Gulf and Caribbean Research

Volume 34 | Issue 1

2023

Permit (*Trachinotus falcatus*) Fishing Quality and Conservation Threats in the Florida Keys: A Recreational Angler and Fishing Guide Survey

Morgan Piczak
Carleton University, morganpiczak@gmail.com

Steven Cooke
StevenCooke@cunet.carleton.ca

Aaron Adams
Bonefish & Tarpon Trust, aaron@bonefishtarpontrust.org

Lucas Griffin
GCFIMembers, lucaspgriffin@gmail.com

See next page for additional authors

Recommended Citation

Piczak, M., S. Cooke, A. Adams, L. Griffin, A. Danylchuk and J. Brownscombe. 2023. Permit (*Trachinotus falcatus*) Fishing Quality and Conservation Threats in the Florida Keys: A Recreational Angler and Fishing Guide Survey. Gulf and Caribbean Research 34 (1): 1-12.
Retrieved from https://aquila.usm.edu/gcr/vol34/iss1/3
DOI: https://doi.org/10.18785/gcr.3401.03

Permit (*Trachinotus falcatus*) Fishing Quality and Conservation Threats in the Florida Keys: A Recreational Angler and Fishing Guide Survey

Authors

Morgan Piczak, *Carleton University*; Steven Cooke; Aaron Adams, *Bonefish & Tarpon Trust*; Lucas Griffin, *GCFIMembers*; Andy Danylchuk; and Jacob Brownscombe, *Carleton University*

GULF AND CARIBBEAN

R E S E A R C H

Volume 34
2023
ISSN: 2572-1410

Published by

THE UNIVERSITY OF
SOUTHERN MISSISSIPPI

GULF COAST RESEARCH LABORATORY
Ocean Springs, Mississippi

Gulf and Caribbean Research Vol 34, 1-12, 2023
DOI: 10.18785/gcr.3401.03
Manuscript received August 29, 2022; accepted February 10, 2023

PERMIT (*TRACHINOTUS FALCATUS*) FISHING QUALITY AND CONSERVATION THREATS IN THE FLORIDA KEYS: A RECREATIONAL ANGLER AND FISHING GUIDE SURVEY

Morgan L. Piczak[a*], Steven J. Cooke[a], Aaron J. Adams[b,c], Lucas P. Griffin[d], Andy J. Danylchuk[d], and Jacob W. Brownscombe[a]
*[a]Department of Biology, Carleton University, Ottawa, Ontario K1S 5B6, Canada; [b]Bonefish & Tarpon Trust, 2937 SW 27th Ave., Suite 203, Miami, FL 33133, USA; [c]Florida Atlantic University, Harbor Branch Oceanographic Institute, 5600 US–1, Fort Pierce, FL 34946, USA; [d]Department of Environmental Conservation, University of Massachusetts Amherst, 160 Holdsworth Way, Amherst, MA 01003, USA; *Corresponding author: morganpiczak@gmail.com*

Abstract: Permit (*Trachinotus falcatus*) support recreational fisheries in South Florida, and there is limited monitoring to assess population trends. To address this knowledge deficiency, we conducted a survey of Permit anglers and fishing guides to collect local ecological knowledge (LEK) on fisheries trends, focused mainly on the Florida Keys. Respondents indicated a significant decline in Permit fishing quality starting in 1995 and through 2019, with greater declines in the Upper Florida Keys and Biscayne Bay. Further, declines in Permit fishing quality were more pronounced on flats habitats compared to nearshore reefs and shipwrecks. Reduction in Permit body size, an indicator of fisheries overexploitation, was not reported. Specifically, there were no significant reported differences in Permit size across time and regions. Respondents indicated the greatest potential drivers of changes in fishing quality were water quality, boat traffic, and habitat quality. As a species that aggregates on reefs and shipwrecks to spawn but also relies on nearshore flats for foraging, Permit are potentially vulnerable to a wide range of stressors that need to be included in intervention and local fisheries management plans. Given the inherent challenges with implementing biological surveys for Permit, LEK derived from the recreational fishing sector represents an important source of knowledge, notwithstanding the biases that are associated with such approaches.

Key words: recreational fishing, marine biology, fisheries management, local ecological knowledge

Introduction

Permit (*Trachinotus falcatus*) support popular recreational fisheries in many regions of their range in the Western Atlantic Ocean, Caribbean Sea, and Gulf of Mexico (GOM), including economically valuable fisheries in South Florida, United States. Their ecology involves aggregate spawning in proximity to nearshore/offshore reefs, both natural and artificial (i.e., shipwrecks), as well as predominantly foraging in shallow (<5 m) nearshore seagrass flats habitats (Adams and Cooke 2015, Brownscombe et al. 2019a). Recent research in the Florida Keys has shown that Permit move frequently between the seagrass flats where they forage and spawning sites on the Florida Reef Tract (Brownscombe et al. 2022). Further, there is a distinction between these fish and those that solely reside near offshore shipwrecks in the GOM and Western Atlantic Ocean (Brownscombe et al. 2019b, Brownscombe et al. 2020).

Recreational angling for Permit is divided into 2 distinct fisheries linked to the habitat types they occupy: seagrass flats and offshore reefs. The flats fishery is primarily catch—and—release with generally lower catch rates relative to nearshore reef fisheries. In offshore Permit fisheries, anglers target aggregations resulting in higher catch efficacy with a greater tendency to harvest. Additionally, in the offshore fisheries, angling—related depredation rates by sharks can be quite high (Holder et al. 2020). The Special Permit Zone was established in 2011 in the southern coastal region of Florida to regulate Permit fisheries where Permit harvest is more restricted, including a recently extended closed season of April through July (https://myfwc.com/fishing/saltwater/recreational/Permit/; Brownscombe et al. 2019c). Further, a Marine Protected Area was recently established in the region surrounding Western Dry Rocks to protect spawning aggregations of Permit, amongst other species (https://myfwc.com/fishing/saltwater/recreational/wdr/).

As an aggregate spawning species, Permit are potentially vulnerable to the effects of overfishing, which is reflected in the increasing regulations surrounding the recreational fisheries for species with this type of ecology (see Sadovy and Domeier 2005, Sadovy de Mitcheson et al. 2008). Indeed, overexploitation at spawning aggregation sites is a major conservation concern for this species (Holder et al. 2020, Brownscombe et al. 2022). Further, Permit rely on a broad range of habitat types, including sensitive seagrass flats, which are particularly vulnerable to anthropogenic stressors (Unsworth et al. 2019). Yet Permit population dynamics are not monitored with any type of standardized approach, and their population trends are currently unknown. The diverse habitats they occupy combined with their diffuse distribution make traditional field—based biological surveys (i.e., stock assessments) largely ineffective and unfeasible–a common characteristic of flats fishes (Zurcher et al. 2007). Further, being considered more catch—and—release—oriented fisheries, stock assessments are generally rarely done with flats fish species such as Permit. Without population monitoring (i.e., data—poor), fish population declines often occur cryptically (Post et al. 2002). This is especially true with aggregate spawning species exploited by fisheries (Erisman et al. 2011). It is therefore important to generate an assessment of historical Permit population patterns to assess the efficacy of current regulations and any conservation concerns that may require further management intervention.

Local ecological knowledge (LEK) is locally held and mobilized knowledge, which can include knowledge used by Indigenous peoples with a historic use of resources (Sillitoe 1998) or non—Indigenous natural resources users, such as anglers (Berkström et al. 2019). The objective of this research was to acquire LEK with a recreational angler and fishing guide survey. Similar approaches have been applied recently to Bonefish (*Albula vulpes*; Frezza and Clem 2015, Kroloff et al. 2019, Rehage et al. 2019), another flats fish that is recreationally and economically important to the Florida Keys yet difficult to monitor with traditional biological surveys. Further, LEK can make a meaningful contribution to fisheries management as anglers can provide new information regarding ecology, behaviour, and abundance of fish (Neis et al. 1999, Silvano and Valbo—Jørgensen 2008). Through our survey targeting LEK holders, we assessed the sentiments of all respondents, as well as only highly active anglers and/or guides who fish more than 50 days annually (i.e., experts). Specifically, it was our aim to characterize Permit fishing quality trends over recent decades (from 1975 to 2019) across multiple regions within the Florida Keys, as well as habitat and fisheries types (flats and reefs). Further, we examined changes in Permit body size across time and regions. Finally, in response to Permit fishing quality and size, we identified perceived conservation threats to the species in the region. The findings of this study will further inform local fisheries management within the Florida Keys.

