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Using recreational tournament records to construct a 53-year time series of the Florida Keys recreational Bonefish fishery

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Abstract Recreational fisheries managers are often challenged by the lack of long-term data to monitor the status and trends of fisheries. Tournament records may provide a useful source of information to identify long-term trends in recreational fisheries. The Bonefish fishery in the Florida Keys (USA) has experienced a long-term and sequential period of decline that has been quantified with multiple data-poor assessments. The fishery also has a long tradition of supporting recreational fishing tournaments that date to the late 1950s. Here, we use recreational fishing tournament records to track the status and trends of the Bonefish fishery. We validated trends in tournament records by comparing time series changepoints with changepoints observed with angler logbooks and Local Ecological Knowledge (LEK) surveys. We compiled partial records for nine candidate tournaments. Only one tournament had sustained records that were suitable for analysis (Islamorada All Tackle Bonefish Invitational Bonefish and Permit Championship 1968–2021). Changepoint analysis identified several changepoints in catch rates, fish size, and participation that coincide with changepoints identified through analysis of angler logbooks and LEK surveys from previous research. The congruence of changepoints identified among the three data sources suggests that these tournament records are tracking the status and trends of the Bonefish fishery. Optimistically, we identified a recent two-fold increase in Bonefish catch rates beginning in 2015, potentially suggesting a rebound in the fishery, which reflects anecdotal angler reports. Our results highlight the potential for tournament record data to contribute to status and trend assessments of recreational fisheries.

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Introduction

Recreational fisheries management decisions are often challenged by the lack of long-term, fisheries-independent, or fisheries-dependent monitoring data (Cooke and Cowx 2004). Several tools are available to assess the status and long-term trends in recreational fisheries in the absence of formal and sustained monitoring programs. These tools include Local Ecological Knowledge (LEK) surveys (Larkin et al. 2010; Beaudreau and Levin 2014), key informant approaches (Kroloff et al. 2019), stakeholder logbook programs (Santos et al. 2017), and fishing tournaments (Larkin 2011; Curtis et al. 2014), among others. Over the last 30 years, there has been a rapid increase in the number of recreational fishing tournaments globally. For instance, in the Southeastern USA from 2009 to 2011, the average annual number of recreational fishing tournaments held in 14 states was 41,939, a 124% increase from 2002 to 2004 (Driscoll et al. 2012). Recreational fishing tournament records may be particularly valuable since some tournaments have been ongoing for decades, and even centuries (Olson and Cunningham 1989; Powers et al. 2013; Curtis et al. 2014).

Bonefish (*Albula vulpes*) are an economically important recreational species targeted throughout their geographic range of the tropical and subtropical western Atlantic Ocean and Caribbean Sea. The Florida Keys (USA) is often considered the birthplace of recreational Bonefish fishing (referred hereafter as Bonefishing), with the earliest accounts of anglers targeting the species post-World War II (Frezza and Clem 2015). The fishery helped shape the cultural identity of the Florida Keys as the sportfishing capital of the world (https://fla-keys.com/islamorada/fishing), and interest in the fishery continues to grow. Bonefish is one of three species that contributes to the flats fishery (Atlantic tarpon, *Megalops atlanticus*, and permit, *Trachinotus falcatus*, are the other species) in the Florida Keys, generating $465 million USD per year in economic impact (Fedler 2013). The Florida Keys Bonefish fishery is unique relative to other Bonefish fisheries globally in the abundance of large fish (due to higher growth rates) directly accessible in a developed nation and in proximity to a metropolitan area. For instance, in the Florida Keys, a 472 mm Bonefish is four years old, whereas in the Bahamas, a fish of the same length is 8 years old (Adams et al. 2008). As such, more International Game Fish Association world records for Bonefish have been caught in the Florida Keys relative to everywhere else in the world (IGFA.com), despite the species having a large distribution over the Caribbean and subtropical western North Atlantic.

From a fisheries management perspective, the Bonefish fishery in the Florida Keys has been considered a culturally regulated catch and release fishery, and since 2013, the fishery has been regulated as a catch and release only species (https://myfwc.com/fishing/saltwater/recreational/bonefish/). Restrictions are also in place to reduce harmful handling practices, such as the transport of fish in livewells for live-release fishing tournaments (Brownscombe et al. 2019). Flyfishing, the traditional fishing method used to catch the species, is inefficient, which results in low catch per unit effort. For example, when catch rates were highest in the early 1990s, professional fishing guides participating in Bonefish tournaments would catch approximately 1–2 fish per day (Larkin 2011). Catch and release mortality for the species varies depending on handling practices and the presence of predators such as sharks and Barracuda (*Sphyraena barracuda*; Danylchuk et al. 2007). If air exposure is minimized and predators are in low abundances, post release survival is near 100% (Cooke & Phillip 2004). However, if sharks are present and air exposure is prolonged, then mortality rates can exceed 39% (Danylchuk et al. 2007). Since the historical harvest, catch rates, and discard mortality are assumed to be sustainable, fisheries management agencies have not supported long-term monitoring of Bonefish populations nor studies of their biology and ecology.

