

Angler Differences Within the Shore-Based Shark Fishery: are Great Hammerhead Anglers a Distinct Community?

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Abstract

Sharks are an important predator in many ecosystems, yet many shark populations have been in decline through recent years. Overexploitation and habitat loss are among the most significant factors contributing to their decline. Much of the recent research conducted has focused on the commercial fishing sector to determine quota counts and the best fishing gear that will ensure stable shark populations and individual shark survival. Although assumed to be less threatening to shark populations, recreational shark fishing may impact sensitive species, including the endangered great hammerhead (*Sphyrna mokarran*). To better understand recreational fishing, both shore-based and boat angling, it is important to characterize the motivations and demographics of the anglers. This study provides the first overview of great hammerhead shark anglers and provides key differences that distinguish these anglers from other shore-based anglers. A survey was distributed to shore-based fishing permit holders in the state of Florida, USA to gather information on angler demographics and motivations for angling. Great hammerhead anglers were differentiated from other shore-based anglers based on their preferred shark species to target. Key differences in gear types and angling behaviours were identified between the two groups that could prove useful to managers to ensure great hammerhead shark survival. Anglers that had reported catching a great hammerhead shark unintentionally revealed that many anglers may be unprepared in bycatch events and highlights the vulnerability of great hammerheads to bycatch from shore-based anglers that are targeting other species. This demonstrates the need to educate the shore-based anglers, new and experienced, on proper angling techniques and handling procedures. These results emphasize

the need for effective communication between the anglers and managers that encourages positive perspectives on shark conservation by shore based anglers and ensure shark survival.

Introduction

All species have an important role in influencing an ecosystem's composition, yet human activity continues to alter ecosystems and communities around the globe, and has caused many populations to decline. Sharks, a critical species to healthy ecosystems (Roff *et al.*, 2018), have experienced dramatic population declines in recent years, with only one-third of all shark species not at immediate risk of extinction (Dulvy *et al.*, 2014). As with other predatorial animals, sharks are a long-living species with low annual recruitment and are especially sensitive to changes in their communities (Purvis *et al.*, 2000; Ripple *et al.*, 2014).

Overexploitation in many shark fisheries has contributed to the decline of numerous shark species (Roff *et al.*, 2018). Globally, commercial shark fisheries contribute \$800 million (USD) for meat and fins trade (FAO, 2010), and the volume of sharks captured since 1950's has steadily increased. In 2019 alone, the Fisheries and Aquaculture Information and Statistics Branch reported that a total of 692,423 tonnes had been captured, a dramatic increase from 278,465 tonnes caught in 1950 (FAO, n.d.). Despite the assumption that commercial shark fisheries are a greater threat to shark populations than recreational shark fisheries, there is evidence that even a small number of sharks removed from a population, from activities such as recreational angling, can have long-lasting negative impacts (French *et al.*, 2019; Gallagher & Klimley, 2018).

Recreational angling for sharks is the practice where individuals fish for sharks either from the shore by casting, or in deeper waters by boat, primarily using hook and line (Morgan &

Carlson, 2010a). Given the sensitivity of sharks to even modest amounts of harvest (French *et al.*, 2019), recreational angling has the potential to have great effects on shark populations (Morgan & Carlson, 2010b; Roff *et al.*, 2018). Unlike commercial shark fisheries which are permitted during certain seasons, recreational shark fishing can occur year-round (Austin J. Gallagher, Cooke, & Hammerschlag, 2016), increasing potential capture occurrences and opportunities for mishandling events. Recreational fishing practices also tend to have a greater range of locations and gear, creating challenges for management (Shiffman *et al.*, 2017). In addition, commercial fisheries operate in mandated fishing areas, whereas recreational anglers are extremely mobile and able to follow sharks to more sensitive or hard to reach locations. Anglers fishing from shore, such as from beaches and/or piers, are also able to continue fishing in weather conditions unsafe for boating, making these anglers very adaptive and mobile.

Sharks are often caught as bycatch, the incidental capture of non-target species, by commercial fisheries or by recreational anglers targeting other species. Physiological stress and injuries from these events can be harmful to sharks (Borucinska, Kohler, Natanson, & Skomal, 2002). Sharks that are captured as bycatch may be less likely to survive due to certain angler behaviours (Brownscombe *et al.*, 2018). Stressors such as increased air exposure and inappropriate gear can cause injury and physical damage that can lead to mortality. For example, using the incorrect hook size and shape can increase deep hooking occurrences and can increase air exposure when the shark is landed (Alós, 2009; Brownscombe *et al.*, 2018; Wilde, Pope, & Durham, 2003). This puts higher pressure on shark populations as the risk of bycatch or mishandling errors increases the possibility of mortality. Bycatch in both recreational and commercial shark fishing is often recorded inaccurately, or not recorded at all. Despite

management practices implemented to limit bycatch of sharks, such as gear restrictions and permit applications, there is still a high number of off-target sharks that are caught as bycatch (Brownscombe et al., 2018).

Anglers can fish for sharks from shore such as from piers, bridges, or beaches using a variety of different gear depending on the species of shark being targeted. This type of fishing is known as shore-based shark fishing (SBSF) or land-based sharking fishing (LBSF), and targeted sharks are often caught and released for sport or harvested for meat in this fishery (French et al., 2019). The angler demographics and behaviour for those participating in SBSF have been of interest for conservation managers and stakeholders as populations continue to decline and interest in shark fishing increases (Gallagher et al., 2016; Shiffman et al., 2017). Understanding demographics and behaviours of anglers is critical to ensure that effective management and communication tactics are implemented. Many SBSF anglers have demonstrated knowledge about restrictions and management practices that are put in place. For example, one survey-based study found that anglers' ability to identify threatened or endangered shark species was dependent on their familiarity with conservation issues (Gallagher et al., 2016). Gallagher *et al.* (2016) noted in their survey that angler knowledge of great hammerhead shark (*Sphyrna mokarran*) status was associated with subjective conservation opinions. A few behavioural and socio-demographic angler profiles have also been identified by other recreational shark fishing studies. Shiffman *et al.* (2017) noted that participants in their study were cautious of the threat that commercial shark fishing poses to shark populations but were not concerned about recreational angling effects on populations. Moreover, many were not as approving of recreational angling restrictions. Nevertheless, many are also part of a conservation-based club

which may be important for effective communication between anglers and policymakers (Shiffman et al., 2017). A more recent study revealed that experienced anglers are using the correct gear for their targeted species and reported that they would change where they fished and their fishing habits if this increased the chances of shark survival after being released (Guay *et al.*, 2021). Increased concern amongst recreational anglers for shark populations has resulted in many anglers switching to catch and release practices from catch and kill practices (Gallagher et al., 2016; Gallagher, Hammerschlag, *et al.*, 2017; Shiffman et al., 2017).