Materials and Methods

Study site

Our study focused on the Permit fisheries of Florida, specifically the Upper, Middle, and Lower Florida Keys, as well as Biscayne Bay (Figure 1). The Florida Keys are located in southern Florida and are mainly delineated by islands: Upper (Key Largo to Lower Matecumbe Key), Middle (Long Key to Seven Mile Bridge), and Lower (Seven Mile Bridge to the Marquesas).

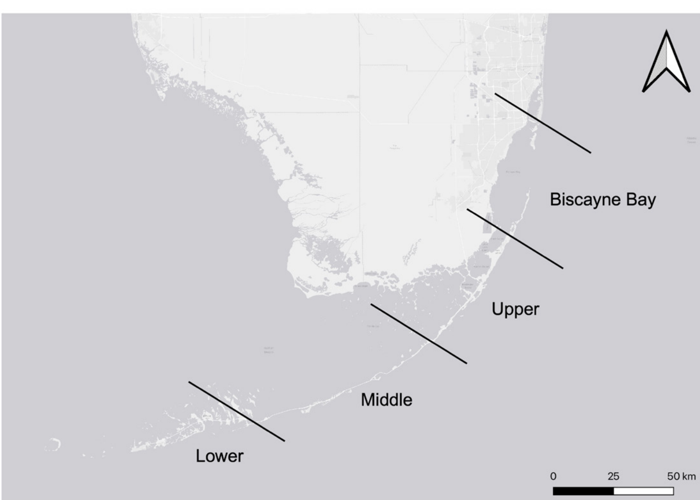


FIGURE 1. *The 4 main regions of the online angling survey for Permit within Florida, USA: Biscayne Bay, and the Upper, Middle, and Lower Florida Keys*

These limestone islands extend southwest from mainland Florida into the GOM on the west side and the Atlantic Ocean on the east side. The Florida Keys form an archipelago that consist of mangrove forests and islands, shallow—water seagrass flats, and coral reefs. Specifically, on the eastern side of the Florida Keys is the Florida reef tract, which is a large barrier reef ecosystem. Additionally, there are artificial reefs throughout the region derived from shipwrecks. Biscayne Bay, a shallow estuarine lagoon, is east of the city of Miami.

Survey development and distribution

Permit angler and fishing guide surveys were conducted from May–August 2019 via an online survey (see **Supplementary Material, Permit survey**), distributed through Bonefish and Tarpon Trust (BTT) social networks (social media and email list). The BTT is a habitat—dependent outdoor recreational and conservation organization (HDORCO) (Raynal et al. 2020) that regularly interacts with the flats fishing community to conduct research and engage in conservation actions.

The survey included 22 questions aimed at characterizing angler and guide demographics, regions of fishing activity, fishing experience and frequency, the perception of Permit fishing quality, and the sizes of angled Permit in 10 year intervals from 1975–2019 on both the flats and reefs/shipwrecks separately. Respondents were also asked to rate changes in Permit fishing quality in their time participating in the fishery on a Likert scale (1, severely declined; 2, declined; 3, the same; 4, improved; 5, greatly improved). Next, respondents were asked to rate fishing quality each year they participated in Permit angling based on number of shots per day fishing (number of opportunities to cast to Permit) and on a Likert scale (1, very poor (<3 shots per day fishing); 2, poor (3—5 shots); 3, fair (5—10 shots); 4, good (10—20 shots); 5, very good (>20 shots)). This rating scheme was based on expert opinion of the researchers based on experience in the fishery working directly with a wide range of fishing guides across the entirety of the Florida Keys from 2015–2019. Next, respondents were asked to rate changes in Permit size over time also on a Likert scale (1, small; 2, medium; 3, large; or 4, very large). Lastly, respondents were asked to identify the factors that have influenced fishing quality to identify potential conservation threats by region from a selection of options (see Supplemental Material).

Methodological Limitations

Several sources of systematic bias could potentially impact results when considering data collected from retrospective surveys. Our survey was distributed by the HDORCO BTT and respondents could have high avidity biases as they follow BTT social media. The BTT is also connected mainly with those engaged in the flats fishery, and therefore, responses from offshore—oriented fishers were likely less represented. Recall bias refers to differential responses to interviews or surveys (Chu et al. 1992). Common in self—reporting studies, incomplete or inaccurate recollection of events can bias results; however, to mitigate recall bias we aimed to design our survey to capture specific and complete information. Another source of bias stems from occurrences when individuals do not respond to a survey, which could introduce nonresponse bias (Connelly et al. 2000). In these cases, the characteristics and information of those who did not respond could be different from those who did (Fisher 1996) and it can be difficult to estimate the response rate, especially for online surveys (Vehovar and Manfreda 2008).

Data analysis and modeling

We generated 3 datasets for analyses: all respondents (survey results as a whole), highly active respondents (highly active Permit anglers and fishing guides that spend >50 days Permit fishing per year), and experienced anglers (respondents who fished for Permit for >30 years). The number of responses were tallied per region, year, and survey question. Data were managed and analysed in R Statistical Environment (3.6.3; R Core Team 2021) using the MASS package with the function polr (Venables and Ripley 2002), as well as dplyr (Wickham et al. 2021) and ggplot2 (Wickham 2016).

For all statistical analyses, we generated candidate models and model selection was used to determine final model structure with Akaike information criterion with small sample size correction (AICc; Aikaike 1973). If AICc values were within 2.0 of the top models, they were also considered plausible models. First, we examined drivers of Permit fishing quality (ordered categorical) with an ordinal regression, where explanatory variables included year (1975, 1985, 1995, 2005, 2010, 2015, and 2019), habitat (flats or reefs/shipwrecks), and region (Biscayne Bay, Lower, Middle and Upper Florida Keys), which were all categorical. Permit size (ordered categorical) was also modeled with ordinal regression, where explanatory variables included year and region, as well as their interaction. Habitat was not included in the Permit size model, as all respondents answering that question fished only flats (i.e., not reefs or shipwrecks). For fishing quality, models were each fit to 3 datasets: all respondents, highly active respondents, and experienced respondents. Habitat was not included in the Permit fishing quality model for only experienced anglers due to insufficient sample size, so the number of responses was pooled across reefs and flats. For Permit size, models were fit to 2 datasets: all respondents and highly active respondents. Post—hoc tests were completed for each of the top candidate models with Tukey's HSD test, as well as the models that were within 2.0 of the top models. All model assumptions were checked for violation of assumptions following the outlined protocols in Zurr et al. (2010; i.e., diagnostic plots).

