TECHNOLOGICAL AND GEAR CHANGES AFFECTING THE CAPTURE OF BILLFISH 1973-2019

Briana R. Gibbs[1, 2], Michael J. Schirripa[3], Peter Chaibongsai[2]

SUMMARY

ICCAT stock assessments on blue and white marlin have assumed constant catchability for marlin species throughout the duration of the National Marine Fisheries Service Recreational Billfish Survey (RBS, 1973-2019). However, scientists and anglers have both expressed concerns that there has been an increase in catchability throughout the 46-year dataset. Tournament fishers are highly motivated to adopt measures that increase the probability of successful trips. Literature review and in-person interviews revealed numerous changes in gear and technology utilized by the recreational fishery which have likely contributed to an increase in billfish catchability since 1973.

RÉSUMÉ

Les évaluations des stocks de makaires bleus et de makaires blancs de l'ICCAT ont postulé une capturabilité constante pour les espèces de makaires pendant toute la durée de la prospection de la pêcherie récréative ciblant les istiophoridés du Service national des pêches marines (RBS, 1973-2019). Cependant, les scientifiques et les pêcheurs à la ligne ont tous deux exprimé leur inquiétude quant à l'augmentation de la capturabilité tout au long de la série de données sur 46 ans. Les pêcheurs de tournoi sont très motivés pour adopter des mesures qui augmentent la probabilité de réussite des sorties. L'examen de la littérature et les entretiens en personne ont révélé de nombreux changements dans les engins et la technologie utilisés par la pêcherie récréative, qui ont probablement contribué à une augmentation de la capturabilité des istiophoridés depuis 1973.

RESUMEN

Las evaluaciones de ICCAT de los stocks de aguja azul y aguja blanca han supuesto una capturabilidad constante de las especies de marlines a lo largo de la duración de la National Marine Fisheries Service Recreational Billfish Survey (RBS, 1973-2019). Sin embargo, los científicos y pescadores con caña han expresado su preocupación por el hecho de que se ha producido un incremento en la capturabilidad a lo largo del conjunto de datos que cubre 46 años. Los pescadores de los torneos están muy motivados por adoptar medidas que incrementen la probabilidad de mareas con éxito. La revisión de la bibliografía y las entrevistas personales revelaron numerosos cambios en los artes y tecnologías utilizadas por la pesquería de recreo que posiblemente hayan contribuido a un incremento en la capturabilidad desde 1973.

KEYWORDS

Atlantic Billfish, CPUE, Catchability, Recreational Billfish Survey, White Marlin, Blue Marlin

[1] University of Miami, 4600 Rickenbacker Causeway, Miami, FL, 33149, b.gibbs@miami.edu
[2] The Billfish Foundation, 5100 N. Federal Highway Suite 200, Fort Lauderdale, FL, 33308
[3] U.S. Department of Commerce, National Marine Fisheries Service, Southeast Fisheries Science Center, 75 Virginia Beach Dr, Key Biscayne, FL, 33149

1. Introduction

The National Marine Fisheries Service, a part of the National Oceanic and Atmospheric Administration, has been conducting the Atlantic Recreational Billfish Survey (RBS) since the early 1970s (Ortiz and Brown, 2002). The goal of the RBS is to monitor billfish behavior and encounter rates in order to estimate the abundance of billfish in the Atlantic. Billfish species include marlin, sailfish, and spearfish. In the Atlantic, billfish are managed by both the U.S. Secretary of Commerce as well as the International Commission for the Conservation of Atlantic Tuna (ICCAT). Billfish management mirrors that of other highly migratory fish species: through models which use estimates of catch per unit effort (CPUE) to determine catch limits. The recreational data billfish fishery is monitored using data collected at tournaments throughout the year, with some effort to quantify catch outside of tournaments (Goodyear and Prince, 2003). The inclusion of tournament data instead of estimates of catch outside of tournaments is largely due to the time parameter associated with calculation of CPUE. Tournament data have reliable time estimates, in addition to the number of boats on the water for the duration of each tournament, while estimates of catch outside of tournaments are inexact. The data collected from these tournaments is relatively limited including only number of each species taken and number released (Lent 1998, Venizelos, 2019). For better CPUE estimates, it would be helpful for the RBS to account for time on the water, fate of billfish, and morphometric characteristics (Browder and Prince 1988; Ortiz and Farber, 2001; Diaz *et al.,* 2007)