Unfortunately, beginning in the mid-1990s, the Florida Keys Bonefish fishery experienced a gradual decline, punctuated by a high mortality event associated with an extreme cold spell in 2010 (Boucek and Rehage 2014; Santos et al. 2016), reducing the fishery's quality to a level considered collapsed by stakeholders (Kroloff et al. 2019; Rehage et al. 2019). To quantify the decline, Santos et al. (2017 and 2019), Rehage et al. (2019), and Kroloff et al. (2019) used a mixed methods approach, combining qualitative and quantitative information to characterize the spatiotemporal trends of the fishery by analyzing guide logbooks, semi-structured key informant interviews with for hire-captains, and LEK surveys. Their results showed an increase in the proportion of trips Bonefish were caught in 1989, followed by a 45–65% decline in catch rates that began in the mid-to-late 1990s. In addition to the decrease in catch rates, a decline in the perceived size of Bonefish was also identified in 2005

(Rehage et al. 2019), which was followed by an accelerated decline in catch rates in the mid-to-late 2000s, prior to the 2010 cold spell (Rehage et al. 2019). Last, Rehage et al. (2019) and Santos et al. (2019) showed distinct regional trends in the magnitude of the perceived decline. Following these studies, recent trends in the Florida Keys Bonefish fishery have not been documented.

Here, we use tournament records to quantify trends in the Florida Keys Bonefish fishery since those earlier efforts. We located and cataloged records from nine Bonefish tournaments throughout the Florida Keys and used those to construct time series for Bonefish catches. This work aims to build upon the time series constructed by Larkin (2011), which archived records from four Bonefish tournaments dating to the late 1960s (1968–2010). To validate these tournament records, we compared breakpoints found in tournament record time series with previously constructed time series from LEK and guide and angler logbooks published in Santos et al. (2017), Rehage et al. (2019), and Kroloff et al. (2019). Matching patterns established in previous work, we expected tournament records to identify a sequential pattern in declines beginning with decreases in catch in the mid-to-late 1990s, followed by decreases in the size of Bonefish in the early-to-mid 2000s, and an accelerated decline in mid-to-late 2000s. Second, we expected tournaments in different regions to show regional differences in the magnitudes of decline. We used time series analysis to identify trends in catch rates and fish size across tournaments throughout the Florida Keys. Last, we explored trends in tournament participation, which may serve as a proxy for perceived fishing quality.

Methods

Species profile

Bonefishes (*Albula* spp.) are a circumtropically distributed genus that includes 12 species (Wallace 2015; Pickett et al. 2020). In many areas throughout their range, Bonefish contribute to economically important catch and release fisheries. Four Albula species occur within the Caribbean and The Bahamas, with *Albula vulpes* supporting the recreational fishery (Wallace and Tringali 2016). Hereafter, Bonefish refers to *A. vulpes* since > 98% of Bonefish sampled from the recreational fishery in the Florida Keys, Caribbean Sea, and The Bahamas were genetically identified as *A. vulpes* (Adams et al. 2008; Wallace and Tringali 2016). To sustain the fishery, Bonefish require an intact coastal habitat mosaic to support the post-larval stages of their lifecycle. At the juvenile stage, Bonefish associate with shallow, and wind protected habitats, whereas adults prefer more open shallow-water sand and seagrass flats habitats (Danylchuk et al. 2007; Murchie et al. 2013; Haak et al. 2018, 2019). For reproduction, primarily around the new and full moons from October to May, adults undergo long-distance migrations where they aggregate at pre-spawning sites (Danylchuk et al. 2011; Lombardo et al. 2020). Pre-spawning sites are in deeper water (> 2 m), are smaller in area than flats habitats (< 1 km^2), and occur in areas adjacent to or near water of abyssal depths (> 300 m) typically removed from the flats where anglers target Bonefish. At dusk, Bonefish swim to pelagic environments where they spawn over an 8-h duration at depths greater than 50 m (Danylchuk et al. 2011; Lombardo et al. 2020). Many habitats used throughout Bonefish ontogeny are threatened by anthropogenic degradation, necessitating proactive habitat conservation measures that promote the sustainability of the species and fishery (Adams et al. 2011; Brownscombe et al. 2019). An International Union for the Conservation of Nature (IUCN) assessment classified Bonefish as near threatened, as a result of habitat degradation and fragmentation (particularly mangroves and seagrasses), coastal development and urbanization, declines in water quality, and harvest by commercial, artisanal, and recreational fisheries (Adams et al. 2011).

