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#Sawfish: Social media to assess public perceptions, behaviors, and attitudes towards a critically endangered species

Julia Saltzman[1,2]*, Jasmin Graham[3], Julia Wester[2,4,5], Easton R. White[1] and Catherine C. Macdonald[2,6]

[1]Department of Biological Sciences, University of New Hampshire, Durham, NH, United States, [2]Field School, Coconut Grove, FL, United States, [3]Minorities in Shark Sciences, Bradenton, FL, United States, [4]Field School Foundation, Coconut Grove, FL, United States, [5]Abess Center for Ecosystem Science and Policy, University of Miami, Coral Gables, FL, United States, [6]Department of Environmental Science and Policy, University of Miami Rosenstiel School of Marine, Atmospheric Science, and Earth Science, Miami, FL, United States

Monitoring population size and dynamics of threatened or low-density species is often both logistically difficult and costly. Recently, social media has emerged as a new tool for species monitoring. In this study, we expand on the use of social media posts as a tool to monitor the spatial and temporal distribution and public perceptions toward the smalltooth sawfish *Pristis pectinata*. We recorded 442 encounters with smalltooth sawfish from 2018 to 2021 in the form of Instagram posts. We identified locations of encounters within the following regions: Florida Keys, Everglades, South Florida (Miami/Fort Lauderdale), Caloosahatchee River, Bahamas, Upper Charlotte Harbor, Port St. Lucie, Ten Thousand Islands, Tampa, Naples, and Cape Canaveral. We found the greatest number of encounters occurred in the Florida Keys. In addition to spatiotemporal analysis, we used the captions of the posts to assess public attitudes and behaviors toward this charismatic species. This revealed individuals who encounter sawfish feel in general positive about their experience (over half described their encounter using positive language). We also found that sawfish were frequently caught as bycatch when other species (e.g., shark, tarpon, bonefish) were being targeted. Notably, in 12.6% of cases where sawfish were caught, they were being directly targeted. We also identified specific problematic or illegal handling behaviors from image and caption analysis. In addition to captured sawfish, we found sawfish are also frequently observed by beachgoers, boaters, and divers— however, in many cases these encounters may not be reported.

Introduction

The smalltooth sawfish (Pristis pectinata) is an easily distinguishable shark-like ray characterized by a unique toothed rostrum (Figure 5B) and a member of family Pristidae, a group of batoids considered to be the one of the most imperiled of all shark and ray families (Dulvy et al., 2014). Sawfishes were once common across marine and estuarine habitats (Poulakis and Seitz, 2004). The smalltooth sawfish was historically found in the eastern Atlantic along the west coast of Africa, and in the western Atlantic on the US Atlantic Caribbean, and Central American coasts, including throughout the Gulf of Mexico (Brame et al., 2019). However, throughout the nineteenth and twentieth centuries, the smalltooth sawfish was overfished as a result of unintentional catch due to their propensity for entanglement in fishing nets). Beyond bycatch in net fisheries, globally most species of sawfish have been targeted for human consumption, leather production, religious rituals, and traditional medicinal purposes (Seitz and Poulakis, 2006).

Currently, the smalltooth sawfish is found in only 20% of its historic range, with its only remaining population in the USA being a 'lifeboat' population located primarily in Florida waters (Dulvy et al., 2016). Telemetry has shown that many, but not all, smalltooth sawfish across life stages make migrations along the Gulf and Atlantic coasts of Florida (Graham et al., 2021). Florida waters are also a popular destination for recreational fishing, with the state issuing 2.3 million fishing licenses in the 2018/19 fiscal year (FWC, 2019). Throughout the current range of the smalltooth sawfish, there is high potential for human-sawfish interactions, especially fisheries-related interactions. This is of major conservation concern, as interactions between humans and smalltooth sawfish may result in injuries to the fish (Seitz and Poulakis, 2006). Mortality as a result of commercial and recreational fisheries is the primary threat responsible for the decline of smalltooth sawfish populations (Poulakis and Grubbs, 2019).

One way to monitor encounters and interactions with charismatic species is using social media (Di Minin et al., 2015). Social media is a practical tool to monitor the extent to emerging threats to species; for example, the illegal trade of the Asian small clawed otter and smooth coated otter was monitored and quantified using Facebook (Siriwat and Nijman, 2018). Online media has also been employed to monitor emerging conversation concerns across species lines: a 2021 study analyzed online media to collect 503 records from 51 countries of occurrences of animals (of 115 taxa) being trapped in discarded containers (Kolenda et al., 2021). Social media is an especially useful tool for species which are rare, geographically dispersed, and likely to be posted about when encountered (i.e., encounters are novel and exciting) (Marcenò et al., 2021; Morais et al., 2021).

Through data-mining of geocoded public information, scientists can effectively assess where, when, and under what circumstances members of the general public encounter a species (Hausmann et al., 2017). Through data-mining and content analysis of YouTube videos, a 2020 study examined seasonal patterns in harvest and differences in appreciation of successful catches in a Mediterranean recreational fishery (Sbragaglia et al., 2020). Similar data-mining methodologies have been employed to examine how people "feel" about encounters with different species or habitats. For example, data shared by visitors to national parks on social media was employed to understand how nature-based recreational experiences are perceived by participants (Hausmann et al., 2020). Posts across several image-based social media platforms were quantified to differentiate landscape values across geo-political boundaries (van Zanten et al., 2016) and social media/online news data about iconic threatened species was mined to examine reactions to events important to conservation outcomes (e.g., poaching) (Fink et al., 2020).

Information about where, when, and under what circumstances species are encountered can have critical conservation implications (Wu et al., 2018; Kroetz et al., 2021). This kind of information can be employed to improve management, identify gaps in public education, and shape outreach campaigns. Furthermore, data-mining of online media can effectively complement traditional social science survey methods; for example, geocoded posts provide a spatiotemporal component which is not typically accurately available from traditional survey methods (e.g., stakeholder surveys, focus groups, or interviews) (Heikinheimo et al., 2017; Hausmann et al., 2018).