Great hammerhead sharks have recently been listed as an endangered species (IUCN), and are consequently prohibited to be landed in Florida, yet are still a target of both recreational and commercial fishing, or caught as bycatch. Great hammerhead sharks mainly inhabit coastal waters but can also migrate through deep waters (Morgan & Carlson, 2010a) including waters off the coast of Florida (Gallagher & Klimley, 2018). Great hammerheads use ram-ventilation which makes them especially vulnerable to physiological stress from being caught (Gallagher, 2014). It has been predicted that over half of the great hammerhead sharks reeled in die within 3.8 hours of being released (Austin J. Gallagher & Klimley, 2018). Although most SBSF anglers demonstrate a general understanding for shark conservation (Guay *et al.*, in press), understanding the demographics and behaviour of these anglers could help with the administration of effective management plans to protect great hammerhead populations and support angler-manager cooperation.

This study aims to identify SBSF angler characteristics that can be used to implement regulations specific to great hammerhead anglers. A survey was distributed to SBSF anglers through the Florida Fish and Wildlife with questions about angler demographics, gear used to

catch sharks, and motivations for shark fishing. We compared anglers who target great hammerhead sharks to the rest of the survey participants to identify differences in gear types and angling practices. Consequently, the objective of this research is to uncover angler demographic variables, gear types, and angling practices of great hammerhead shark anglers that can be utilised to distinguish them from other shore-based anglers. Managers and stakeholders can better execute effective regulations using these identifiers. We determined disparities in angling gear and tactics within all shore-based anglers, as well as within the great hammerhead angler community specifically. We compared the size and number of great hammerhead sharks caught by great hammerhead anglers to see whether there were any differences between those who used the proper gear to target larger sharks and those who did not. Managers and stakeholders may find this information useful in putting in place restrictions and education services to guarantee that anglers are utilising the right gear and methods to maximise shark survival.

Methods

An online survey was distributed to SBSF permit holders with the Florida Fish and Wildlife Conservation Commission. The survey was distributed between March 13th, 2020 and April 2nd, 2020. The survey addressed questions on demographics, preferences, motivations, and behaviour of the anglers within the shore-based shark fishing community. The survey comprises a total of 40 questions that included multiple choice, 5-point Likert scales and open-ended questions. Since the focus of this study was to determine differences amongst SBSF anglers and identify unique characteristics of anglers targeting great hammerhead sharks, only

a component of the survey was included in the analysis. Questions related to gear, angler demographics, and fishing behaviour were included.

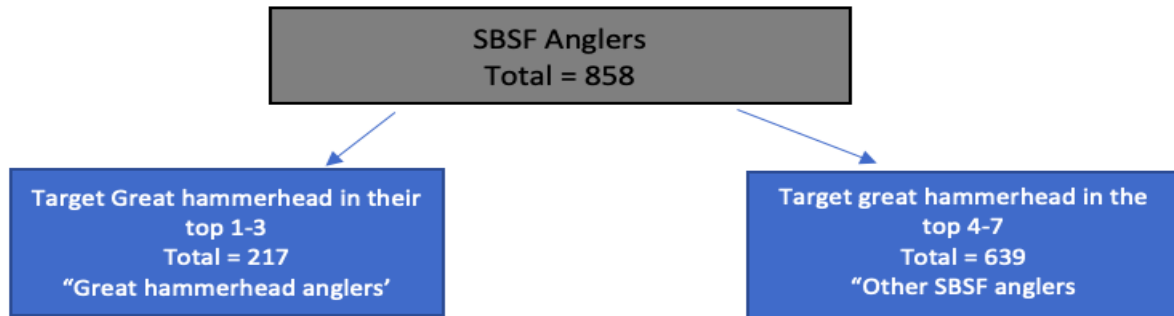


Figure 1a. Groups that were used for the analysis comparing great hammerhead anglers and other SBSF anglers.

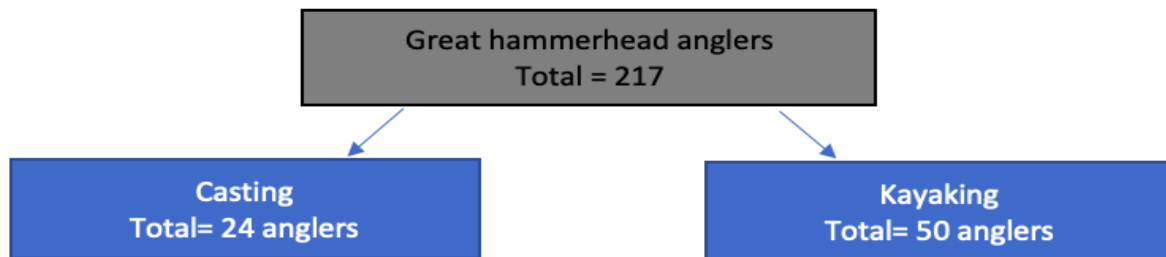


Figure 1b. Grouping of great hammerhead anglers into two groups based on how their bait was deployed; casters and kayakers (only 78 responses to this question).

A total of 1895 surveys were completed. Respondents who answered that they do not target sharks and do not fish from shore were excluded from the analysis, resulting in 858 survey responses being used for analysis. These survey responses were split into two groups based on the species of shark they prefer to target. Anglers who ranked great hammerhead in their top 1-3 preferred target species were categorized as 'great hammerhead anglers'. Anglers who ranked great hammerhead between 4-7 were categorized as 'other SBSF anglers'. The flowchart in Figure 1a shows how the anglers were organized into two groups for the analysis.

Variables for gear types, fishing behaviour variables, and demographic variables from the survey were chosen to distinguish differences between the two groups. The variables for reel type, rod type and length, hook size, and how the anglers deploy their bait were used to determine differences in gear types between great hammerhead anglers and other SBSF anglers. We selected results from three questions on time during which bait is in the water, unhook and release time, and fight time. The survey also included a question concerning the location the anglers' last great hammerhead shark was caught. This produced a heat map showing the most popular places where a great hammerhead was caught (Figure 6).

A student's t-test was used for all two- way comparisons between great hammerhead anglers and other SBSF anglers such as the average size of great hammerhead sharks caught or the number of sharks caught by anglers. A chi-square test of independence was used for multiple-comparisons between great hammerhead anglers and other SBSF anglers such as skill level, fight time and unhook time. These analyses were conducted using RStudio (version 1.3.1093).

