ARTICLE





Willingness of Recreational Anglers to Modify Hook and Bait Choices for Sea Turtle Conservation in Mobile Bay, Alabama, Gulf of Mexico

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ABSTRACT

Saltwater angling is a culturally significant and economically vital coastal recreational activity, particularly in the Gulf of Mexico that attracts enthusiasts worldwide and contributes significantly to the well-being of Gulf Coast communities. However, angling can threaten ecologically important species, notably sea turtles, which are federally protected under the Endangered Species Act. In commercial fisheries, using circle hooks over traditional "J" hooks and using specific bait types can reduce sea turtle bycatch and fishing gear interactions. However, angler willingness to use these techniques is unknown. Our study aimed to assess the willingness of recreational anglers to adopt tackle modifications to support sea turtle conservation. A mixed-mode survey was used to gather data on angler knowledge, behaviors, and attitudes toward sea turtle-friendly practices. Factors such as gender, state residency, recreational and fishing motivations, and ecological knowledge influenced angler willingness to adopt sea turtle-friendly tackle modifications. We conclude that conservation strategies and educational outreach must be tailored to specific fishery management objectives.

1 | Introduction

Saltwater angling is one of the most prominent and culturally important coastal recreation activities in the United States, particularly in the Gulf of Mexico (hereafter "the Gulf") (Li, Vogel, and Viswanathan 2019). The Gulf's diverse marine life and robust fisheries attract tourists and fishing enthusiasts from around the world (Ditton, Holland, and Anderson 2002). Saltwater fishing is a significant economic driver that includes charter services, fishing equipment, license sales, and tourism-related businesses, which ultimately create jobs and stimulate economic growth in states surrounding the Gulf (National Marine Fisheries Service 2022; Carter and Liese 2012). Saltwater fishing is also a culturally significant form of outdoor recreation. Access to recreational fishing improves the overall quality of life for Gulf Coast inhabitants and visitors alike, by linking communities to their marine heritage and fostering a connection with local ecosystems (Thomas and Vogelsong 2004; Young, Foale, and Bellwood 2016). Anglers also serve a vital role in conservation efforts, by contributing valuable data to scientific

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research that informs regulations and improves fishery management (Fedler and Ditton 1994; Venturelli, Hyder, and Skov 2017; Taylor et al. 2022). Ultimately, sustainable management of recreational fishing and marine resources is crucial for preserving the Gulf's economic, cultural, and ecological vitality. However, many marine species face global conservation threats due to bycatch (the unintentional capture of nontarget species while fishing for another species) and negative interactions with fishing gear, especially charismatic and ecologically important species like sea turtles.

Five of the seven sea turtle species in existence worldwide are found in the same Gulf of Mexico waters that are popular among recreational anglers, including loggerhead (Caretta caretta), green (Chelonia mydas), leatherback (Dermochelys coriacea), hawksbill (Eretmochelys imbricata), and Kemp's ridley (Lepidochelys kempii) (hereafter "sea turtles") (Ward 2017). All sea turtle species found in US waters are listed as threatened or endangered under the US Endangered Species Act of 1973 (ESA). The ESA safeguards sea turtles and their populations from anthropogenic activities by listing them as endangered or threatened, thereby making any form of what the law refers to as "take" illegal (as defined under the ESA, "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct"). Once a species is listed, federal agencies must enforce the prohibition of take, designate critical habitat, and develop and implement recovery plans (Valdivia, Wolf, and Suckling 2019). Many US fisheries have regulations to minimize bycatch or interaction of protected species, including sea turtles. Sea turtles present unique conservation challenges because they spend important parts of their lives both at sea and on land. Two federal agencies share jurisdiction over their conservation: the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service and the US Fish and Wildlife Service (FWS). NOAA oversees sea turtles in marine environments, while FWS manages nesting beaches and other terrestrial environments (Moore et al. 2009). However, even with such federal protections, sea turtles that reside in or near human-populated coastal ecosystems may be more vulnerable to anthropogenic threats, including recreational fishing (Ditton, Holland, and Anderson 2002).

Recreational saltwater fishing can present challenges to the conservation of sea turtles (Figure 1). Nearshore recreational hookand-line captures are identified as a threat in recovery plans for all Gulf species, except the leatherback, whose major threats are pelagic longline commercial fisheries (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1991, 1993, 2008, 2024; Swimmer, Zollett, and Gutierrez 2020; Lewison, Freeman, and Crowder 2004; U.S. Fish and Wildlife Service et al. 2011). Recently, bycatch of sea turtles has increased, especially by hook-and-line fishers from fishing piers while using lines, hooks, and nets (Cook, Dunch, and Coleman 2020; Putman, Hawkins, and Gallaway 2020). Bycatch often results in injuries or fatalities if sea turtles become entangled in gear, which can lead to physical trauma, increased risk of drowning, starvation, infection from gear cutting into their flesh, and increased likelihood of vessel strikes as they struggle to navigate waters freely (Duncan et al. 2017; Foley et al. 2019; Himpson, Dixon, and Le Berre 2023; Innis et al. 2010). Furthermore, ingestion of fishing gear can damage the esophagus and gastrointestinal tract, thereby hindering feeding, all of which can be fatal (Wilcox et al. 2018; Lima et al. 2022; Heaton et al. 2016). The frequency of sea turtle bycatch depends on variables such as hook style, bait type and accessibility, depth, and gear setting or retrieval (the way an angler reels in an accidentally captured turtle) (Swimmer, Zollett, and Gutierrez 2020; Shelley et al. 2014). Thus, if anglers adjust their gear and methods, they may save protected wildlife, including sea turtles.