Kroetz et al. (2021) successfully identified the utility and versatility of social media as a tool for social-ecological assessment of human interactions with the smalltooth sawfish. In our study, we expand on the framework and results of this study, examining in detail a larger number of posts across a shorter time frame (442 posts from August 2018 through August 2021) for an increased number of variables to further characterize angler motivations, attitudes, and behavior. Specifically we use Instagram posts to 1) examine the contexts in which people are encountering sawfish 2) determine target species when sawfish are caught, 3) examine handling and/or approach behaviors of those who encountered sawfish, 4) quantify and identify injuries of caught sawfish, 5) explore the related perceptions and sentiments expressed in photo captions about the encounter, and 6) use these findings to identify areas of potential effective outreach and management action.

Methods

We obtained the data for this study from publicly available posts on the social media platform Instagram. We secured all data following the terms and conditions set by Instagram to protect users (found here: Meta privacy policy - how meta collects and

uses user data). In order to monitor smalltooth sawfish encounters, we coded relevant posts with the hashtags related to sawfish (#sawfish, #smalltoothsawfish, #sawshark) from August 2018-August 2021. Thematic and content codes included *a priori* categories meant to capture data relevant and comparable to current sawfish research and conservation (e.g., location, size class, contact with management and research authorities, types of activities and encounters). We also developed a priori codes to characterize basic sentiments toward encounters, conservation efforts, and management (e.g., positive/negative sentiments, mentions of population status and protection, mentions of best practices pushed in current outreach materials from NOAA or FWC). Finally, we included themes that emerged from the text of the captions after initial close reading and discussion (e.g., descriptions of sawfish as prehistoric in appearance or especially novel). After the research team discussed and drafted coding categories, an initial set of 100 posts was coded by two authors (JS and JW). Codes were then discussed, and definitions were refined and finalized. All posts were then coded by the same two authors and Cohen's Kappa was calculated for each category. Kappa values ranged from 0.69 to 1 (m = 0.82, SD = 0.09) or substantial to almost perfect, using guidelines established by Landis and Koch (1977). Finally, coding disagreement was reconciled through discussion. The first author's (JS) coding was used for all further analysis.

Where, when, and under what circumstances sawfish are encountered

We recorded A) account handle, B) location (based upon geotag and statements made in the caption of the post), C) date of post, D) estimated life stage of sawfish, and E) who makes the post (e.g., angler, scuba diver, charter captain), F) link to post, G) target species (if applicable). For the purpose of this study, we separated those who encounter sawfish into five groups: anglers, charter captains, observers not physically interacting with the sawfish, scientists, and others. With respect to anglers and charter captains, when possible, we identified their target species. Target species were identified from photos, captions, or biographies (e.g., target species would be labeled as "tarpon" if a photo of tarpon caught the same day or caption stating, "out tarpon fishing". If the target species was not identifiable, this category was labeled as "unspecified".

Human behaviors during encounters with sawfish

We recorded the following information about human behaviors during encounters with sawfish: A) presence or absence of capture-related injury and description of injury, B) gills wet or dry (if applicable), D) posing with fish (defined as

poster holding the fish, with gills out of the water, and looking at the camera), C) use of rope to secure the fish, and D) use of bolt cutters/pliers to remove the hook.

Expressed attitudes, sentiments, and perception of sawfish encounters

We developed qualitative categories for expressed attitudes, sentiments, and perceptions of sawfish based on trends which emerged upon initial review of captions. We recorded the following parameters (based on post captions), scored using either a 1 for presence or 0 for absence: A) mention of sawfish being on a bucket list, B) science communication, C) portrayal of sawfish with novelty (e.g., rare, weird, cool) D) sawfish referenced as "prehistoric", E) positive description, F) negative description (dangerous, concern about injury, using the word monster, G) reference of visual beauty, H) reference IUCN status, I) reference conservation, J) tag a management agency, K) reference "fight" with a fish, L) reference politics, M) reference taxidermy, N) presence of an inquiry about the encounter. Examples of each of these parameters are in Table 1. In several identifiable circumstances, the same sawfish encounter was posted about multiple times– this was determined based on locations, timestamps, and mutual tags by the posters. For these cases, the encounter was counted once, but the captions were combined and coded.

Results

All results are summarized in Table 2.

Where, when, and under what circumstances sawfish are encountered

We recorded 442 discrete encounters with smalltooth sawfish between August 2018 and August 2021 on Instagram by searching "#Sawfish", "#SmalltoothSawfish, and #Sawshark and recording the posts which included legitimate and decipherable encounters. We identified encounters with adult (215), subadult (77), and juvenile (152) sawfish. Sawfish were encountered by anglers (n=162), charter captains (n=59), observers (n=124), scientists (n=67), and others (n=30) (Figure 1).

Based upon our findings, and adapting geographic groupings from previous literature (Simpfendorfer et al., 2011), we binned the locations of sawfish encounters into the following regions: Florida Keys, Everglades, South Florida (Miami/Fort Lauderdale), Caloosahatchee River, Bahamas, Upper Charlotte Harbor, Port St. Lucie, Ten Thousand Islands, Tampa, Naples, and Cape Canaveral (Supplement 3). The greatest number of encounters occurred in the Florida Keys (n=109). Smalltooth

TABLE 1 Categories from caption codebook (parts of captions which reveal identity of posters have been omitted).