A deeper analysis on differences within great hammerhead anglers was completed. Great hammerhead anglers were separated into two groups; anglers who cast from shore and anglers who kayak to deploy their bait. While generally male great hammerheads range from 155 to 217 cm total length at maturity and females between 145 to 237 cm (Austin J. Gallagher & Klimley, 2018), great hammerhead sharks are one of the larger species of sharks found in Florida's near shore habitats (Gibson *et al.*, 2019). This could suggest that anglers who deploy their bait farther out (via kayak) are more likely to catch a larger shark, which is the primary reason for great hammerhead anglers being separated into two smaller groups. Figure 1b is a

flowchart that illustrates the groups that were used for this part of the analysis. Gear was analyzed using a chi-square test of independence to reveal any angling gear that are favoured between shore casters and kayakers. The number of great hammerhead sharks caught, and the average size of great hammerheads landed were compared between shore casters and kayakers using a student's t-test to uncover any size differences between sharks caught closer to shore by shore casters or farther from shore by kayakers.

Gear Index

Each reel type, rod type, and rod length were ranked on a scale from 1-4 based on the size of fish they are intended to catch (see Table 1 below). For example, to target a large shark such as a great hammerhead it would be expected that the angler used heavy weight gear like a conventional 130# reel, and an 80lbs, short rod, and, as such, each would be ranked '4'. The ranked scores for reel type, rod type and rod length were added, resulting in a total between 2 and 12. Anglers whose gear index was 11 or 12 were classified as using 'Ultra Heavy' gear and anglers whose gear index was 9 or 10 were classified as 'Heavy' gear. Anglers whose gear index was between 6 and 8 were classified as using 'Medium' gear while anglers whose gear index was between 2 and 5 were classified as using 'Light' gear. Examples of the added gear indices can be found at the bottom of Table 1. Using the final weighted gear categories, a chi-square test was used to determine differences between angling gear of great hammerhead anglers and other SBSF anglers. Fight time and unhooking/release time were also compared with the gear index categories using a chi-square test.

Table 1. Gear types and their corresponding rank on the gear index. Examples of combinations of gear ranked on the gear index are listed at the bottom of the table where a score of 4 is ultra heavy gear typically targeting large sharks while a score of 1 is light gear typically targeting smaller sharks.

Gear	Gear type	Ranking score	Description
Reel Type	Conventional 130#	4	Ultra Heavy
	Conventional 80#	4	Ultra Heavy
	Conventional 50#	3	Heavy
	Conventional 30#	2	Medium
	Saltwater 50lbs	3	Heavy
	Saltwater 20-30lbs	2	Medium
	Saltwater 15-20lbs	1	Light
	Spinning 15-20lbs	1	Light
	Spinning 10-15lbs	1	Light
	Spinning 6-10lbs	1	Light
Rod Type	200lb	4	Ultra Heavy
	180lb	4	Ultra Heavy
	80lb	3	Heavy
	50lb	2	Medium
	30lb	1	Light
Rod Length	5-8 feet	4	Ultra Heavy
	9-11 feet	2	Medium
	12 feet & over	0	Light
Example gear index rank score:			
Conventional 80# reel type (ranked= 4) + 180 lbs rod type (ranked = 4) + 5-8ft rod length (ranked = 4) = 12 = Ultra heavy			
Saltwater 50lbs reel (ranked =3) + 80 lbs rod (ranked = 3) + 5-8 foot rod (ranked = 4) = 10 = Heavy			
Conventional 30# reel (ranked= 2) + 80 lbs rod (ranked= 3) + 9-11 foot rod (ranked = 2) = 7 = Medium			

Results

A total of 1895 surveys were completed. After removing survey respondents not actively participating in shore-based fishing, do not fish for sharks, and incomplete surveys, a total of 856 survey responses were used for the analysis. The response rate for the surveys

completed was 17.2%. The response quality rate was 98% based on Qualtrics XM (2020).

Further, a sub-component of survey questions that focused on great hammerhead fishing were used for this analysis.

From the 856 survey responses, there were responses from 217 anglers who actively target great hammerhead from shore (ranked great hammerhead 1-3 in their preferred target species). These anglers were compared to the rest of the survey respondents (639 respondents) who ranked great hammerhead between 4-7 of preferred target sharks when fishing from shore.

Demographic Distribution

Most great hammerhead anglers were under the age of 20 (28.70% of N=216) and 31-40 years old (22.69% of N= 216). Other SBSF anglers were slightly older with most between 41 and 60 years of age (distribution was 21.27% between 41- 50 years of age and 20.75% between 51- 60 years of age (N= 583)). Generally, most great hammerhead anglers responded that they had been fishing for sharks for 1-5 years (44.70% of N=217). Great hammerhead anglers had been in the shore-based shark fishery for an average of 9.48 years (SD= 11.19 years, min= 0 years, max= 51 years) and other SBSF anglers were in the fishery for an average of 10.96 years (min=1 year, max= 54 years). Although statistically different, the time anglers had been in the fishery only varied by about a year. Interestingly, 67.59% (of N=216) of great hammerhead anglers reported that they were part of at least one fishing club, Facebook group, or fishing forum. 61.03% (N=213) of great hammerhead anglers reported that they had a college/university degree or trade certificate and were employed full time (63.43% of N=216).

Angler Behaviours

Collectively, most shore-based shark anglers ranked their fishing skill level as 'advanced' (45.54%, N=591) and 'intermediate' (41.79%, N= 591). A majority of great hammerhead anglers ranked themselves as 'Advanced' (56.68%, N= 217) in fishing skill level (Table 2), while most other SBSF anglers ranked themselves as 'Intermediate'. Skill rank was significantly different between great hammerhead anglers and other SBSF anglers (Table 2). About 43.78% (N= 217) of great hammerhead anglers reported catching at least one great hammerhead within the last year. Unexpectedly, 50.69% (of N= 217) of great hammerhead anglers responded that they had never caught a great hammerhead shark but would be interested. On the contrary, most of other SBSF anglers (42.30% of N=591) reported that they had never caught a great hammerhead shark before and were not interested in catching one ($p < 2.2e-16$).

A comparison between great hammerhead anglers and other SBSF anglers revealed numerous differences between the two groups. Great hammerhead shark anglers on average actively fished for a longer duration of time than other SBSF anglers ($p < 0.001$). Great hammerhead shark anglers on average had their bait in the water for 6 hours (SD= 4.03, mean=6.16, range= 1-14 hours). Other shark anglers had their bait in the water for an average of 5.1 hours. The average time an anglers' bait was in the water was statistically different, but not a suitable characteristic to distinguish between the two groups, as there may be bias in the anglers response. Fight time was statistically different between great hammerhead anglers and other SBSF anglers ($p = 0.03593$). Fight time was categorized into <10 minutes, 10-30 minutes, 31-45 minutes, 45-60 minutes and 60+ minutes. Generally, great hammerhead anglers had a

fight time of between 10-30 minutes (32.63% of N=95) and 31-45 minutes (25.26% of N=95) while other SBSF anglers reported a fight time of 10-30 minutes (42.37% of N=118) or <10 minutes (22.88% of N=118). There was no difference between the two angler types with respect to time to unhook and release the shark (0.9633), generally taking less than five minutes to unhook and release the shark (Table 2).

