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Characterizing a century of shark depredation in US Atlantic recreational fisheries

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Abstract

Shark depredation on target species in US Atlantic recreational fisheries is a growing source of human-wildlife conflict. Efforts to mitigate this conflict require an understanding of how its three principal components—anglers, fisheries, and sharks—have evolved over time. Through a historical perspective, we offer a conceptual framework that characterizes the dynamics of these components in the context of complex management systems for the affected fisheries. Specifically, we integrated observations of shark depredation from the published literature, angler surveys, and social media content to provide a comprehensive overview of the breadth of shark depredation in recreational fisheries in US Atlantic waters from Maine to Texas, and the US Caribbean. This exercise revealed that shark depredation is widespread, with 207 unique target-depredator connections (at least 51 target species impacted by 22 shark depredators). The most prevalent shark depredators included both authorized species that may be harvested (e.g. bull sharks *Carcharhinus leucas*) and prohibited species that may not (e.g. sandbar sharks *C. plumbeus*). This broad characterization further clarifies the actors (anglers, fisheries, sharks, and managers) that should be considered in ongoing efforts to establish valid shark depredation solutions, evaluates mitigation options given US regulatory constraints, and identifies priorities for future research.

Keywords human-wildlife conflict, shifting baselines, lifting baselines

Introduction

Human-wildlife conflict, or direct interactions between humans and wildlife resulting in adverse outcomes, is accelerating given lifting baselines (Drymon et al. 2024), expanded spatial and temporal overlap between humans and wildlife (Abrahms 2021), and the combined effects of environmental variability and long-term change (Abrahms et al. 2023). Arguably, the human-wildlife conflict that has recently received the most attention in the marine environment is shark depredation (Mitchell et al. 2023), defined as the partial or complete removal of a captured species by a shark. While shark depredation has impacted recreational anglers for generations (Hemingway 1935), US anglers have been contributing increasingly frequent anecdotal reports of shark depredation and complaints to fisheries management bodies concerning economic losses from shark depredation (NMFS 2022). This activity has fueled scientific interest in the characterization and potential mitigation of shark depredation, with particular emphasis on recreational fisheries off the southeastern USA (Casselberry et al. 2022, Prasky et al. 2023, McCallister et al. 2025). However, data regarding the magnitude and trends of shark depredation, the species involved, and effective mitigation solutions remain limited (Tixier et al. 2021, Mitchell et al. 2023).

Overlap

At its essence, shark depredation is the result of human-wildlife overlap; in this case, spatially and temporally dynamic overlap

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between recreational anglers and sharks competing for a shared resource. Navigating the challenges associated with recent increases in shark depredation (real or perceived) requires a broader understanding of how this overlap has evolved over time (Drymon et al. 2024). Therefore, we present a conceptual model incorporating historical information to broadly characterize a century of overlap between US Atlantic recreational anglers, target fishery species, and sharks. This framework provides insights into the high-level drivers of this human-wildlife conflict and informs potential paths to mitigation while acknowledging the inherent intricacies and realities of US fisheries management. We then introduce a compilation of recent shark depredation observations to demonstrate the breadth and complexity of its impacts and affected fisheries. Together, these elements clarify which species, fisheries, and management entities should be engaged as we collectively work toward data-informed solutions.

Baseline overlap (1925–1950)

Shark depredation in US Atlantic recreational fisheries has been decried by anglers for more than a century. In the early 1930s, Ernest Hemingway documented some of the earliest instances of depredation by sharks (Drymon et al. 2024). By 1940, global tensions were mounting prior to the start of World War II, when German U-boats halted trans-Atlantic shipments of cod liver oil to the USA. The sudden need to find a suitable substitute for the vitamins contained in cod liver oil sustained an emerging shark fishery in Port Salerno, Florida. A description of this fishery concludes, “Thus the shark, a pest and menace to Florida fishermen and sport lovers, the scourge of Florida waters, is being transformed into one of the most valuable creatures of the sea” (Rusoff 1939). This period is a reasonable representation of the initial overlap between anglers, fisheries, and sharks in a relatively untouched ecosystem (Fig. 1a).

