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Perceptions regarding the recreational cobia fishery in relation to manta ray conservation

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Abstract

1. Understanding fisheries requires not only traditional modelling approaches but also the incorporation of local ecological knowledge (LEK) which can provide other types of essential contextualizing knowledge.
2. Recreational anglers within the cobia fishery on the east coast of central and northern Florida target cobia by seeking out the manta rays cobia often follow and associate with, and casting at or near them. Results suggest this fishery poses a threat of entanglement, injury and disturbance to mantas in the region, especially associated with the practices and behaviours of inexperienced anglers.
3. Expert angler responses in interviews described changes in manta and cobia habitat use and reductions in cobia abundance
4. Experienced anglers pointed to social media as a key driver of the expansion of this fishery and as an explanation for their perception of the growing presence of novice anglers engaged in these practices. Respondents proposed best practices and potential management interventions and generally supported conservation action, including through willingness to engage with researchers and support management and enforcement measures related to the fishery.

KEYWORDS

cobia, conservation, entanglement, local ecological knowledge (LEK), manta ray, recreational fishing

1 | INTRODUCTION

Often fisheries management decisions are based solely on stock assessments and traditional fisheries models, however, exclusively using these tools to inform management strategies may elicit incomplete, inaccurate or biased model results, particularly for newly threatened or understudied species (Berkstrom et al., 2019; Gilchrist et al., 2005; Lima et al., 2017; Silvano & Valbo-Jorgensen, 2008). Local ecological knowledge (LEK) supplements and sometimes challenges knowledge derived through traditional fisheries management methods and has been essential in driving sustainable fisheries management in some locations (Aswani & Hamilton, 2004; Cardoso da Silva et al., 2020; Gervasi et al., 2021; Olsson & Folke, 2001). An overarching theme in successfully managed fisheries is the involvement and adaptive capacity of expert anglers (including recreational, commercial and subsistence fishers), as well as a deep understanding of both the technical and ecological systems involved (Gervasi et al., 2021; Grant & Berkes, 2007; Leduc et al., 2021). Many examples exist in which engagement with stakeholders has provided managers with essential knowledge (Mackinson et al., 2011) or improved the outcomes of management interventions (Pomeroy & Douvere, 2008).

Fisheries modelling of shark and ray species is particularly complex due to their general life history traits (e.g. late age-at-maturity, production of relatively few offspring) which create vulnerability to

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overfishing, a lack of available data on many species, unreliable harvest reports, wide range of habitats and the economic importance of these fisheries (Bangley & Shiffman, 2014; Blasco et al., 2020; Dulvy et al., 2014a; Dulvy et al., 2014b; Talwar et al., 2022). There is also evidence that many fisheries stock assessments for chondrichthyans are likely underestimating threats and subsequently misrepresenting risks of extinction (Bangley & Shiffman, 2014). Large-bodied and coastal sharks and rays, such as the giant manta ray (*Mobula birostris*), are particularly vulnerable to fishing-related mortality (Dulvy et al., 2014a).

Giant manta rays are listed as Threatened under the United States Endangered Species Act (ESA) and as Endangered by the International Union for Conservation of Nature (IUCN) Red List (Marshall et al., 2023; NOAA, 2018). The largest cause of direct mortality of manta rays globally is targeted fishing and capture as bycatch (Croll et al., 2016), though they face a range of other threats including marine pollution, vessel strikes and entanglement. ESA listing was based on declines in abundance in the Indo-Pacific and eastern Pacific regions, however, there is very little available data about manta ray populations in the Atlantic and Gulf of Mexico (NOAA, 2018). Recently identification of a possible nursery site in south Florida (Pate & Marshall, 2020) as well as evidence of important foraging and reproductive habitat in central and north Florida (Pate, unpublished data) demonstrates a need for further study of local threats and identification of potentially critical habitats. Assessing the conservation of mantas in the region is further complicated by the possible classification of the manta ray population in Florida as a separate species (*M. cf. birostris*) which likely occurs in sympatry with *M. birostris* (hereafter 'manta ray' refers to both species; Hosegood et al., 2020; Marshall et al., 2009; NOAA, 2019).

Due to their low fecundity and late age of maturation, manta ray populations are slow to recover from fishing pressure and are especially vulnerable to even very low fishing mortality rates (Dulvy et al., 2014b). In Florida, manta rays are prohibited from targeted catch (FWC, 2023; NOAA, 2018). Despite these protections, they are often seen trailing fishing gear, which is not necessarily or immediately fatal, but may impair feeding and swimming behaviours or cause serious bodily injury and direct mortality as a result of entanglement and subsequent drowning (Deakos et al., 2011; Gallagher et al., 2014; Pate et al., 2020; Pate & Marshall, 2020). Although recreational fishing has been understood as having both potential benefits and risks in marine conservation, in comparison to commercial fishing, its negative effects are historically understated (Carreno & Lloret, 2021; Freire et al., 2020; Potts et al., 2019).