Table 2. Results of statistical tests for selected variables between great hammerhead anglers and other SBSF anglers.

Variable	Df	p-value	Mean	
			Great hammerhead angler	Other SBSF anglers
Skill Rank*	3	0.029	-	-
When last great hammerhead was caught*	4	< 0.0001	-	-
# of great hammerhead caught*	116.5	<0.0001	0.8 sharks +/- 2.11	0.2 sharks +/- 1.12
Size of great hammerhead caught*	184.0	0.0068	8.8 ft +/- 4.69	7.9 ft +/- 3.19
Bait deployment method*	3	0.0008	-	-
Time in fishery*	444.6	0.076	9.48 years +/- 11.19	10.96 years +/- 11.90
Reel type (ranked)	3	0.59	-	-
Rod type (ranked)	3	0.43	-	-
Rod length (ranked)	2	0.12	-	-

Hook Size (ranked)	3	0.08	-	-
*Blank cells are instances of categorical answers				

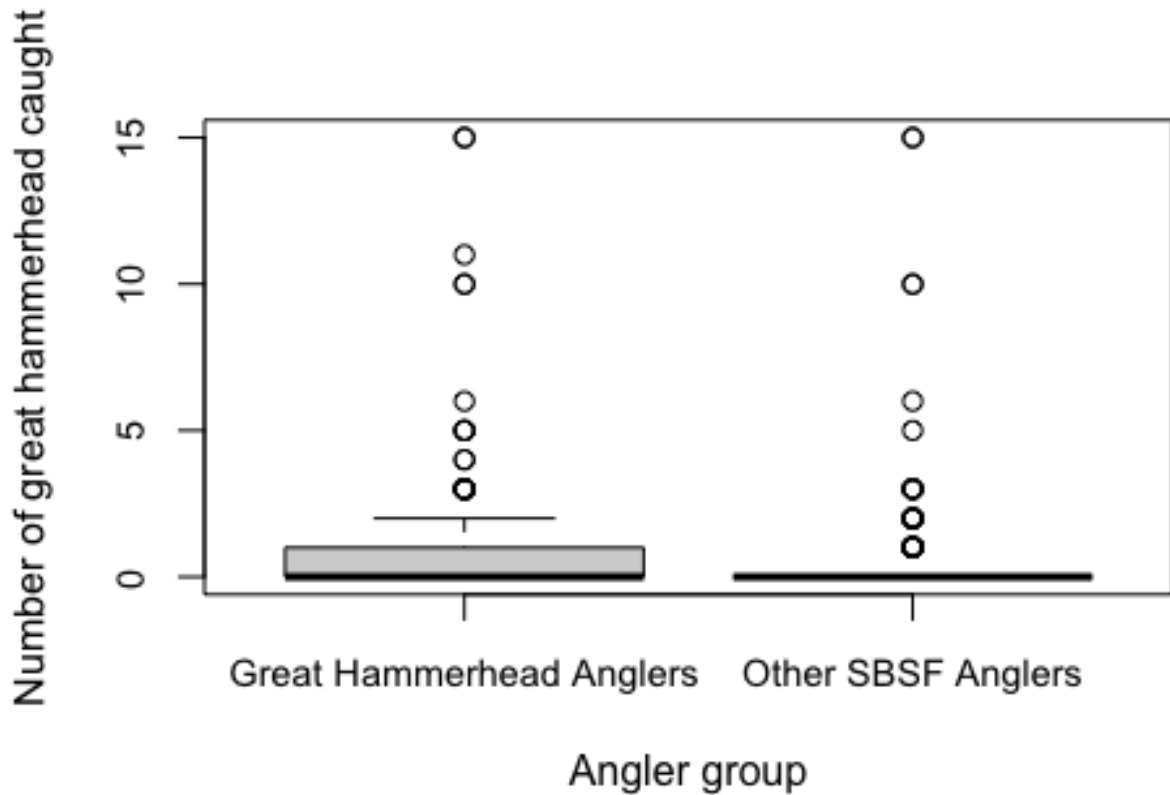


Figure 2. The average number of great hammerhead sharks caught by great hammerhead anglers was 0.8 great hammerhead sharks per angler, higher than that of other SBSF anglers, who on average caught 0.2 great hammerhead sharks per angler. Sharks caught by other SBSF anglers are considered bycatch.

As one might anticipate, there was a significant difference in the number of great hammerhead anglers who have caught a great hammerhead shark and those who target other shark species but have caught a great hammerhead as bycatch ($p < 0.001$) (Figure 2). Of the survey respondents the great hammerhead anglers reported catching 178 great hammerhead

sharks (N=62 anglers). Other SBSF anglers reported catching a total of 126 great hammerhead sharks within the last year (N=55 anglers), although some of the responses were noticeably higher and could have been a result of misidentification. The size of great hammerhead sharks caught were statistically different between the two types of anglers, but survey responses are inherently biased due to the participants self-reporting in the survey. The average size of a great hammerhead shark caught by an angler targeting them was 8.8 feet (SD= 4.69ft), which is larger than that reported by other SBSF anglers (mean= 7.9 feet, SD= 3.19ft). The difference in the size of shark and the time for the shark to be reeled in (fight time) was statistically significant ($p= 6.05e-10$). The distribution of the anglers' fight time and the size of great hammerhead shark caught are shown in Figure 3. Surprisingly, other SBSF anglers did have greater fight times with larger sharks. Similarly, great hammerhead anglers did not have significantly lower fight times than other SBSF anglers. Most anglers reported that the great hammerhead survived after it was released and did not differ between the two groups ($p=0.6988$). Most SBSF (96.84% of N=95) and great hammerhead anglers (97.32% of n=112) reported that the great hammerhead survived after it was released.

