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ORIGINAL PAPER

Characterization of the Recreational Fisheries associated with the Flower Garden Banks National Marine Sanctuary (USA)

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Abstract
The demand on our marine resources is increasing at unsustainable rates at the same time that many fish stocks are overfished, already collapsed or at risk of extinction. In 2006, recreational anglers landed about 4,809 mt of coastal pelagic species in the Gulf of Mexico, which was above the Maximum Sustainable Yield estimate (4,702 mt). Despite this urgency, marine policy and management is complex, controversial, and time consuming. One tool that resource managers use for managing, protecting, and conserving marine resources is designating Marine Protected Areas (MPAs). Presently, the public is concerned with the impacts of fishing on the status of fish stocks associated with the Flower Garden Banks National Marine Sanctuary (FGBNMS). Recreational fishing is among the most popular marine activities associated with MPAs; however, few studies have evaluated the impact of this activity on the local resources. Given these conservation and social issues, the main goal of this study was to provide a characterization of the recreational fisheries associated with the FGBNMS. Findings showed that recreational landings were dominated by red snapper, vermilion snapper, and gray triggerfish. Cumulative landings and catch rates varied significantly by species, month and location. Overall, the highest fishing effort was in summer, and the highest catch rates were in winter. The greatest catch rates for reef fish and coastal pelagic species were in the southernmost (Laguna Madre) and northernmost (Galveston) origination ports, respectively. Based on monthly catches, there was some evidence that recreational anglers target spawning snapper aggregations. The annual mean weight for gray triggerfish was stable, but the mean weight of both red and vermilion snapper declined between 1986 and 2006.

Introduction

The demand on our marine resources is increasing at unsustainable rates at the same time that many fish stocks are overfished, already collapsed, and at risk of extinction [1, 2]. This dire phenomenon has been driven by many reasons, such as advancements in fishing gear, marine technology (e.g., GPS and navigation, side scan sonar, depth and fish finders) and economics [3]. Besides direct impacts from fisheries (commercial and recreational), marine species and the habitats they rely upon are also threatened by other factors, such as habitat degradation and pollution. Despite the overwhelming evidence that most fish stocks are depleted and there is an urgency to conserve, protect, and recover these stocks, marine policy and fishery management is complex, controversial, time-consuming, and often a reactive process [4]. One tool that resource managers use for managing, protecting, and conserving marine resources is designating protected areas, such as Marine Protected Areas (MPAs) [5]. Under the National Marine Sanctuaries Act, MPAs in the Unites States are defined as "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein" [6].

In the Unites States, there are about 1,700 different MPAs [7]. One of the first types of MPA designated in the United States was National Marine Sanctuaries (NMSs). The first NMS (USS *Monitor*, off the coast of North Carolina) in the United States was nominated, approved, and designated by President Gerald Ford on 30 January 1975. Today, the NMS system consists of 14 MPAs and includes 13 NMSs that encompass more than 241,500 km^2 of marine and Great Lakes waters. Located in the Gulf of Mexico, off the coasts of Louisiana and Texas, is the Flower Garden Banks NMS (FGBNMS), which was designated on 17 January 1992 [8, 9]. The FGBNMS is managed through a variety of methods including education, science, resource protection, and regulatory programs [8]. To ensure that recent scientific discoveries, advancements in managing marine resources, and new resource management issues are adequately addressed in existing Sanctuary Management Plans (SMPs), Management Plan Reviews (MPRs) are supposed to be completed every five years [9]; however, many SMPs are over 10 years old [10].

To begin the MPR process for the FGBNMS, sanctuary staff held several public scoping meetings (17, 19, 24 October 2006) to discuss a range of alternatives for addressing concerns and issues at the sanctuary. Based on the public comments received, most (66%) of the concerns were about the direct and indirect impacts fishing had on the local fish populations associated with the sanctuary [11]. Following the public scoping meetings, National Oceanographic Atmospheric Administration (NOAA) hosted a special meeting of the Sanctuary Advisory Council (SAC) who established a fisheries subcommittee [11, 12]. The fisheries subcommittee drafted the following guideline statement to assist the group with its goal of addressing fishing impacts:

"*Fishing activities may negatively impact and threaten the natural living resources at the FGBNMS. Information on the influence of fishing activities on the resources of the FGBNMS are unavailable, but concerns are mounting about the impacts on the marine ecosystems in a variety of ways, both directly* (*reduced fish biomass*) *and indirectly* (*e.g., secondary impacts on species interactions, habitat alteration/damage, marine biodiversity impacts, economic impacts*)" [12].

More specifically, the subcommittee identified fishery management issues that needed to be addressed which included targeted fishing efforts that may impact snapper (Lutjanidae), grouper (Serranidae) and wahoo (*Acanthocybium solandri*) populations and focused fishing effort during spawning aggregations [12].

Recreational fishing is among the most popular marine activities in the world that often takes place at MPAs including the FGBNMS; however, few studies have evaluated the recreational fisheries associated with a MPA, or evaluated the potential impacts of imposing restrictions on these activities on user groups within a given MPA [13, 14]. Although there is some information about the potential impacts and benefits of MPAs, and other factors that impact reef-fish sustainability [15], only limited information is available about the potential impacts of establishing a MPA or imposing additional restrictions on the human environment, such as changes in spatial fishing effort distribution, user activity, or socio-economics [16]. In general, assessing recreational fishing effort and harvest of marine species is extremely difficult and often costly, but it is essential for making informed decisions about establishing MPA rules and regulations [17]. Dayton *et al*. [18] emphasized that logistical and data challenges usually prohibit benchmark studies from being conducted, given that long-term data are usually lacking for assessing population changes or regime shifts. Understanding this concept, Lynch [16, 19] stated that the incorporation of recreational fishing effort associated with a MPA is among the most important types of user activity information that decision makers need during the MPA design process, or when proposing new restrictions for a MPA. The importance of evaluating recreational fisheries information was also emphasized by resource managers for the Channel Islands NMS off the California coast (USA) under the sanctuary's social science plan [20].