The Florida Keys ecosystem

The recreational Bonefish fishery areas in South Florida extend approximately 400 km from Biscayne Bay to the Marquesas (Fig. 1). The area is particularly vulnerable to adverse changes from human population growth, coastal development, and associated anthropogenic practices, resulting in ecosystem degradation and fishing exploitation (Rehage et al. 2019). Our study focused on four regions, which are distinct management zones designated by the Florida Keys National Marine Sanctuary. Moving along an East–West gradient, these zones are Biscayne Bay,

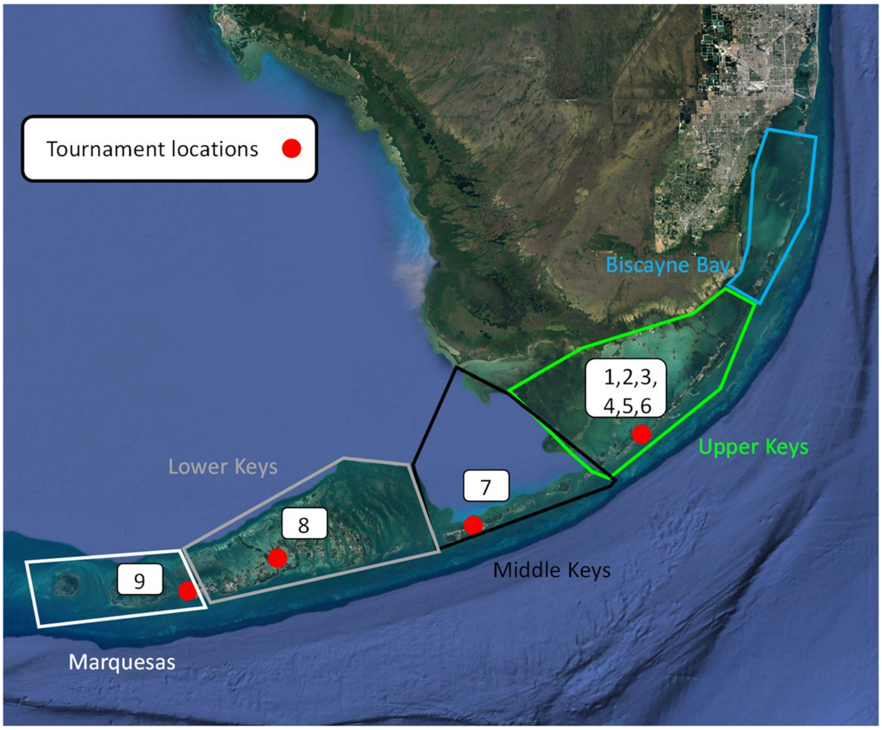

Fig. 1 Map of the Florida Keys. Polygons show the four management zones in the Florida Keys designated by Florida Keys National Marine Sanctuary. Red dots indicate locations of tournaments, and numbers around the dots correspond to tournaments listed in Table 1. *Base map is provided by Google Earth*

Upper Keys, Middle Keys, Lower Keys, and Marquesas (Fig. 1). Biscayne Bay is a shallow-water subtropical lagoon located adjacent to the city of Miami, with more than half of the bay situated within Biscayne National Park (Ross et al. 2001). The Upper Keys is embedded within is the largest estuary in Florida, with 80% of the estuary contained within Everglades National Park (Rehage et al. 2019). The Upper Keys region is characterized by a patchwork of interconnected basins, shallow mud banks, seagrasses, mangrove islands, and tidal channels in Everglades National Park, and is the historic center of the Bonefish fishery (Larkin et al. 2010; Larkin 2011). The Middle Keys is marked with enhanced tidal exchange between the Atlantic and Gulf of Mexico, and habitats consist of a mix of shallow mixed seagrass and hard bottom habitats, and seagrass covered banks that bracket major tidal flow ways (NOAA 1996; Burke et al. 2012). The Lower Keys consist of a chain of islands surrounded by extensive seagrass meadows, hardbottom, and reef areas. And, the Marquesas region is defined by two atoll formations, surrounded by seagrass meadows, enhanced tidal exchange, and minimal anthropogenic development west of Key West (NOAA 1996).