Category	Examples
A. Reference Bucketlist	"What a bucketlist fish for so many people in the world!!"
	"#Bucketlist diving on Bonnie's Divesite TODAY! 🤿 🔪 🐟 Next #Sawfish exploration dive scheduled for 28 Jan."
	"Catching a lifetime dream a Monster sawfish."
	"This sawfish was my favorite catch and fishing experience and it probably will be till the day I die. I've always wanted to catch one of these since I was a little boy."
B. Science Communication	"If you accidentally catch a sawfish please report your sighting!"
	"Critically endangered smalltooth sawfish are impressive predators. Their rostrums contain Ampullae of Lorenzini (electro-reception) and when they detect prey they will swing their rostrum back and forth to stun or impale the fish."
	"Happy International #sawfish day! Today we celebrate and raise awareness for these critically #endangered marine #fish. One of the most spectacular forms conceived in #nature, with a tooth-studded nose called a #rostrum. This appendage is great for slicing small fish in an ambush but also problematic for getting heavily ensnared in fishing nets."
C. Novelty	"Of all the animals I have come across in my life the smalltooth sawfish is one of the coolest and craziest looking."
	"While the right whales evaded me I did come across this sexy sawfish the other day! I've only ever seen them in Florida Bay, so this was a real treat."
D. Prehistoric	"Not a bad day catchin dinosaurs, sharks, and all the trout you could possibly want."
	"Witnessing this adult fish alive, healthy, and in person, was a truly humbling experience last week. A prehistoric dinosaur for sure, showing us what amazing creatures live out there in the ocean."
	"I caught my first Black Drum and a Sawfish, which is way prehistorically cool!"
E. Positive Description	"Incredible animal to see and tag today!"
	"While down there I caught a sawfish which is one of my all-time favorite marine animals. For full clarity and to stop any possible misrepresentation, this animal got foul hooked as a by-catch for redfish and got well wrapped in the line."
	"Sometimes it's more about the experience than the quality of the photo. In this case, it was the chance to watch a large 9 ft (3 m), critically endangered, smalltooth sawfish (Pristis pectinata) feeding for crustaceans in the seagrass beds in Florida Bay."
F. Negative Description	"Caught a living chainsaw, craziest looking fish I've ever seen #sawfish"
	"Sea Monster #sawfish #seamonsters"
	"Armed and dangerous #packin #sawfish #shark"
G. Reference Visual Beauty	"Cool to see one of these things up close, was released safely. #sawfish #thekimberley#beautiful #fishing"
	"A beautiful sawfish on a 3/8oz sparkie head bucktail. The sawfish was untangled and released safely. #gettinjiggy #mustad #sawfish #shark #everglades #enp #florida"
	"First ever Small-tooth Sawfish encounter (Pristis pectinata) and SHE WAS A BEAUTY ❤️."
H. Reference IUCN Status	"All species of Sawfish are critically endangered due to overfishing, unsustainable fishing methods, entanglement of their long, tooth-covered rostrums (snouts) in fishing nets, poaching and habitat loss (mangroves forests, estuaries and coastal waters used in their juvenile and mature stages)"
	"Smalltooth sawfish are among the world's most threatened marine fishes. They are currently listed as critically endangered on the IUCN Red list due to loss of habitat as well as fishing mortality, mainly as by-catch."
	"Cool one from this summer, a critically endangered smalltooth sawfish!"
I. Reference Conservation	"All five species of sawfish are threatened with extinction, so it's critically important we minimize threats to them as well as support conservation efforts."
	"An amazing sight to see in Florida Bay, a critically endangered Smalltooth Sawfish cruising the shoreline. Why are they critically endangered??.Pretty much like everything else, due to stupid ass humans via hunting and habitat loss."
J. Tag Management Agency	"Nothing like catching a sawfish as bycatch. Fish was released without delay and promptly reported to FWC."
	"Thankfully some bystanders were there to capture it. The fish has been reported to FWC, and I feel privileged to interact with such an amazing creature."
K. Reference Fight	"Thankful to have put :_ on an epic fight with a Sawfish!!!"
	"Easy 14-15 foot SawFish (45 min fight)"
L. Reference Politics	"The Trump Administration announced new rules limiting ways the ESA is applied. The ESA has bipartisan support so in lieu of completely killing the act, this administration is instead gutting the regulations that make it effective. This will benefit oil, gas, and development interests. To value wildlife and wild places and to possess a desire to protect them for future generations is incompatible with supporting this administration."
	"#sawfish #bassproshops #mustad #penn #seahuntboats #photooftheday #lifeisgood #livingthedream #bucketlist #dinosaur #saltlife #gopro #goprohero #trump2020 #iloveyou #family #fishing #cabelas"
M. Reference Taxidermy	"Huge sawfish from yesterdays charter! Don't see these ones everyday! #:_taxidermy"
	"Careful Tommy Boy!! Our good friend :: in Key West working his magic on this trophy #sawfish!! Don't forget to ask your Captain or Mate about immortalizing your trophy catch with :_ Taxidermy"
N. Presence of Inquiry about Encounter	"Hey :_! We house the International Sawfish Encounter Database (ISED) to track the global population. We'd love to hear about your encounter: http://www.flmnh.ufl.edu/fish/sawfish/report-encounter/"

sawfish of all life stages were encountered in all seasons. Across life stages, 16% encounters occurred in fall, (September-November), 22% occurred in winter (December-February), 41% of encounters occurred in spring (March-May), 21% occurred in summer (June-August) (Supplement 4).

We found that a variety of species were being targeted when sawfish were caught(Figure 2A). Target species with low frequency were binned in the category "other"; however, this category is quantified in detail in Figure 2B. The most common target species were charismatic sport fish with shark anglers (27.9%), and bonefish/tarpon anglers (20.9%), making up a substantial proportion (48.8%) of anglers interacting with sawfish. It is notable that sawfish were also caught by anglers or charter captains who reported directly targeting them (11.2%).

The FWC and National Marine Fisheries Service Smalltooth Sawfish Recovery Team website states, "if you are diving and see a sawfish, observe at a distance. Do not approach or harass them. This is illegal and this guidance is for your safety as well as theirs." Through our data mining, we observed this rule is not being followed by all divers or dive operators. In this study, there were multiple cases where dive charters marketed "sawfish dives". In addition, there were cases of divers swimming directly up to sawfish to pose for photos, and even spear fishing for Cobia directly next to sawfish.