Recreational fishers often have positive attitudes towards marine conservation and have in some cases made significant contributions to improving fishery management (Hillborn et al., 2020; Pate et al., 2020). When there is meaningful communication between anglers, researchers, management organizations and other stakeholders, conservation efforts may be more successful (Dedual et al., 2013; Sutinen & Johnston, 2003). Anglers are often wary that scientific research will impede their lifestyles or livelihoods, however, in some cases, anglers have suggested even more restrictive conservation measures than scientifically advised (Dedual et al., 2013; Miller et al., 2010). When anglers are active contributors to research-based activities, they may also self-impose stricter conservation measures than state or national regulations, creating a voluntary and informal institution among avid local anglers (Cooke et al., 2012; Dedual et al., 2013).

On the Atlantic coast of central and north Florida, there is a locally well-known and historically active fishery in which anglers track manta ray migrations for the purpose of targeting and landing cobia (*Rachycentron canadum*) (e.g., Bishop, 1999; McNally, 2012; Roberts, 2022). While relatively small by the standards of the major recreational fisheries in Florida, it has the highest landings of recreational fisheries for cobia among the Atlantic or Gulf Coast states (NOAA, 2019). Mantas are often followed by and associated with smaller fish, such as cobia, that use the significantly larger rays as a host that offers protection from predation (Nicholson-Jack et al., 2021; Figure 1). This study gathered data on angler knowledge, perceptions and behaviour in relation to the cobia fishery in central and north Florida and its relationship with resident and migrating manta rays. Data was collected and analysed in order to contribute to future management and conservation efforts and develop best practice guidelines grounded in the knowledge of experienced anglers within the fishery. Semi-structured interviews conducted with established anglers in the region may also provide otherwise missing current or historical data regarding the fishery and its potential effects on the manta ray population.

2 | MATERIALS AND METHODS

A fundamental aspect of LEK in resource management is the use of semi-structured interviews with local experts, also described as key informants (Kroloff et al., 2019; Tremblay, 1957). Participants should be selected for interviews based on their skill, experience and position relative to the resource and harvest, and therefore should not be selected randomly (Kroloff et al., 2019). Close-ended surveys and questionnaires are useful for eliciting quantitative data and for confirming or supplementing established information but leave little room for fully understanding the perceptions and attitudes of participants (Boniface & Burchell, 2000; Dongol & Heinen, 2012; Goyder et al., 2002; White et al., 2005). Semi-structured interviews are open-ended and allow space within conversations to reflect and expand on topics and contribute to developing relationships between interviewees, researchers and other stakeholders (Dongol & Heinen, 2012; Kroloff et al., 2019).

This project proceeded in two phases: first, in-depth semi-structured interviews were conducted with anglers (*initial interviews*). The results and key recommendations for policy and practice were summarized and sent back to the anglers for review and comment (*post hoc survey*). Data collection activities were conducted under University of Miami Institutional Review Board approval (protocol # 2018-1114).