Results

The survey received 86 responses from 18 fishing guides and 68 anglers, of which 55 fish for Permit in the Lower Florida Keys, 28 in the Middle Florida Keys, 20 in the Upper Florida Keys, and 25 in Biscayne Bay (Table 1). Anglers also reported fishing for Permit in the Everglades, Palm Beach, Tampa Bay,

TABLE 1. *Number of responses for each question from the Permit angler surveys grouped by region, FK = Florida Keys.*

Question	Answer Choice	Biscayne Bay	Lower FK	Middle FK	Upper FK	Total
Region Fished	N/A	25	55	28	20	128
Habitat Fished	Flats	25	55	27	20	127
	Nearshore reef/Shipwreck	4	6	6	6	22
	Offshore Shipwreck	9	9	3	2	23
	Florida Reef Tract	4	4	2	4	18
Respondent Gender	Male	25	54	27	20	126
	Female	0	0	1	1	2
Years Fished	1–10	2	13	4	4	23
	11–20	5	14	7	4	30
	21–30	6	17	7	6	36
	31–40	5	12	4	1	22
	41–50	4	6	3	2	15
	51–60	3	4	3	3	16
Days Fished Annually	<50	13	37	20	10	80
	50–100	5	7	3	3	18
	100–150	3	2	2	2	9
	150–200	2	5	2	2	11
	200–250	1	4	1	3	9
	250+	0	0	0	0	0
Gear Type	Fly	21	50	23	19	113
	Spin	25	55	28	20	128
Harvest	Never	24	51	28	20	123

TABLE 2. *Number of responses per year for Permit fishing quality across regions and habitats. A. All respondents. B. Highly active respondents. C. Experienced respondents (the number of responses across habitat types are pooled).*

	Year	Biscayne Bay			Lower Florida Keys			Middle Florida Keys			Upper Florida Keys		
		Flats	Reefs	Annual Total	Flats	Reefs	Annual Total	Flats	Reefs	Annual Total	Flats	Reefs	Annual Total
A	1975	7	3	10	12	6	18	6	5	11	4	2	6
	1985	10	4	14	16	6	22	9	5	14	4	3	7
	1995	13	5	18	28	7	35	12	5	17	9	4	13
	2005	17	5	22	37	8	45	18	6	24	12	4	16
	2010	20	5	25	43	8	51	21	7	28	16	5	21
	2015	21	6	27	48	9	57	23	8	31	16	6	22
	2019	21	7	28	49	11	60	23	9	32	17	7	24
Grand Total		109	35	144	233	55	288	112	45	157	78	31	109
B	1975	4	2	6	5	3	8	2	1	3	3	2	5
	1985	5	2	7	6	2	8	3	1	4	3	2	5
	1995	6	3	9	14	3	17	5	1	6	5	3	8
	2005	8	3	11	18	4	22	6	1	7	7	3	10
	2010	10	3	13	20	4	24	4	1	8	9	3	12
	2015	10	3	13	20	4	24	7	1	8	9	3	12
	2019	10	5	15	19	5	24	7	3	10	9	5	14
Grand Total		53	21	74	102	25	177	37	9	46	45	21	66
C	1975		7			16			10			7	
	1985		7			16			9			7	
	1995		7			15			9			7	
	2005		7			16			9			7	
	2010		7			15			8			6	
	2015		7			16			9			7	
	2019		7			16			9			7	
Grand Total			49			110			63			48	

TABLE 3. *Number of responses indicating size of Permit captured. A. All respondents. B. Highly active respondents across regions.*

	Year	Biscayne Bay	Lower Florida Keys	Middle Florida Keys	Upper Florida Keys
A	1975	8	10	6	5
	1985	9	12	5	6
	1995	14	22	9	10
	2005	17	34	13	13
	2010	17	42	16	15
	2015	19	45	20	15
	2019	21	46	23	18
Grand Total		105	211	92	82
B	1975	4	5	2	3
	1985	4	5	2	3
	1995	7	12	5	6
	2005	8	18	6	7
	2010	8	19	6	7
	2015	8	19	7	7
	2019	11	18	8	10
Grand Total		50	96	36	43

Charlotte Harbor, Bonita Springs, Stuart, and Chokoloskee. A near majority of respondents undertook fishing for Permit on flats, followed by offshore shipwrecks, nearshore reefs/shipwrecks and then the Florida Reef Tract. Further, the majority of respondents were male, with only 2 females (Table 1). The highest number of respondents reported fishing for Permit for 21–30 years (Table 1). The majority of respondents fished for fewer than 50 days per year, with a decline in the number of

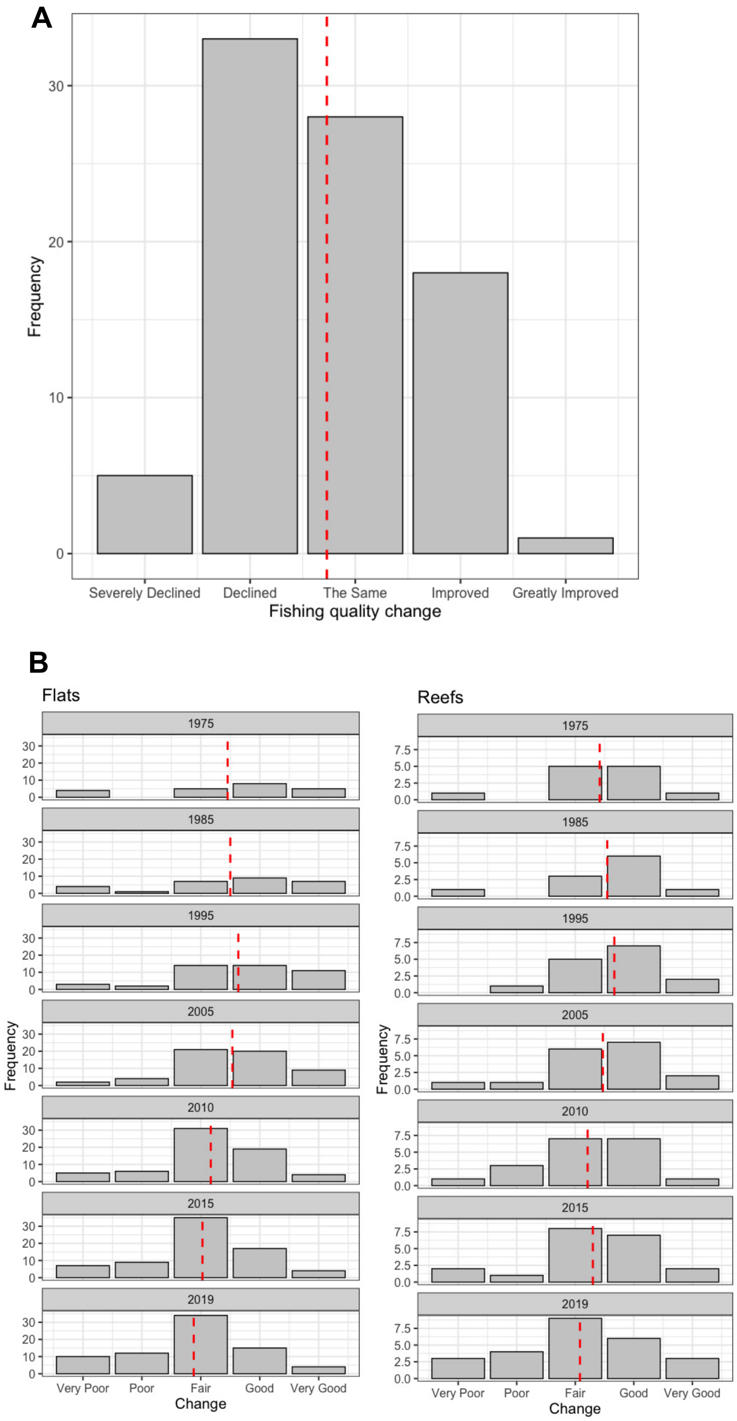


FIGURE 2. *Angler reported Permit fishing quality from all angler survey responses. A. Overall. B. Fishing quality on flats (left) reefs (right), from 1975–2019. Dashed lines indicate mean values.*