Human behavior during encounters with sawfish

Where possible, we examined handling behavior seen in the posts. Of "hooked" or "captured" sawfish, 64.1% had their gills submerged and 35.9% had their gills fully out of the water. Juveniles experienced higher rates of dry gills than adults (Figure 3). 19.6% of caught sawfish had visible injuries, for a total of 87 capture-related injuries. Injuries were binned into

four locations: mouth, rostrum, eye, and body (Figure 4B). Of these injuries, 84% were injuries to the rostrum. The remaining 16% of capture-related injuries were on the body (7%), eyes (6%), and mouth (3%) (Figure 5A). These injuries were predominantly caused by anglers (69%) and charter captains (28%), the anglers and charter captains whose sawfish presented with catch-related injuries were targeting a variety of species; however, the greatest proportion of sawfish injuries occurred during the targeting of bonefish/tarpon (38%) and sharks (24%) (Figure 5C). Adult sawfish were most likely to show visible injuries (48.3%, n=42), followed by juveniles (34.5%, n=30), and subadults (17.2%, n=15) (Figure 5D). Because regulations state that anglers should "never use a gaff or rope to secure a sawfish" and should "cut the line as close to the hook as possible" (e.g. not use pliers or bolt cutters for hook removal), we also recorded the frequency of the use of ropes and gaffs (n=29) and identified when fishers were clearly using bolt cutters or pliers to remove the hook from the jaw of the fish (n=5). Finally, in 30.2% (n=52) of images of anglers/charter captains, they were posing with the fish.

We also observed several individual behaviors which were notable outside of specified coding categories. Several fishers referenced "sight casting" at sawfish, although this practice is illegal under Florida law (Rulemaking Authority Art. IV, Sec. 9, Fla. Const. Law Implemented Art. IV, Sec. 9, Fla. Const. H). We also identified multiple occasions where spear fishers targeted cobia which were swimming directly beside sawfish. Despite low sawfish population numbers, charter captains and anglers frequently used language where they referenced a high abundance of sawfishes. For example, a charter captain stated, "no shortage of sawfish these days", a diver stated "sightings of sawfish in Jupiter waters seem to be on the increase, or are there simply more divers in the water", and a shore-based angler stated "6 with an endangered sawfish, keep catching them bud and I might think they're more than they say".
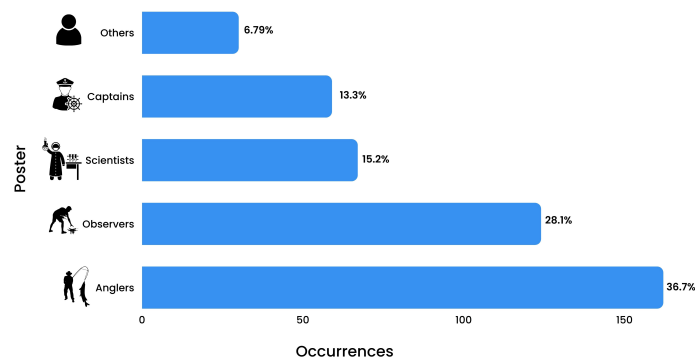

FIGURE 1
Number of occurrences and percentages of Instagram posts in sawfish-related hashtags who encountered the smalltooth sawfish from August 2018-August 2021.

TABLE 2 Summary of all results.

	Category	Rounded Percent
Sawfish Life Stages	Juvenile	34.4%
	Subadult	17.4%
	Adult	48.6%
Sawfish Encounterers	Anglers	35.6%
	Charter Captains	13.3%
	Observers	28.1%
	Scientists	15.2%
	Others	7.8%
Season of Encounter	Fall	16%
	Winter	22%
	Spring	41%
	Summer	21%
Target Species of Anglers	Bass	1.4%
	Bonefish/Tarpon	20.9%
	Grouper/Snapper	1.9%
	Sawfish (direct targeting)	11.2%
	Unspecified Fishes	25.1%
	Boat Based Shark	9.3%
	Land Based Shark	18.6%
	Others (e.g., billfish, sailfish, mantas)	4.7%
Visible Injuries	Adults	48.3%
	Subadults	17.2%
	Juveniles	34.5%
Illegal Tool Use	Ropes and Gaffs	6.6%
	Bolt Cutters or Pliers	1.1%
Expressed attitudes, sentiments, and perception of sawfish encounters	Fighting the fish	3.6%
	Bucket List Catch	3.6%
	Visual Beauty	7.5%
	Negative Language	2.7%
	Novelty	36.4%
	Prehistoric	11.5%
	Scientific Communication	20.1%
	IUCN	28.1%
	Conservation Importance	23.1%
	Plans to Taxidermy	1.4%
	Political Reference	0.68%
	Tag Management	16.2%
	Inquiry Present	28.6%
	Anglers/Charter Captains Posing with Fish	30.2%