Increased overlap and shifting baselines (1951–1975)

By the late 1940s, the widespread availability of synthetically produced vitamins rendered US shark fisheries obsolete, and in July 1950, the Port Salerno shark processing plant was closed. While US commercial shark fisheries dwindled, commercial fisheries for other species (e.g. red snapper *Lutjanus campechanus*) rapidly expanded (Hood et al. 2007). At the same time, recreational fishing became more available to the masses, fueled by increased leisure time as well as technological advancements in fiberglass boats and outboard motors. Recreational fishing for sharks flourished, which led to the birth of the National Marine Fisheries Service Cooperative Shark Tagging Program in 1962 (Kohler and Turner 2019). In February 1974, Peter Benchley published the novel “Jaws,” which remained on the best-seller list for the rest of the year before being released as the first-ever summer blockbuster during 1975. It would be difficult to overstate the impact of “Jaws” on the public’s perception of sharks, a concept coined “the Jaws Effect” (Neff and Hueter 2013). Increases in the number of anglers coupled with decreases in target fish species likely concentrated overlap of fish and anglers with sharks during this period, increasing the potential for depredation (Fig. 1b).

Reduced overlap and (further) shifting baselines (1976–2000)

In 1976, the Magnuson-Stevens Fishery Conservation and Management Act was passed (16 U.S.C. 1801–1882, 90 Stat. 331). This Act, and its subsequent amendments, dictate how management agencies must respond once US fish stocks are determined to be overfished or experiencing overfishing. After the passage of this hallmark legislation, commercial shark fisheries were explored as an underutilized resource (Otwell 1985 et al. 1985), and public interest in recreational shark fishing continued to grow (Cook 1987). Expanding trade relations with China during this period also offered massive new markets for US seafood exports, including shark fins (Dent and Clarke 2015). Consequently, commercial shark landings escalated by an order of magnitude, from 135 tons in 1979 to 7172 tons in 1989 (Castro 2016), yet it wasn’t until 1993 that the first fishery management plan for US Atlantic sharks was enacted (NMFS 1993). By then, most primary targets of commercial shark fisheries (e.g. sandbar shark *Carcharhinus plumbeus*, dusky shark *C. obscurus*) were overfished. At the same time, public interest in sharks heightened in the 1990s, marked by a change in perception from fear to curiosity (O’Bryhim and Parsons 2015, Castro 2016). Angler populations continued to increase, target fishery species continued to decrease, and shark populations decreased. Thus, during this period, overlap between these three groups was likely at an all-time low (Fig. 1c).

Greatest overlap and lifting baselines (2001–2025)

The new millennium ushered in the birth of the modern shark conservation movement, characterized by the public’s growing understanding of the importance of sharks to marine ecosystems (Simpfendorfer et al. 2011). During this time, management restrictions led to decreases in US commercial shark landings while recreational fishing effort continued to intensify. Concurrently, many studies noted the prevalence of positive attitudes from the general public toward sharks (e.g. Friedrich et al. 2014). Yet, a growing body of recreational anglers were expressing concerns that proliferating shark populations were causing increases in depredation. Collectively, these anglers were vocalizing a shift in attitude from “sharks threaten our safety” in the 1980s to “sharks threaten our recreational fishing opportunities” (Drymon and Scyphers 2017). This led recreational anglers to associate rising depredation with management measures that protect sharks (Prasky et al. 2023). These frustrations are presently reflected in the SHARKED Act, legislation introduced into the US Congress (2025) to “…address problems posed by increased depredation…” (H.R. 207–119th Congress). Today, there are more anglers than ever before (NASEM 2021, MRIP 2023, Hyman et al. 2025), shark populations are rebuilding following three decades of management (Peterson et al. 2017, Pacoureau et al. 2023), and many target fishery species are recovering from overfishing (NMFS 2023a). Thus, overlap between these three groups is likely at an all-time high (Fig. 1d).

Compiling observations

Given the dynamic relationships between the three groups (anglers, fisheries, and sharks) involved in shark depredation in

