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Fishery-independent camera surveys provide novel observations of white sharks (*Carcharodon carcharias*) off coastal Alabama

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Determining the distributions of marine animals is a challenge, particularly for highly migratory species like sharks. In the United States, several shark populations are beginning to recover following exploitation, including the white shark (*Carcharodon carcharias*). Recently, reports of white sharks have increased in the northern Gulf of Mexico (hereafter Gulf), but determining whether these reports represent actual changes in distribution is difficult. Therefore, we examined two long-term fishery-independent camera datasets to assess whether the recent increase in reports of white sharks reflects changes in distribution or typical (albeit rare) events. Long-term fishery-independent stereo-baited remote underwater video (sBRUV) and remotely operated vehicle (ROV) datasets were examined. From 2010 – 2024, 8368 sBRUV and 2199 ROV surveys were conducted. From 2010 – 2023, no white sharks were seen on either camera gear, but two white sharks were observed on ROV videos in 2024. The first was a female estimated at 239 cm total length and the second was a male estimated at 191 cm total length. These observations lend support to the notion that recent reports of white sharks in the northern Gulf may indicate early evidence of range-edge expansion rather than increases in telemetry efforts or citizen observations. Studies like this one highlight the value of long-term, randomized, fishery-independent camera surveys for documenting changes in distribution for rare species.

KEYWORDS

shark, HMS, range-edge expansion, population recovery, Western North Atlantic Ocean

Introduction

Assessing species' distributions is a fundamental precursor to determining their population dynamics, understanding their ecological contributions, and implementing appropriate management or conservation strategies. An increasing body of research has demonstrated that species distributions are rarely static and can be impacted by myriad factors (Robinson et al., 2011). For wide-ranging species, population shifts can be subtle and difficult to distinguish. This is particularly true in the marine environment, where quantifying distributional changes remains a challenge.

Sharks epitomize the challenges associated with quantifying distributional changes in the marine environment given their vagility, wide-ranging distributions, and often solitary nature. Shark fishing in the Western North Atlantic Ocean expanded in the 1970s and 1980s, yet the first fishery management plan for U.S. sharks was not enacted until 1993 (NMFS, 1993). Consequently, some shark populations are beginning to recover following exploitation (Peterson et al., 2017; Pacoureau et al., 2023). As these populations rebuild after 30 years of management measures, they may expand into areas where they were historically rare or extirpated. Identifying these range expansions is complicated, particularly considering increasingly recognized climate-related shifts in distribution (e.g., Hammerschlag et al., 2022) and relative abundance (e.g., Mullins et al., 2024).

The white shark (*Carcharodon carcharias*) is a wide-ranging, solitary species that has shown clear signs of population recovery (Curtis et al., 2014; Pacoureau et al., 2023). Many regions are reporting white sharks for the first time, and several of these initial reports are based on telemetry tags (e.g., Guttridge et al., 2024 in the Bahamas) or photographs from eye-witness accounts (e.g., Salinas-de-León et al., 2024 in Ecuador). While valuable, it is difficult to determine whether reports of white sharks in new areas represent actual changes in distribution rather than escalating telemetry studies (Hussey et al., 2015; Nathan et al., 2022), increases in anglers' use of technology (e.g., underwater cameras; Cooke et al., 2021), or greater observation effort (e.g., McPherson and Myers, 2009).

Advances in satellite and acoustic telemetry have enhanced our understanding of the movements and migrations of white sharks in the Western North Atlantic Ocean (Skomal et al., 2017; Franks et al., 2021). Typically, white sharks occupy areas off Massachusetts north to Canada during the summer, moving south of Cape Hatteras to overwinter (Curtis et al., 2014; Franks et al., 2021). During this overwintering period (December – May), white sharks are found from Cape Hatteras south to Florida and into the eastern Gulf of Mexico (hereafter Gulf) (Adams et al., 1994; Curtis et al., 2014; Franks et al., 2021). Recently, reports of white sharks have increased in the northern Gulf. For example, in March of 2023, anglers landed what is thought to be the first white shark caught from a beach in Alabama (https://www.al.com/news/2024/05/a-great-white-shark-has-been-spotted-off-alabamas-coast-for-the-first-time.html); less than a year later, a white shark washed ashore along the Florida panhandle (https://www.fisheries.noaa.gov/feature-story/necropsy-offers-rare-opportunity-study-white-shark-biology). Understanding the distribution of white sharks outside of well-characterized hotspots has been designated by experts as a research priority (Huveneers et al., 2018). Accomplishing this will require disentangling increases in scientific research or observation effort from true range expansions or climate-driven habitat shifts. Therefore, we examined two long-term fishery-independent camera datasets to assess whether the recent increase in reports of white sharks reflects changes in distribution or typical (albeit rare) events.