Tournament record acquisition

As a result of the year-round availability of Bonefish and popularity of Bonefishing in the Florida Keys, numerous tournaments occur throughout the year. Bonefish tournaments are usually structured as two person teams that are awarded points based upon success in catching the largest Bonefish and the most Bonefish. One member of the team is a hired professional fishing guide, and the other is a skilled angler. Since the Florida Keys Bonefish fishery historically supported an abundance of large Bonefish, winning generally predicated on catching several large or trophy Bonefish. Points are awarded in a tiered approach. To receive any points, teams must catch at least one fish larger than 3.6 kg (known as a weight fish). If a team catches a 3.6-kg fish, then supplemental scores were given based on the number of fish caught that were under 3.6 kg (known as release fish) in addition to points awarded from weight fish. Teams were only allowed to submit a pre-determined number of weight fish for scoring, which varies between tournaments. If a team caught more weight fish than the pre-determined number, then the largest fishes would be used for scoring, and the additional weight fish would count as release fish. Points per weight fish were determined based on the weight of the fish, and points awarded proportionally increased with fish weight. If a team attempted to submit a weight fish that was smaller than 3.6 kg, they would receive a penalty. At the end of the tournament, teams' scores were calculated as the number of points generated from the aggregate weight of the pre-determined number of weight fish and supplemental points awarded from release fish. Tournaments are usually held on the same days each calendar year, lasting 2 to 5 days, depending on the specific tournament. Traditionally, all participants are required to depart from the same marina at a specified start time and return each day before a certain time to verify their catch. Participants can and often travel up to 80 km away from the starting point to fish per day. As such, Bonefish tournament records may represent fishery trends in an 80-km distance surrounding the starting point. Prior to 2013, fish larger than 3.6 kg were transported alive via a livewell and weighed at the tournament station, regardless of where they were caught. Fish less than 3.6 kg were tallied using an honor system. Post 2013, in response to a new Florida Fish and Wildlife Conservation Commission (FWC) regulation prohibiting possession or transport of Bonefish, catches were recorded by photographs of fish, and the scoring metrics switched from weight measurements to length measurements.

We relied on current and former participants and organizers of each tournament to share documents—overall results, tournament handbooks, and press releases. Additionally, we utilized photos of scoreboards displaying the tournament's final results posted to social media by tournament officials or participants as an additional source of tournament records. If the post only included results in terms of points, rather than delineating catches by each angler and guide team, we cross-referenced the scoring with available tournament handbooks to determine how many fish were caught by each angler/guide team.

Analysis

Based on our list of tournament records, we excluded tournaments that did not have at least 10 years of records prior to 2010, the year of the extreme cold spell. Also excluded were tournaments that did not have at least 5 years of records following 2010. From the tournament records, we extracted the average number of Bonefish caught per boat per day as an index of catch, the largest fish caught in the tournament as an index of Bonefish size, and the number of tournament anglers as a measure of participation. Many available tournament records only included the weight of the largest rather than the weight of all recorded fish. As such, our index of size is based off the single largest fish caught per tournament per year. We acknowledge that using the weight of a single fish rather than a measure of average weight of all fish recorded per year provides only a coarse estimate of how the demographics of the Bonefish fishery may have changed overtime. Nonetheless, given what is available, we feel this metric does capture broad scale changes occurring in the fishery. We used length–weight conversions described in Crabtree et al. (1996) to estimate Bonefish weights for tournaments held post-2013, when FWC regulations prohibited the possession and transport of Bonefish during tournaments. For our metric of participation, we omitted participation records prior to 1980, as many tournaments instituted a new rule limiting tournament participation following 1980 due to concerns of overexploitation of the fishery during tournament days (Larkin 2011).

We used cumulative sum charts (CUSUM) to explore patterns of catch rates, fish size, and participation (Manly and MacKenzie 2000; Regier et al. 2019). CUSUMs are a simple, efficient statistical method developed for process control and increasingly used to determine underlying features of time series. The description of the method and its benefits over other conventional approaches are described in detail in Regier et al. (2019). This analytical approach overcomes challenges; goodness-of-fit metrics encounter with auto-correlated time series, data gaps, different statistical distributions, and noise (Regier et al. 2019).

CUSUM or Z-CUSUM charts are the cumulative sum of standard deviations from a target specification (the time series grand mean) plotted against time, calculated as a running sum of data, and normalized to the dataset mean and standard deviation. This approach removes high-frequency noise and smooths the data, providing an intuitive visualization to identify non-linear changepoints or proportional trends over time. Once suspected shifts were identified in the Z-CUSUM charts, original datasets were analyzed for structure breaks (Change-point Analyzer®, Taylor 2000). This procedure uses an iterative combination of CUSUM charts and bootstrapping (1000 bootstraps) to detect breaks in the slope and provides both confidence levels (CL, a measure of significance) and 95% confidence intervals for each change (Hinkley 1971; Hinkley and Schechtman 1987). Breaks were considered significant if the confidence level (CL) of the changepoint was above 90% (Briceño and Boyer 2010).