Accurate characteristics of the current recreational fishery (e.g., fishing effort, landings, and size frequency of fish caught) associated with the FGBNMS must be available to not only gauge the potential effect of management decisions on users, but to evaluate current and future stochastic influences of anthropogenic and natural events on local fish populations. This type of activity information can also be used to help understand and overcome the shifting baseline syndrome [21] and to test the effectiveness of management decisions with respect to intended objectives [22]. Given this management need to characterize the recreational fisheries associated with the FGBNMS, the goal of this investigation was to provide a baseline (benchmark) and profile of the recreational fisheries within the vicinity of the FGBNMS to facilitate objective informed decision-making. The specific objectives were to compile existing recreational fishing data, identify trends (or lack thereof) in recreational fishing landings, fishing effort, and catch-per-unit-effort (CPUE) for the primary fish landed by recreational anglers.

Methods

Study area

The FGBNMS consists of three main banks (reefs) that encompass 143.02 km^2 (88.8 mi^2): East Flower Garden Bank (27.9°N, 93.6°W), West Flower Garden Bank (27.83°N, 93.83°W), and Stetson Bank (28.15°N, 94.28°W) [25]. The East Flower Bank encompasses 66 km^2 (41 mi^2) and is located about 222 km (120 nautical miles [nm]) south, southwest of Cameron, Louisiana. The West Bank encompasses 77 km^2 (47.8 mi^2) and is located about 204 km (110 nm) southeast of Galveston, Texas. Stetson Bank, the smallest reef, encompasses 3 km^2 (1.9 mi^2) and is located 48 km (26 nm) northwest of the Flower Gardens (Fig. 1).

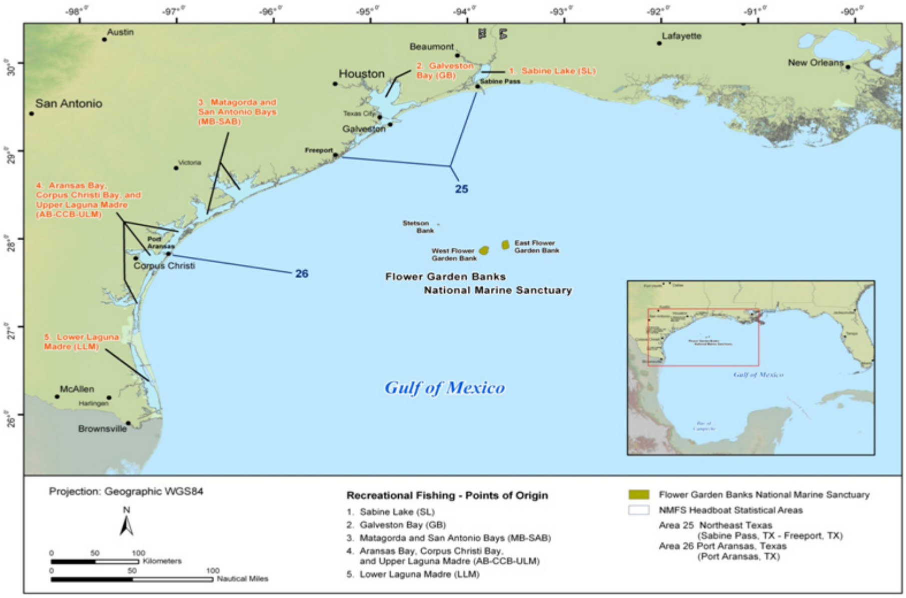

Fig. 1: Study area. Recreational fishing ports (points of origin) in the Gulf of Mexico defined by the Texas Marine Sport Harvest Monitoring Program and the National Marine Fisheries Service Southeast Regional Headboat Survey.

Data

Recreational fishery catch characteristics and fishing activity for the Gulf of Mexico was evaluated using a multi data approach that consisted of three different datasets: creel, logbook, and fishing news reports. These recreational fishing data were obtained from state (Texas Parks and Wildlife Department [TPWD] and federal (National Marine Fisheries Service [NMFS], Southeast Regional Headboat Survey [SERHS]) fishery monitoring programs, and local fishing news reports (Galveston County: *The Daily News* Reel Report [TDNRR]). Depending on the dataset, each time-series varied by survey duration: TPWD (15 May 2003–14 May 2008), SERHS (1986–2006), and TDNRR (August 2006–13 September 2008). For these analyses, the sale of catch was used to distinguish between commercial and recreational fishing sectors. Using this criteria, the data was treated as recreational fishery data since the anglers under each of these fishery-dependent programs did not sell their catch. All catch estimates were based on the number of fish landed and retained, and it did not include the number of fish filleted or released back to the water (alive, dead, or used as bait). A charter vessel was defined as a vessel less than 90.8 gross mt (100 t) that met the requirements of the U.S. Coast Guard to carry six or fewer passengers for-hire, while a headboat was defined as a vessel that held a valid Certificate of Inspection issued by the U.S. Coast Guard to carry passengers for-hire.

The state (TPWD) creel survey data consisted of recreational fishing activity information from anglers fishing with hook-and-line gear aboard private and charter vessels that had reported fishing in federal waters (Exclusive Economic Zone [EEZ]) off Texas (i.e., 16.7–370 km [9–200 nm]). The survey methodology was an access-point angler intercept approach on randomly selected days, stratified by day type (weekday/weekend). The boat access sites were selected at random, but selection was weighted according to mean trailer counts obtained from roving counts from the three previous years. The creel survey was conducted year-round (15 May−14 May) and the spatial resolution was according to Texas bay system or Gulf area. The precision resolution was by individual fishing trip (number of angler hours). All anglers intercepted at boat ramps (fishing trip origination areas) were shown maps of the study area and asked where they had recently fished during their trip. So anglers could understand the purpose of the study, they were given background information and a description of the survey process. Data were examined from five distinct fishing trip origination areas: (1) Sabine Lake (SL); (2) Galveston Bay (GB); (3) Matagorda and San Antonio Bays (MB-SAB); (4) Aransas and Corpus Christi Bays and upper Laguna Madre (AB-CCB-ULM); and (5) lower Laguna Madre (LLM) (Fig. 1).

The federal (SERHS) survey data consisted of recreational fishing activity information from anglers fishing with hook-and-line gear aboard headboat vessels. Recreational headboat fishing activity information was collected through logbooks that were completed by headboat operators, which was a federal requirement of their permit. The survey methodology was a complete census (logbook) and access-point intercept approach that was conducted year-round. The spatial resolution was by geographical fishing area (NMFS statistical grid system), and the precision resolution was by individual fishing trip (per day). However, it should be noted that precision data was unable to be used for these analyses given confidentiality issues. Similar to the NMFS statistical grid system used for monitoring commercial fisheries in the United States, NMFS divides the Southeast Region into 27 different fishing areas. For these analyses, logbook (SERHS) data were examined from the two NMFS statistical grid areas neighboring the FGBNMS: Area 25 (Northeast Texas [Sabine Pass-Freeport, TX] and Area 26 (Port Aransas, Texas [Port Aransas, TX]) (Fig. 1).