Expressed attitudes, sentiments, and perception of sawfish encounters

To better understand the data related to perceptions of sawfish encounters, we also described and quantified the information from captions (Figures 4A, B). 3.6% of posters (n=16) specifically referred to "fighting" the sawfish, and often referenced prolonged fight time. 3.6% of anglers who caught sawfish (n=16) described them as a "bucket list catch" or on their "bucket list". 50.2% (n=222) described their encounter using positive language or in a positive light. Under the category of positive language, 7.5% (n=33) expressed their sense of the visual beauty or aesthetic appeal of the sawfish they encountered. 2.7% (n=12) described their encounter using negative language (e.g., "armed and dangerous"). Remaining respondents didn't use positive or negative language. 36.4% (n=161) described their
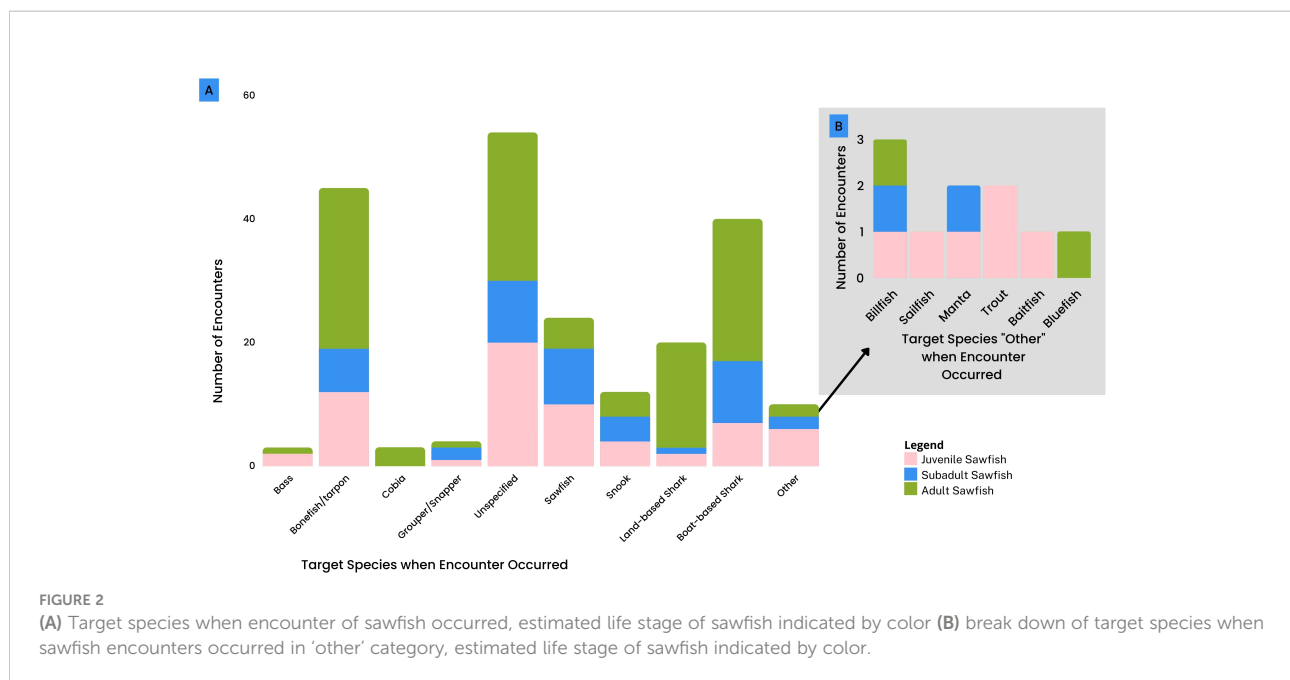
FIGURE 2
(A) Target species when encounter of sawfish occurred, estimated life stage of sawfish indicated by color **(B)** break down of target species when sawfish encounters occurred in 'other' category, estimated life stage of sawfish indicated by color.

encounters as novel or unexpected, (e.g., "once in a lifetime" or "couldn't quite believe my eyes when I realized what it was"). It is important to note that novelty/unexpectedness and positivity were treated as separate categories for the purpose of this study. 11.5% (n=51) of those who encountered sawfish described them as "dinosaurs" or as being "prehistoric". 20.1% (n=88) of posters used their posts for some sort of scientific communication (e.g., sharing facts about sawfish biology, ecology, or research). This included anglers (7.2% of science communication), scientists (53.2% of science communication), observers (7.2% of science communication), charter captains (34.2% of science communication), and others (0.90% of science communication).
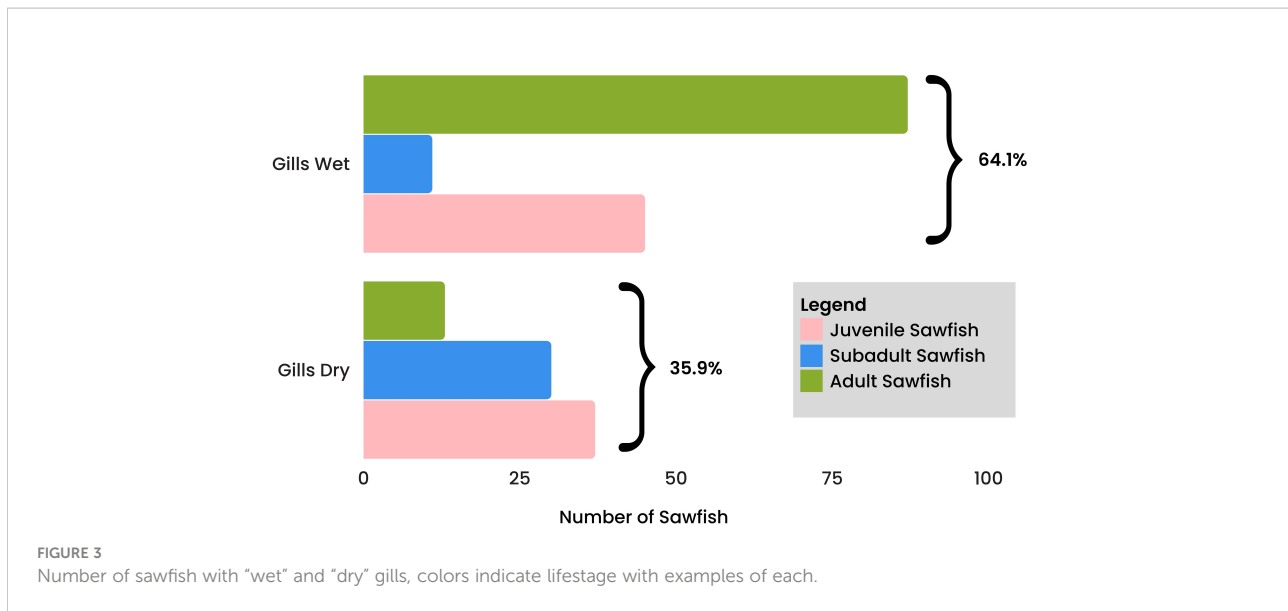
We also examined the knowledge displayed in the captions by those who encountered sawfish. 28.1% (n=124) of those who encountered sawfish included their IUCN status in the caption of the post. 23.1% (n=102) expressed the importance of conserving sawfish. 1.35% (n=6) stated plans to mount or taxidermy their catch. It was not clear from posts if this was a reference to mounting the physical animal or having a model made. 0.68% (n=3) referenced politics, specifically tagging the Trump Campaign account or used "#MAGA" in their post.