Fisheries-dependent datasets are often fitted with a standardization to remove variation within a time series that can be explained by environmental or other external factors (Maunder and Punt 2004). We opted to use raw data rather than a standardized dataset. Larkin (2011) applied a standardization that combined four tournament records spanning from 1968 to 2010 into a single metric, and accounted for variation caused by wind conditions, rainfall, moon phase, and angler skill level. We conducted time series analyses on CPUE from 1968 to 2010 using his standardized data, and raw data from a focal tournament that met our criteria for analysis. We compared results to determine if standardized data and raw data identified different changepoints. Time series analyses identified identical changepoints between standardized and raw data (Supplemental Information), affirming that raw values are an adequate representation of trends in the tournament fishery.

Results

We located records for nine different Bonefish tournaments in the Florida Keys (Table 1). Six of the nine tournaments occur in the Florida Bay region of the Florida Keys. One tournament is held in the Middle Keys, one tournament occurred in the Lower Keys, and one occurred in the Marquesas region (Fig. 1). Two of the nine tournaments exclusively used flyfishing techniques, while the other seven accepted entries from fish caught with all conventional hook and line methods. Of these nine tournaments, only one had records that pre- and post-dated 2010 while having more than 5 years of record following 2010. As such, our analysis focused on this tournament, the Islamorada Fall All Tackle Bonefish and Permit Challenge (https://www.facebook.com/The-Islamorada-All-Tackle-Bonefish-and-Permit-Championship-298564124307830/). Over the course of the 53-year Fall All Tackle time series, teams caught an average of 1.9 fish per day (S.E. ± 0.1). The average size of the largest Bonefish caught per tournament was 5.5 kg (S.E. ± 0.2), and the mean number of participants was 14 (S.E. ± 1).

CUSUM analysis identified three changepoints in the 53-year catch rate time series (Fig. 2A, Table 2). The first changepoint occurred in 1981, where the number of fish caught per boat per day increased by 68% relative to the 1968–1980 timestep (CL 97%). From 1981 to 1997, the number of fish caught per boat per day was generally above the overall mean of the fish caught per boat per day for the 53-year

Table 1 Summary of all Bonefish tournaments within the Florida Keys. Completeness of record corresponds to the percentage of years between the first year we have a record for and the last year we have a record. Numbers in parentheses correspond to tournament locations in Fig. 1

Name	Location	Month	# of days	Beginning year	First record	Last record	Completeness of record
Baybone Islamorada (1)	Upper Keys	Oct	3	2014	2014	2018	100%
Fall All Tackle (2)	Upper Keys	Oct	3	1968	1968	2021	68%
Fall Fly (3)	Upper Keys	Sept	3	1975	1975	2021	63%
Redbone (4)	Upper Keys	Nov	2	2014	2014	2020	85%
Spring All Tackle (5)	Upper Keys	March	3	1975	1996	2010	93%
Spring Fly (6)	Upper Keys	April	3	1975	1981	2010	100%
Marathon International (7)	Middle Keys	Sept	1	1959	2008	2020	66%
Sugarloaf Showdown (8)	Lower Keys	Nov	2	2006	2019	2020	100%
SLAM (9)	Marquesas	Sept	2	2000	2016	2019	75%

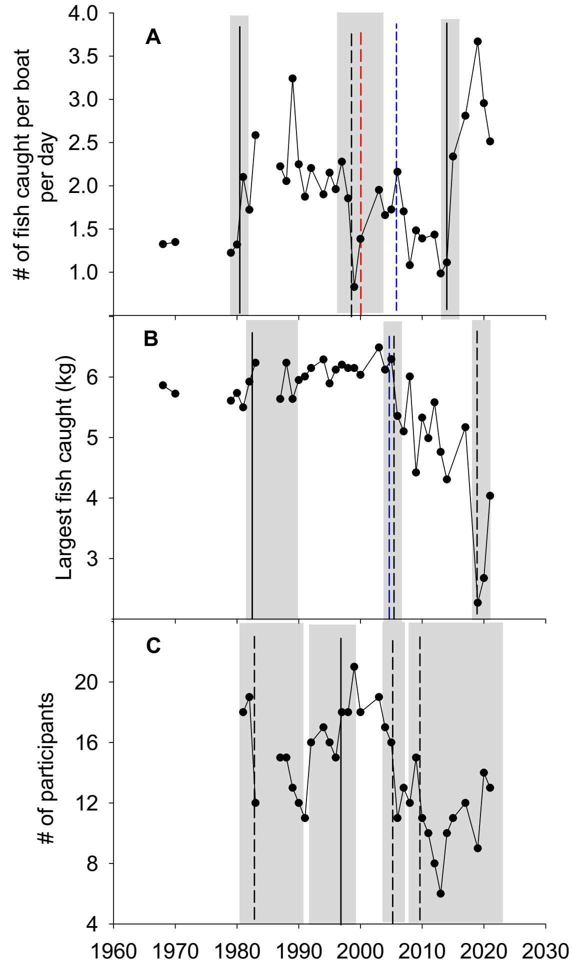

Fig. 2 The number of fish caught per boat per day during the Islamorada Fall All Tackle Bonefish and Permit Challenge (**A**). The size of the largest fish caught per tournament (**B**), and the number of participants (**C**). Vertical lines identify changepoints found in this study (black lines), in Rehage et al. 2019 (blue lines), and in Santos et al. 2017 (red lines). Dashed lines indicate a negative changepoint, and solid lines indicate a positive changepoint. Gray shading marks confidence intervals associated with each breakpoint from this study