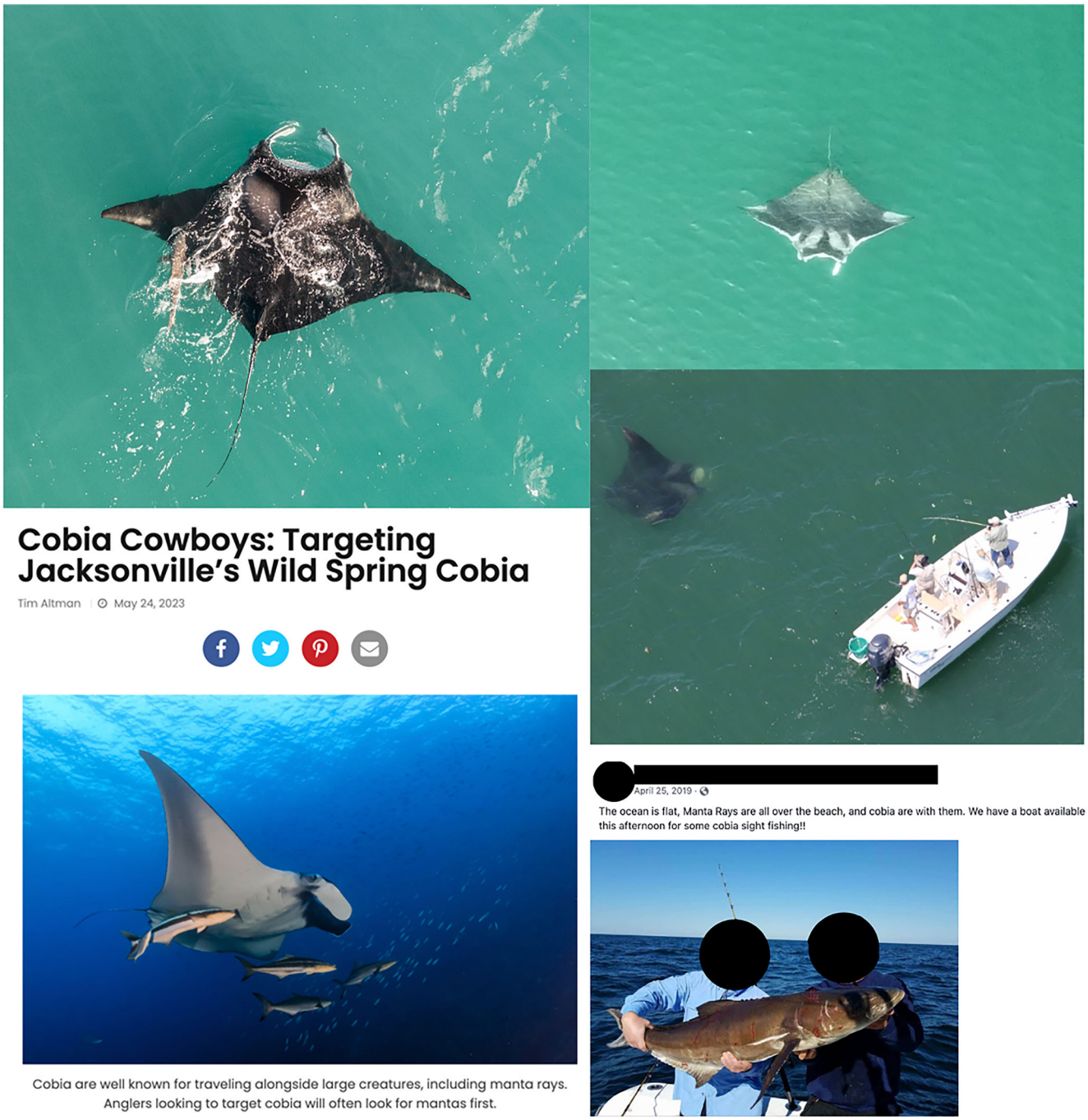

FIGURE 1 (from top left clockwise): Manta feeding at the surface with a cobia; manta ray with a missing right cephalic fin, an injury typically caused by fishing line entanglement; a boat casting at a cobia and a manta ray; example of social media post advertising manta ray aggregation; Florida Sportfishing article about fishing cobia around manta rays. (https://floridasportfishing.com/cobia-cowboys-targeting-jacksonvilles-wild-spring-cobia/).

2.1 | Initial interviews

Local expert anglers were identified through snowball sampling, in which interviewees are asked to suggest other potentially relevant individuals, and through Google searches of relevant keywords (e.g. 'cobia fishing St. Augustine'). Two anglers approached refused to participate in the study, citing a general distrust of researchers. Transcribed interviews ($n = 15$) were read by the authors and a code book was established to capture the breadth of responses and themes that emerged. Coding was then completed to quantify patterns and themes that arose across interviews regarding the following core topics: fishing methods used, attitudes towards current management

and regulatory approaches, perceived opportunities for management improvement, observed historical trends in species populations and sizes, and perceived changes in fishery norms and practices.

2.2 | Post hoc surveys

Findings from the interviews were summarized to capture overall descriptions of the fishery and its relationship to manta rays, as well as best practice recommendations associated with approaching manta rays, what gear to use, and how and when to cast near a manta. For each of these topics, anglers were asked to provide further comments, including whether they agreed with the summary, how common they believed practices were and how difficult they felt changes in practice would be to implement. Finally, anglers were asked about their interest in engaging in future outreach or conservation activities. A total of 80% of original interviewees (12 out of 15) participated in the *post hoc* surveys. In both original interviews and *post hoc* surveys, not every angler answered all questions.

3 | RESULTS

3.1 | Demographics and experience

Key informants were comprised of anglers who have been fishing professionally for an average of 22 years (range: 5–40 years). On average, we spoke to each angler for approximately 40 min (range: 15–75 min). The participants were all male. A total of 80% of anglers reported fishing professionally for more than 10 years. Participating anglers operated from boats with an average length of 28.7 feet, based out of the East coast of Florida ranging from St Augustine (29.9012° N, 81.3124° W) to Stuart (27.1975° N, 80.2528° W). Participants' businesses include guiding and chartered fishing trips, although one angler indicated that a large percentage of their business includes commercial fishing and corporate fishing sponsorships.

3.2 | Locating cobia

In initial interviews, all anglers reported sighting manta rays to fish for cobia, and 46.6% stated that they use manta rays as their primary method for locating cobia. Other methods reported include sighting turtles, bull sharks, floating debris or garbage, weed lines, wrecks, bait or plankton at the water surface, and looking for free-swimming cobia. Additionally, 60% of anglers reported actively tracking temperature changes in coastal waters to predict migration trends of both manta rays and cobia. They generally reported that once water temperatures fall between 68 and 72° Fahrenheit, cobia are more abundant closer to the beach near manta rays due to shared migration patterns. Anglers mentioned March and April as peak migration times for the mantas, though specific timing varies with water temperature.