The fishing news reports (TDNRR) were data that consisted of recreational fishing activity information from anglers fishing with hook-and-line gear aboard charter vessels. The TDNRR was recreational fishing information that was reported to the Galveston County newspaper-*The Daily News* by the local charter vessel fishing captains on a voluntary basis. Much different than the other datasets, these data were not collected through any standardized state or federal fishery collection program. The Daily News did not collect the fishing activity for every charter vessel in Galveston, Texas, but it did report the fishing activity for many of the larger and more popular charter vessels in the area on a daily basis (M. Nuttall, NMFS, pers. Comm., 19 January 2009). Given this lack of standardized methodology, these data were bias because the newspaper did not systematically solicit fishing activity information from every vessel captain on a regular basis, but relied on individual fishing captains to voluntarily report their catch. In addition, since this information was voluntary, it is highly probable that many of the fishing captains did not report their catch on a regularly basis, especially on the days when they did not catch any fish. Nonetheless, these data were used because most anglers use newspaper columns (daily reports) and fishing articles to acquire fishing information and plan fishing trips [24]. Another reason these data were used in these analyses was to gauge the effectiveness of this type of opportunistic data.

Data Analyses

Prior to analyses, the datasets were tested for normality and homoscedacity using Kolmogorov-Smirnov [25] and Bartlett's [26, 27] tests, respectively. To ensure robustness, normality was also checked by constructing a normal probability plot of the residuals. As part of the data assessment process, all outlier observations were investigated before they were rejected or retained. If the datasets passed the normality test, then parametric procedures were employed; otherwise, the data were transformed using the appropriate transformation process (e.g., log, square root, and arcsin square root transformations) to meet the underlying assumptions of normality [25]. However, if the data still did not meet the assumptions of normality after transformation, then non-parametric tests were applied. For all analyses, statistical significance was defined as $P < 0.05$. In the presence of significance at the 95 percent confidence level for the omnibus Analysis of Variance (ANOVA) or Kruskal-Wallis non-parametric multi-sample test, a *post-hoc* multiple comparison test (e.g., Student Newman-Keuls [SNK] or Tukey) was used to perform pairwise comparisons and differentiate the differences among the population means (parametric) and medians (non-parametric). All analyses were conducted using Microsoft Excel® and SYSTAT® Version 12.

Catch Characteristics

Annual and monthly total landings were summarized and graphed by individual species for each of the datasets. A one-way ANOVA or Kruskal-Wallis test was used to test the null hypothesis that the monthly mean number of fish landed for a particular species by area was equal. The annual total number of fish landed for the primary species in each area was examined using a simple linear regression to categorize the slope of the fitted trendline as increasing (positive) or decreasing (negative). A two-way ANOVA was used to test the null hypothesis that the mean total landings by area, year, or the interaction (area and year) were equal. A two-way ANOVA was also used to test the null hypothesis that the mean total landings by area, species, or the interaction (Area and species) were equal.

Fish were identified to species and the total weight (kg) per trip by species was taken. To estimate the average weight of an individual species, the total number of fish landed was divided by the total weight for the given species. The annual mean weight for the primary species landed in each area was examined using a simple linear regression to categorize the slope of the fitted trendline as increasing (positive) or decreasing (negative). A one-way ANOVA or Kruskal-Wallis test was used to test the null hypothesis that the mean weight among species was equal. In addition to descriptive statistics, frequency and cumulative frequency histograms were used to evaluate individual species weights.

Fishing Effort and Catch Trends

Overall fishing effort was examined using descriptive statistics, while monthly and annual catch rates were calculated using the catch-per-unit-effort (CPUE) metric defined as the total number of fish landed per hour, angler, and trip. Catch rates were calculated as a mean of ratios using the following equation:

$$\text{CPUE} = \frac{\sum_{j=1}^{n} (c_{i,j}/h_j)}{n}$$

where *i* referred to the species, *ci,j* was the total catch of angler *j*, *hj* was the number of hours fished by angler *j*, and *n* was the total number of anglers interviewed [28].

Standard errors for the most dominant species (total catch rates) were calculated per strata. In some instances, the total number of anglers was not reported (TDNRR dataset), so the average number of anglers from the proceeding fishing trips within the same month was used as a substitute. Annual and monthly catch rates for each dataset and fishing mode (private and charter vessels) were calculated, graphed, and evaluated by area. Annual and monthly cumulative catch rates and species-specific catch rates were examined using a simple linear regression to categorize the slope of the fitted trendline. Two separate one-way ANOVA or Kruskal-Wallis tests were used to test the null hypothesis that the mean annual and monthly catch rate by area was equal.

Results

Catch Characteristics

Ninety-two percent of the recreational headboat catches during 1986 through 2006 were dominated by six species: red snapper (*Lutjanus campechanus*), vermilion snapper (*Rhomboplites aurorubens*), gray triggerfish (*Balistes capriscus*), Atlantic sharpnose shark (*Rhizoprionodon terraenovae*), King mackerel (*Scomberomorus cavalla*), and Atlantic spadefish (*Chaetodipterus faber*) (Fig. 2). Overall, there were 7,584,496 (11,133.8 mt) fish taken by anglers aboard headboats in Areas 25 (*n* = 4,902,177 or 5,936.8 mt) and 26 (*n* = 2,682,319 or 5,197.1 mt) during 1986 through 2006 (Fig. 2), and 34,037 fish taken by anglers aboard charter vessels in the Gulf of Mexico during 2006 through 2008 (Fig 3). Red snapper (49%; *n* = 4,372,748), vermilion snapper (16%; *n* = 1,432,210), and gray triggerfish (5%; *n* = 449,792) represented most of the recreational headboat catch (F [5, 11] = 4.543, P = 0.048; Fig. 2).