time series. The second changepoint occurred in 1998, where the number of fish caught per boat per day decreased by 32% (CL 96%) relative to the mean number of fish caught per boat per day from 1982 to 1997. From 1998 to 2014, the number of fish caught per boat per day per year was generally below the overall mean of the fish caught per boat per day for the 53-year time series. And, in 2015 to the end of the time series, the number of fish caught per boat per day more than doubled relative to the previous time

Table 2 Summary statistics of the time series analysis. Plus and minus signs adjacent to the estimated changepoint identify whether the changepoint was positive or negative

Estimated changepoint	Confidence interval	Confidence level
# of fish caught/boat/day		
1981 +	1981, 1982	93%
1998 –	1995, 2004	97%
2015 +	2014, 2015	98%
Largest fish caught		
1982 +	1982, 1990	93%
2006 –	2005, 2008	100%
2019 –	2017, 2021	89%
Participation		
1983 –	1983, 1992	94%
1997 +	1992, 1999	91%
2006 –	2006, 2007	96%
2010 –	2007, 2021	92%

step (1999–2014), exceeding catch rates observed earlier in the time series (CL 99%).

Three changepoints were observed in the time series of largest fish caught (Fig. 2B; Table 2). In 1982, the largest fish caught per tournament increased by 8% (CL 93%) relative to the mean largest fish caught per tournament from 1968 to 1981. From 1982 to 2005, the weight of the largest fish caught per year was generally above the overall mean weight of the largest fish caught per year for the 53-year time series. Following 2006, the largest fish caught per tournament decreased by 17% (CL 100%) relative to the mean largest fish caught per tournament from 1982 to 2005. From 2016 through the remainder of the time series, the weight of the largest fish caught per year was generally below the overall mean weight of the largest fish caught per year for the 53-year time series. We also detected a marginally significant changepoint that occurred in 2019, where the largest fish caught per tournament further decreased by 42% relative to the previous timestep (CL 89%).

Participation was more dynamic over time, and we identified four changepoints (Fig. 2C, Table 2). The first changepoint occurred in 1983, where tournament participation decreased by 23% (94% CL) relative to participation from 1980 to 1982. From 1983 to 1996, the number of participants per year was generally below the average number of participants for the entire time series. In contrast to catch rates, tournament participation increased by 31% in 1997 (CL 91%). Tournament participation per year remained generally above the average number of participants per year for the entire time series from 1997 to 2005. Following a period of increased participation, participation then decreased by 29% in 2006, relative to participation in the previous timestep (1997 to 2005; CL 96%). Tournament participation for the remainder of the time series remained generally below the average number of participants for the entire time series. A further decrease in participation was observed in 2010, where participation dropped by another 18% relative to the previous time step and has remained depressed in all subsequent years (92%).

Discussion

Identifying long-term trends in recreational fisheries remains a central challenge for conservation and management (Cooke and Cowx 2004; Gervasi et al. 2022). Tournament records have been a source of information used globally to characterize recreational fishery trends (Olson and Cunningham 1989; Praderand et al. 2007; Rodríguez-Ferrer et al. 2007). Despite availability of records for nine tournaments, only one tournament maintained at least a partial record of catches and fish weights suitable for analyses. From the analysis of this tournament time series, changepoints identified a decline in Bonefish catch rates followed by declines in size that aligned with trends reported in previous work (Larkin 2011; Santos et al. 2017, 2019; Rehage et al. 2019), and temporally dynamic participation. Unfortunately, due to the lack of availability of tournament records in other Florida Keys regions, we were unable to evaluate and compare spatiotemporal trends in our tournament data to those reported by previous fisheries-dependent efforts (Santos et al. 2017, 2019; Rehage et al. 2019). Importantly, tournament records provided evidence of a recovering Bonefish fishery in recent years, agreeing with angler reports of increasing Bonefish numbers (Florida Keys Fishing Guides Association pers. comm.). Since trends in Bonefish tournament records are aligned with other assessments (Larkin 2011; Santos et al. 2017, 2019; Rehage et al. 2019), we suggest that tournament records provide useful information to inform scientists and managers of the status and trends of the fishery, particularly if they are used along with other tools.