Anglers indicated that although cobia fishing makes up a very small proportion of their total annual fishing effort, during manta ray migrations, they might exclusively turn their attention towards the cobia fishery until the water temperature changes or they can no longer reliably locate manta rays.

3.3 | Changes in abundance and location of cobia and manta rays

There was consensus among key informants in both initial interviews and the *post hoc* survey that the cobia fishery has changed significantly in the last one to two decades, although specific details of described changes varied across respondents. Anglers who addressed changes in cobia populations in initial interviews (9 out of 15 responded) reported that the average number of cobia trailing manta rays used to be approximately 15 cobia per manta ray (range: 6–40). Anglers (11 out of 15 responded) reported that today they feel lucky to see one or two cobia near a manta ray. Most anglers in initial interviews reported that it is now common to see manta rays without any cobia around them. In general, anglers reported that the fishery is 'not what it used to be', and they 'feel lucky if there's one, real lucky if there's two'. In the *post hoc* survey, 72.7% of anglers (11 out of 12 responded) agreed that the cobia population in central and north Florida has decreased in the last 10–20 years (Table 1).

Post hoc responses indicated that 63.6% of anglers (11 out of 12 responded) believe that manta ray habitat use and/or abundance has changed in the last 10–20 years. In initial interviews, there was a lack of consensus of how manta abundance has changed over time, with anglers reporting perceived increases (1 angler), decreases (2 anglers) and a lack of change (5 anglers) in abundance. Participants speculated that manta rays have learned to avoid boats, may be more spread out than in previous years, or may be changing their preferred habitat, spending more time on the reefs or in deeper or shallower water. Respondents (53.3%) in initial interviews agreed that any variation in the prevalence of manta rays can be predominantly associated with changes in temperature and food availability.

TABLE 1 Selected representative quotes from semi-structured interviews with professional anglers that target cobia that reference perceptions of changes in the number of cobia they find near manta rays. The numbers assigned to each quote correspond to individual angler interviews.

'back in the day, every time you saw a manta, there'd be cobias on them'[1]
'It's getting worse and worse every year'[3]
'I feel lucky if there's one, real lucky if there's two'[5]
'back in the day there'd be 25, but now there's a hundred and fifty boats out there so you know now, sometimes you see one, sometimes you see three, but you know it's not like it used to be and it's not because of the cobias, it's because of the people beating up the rays, and they get you now, split up.'[6]

3.4 | Angler interactions with manta rays

In initial interviews, all anglers reported that they believe there are problems within the cobia fishery. A total of 80% of participants mentioned significant increases in fishing pressure as one of the major causes of stakeholder conflict within the fishery. They reported perceived declines in cobia presence and identified other potential harms to manta rays in central and north Florida. Anglers reported seeing an average maximum of 22 boats (range: 1–50) surrounding a single ray or group of rays at the same time and indicated that the number of vessels has increased over time. One angler described these crowds of boats around manta rays as 'parking lots'. Anglers identified a lack of respect and/or fishing ethics among anglers, as well as a lack of regulation, as driving problems within the cobia fishery. However, one angler mentioned that while vessel strikes of manta rays do occur within the fishery, they believed these incidents to be rare.

In initial interviews, 86.6% of anglers reported that they have inadvertently hooked a manta and/or have had their clients hook a ray on one of their charters. While 73.3% of anglers attribute these incidents to poor casting or client error, 93.3% agree that inexperienced anglers are more likely than experienced anglers to hook a ray when fishing for cobia, and one mentioned not letting his most inexperienced clients cast at mantas. In the *post hoc* survey, 91% of anglers (11 out of 12 responded) reported having seen mantas with hooks, jigs, trailing lines or evidence of boat strike injuries. In reference to gear left in the rays, anglers in initial surveys described hooked or entangled mantas as looking 'like a Christmas tree', 'like Mardis Gras' or 'full of chartreuse' (Table 2).

All study participants agreed that once a hook or jig is set in a ray, it is not possible to retrieve the gear. They all reported that the fishing line breaks, or they purposefully break it once they are aware they have accidentally hooked a ray. Some anglers (26.6%) reported that if the hook is not set, they are sometimes able to open their spools to avoid setting the hook and carefully navigate around the ray to 'pop' the hook out before it sets, but indicated that this is not recommended for inexperienced anglers or boat captains. One angler reported hearing rumours about anglers intentionally attempting to catch manta rays in order to keep cobia near the boat to land them, but none said that they had done this themselves or knew anyone who had.