Methods

Two long-term fishery-independent camera datasets were examined. The first dataset is from a stereo-baited remote underwater video (sBRUV) survey. The sBRUV stations are randomly selected as part of a long-term survey of natural and artificial reef habitats on the central West Florida Shelf. Briefly, each sBRUV array consists of two stereo video units facing 180° apart. Each unit contains a pair of stereo cameras (Point Gray Blackfly cameras, model BFLY-U3-23S6M-C) and a hard drive housed in an aluminum casing. Before each deployment, sBRUVs are baited with 0.45 kg of Atlantic Mackerel (*Scomber scombrus*). At each station, the sBRUV is deployed for approximately 30 minutes. All species are enumerated to the lowest possible taxon. For complete details of the sBRUV survey, see Switzer et al. (2023).

The second dataset is from a remotely operated vehicle (ROV) survey. The ROV survey stations are a) randomly selected as part of a long-term ecosystem monitoring program, b) targeted as part of an artificial reef monitoring program, or c) purposely sampled as part of synoptic single-species assessments (e.g., the Great Red Snapper Count). Briefly, the ROV survey uses a high-definition video camera on an inspection class ROV. The ROV is also equipped with sonar, a GoPro camera, and a pair of Digi-Key 5-mW red lasers aligned in parallel for reference. At each station, the ROV records approximately 10 minutes of video footage. All species are enumerated to the lowest possible taxon. For complete details of the ROV survey, see Powers et al. (2018).

Results

From 2010 – 2023, 8368 sBRUVs were deployed and from 2011 – 2024, 2199 ROV videos were recorded (Table 1; Figure 1). No white sharks were observed in sBRUVs, but two white sharks were observed in ROV videos (Figure 1). The first white shark was a female, recorded by the ROV on April 24, 2024 and estimated at 239 cm total length (Figures 2A, B). The second white shark was a male, recorded by the ROV on May 7, 2024 and estimated at 191 cm total length (Figures 2C, D). A video compilation of these two individuals is included as Supplementary Material.

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TABLE 1 Yearly effort (number of stations) from fishery-independent remotely operated vehicle (ROV) surveys and stereo-baited remote underwater video (sBRUV) surveys from 2010 – 2024.

Year	Effort (number of stations)	
	ROV	sBRUV
2010	na	158
2011	32	222
2012	48	237
2013	40	185
2014	61	410
2015	124	426
2016	237	815
2017	188	742
2018	229	887
2019	355	1053
2020	262	927
2021	218	850
2022	169	717
2023	154	739
2024	82	na

The sBRUV data from 2024 were not available at the the time of publication.

Discussion

Examination of 15 years of data from two concurrent fishery-independent camera surveys lends support to the notion that recent reports of white sharks in the northern Gulf indicate early evidence of range-edge expansion rather than increases in telemetry efforts or citizen observations. Historical accounts of white sharks in the Gulf are primarily from the west coast of Florida (e.g., Sarasota; Bigelow and Schroeder, 1948). Previous examination of long-term datasets has confirmed that white sharks make seasonal movements into the Gulf, confined primarily to the west coast of Florida (Adams et al., 1994; Curtis et al., 2014). West of Florida, there are only a few documented instances of white sharks in the Gulf (Casey and Pratt, 1985; Curtis et al., 2014; Franks et al., 2021). If white sharks are routinely venturing further west into the Gulf, standardized camera surveys offer a robust platform for quantifying a potential range-edge expansion.

During our fishery-independent surveys, both individuals were seen in spring, which aligns with our current understanding of the seasonal distributions of white sharks in the Western North Atlantic Ocean. Typically, white sharks demonstrate predictable seasonal distributions, characterized by summer/fall residency off Canada, New England, and New York followed by a southern migration to the southeastern U.S. in October and November (Skomal et al., 2017; Franks et al., 2021). If white sharks enter the Gulf, it typically occurs during the overwintering phase (December – May; Franks et al., 2021). The end of the overwintering period (April/May)