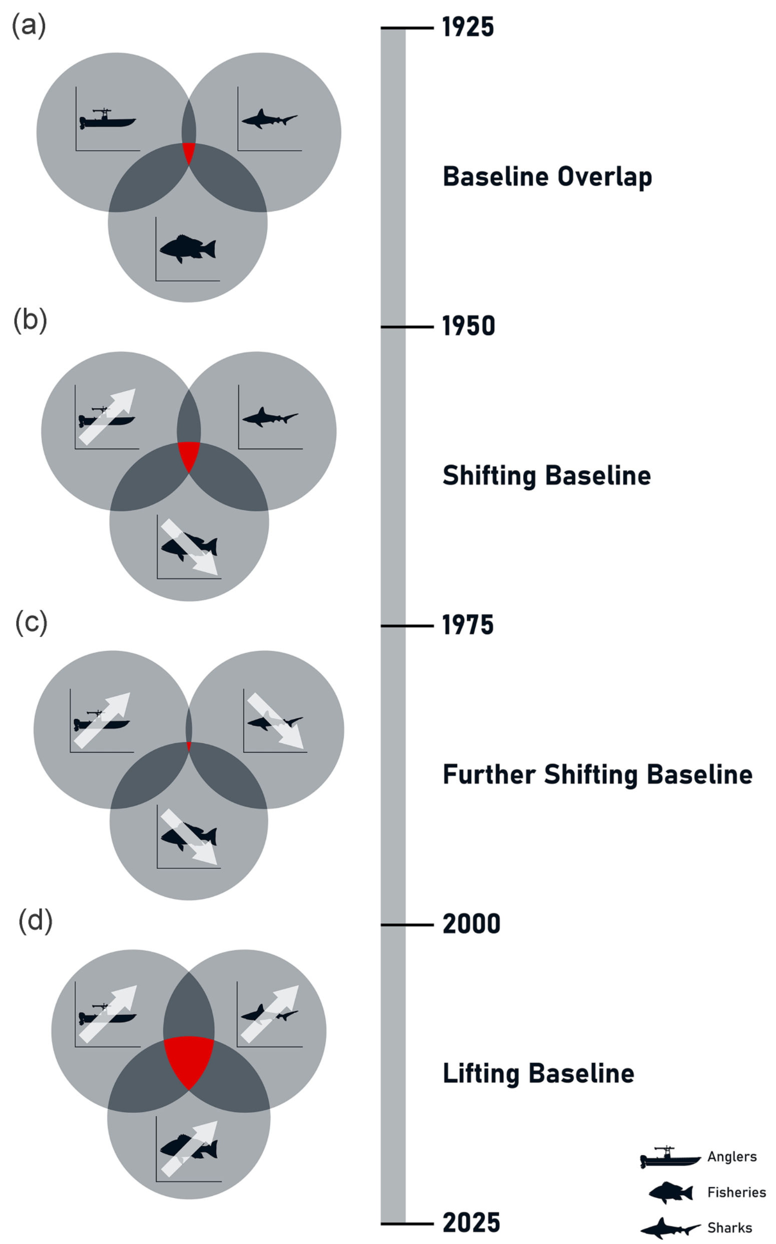

Figure 1 Timeline of anglers, fisheries, and sharks overlap from 1925–2025. General population trajectories are illustrated with light gray arrows, and Venn diagram overlap is shown in red.

recent decades, we compiled shark depredation information from the US Atlantic region (Maine to Texas, including the US Caribbean) to better understand the interactions between key depredator species and affected target fishery species. Specifically, we integrated observations of shark depredation from the published literature, angler surveys, and social media content. The aim was not to quantify the frequency of depredation in each fishery, but rather to identify as many unique, species-level target-depredator combinations as possible. In instances where species identification could not be unequivocally confirmed (e.g. social media images or anecdotal reports), we included novel species based on the collective observations of the authors. This liberal approach is likely to better embrace local ecological knowledge from anglers and capture the maximum potential breadth of interactions.

Shark depredation is complicated

The resulting matrix revealed 207 unique target-depredator connections, involving 51 target species impacted by 22 shark depredators (Figs 2 and 3, Supplemental Table 1). Collectively, these interactions include sharks that are federally prohibited (8 of 22 species) and target species that are managed by multiple state and federal agencies, interstate commissions, and regional fishery management councils, underscoring the regulatory complexity associated with depredation across jurisdictions.

Pairwise Jaccard similarity indices were calculated using the *vegan* package (Oksanen et al. 2025) in R (R Core Team 2025) to quantify overlap in depredation interactions, with similarity values reflecting the proportion of shared depredator species