3.5 | The social media problem

In initial interviews, 40% of key informants, unprompted, identified social media as a driving force behind issues relating to the cobia fishery around manta rays. When directly asked about social media in the *post hoc* survey, 91% (11 out of 12 responded) agreed that social media has encouraged anglers to cast at manta rays, with one of the anglers emphasizing that social media teaches novice anglers bad habits. Respondents reported that social media 'has killed the fishery', 'completely ruined cobia fishing', or at the least, 'has not helped at all'.

TABLE 2 Selected representative quotes from semi-structured interviews with professional anglers that target cobia that reference perceived problems with the cobia fishery in the region. The numbers assigned to each quote correspond to individual angler interviews.

'Anyone who has fished for cobia has hooked a manta'[4]
'when you snag a manta ray, you just ruined your chance of catching the cobia that are on it'[14]
'I think people are unconcerned about the rays, so they hook them and the idea is, you can just tie on another jig.'[2]
'Social media has killed this fishery. Everybody starts posting about it, talking about how great it is, showing videos, and everybody wants to get in on the action.'[3]
'I wouldn't mind it being a catch and release fish.'[4]
'I net them if they want a picture, and we-and I release them. I just feel like… there's not enough of them around anymore so I just release 'em.'[5]
'Now when someone catches one, of course they want to put their picture up the same moment that they caught it, which alerts their friends, which alerts… it's like wildfire. I mean I've seen it happen, you know, nobody would be out one day and the next day there's literally hundreds of boats looking for them'[5]
'I haven't seen an FWC officer in the water in a long, long time'[6]
'I personally would like to see them just close cobia in Florida. Until the stocks rebound.'[13]
'information used to be very guarded. You used to have to learn things from years of experience or earn the respect of other anglers who were skilled themselves, who would teach you things, and nowadays there's people on the internet that just for clicks, and likes, and views will create videos on YouTube and other places that basically tell everybody everything that they wanna know, and unfortunately that's fast tracking the learning process for people and you end up with a situation where you have people that know how to go do something, that put no effort into learning that themselves, and as a result, they don't have the respect for what they're doing.'
'But I also worry that people are just gonna go out and catch cobia and just keep fishing and probably throw fish back out of the boat that have been killed and harvested already if they catch a bigger one, rather than just releasing. But people do that already, no matter what.'[14]

A total of 80% of participants mentioned significant increases in fishing pressure as one of the major causes of satkeholder conflict within the fishery. They reported perceived decreases in cobia presence, and identified other potential harm to manta rays in central and north Florida. To avoid this, respondents generally reported waiting for a period of days to weeks before posting on social media about their interactions with mantas and cobia. Despite general criticisms of the effects of social media on the fishery, 20% of anglers interviewed reported being featured on popular fishing shows on television or having amassed a substantial following on social media platforms like YouTube and Instagram based on their fishing careers.

3.6 | Management suggestions and conservation attitudes

This fishery is currently managed by the Florida Fish and Wildlife Conservation Commission (FWC). Proposed best fishing practices

identified by the interviews and reviewed by key informant anglers are provided in Appendix A. Although 80% of anglers in initial interviews reported believing that there is a problem with too many boats on the water or overcrowding of manta rays, all said that vessel limits around mantas would be too difficult to enforce and would not represent a feasible strategy for managing this fishery (Table 3). Anglers suggested other management strategies, including seasonal or yearly closures of the fishery, bag and slot size adjustments, limits on how many people or rods are allowed on each vessel and an overall declaration of cobia as a catch-and-release fishery. Other suggestions included mandatory fishing and/or boating courses and more law enforcement officers on the water checking boats for illegal catches. Additionally, anglers called for more responsible fishing practices, such as not casting at or gaffing undersized fish.

All informants expressed interest in marine conservation and concerns about fishery sustainability, including the need for the protection of cobia and manta rays. Some motivations for these concerns include wanting to continue fishing, and a desire to ensure their children can enjoy fishing as well. Although levels of enthusiasm for managers and management action varied, all anglers were willing to maintain a relationship with the interviewer in terms of sharing information about manta ray sightings. In the *post hoc* survey, 75% expressed willingness to participate in conservation outreach media, and 91.6% expressed willingness to report manta ray sightings.

TABLE 3 Selected representative quotes from semi-structured interviews with professional anglers that target cobia that reference perceived lack of codes of conduct and increases in boat presence surrounding the cobia fishery in relation to manta rays. The numbers assigned to each quote correspond to individual angler interviews.