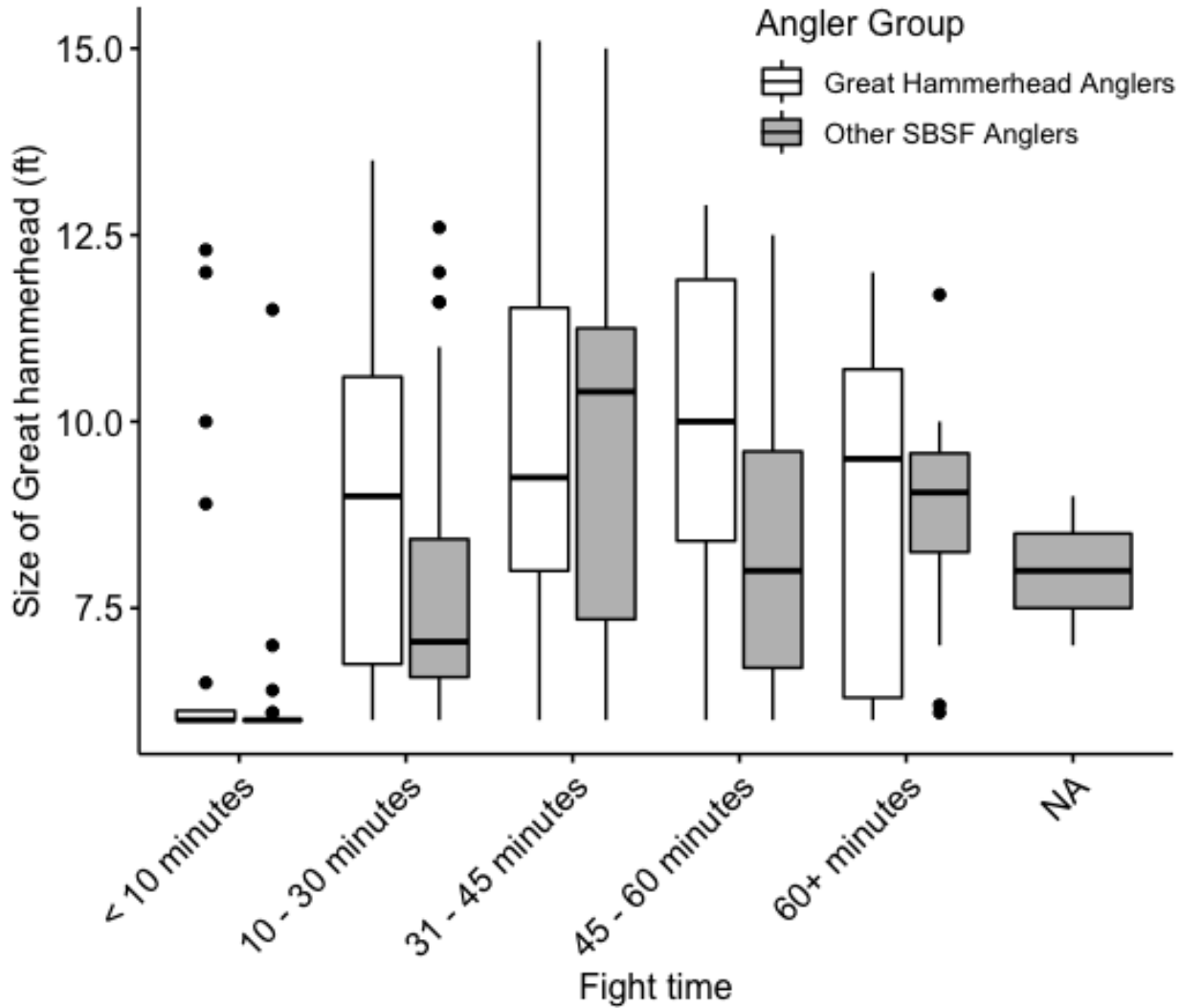


Figure 3. The fight time was compared with the size of the great hammerhead caught. If great hammerhead anglers are more experienced in catching great hammerhead sharks, they should have a short fight time which was not exhibited in our study. The fight time and size of great hammerhead is compared between great hammerhead anglers and other SBSF anglers in the figure above.

Angler Gear

Angler gear was compared between great hammerhead anglers and other shark anglers and is shown in Table 1. The most common reel type used by great hammerhead shark anglers was conventional #80 reel (28.57%, N= 91). Other SBSF anglers also reported commonly using

conventional 80# (31.78%, N=107) (table 3). The most common rod type used by great hammerhead anglers was an 130lbs rod (33.33%, N=90). Other SBSF anglers reported use of an 80lbs rod (33.33%, N= 105) (table 4) most often. Most great hammerhead anglers used shorter rods between 5-8 ft rod (68.88%, N=90) (table 5). The rod type ($p=0.4298$) and rod length ($p=0.1192$) showed no difference between great hammerhead shark anglers and other SBSF anglers (table 2). Hook size among great hammerhead anglers was evenly spread, 36.26% using 6-10/0 size hooks, 36.26% using 12-18/0 hooks and 24.18% (N=91) using 20/0+ hooks (table 6). There was no significant difference between hook size in great hammerhead anglers and other SBSF anglers ($p= 0.07483$). Bait deployment was significantly difference between hammerhead anglers and other shark anglers ($p<0.001$). 64.10% (of N=78) of great hammerhead shark anglers used kayaks to deploy their bait and most other SBSF anglers cast from shore (53.26%, N= 92) (figure 4).

Table 3. Common reel types used by great hammerhead and other SBSF anglers.

Reel Type & Size	Con. 130#	Con. 80#	Con. 50#	Con. 30#	Salt. 50lb	Salt. 20-30lb	Salt. 15-20lb	Spin. 15-20lb	Spin. 10-15lb	Spin. 6-10lb	N/A
Great hammerhead angler count	22	26	7	4	11	11	0	5	0	0	5
Other SBSF angler count	16	34	9	2	11	17	-	8	2	1	7

Table 4. Counts of common rod types used by anglers.

Rod Type	30lb	50lb	80lb	130lb	200lb	N/A
Great hammerhead angler count	10	11	26	30	8	5
Other SBSF angler count	15	17	35	22	10	6

Table 5. Counts of common rod lengths used by anglers.

Rod Length	5-8 feet	9-11 feet	12 feet & over	N/A
Great hammerhead angler count	62	24	3	1

Other SBSF angler count	78	18	9	1
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Table 6. Counts of common hook sizes that are used by anglers.

Hook Size	6-10/0	12-18/0	20/0+	N/A
Great hammerhead angler count	33	33	22	3
Other SBSF angler count	52	35	12	6