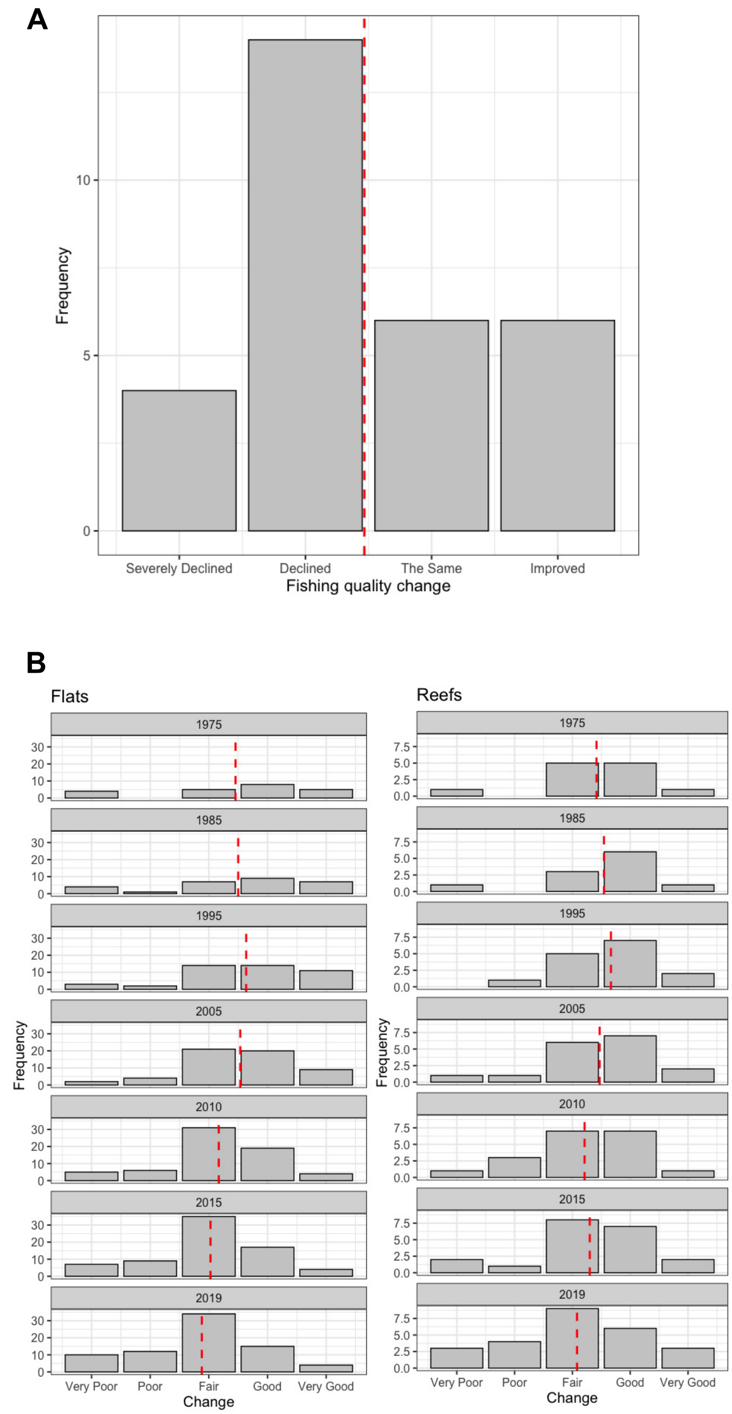


FIGURE 3. *Permit fishing quality reported from highly active respondents. A. Overall. B. Fishing quality on flats (left) reefs (right) from 1975–2019. Dashed lines indicate mean values.*

respondents as the number of days fished increased. Of the 86 respondents, 30 were categorized as highly active respondents (fishing or guiding for Permit for more than 50 days per year) and/or guides. Most respondents used both fly and spin gear types and the majority of respondents never harvested Permit (Table 1). Generally, the number of respondents across all regions increased over the years from 1975–2019 for both Permit fishing quality (Table 2) and fish size (Table 3), with the highest number of respondents from Lower Florida Keys.

Respondents indicated a range of perceived changes in Permit fishing quality since they started Permit fishing, from severely declined to greatly improved; however, on average, anglers indicated Permit fishing quality has declined (Figures 2A and 3A). The top 2 models for all 3 datasets (all respondents, active anglers and experienced anglers) for Permit fishing quality were habitat and year, and year (Table 4). Post—hoc analyses

TABLE 4. *Model selection statistics for ordinal model outputs of Permit fishing quality. A. All respondents. B. Highly active respondents. C. Experienced respondents. AICc–Akaike information criterion with small sample size correction; df–degrees of freedom.*

	Explanatory Variables	AICc	df
A	Habitat + Year	5151.6	7
	Year	5152.1	6
	Habitat + Region + Year	5157.6	10
	Region + Year	5158.2	9
	Habitat	5277.1	1
	Region + Habitat	5283.1	4
	Region	5286.2	3
B	Year	2249.6	7
	Habitat + Year	2251.4	6
	Region + Year	2255.6	10
	Habitat + Region + Year	2257.5	9
	Habitat	2430.7	6
	Region	2434.8	18
	Region + Habitat	2436.7	24
C	Year	1630.8	5
	Habitat + Year	1631.0	6
	Region + Year	1636.9	5
	Habitat + Region + Year	1637.1	9
	Habitat	1696.1	1
	Region	1701.4	2
	Region + Habitat	1702.2	3

TABLE 5. *Post–hoc test for the top model candidate from Table 4 for the impact of year on Permit fishing quality with sequential year to year comparison and first to final year comparisons. A. All respondents. B. Highly active respondents. C. Experienced respondents. * indicates significant difference, Tukey's HSD test.*

	Year	Value	Standard Error	Z value	P value
A	1975 – 1985	0.13	0.22	0.59	0.99
	1985 – 1995	0.05	0.19	0.30	0.99
	1995 – 2005	–0.28	0.16	–1.76	0.57
	2005 – 2010	–0.65	0.14	–4.50	**<0.001** *
	2010 – 2015	–0.15	0.14	–1.13	.091
	2015 – 2019	–0.31	0.13	–2.38	0.2
	1975 – 2019	–1.22	0.19	–6.42	**<0.001** *
B	1975 – 1985	0.33	0.34	0.96	0.96
	1985 – 1995	0.13	0.30	0.44	0.99
	1995 – 2005	–0.68	0.24	–2.80	0.07
	2005 – 2010	–1.17	0.22	–5.30	**<0.001** *
	2010 – 2015	–0.28	0.20	–1.32	0.81
	2015 – 2019	–0.36	0.20	–1.77	0.56
	1975 – 2019	–2.02	0.29	–6.99	**<0.001** *
C	1975 – 1985	0.05	0.28	0.19	0.99
	1985 – 1995	–0.28	0.29	–0.99	0.96
	1995 – 2005	–0.34	0.28	–1.18	0.90
	2005 – 2010	–0.82	0.27	–2.96	0.04*
	2010 – 2015	–0.03	0.27	–0.145	0.99
	2015 – 2019	–0.27	0.28	–0.98	0.95
	1975 – 2019	–1.70	0.29	–5.88	**<0.001** *

revealed that for all respondents, highly active respondents, and experienced respondents, there was a significant decline in Permit fishing quality from 1975–2019 (Table 5). For all respondents and highly active respondents, declines in Permit fishing quality were greater for flats (significant declines from 2005–2010 and overall from 1975–2019) compared to reefs, which were more stable over time (Figures 2B and 3B; Table 6). Reports indicate Permit fishing quality peaked in 1995 and was lowest in 2019. The change in Permit fishing quality was variable across regions, whereby Biscayne Bay and Upper Florida Keys had severely declined, while the Lower and Middle Florida Keys remained the same (Figure 4A). Respondents who had been fishing for Permit for < 30 years indicated a decline in Permit fishing quality, while those fishing for > 30 years reported that fishing quality stayed the same (Figure 4B). Respondents reported a range of perceived factors influencing Permit fishing quality that were generally consistent amongst regions fished; the most common concerns were related to water quality, habitat quality, and boat traffic, with fewer respondents reporting issues stemming from oil spills, predation, or overharvesting (Figure 5).

Respondents indicated that size of Permit they observed was generally stable over time (Figure 6A), with highly active respondents stating that on average Permit size was large (Figure 7A). Across all respondents and highly active respondents, the top model candidates for Permit size included year (Table 7A) and region (Table 7B), respectively. Post–hoc analyses determined that there were no significant changes year to year for all respondents for Permit size (Supplemental Table S1; Figure 6B); however, there were some modest declines in Permit size for all years except for 1975–1985 and 2010–2015. For highly active respondents, post–hoc tests showed that there were also no significant differences for Permit size across regions (Supplemental Table S1). Further, for highly active respondents, Permit size was also consistent across years (Figure 7B).