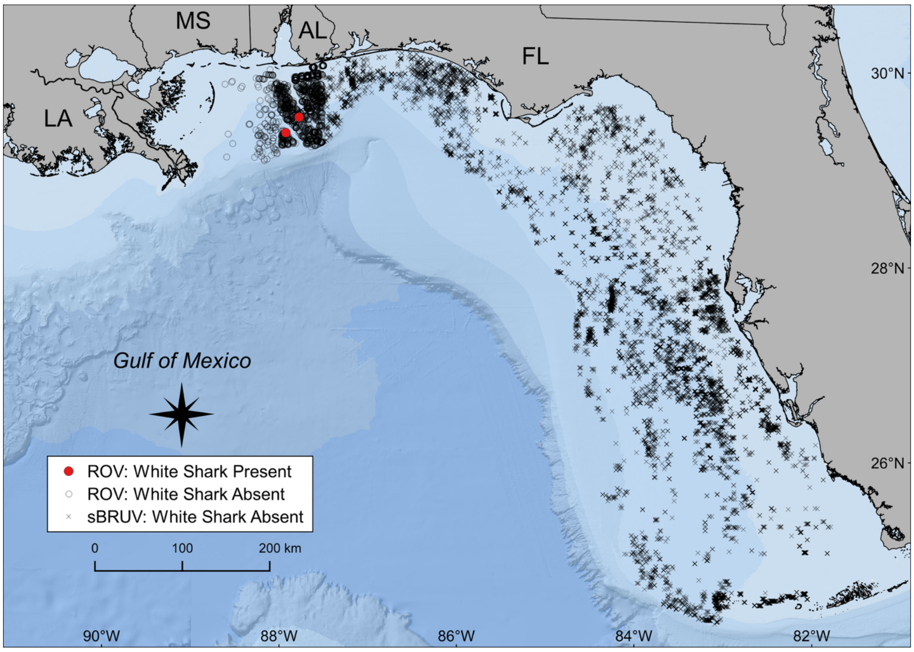

FIGURE 1
Locations of stations where fishery-independent remotely operated vehicle (ROV) surveys and stereo-baited remote underwater video (sBRUV) surveys were conducted. The ROV videos were collected from 2011 – 2024 (n = 2199) and the sBRUVs were collected from 2010 – 2023 (n = 8368). White shark observations are indicated by red circles.

FIGURE 2
Images of the white sharks observed in coastal Alabama on April 24 **(A, B)** and May 7 **(C, D)**, 2024 from fishery-independent remotely operated vehicle (ROV) footage. Images in panels **(B, D)** include lasers used to generate length estimates.

marks the largest monthly shift in median latitude for Western North Atlantic white sharks. During this time, the median latitude of occurrence shifts from 28°N to 40°N (Curtis et al., 2014). Thus, we speculate that these two white sharks were moving out of the Gulf toward more northern latitudes.

While Western North Atlantic white shark movements are highly correlated with seasonal shifts in temperature, foraging opportunities offer an equally plausible, yet difficult to quantify, mechanism to explain distribution patterns. Subadult white sharks in other regions have a large dietary breadth, consuming a wide range of teleost, elasmobranch, and marine mammal prey items (Clark et al., 2023). Bottlenose dolphins (*Tursiops truncatus*) are one of the most abundant marine mammals in the northern Gulf (Vollmer and Rosel, 2013); an increase in bottlenose dolphin strandings across the northern Gulf (Carmichael et al., 2022) may offer a seasonal pulse of food for white sharks (Adams et al., 1994). Similarly, an increase in some coastal shark populations (*sensu* Peterson et al., 2017) may be providing more foraging opportunities for white sharks. However, a better understanding of white shark diet during the overwintering period is needed to support this notion. Future studies could attempt this through nonlethal dietary tracers and food web modeling (Huveneers et al., 2018).

Acknowledging the innate limitations of presence-only data (Curtis et al., 2014), the current study contributes additional insights into the distributions of Western North Atlantic white sharks, despite a low sample size. This population has been managed since 1993 and listed as prohibited since 1997, and there are now clear indications of population recovery (e.g., Curtis et al., 2014). While we do not know if or why white sharks may be moving further west into the Gulf more regularly, we speculate that continued population recovery will increase the prevalence of white shark sightings like those reported here. Consequently, studies like this one highlight the value of long-term, randomized, fishery-independent camera surveys for detecting the presence of rare species and documenting potential range-edge expansions over time.

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.

Ethics statement

Ethical approval was not required for the study involving animals in accordance with the local legislation and institutional requirements because the camera gears used did not change, affect, or interfere with the fishes' behavior.

Author contributions

JD: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. AJ: Visualization, Writing – original draft, Writing – review & editing. TS: Data curation, Funding acquisition, Investigation, Resources, Writing – review & editing. CH: Data curation, Formal analysis, Investigation, Writing – review & editing. SP: Funding acquisition, Investigation, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

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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.2025.1628084/full#supplementary-material

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