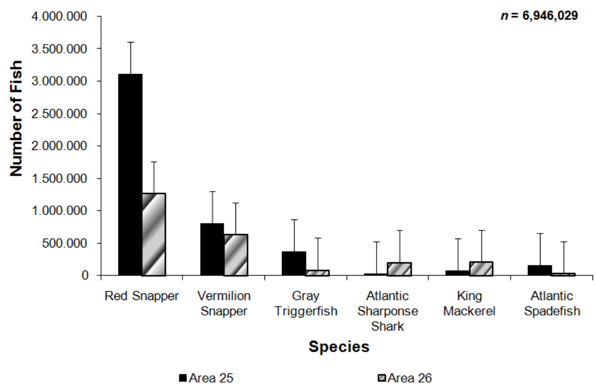

Fig. 2: Gulf of Mexico cumulative recreational headboat landings (Number of Fish) for Areas 25 and 26 during 1986 through 2007. Area 25 is defined as Northeast Texas (Sabine Pass-Freeport, TX) and Area 26 as Port Aransas, Texas. The vertical error bars indicate ± 1 standard error.

A SNK comparison detected there were more red and vermilion snappers taken by anglers aboard headboats than any of the other fish. Red and vermilion snappers (55%; *n* = 16,936) were also the primary fish taken by anglers aboard charter vessels, but anglers also caught a large number of Atlantic spadefish (13%; *n* = 4,052; Fig. 3). Overall, the number and types of fish taken by anglers aboard charter vessels was similar (Kruskal-Wallis, $P = 0.647$). Including red snapper, vermilion snapper, gray triggerfish, and King mackerel, findings showed that anglers fishing aboard private and charter vessels (TPWD creel survey data) also caught cobia (*Rachycentron canadum*) and dolphinfish (*Coryphaena hippurus*) during 2003 through 2007.

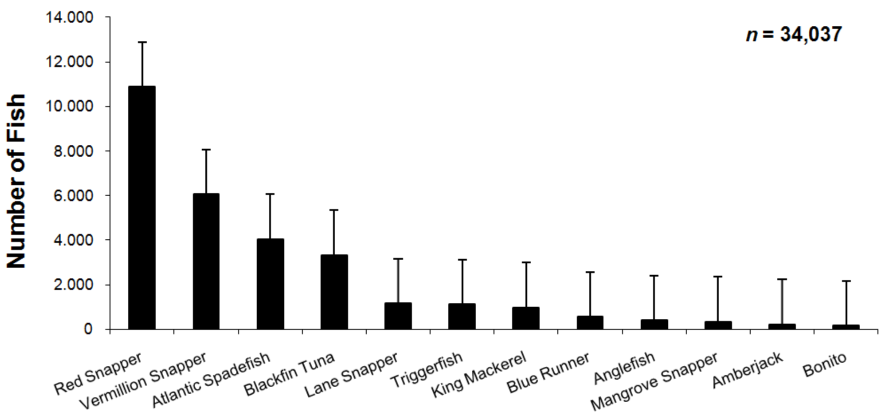

Fig. 3: Gulf of Mexico recreational charter vessel landings (Number of Fish) in Texas during August 2006 through June 2008. The vertical error bars indicate ± 1 standard error.

In Areas 25 and 26, the major species landed (red snapper, vermilion snapper, and gray triggerfish) represented 70% (*n* = 6,254,832) of the total catch. There were more primary species taken in Area 25 (78%; *n* = 4,271,417) than in Area 26 (22%; *n* = 1,983,093) ($P = 0.045$; Fig. 4). Overall, there were more red snapper, vermilion snapper, gray triggerfish, and Atlantic spadefish taken in Area 25 than in Area 26, and more Atlantic sharpnose shark and King mackerel taken in Area 26 than in Area 25 ($P < 0.05$).

The total number of fish taken by anglers, recorded through the SERHS federal dataset, varied by month with more fish taken during May through September (88%; *n* = 5,507,967; Fig. 4). These findings were similar to the charter vessel (TDNRR) data, which showed that recreational catch increased from January to June and declined from July to December (Fig. 5). The monthly number of fish taken by area ($P = 0.467$) and the interaction (species and area) was similar ($P = 0.419$); however, there was a significant difference detected in the monthly number of fish taken by individual species ($P < 0.05$). A *post-hoc* Tukey multiple comparison test showed there was a significant difference in monthly catch of red snapper and gray triggerfish in Areas 25 and 26, respectively. There was also a significant difference between the number of red and vermilion snappers, and gray triggerfish taken in Area 26. The total number of fish taken in Areas 25 and 26 (cumulative) significantly varied by month ($P < 0.05$), but not by area ($P = 0.467$), or the interaction between area and month ($P = 0.959$). In Area 25, a *post-hoc* Tukey multiple comparison test showed there were more fish taken in May than in December.

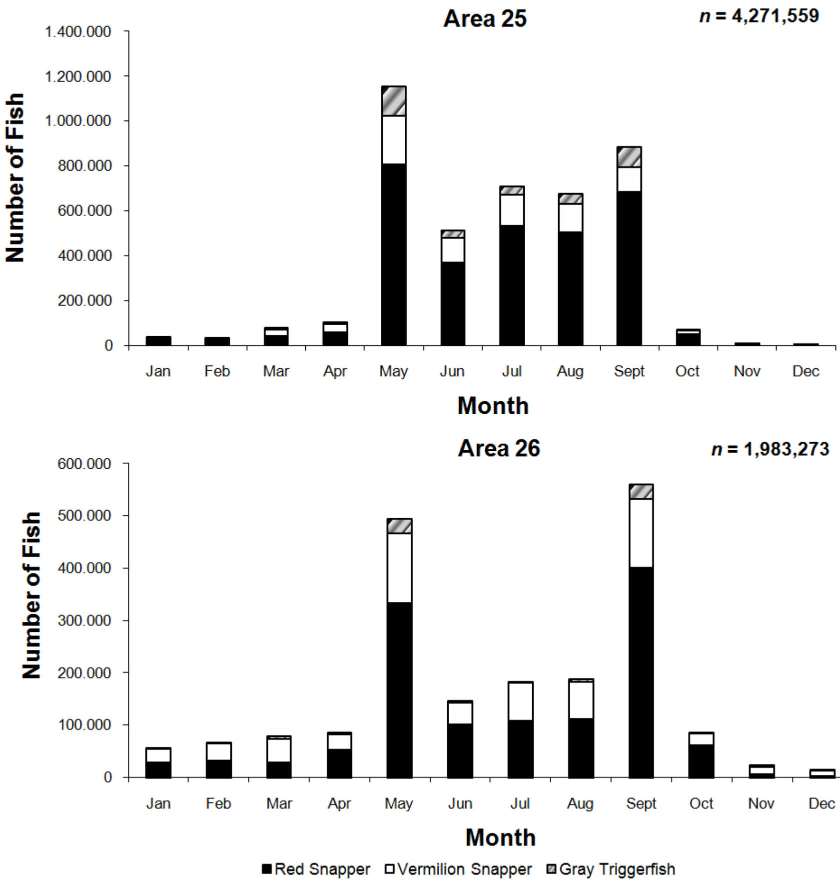

Fig. 4: Gulf of Mexico monthly recreational headboat landings (Number of Fish) by species for Areas 25 and 26 during 1986 through 2006. Area 25 is defined as Northeast Texas (Sabine Pass-Freeport, TX) and Area 26 as Port Aransas, Texas (Port Aransas, TX).