We identified "inquiries" which were defined as someone (e.g., a conservationist or scientist) commenting on the post in an attempt to get more information about the encounter. 20.6% of encounters had some sort of inquiry from an authority on sawfish or social media influencers who focus on shark conservation. The most common inquirer was University of Florida Shark Research, asking the poster to submit their encounter to the international sawfish encounter database. However, there were instances where various people tagged "@FWC" in the comments, in an attempt to make the Florida

Wildlife Conservation Commission aware of the encounter. 16.2% (n=72) of those who posted about an encounter with smalltooth sawfish tagged a management agency in their posts. This combined with the 91 recorded inquiries leaves 63.1% (n=279) of encounters which show no reporting information or evidence of interaction with managers.

Discussion

The largest group of anglers who caught sawfish were recreationally targeting sharks. In Florida waters, "non-offset, non-stainless-steel circle hooks are required when targeting or harvesting sharks when using live or dead natural bait (when fishing from shore and from a vessel)," and "the possession/use of a device capable of quickly cutting the leader or hook when targeting sharks is required (when fishing from shore or a vessel)." If the anglers catching sawfish have gone through FWC training to receive a shark fishing license, they have completed a training incorporating these rules. Circle hooks are an effective tool in recreational catch-and-release fisheries; mortality rates are lower for circle hooks than j-style hooks, and they more frequently hook the jaw as opposed to in the gut when compared with j-style hooks (Cooke and Suski, 2004). The mandatory use of circle hooks by shark anglers is positive news for sawfish, since sawfish are caught frequently by recreational shark anglers. Nevertheless, a large portion of anglers who caught sawfish were targeting teleosts such as bonefish, tarpon, and grouper. In these fisheries, while the use of circle-hooks is encouraged, it is not mandatory (Reef fish gear rules Florida fish and wildlife conservation commission)

FIGURE 3
Number of sawfish with "wet" and "dry" gills, colors indicate lifestage with examples of each.

(Rulemaking Authority Art. IV, Sec. 9, Fla. Const. Law Implemented Art. IV, Sec. 9, Fla. Const. History–New 9-1-13). Since many of these anglers are specifically targeting teleosts, and do not necessarily have a shark-fishing license, they are not required to have completed the same training as shark anglers orienting them to sawfish-related policies. Our surveys found frequent external foul-hooking of smalltooth sawfish by recreational teleost anglers (i.e., jaw hooking of sawfish is rare). Circle hooks may reduce rates of foul-hooking or prevent severe injury of sawfish when they are caught.

Given the frequency of sawfish interactions among those targeting tarpon and other teleost fishes, incorporating best handling practices for sawfish into the saltwater fishing license process may improve angler awareness of sawfish-specific regulations. While this may seem necessary only for those using heavier tackle, many juvenile sawfish in this study were caught using light tackle by anglers fishing from shore. Best-practices for handling of sawfish are different from general practices in recreational fishing, where removal of hooks is encouraged where possible, reporting of most catches is neither expected nor required, and moderate levels of handling, including briefly removing animals from the water, may be normal and accepted (Cooke et al., 2021). When handling sawfish, Florida regulations call for cutting line rather than removing hooks, limited use of tools beyond those needed to cut the line, and no removal of animals from water or restraint beyond what is essential to prepare an animal for release. Because of these differences, even well-intentioned and experienced anglers may not know to follow sawfish-specific best handling practices. Furthermore, when fishing in some areas in Florida, anglers are required to have dehooking tools on their vessels (FWC, 2022).

We found that juveniles were taken out of the water and posed with at a greater frequency than adults, and more often than not this was by anglers using light tackle targeting small fishes. This is relevant because juvenile elasmobranchs may face lethal or sub-lethal physiological consequences as a result of an exhaustive fight on a line, particularly in warm shallow coastal waters (Danylchuk et al., 2014). Additionally, several studies have revealed juvenile elasmobranchs are especially vulnerable to mortality (Heupel and Simpfendorfer, 2002) and can be more stress intolerant than adults of the same species, pointing to a greater importance of reducing stress on juvenile elasmobranchs (Giesy, 2021). Most notably, a 2018 study found that metabolic stress in our study species, the smalltooth sawfish, changes across ontogenies, with young of the year (YOY) sawfish exhibiting the greatest physiological stress response to capture (Prohaska et al., 2018). The same study suggested sawfish may exhibit greater levels of chronic stress in anthropogenically altered locations (e.g., the Peace and Caloosahatchee rivers) (Prohaska et al., 2018). The locations where sawfish exhibited higher levels of chronic stress as identified by Prohaska et al. are some of the same locations where we identified frequent incidence of juvenile and YOY sawfish capture. Additionally, our identification of sawfish being taken out of the water following angling events is relevant because sublethal impairments due to air exposure following angling events have been documented across many species (Cook et al., 2015). In fish, air exposure can cause physical damage to gills, such as collapse of the gill lamellae (Ferguson and Tufts, 1992). For juvenile and subadult sawfish, delayed recovery due to air exposure could lead to post-release predation. In bonefish, longer air exposure led to loss of equilibrium which can increase post-release predation six-fold (Danylchuk et al., 2007).
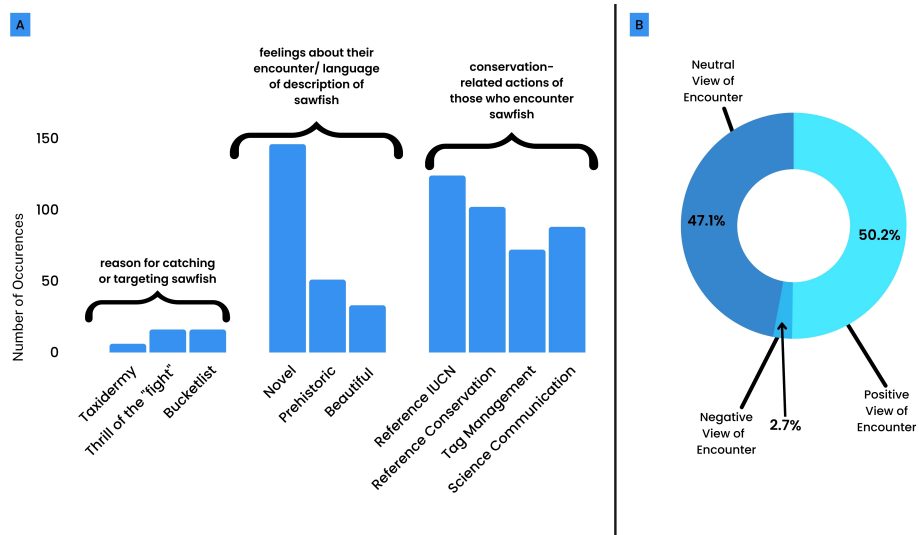
FIGURE 4
(A) caption analysis of 'reason for catching or targeting sawfish', 'feeling about their encounter/language of description of sawfish', and 'conservation related actions of those who encounter sawfish'. **(B)** breakdown of positive, negative, and neutral view of encounter based on captions.