As a measure of abundance CPUE is related to the population size by the catchability coefficient (q) with units defined by the way catch (C) and effort (E) are measured. Catch may be actual removals (brought back to port) or include fish released, so long as the method does not change the proportion of the population represented for a unit of effort during a time series. For the RBS, catch refers to the sum which transitioned from mostly retained to mostly released during the time series (Goodyear et al., 2003). In addition to changes in population size, CPUE can change because of changes in catchability over time. Reasons can include such things as an improved ability to locate fish due to new technologies which increases the ease of fish capture, or an increased ability to spend time on the water which increases the probability of encountering fish, etc. Accurate CPUE estimation not only improves management of the species, but it allows for better understanding of population changes over the course of data collection. Accounting for any changes in catchability over time will improve stock assessment methods, conversely, not allowing for time-varying catchability could produce biased estimates (Wilberg and Bence, 2006). In the case of Atlantic billfish, retained recreational catch makes up very low percentages of the overall take from Atlantic populations.

In recent stock assessments of both blue and white marlin conducted by the ICCAT in 2018 and 2019 respectively, the assumption for the use of CPUE as an indicator of abundance of CPUE was that catchability has remained constant over the entire course of recreational marlin fishing (Anonymous, 2019). Numerous scientists and papers believe this to be an inaccurate assumption (McCluskey and Lewison, 2008; Eigaard, *et al.,* 2014; Schirripa, 2019; Forrestal, 2019). Billfish angling, similar to other fisheries, has expanded over the course of the RBS, and as such, the changes in technology and gear which improve catchability must be documented for the correct assessment of billfish populations, in addition to fully understanding the impacts of both commercial and recreational fishing. This report begins to describe the technological and gear changes in the recreational fishery that may have contributed to an increase in catchability in billfish recreational angling.

2. Materials and methods

In order to establish the key elements that had the greatest impact on the fishery, multiple opportunistic data sources were utilized. The first step in this timeline was an extensive literature review searching for key terms with respect to gear and technology utilized by recreational billfish anglers. In addition to a literature review, online research was conducted for information that was unlikely to be found in journals such as: the estimated dates for the popularization of various pieces of technology, including the internet or smart phones. Finally, in-person and phone interviews were conducted of: captains, fisheries scientists, industry professionals, and tournament directors to confirm which pieces of technology and gear were the most important for the fishery throughout the course of the timeline.

3. Results

The changes in tools used by recreational anglers fall into two separate categories: technology and gear. In this paper, technology is used to describe any instrument which is chiefly electronic in its form and function, whereas gear refers to the parts of angling which are mainly mechanical in form and function.

3.1 Technology changes throughout the RBS

The RBS began in 1973, so this report of technology that has changed recreational billfish catch begins that year as well. With this arbitrary start date, some key technology was already available to anglers including VHF radios as well as Loran-A technology for navigation. Technologies which have been highlighted as most important have fallen under three main categories: communication, navigation, and ability to locate fish within the water column.

VHF radios serve the purpose of allowing for communication between anglers - communication has proved a key part of recreational billfish angling, and has been highlighted as one of the most important pieces of technology that has changed over time by personal communications with active members of the fishery (Bowden, 2019; Navarro, 2019; Dunn, 2020; DiGiulian, 2020). The invention of the internet allowed for improved communications and access to new information: be it media, news, or applications for the reporting of billfish capture. 1989 marked the invention of the Internet, and from there it grew quickly in its utility and popularity (Pew Research Center, 2014). Though the world wide web was in its infancy in the 1990s, by the early to mid-2000s the internet was extremely popular among anglers. Communication, weather updates, and sea conditions could all be accessed from an angler's home. Another piece of technology that has been claimed by one captain as the most important development in billfish angling since he started fishing almost 40 years ago was the smartphone. According to the Pew Research Center, by 2013, ~50% of adults had smartphones. The utility of a smartphone to an angler is the access to both communication and navigation functions while being on the water. Through access to the internet on the water, anglers can see in real-time the changes in weather or oceanographic conditions, both of which may have an effect on billfish behavior. In addition, having reliable navigation though a smartphone decreases the number of tools necessary to be out angling.