Any approach to build long-term trends for data-poor or data-limited fisheries suffers from inherent biases. Relying on LEK or key informant interviews to build time series often faces recall bias, where participants preferentially recall the good times of the past (Daw 2010), although Rehage et al. (2019) apply a time calendar approach used in medical and social sciences that is shown to reduce this effect. The use of voluntary catch reporting programs often suffers from the challenge of maintaining long-term participation, while mandatory reporting programs may suffer from participants falsely reporting records (Sampson 2011; Crandall et al. 2018). The use of tournament records to identify long-term trends in data-poor fisheries has their own biases. Tournament participants are often more efficient than the general angling population and are motivated more by catching fish rather than non-catch factors associated with outdoor recreation (Falk et al. 1989). And, technological advancements that increase angler efficiency are likely more pronounced in the tournament fleet compared to their influence in the general angling population (Detmer et al. 2020; Cooke et al. 2021). For instance, Maggs et al. (2015) contrasted catch records from competitive anglers and catch records for the total angling population for the *Lichia amia* fishery in South Africa and found that competitive angling catch rates remained stable while a progressive decline in catch rates was observed in the general angling population. Maggs et al. (2015) attributed this hyperstability effect within the competitive sector to differences in competitive angler efficiencies relative to the general angling population, rapidly improving technology utilized by competitive anglers, and open communication networks among competitors. As such, tournament records may be resistant to identify declining trends relative to what is observed by the overall recreational fleet (Feiner et al. 2020; i.e., hyperstability).

Using tournament records, we observed a period of decline in catch rates during the late 1990s which was also identified by Larkin (2011) and Santos et al. (2017). However, tournament catch rate records failed to detect the period of accelerated decline observed in Rehage et al. (2019). Second, we detected a positive changepoint in our fish size index (1982) that was not detected by Rehage et al. (2019). Rehage et al. (2019) did observe a slight increase in the perceived size of Bonefish in 1985, although it was not significant. Both of these mismatches may be a function of tournament angler efficiency. In the Florida Keys, tournament anglers and tournament guides are generally regarded as the best in the fishery. Through sponsorships, those teams have access to innovative boats, fishing tackle, and marine electronics. Tournament guides also have developed communication networks among other skilled professionals who generally share real-time information about the fishery with each other. It is likely that during the period of accelerated decline, tournament anglers maximized knowledge, angler skill, best available technology (i.e., high performance boats capable of running long distances), and communication networks to locate and exploit the few remaining productive locations. In contrast to tournament anglers and guides, the general angling population likely did not have the motivation, skill, and resources to locate and successfully catch Bonefish under those fishery conditions. Similarly, the positive breakpoint we observed early in the time series, that Rehage et al. (2019) did not detect, may be caused by the same underlying driver. It is possible that advances in technology combined with angler skill allowed tournament participants to locate and exploit the largest and rarest fish in the population as they age and continue to grow, which were otherwise less detectable and catchable by the general angler population.

Tournaments are generally not created with the intention of monitoring the status or trends of their target species. Tournament organizers may change tournament rules to increase participation or create more parity among participants (Gartside et al. 1999). In the Florida Keys, the focal tournament used here enacted several rule changes to increase participation and accommodate new fishery regulations. Due to the Bonefish decline, tournament organizers added a second target species (permit, *Trachinotus falcatus*, rule change 2012). Second, because of a regulation prohibiting the transport of fish in livewells, tournament organizers removed the requirement of catching a fish greater than 3.6 kg to score points, and scored fish based on length measured from the boat rather than a weight measured on a certified scale (rule change 2013). And, again attempting to boost participation, the tournament allowed boats to be trailered to other locations rather than only permitting vessel to travel by water to fishing grounds (rule change 2017). The additional focal species likely reduced fishing effort on Bonefish. While at the same time, relaxing minimum size restrictions may have reduced anglers' focus on targeting large fish, shifting angler effort to focus on maximizing catching more smaller fish. And fourth, relaxing travel restrictions may have increased catch rates by giving participants access to more distant fisheries. Although a marginally significant changepoint was observed during these rule change periods (decrease in size in 2019; CI 2017–2021), it is difficult to determine the effect these rule changes may have had on the recent tournament records used in our analyses. These qualifiers highlight the importance of using multiple lines of evidence when reconstructing time series for data-poor recreational fisheries (Gartside et al. 1999). Nonetheless, trends identified here do provide useful information to inform future LEK studies, and at minimum, serve as a hypothesis generation tool that can be addressed with other fisheries-dependent datasets (Gervasi et al. 2022).