Use of large circle hooks, rather than traditional "J" hooks that are narrower with prominent barbs (Figure 2), can reduce the risk of serious injury to sea turtles and other marine life by reducing deep hooking in commercial pelagic longline fisheries (Watson et al. 2005; Sales et al. 2010; Santos et al. 2012; Stokes, Epperly, and McCarthy 2012; Gilman et al. 2015; Pacheco



FIGURE 1 | Sign educating visitors about sea turtle laws and protections on a fishing pier in Fort Morgan, Alabama. Photo taken by the author.

et al. 2011). Deep hooking occurs when the hook is swallowed in the esophagus or deeper, rather than being hooked in the mouth or superficially on the body, referred to as foul hooking (caught by a hook anywhere on its body except in its mouth) (Parga 2012; Epperly et al. 2012). However, further research is needed to assess the effectiveness of circle hooks in recreational fisheries, especially smaller circle hooks, because the large size of hooks (such as 16/0 and 18/0) is a key factor in preventing sea turtles from swallowing them. Additionally, certain baits that are more attractive to sea turtles based on their diet (Table 1) may increase the risk of negative interactions (Stringell et al. 2016; Plotkin, Wicksten, and Amos 1993; Dodge, Logan, and Lutcavage 2011; Ramirez et al. 2020; Seney 2016; Mariani et al. 2023). The way that sea turtles select bait to pursue is influenced by variables including visual size, shape, color, physical texture, chemical aroma or flavor, and other sensory factors (Pacheco et al. 2011; Yokota, Kiyota, and Okamura 2009; Piovano, Farcomeni, and Giacoma 2012; Southwood et al. 2007). Whole finfish baits, such as mackerel and mullet, contrary to squid bait, reduce sea turtle bycatch in some commercial saltwater pelagic fishing industries (Watson et al. 2005; Gilman et al. 2015, 2007, 2020; Rueda et al. 2006; Brazner and McMillan 2008; Jribi et al. 2011; Bach, Gamblin, and Lucas 2008). Since live finfish are not a major dietary component for four out of the five Gulf sea turtle species, using finfish as a bycatch mitigation strategy might improve



FIGURE 2 | Comparison of fishing hook designs: (a) J-hook and (b) circle hook (Kaminsky and Schwipps 2020).

unintentional capture among the majority of turtle species besides the Kemp's ridley (Ramirez et al. 2020). However, the success of hook-and-bait-based mitigation techniques is contingent on fishery-dependent factors, including bait and gear type, turtle species and life stage, season, and specific ocean that require careful evaluation for each fishery (Swimmer, Zollett, and Gutierrez 2020; Read 2007; Foster et al. 2012).

We sought to determine if recreational anglers would be willing to adopt sea turtle-friendly tackle modifications (fishing equipment used to catch fish, including rods, reels, lines, lures, baits, and hooks), such as changing bait and hook styles, which can dramatically influence the risk recreational fishing poses to sea turtles and other taxa (Foley et al. 2019). Significant research has been used to develop and evaluate sea turtle-safe fishing practices in the commercial fishing industry, but few studies have investigated recreational angling, one of the largest and most widespread stakeholder groups in sea turtle conservation. Using a mixed-mode survey, we evaluated the willingness of anglers to modify their tackle use and relationships between that willingness and factors that can inform fish and wildlife managers about potential barriers and incentives. Thus, our findings could facilitate the development of targeted and effective educational campaigns and outreach programs. Social science research of this kind not only enables the promotion of environmentally responsible fishing practices but also fosters a collaborative approach wherein anglers become active participants in the preservation of marine ecosystems (Brinson and Wallmo 2017; Virgili et al. 2024; Gray and Jordan 2010; Grooms et al. 2022). Moreover, a willingness to adopt wildlife-friendly behaviors, while engaging in outdoor recreation, can be applied in settings beyond the Gulf, with other protected species.

2 | Methods

2.1 | Study Site

The study was in the Mobile Bay ecosystem (Figure 3), an expansive estuary in coastal Alabama that ranks as the 6th largest estuary in the continental United States (Handley et al. 2013). Renowned for its ecological significance, Mobile Bay serves as a critical habitat for a diverse array of marine fish and wildlife

TABLE 1 Diets of adult sea turtles found in Gulf of Mexico waters.

Species	Publications	Classification	Adult Diet
Loggerhead (Caretta caretta)	Mariani et al., (2023) Plotkin, Wicksten, and Amos (1993)	Carnivore	Crabs, mollusks, horseshoe crabs
Green (Chelonia mydas)	Stringell et al., (2016)	Herbivore	Algae, seagrasses, seaweed
Leatherback (Dermochelys coriacea)	Dodge, Logan, and Lutcavage (2011)	Gelatinivore	Soft-bodied invertebrates
Hawksbill (Eretmochelys imbricata)	Stringell et al., (2016)	Spongivore	Sponges
Kemp's ridley (Lepidochelys kempii)	Ramirez et al., (2020) Seney (2016)	Carnivore	Crabs, fish



FIGURE 3 | Study area where recreational angler willingness to change hook and bait types was evaluated in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023. Map provided by the Alabama Department of Conservation and Natural Resources Marine Resources Division.