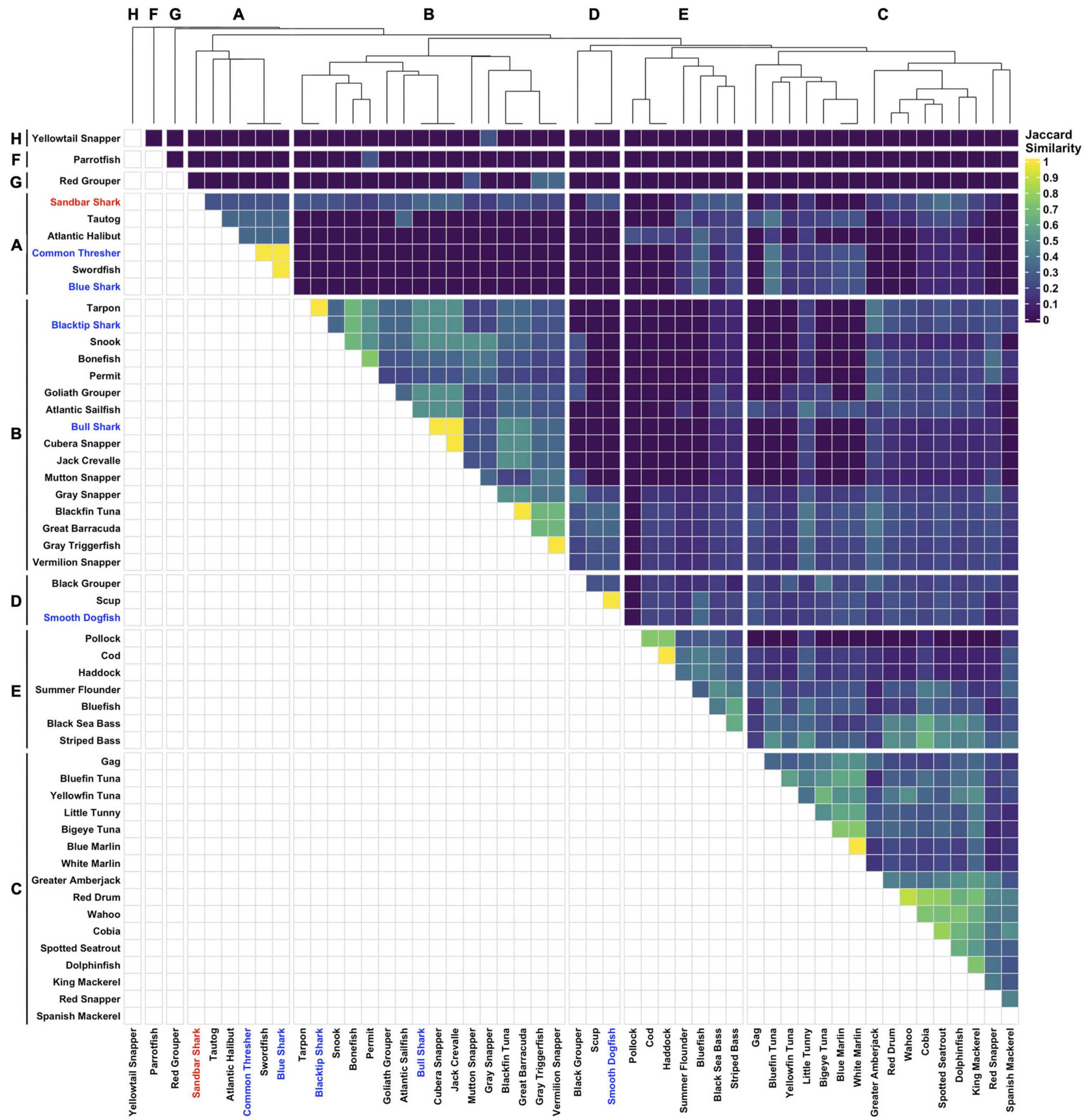

Figure 2 Pairwise Jaccard similarity indices (color) representing overlap in depredation interactions among US Atlantic recreational fishery target species based on shared shark depredator taxa. Target species are ordered by hierarchical agglomerative clustering (average linkage), with the corresponding dendrogram shown above the heatmap. Cluster structure is indicated by gaps between row and column grid cells and by labels (A–H) along the y-axis. Shark species color indicates federally prohibited shark species (red) and nonfederally prohibited species (blue).

among targets (Fig. 2) or shared target species among depredators (Fig. 3). Hierarchical agglomerative clustering using average linkage was applied to Jaccard dissimilarity (1 − similarity) matrices to identify structure in depredation interaction patterns. Clustering solutions were evaluated across a range of candidate cluster numbers (k = 2–10) using silhouette analysis. For each k, silhouette widths were calculated to assess how closely each species resembled others within its assigned cluster relative to neighboring clusters. The optimal number of clusters was selected as the value of k that maximized the average silhouette width, providing a data-driven criterion that balances high within-cluster similarity and strong separation among clusters.