In some cases, we identified specific locations on shore where sawfish are frequently encountered. These areas could benefit from signage encouraging people to report sawfish encounters or outlining best practices for sawfish handling. Signage is an effective way to reduce human impact (Medeiros et al., 2007; Allbrook and Quinn, 2020) and increase knowledge (Godinez and Fernandez, 2019). Furthermore, a recent study

found that unguided visitors who were previously ignorant of rules and regulations related to the environment are likely to read signs explaining rules, and follow the respective rules (Donnelly et al., 2021). We believe signage encouraging immediate release and reporting of sawfish encounters will likely be successful, especially for land-based shark anglers who generally have a strong conservation ethic toward sharks,
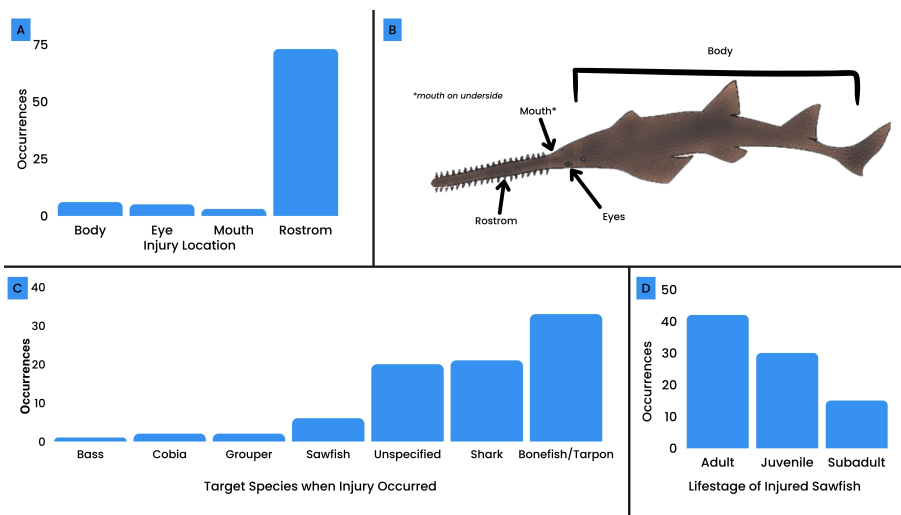

FIGURE 5
(A) frequency of sawfish injuries at body, eye, mouth, and rostrom. **(B)** diagram of injury location classification on the smalltooth sawfish. **(C)** species being targeted when injury occurred. **(D)** life stages of sawfish when injury occurred.

and value healthy shark populations (Shiffman et al., 2014), and casual anglers who may not otherwise be aware of sawfish conservation (e.g., for discussion of Florida shore-based angler knowledge about manta conservation, see Pate et al., 2021).

In this study, we mined social media posts to understand human-sawfish interactions (e.g., knowledge about fishing regulations, understanding of species conservation and management, behavior during interactions). These posts, while public, were not necessarily intended to be shared with scientists. For this reason, we were able to potentially capture different perspectives on these behaviors than would be offered by conducting a survey or looking at reported encounters. If this data was collected via traditional survey methods, such as interviews or focus groups, it could have been impacted by the social desirability bias, a phenomenon can result in inaccurate survey results due to self-presentation concerns related to illegal behaviors (e.g., illegally catching, targeting, or injuring an endangered species) (Fisher and Katz, 2000; Chung and Monroe, 2003; Krumpal, 2013). We recognize that analysis of social media posts has limitations, including the potential for being influenced by social desirability bias. For example, people may refrain from posting an encounter with a sawfish if they know their behavior is illegal, therefore, we may only have quantified those who are unaware their behavior is illegal or do not care if their behavior is illegal. Additionally, we surveyed posts which contained hashtags. With this method, there is potential for those exhibiting known illegal behaviors to still make posts; however, they may also omit hashtags in an attempt to avoid detection. Because of this, we suggest future studies use hashtags as well as other data-mining methods for social media surveys; for example, searches for sawfish encounters could be made with image searches or by location.

Our analysis of angler perceptions of their encounters via Instagram captions revealed reference to sawfish being a "bucket list" catch or a "bucket list" fish to encounter. Bucket list experiences are desirable experiences which people highly value; for example, in the tourism industry bucket lists are used to define worthy experiences (Thurnell-Read, 2017). We also recorded anglers referencing the "fight" with sawfish. This is consistent with past studies, which found that recreational anglers in Florida catch sharks for the challenge of fighting a large fish, seeking out a specific species, or for a sport (Falk et al., 1989; Fedler and Ditton, 1994; Shiffman et al., 2014; Mcclellan Press et al., 2016; Gallagher et al., 2017; Crandall et al., 2019; French et al., 2019).There are major conservation implications of anglers targeting sawfish specifically to "fight" them; prolonged fight time increases stress levels and post-release mortality in elasmobranchs (Hoffmayer and Parsons, 2001; Skomal and Mandelman, 2012; Whitney et al., 2017; Jerome et al., 2018; Wosnick et al., 2019; Rangel et al., 2021). Our analysis of caption

displayed that despite their rarity, catching a sawfish is a highly-valued experience, which is specifically sought out by some anglers.