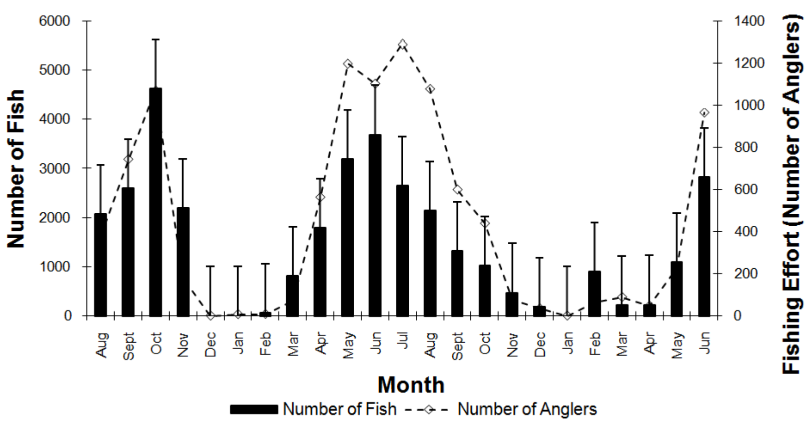

Fig. 5: Gulf of Mexico monthly recreational charter vessel landings (Number of Fish) and fishing effort (Number of Anglers) in Texas during August 2006 through June 2008. The vertical error bars indicate ± 1 standard error.

The number of red snapper landed by headboat anglers increased from winter to summer and peaked in May (26%; *n* = 1,138,388) and September (25%; *n* = 1,084,053) in Areas 25 and 26; red snapper catch decreased after September. In Area 26, vermilion snapper catch mimicked red snapper catch peaking in May (21%; *n* = 133,970) and September (21%; *n* = 132,032). However, peak vermilion snapper catch occurred in May (28%; *n* = 220,101) and August (16%; *n* = 126,399) in Area 25. Red snapper catch by charter vessel (TDNRR) anglers also showed an increase in catch from winter to summer, but a decrease from summer to fall (Fig. 6). In 2006 (September [39%; *n* = 1,860]) and 2007 (October [4%; *n* = 237]), there was, however, an increase in red snapper catch during fall, which complimented the findings for headboat landings.

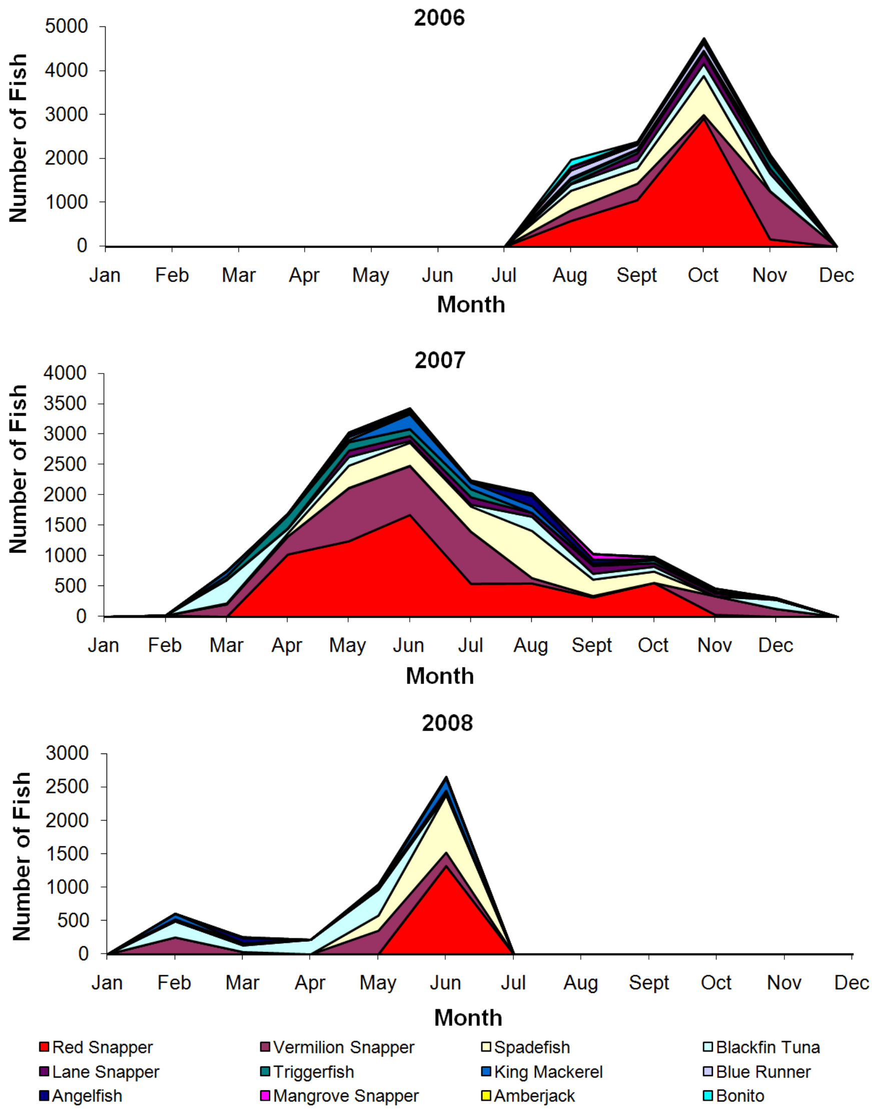

Fig. 6: Gulf of Mexico monthly recreational landings (Number of Fish) in Texas by species during August 2006 through June 2008. The solid line represents the moving average for red snapper catch.

