gulf of California making it an area characterized by complex oceanographic attributes. The bathymetry and oceanographic factors of this marine region make it an ideal habitat for deep water species of sharks, where up to 26 species of chondrichthyans have been reported [Figure 1; (9)].

To determine the presence of prickly sharks, a multifaceted approach was used, integrating literature review, citizen science, and local ecological knowledge. The citizen science program involved engaging nature-based tourism operators and divers to report sightings of megafauna around Cerralvo Island. Outreach campaigns were conducted to recruit participants, utilizing emails, phone calls, and social media platforms to connect with companies and organizations. Participants were provided with clear instructions on how to record and report their observations, which included the date, time, and GPS location of sightings. They were also encouraged to submit digital materials, such as photos and videos, via email. Additionally, the photographs capturing a predation event of a prickly shark by orcas were used to study the hunting strategies, coordination, and communication methods of the orcas. Divers were requested to grant permission for their digital materials to be analyzed and published.

Interviews and informal conversations were conducted with artisanal shark fishermen from the Agua Amarga community that operate on Cerralvo Island, 100% fishermen had elementary school level, with over 10 years of fishing experience. These interactions provided insights into sightings, locations, habitat preferences, sizes, and historical trends of prickly sharks over a four-year period from 2020 to 2024. Local fishermen helped verify the species based on photographic evidence and diagnostic characteristics, with confirmation from shark experts. Additionally, existing fish collections preserved by local institution were reviewed to gather historical data on the presence of prickly sharks in the region. Maturity information was based on observations published by Last and Stevens (15), noting that prickly sharks reach sexual maturity at 290 cm total length (TL) for females and 240 cm TL for males (4).

The study area described is not protected by the Mexican authorities and is potentially exposed to industrial fishing activities registered in the region. To assess the extent of these activities, data on industrial fishing efforts from 2020 to 2024 were analyzed. This analysis utilized Automatic Identification System (AIS) and Vessel Monitoring System (VMS) data, which track the movements and activities of fishing vessels. These datasets were obtained from Global Fishing Watch (GFW; http://www.globalfishingwatch.org). GFW employs advanced algorithms to interpret the AIS and VMS data, identifying when and where industrial fishing activities occurred.

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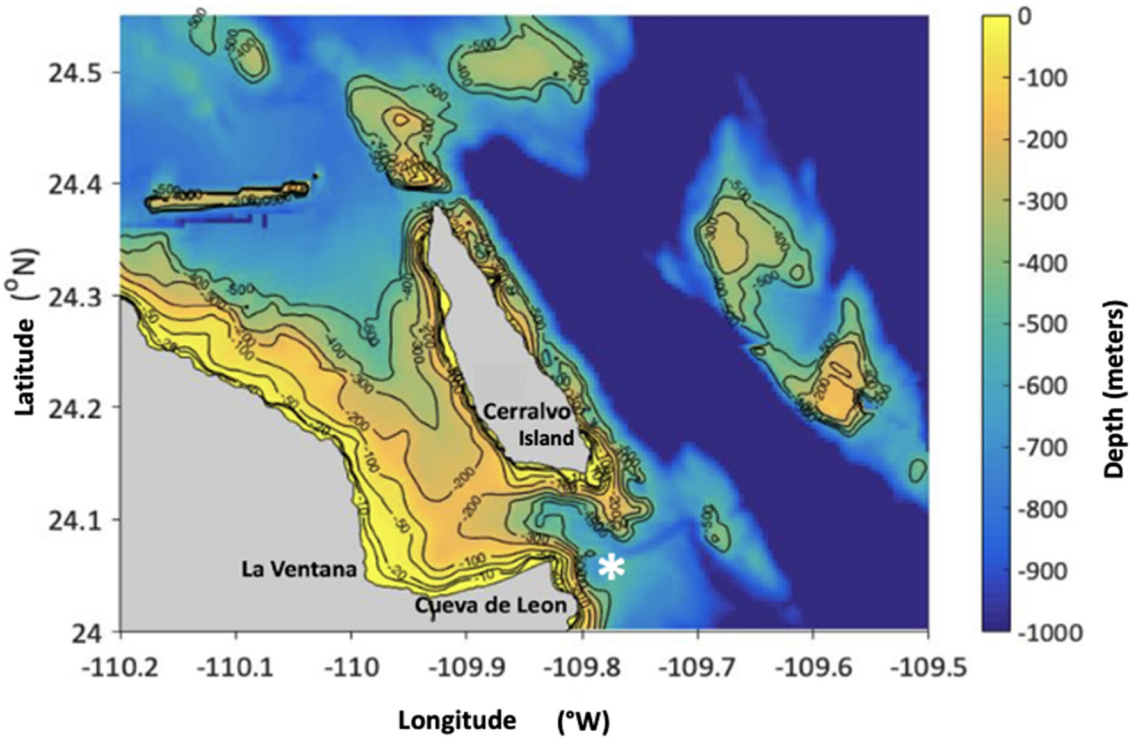