In contrast with the many of the posts which reflected an overall positive view of those who encountered sawfish toward their encounter, we identified a small subset of anglers who referenced catching sawfish to "immortalize" them through taxidermy (Figure 4A). In order to maintain anonymity of this subset, we removed the names of shops referenced. It is important to note that these shops may not have been mounting sawfish bodies–but rather creating a replica based on a photo of the catch; however, it was not possible to differentiate from the social media posts.

Our assessment of encounters found that in general people had a positive attitude toward sawfish. While sometimes they were called "monsters", more frequently people were excited to encounter them, referenced their conservation, and were in awe of their visual beauty. For this reason, we believe that a nudge in the right direction via signage and outreach could lead to more encounters being reported and a potential increase in compliance with handling regulations for sawfish. Furthermore, across many fishing communities there is support for conservation efforts; for example, a study which conducted surveys of anglers indicated that they could serve as allies for the implementation of species-specific, catch-and-release guidelines (Mcclellan Press et al., 2016). Similarly, recreational spear-fishers have a history of supporting and helping to implement management plans (Sbragaglia and Arlinghaus, 2020). There is evidence for support of conservation by some anglers, even when there is conflict between anglers and the species of conservation concern (e.g., support for conservation of sharks despite depredation) (Coulson et al., 2022). One study found anglers support conservation of manta rays, another threated species of ray, which like sawfish are unlikely to be in direct conflict with anglers (Pate et al., 2021). With this in mind, we believe that angler support for conservation of sawfish is very likely, because sawfish-angler conflict is limited, and anglers are often excited about encountering sawfish.

We suggest facilitating a direct line of communication with those dive companies which are running "sawfish dives" to ensure they are following the FWC and the National Marine Fisheries Service Smalltooth Sawfish Recovery Team's guidelines. Outreach to those engaged in shark and ray ecotourism may be effective, as people who participate in ecotourism are often conservation-minded (Sutcliffe and Barnes, 2018). Similarly to signage in marinas, we suggest a collaboration between managers and dive shops, where dive shops have signs and brochures about what to do if a sawfish is encountered while diving. The Sawfish Recovery Team follows a recovery plan which was published in 2009 and "recommends specific steps to recover the population, focusing on

(1) educating the public to minimize human interactions with sawfish and any associated injury and mortality, (2) protecting and/or restoring important sawfish habitats, and (3) ensuring sawfish abundance and distribution increase" (Sawfish Recovery Team, 2022). The recovery team facilitates and conducts extensive outreach, especially in fishing communities; however, in this study we highlight areas where this work could be extended (e.g., by suggesting additional locations and stakeholder groups).

Unlike other science programs which may intentionally encourage public engagement with research by non-scientists and stakeholders, it is illegal for members of the public to target, handle, or seek out sawfish. Through this study, we identify where these encounters are most commonly occurring, who encounters sawfish, and their perceptions of the encounter. The purpose of this study is not to create a public sawfish science campaign; but rather, to identify the details surrounding current encounters to minimize them, promote animal welfare, and most of all encourage people to report encounters when they occur. It is important to recognize that sawfish encounters and sawfish bycatch at some frequency is unavoidable. However, outreach and stakeholder intervention can help to reduce the frequency of unreported sawfish bycatch, and potentially help to reduce bycatch and some of the most potentially harmful angler behaviors that are currently occurring. The data in this study provides detailed information which can be used for developing targeted outreach, which could prevent sawfish mishandling and bycatch and promote reporting of encounters

Conclusion

In this study, we use open-source and easily accessible Instagram posts to provide insights into the attitudes and behaviors of those who encounter smalltooth sawfish. These posts allowed us to obtain conservation-relevant data without completing formal surveys or focus groups which are relied on traditionally in environmental social science studies (Roberts, 2001; Arterburn et al., 2002; O'Malley et al., 2017; Pate et al., 2021). While these methods are effective and often produce data which can inform environmental policy and management, they can also be time consuming, expensive, and logistically difficult. This is particularly true when attempting to elicit the type of specific information examined here: surveying members of the public who have encountered a rare, geographically dispersed species would require considerable effort and resources with relatively low return. Further, the spatial and temporal specificity of the information gathered, as well as the details of personal conduct, would be more difficult to obtain from self-reported data on a survey in which one had to recall a particular incident. Our results are relevant not only to management and outreach strategies specific to smalltooth sawfish, but the methodology used in this study can be used as a framework for future studies of angler practices related to other charismatic and easy-to-identify species.

This study shows that relevant data on public perceptions, conservation knowledge, and behavior toward an endangered species can be obtained through open-source social media posts. Open-source data and low-cost methodology can improve the accessibility of science (McKiernan et al., 2016) and allow for more people to conduct conservation-relevant social science research, while contributing key data that can help inform management strategies, managers, and NGOs. Here, we quantified human-sawfish encounters documented on Instagram, and the details surrounding these encounters (e.g., the perceptions of the anglers, the handling behavior, and location of the encounter). With these details, targeted campaigns to reduce illegal behaviors and prevent sawfish bycatch and harassment can be developed by managers and NGOs.

Data availability statement

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

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements. Ethical review and approval was not required for the animal study because no animals were ever physically handled.

Author contributions

JS conceived and designed the research project, analyzed the data, and wrote the manuscript. JG assisted in writing of the manuscript, interpretation of the results, and consulted on ecological significance. JW helped develop the codebook, conducted ICR analysis, and assisted with interpretation of social science results. EW assisted in data analyses and writing. CM helped design the project, develop ecological codebook, write manuscript, and interpret results. All authors critically reviewed the manuscript. All authors contributed to the article and approved the submitted version.

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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/fcosc.2022.987909/full#supplementary-material

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