(Handley et al. 2013). This biodiversity, coupled with varied habitats, attracts thousands of visitors annually, especially those interested in marine recreational activities like boating and fishing (Zhang, Li, and Guo 2015).

Mobile Bay has earned its reputation as a recreational fishing hub, recognized as the "Red Snapper Capital of the World," a title earned through its remarkable contribution to Gulf recreational catch. This achievement is attributed, in part, to the state's innovative Artificial Reef Program, initiated in the 1950s, which strategically places materials such as car bodies, ships, and planes as artificial reefs (Minton and Heath 1998; Patterson et al. 2007). These artificial reefs have significantly enhanced species diversity, particularly by benefiting valuable reef and sport fish sought by anglers. The region is further distinguished by its jubilees, a globally rare phenomenon where fish and crustaceans migrate into shallow shorelines and beaches every year in response to seasonal oxygen depletion (May 1973; Loesch 1960). Although jubilee events can occur elsewhere in the world, Mobile Bay is one of the only bodies of water on Earth where this phenomenon is regularly observed, typically in summer, with a high degree of predictability

(Dybas 2005). This aspect adds to the allure of Mobile Bay, by making it a unique and special destination for both recreational fishing and maritime culture.

The recreational fishing industry is integral to Alabama, by supporting local livelihoods, preserving cultural heritage, and contributing to the overall well-being of coastal communities. Concurrently, five of the seven sea turtle species worldwide use Alabama waters, and three use beaches directly for nesting (loggerhead, green, and Kemp's ridley) (Guyer, Bailey, and Mount 2015). This dynamic combination of ecological richness and recreational appeal makes Mobile Bay an ideal setting for our study to explore angler willingness to adopt conservation measures that benefit sea turtles in the greater Gulf of Mexico.

2.2 | Survey Instrument and Data Collection

A mixed-mode survey was used to understand Alabama angler demographics, knowledge, and attitudes toward sea turtles, and their interactions with these species. The survey included 46 questions, including text entry, matrix tables, and multiple-choice 5-point Likert-type scales, to gather detailed demographic data about anglers who fished in coastal waters (Supporting Information). The project was a collaboration between the Alabama Department of Conservation and Natural Resources Marine Resources Division (ADCNR/MRD), NOAA, and social scientists at the Auburn University College of Forestry, Wildlife, and Environment. The survey adhered to guidelines and requirements of the Auburn University Institutional Review Board, approved under reference 22–502 EX 2211.

Surveys were voluntary, and only those who had visited the Alabama coast in 2023 and were at least 19 years old were eligible to participate. Participants were categorized by residency type to assess differences in engagement and perspectives. Residency types included residents who live in the state or on the property year-round; seasonal residents who reside only part of the year; and short-term visitors who visit one to three times, four to six times, or six or more times annually. The survey was available online and on paper to promote accessibility and increase response rates. The primary method for gathering data in person was an intercept approach at locations frequented by coastal visitors, such as marinas, piers, and beaches, and recommended coastal businesses like restaurants, lodging facilities, and retail establishments, as advised by the ADCNR/ MRD. To address nonresponse bias and provide accommodations for visitors who were unable to participate in person, flyers with a QR code for the survey were posted in well-known areas throughout Mobile Bay. The online survey was made available by Qualtrics software and was distributed on web-based forums devoted to fishing activities in Mobile Bay on social media sites such as Facebook. The survey took ~15min to complete, although respondents had unlimited time to complete the survey. Surveys that did not match qualifying requirements (visiting the Alabama coast in 2023 and being over 19 years old) were not included in this analysis.

2.3 | Analysis

Respondent willingness to adjust their fishing practices to benefit sea turtle populations was evaluated with the question: "Please select your willingness to adjust certain behaviors if it means that wildlife populations increase." Responses to this question were recorded on a Likert scale (1–5), where 1 indicated "very unwilling to change this behavior" and 5 indicated "very willing to change this behavior." To facilitate use of binomial generalized linear models (GLMs), the Likert scale was converted into a binary variable: scores of 1 and 2 (very unwilling and unwilling) were categorized as "Less willing" (coded as 0), and scores of 4 and 5 (willing and very willing) were categorized as "More willing" (coded as 1). The middle score of 3 was considered neutral and was excluded from binary categorization.

Two binomial GLMs were used to analyze factors potentially influencing two key variables: willingness to change hook styles and willingness to change bait choices. To ensure that GLMs were based on relevant data, a subset of data included only responses by participants who indicated they used hook-and-line gear. This subset was chosen to exclude responses from other angler types (e.g., casting net, speargun, gillnet, trawls, skimmers, and trap pots) that are less influenced by hook and bait

TABLE 2 | Explanatory variables for predicting recreational angler willingness to change hook and bait types while fishing in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023.