FIGURE 1
Location of the record of predation on a prickly shark (*Echinorhinus cookei*) by orcas (*Orcinus orca*) in the southwestern Gulf of California. The white asterisk marks the location of the predation record.

TABLE 1 Historical records of prickly sharks in the Mexican Pacific and Gulf of California.

Reference	Location	TL (cm)	Depth (m)	Fishing gear
Mariano-Meléndez and Villavicencio-Garayzar (16)	Socorro Island, Revillagigedo	295, 306	120–130	Gill net
	San José Island, Gulf of California	131, 170, 168, 211	144–160	Gill net
	La Paz Bay, Gulf of California	145.4		Unkown
	Cerralvo Island, Gulf of California	280	270	Unkown
Aguirre and Virgen (17)	Michoacan, Mexican Pacific	Unknown	Unkown	Unkown
Alvarez-León and Castro-Aguirre (18)	Mazatlan, Mexican Pacific	Unknown	25	Hook and line
Ruiz et al. (19)	Punta Lobos, Mexican Pacific	294	Near surface	Longline
	Off Magdalena Bay, Mexican Pacific	81	127–181	Crab trap
Rosales-Vasquez et al. (12)	Bahía de los Ángeles, Gulf of California	262.7	Unkown	Naturally stranded
This study	Cerralvo Island, Gulf of California	180	Near surface	Predation event

Results

From June to August (2020–2024), local shark fishermen in Agua Amarga reported consistently catching prickly sharks in the waters around Cerralvo Island, with an average of 10–12 sharks captured each year. They captured individuals using benthic gill nets deployed to target angel sharks (*Squatina californica*) in demersal areas. The individuals were typically encountered at depths ranging from 100 to 150 m, ~200 meters offshore. Captured sharks exhibited total lengths ranging from 1.5 m to 3 m, indicating that a mix of juvenile and sub-adult individuals inhabit the region. According to literature, there are 12 records of prickly sharks in the Mexican Pacific and Gulf of California (Table 1).

The recorded predation event was provided by citizen scientists. The photographs were taken with a SONY Alpha 1, from a distance of 15 m. Species identification was determined based on taxonomic features observed in the photographs (Pers. comms. Hoyos and Ebert). This event revealed a coordinated hunting strategy employed by a pod of orcas targeting a solitary prickly shark. The encounter lasted approximately 40 min, during which the pod of orcas employed tail slaps and strategic positioning,