From a management perspective, these clusters highlight the multifaceted nature of shark depredation, as they group species spanning distinct habitats (e.g. coastal vs. pelagic), geographies (e.g. northeast USA vs. southeast USA), life-history strategies, and fishery contexts. Importantly, clusters often included species managed under different regulatory frameworks, demonstrating that depredation dynamics transcend traditional management boundaries. This framework provides a basis for evaluating depredation

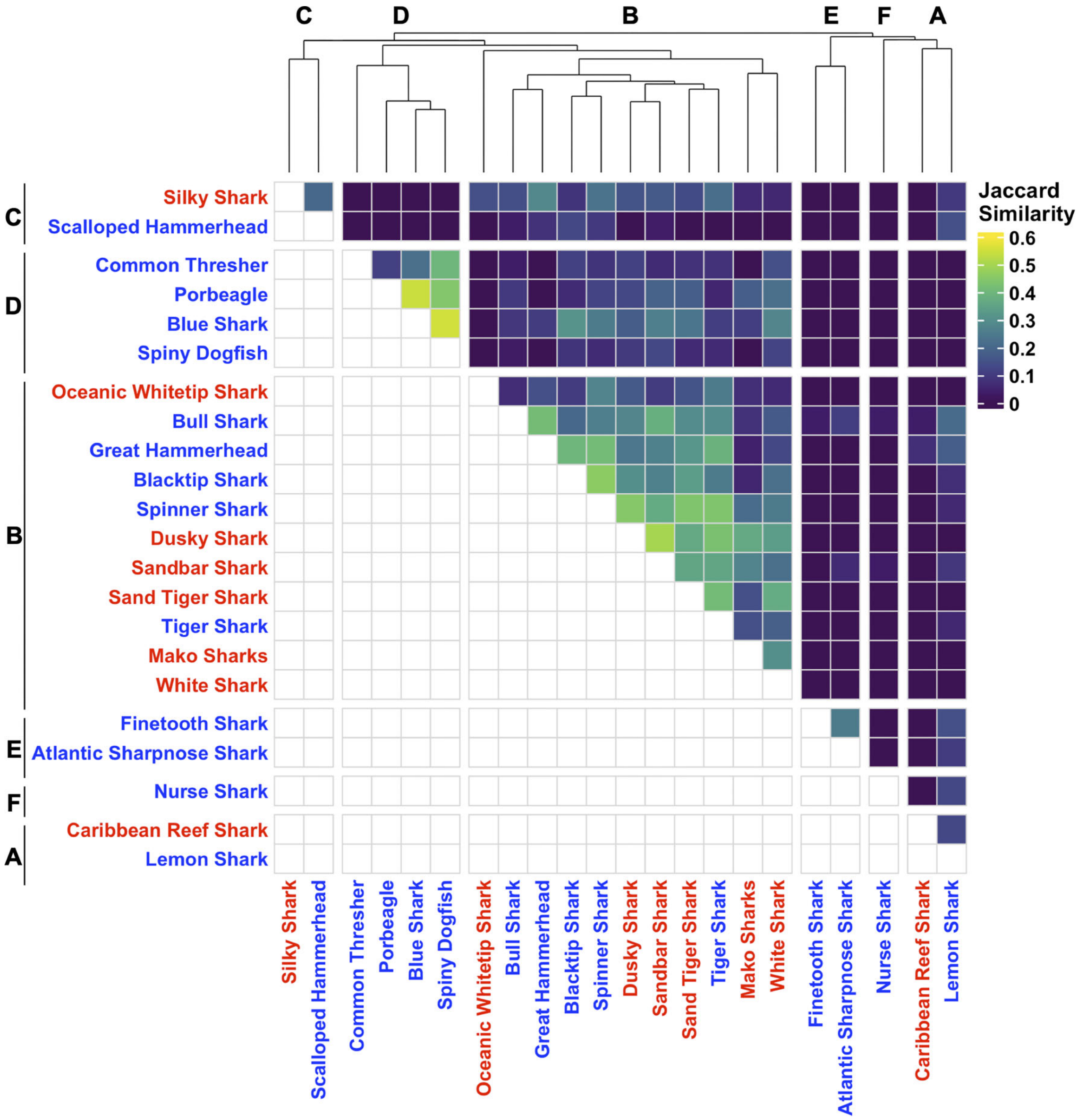

Figure 3 Pairwise Jaccard similarity indices (color) representing overlap in depredation interactions among shark depredator taxa across US Atlantic recreational fishery target species. Depredators are ordered by hierarchical agglomerative clustering (average linkage), with the corresponding dendrogram shown above the heatmap. Cluster structure is indicated by gaps between row and column grid cells and by labels (A–F) along the y-axis. Shark species color indicates federally prohibited shark species (red) and nonfederally prohibited species (blue).

impacts across management jurisdictions and conservation categories, including federally prohibited and nonprohibited shark species.