Variable name	Туре	Answer options
Age	Discrete	The age of the participants in the study
Race	Categorical	White, Native American, Black, Asian
Gender	Categorical	Male, Female, Other
State residency	Categorical	From Alabama or from elsewhere
Highest level of education	Categorical	Higher education (graduate or professional school, college graduate/BA or BS, some college/AA or AS) or lower education (technical/vocational school, high school graduate/GED, did not graduate high school/no GED)
Target species	Categorical	Reef fish, mackerel, mullet
Motivation for visit to the Alabama Coast	Categorical	Viewing dolphins, viewing sea turtles, viewing other wildlife (i.e., birds, etc.), fishing from the beach, fishing from the jetty, fishing from a boat, boating (motor), and boating (sailing)
Knowledge of sea turtle policy	Continuous	Calculated score based on correct answers to sea turtle policy questions
Knowledge of sea turtle ecology	Continuous	Calculated score based on correct answers to sea turtle ecology questions

TABLE 3 | Gender, race, age, educational level, residency, and visitor type of recreational anglers fishing in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March-September 2023.

GenderFemale61348Male28159Other14I prefer not to answer1056Total567567Race899Black847Asian423Other/I prefer not to answer424Total567567Do you identify with Latino, Hispanic, USPANIS567Pack54282No39198I prefer not to answer787Total787Total567564Age ranges116219-2474025-345028435-442513945-54116255-6431865+420Itighest level of education212Highest level of education212Fechnical/vocational school22124Some college/AA or AS (2-)23133year degree)6729163Graduate or professional844School7163	Demographic variables	Percent (%)	Count
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Graduate or professional844school567	College grad/BA or BS (4- year degree)	29	163
Total 567	Graduate or professional school	8	44
	Total		567

(Continues)

TABL

Note: T comple

Alabama residency		
From Alabama	35	198
From elsewhere	65	369
Total		567
Visitor type		
Resident	29	164
Seasonal resident	29	162
Short-term visitor (1-3/year)	22	126
Short-term visitor (4-6/year)	15	83
Short-term visitor (6 or more times)	5	28
Total		563

choices. This approach was used to focus on respondents who used gear directly related to the study objective. Narrowing the analysis to this group provided more accurate insights into the behaviors and preferences of individuals directly affected by the gear types in question.

During preliminary analysis, Asian respondents consistently reported a high willingness to change, with few responses in the "Less willing" category. This lack of variability among Asian respondents hindered statistical convergence and reduced effective sample size. To address this issue, Asian respondents were excluded from further analysis. The exclusion was necessary to avoid skewed results and to ensure that sample size was adequate for analysis.

Subsequent GLM analyses were conducted using this subset of data to evaluate factors influencing respondent willingness to change gear and bait choices. Explanatory variables were composed of 19 participant demographic traits (age, race, gender, state residency, and highest level of education), target fish species (reef fish, mackerel, mullet), motivation for visiting the coast, and knowledge of sea turtle policy and ecology (Table 2). Knowledge variables were calculated as the proportion of questions correctly answered by each participant to reflect their knowledge level in each subject area. Our use of binomial GLMs was grounded in established methods frequently applied in social science research (Dunteman and Ho 2005; Fox 2015; Warne 2020; Hosmer and Lemeshow 1989).

Multicollinearity among predictor variables in models was evaluated using the variance inflation factor (VIF) for each variable. Variables with VIF scores < 2 suggested minimal multicollinearity. The odds ratio was used to measure and quantify strength and direction of the relationship between independent and response variables (either changing hook style or bait choice) and was based on the exponentiated coefficient parameter estimate (β), to assess the association between explanatory



FIGURE 4 | Residency of recreational anglers fishing in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023. This map illustrates the number of respondents per state (selected from a drop-down list) and respondent-provided zip code locations. Discrepancies in counts may occur due to respondents providing zip codes from different states or incomplete reporting.



FIGURE 5 | Number of participants (%) motivated by various coastal activities for visiting the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023.

variables and participant's willingness. The "confint" function in the R package "stats" was used to generate confidence bounds for each variable. Analyses used R statistical software version 4.3.1 (R Core Team 2023).

3 | Results

Survey responses were collected from 567 recreational anglers who participated through online and in-person methods from

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March through September 2023. GLMs relied on a subset of 322 responses from hook-and-line anglers. Sample sizes were adequate because they exceeded the minimum sample sizes recommended for regression analysis (Green 1991; VanVoorhis and Morgan 2007).

Respondents were mostly white (66%), female (61%), middleaged, and averaged 35 years old (Table 3); Latino, Hispanic, or Spanish origin (54%); of varied education levels, with 29% holding a bachelor's degree; and 35% were from Alabama (Figure 4). Residents (29%) and seasonal residents (29%) were among the two largest visitor types. Tourists visit the coast mostly to view dolphins (Figure 5).

Mackerel was the most frequently sought species (49%), with hook and line as the predominant fishing method (56%) and live bait as the most popular choice (59%) (Table 4).

Notably, 79% of anglers correctly recognized that sea turtles were protected under the ESA (Table 5). Comparably, 62% of anglers

TABLE 4 | Species targeted, gear used, and bait used by recreational anglers in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023.

Question	Percent (%)	Count	
Please select the main species of fish that you're trying to catch (select all that apply)			
Mackerels	49	276	
Reef fish	44	248	
Shrimp	36	203	
Mullet	35	197	
Blue crab	28	157	
Total		567	
What gear do you use (select al	l that apply)?		
Hook and line	56	322	
Casting net	32	182	
Trawls	29	163	
Speargun	28	161	
Gillnet	26	145	
Trap pots	16	90	
Skimmers	14	80	
Total		567	
What bait do you use (select all that apply)?			
Live bait	59	336	
Top water lures	45	256	
Cut bait	43	241	
Frozen bait	39	223	
Total		563	

Note: The totals listed in this table represent the number of surveys that completed the specific question.

understood that it was prohibited to touch any living sea turtle, while 38% held misconceptions about touching a protected sea turtle. Only 51% of anglers correctly identified the NOAA Sea Turtle Stranding Hotline.