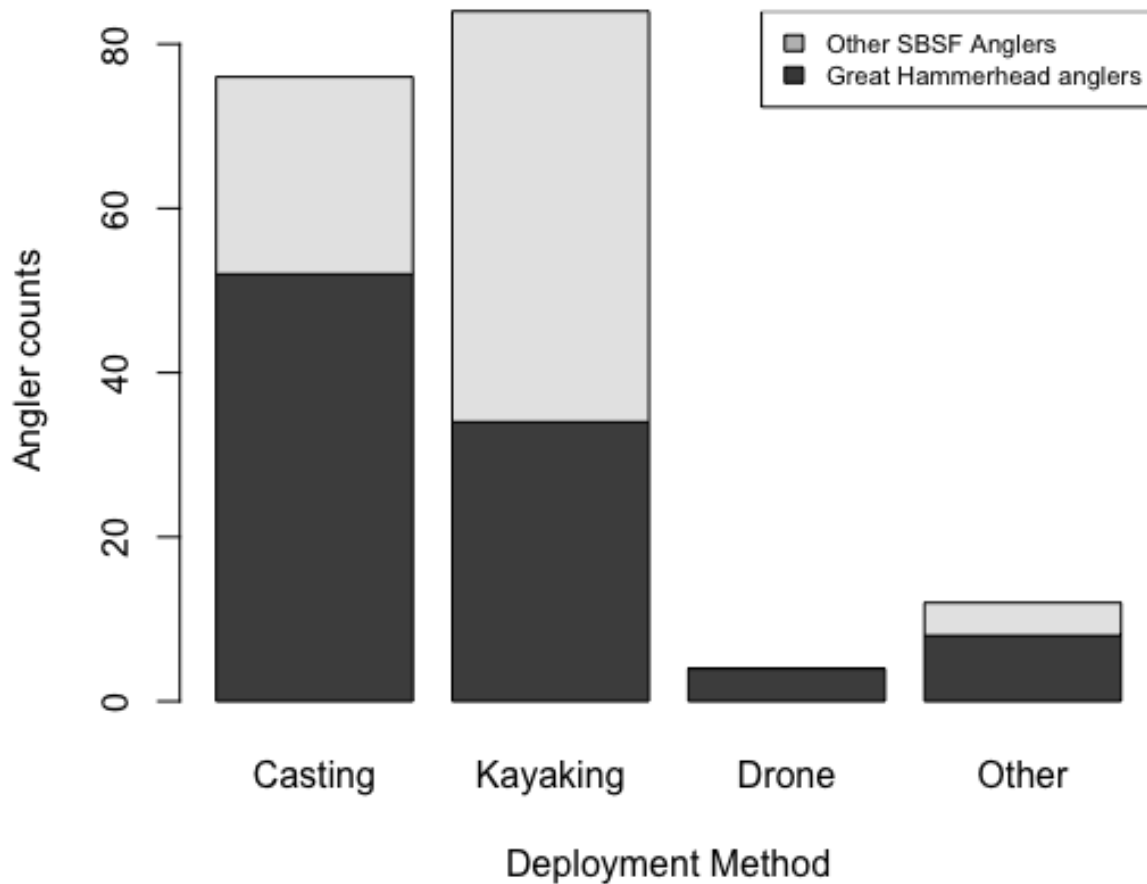


Figure 4. Great hammerhead angler and other SBSF angler counts comparing their method of bait deployment. Most shore based shark anglers kuse casting or kayaking as their preferred method of bait deployment.

Gear index

The gear index was compared between great hammerhead anglers and other SBSF anglers using a chi-square test. Table 7 shows the total number of anglers in each gear index category.

The results determine that there was no significant difference in the gear used by great hammerhead anglers and other SBSF anglers (0.9726). The gear index was compared against fight time of all SBSF anglers who reported catching a great hammerhead shark. There was a significant difference between gear index categories and the fight time ($p=0.00502$) (Figure 5).

Anglers using Ultra Heavy and Heavy ranked gear typically had a fight time between 10 to 30 minutes. There was no significant difference between the gear index categories and the time to unhook and release the shark back into the water.

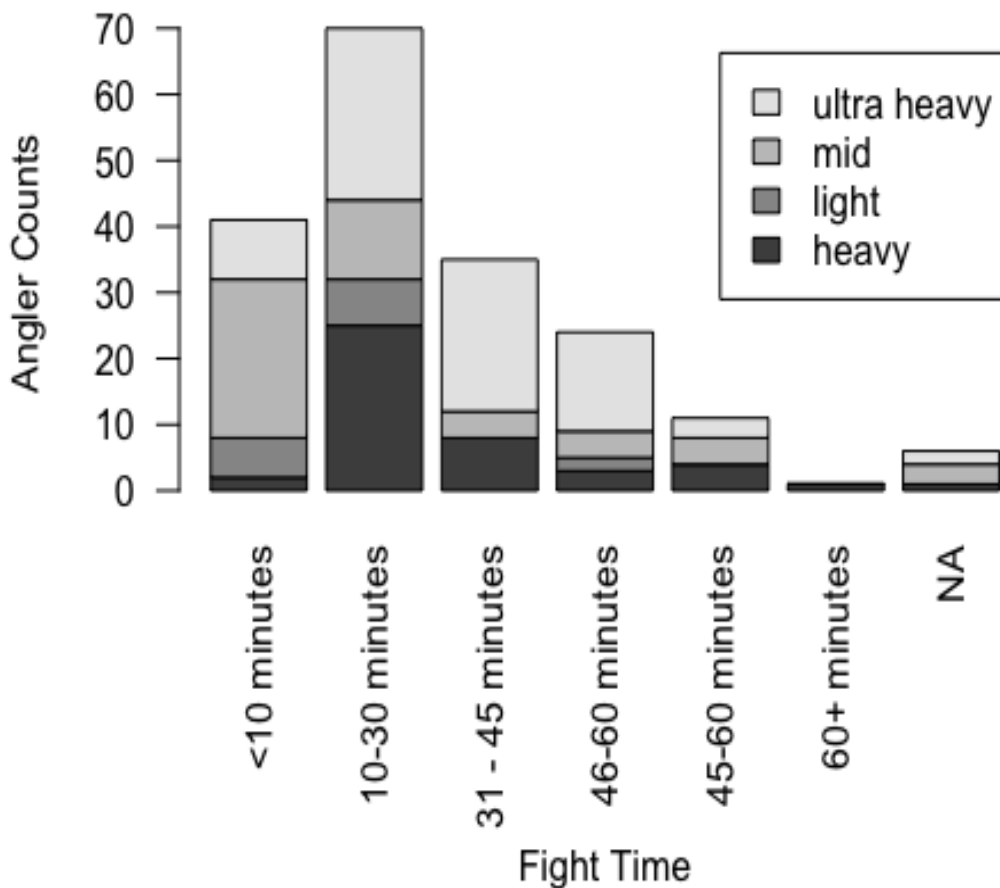


Figure 5. Angler counts of all shore based shark anglers who responded they had caught a great hammerhead within the last year. The categorical gear index was used and compared with the fight time of the last great hammerhead they caught.

Table 7. Ranked scores assigned to fishing gear used by shore based shark anglers from Florida, USA. Anglers were split into groups based on preference for targeting Great Hammerhead (*Sphyrna mokarran*). Only responses where complete gear information was provided was included in the analysis.