Loran-A stands for Long Range Navigation, and the technology was originally developed for the U.S. military. Loran-A became popular among fishermen in the 1970s due to its relatively inexpensive nature and it allowed for better navigation. Loran technology works by using charts with lattice lines on them, which detail the lines of sound generated by transmitters from shore. One of the shortcomings of Loran technology, is that it only allows for location accuracy within hundreds of feet. Navigation is another aspect of the fishery that has proved important throughout the course of this timeline. Loran-A became somewhat obsolete in the 1980s as Loran-C became a more important piece of navigational equipment. The 2000s brought Global Positioning Systems (GPS) as a form of navigational aid, one more precise than Loran technology. GPS receives information from GNSS satellites and calculates the device's geographical location, which allowed anglers to return to the same fishing spot, time and again. Finding the same spot where fish are biting days in a row allows for increased ease of billfish catch, something which dramatically affects catchability. Maps with improved details on the ocean floor allow for better knowledge of seafloor features, could increase the catchability of billfish species off the U.S. Atlantic coast. One example of this product is the Garmin product called High-Resolution Relief Shading Coverage, which shows significant detail about the ocean floor surrounding the U.S. East Coast and Gulf of Mexico offshore.

Fish finding technology has also changed significantly over the course of this timeline. The first acoustic detection of fish occurred in 1929, and throughout the 1970s and 1980s, acoustic technology, including SONAR (sound navigation ranging), was evaluated for the limitations of fish detection (Simmons and MacLennan, 2005). The most basic fish finders used two frequencies, 50 and 200 kHz, which limited what the angler could "see" in the water column and at depth (Simmons and MacLennan, 2005; Dunn, 2020). These early acoustic devices used paper to show what was occurring at depth, which changed when LCD (liquid crystal display) screens were popularized. LCD screens were monochrome sonars that introduced more detail into the observation of the ocean and fish beneath an angler's boat. Color was introduced to sonars in the last 15 years, after the use of monochrome systems, which allowed for easier differentiation between biomass and seafloor. Most recreational anglers have utilized this system today. In the last eight to nine years, CHIRP (compressed high intensity radar pulse) sonar has been introduced which uses a range of frequencies to look for fish in the water column. CHIRP sonar has a better target signal than that of the commonly used sonars today, which could impact catchability in the future.

Education about billfish behavior has been listed as an important aspect of billfish angling. An interviewed captain suggested that educational groups such as The Billfish Foundation and having access to more information allows for anglers to be more effective at capturing the billfish (DiGiulian, 2020). If the behavior of the species is known, it allows anglers to select a style of fishing that matches the behavior of the fish in the region. For example, kite fishing is popular among anglers south of Jupiter, FL, while trolling is the main method of fishing north of Jupiter. This has to do with the behavior of billfish: north of Jupiter they are foraging, while south of Jupiter they are migrating (DiGiulian, 2020).

A final piece of technology that has made a difference to anglers is the wider use of gyrostabilizers such as Seakeepers (Bowden, 2019; DiGiulian, 2020). Gyrostabilizers are attachments to boats that respond to sea conditions and have the overall effect of steadying the boat. This piece of technology has been taken off due to the lower price and reliability of the technology to the recreational fishery in the last five years and allows for increased time at sea, as well as accessibility for anglers who may otherwise experience sea sickness. Both of these attributes contribute to catchability, and as an emerging piece of technology should be monitored for the overall effect on catchability within the fishery.

3.2 Gear changes throughout the RBS

Many pieces of mechanical gear are used for the recreational capture of billfish, however the trends within rods, reels, hooks, line, and leaders have made a difference to anglers within the fishery. In addition, fish aggregating devices (FADs) have changed some recreational grounds for angling for billfish.