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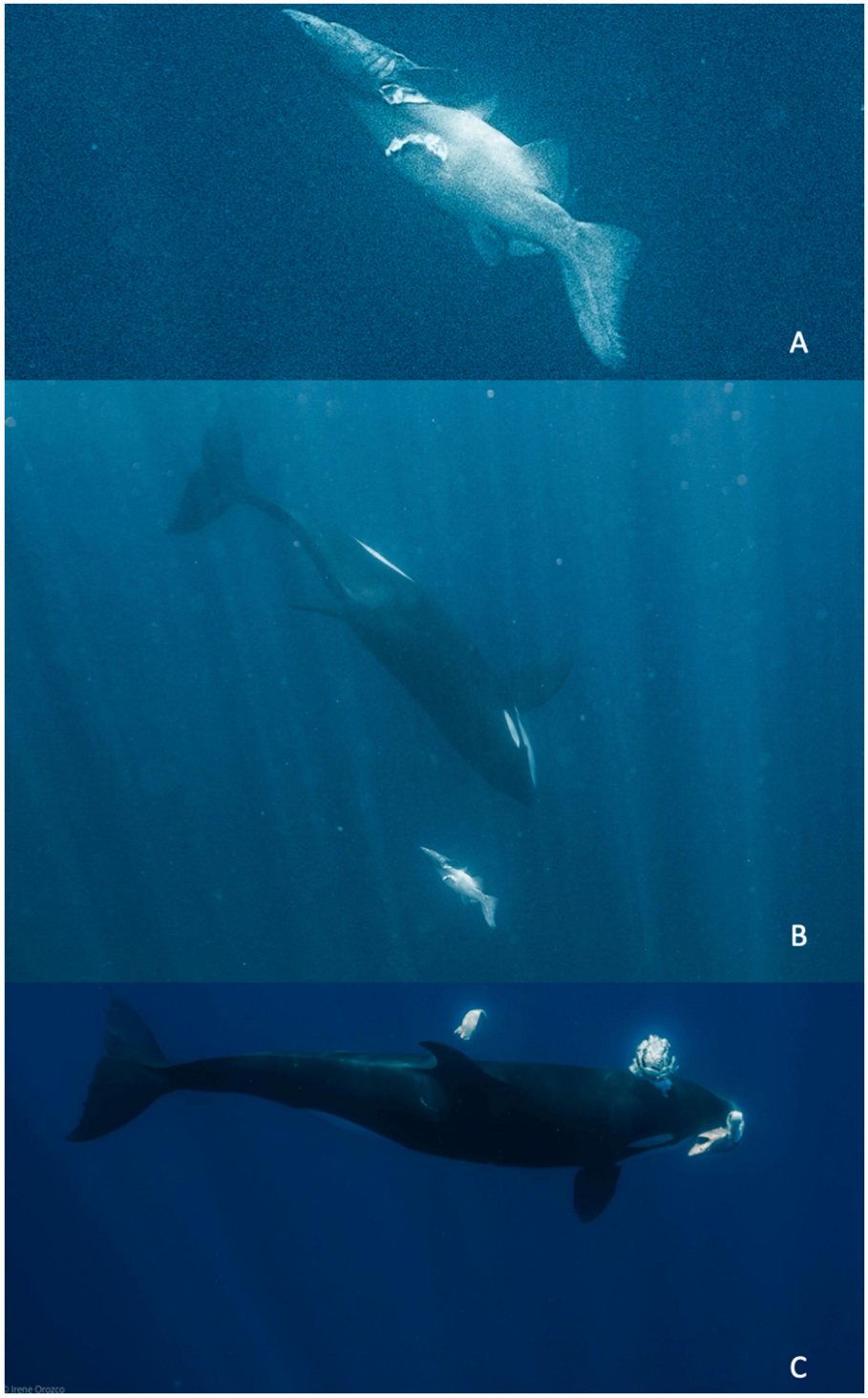

FIGURE 2
Record of predation on a prickly shark by orcas in the southwestern Gulf of California (Photography taken by Irene Orozco): **(A)** A prickly shark with a large bite by orcas; **(B)** orcas approaching a prickly shark; **(C)** Orca splitting a prickly shark in two parts.

along with observed teamwork, to immobilize the shark. Despite its defensive adaptations, including spiny dermal denticles, the shark was ultimately subdued by the coordinated assault of the pod. The predation event provided a rare opportunity to observe the feeding behavior of orcas in a deep-sea environment and highlighted their adaptability and versatility as apex predators (Figure 2).

The results of industrial fishing effort, determined by AIS and VMS data from 2020 to 2024, highlight the significant industrial fishing activities within the area where prickly sharks have been reported. In certain areas within the region, the data indicated that fishing efforts exceeded 100 h per 8 square kilometers (Figure 3). This high level of activity poses a potential threat to the local marine ecosystem and species like the prickly shark.