Weight Index	Score (adding ranked values)	# of Great Hammerhead Anglers	# of Other anglers
Ultra Heavy	12	Total Anglers = 38	Total Anglers = 40
	11		
Heavy	10	Total Anglers= 20	Total Anglers = 24
	9		
Medium	8	Total Anglers= 22	Total Anglers = 29
	7		
	6		
Light	5	Total Anglers= 5	Total Anglers = 10
	4		
	3		
	2		
	1		

Differences Among Great Hammerhead Anglers

Comparisons among great hammerhead anglers revealed some key differences in angler behaviour (Table 8). Most great hammerhead anglers used kayaks (64.10%) to deploy their bait, but a subset of anglers also cast from shore (30.77% of N=78). Although the number of great hammerhead sharks caught did not significantly differ between kayakers and shore casting ($p=0.4073$), there was a significant difference between the shark size ($p= 0.000112$). The average great hammerhead shark caught by casting the bait was 7.33 feet (SD= 2.18, range 6 ft-

13.5ft) while the average caught using a kayak to deploy the bait was 9.62 feet (SD= 2.36 , range= 6ft- 15.1 ft) (table 8). Reel type and rod type were significantly different between kayaking and casting anglers. Anglers casting from shore used Light to Heavy reel and rod types (N=23) while anglers using kayaks used mainly Ultra Heavy reels (72.92%, N= 48). Rod type varied evenly between Light (31.81%), Medium, (22.72%), Heavy (27.27%), and Ultra Heavy (18.18%, n=22) in casting anglers and mainly Heavy (34.04%) and Ultra Heavy (55.32%, N=47) in kayaking anglers. Rod length did not differ between kayaking and shore casting great hammerhead anglers (p=0.5906, Table 8).

Table 8. Results from the statistical tests comparing the gears and fishing techniques that were compared between the different bait deployment methods (casting and kayaking) used by great hammerhead anglers. An asterisk (*) symbolizes stastically significant results.

Variable	Df	p-value	Mean	
			Casters	Kayakers
# of great hammerhead caught	64.3	0.4	1.5 sharks	2.0 sharks
Reel type	3	<0.0001*	-	-
Rod type	3	0.0007*	-	-
Rod length	3	0.79	-	-
Shark size	49.0	0.00011*	7.3 ft	9.6 ft

Discussion

This study aimed to characterize shore-based shark fishers who target great hammerhead sharks based on participant gear use and fishing behaviours. Skill rank differed between the great hammerhead anglers and other SBSF anglers, where most great hammerhead anglers ranked themselves as ‘Advanced’ and other SBSF anglers were split between ‘Intermediate’ and ‘Advanced’. The self-ranking could be attributed to the degree of specialization that is required to target a specific species. Knowledge of specialized gear and

techniques is required for success in catching the targeted fish (Hall et al., 2019). To increase likelihood of successful capture, anglers targeting great hammerhead sharks would also need to be aware of the locations and time of day when great hammerheads are most active. The heat map (Figure 6) that was created from the survey exposed the locations with the highest catch rate and are shown in darker red. This being said, locations where great hammerhead sharks are frequently caught can be utilized by managers. Skill level could also be linked to the amount of time that anglers spend fishing. Interestingly, most great hammerhead anglers were between the ages of 21-30 years or under 21 years of age and had been fishing for sharks for 1-5 years, unlike other popular fisheries in Florida. In the bonefish fishery, most anglers reported being over the age of 55 (Rehage et al., 2019), similar to swordfish anglers in Florida where most are over the age of 50 (Lerner, *et al.*, 2017).

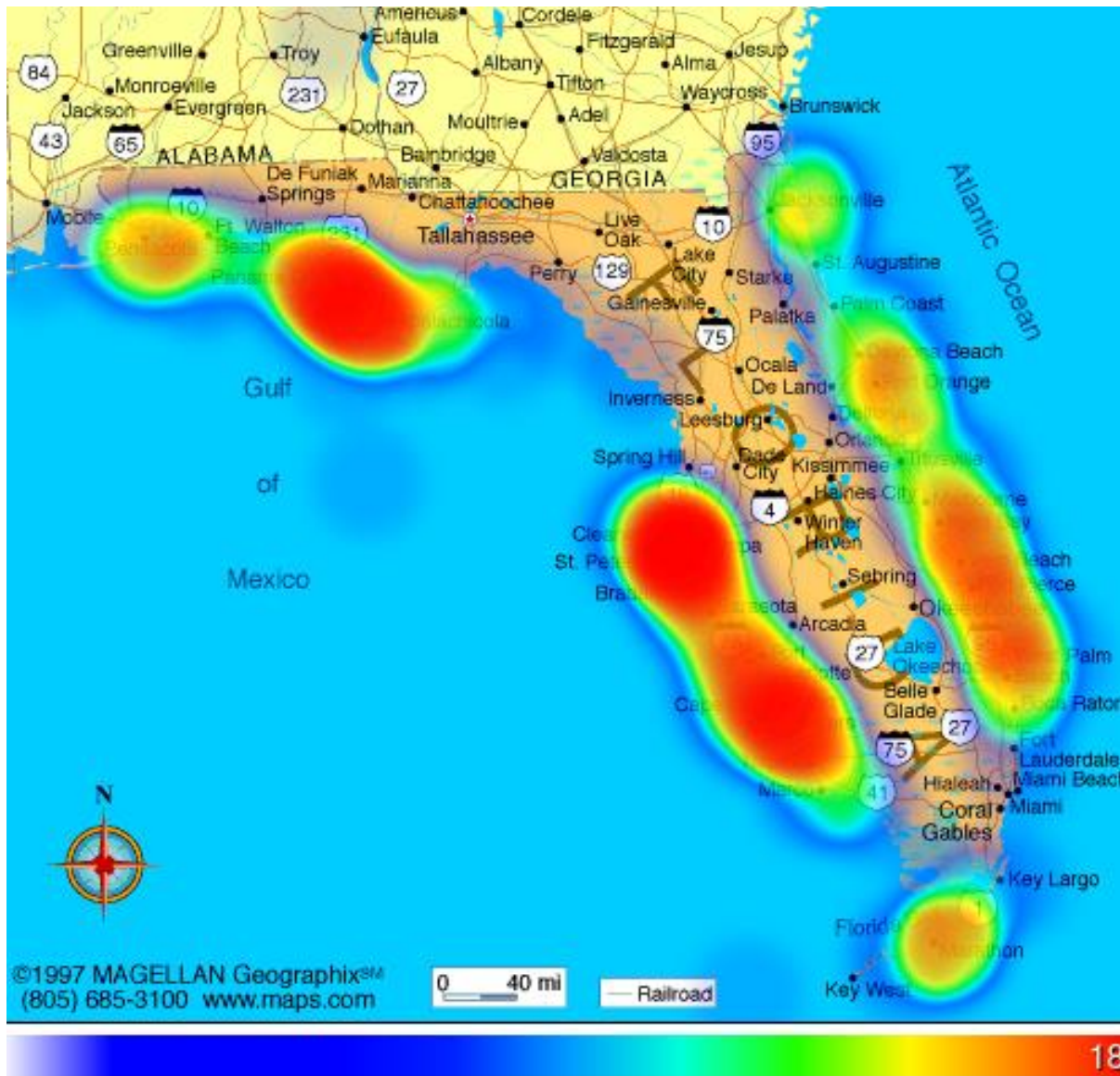


Figure 6. Heat map demonstrating the last location the angler has caught a great hammerhead around the coast of Florida, USA.