'It's gotten a lot worse though. there's so many boats and so few fish, it seems like everyone's bombing the same ray you know with the- and that same manta ray that just swam by is gonna see another 50 jigs in his face, you know and that's just what it became.'[4]
'it's a rodeo out there It's the wild wild west.'[11]
'It all depends on who the people are, but as a rule people are very aggressive. People are-- because of the lack of fish, you know the opportunity to catch one, you know, a lot of guys say they haven't seen one for three years, and here are manta rays and cobia… And you know, they wanna catch one so bad. They're very aggressive.'[13]
'Typically earlier in the season, when the fish are first showing up, only the most knowledgeable anglers are on them, and people are trying to keep that information quiet, that the fish are in one certain area.'[14]
'we call it a parking lot'[1]
'It's hard when you got 50 boats on one little pack of rays running. We call it running and gunning cause they just see them and zoom full throttle. I mean you got six of them doing the same things at once.'[6]
'It's just courtesy. It's just people freak out, they've never done it before and they just wanna get in on it so bad that they just don't care. Like I literally been fighting a fish and had somebody you know, throw a line over my line and they hooked my line while I'm fighting a fish. It's like, you're about to break me off because you're getting greedy. Like, dude there's 20 rays out here, go pick another ray.'[3]
'Oh yeah, I've seen many people yell at each other and almost get into fist fights, thrown stuff at each other, and threaten each other over these fish. I mean, it's just, that's just normal. And it shouldn't be.'[3]
'you try to, you know, to set yourself up in the right position and usually those guys will bulldoze in and throw their jigs, you know, and they can't even see the ray.'[11]
'it's like a free for all and a rodeo. You know, they jump up on you and throw jigs. I've had people's jigs land in my boat when they're trying to throw on a manta ray right next to- that I'm trying to work,'[11]
'I mean they're totally harassing the rays, and at some point the rays go down'[13]
'they're just trying to you know race to where they saw a ray jump faster than they normally would because there's somebody else racing there and they're trying to beat them there to get that shot.'[14]

4 | DISCUSSION

Anthropogenic threats facing south Florida juvenile manta rays (Pate & Marshall, 2020) are better known compared with threats to adult manta rays in central and north Florida. This lack of information is largely due to the difficulty of obtaining individual photo identification and physical evidence of incidental fishing gear interaction or boat strikes in the turbid waters of central/north Florida. In south Florida, 23.1% of observed manta rays are seen with trailing fishing gear, including hooks, line and weights (Pate, unpublished data), and most interactions appear to result from mantas swimming into set fishing gear, not from direct casting at rays (Pate et al., 2020). Cobia are rarely seen with manta rays in south Florida (Pate & Marshall, 2020) and only 6.1% of shore-based anglers in the region mentioned the existence of a relationship between cobia and manta rays (Pate et al., 2020). The variation in the threat of recreational fishing interactions to manta rays between anglers in south versus north/central Florida highlights the need for region-specific information in quantifying threats and creating management plans.

Western Atlantic cobia are divided into two stocks: the Atlantic cobia stock (Georgia to New York) and the Gulf cobia stock (Florida) (Perkinson et al., 2019). These fisheries are unique in that the vast majority of cobia catch is by recreational anglers (95% for Gulf Stock, Foss et al., 2022; 92% for Atlantic stock (SEDAR, 2020)). Gulf stock cobia was recently described as undergoing overfishing (SEDAR, 2020), which led to updated FWC regulations for cobia, including increases in minimum size (from 33 to 36 in. fork length) and reductions in commercial bag and vessel limits (maximum of one fish per harvester and two fish per vessel) (FWC, 2022). In agreement with current stock assessments, respondents reported dramatic declines in both abundance and average body size of cobia in the region. Anglers in this study emphasized a need for more conservative regulation of cobia and for further study into stock differentiation, habitat use and migration patterns. When asked to provide recommendations for improving the management of the cobia fishery, anglers suggested actions ranging from limits on the number of rods on boats and mandatory boating and fishing classes to more stringent measures such as seasonal closures (during the spring months of

March, April and May) and only allowing catch and release of cobia. Multiple anglers stressed the need for more law enforcement on the water to prevent the illegal harvest of cobia.

In addition to conservation concerns around declines in cobia populations, all anglers reported being aware of the high prevalence of incidentally hooking manta rays while targeting cobia. Most anglers (86.6%) reported having hooked mantas themselves, although most indicated that these incidents occurred early in their careers. Inexperience was cited as the number one cause of incidental hooking. This indicates a need for training of fishers in best practices and consideration of manta ray protections when evaluating regulations around the cobia fishery both in state (FWC) and federal (NOAA) waters. Although one angler mentioned tripletail (*Lobotes surinamensis*) as another species that can be found near manta rays, no other targeted fishery is known to be similarly associated with incidental hooking of manta rays in the region. Anglers pointed to the fishery as contributing to harmful anthropogenic effects on manta rays, suggesting the value of further study and exploration of potential conservation and management strategies to reduce risk. Respondent reports that a growing number of boats on the water targeting cobia around mantas could cause increased occurrence of incidental hooking. The significant increase in boat sales and vessel traffic in Florida in recent years, likely related to the COVID-19 pandemic, may exacerbate some of these risks as fishing and boating pressures increase (Hanson & Sauls, 2011; FWC, 2021; Stacy, 2021; Tsai, 2021; Wagner, 2022; NMMA, 2022). However, there is substantial variability in the extent to which changes to cobia fishery management would be likely to directly benefit manta ray conservation, with some proposed measures (seasonal or yearly closures) potentially offering significant benefits, while others (decreases in bag limits, limits on number of people or rods per vessel) would likely have more ambiguous effects. Similarly, increases in the minimum legal size for cobia or shifts to a fully catch-and-release fishery may not have any effect on bycatch or entanglement risks.