Reels have changed since the 1980s, a fact which has benefitted anglers. In general, reels are made tougher, have less material breakdown, and require less maintenance. The main purpose of the reel is to spool the line on which the billfish is caught. It is a line management tool which allows the angler to release the line or bring the line back in. There are multiple types of reels depending on the style of fishing and target species. The strength and smoothness of the drags, the angler adjusted tension that keeps line on the reel and allows for better retrieval of the line, has allowed for less gear breakage when reeling in a billfish, which have contributed to higher catch rates and thus increased catchability. Additionally, the retrieval rate has increased from 2:1 to 7:1, which allows more time for having hooks in the water, increasing the angler's ability to capture billfish (DiGiulian, 2020). Fishing rods have largely remained in the same shape throughout the RBS, however more advanced materials have been introduced into their construction, these new materials causing rods to be lighter.

Across multiple gears associated with recreational angling, there has been a documented trend of increased strength alongside more effective tools. According to one captain interviewed, line of the same strength test has gotten much stronger over the years (DiGiulian, 2020). In addition to being more uniform in strength, line has begun to weigh less. Nylon monofilament line is the most common type used, however there are other popular variants of fishing line, including Chlorofluorocarbon monofilament, Dacron multifilament, and braided multifilament. Swivels are used to prevent line twist which weakens the line when it happens repeatedly. Since the 1970s the same strength of swivel is much smaller and lighter than those historically used. This allows for that hardware to be less obvious to the target species as well as for other species to be attracted to it during a battle. Leaders are frequently paired with swivels. Leaders are a designated length of high-quality fishing line or wire which aid in avoiding line breaks. Leader materials exhibit a similar trend to swivels – an increase in strength and a decrease in weight throughout the timeline. In the case of leaders, the decrease in weight is due in large part to a shift in material choice from wire leaders to lighter and less visible nylon monofilament leaders. Lures have followed a similar trend with developments in material and design since the 1970s leading to more lifelike artificial lures.

An important gear shift occurred in the billfish fishery beginning in the late 1990s: the circle hook. Circle hooks are an alternative to the historically popular J hook. The shift from J to circle hooks has been encouraged in both the recreational billfish fishery as well as commercial longlining where billfish are common bycatch species (Graves *et al.*, 2012). Circle hooks exhibit similar catch rates as J hooks and have been well-documented to reduce post-release mortality in captured billfish (Cooke and Suski, 2004; Serafy *et al.*, 2009; Graves *et al.*, 2012). In addition to reducing post-release mortality, circle hooks have reduced the event known as deep hooking, which also contributes positively to overall billfish survival (Serafy *et al.*, 2009). The use of circle hooks in U.S. commercial fisheries has resulted in decreased rates of billfish bycatch as well as a higher number of living billfish at haulback (Graves *et al.*, 2012). This gear shift matters to the change in catchability of billfish because the lowered mortality due to capture means that there are more fish available for capture by recreational anglers. One angler noted that in addition to better survival, circle hooks allow for better specificity of target billfish (DiGiulian, 2020).

Another important piece of gear that has changed the accessibility of billfish are FADs. The two main types of FADs are anchored and drifting. Various studies have estimated that tens of thousands of these FADs are being or have previously been deployed in the world's oceans every year (Itano, 2017). Multiple species of billfish have been documented to show associative behavior with FADs including marlin and sailfish (Taquet *et al.*, 2007; Hare *et al.*, 2015). The reasons hypothesized for why fish are attracted to FADs include shelter from predators, food supply, locating schooling companions, as well as substrate for species undergoing a life cycle shift (Deudero *et al.*, 1999). The use of FADs allows fishermen to visit and have a higher probability of billfish capture, which directly has impacts on catchability calculation. The fact that there were very few, if any, purpose built FADs in open ocean habitats, prior to 2000 demonstrates the vastly disparate habitat availabilities in the years covered by the RBS.

According to Samuels (2020), the size of fishing boats has increased over time. His work with monohulled center console diesel powered fishing boats illustrated a change in the length of boat in the recreational fishery in the last twenty years. In 2000 his experience was the average size of billfish boat was between 50 and 52 feet, which has increased to between 72 and 80 feet today. The difference in size affects the horsepower necessary to achieve desirable speeds, however, he noted that the speed at which anglers are fishing today is the same as it was in 2000. Although the speed at which fishing occurs has remained the same over the timeline, the ability to reach farther locations in more adverse conditions has improved with higher horsepower engines and larger average size of boats.