We further visualized depredation interactions as a directed network using the *igraph* (Csárdi and Nepusz 2006) and *ggraph* (Pedersen 2025) packages in R, in which target species and depredators are represented as two sets of nodes, and directed edges indicate depredation from predator to prey (Fig. 4). The bipartite network layout presented a two-column format that minimized edge crossings by ordering interacting species closer together. Node sizes were scaled according to the number of unique interactions associated with each species.

The network analysis further demonstrated the complexity of shark depredation by revealing dense, interconnected relationships among multiple depredators and target species across diverse habitats, fisheries, and biological assemblages. The two most commonly implicated sharks include a nonprohibited species (bull shark *Carcharhinus leucas,* Fig. 5a) and a prohibited species (sandbar shark*,* Fig. 5b), highlighting the management challenges associated with depredation across species with differing regulatory status.

The fisheries management entities affected by depredation include every federal, regional, and state fishery management agency and organization from Maine to Texas and the US Caribbean. Apart from spiny dogfish (*Squalus acanthias*), all the shark species implicated as depredators are managed by the National Marine Fisheries Service Atlantic Highly Migratory Species Management Division in federal waters. In state waters, the implicated shark species are managed jointly by regional fishery management commissions and/or individual states. Collectively, these

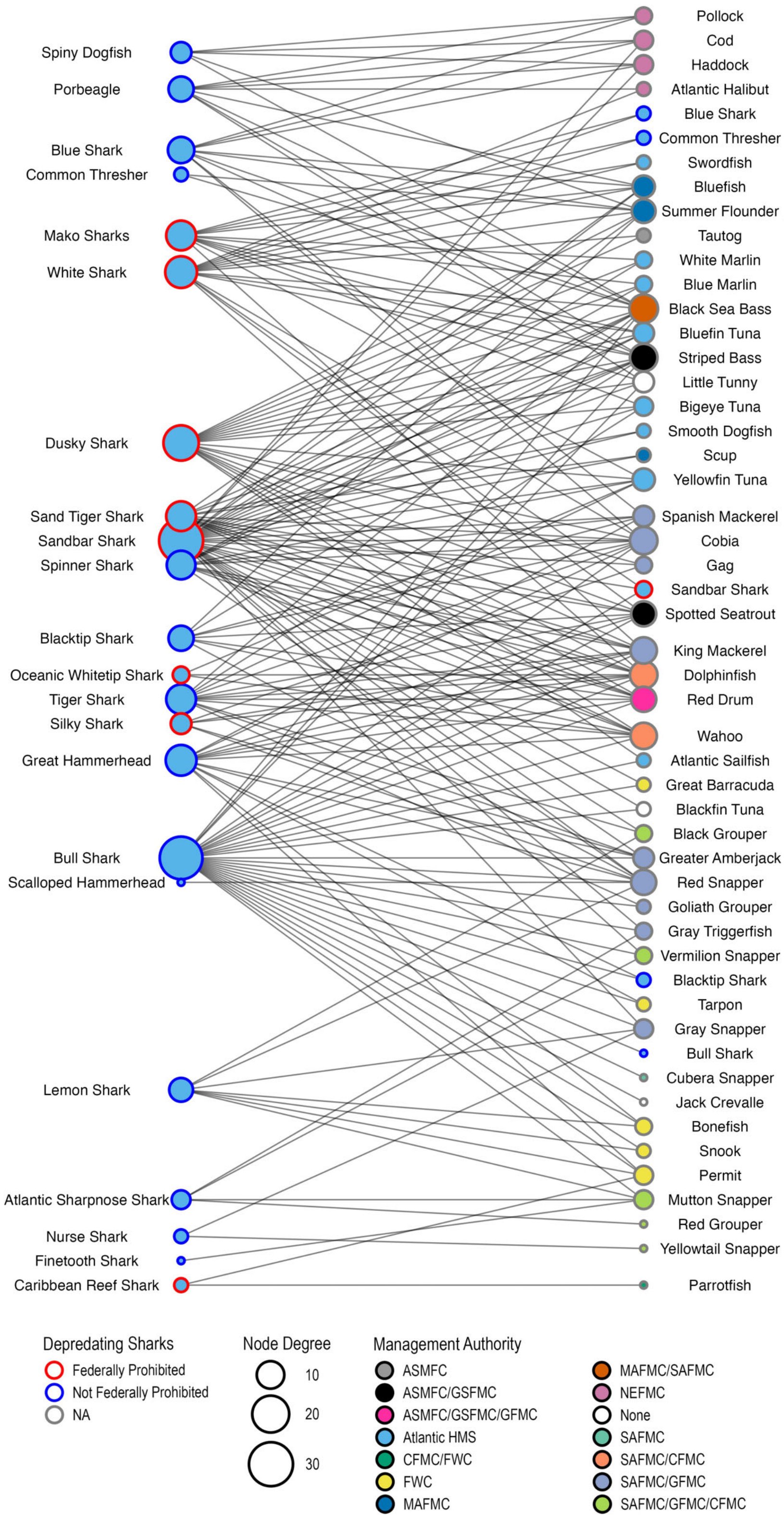

Figure 4 Bipartite network of species depredation interactions and management status in US Atlantic recreational fisheries. Edges (lines) represent documented depredation interactions between nodes (circles) with shark depredator taxa (left) connected to recreational fishery target species (right). Node size is proportional to the total number of depredation interactions for each species. Node fill color denotes the primary federal and regional management authorities responsible for each species, while node outline color indicates federally prohibited shark species (red) and nonfederally prohibited species (blue). Management authorities include the Atlantic States Marine Fisheries Commission (ASMFC), Atlantic Highly Migratory Species (HMS) Management Division, Caribbean Fisheries Management Council (CFMC), Florida Fish and Wildlife Conservation Commission (FWC), Gulf Fishery Management Council (GFMC), Gulf States Marine Fisheries Commission (GSMFC), Mid-Atlantic Fishery Management Council (MAFMC), New England Fishery Management Council (NEFMC), and South Atlantic Fishery Management Council (SAFMC).