NOAA released Safe Handling and Release Guidelines for Manta and Devil Rays, which recommended bringing a hooked ray to the boat to remove hooks (Carlson et al., 2018; Horn, 2021;). Smaller mobulid species (such as *Mobula hypostoma*) are considerably easier for anglers to handle and release, whereas it is unlikely that anglers on smaller recreational fishing boats can safely handle manta rays due to their large body size, and it is even less likely that anglers are able to keep the rays on the line long enough to remove hooks, as manta rays will typically break recreational strength lines with relative ease. Cases where anglers with heavy tackle have attempted to bring hooked manta rays to shore have resulted in long fight times (30–180 min) which could cause significant stress in the rays (Gallagher et al., 2014; Pate et al., 2020). Participants in our study indicated that in 100% of incidents in which rays are hooked while targeting cobia, the line is then cut or broken. This suggests that current best practices may not be directly applicable to the recreational cobia fishery and that the development of guidelines geared towards the prevention and mitigation of recreational incidental interactions (Appendix A) may be a useful supplement to NOAA's existing guide, which would then need to be adopted and enforced by FWC. Guidelines include encouragement for anglers to cut or break the line as close to the ray as possible, which leaves less line that can wrap around the body and fins during somersault feeding. These entanglements can result in amputation or truncation of the cephalic and pectoral fins, and mantas missing cephalic fins have been observed in central Florida (Figure 1; Pate, unpublished data). Missing cephalic and pectoral fins could impede a manta ray's ability to forage, swim efficiently or even communicate with other mantas (Perryman et al., 2021).

Some respondents in this study described their belief that manta rays are learning to avoid boats, which may contribute to variations in manta behaviour and habitat areas used. Research into manta social behaviour and capacity to learn may support the feasibility of this claim (Perryman et al., 2019). Chondrichthyan species have complex learning capabilities, although the extent of these capabilities is still poorly understood due to difficulties in handling and maintaining many species of sharks and rays in captive or semi-captive environments (Brown & Schluessel, 2023; Guttridge et al., 2009). Thus, it is reasonable to assume that manta rays have the potential to learn to avoid boats in the area to avoid accidental hooking, boat strikes or harassment. This possibility has value as a potential area for outreach to anglers, as to the extent they perceive fewer or more skittish mantas as the result of their own boating and fishing behaviour (e.g. fast or too-close approaches, crowding, accidental hooking and boat strikes) they may be motivated to interact more carefully out of perceived self-interest.

However, there are also questions about the ability of some anglers to successfully alter their behaviour to improve conservation outcomes in this fishery. All expert angler respondents cited inexperience as the overwhelming cause of incidental hooking of manta rays in the cobia fishery. They reported that more boats on the water and increased availability of online information on how and where to find manta rays and catch cobia have led to the fishery becoming more popular among novice anglers. Wilson (1990) describes fishing experience as intellectual property, observing that no one angler can successfully exploit the entire ocean, but that an exchange of intellectual property in the form of experience and knowledge allows for a higher level of overall exploitation. In the age of social media, information is shared much more easily and frequently than it was historically (Guay et al., 2023). Most survey respondents (82% in the *post hoc* survey) described social media as a significant contributor to incidental manta hooking, as it facilitates quick distribution of information when manta rays are in the area, causing novice or inexperienced anglers to crowd the areas. With approximately half of the world's population online in some form, social media has been shown to have the potential to both positively and negatively impact wildlife conservation (Bergman et al., 2022). When used irresponsibly, social media may indirectly increase the risk of exploitation, visitor pressure and the spread of misinformation, while positive effects can include increases in conservation funding or behaviour, and pro-environmental policy changes (Bergman et al., 2022). Increased use of the internet by novice or inexperienced anglers in order to learn how to fish a certain species is not inherently

negative and may give them opportunities to learn from experienced anglers, but could also lead to misunderstandings and improper handling, especially in cases where instructional videos on YouTube or other online platforms include outdated information and/or are from states with different fisheries regulations, leading to unintentional or accidental illegal fishing practices (Guay et al., 2023).