Among respondents, 65% accurately recognized that the main threat to sea turtles was accidental capture by recreational hookand-line fishers, whereas 35% did not (Table 6). Furthermore, 75% of participants understood that sea turtles needed to breathe air but stayed submerged for long periods of time, whereas 25% did not.

Willingness to change hook type was significantly associated with gender and residency, but not age, race, or education level (p > 0.27; Table 7; Figures 6–10). Female anglers were 5.5 (95% CL=2.0–18.0) times as likely to change hook styles than male anglers (p=0.0024) and Alabama residents were 4.0 (95% CL=1.6–11.5) times as likely to change hook styles than nonresidents (p=0.0056). Anglers motivated to go to the beach were

TABLE 5|Knowledge of relevant sea turtle policies by recreationalanglers fishing in the Mobile Bay Estuary, Alabama, Gulf of Mexico,during March–September 2023.

Question and answer	Percent correct (%)	Percent incorrect (%)
Sea turtles are protected under the Endangered Species Act (True)	79	21
It is illegal to touch any living sea turtle in Alabama (True)	62	38
In the event that I encounter an injured sea turtle, I call (NOAA Sea Turtle Stranding Hotline)	51	49

Note: Proportion of correct and incorrect answers by participants for the sea turtle policy knowledge test section. Answers are represented as percentages by question.

TABLE 6 | Knowledge of sea turtle ecology and threats by recreational anglers fishing in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023.

Question and answer	Percent correct (%)	Percent incorrect (%)
Accidental capture of sea turtles by hook-and-line recreational fishermen is one of the main threats that sea turtles face (True)	65	35
Sea turtles breathe air; however, they can remain submerged underwater for hours (True)	75	25

Note: Proportion of correct and incorrect answers by participants for the sea turtle ecology knowledge test section. Answers are represented as percentages by question.

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	Estimate	Std. error	z	р
Intercept	-1.233307	1.280093	-0.963	0.33532
Age	-0.006051	0.019754	-0.306	0.75937
Native American	-0.600591	0.540488	-1.111	0.26648
Black	-0.160498	0.721858	-0.222	0.82405
Female	1.704300	0.561408	3.036	0.00240**
"Other" gender	-1.263748	1.176011	-1.075	0.28255
Alabama resident	1.396586	0.504327	2.769	0.00562**
Higher education	0.106988	0.451822	0.237	0.81282
Motivated to visit the beach	1.559534	0.549539	2.838	0.00454**
Motivated to view turtles	-0.014122	0.532578	-0.027	0.97885
Motivated to view dolphins	-0.062597	0.623206	-0.100	0.91999
Motivated to view other wildlife (birds, etc.)	0.755203	0.515160	1.466	0.14266
Motivated to fish on the beach	-1.153153	0.554758	-2.079	0.03765*
Motivated to fish on the jetty	-1.421533	0.594841	-2.390	0.01686*
Motivated to fish on a boat	1.227437	0.541028	2.269	0.02329*
Motivated to go boating (motor)	-0.696193	0.530180	-1.313	0.18914
Motivated to go boating (sail)	0.844246	0.499831	1.689	0.09121
Knowledge of sea turtle policy	-0.709662	1.213137	-0.585	0.55856
Knowledge of sea turtle ecology	2.438664	0.947417	2.574	0.01005*
Reef	0.107696	0.424222	0.254	0.79960
Mackerel	-0.409664	0.411652	-0.995	0.31965
Mullet	0.765084	0.481371	1.589	0.11197

TABLE 7 | Generalized linear model estimates for factors explaining recreational angler willingness to change hook styles while fishing in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023.

Note: Odds ratios can be calculated by exponentiating the beta. For all categorical variables, one category is used as a reference, which is why it is not explicitly included in the table. *p < 0.05.

***p*<0.05.

4.6 (95% CL=1.7-14.5; p=0.0046) times as likely to change hook styles than those not motivated to visit the beach. Anglers who fished from shore were 0.32 (95% CL=0.10-0.90; p=0.038) times as likely and anglers who fished from a jetty were 0.24 (95% CL=0.07-0.74; p=0.017) times as likely to change hook styles than other anglers. In contrast, anglers who fished from a boat were 3.4 (95% CL=1.2-10.2; p=0.023) times as likely to change hook styles than other anglers. Knowledge of sea turtle policy did not significantly predict angler willingness to change hook type (p=0.56), but knowledge of sea turtle ecology was significant. For each 50% increase in angler knowledge of sea turtle ecology, an angler was 3.4 (95% CL=1.3-8.6; p=0.010) times as likely to change hook types in support of sea turtle conservation.