The number of vermilion snapper and Atlantic spadefish landed by charter vessel anglers increased from spring to summer and peaked in May and August, respectively; overall catches declined during winter. In Areas 25 and 26, the annual vermilion snapper and gray triggerfish catch by headboat anglers was stable from 1986 to 2006; however, red snapper catch declined in Area 25 (Fig. 7). The negative correlation between annual red snapper catch and time was described by the following simple linear regression equation: y = -11269x + 271194 ($r^2 = 0.60$, $n = 21$). In Area 26, the annual red snapper catch spiked in 1989, but remained stable from 1990 to 2006.

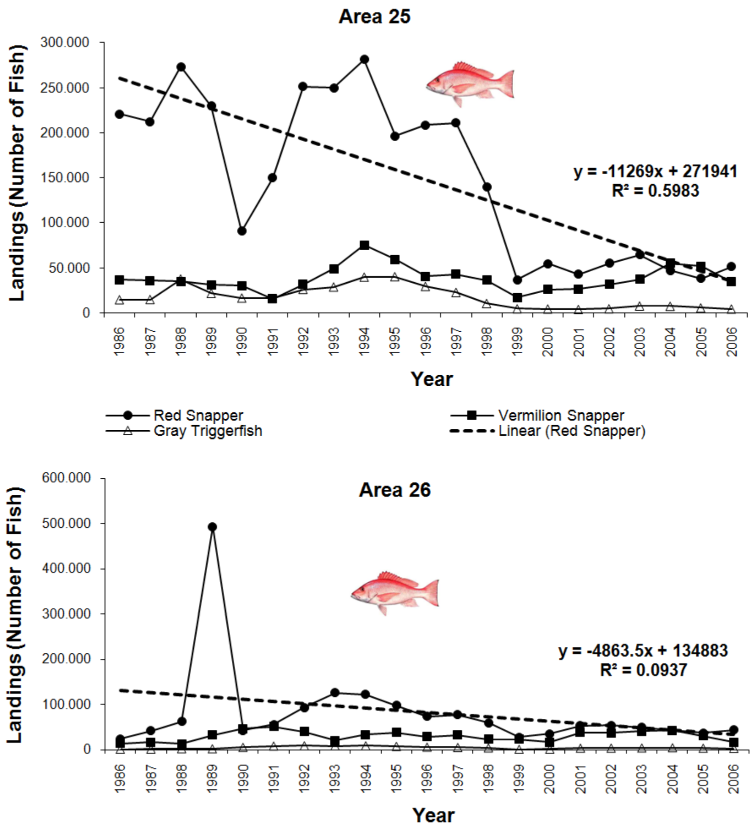

Fig. 7: Gulf of Mexico recreational headboat landings for Areas 25 and 26 during 1986 through 2006. Area 25 is defined as Northeast Texas (Sabine Pass-Freeport, TX) and Area 26 as Port Aransas, Texas (Port Aransas, TX). The dash line represents the linear correlation between landings and year for red snapper catch.

Examination of the annual weight distribution for the primary species landed by headboat anglers during 1986 through 2006 revealed that the estimated mean weight of gray triggerfish was stable over the 21-year time period, but the estimated mean weight of red and vermilion snapper declined (Fig. 8). The negative correlation between red snapper mean weight and time was described by the following simple linear regression equation: y = -0.0642x + 128.94 ($r^2 = 0.71$, $n = 21$), while the negative correlation between vermilion snapper mean weight and time was described by: y = -0.0871x + 176.18 ($r^2 = 0.54$, $n = 21$). The average weight among the three primary species (red snapper, vermilion snapper, and gray triggerfish) landed was significantly different (F [2, 60] = 38.339, P < 0.001; Figs. 8, 9). A Tukey multiple comparison test revealed that the average weight of vermilion snapper was significantly heavier than the average weight of red snapper and gray triggerfish (P < 0.05). The vermilion snapper weight ranged from 0.39 to 6.2 kg (0.86−13.7 lbs) with a mean of 2.07 kg (S.E. ± 0.04 kg), while the red snapper weight ranged from 0.22 to 4.2 kg (0.49−9.3 lbs) with a mean of 0.79 kg (S.E. ± 0.02 kg). The gray triggerfish weight ranged from 0.49 to 2.93 kg (1.1−6.46) with a mean of 1.28 kg (S.E. ± 0.016 kg). Weight-frequency histograms for red and vermilion snappers landed by recreational anglers aboard headboats also suggested that catches were skewed toward smaller sizes.

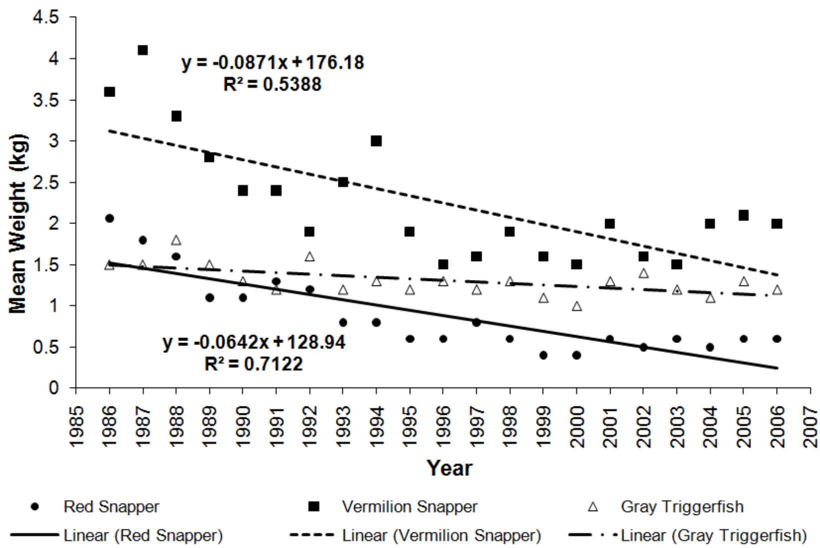

Fig. 8: Mean weight by year for the primary species landed by recreational anglers aboard headboats fishing in the Gulf of Mexico (Areas 25 and 26) during 1986 through 2006. Area 25 is defined as Northeast Texas (Sabine Pass-Freeport, TX) and Area 26 as Port Aransas, Texas (Port Aransas, TX). The horizontal lines represent the linear correlation between mean weight and year for each species. The vertical error bars indicate ± 1 standard error.