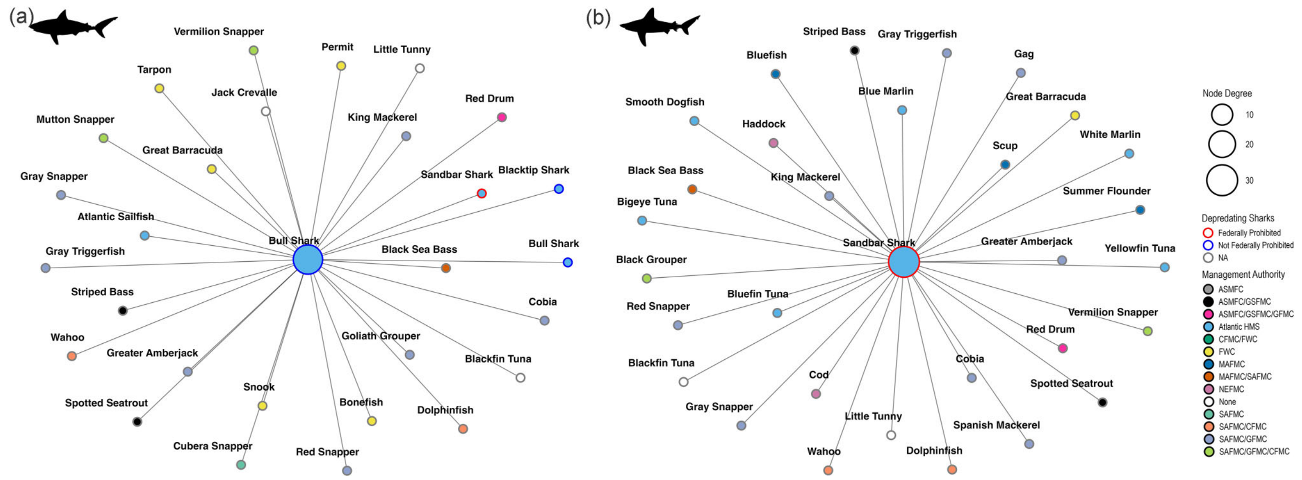

Figure 5 Force-directed network of bull shark (a) and sandbar shark (b) depredation interactions and species management status in US Atlantic recreational fisheries. Edges (lines) represent documented depredation interactions between shark depredator taxa and recreational fishery target species. Node (circle) size is proportional to the total number of depredation interactions for each species. Node fill color denotes the primary federal and regional management authorities responsible for each species, while node outline color indicates federally prohibited shark species (red) and nonfederally prohibited species (blue). Management authorities include the Atlantic States Marine Fisheries Commission (ASMFC), Atlantic Highly Migratory Species (HMS) Management Division, Caribbean Fisheries Management Council (CFMC), Florida Fish and Wildlife Conservation Commission (FWC), Gulf Fishery Management Council (GFMC), Gulf States Marine Fisheries Commission (GSMFC), Mid-Atlantic Fishery Management Council (MAFMC), New England Fishery Management Council (NEFMC), and South Atlantic Fishery Management Council (SAFMC).

federal, regional, and state fisheries managers must be aware of potential cryptic mortality impacts of shark depredation. In essence, depredated fishes are dead discards that are not well documented in fishery-dependent data collection efforts. In assessments where depredation rate data are incorporated, the impact can be substantial. For instance, accounting for sperm whale (*Physeter macrocephalus*) depredation in the stock assessment for Alaska sablefish (*Anoplopoma fimbria*) resulted in a 3% higher quota recommendation (Hanselman et al. 2018).

Looking toward the future

There are no “silver bullet” shark depredation solutions that will work across all the fishery scenarios identified in our analysis. Ideally, any approach should simultaneously maximize access to target fishery species while minimizing shark interactions. Yet, in reality, potentially available mitigation options may only marginally reduce conflict, not eliminate it. Depredation mitigation options currently include three primary mechanisms: *(1) using technical/physical deterrents, (2) modifying fishing behaviors,* or *(3) reducing shark populations* (Tixier et al. 2021, Mitchell et al. 2023, Casselberry et al. 2024). Increasingly, researchers are testing the efficacy of technical/physical deterrents with promising results. For example, the RPELX has been shown to reduce shark depredation by 63% in the Cocos-Keeling Islands off the coast of Australia (Mitchell et al. 2026). Further testing of depredation deterrents should follow established best practices (e.g. Mitchell et al. 2023) while involving anglers in development and field-testing processes. In addition to technical/physical deterrents, modifications to fishing behaviors such as changing locations and using electric reels are likely to reduce depredation. While some anglers are adopting these approaches (e.g. Mitchell