Novice anglers who learn fishing methods on the internet (or through a combination of the internet and interpersonal relationships) may become more conservation-oriented and willing to change their behaviour to support fishery management due to ease of access or exposure to conservation-oriented materials (Guay et al., 2023). This assumes that the majority of information on the internet around a particular fishery is conservation-oriented—so conversely, ease of access to misinformation might cause novice anglers to change their behaviour in potentially harmful ways, as research suggests harmful behavioural messages can be normalized or reinforced through online exposure (e.g. Campaioli et al., 2017). The relationships built with expert anglers through this project present an opportunity for fishery and conservation managers to collaborate with experienced anglers who already have social media platforms to inform and educate newer anglers. Stakeholder collaboration has the potential to bridge the distrust of researchers and managers and strengthen relationships in order to positively influence the management and protection of both cobia and manta rays in Florida (Shiffman et al., 2017; Suman et al., 1999).

5 | CONCLUSION

By compiling attitudes and knowledge from experienced anglers in Florida who have been fishing for cobia for many years, we were able to use LEK to identify recreational fisheries-related threats to manta rays in the region. We were also able to compile anecdotal evidence of changes in population and habitat use of both cobia and manta rays. As anglers continue to perceive cobia fishing as less reliable and turn their efforts towards other fish stocks, observational and historical knowledge on the fishery may be lost (Colloca et al., 2020). These compiled data may provide support for effective management action moving forward. We found that expert anglers are generally mindful and enthusiastic about supporting conservation measures for cobia and manta rays and are willing to maintain relationships with researchers. Enhancing pathways for reliable shared information between novice and seasoned anglers and fostering positive relationships between researchers and stakeholders may be an important step in fostering collaborative conservation measures to protect both cobia and manta rays in Florida.

We echo best practice suggestions from anglers (included in Appendix A) and encourage the implementation of optional supplementary educational courses by FWC for those pursuing fishing licences to increase awareness of best practices for fishing taking place near non-target marine megafauna. We encourage efforts to increase internet and social media exposure to expert knowledge to reduce the risks of misinformation and improper fishing methods. Additionally, we join expert anglers in encouraging an increased presence of wildlife law enforcement on the water and at landing points, particularly during peak manta ray migration periods each spring.

AUTHOR CONTRIBUTIONS

Raquel Braun: Writing—original draft; data curation; formal analysis; investigation; validation; visualization. **Julia Wester:** Supervision; data curation; methodology; validation; writing—review and editing. **Catherine Macdonald:** Supervision; validation; writing—review and editing. **Jessica H. Pate:** Conceptualization; supervision; data curation; funding acquisition; investigation; methodology; project administration; resources; validation; visualization; writing—review and editing.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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APPENDIX A

Best practices for cobia fishing around manta rays

In speaking with experienced anglers in Florida, we have compiled a list of best practices for fishing cobia near manta rays in order to reduce disturbance and harm to manta rays.

Approach:

- Once an angler spots a manta ray, it is best to approach slowly and maintain your speed at an appropriate distance from the ray.
- Assess its behaviour and watch for signs of distress or avoidance.
  - That is, change in direction or diving deeper in the water column
  - Look for the white cephalic fins ('horns') to identify the head of the manta
- If the ray is calm, continue in the same direction, parallel to the ray. Do not block its path of travel. If the ray comes towards the boat, shift to neutral.
- Patiently maintain course, and if the ray is undisturbed and maintaining its speed and direction, proceed with casting.
  - If more than one angler is on the boat, take turns casting one at a time.
- Practice 'first come, first serve' courtesy. If a boat is near a ray, do not approach it. Try to find another ray.
- Do not speed towards breaching mantas. If you see a 'jumper' motor slowly towards the area. Feeding manta rays will likely remain in the same area and speeding boats will only scare them. Practice patience and wait for the ray to resurface.
  - Changing RPMs may discourage the ray from resurfacing.
  - Boating at high speeds in areas where manta rays are seen jumping may increase the likelihood of a vessel strike.

Gear:

- Circle hooks may be less likely to snag the ray if you cast too close to the ray.
- Non-stainless steel hooks will rust and eventually fall from the ray if one is accidentally hooked.
- If you make an inaccurate cast, quickly sinking lures are more likely to hook a manta ray.
  - Consider using lighter or floating lures, weedless lures or popping corks.
- Consider using a trolling motor in areas with manta rays. A slower, quieter motor may be more conducive to approaching rays.

Casting:

- Avoid casting too close, on top of or in front of the ray. Ensure your hook lands outside of the ray's wingspan.
  - The lure does not need to be especially close to entice the cobia out from under the ray.
- When possible, cast with the wind behind you to ensure a more accurate cast.
- Cast between the ray and the boat rather than across the ray.
- If you do not feel confident, do not make the cast.
- If you make a bad cast, immediately reel in the line to decrease the chance of hooking the ray.
- Practice makes perfect. Practice casting when manta rays are not around to improve accuracy.
- If you do accidentally hook a ray, palm the spool or lock your drag. Doing this will break the line as close to the hook as possible. A long trailing line can become entangled around a ray and cause serious injuries.

Consider hiring an experienced guide if you are new to cobia fishing.