Fishing Effort

In total, there were 81 headboat vessels that reported recreational fishing landings in the Gulf of Mexico (Areas 21−27) during 1986 through 2006 (Table 1). Of these, 19.7% (n = 16) of the headboats reported landings within vicinity of the FGBNMS (Areas 25 and 26). Unfortunately, more detailed fishing effort (i.e., number of trips) information was only available for anglers aboard charter and private vessels. Charter vessel captains reported taking between 0 and 8 fishing trips per month for a total of 283 trips during 2006 through 2008 (94.3 fishing trips/year). In total, fishing captains reported that 10,237 anglers landed 34,037 fish. Charter vessel captains also reported fishing between 16.1 and 241.4 km (8.6−130 nm) from shore with a mean offshore distance of 79.5 km (43 nm). The number of fishing trips varied by month ranging from 0 in December and January (2007 and 2008) to 29 in June (2007). The number of anglers per trip also varied seasonally ranging from 0 in December and January (2007 and 2008) to 53 in September (2006). Overall, fishing effort (total number of

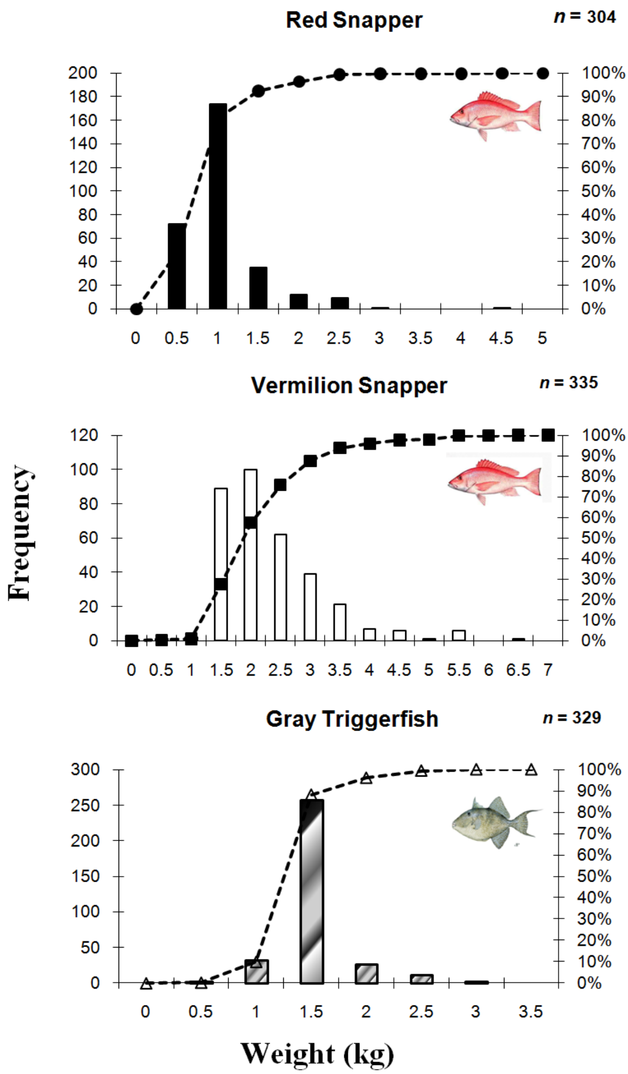

Fig. 9: The weight-frequency distribution of the primary species landed by recreational anglers aboard headboats fishing in the Gulf of Mexico (Areas 25 and 26) during 1986 through 2006. Area 25 is defined as Northeast Texas (Sabine Pass-Freeport, TX) and Area 26 as Port Aransas, Texas (Port Aransas, TX).

Table 1: Total number of headboats reporting landings in the Gulf of Mexico during 1986 through 2006. Areas are defined as the following: 21 = Southwest Florida (Naples-Cedar Key); 22 = Florida Middle Grounds (Vessels docked on Florida west coast); 23 = Orange Beach, Alabama (Carrabelle, FL-Orange Beach, Alabama; 24 = Louisiana (Empire-Grand Isle, LA); 25 = Northeast Texas (Sabine Pass-Freeport, TX); 26 = Port Aransas, Texas; 27 = Southeast Texas (South Padre Island, TX).

Number of Headboats	Area	Port Location
24 (29.6%)	21	Tarpon Springs, FL; Ft. Myers, FL; Sarasota, FL; John's Pass, FL; Placida, FL; Crystal River, FL; Clearwater, FL; Naples, FL; Hernando, FL; Englewood, FL
3 (3.7%)	22	Clearwater, FL
22 (27.1%)	23	Panama City, FL; Destin, FL; Orange Bch, AL; Pensacola Bch, FL; Dauphin Island, AL
10 (12%)	24	Empire, LA, Port Fourchon, LA; Grand Isle, LA; Cocodrie, LA
7 (8.6%)	25	Freeport, TX; Galveston, TX
9 (11.1%)	26	Port Aransas, TX
6 (7.4%)	27	Port Isabel, TX; South Padre Island, TX

anglers) during 2006 through 2008 generally increased 99% from January (*n* = 7) to July (*n* = 1,290) and decreased from August to December (Fig. 10). In 2006, the fishing effort increased 47% (*n* = 689 anglers) from August to October and decreased 100% (*n* = 183 anglers) from November to December. However, fishing effort in 2007 increased from January (*n* = 3 anglers) to May (*n* = 48 anglers), decreased in June, and remained stable in July and August. Fishing effort also increased slightly from 33 anglers per trip in September to 39 anglers per trip in October.

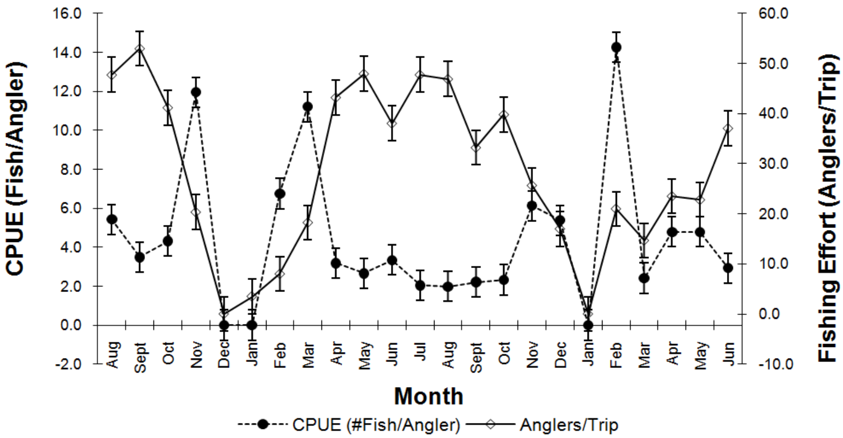

Fig. 10: Gulf of Mexico monthly recreational charter vessel catch rates in Texas during August 2006 through June 2008. The vertical error bars indicate ± 1 standard error.