Willingness to change bait was not significantly related to age, race, education level, or state residency (p > 0.30; Table 8, Figures 7–11). However, female anglers were 2.7 (95% CL = 1.1–7.5; p = 0.045) times as likely to change bait than male anglers. Anglers who were motivated to visit the beach were

3.7 (95% CL=1.4–10.6) times as likely to change their bait than those not motivated to visit the beach (p=0.011). Anglers who were motivated to view dolphins were 5.9 (95% CL=1.9–19.7; p=0.003) times as likely to change their bait and anglers who were motivated to view sea turtles were 0.29 (95% CL=0.08–0.90; p=0.042) times as likely to change their bait than those not motivated to view these species. In contrast, the motivation to view other wildlife was not significantly related to willingness to change bait (p=0.35). Lastly, anglers targeting reef fish were 2.9 (95% CL=1.3–6.8; p=0.012) times as likely to change bait types than those not motivated to fish reef species.

4 | Discussion

This study enhances our understanding of the intersection between saltwater recreational fishing and sea turtle conservation, by highlighting how demographic characteristics, knowledge level, motivation, and fishing techniques influence



FIGURE 6 | The odds ratios and 95% confidence intervals for significant predictors influencing anglers' willingness to change hook types while fishing in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023. Significant predictors include demographic variables (e.g., gender and residency), fishing motivations (e.g., motivated to fish on a jetty and fish from a boat), and knowledge of sea turtle ecology. Odds ratios greater than 1 indicate a higher likelihood of willingness to change hook types.

angler conservation behavior. Our findings provide important insights for developing targeted campaigns, evaluating incentives for sea turtle-friendly tackle modifications, and fostering productive angler engagement efforts. Such endeavors are pivotal because mitigation strategies must be effective and viable to be fully adopted by anglers (Gilman et al. 2006). Educational programs that equip anglers with best-practice knowledge for marine stewardship may then voluntarily modify their tackle and behavior, which has a significant potential for accomplishing management goals and objectives (Cooke et al. 2013). Similar studies have shown how cooperation with fishers can provide extensive monitoring of sea turtles, by gathering information on spatial distribution, bycatch, and fishing effort for enhanced conservation planning (Baldi et al. 2022; Cornwell and Campbell 2012).

Our findings from the sea turtle policy knowledge assessment provided insights into the awareness and understanding of key legal and conservation aspects among recreational anglers in the Mobile Bay ecosystem. While a substantial proportion (79%) recognized that sea turtles were protected under the ESA, only 62% of anglers were aware that touching sea turtles was illegal. A general interpretation of the ESA prohibits actions that could harm or harass sea turtles, complemented by local regulations under the Alabama Administrative Code (Ala. Admin. Code r. 220-3-0.33), which restricts actions disrupting normal sea turtle behavior. However, this code does not explicitly ban all forms of touching, especially safe release. Building on previous research on human-sea turtle encounters during ecotourism activities, our finding highlights a need for targeted education to improve public awareness of specific legal restrictions, to foster informed and conservation-conscious behavior (Lamb 2021; Nichols 2007; Meadows 2004). Additionally, only 51% of anglers knew that contacting the NOAA Sea Turtle Stranding Hotline was the appropriate action when encountering a dead or injured sea turtle. Greater public knowledge about reporting procedures is crucial for effective and timely responses to distressed wildlife, especially when anthropogenic threats to sea turtles increase in coastal tourism areas (Santos et al. 2018; Willette et al. 2023).

Our findings highlight a moderately high level of awareness among anglers about sea turtle ecology. For example, 75% of participants correctly understood that sea turtles need to breathe air but can remain submerged for extended periods. However, 25% of anglers who incorrectly responded may have had



FIGURE 7 | Ages of recreational anglers in relation to their willingness to change hook and bait types (1 = very unwilling to 5 = very willing) while fishing in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023. The plot includes jittered points to show individual data points within each category, providing a detailed view of the age distribution for different levels of willingness.



FIGURE 8 | The proportion of anglers of different racial groups in relation to their willingness to change hook and bait types (1 = very unwilling to 5 = very willing) while fishing in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023.

Willingness to change bait

Willingness to change bait



FIGURE 9 | The proportion of anglers of different genders in relation to their willingness to change hook and bait types (1 = very unwilling to 5 = very willing) while fishing in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023.

misconceptions about sea turtle respiratory abilities, thereby indicating a need for improved public education on this aspect of sea turtle biology. Awareness of sea turtles' need for air can help anglers adopt preventive measures, such as setting time limits for gear in the water to reduce drowning risks. Additionally, 65% of respondents correctly identified accidental capture by recreational hook-and-line fishers as a major threat to sea turtles. Recent studies suggest that bycatch in recreational fisheries can be substantial, particularly for species like green and Kemp's ridley turtles (Putman et al. 2023). Our findings therefore reflect a general awareness of the potential impact of recreational fishing, although bycatch is just one of several threats, including commercial fishing bycatch, habitat loss, vessel strikes, and marine debris (Donlan et al. 2010).