Discussion

With formal stock assessments for Permit being absent, our goal was to use an online survey to collect LEK to assess long–term trends in Permit fishing quality and conservation threats from the perspective of Permit anglers and fishing guides in the Florida Keys. Although response rates were not high (n = 84 total, n = 30 highly active respondents, n = 17 experienced anglers), this LEK provided some insights into the Permit fishery that likely reflect Permit population trends and potential conservation issues. Overall, respondents indicated that Permit fishing quality has decreased over time, with a marked shift toward decline starting in 1995 that persisted into 2019 the last year of the survey. However, Permit size was stable throughout the study years and across regions. Respondents identified perceived threats to Permit within the Florida Keys, where water quality, boat traffic, and habitat quality were the most reported.

Our results suggest that Permit fishing quality in the Florida Keys has declined. This decline appears to be modest compared to the degree of the major bonefish decline in South Florida that became apparent at the turn of the 21st century

TABLE 6. *Post–hoc test of the top model candidate for the impact of year + habitat on Permit fishing quality, with sequential year to year comparison and first to final year comparisons. A. All respondents. B. Highly active respondents. * indicates significant difference, Tukey's HSD test.*

	Year	Habitat	Value	Standard Error	Z value	P value
A	1975 – 1985	Flats	–0.01	0.28	–0.07	0.99
	1985 – 1995	Flats	0.04	0.24	0.19	0.99
	1995 – 2005	Flats	–0.30	0.18	–1.60	0.93
	2005 – 2010	Flats	–0.71	0.17	–4.26	**<0.01** *
	2010 – 2015	Flats	–0.25	0.15	–1.64	0.92
	2015 – 2019	Flats	–0.28	0.15	–1.91	0.80
	1975 – 2019	Flats	–1.53	0.23	–6.44	**<0.01** *
	1975 – 1985	Reefs	0.31	0.37	0.85	0.99
	1985 – 1995	Reefs	0.04	0.35	0.14	0.99
	1995 – 2005	Reefs	–0.28	0.31	–0.88	0.99
	2005 – 2010	Reefs	–0.49	0.30	–1.65	0.92
	2010 – 2015	Reefs	0.21	0.29	0.72	0.99
	2015 – 2019	Reefs	–0.45	0.28	–1.62	0.93
	1975 – 2019	Reefs	–0.66	0.32	–2.01	0.71
B	1975 – 1985	Flats	0.22	0.41	0.53	0.99
	1985 – 1995	Flats	0.06	0.35	0.17	0.99
	1995 – 2005	Flats	–0.89	0.40	–2.22	0.59
	2005 – 2010	Flats	–1.20	0.25	–4.81	**<0.01** *
	2010 – 2015	Flats	–0.39	0.23	–1.73	0.89
	2015 – 2019	Flats	–0.28	0.23	–1.22	0.99
	1975 – 2019	Flats	–2.26	0.35	–6.42	**<0.01** *
	1975 – 1985	Reefs	0.46	0.61	0.76	0.99
	1985 – 1995	Reefs	0.31	0.56	0.56	0.99
	1995 – 2005	Reefs	–0.77	0.48	–1.60	0.94
	2005 – 2010	Reefs	–1.06	0.46	–2.32	0.51
	2010 – 2015	Reefs	0.15	0.43	0.35	0.99
	2015 – 2019	Reefs	–0.68	0.42	–1.63	0.93
	1975 – 2019	Reefs	–1.59	0.49	–3.23	0.06

(Frezza and Clem 2015, Brownscombe et al. 2019b). Yet, our findings are congruent with a time–series of fishing guide reports that also revealed declines in bonefish (Santos et al. 2017). When fisheries are data–limited (in the case of most flats fish), use of angler (or guide) reported data can be a useful proxy notwithstanding some biases (discussed below). Further, we found that declines of Permit fishing quality were more pronounced in the flats fishery compared to reefs and shipwreck habitats. The threats facing fish in various life stages or locations can differ, although this may not always manifest in location–specific perceptions of fishing quality. This is especially true for Florida Keys Permit, the majority of which move frequently between habitat types and fisheries. Threats facing fish while on the flats are largely related to habitat quality, while at the more offshore sites, the primary threat is likely depredation when fishing during the spawning period (e.g., Holder et al. 2020) and harvest.

Respondents indicated little change in the mean size of Permit caught over time, which is a positive sign given that fisheries–driven population declines are often associated with decreases in mean fish size (Trippel 1995). However, the ecology of Permit is such that the signs of population decline documented here should be taken seriously and proactive conservation measures taken where possible. It is possible that Permit are exhibiting signs of hyperstability where indicators of fishing quality fail to fully represent the state of a population (Erisman et al. 2011). The lack of change in mean fish size may indicate that large (mature) fish are abundant, yet it is unclear how many smaller (sub–adult) fish are present. Most Permit anglers target large fish which inherently biases such methods, but nonetheless future surveys should specifically ask anglers about encounters with sub–adult fish to potentially detect any evidence of recruitment failure. For example, the pattern of large fish dominating the fishery while fewer young fish recruited to the fishery is the same pattern as observed in the Florida Keys bonefish fishery, which suffered a dramatic decline (Santos et al. 2019, Rehage et al. 2019).

Permit are an aggregate spawning species, and are commonly targeted by anglers at spawning sites; in these cases, population decline can occur rapidly and cryptically (Erisman et al. 2017). This is the major thrust behind a recent extension to Permit harvest restriction, to protect Permit during the spawning aggregation period (Brownscombe et al. 2019c). Yet, catch–and–release has potential for negative population impacts on Permit, as shark depredation can be very high in certain aggregation locations (Holder et al. 2020). This was one of the factors driving the creation of Western Dry Rocks Marine Protected Area, to eliminate fishing pressure at a key Permit spawning site during the main spawning period from April through July (https://myfwc.com/fishing/saltwater/recreational/wdr/). This is surely a valuable conservation step, although there are likely many Permit spawning aggregation sites throughout the coastal Florida Keys (Brownscombe et al. 2020), where catch–and–release fishing is allowed during the spawning period (i.e., March–June). Taken as a whole, further work should address the reliance of Permit on various spawning sites and the extent to which fishing may be a conservation threat (mainly through fishing pressure and depredation) at these sites to design an effective management strategy.

In addition to being an aggregate spawning species, Permit also move frequently amongst a variety of habitats, including natural and artificial reefs and seagrass flats. The latter serve as a key source of food for adult Permit throughout the Florida Keys, as determined by fish tracking and stable isotope analysis (Brownscombe et al. 2022). Seagrass flats in the region are subject to a range of stressors (Sargent et al. 1995, Hall et al. 2017), which are of concern for Permit conservation. Indeed, respondents indicated the most common stressors that may be impacting Permit fishing quality were water quality, habitat quality, and boat traffic. These stressors are likely most relevant to flats fisheries, where they have also been cited as a common