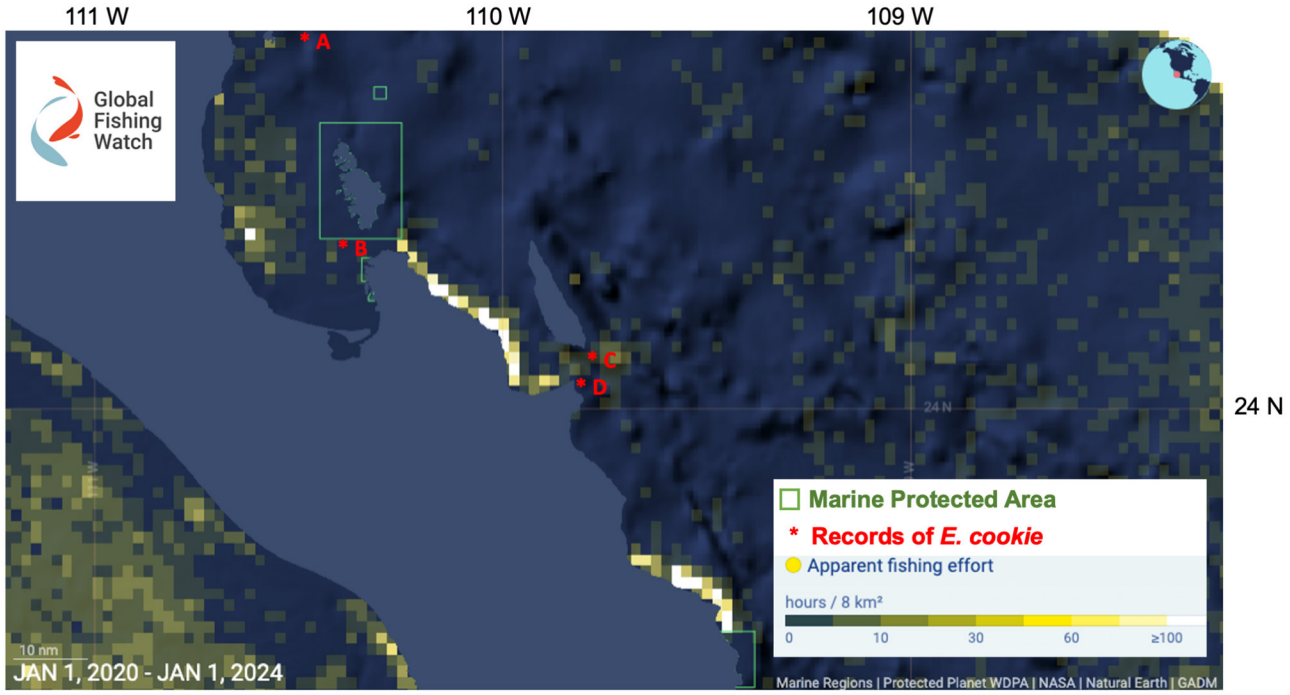

FIGURE 3
Comparison of the fishing industry activity and the records of prickly sharks. Yellow dots show the apparent fishing effort in hours per 8 square km obtained from GFW (http://www.globalfishingwatch.org); the red dot shows the locations of past records of prickly sharks: **(A)** San Jose Island, Gulf of California described by Mariano-Meléndez and Villavicencio-Garayzar (16); **(B)** La Paz Bay, Gulf of California described by Mariano-Meléndez and Villavicencio-Garayzar (16); **(C)** Cerralvo Island, Gulf of California described by Mariano-Meléndez and Villavicencio-Garayzar (16) and **(D)** this present study.

Discussion

Interaction between orcas and prickly shark: a game between predator and prey

Based on the results of this study, it is apparent that both orcas and prickly sharks coexist in the waters surrounding Cerralvo Island. According to previous studies, orcas have developed specialized hunting techniques or preferences for specific prey items (Table 1). Higuera-Rivas et al. (20) observed the same pod of orcas on five different occasions hunting groups of rays (*Mobula munkiana, Rhinoptera steindachneri and Pteroplatytrygon violacea*) close to the study area. Orcas in the Gulf of California have also been reported to prey on marine mammals like *Delphinus delphis* (21). Furthermore, their teeth have been found to be completely worn down during examination of stranded individuals (22). This finding coincides with offshore ecotype orcas in Canada that prey on sharks and likewise exhibit tooth abrasions caused by contact with dermal denticles that compose shark skin (23). This suggests that some pods in the Gulf of California may also favor sharks as prey (22).