4. Discussion

Based on the preliminary findings of this study, the authors conclude that there is sufficient evidence that the catchability of the recreational billfish fleets has increased. The changes in catchability demonstrated by this study show that CPUE estimates calculated using the assumption of a constant catchability provides biased estimates of stock size, suggesting an increase in fish abundance which may actually be caused by this changing catchability value. If CPUE estimates are used which have a changing value of catchability without accounting for that time-varying catchability, this increase in CPUE may suggest increasing stock sizes instead of the true cause of the change in CPUE, which is the change in catchability over time. Overestimation of stock size could lead to management implications including raising catch values on an already overfished population because of the belief that stock size is increasing, rather than catchability.

It has been documented that changes in fishing practices and technology can lead to changed trends in catchability over time (Hilborn and Walters 1992). Other studies have also shown that use of sonar and GPS plotters have improved catchability over time in other fish stocks (Robins *et al.,* 1998; Thurstan *et al.,* 2018) Though this paper focuses on the U.S. RBS, there are other recreational billfish fisheries in the Atlantic, which have likely also seen changes in catchability due to the use of the technology and gears mentioned in this paper. Use of this timeline will allow for quantification of the change in catchability for CPUE models calculated for the recreational billfish fishery in the Atlantic Ocean using general linear models (GLMs), etc. The authors estimate that the gears listed in the above report provide an effective first step for the estimation of parameter values for the models used in billfish management, and will allow for a better understanding of how the recreational fleet is contributing to global catch of these species. It is quite possible that the changes in effort that have taken place over the history of the RBS would cause the CPUE to be biased upward over that time period.

Though this study does not include legislation that has affected billfish management and recovery, it does provide the most significant gear and technology selected by both the fisheries scientists who provide information and recommendations to entities who manage the fishery as well as those selected by anglers. The 1988 Atlantic Billfish Fishery Management Plan marks a key piece of legislation which prohibited commercial fisheries from keeping or selling billfish, as well as the catch and release practice observed in recreational tournaments. Though this law mainly affects the commercial sector, the commercial sector including both U.S. and international commercial fishing fleets, is responsible for the capture of the vast majority of billfish in the Atlantic Ocean.

All of the variables discussed here and more are additive to and with each other. For instance, a bigger boat is more comfortable so the anglers and crew are less fatigued before, during, and after the daily fishing efforts. Add to that better fishing reels and rods that are lighter and stronger and there is additional reduction of fatigue. Add to that that there is electronic assistance with radar, navigation (GPS), Sonar, and Internet based oceanographic feature definition so there is even more relief (mental) for the fishing constituents. All of this adds up to a less burdened fishing team in comparison to what the teams went through at the beginning of the RBS. This can improve their performance and increase their productivity during the tournament hours in a day of fishing and throughout the duration of the event.

Each change in either gear or technology provide strong evidence to support that there has been time-varying catchability for billfish in the recreational billfish fishery. Modeling CPUE of recreational catch including the changes in catchability for marlin over the RBS will improve understanding of billfish stock behavior over multiple decades and aid in providing more accurate estimates of population size. Time varying catchability additionally helps prevent hypterstability in stock assessment models (Wilberg *et al.,* 2010). Hyperstability occurs when catchability is assumed to be constant over a given time period and can cause estimates of CPUE to increase while the population remains the same (Wilberg *et al.*, 2010). The use of time varying catchability recommended by the authors will aid in revealing more accurate population estimates.

Pairing the results of this initial exploration of the changes in gear and technology with the typical assessment of CPUE in recreational fisheries using tournament data will allow for a more thorough understanding of how the populations have changed over the course of the RBS. This report has the potential to unlock the key pieces of technology and gear which have affected catchability since the 1970s and will likely affect catchability in the future. In addition to the integration of the GLMs expected to be generated from this report, angler apps could provide additional sources of CPUE and catchability data moving forward, as proposed by Venturelli *et al.* (2017). With organizations such as The Billfish Foundation that have good working relationships with anglers, the promotion of applications on phones could be a way for fisheries managers and scientists to connect with anglers and have improved data accessibility for the purpose of stock assessments and conservation of billfish species.

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