Given that fishing is often a life-long activity, anglers that target great hammerhead specifically appear to be relatively new to shark fishing in general. The younger age demographic of great hammerhead anglers presents an intriguing avenue for management to pursue, especially as technological advancements continue to alter the fishery. Because these anglers are new to great hammerhead angling, managers and stakeholders can hold seminars and create restrictions to ensure that these new anglers use sustainable angling practices that

they can pass on to friends and family for the future. Given that more than two-thirds of great hammerhead anglers are members of at least one fishing forum, Facebook group, club etc., this could be an effective way to disseminate information about appropriate angling practices, as well as information on new or most effective gear (unpublished data).

In terms of bait deployment methods, there are a few common methods anglers prefer to use. Kayaking, where the angler deploys bait with a kayak and returns to shore to fish, and casting from shore are the two most common. New methods, such as drones, are becoming more popular in the SBSF community, but they are not yet widely used. Differences in deployment methods among great hammerhead anglers alone presented an interesting linkage between the size of great hammerhead caught and how their bait was deployed. Casting can often deploy bait up to 90 metres from shore, whereas kayaking may deploy bait up to 370 metres. From our results, casters generally catch smaller great hammerhead sharks than those caught by kayaking out the bait.

Great hammerhead sharks are often encountered in shallow waters (<2 m), depending on the level of site fidelity and feeding opportunities (Guttridge et al., 2017). MacDonald *et al.* (2021) conducted a study in a shallow bay on the coast of Florida and found individual great hammerhead sharks measuring less than 200cm in length, suggesting the individuals are juvenile age, for periods longer than 10 months. Although the primary focus of their study was to locate and identify possible nursing habitats for great hammerhead sharks, the study could help to explain why casters and kayakers catch different sizes of great hammerhead sharks depending on distance from shore. Since pupping depends on season, further analysis of the time of year during which great hammerhead sharks were caught would be beneficial. As new

bait deployment technologies advance, avoiding areas that juvenile great hammerhead sharks inhabit can enhance juvenile survivorship and further help to enhance the population (Macdonald et al., 2021; Piercy, *et al.*, 2010).

Gear type and size are dependent on the preferences of the angler and size of shark targeted. Ranking the reel type, rod type and reel length allows for an overall assessment of gear used based on different combinations of gear that is used by anglers. Decreasing fight time through the correct gear use is a simple and effective angling practice that can reduce physiological stress and immediate or delayed mortality risk post-release (Skomal, 2007). A study investigated physiological stress responses in several shark species, including the great hammerhead and discovered elevated lactate levels and increased reflex impairment in great hammerhead sharks that had endured longer fight times (Gallagher, et al., 2014). This outlines the physiological consequences that develop when fight times exceed the shark's anaerobic threshold and the importance of using the correct gear to reduce the stress caused by the fight time (Brownscombe, *et al.*, 2016; Cooke & Suski, 2005). Using the combined gear index, we were able to find that the majority of great hammerhead anglers use Ultra Heavy and Heavy ranked gear (which are appropriate for larger fish), suggesting that this subset of SBSF anglers has the experience and skill level they had claimed in their survey response. While the majority of respondents reported using gear appropriate for targeting large sharks, restrictions on specific gear types may be an effective management strategy and could be applied to anglers who are targeting more than one species in a single fishing event. With this in mind, some anglers enjoy longer fight times as it enhances their fishing experience. Thus, communication between anglers and managers is necessary to ensure that restrictions put in places are

effective and endorsed. Educating anglers obtaining their SBSF permit about shark species' vulnerability to longer fight duration and air exposure could help reduce mortality incidents. Anglers who are new to fishing from shore should familiarize themselves with necessary equipment in order to safely pursue large hammerhead sharks (Brownscombe, *et al.*, 2016).

Great Hammerhead Bycatch

Our survey respondents reported catching a total of 304 great hammerhead sharks in the year prior to the survey's release. 178 were caught by great hammerhead anglers and 126 were caught by other SBSF anglers. Due to the inherent nature of the survey, there are some biases and discrepancies in the responses that may be attributed to misidentification or misinterpretation of the question. For example, there were a few other SBSF anglers that reported catching over 10 great hammerhead sharks within the past year. Bonnethead sharks (*Sphyrna tiburo*) and scalloped hammerhead sharks (*Sphyrna lewini*) are related to the great hammerhead and are similar in appearance, but do not grow as large, likely leading to misidentification errors of the species landed. Unlike their relatives, bonnetheads sharks are more abundant in Florida waters and are a popular shark to target from the shore (Heupel, *et al.*, 2006), and may be what the anglers have misidentified as a great hammerhead. Similarly, our results showed that anglers who caught a great hammerhead as bycatch reported shorter fight times than great hammerhead anglers who target this species. This may also be a result of misidentification of the species caught, which may have been bonnethead or scalloped hammerhead sharks.

Great hammerhead sharks that are caught, whether intentionally or as bycatch, are especially sensitive to long periods of time out of water due to their need for constant movement in order to pass oxygen through their gills (AJ. Gallagher, Cooke, & Hammerschlag, 2016). Although most SBSF anglers who unintentionally caught a great hammerhead shark responded that the shark survived, anglers unfamiliar with great hammerhead angling may have expected that the shark survived if it swam away. In many cases, mortality occurs some time after the shark has swam away, resulting in a 50% post-release mortality rate (Cooke & Suski, 2005; Gallagher, *et al.*, 2014; Guttridge *et al.*, 2017; Morgan & Carlson, 2010). Other non-shark fisheries have focused on research to reduce bycatch events, such as limiting handling time (Molina & Cooke, 2012). Great hammerhead anglers should be aware of the appropriate handling times and air exposure thresholds to ensure shark survival, but other SBSF anglers may not be aware of the sensitivity that great hammerheads have to overexposure (Gallagher *et al.*, 2016). Nonetheless, all anglers should ensure that they can identify species that are commonly encountered in their area when applying for an SBSF permit, especially if they are a listed species. If anglers want to improve their knowledge and understanding of shark species in the area, it may be beneficial for managers and other organisations to hold seminars or training courses.

Conclusion and Future Research

Our research provides insightful information on the demographics of great hammerhead shark anglers. We found significant differences between great hammerhead anglers and other SBSF anglers. The differences in gear types suggest that educated great hammerhead anglers

are using the correct gear to target larger sharks. There were differences found among great hammerhead anglers in gear types, and continuing this research may help to identify angling trends among the SBSF community. As shore-based shark fishing becomes more popular, research should focus on the attitude and behaviour of anglers towards shark conservation, as well as efficient communication of research-based information between anglers and fishery managers. Educating new and experienced anglers on current catch-and-release practices can help ensure proper handling techniques and limit air exposure (Adams, 2017). Given that great hammerhead anglers are relatively new to the fishery, education would be an important factor in ensuring these anglers use the proper techniques. Management should aim to take these results into account by educating shore-based shark anglers to promote handling practices that would ensure shark survival and conservation.

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