In Cabo Pulmo National Park, a group of orcas was reported repeatedly hunting sharks, with one hunt of a bull shark (*Carcharhinus leucas*) reported as successful. This pod includes three identified orcas known as "Quetzali," "Niich" and "Waay", belonging to the elasmobranch-eating pod of the region (37). Prickly sharks, with their relatively large size and slow-moving nature, are likely a suitable target for this group of orcas, particularly when other preferred prey species are scarce. In the Gulf of California, records of Prickly Sharks are scarce and primarily incidental, often associated with deep, cold-water habitats. Our observation near Cerralvo Island represents one of the few documented sightings in shallow waters, suggesting a potential underestimation of their habitat range in this region. This unprecedented sighting challenges prevailing assumptions regarding the habitat preferences of prickly sharks, given the absence of prior records in shallow waters and the limited knowledge of their range in the Gulf of California. Additionally, it calls attention to the importance of interdisciplinary collaboration in marine research. By combining scientific expertise with insights from local communities and citizen scientists, we emphasize the ecological significance of this observation. Further studies using eDNA, tagging, and local ecological knowledge are essential to provide a more comprehensive understanding of the distribution and ecological role of Prickly Sharks in the Gulf of California. Orcas also portray opportunistic feeding behavior, adapting their diet based on the availability of prey, with a few registries reporting predation on whale sharks and sea turtles (24, 25).

Ecological insights; habitat and anthropogenic interactions for prickly sharks

Local ecological knowledge suggests that Cerralvo Island and its surrounding waters provide suitable conditions for prickly sharks,

as evidenced by sightings and the expertise of artisanal fishermen in the area. Observations of prickly sharks aggregating around seamounts in the Eastern Pacific near Panama (26) align with the presence of small hammerhead sharks, which are preyed by prickly sharks (26, 27). Similarly, several seamounts in the southwestern Gulf of California, are also frequented by hammerhead sharks and could be suitable habitat for prickly sharks (26, 28, 29).

Studies of prickly sharks have demonstrated instances of site fidelity for the Monterey Canyon, with 15 individuals exhibiting navigation patterns along the canyon axis over a year of monitoring (30). The southwestern region of the Gulf of California, characterized by its seamounts and submarine canyons—particularly the submarine canyons southeast of Cerralvo Island bordering the Pescadero Basin Complex—may serve as crucial hotspots for prickly sharks and other deep-sea species (31, 32). During the spring season, prickly sharks may migrate to southern coastal zones for reproduction, potentially following cold water currents (38), similar to the migratory patterns observed in dusky sharks, *Carcharhinus obscurus* (4, 39). Additionally, it is possible that prickly sharks migrate to deeper waters, tracking the isotherm of 9–11°C (40). Further research is needed to enhance our understanding of how prickly sharks interact with their environment.

By comparing the overlaps in fishing activity data with sightings of prickly sharks, we achieved a better understanding of the potential impacts of industrial fishing on the distribution and behavior of this species. Overexploitation has already resulted in the decline of top predators in the Gulf of California (33). Consequently, orcas might target deep-sea species, potentially increasing predation pressure on prickly sharks and other deep-sea organisms. This may in turn result in cascading trophic impacts on deep sea food webs, as shown by other studies (34, 35). For instance, the Southern Resident killer whale population, the primary threat to its viability is the scarcity of its preferred prey (41). Meanwhile, for orcas inhabiting the Gulf of California, fishing activity may be influencing their predation habits.

Conclusion

Our research constitutes a notable advancement in expanding our comprehension of the distribution patterns of prickly sharks within the Gulf of California and its relationship with their predators, notably orcas. Prior to our investigation, this region has suffered from a notable gap in comprehensive data concerning the presence and spatial dynamics of this species. This enhanced understanding is instrumental not only for academic pursuits but also for improving conservation efforts and management strategies aimed at safeguarding the biodiversity and ecological integrity of this marine ecosystem. Future research should focus on long-term monitoring and tagging studies to further elucidate movement patterns, habitat preferences, and ecological roles of prickly sharks in this dynamic environment.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The manuscript presents research on animals that do not require ethical approval for their study.

Author contributions

FL-L: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. MG: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft. AQ-P: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frish.2025.1437507/full#supplementary-material

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