Tournament anglers are motivated by catch rather than non-catch factors (Falk et al. 1989), are usually younger, show more preference to catching trophy fish relative to non-tournament anglers (Wilde et al. 1998), and are generally in favor of conservation restrictions during tournaments (i.e., catch and release preference; Oh et al. 2007). Tournament angler motivations may also explain the observed trends in participation. For instance, while catch rates declined during the late 1990s, participation remained relatively high. But angler participation showed a marked decline in 2006, approximately the same time that Rehage et al. (2019) reported a perceived decline in the overall size of Bonefish, and the same year we observed a negative changepoint in the largest Bonefish caught. And, while tournament Bonefish catch rates are now higher than ever before, angler participation remains low. It is possible that tournament anglers participating here are more motivated to catch larger fish. As such, we would expect increases in angler participation if the size structure of the fishery trends toward larger fish. It is also possible that non-catch factors such as the sense of tradition from participating in a long running tournament maintained high participation during early periods of decline. And, economic factors related to the 2008 recession could have also played a role in reducing participation toward the end of the 2000s (Arlinghaus et al. 2021).

The causes behind recent apparent increases in Bonefish catch rates observed both in tournament landings and through conversations with stakeholders (Florida Keys Fishing Guides Association pers. comm.) are unknown and could be attributed to several different mechanisms. Recent genetics work (Wallace and Tringali 2016, Wallace unpub. data) and larval transport estimates (Zeng et al. 2019) suggest that the Florida Keys Bonefish population is an open population, with shared genetic population structure among Florida and several Western Caribbean Nations including Cuba, Belize, and Mexico. It is possible that management actions at these source areas could have promoted increased larval connectivity to the Florida Keys. Given the open population structure, it is also possible that larger ocean atmospheric teleconnections that influence ocean currents, local rainfall, and temperature regimes may play a role in influencing recruitment and survival (Lehodey et al. 2020). In South Florida, the Atlantic Multidecadal Oscillation (AMO) has been associated with fluctuations in numerous ecological processes, and may have some influence on the trends observed in this fishery (Moses et al. 2013; Regier et al. 2016; Childers et al. 2019). Habitat improvements within the Florida Keys may also have played a role. In 2015, the Florida Keys completed a sequential 16-year archipelago-wide initiative transition from septic systems to central sewer systems in a localized effort to improve water quality. Aging septic systems and illegal cesspits previously leached sewage into porous limestone that quickly re-entered coastal and nearshore waters (Paul et al. 2000). These pollutants may have reduced recruitment and survival, as juvenile Bonefish habitats likely occur at shorelines adjacent to residential development.

Fishing behavior has also changed in the last 10 years due to education on catch and release practices, with participants minimizing air exposure when the hook is removed from the Bonefish. Larkin (2011) estimated a fishing mortality rate of 0.126 y^{-1} for the year 2010, but since then, this fishing mortality rate has likely been significantly reduced due to fishers taking steps to minimize air exposure during hook removal. If this recovery continues, it will provide a valuable opportunity to better understand the drivers behind Bonefish population dynamics, which will in turn improve conservation investment. Causes notwithstanding, recent years have experienced a sequence of good recruitment for South Florida Bonefish that has allowed the population to show signs of recovery.

In light of the recent increase in catch rates and assumed increase in overall population size, several important steps can be taken to conserve and promote Bonefish population growth. First, given the uncertainty behind why this increase in catch rates occurred and whether more recruitment will follow, stakeholders must ensure that fishing mortality remains as low as possible to maximize the time these fish remain in the fishery. Since this is a catch and release fishery, emphasis should continue to be placed on catch and release best practices education (Brownscombe et al. 2017). Second, investment in research to identify the causes of this catch rate increase should be prioritized. If, in fact, Bonefish populations are driven by oscillations within the AMO or other similar teleconnections, policy-makers, scientists, and stakeholders can proactively and collaboratively develop resilient business and resource management models for stakeholders tied to the resource, or at least have the capacity to provide warning when the next ebb in the fishery occurs. And lastly, if recovery is attributed to conservation actions across the Caribbean, then more investment in building sustainable and productive fisheries in connected nations may increase the resilience of the Florida Keys Bonefish fishery.

Bonefish tournament records in the Florida Keys capture signals of decline that match previous fisheries-dependent datasets, as well as identify a previously undocumented recovery trend starting in 2015. The match of the tournament data to previous datasets provides confidence in the ability of tournament data to capture trends of the South Florida Bonefish fishery. However, an increased reliance on tournament data necessitates the adoption of standardized practices, improved record keeping, and continued investment in other data-poor assessment tools to validate trends observed in these records. Excitingly, the potential resurgence of Bonefish within the Florida Keys provides some optimism for rebuilding this once world-class Bonefish fishery, and also provides exciting research opportunities to further understand the mechanisms underlying population variability in a catch and release marine recreational fishery.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval No approval of research ethics committees was required to accomplish the goals of this study. Aaron Adams is a Guest Editor of this special issue, but he had no involvement in the peer review of this article and had no access to information regarding its peer review.

Conflict of interest The authors declare no competing interests.

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