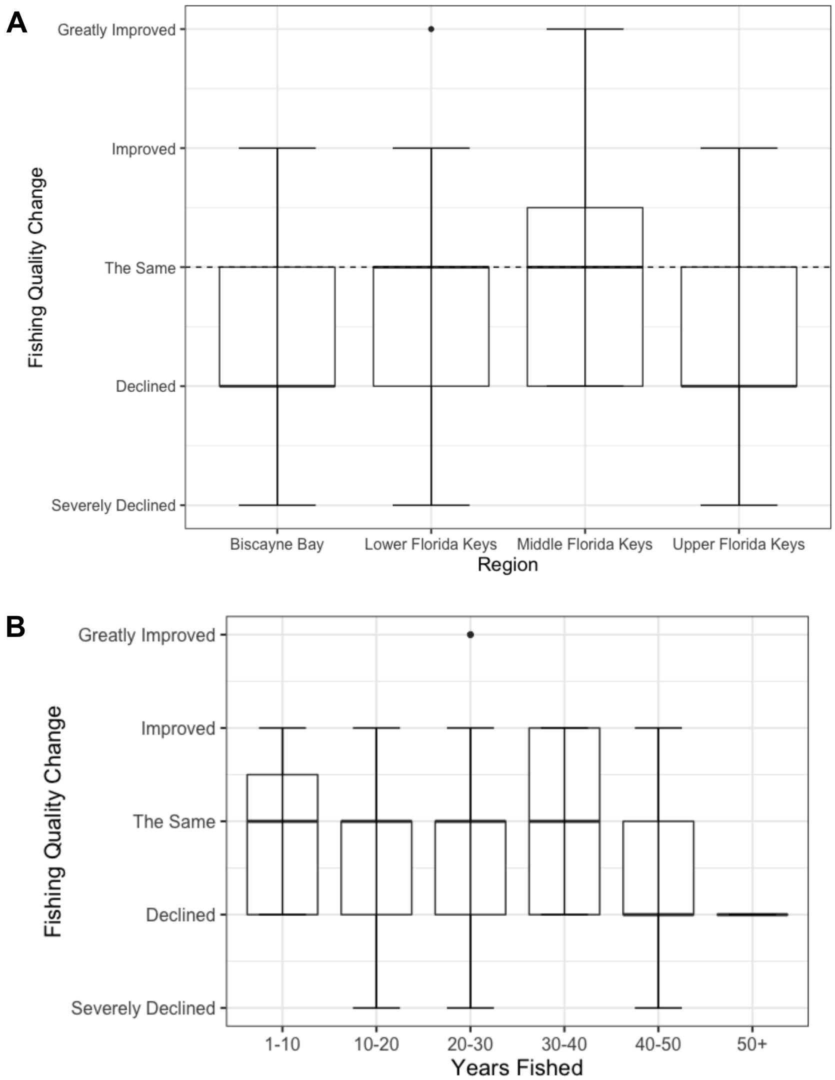


FIGURE 4. *Reported Permit fishing quality changes from angler surveys across all respondents. A. Among regions in the Florida Keys. B. Among years fished. Solid line--mean; boxes–upper and lower 25% quartiles; whiskers–95% confidence intervals; dots–outliers.*

concern (Adams and Cooke 2015). Further, the majority of respondents fished primarily on flats habitats, so future research should investigate potential anthropogenic stressors impacting Permit fishing quality on reef habitats. Water and habitat quality are linked to high level challenges surrounding broad scale land use including coastal development and freshwater flows through the Everglades (Brownscombe et al. 2019b). Boat traffic is a relevant and manageable element to both flats fish conservation and angling opportunities (Frezza and Clem 2015). That is, boat traffic can damage flats habitat integrity directly, or scare fish away from foraging habitats, reducing energy intake (Ault et al. 2001). Angling opportunities are also likely affected directly, as boat traffic reduces the capacity of flats anglers to effectively target fish. Creation of no—motor zones (i.e., pole/troll) and/or idle speed around key foraging and fishing habitats is a measure already taken in areas of the Upper Florida Keys and wider adoption would likely be beneficial.

Like all sampling methods, angler survey data such as those collected here is subject to a number of biases and limitations (Pollock et al. 1994). For example, we do not have a true response rate given uncertainty regarding the potential sampling pool, which is a common characteristic of online surveys (Vehovar and Manfreda 2008). Relatedly, such surveys can be subject to avidity bias whereby respondents represent those with strong feelings about the state of the resource or their relative reliance on the fishery (e.g., for livelihood). The survey was distributed by an HDORCO (Raynal et al. 2020; i.e., Bonefish & Tarpon Trust) which could also influence the characteristics of respondents, in that respondents that follow BTT social media are more likely to have a high avidity bias. Recall bias could have also been introduced

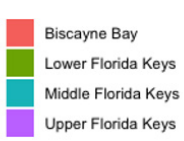
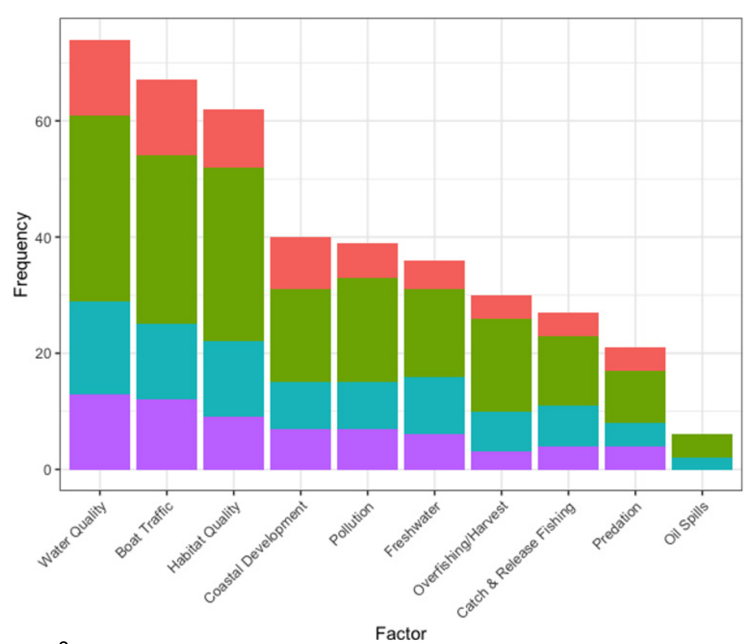


FIGURE 5. *Frequency of reported factors that are believed to be influencing Permit fishing quality from angler surveys, grouped by fishing region in the Florida Keys.*



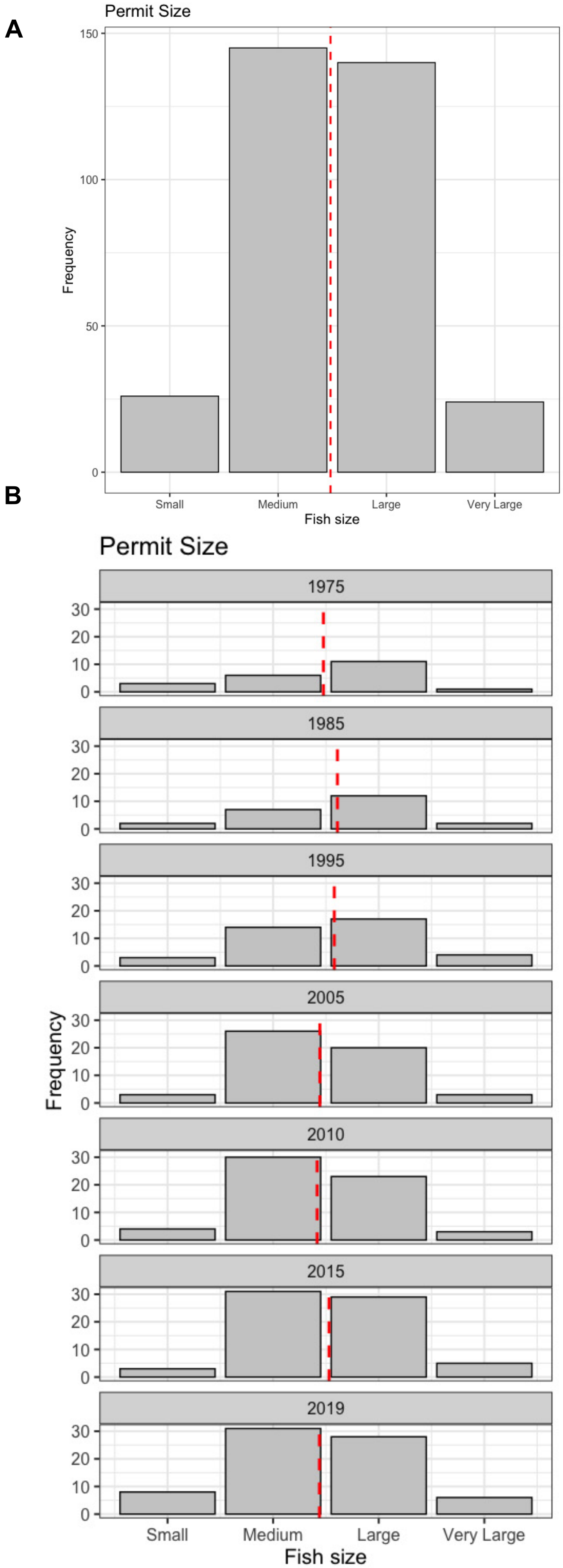


FIGURE 6. *Size of Permit captured by all respondents. A. Overall. B. Change in Permit size across years. Dashed lines indicate mean values.*

FIGURE 7. *Size of Permit captured by highly active respondents. A. Overall. B. Change in size across years. Dashed lines indicate mean values.*

TABLE 7. Model selection statistics for ordinal regression mode outputs of Permit size. A. All respondents. B. Highly active respondents. AICc– Akaike information criterion for small sample sizes; df–degrees of freedom.