et al. 2024), others have indicated that they have not changed the way they fish because of depredation (Prasky et al. 2023). Shark population reduction, either through targeted removal or optimizing sustainable harvest of sharks, is often proposed by anglers as the preferred mitigation option (Casselberry et al. 2022). Killing prohibited species (e.g. sandbar shark) is illegal, while targeted removal of authorized species (e.g. bull shark) without widely marketable products is wasteful and inconsistent with US fisheries law. Recently, existing shark quotas in the US Atlantic have been largely untapped (NMFS 2023b). Optimizing the sustainable harvest of these species will require exploring new domestic markets for shark products, as well as reducing market constraints, including restrictions and regulatory burdens for exporting sustainably managed resources. For recreational anglers, an approach that loosens recreational shark retention regulations while keeping within scientifically supported catch limits may be justified for certain shark species. However, more stock assessments and enhanced population monitoring are required to better identify these limits, especially for the species more frequently involved in depredation. Continued depredation mitigation research, along with enhanced and continuous dialogue with affected fishery participants and relevant managers, is paramount to identifying optimal solutions.

Conclusions

Our analysis identifies the specific complexities (anglers, fisheries, and sharks) and long-term drivers of shark depredation in US Atlantic recreational fisheries. The results clarify the actors affected by shark depredation, thus facilitating future action by scientists, anglers, and fishery managers, who should work collectively and collaboratively to develop options to mitigate depredation. Further efforts to pair magnitude and trend data with the linkages we have identified will help hone depredation mitigation efforts to maximize their impact. We recommend prioritizing research on effective, feasible depredation deterrents, which allow coexistence between anglers, target fishery species, and shark populations.

Working closely with affected anglers to increase buy-in will improve the likelihood of adopting novel technical solutions, such as deterrents. As a secondary management intervention, we recommend that federal, regional, and state fishery managers collaborate to better optimize the sustainable harvest of sharks under existing legal and regulatory limits.

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Author contributions

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Supplementary material

Supplementary material is available at *ICES Journal of Marine Science* online.

Conflicts of interest

None declared.

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Data availability

All depredation interaction data used in this manuscript are available in the online Supplemental Table 1.

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