Demographic data about anglers are vital for understanding diversity of an important coastal user group and how such factors relate to fishing behavior, gear preference, and attitudes toward sea turtle conservation efforts. We found that age, race, and education level did not significantly predict willingness to change hooks or bait, which suggests that these demographic variables may not strongly correlate with conservation attitudes or behaviors, unlike previous research (Hughes et al. 2019; Børresen et al. 2023; Wang et al. 2022). Instead, we found that female

anglers were more inclined to modify their tackle choices to support sea turtle conservation than male anglers, similar to earlier research that suggested females were generally more concerned about environmental issues and were more likely to engage in conservation behaviors, such as willingness to pay for environmentally friendly services or products (Czech, Devers, and Krausman 2001; Kellert and Berry 1987; Kellert 1985). The gender disparity in our study may reflect different perspectives on environmental conservation or a heightened concern for sea turtle welfare among females (Massey et al. 2022; Robinson et al. 2022; Dempson et al. 2012). However, further research is necessary to determine whether female angler motivations for these behaviors differ significantly from males (Carini and Weber 2015). Aside from gender, state residency was the only other demographic variable significantly associated with anglers' willingness to change hook styles. Alabama residents were more likely to adopt sea turtle-friendly modifications, possibly due to a greater sense of responsibility for protecting local marine ecosystems. This pattern aligns with previous findings on seasonal recreation areas and the role of sea turtles as tourism drivers for local economies (Clendenning, Field, and Kapp 2005; Senko et al. 2011).

Our findings support earlier studies that found recreation motivations can influence user willingness to adopt conservation



FIGURE 10 | The proportion of anglers of varying education levels in relation to their willingness to change hook or bait types (1 = very unwilling to 5 = very willing) while fishing in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023.

actions for natural resources and wildlife, including among anglers (Kil, Holland, and Stein 2014; Oh and Ditton 2008). We found that anglers motivated to visit a beach were more willing to change their hook and bait types if they perceived these changes to benefit wildlife populations. This heightened willingness may stem from a broader environmental awareness and concern that often accompanies beach visitation, where individuals engage with nature more holistically (Wyles, Pahl, and Thompson 2014). Such motivations can foster a greater sense of responsibility for health of coastal ecosystems that lead to more proactive conservation behaviors, such as adopting sustainable fishing practices (Johnson et al. 2021).

Our findings highlighted differences in willingness to change bait types based on motivations related to specific wildlife viewing experiences. Anglers motivated by the opportunity to view dolphins were significantly more likely to change bait types, whereas those motivated to see sea turtles were less inclined to make such changes. This discrepancy suggests that the type of wildlife an angler is motivated to see may influence their conservation behaviors. Dolphin viewing, which is often an active and engaging experience, may enhance environmental awareness and encourage anglers to adopt more sustainable practices (Barnhill et al. 2022). In contrast, sea turtles are frequently perceived as vulnerable and already subject to protective measures, which may lead some anglers to believe that current conservation efforts are adequate, reducing their perceived need to change their behaviors.

We found a significant relationship between knowledge of sea turtle ecology and willingness to change hook types, but not bait types. One possible explanation for this difference is that circle hooks are more normalized and accepted within the fishing community. For example, in Alabama, non-stainless steel circle hooks are required when fishing for sharks and Gulf reef species using natural bait (Alabama Department of Conservation and Natural Resources 2024). This standardization and familiarity with circle hooks could make anglers more receptive to changing hook types than bait types. Changing bait may be viewed as a more significant deviation from established fishing practices because anglers might have strong preferences or habitual practices regarding bait that make them more resistant to change (Quintana 2015). Additionally, the perceived effectiveness of different bait types for catching target species might overshadow conservation benefits of switching bait types. This resistance to changing bait could be due to a lack of perceived direct impact on sea turtle conservation rather than more regulated, visible effects of changing hooks. Anglers may require more information

	Estimate	Std. error	z	р
Intercept	-1.225643	1.101624	-1.113	0.26589
Age	0.003984	0.019395	0.205	0.83723
Native American	-0.278906	0.579131	-0.482	0.63009
Black	-0.344786	0.709790	-0.486	0.62714
Female	0.984642	0.491910	2.002	0.04532*
"Other" gender	-18.938167	1290.520178	-0.015	0.98829
Alabama resident	0.481902	0.460553	1.046	0.29540
Higher education	-0.015451	0.459573	-0.034	0.97318
Motivated to visit the beach	1.309428	0.514580	2.545	0.01094*
Motivated to view turtles	-1.220847	0.599368	-2.037	0.04166*
Motivated to view dolphins	1.768922	0.594546	2.975	0.00293**
Motivated to view other wildlife (birds, etc.)	-0.491730	0.530027	-0.928	0.35354
Motivated to fish on the beach	-0.793964	0.560457	-1.417	0.15659
Motivated to fish on the jetty	-0.667874	0.539868	-1.237	0.21605
Motivated to fish on a boat	0.430341	0.529796	0.812	0.41663
Motivated to go boating (motor)	0.130720	0.528782	0.247	0.80475

0.657614

0.897676

0.793207

1.060492

-0.735557

-0.002164

TABLE 8 | Generalized linear model estimates for factors explaining recreational angler willingness to change baits for sea turtle conservation while fishing in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023.

Note: Odds ratios can be calculated by exponentiating the beta. For all categorical variables, one category is used as a reference, which is why it is not explicitly included in the table. *p < 0.05.

**p<0.01.

Reef

Mackerel

Mullet

Motivated to go boating (sail)

Knowledge of sea turtle policy

Knowledge of sea turtle ecology

about impacts of bait types on sea turtle conservation to motivate changes in practices. These findings suggest that while increasing ecological knowledge can influence conservation behaviors, the nature of the change—whether it involves hooks or bait—and existing practices within the fishing community play crucial roles in shaping these behaviors. Tailoring conservation strategies to address these specific barriers and perceptions could enhance their effectiveness and lead to more widespread adoption of sustainable and voluntary fishing practices (Crandall et al. 2018).