	Explanatory Variables	AICc	df
A	Year	2992.8	6
	Region	2998.4	3
	Region + Year	2998.9	9
B	Region	1262.0	3
	Year	1265.0	6
	Region + Year	1271.0	9

with our survey with some respondents fishing for decades (i.e., some respondents had been fishing for 50+ years). Additionally, survey participants had varying levels of fishing experience (ranging from one year to over 60) and it is likely that more experienced anglers have different perceptions relative to less experienced ones. Specifically, we found that respondents who had been fishing for more years perceived greater decline relative to those that had been fishing for Permit for fewer years, therefore indicating potential shifting baselines. The findings presented here should be interpreted with caution; however, the respondents could be classified as key informants based on their time fishing (see Muellmann et al. 2021). Nonetheless, the consistent observation of perceived declines in fishing catch suggests the need for formal stock assessment methods and more rigorous and statistically—valid angler surveys. Fishery independent data is needed given that decreases in catchability may give the illusion of population declines in recreational fisheries (Arreguin—Sanchez 1996, Askey et al. 2006). Yet, in some instances catch rates can remain hyperstable even when populations are in great decline (Erisman et al. 2011, Maggs et al. 2016). Methods such as hydroacoustic surveys and acoustic cameras provide some promise for abundance assessments of Permit.

Conclusions

Using angler surveys to collect LEK, we determined that perceived Permit fishing quality within the Florida Keys has significantly decreased over recent decades, with a marked decline starting in 1995. Trends identified by respondents indicated that declines in Permit fishing quality were more pronounced on flats habitats compared to nearshore reefs and shipwrecks. With limited population monitoring, these declines in Permit fishing quality reflect concerns regarding decreasing populations. We also found that Permit size showed a smaller decline relative to fishing quality across study years, with no substantial differences across different regions within the Florida Keys. However, modest declines in Permit size should be taken into consideration for local fisheries management as fisheries—driven population declines are often associated with decreases in mean fish size. Finally, water quality, boat traffic and habitat quality were the most frequently cited concerns regarding Permit fishing quality. This aggregate spawning species extensively use productive nearshore flats for growth and development, which is often where these stressors can be concentrated. In efforts to conserve populations and maintain sustainable fisheries, proactive measures including decreasing pollution and establishing no—motor zones should be undertaken to alleviate Permit from these stressors.

Acknowledgements

We thank all the anglers and fishing guides who participated in this survey. Cooke and Danylchuk are Bonefish & Tarpon Trust Research Fellows. Piczak is supported by the National Sciences and Engineering Research Council of Canada. Surveys were conducted under the Carleton University Research Ethics Board-B Project #110697.

Literature Cited

Adams, A.J. and S.J. Cooke. 2015. Advancing the science and management of flats fisheries for Bonefish, Tarpon, and Permit. Environmental Biology of Fishes 98:2123–2131. https://doi.org/10.1007/s10641—015—0446—9

Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. In: B.N. Petrov and B.F. Csaki, eds. Second International Symposium on Information Theory, Springer—Verlag, New York, NY, USA, p. 267–281.

Arreguin—Sanchez, F. 1996. Catchability: A key parameter for fish stock assessment. Reviews in Fish Biology and Fisheries 6:221–242. https://doi—org.ca/10.1007/BF00182344

Askey, P.J., S.A. Richards, J.R. Post, and E.A. Parkinson. 2006. Linking angling catch rates and fish learning under catch—and—release regulations. North American Journal of Fisheries Management 26:1020–1029. https://doi.org/10.1577/M06—035.1

Ault, J.S., S.G. Smith, G.A. Meester, K. Luo, and J.A. Bohnsack. 2001. Site Characterization for Biscayne National Park: Assessment of Fisheries Resources and Habitats. Technical Memorandum 468, National Oceanic and Atmosphere Administration. Miami, FL, USA. 156 pp. https://repository.library.noaa.gov/view/noaa/8519

Berkström, C., M. Papadopoulos, N.S. Jiddawi, and L.M. Nordlund. 2019. Fishers' local ecological knowledge (LEK) on connectivity and seascape management. Frontiers in Marine Science

6:130. https://doi.org/10.3389/fmars.2019.00130

Brownscombe, J.W., L.P.Griffin, D. Morley, A. Acosta, J. Hunt, G.T. Crossin, S.J. Iverson, R. Boucek, A.J. Adams, S.J. Cooke, and A.J. Danylchuk. 2019a. Seasonal occupancy and connectivity amongst nearshore flats and reef habitats by Permit *Trachinotus falcatus*: Considerations for fisheries management. Journal of Fish Biology 96:469–479 https://doi.org/10.1111/jfb.14227.

Brownscombe, J.W., A.J. Danylchuk, A.J Adams, B.D. Black, R.E. Boucek, M. Power, J.S. Rehage, R.O. Santos, R. Fisher, B. Horn, C.R. Haak, S. Morton, J. Hunt, R. Ahrens, M.S. Allen, J. Shenker, and S.J. Cooke. 2019b. Bonefish in South Florida: Status, threats and research needs. Fisheries Research 102:329–348. https://doi.org/10.1007/s10641–018–0820–5.

Brownscombe, J.W., A.J. Adams, N. Young, L.P. Griffin, P.E. Holder, J. Hunt, A. Acosta, D. Morley, R. Boucek, S.J. Cooke, and A.J. Danylchuk. 2019c. Bridging the knowledge–action gap: A case of research rapidly impacting recreational fisheries policy. Marine Policy 104:210–215. https://doi.org/10.1016/j.marpol.2019.02.021

Brownscombe, J.W., L.P. Griffin, D. Morley, A. Acosta, J. Hunt, S.K. Lowerre–Barbieri, A.J. Adams, A.J. Danylchuk, and S.J. Cooke. 2020. Application of machine learning algorithms to identify cryptic reproductive habitats using diverse information sources. Oecologia 194:283–298. https://doi.org/10.1007/s00442–020–04753–2.

Brownscombe, J.O. Shipley, L. Griffin, D. Morley, A. Acosta, A. Adams, R. Boucek, A. Danylchuk, S. Cooke, and M. Power. 2022. Application of telemetry and stable isotope analyses to inform the resource ecology and management of a marine fish. Journal of Applied Ecology 59:1110–1121. https://doi.org/10.1111/1365–2664.14123

Chu, A., D. Eisenhower, M. Hay, D. Morganstein, J. Neter, and J. Waksberg. 1992. Measuring the recall error in self–reported fishing and hunting activities. Journal of Office Statistics 1:19–39.

Connelly, N.A., T.L. Brown, and B.A. Knuth. 2000. Assessing the relative importance of recall bias and nonresponse bias and adjusting for those biases in statewide angler surveys. Human Dimensions of Wildlife 5:19–29. https://doi.org/10.1080/10871200009359192.

Erisman, B.E., L.G.Allen, J.Y. Claisse, D.J. Pondella, E.F. Miller, and J.H. Murray. 2011. The illusion of plenty: Hyperstability masks collapses in two recreational fisheries that target fish spawning aggregations. Canadian Journal of Fisheries and Aquatic Sciences 68:1705–1716. https://doi.org/10.1139/f2011–090.

Erisman, B., W. Heyman, S. Kobara, T. Ezer, S. Pittman, O. Aburto–Oropeza, and R.S. Nemeth. 2017. Fish spawning aggregations: Where well–placed management actions can yield big benefits for fisheries and conservation. Fish and Fisheries 18:128–144. https://doi.org/10.1111/faf.12132.

Fisher, M.R. 1996. Estimating the effect of nonresponse bias on angler surveys. Transactions of the American Fisheries Society 125:118–126. https://doi.org/10.1577/1548–8659(1996)125<0118:ETEONB>2.3.CO;2.

Frezza, P.E. and S.E. Clem. 2015. Using local fishers knowledge to characterize historical trends in the Florida Bay bonefish population and fishery. Environmental Biology of Fishes 98:2187–2202. https://doi.org/10.1007/s10641–015–0442–0.

Hall, M.O., M.J. Durako, J.W. Fourqurean, C. Joseph, and S.E. Jun. 2017. Decadal changes in seagrass distribution and abundance in Florida Bay. Estuaries 22:445–459. http://www.jstor.org/stable/1353210

Holder, P.E., L.P. Griffin, A.J. Adams, A.J. Danylchuk, S.J. Cooke, and J.W. Brownscombe. 2020. Stress, predators, and survival: Exploring Permit (*Trachinotus falcatus*) catch–and–release fishing mortality in the Florida Keys. Journal of Experimental Marine Biology and Ecology 524:151289. https://doi.org/10.1016/j.jembe.2019.151289.

Kroloff, E.K.N., J.T. Heinen, K.N. Braddock, J.S. Rehage, and R.O. Santos 2019. Understanding the decline of catch–and–release fishery with angler knowledge: A key informant approach applied to South Florida bonefish. Environmental Biology of Fish 102:319–328. https://doi.org/10.1007/s10641–018–0812–5.

Maggs, J.Q., B.Q. Mann, W.M. Potts, and S.W. Dunlop. 2016. Traditional management strategies fail to arrest a decline in the catch–per–unit–effort of an iconic marine recreational fishery species with evidence of hyperstability. Fisheries Management and Ecology 23:187–199. https://doi.org/10.1111/fme.12125.

Muellmann, S., T. Brand, D. Jürgens, D. Gansefort, and H. Zeeb. 2021. How many key informants are enough? Analysing the validity of the community readiness assessment. BMC Research Notes 14:85. https://doi.org/10.1186/s13104–021–05497–9.

Neis, B., D.C. Schneider, L Felt, R.L. Haedrich, J. Fischer, and J.A. Hutchings. 1999. Fisheries assessment: What can be learned from interviewing resource users? Canadian Journal of Fisheries and Aquatic Sciences 56:1949–1963. https://doi.org/10.1139/f99–115

Pollock, K.H., C.M. Jones, and T.L. Brown. 1994. Angler survey methods and their applications in fisheries management. American Fisheries Society, Bethesda, MD, USA. 371 p.

Post, J.R., M. Sullivan, S. Cox, N.P. Lester, J. Carl, E.A. Parkinson, A.J. Paul, L. Jackson, B.J. Shuter, A.J. Paul, L. Jackson, and B.J. Shuter. 2002. Canada's recreational fisheries: The invisible collapse? Fisheries 27:6–17. https://doi.org/10.1577/1548–8446(2002)027<0006.

R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R–project.org/

Raynal, J., R. Weeks, R.L. Pressey, A.J. Adams, A. Barnett, S.J. Cooke, and M. Sheaves. 2020. Habitat–dependent outdoor recreation and conservation organizations provide potential for recreational fishers to contribute to conservation of coastal marine ecosystems. Global Ecology and Conservation 24:e01342. https://doi.org/10.1016/j.gecco.2020.e01342

Rehage, J.S., R.O. Santos, E.K.N. Kroloff, J.T. Heinen, Q. Lai, B.D. Black, R.E. Boucek, and A.J. Adams. 2019. How has the quality of bonefishing changed over the past 40 years? Using local ecological knowledge to quantitatively inform population declines in the South Florida flats fishery. Environmental Biology of Fish 102:285–298. https://doi.org/10.1007/s10641–018–0831–2.

Sadovy, Y. and M. Domeier. 2005. Are aggregation–fisheries sustainable? Reef fish fisheries as a case study. Coral Reefs 24:254–262. https://doi.org/10.1007/s00338–005–0474–6.

Sadovy de Mitcheson, Y., A. Cornish, M. Domeier, P.L. Colin, M. Russell, and K.C. Lindeman. 2008. A global baseline for spawning aggregations of reef fishes. Conservation Biology 22:1233–1244. https://doi.org/10.1111/j.1523–1739.2008.01020.x.

Santos, R.O., J.S. Rehage, A.J. Adams, B.D. Black, J. Osborne, and E.K.N Kroloff. 2017. Quantitative assessment of a data–limited recreational bonefish fishery using a time–series of fishing guides reports. PLOS ONE 12(9):e0184776. https://doi.org/10.1371/journal.pone.0184776

Santos, R.O., J.S. Rehage, E.K.N. Kroloff, J.E. Heinen, and A.J. Adams. 2019. Combining data sources to elucidate spatial patterns in recreational catch and effort: Fisheries–dependent data and local ecological knowledge applied to the South Florida bonefish fishery. Environmental Biology of Fish 102:299–317. https://doi.org/10.1007/s10641–018–0828–x

Sargent, F.J., T.J. Leary, D.W. Crewz, and C.R. Kruer. 1995. Scarring of Florida's seagrasses: Assessment and management options. Report number 37. Technical Report, Florida Marine Research Institute, St. Petersburg, FL, USA. 66 p.

Sillitoe, P. 1998. The development of indigenous knowledge: A new applied anthropology. Current Anthropology 39:223–252. https://doi.org/10.1086/204722.

Silvano, R.A.M. and J. Valbo–Jørgensen. 2008. Beyond fishermen's tales: Contributions of fishers' local ecological knowledge to fish ecology and fisheries management. Environment, Development and Sustainability 10:657–675. https://doi.org/10.1007/s10668–008–9149–0.

Trippel, E.A. 1995. Age at maturity as a stress indicator in fisheries. BioScience 45:759–771. https://doi.org/10.2307/1312628.

Unsworth, R.K.F., L.J. McKenzie, C.J. Collier, L.C. Cullen–Unsworth, C.M. Duarte, J.S. Eklöf, J.C. Jarvis, B.L. Jones, and L.M. Nordlund 2019. Global challenges for seagrass conservation. Ambio 48:801–815. https://doi.org/10.1007/s13280–018–1115–y.

Vehovar, V. and K.L. Manfreda. 2008. Overview: Online surveys. The SAGE Handbook of Online Research Methods 1:177–194.

Venables, W.N. and B.D. Ripley. 2002. Modern Applied Statistics with S, 4th edition. Springer, New York, NY, USA, 497 p. https://www.stats.ox.ac.uk/pub/MASS4/.

Wickham, H. 2016. ggplot2: Elegant graphics for data analysis. http://ggplot2.org. (viewed on 03/21/2022)

Wickham, H., R. François, L. Henry, and K. Müller 2021. dplyr: A Grammar of Data Manipulation R package. https://github.com/tidyverse/dplyr (viewed on 03/21/2022)

Zurcher, N., N. Farmer, E. Perusquia, J. Luo, J. Ault, J. Posada, S. Smith, L. Barbieri, R. Humston, and M. Larkin. 2007. Population dynamics and resource ecology of Atlantic Tarpon and Bonefish. In: J. Ault, ed. Biology and Management of the World Tarpon and Bonefish Fisheries, CRC Press, Boca Raton, FL, USA, p. 217–258 https://doi.org/10.1201/9781420004250.sec3.

Zuur, A., E.N. Ieno, N. Walker, A.A. Saveliev, and G.M. Smith. 2009. Mixed Effects Models and Extensions. Springer, New York, NY, USA, 579 p.