Previous research has indicated that public decisions to support protection of species are mostly influenced by existing knowledge of wildlife (Wilson et al. 2004). Charismatic and well-known species like sea turtles typically garner more conservation support than poorly known species, especially those inhabiting less remote areas (Tisdell and Wilson 2006). While ecological knowledge of wildlife species appears to strongly shape individual support for conservation initiatives, we found no significant relationship between policy knowledge and angler willingness to adapt hook or bait styles. Our results suggest that traditional methods of wildlife conservation communication by state and federal agencies, which often emphasize regulation or management-related information, may not always be effective in encouraging practical behavioral changes among certain groups, such as anglers (Keane et al. 2011). Social marketing research on responsible sea turtle viewing among general tourists suggests that factors to encourage desired behavior change may include ease of implementing the behavior, enjoyment, uniqueness, popularity, and alignment of the behavior with personal identity, which can all be incorporated into targeted efforts in an angling community (Abrams et al. 2023).

1.315

0.773

0.911

2.509

-1.745

-0.005

0.18854

0.43930

0.36226

0.01211*

0.08106

0.99600

0.500124

1.160727

0.870627

0.422678

0.421626

0.431696

Our analysis of fishing techniques revealed that different subgroups of anglers—such as beach, jetty, and boat-based anglers—differed in their willingness to change hook styles. Such variation highlights the importance of developing conservation strategies that are specifically tailored to unique characteristics and behaviors of angler subgroups. Tailoring conservation efforts to address specific concerns, preferences, and practices of distinct angler communities can significantly increase effectiveness of these initiatives (Fedler and Ditton 2000).



FIGURE 11 | The odds ratios and 95% confidence intervals for significant predictors influencing anglers' willingness to change bait types while fishing in the Mobile Bay Estuary, Alabama, Gulf of Mexico, during March–September 2023. Significant predictors include demographic variables (e.g., gender), fishing motivations (e.g., motivated to view dolphins and view sea turtles), and targeted fish species. Odds ratios greater than 1 indicate a higher likelihood of willingness to change bait types.

Our findings indicated that anglers targeting reef fish were more willing to change bait types than those targeting other species. Increased willingness may be influenced by regulatory requirements in Alabama, where, since 2019, anglers targeting reef fish were mandated to use circle hooks instead of Jhooks, effectively necessitating a hook change (ADCNR Marine Resources Division 2024). This existing regulation could make reef fish anglers more accustomed to or accepting of gear modifications, and therefore more adaptable in their fishing techniques. Therefore, understanding the diverse motivations and regulatory contexts influencing angler decisions is crucial for designing targeted interventions that promote sustainable fishing practices and foster long-term engagement in conservation efforts (Schuett et al. 2014; Taylor and Sammons 2019). Tailoring strategies to reflect specific needs and existing behaviors of angler subgroups—like those targeting reef fish—can enhance overall success of conservation programs.

While our study provided valuable insights, several limitations should be considered. The geographical focus of the study on the Mobile Bay ecosystem may limit generalization of our findings to other coastal regions with different sociodemographic profiles. Comparative studies across diverse regions are needed to identify variations in angler attitudes and behaviors toward sea turtle conservation, which could inform development of regionspecific conservation strategies. Additionally, our reliance on self-reported data may not accurately reflect actual behaviors or knowledge levels, and response bias could skew results toward more conservation-minded individuals. The study timeframe, March to September 2023, may not have accurately captured seasonal variation in fishing practices or sea turtle interactions, whereas a longer study period could provide a more comprehensive view. Lastly, local cultural, economic, and regulatory contexts could influence angler attitudes and behaviors differently than in other regions. Future research should address these limitations by incorporating a broader range of threats, extending study periods, and exploring contextual factors to enhance the understanding of sea turtle conservation efforts.

5 | Conclusion

Ultimately, understanding recreational angler knowledge, attitudes, and behaviors toward sea turtle-friendly tackle modifications is an integral, yet understudied, step in developing effective conservation initiatives that align with interests of the angling community while ensuring long-term health and conservation of sea turtle populations. We aimed to assess willingness of recreational anglers to adopt sea turtle-friendly tackle modifications and understand factors influencing their decisions to mitigate harm to sea turtles during recreational fishing activities. Our results provided valuable insights into demographics, fishing characteristics, ecological and policy knowledge, and motivations of anglers in the Mobile Bay ecosystem. Understanding these sociodemographic aspects of recreational fisheries is essential for promoting sustainable fishing practices that align with angler practices and preferences, to inform conservation strategies by fish and wildlife agencies, and tailoring educational efforts to specific needs of angling communities. Additionally, by identifying key factors influencing angler willingness to adopt sea turtlefriendly measures, our findings provided actionable insights for development of targeted conservation strategies. Our results emphasized the importance of targeted educational initiatives to enhance public understanding of sea turtle ecology, conservation policies, and appropriate responses to encounters with endangered species, particularly during activities that may threaten sea turtles, including recreational fishing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data utilized in this study are available online at the following link: https://www.gulfspillrestoration.noaa.gov/project?id=143. Additionally, the survey used in this study has been included as Supporting Information.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.