Catch Trends

Overall, monthly catch rates (number of fish taken per angler) by anglers aboard charter vessels varied by month with the lowest catch rates from April to October (Figs. 10, 11), and the highest catch rates in November (2006), March (2007), and February (2008). Monthly catch rates ranged from 0 in January and December to 14.27 fish per angler in February (2007) with mean of 4.42 fish per angler. A simple linear regression did not show any correlation between catch rate and month ($y = -0.0184x + 4.6383$, $r^2 = 0.0011$; Fig. 11), but it did show an opposite pattern to fishing effort (anglers per trip).

Monthly species-specific catch rates were calculated and compared for the primary species taken by charter vessel anglers. The lowest catch rates for red snapper were from July to September and highest catch rates were generally in October. Red snapper catch rates ranged from 0 in March (2007) to 2.73 fish per angler in October (2006) with a mean of 0.79 (S.E. ± 0.17) fish per angler. The lowest catch rates for vermilion snapper were from August to October and highest in February and November. Vermilion snapper catch rates ranged from 0 in October (2007) to 5.93 fish per angler in November (2006) with a mean of 1.16 (S.E. ± 0.35) fish per angler. Atlantic spadefish catch rates showed a flat monthly trend ranging from 0 to 1.16 fish per angler with a mean of 0.31 (S.E. ± 0.07) fish per angler. Although monthly catch rates varied slightly by month, a Kruskal-Wallis test did not show any significant differences in catch rates among the primary species landed by month (red snapper [$P = 0.281$], vermilion snapper [$P = 0.221$], and Atlantic spadefish [$P = 0.322$]).

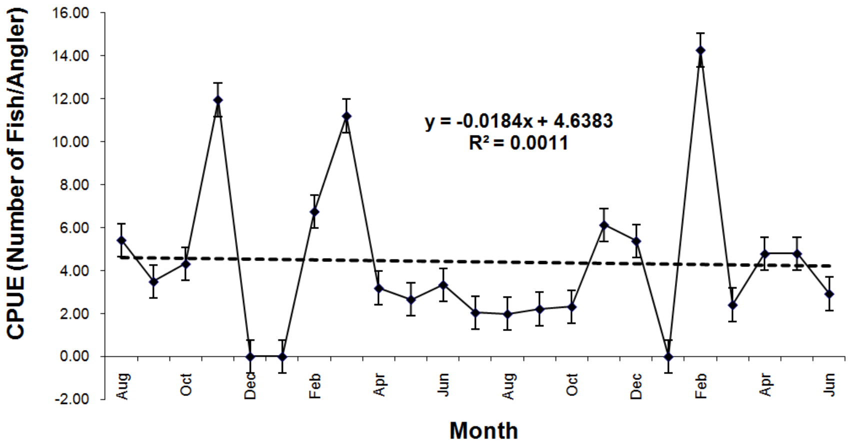

Fig. 11: Gulf of Mexico monthly recreational charter vessel catch rates in Texas during August 2006 through June 2008. The solid line represents the linear correlation between CPUE and month and vertical error bars indicate ± 1 standard error.

Species-specific catch rates for the primary species landed by private vessel anglers were generated for the five distinct fishing origination areas of the state creel program: Sabine Lake (northernmost site); Galveston Bay; Matagorda and San Antonio Bays; Aransas and Corpus Christi Bays and upper Laguna Madre; and lower Laguna Madre (southernmost site).

The mean cumulative (all primary species [red snapper, King mackerel, vermilion snapper, gray triggerfish, cobia, and dolphinfish] and years [2003−2007]) catch rates were lowest (0.02 fish per hour) on trips originating from Aransas and Corpus Christi Bays and upper Laguna Madre and highest (0.05 fish per hour) from lower Laguna Madre. The lowest mean fishing effort (9,320 hours) was for trips originating from lower Laguna Madre and the highest (99,580 hours) for trips originating from Galveston Bay.

The lowest annual mean catch rate (0.05 fish per hour) for red snapper was for trips originating from Aransas and Corpus Christi Bays and upper Laguna Madre and highest (0.27 fish per hour) for trips originating from lower Laguna Madre. King mackerel annual catch rates were lowest (0.02 fish per hour) for trips originating from lower Laguna Madre and highest (0.05 fish per hour) for trips originating from Galveston Bay. In most areas, annual red and vermilion snapper catch rates displayed an alternating (increasing-decreasing) pattern. Annual King mackerel catches showed a similar alternating pattern with catch rates decreasing from 2003 to 2004 and increasing in 2005 and 2006. Annual catch rates for the other species did not display any clear patterns. Besides catches originating from lower Laguna Madre, where red snapper catch dominated, annual catch rates for other species were generally lower than red snapper.

Five separate Kruskal-Wallis tests showed there were significant differences in catch rates among species by origination area (Sabine Lake [$P = 0.0006$], Galveston Bay [$P = 0.0008$], Matagorda and San Antonio Bays [$P = 0.001$], Aransas and Corpus Christi Bays and upper Laguna Madre [$P = 0.001$], and lower Laguna Madre

[P = 0.001]). A Tukey multiple comparison test showed that there was a significant difference between red and vermilion snappers, cobia, and gray triggerfish catch rates (Sabine Lake), and red and vermilion snappers and cobia catch rates (Galveston Bay and Aransas and Corpus Christi Bays and upper Laguna Madre). The test also showed there was a significant difference between King mackerel and cobia catch rates originating from Galveston Bay and those originating from Aransas and Corpus Christi Bays and upper Laguna Madre. The red snapper catch rates also differed significantly from vermilion snapper and gray triggerfish catch rates originating from lower Laguna Madre.

Further analysis showed that there were significant differences in catch rates for specific species by area. A Kruskal-Wallis test showed that there was a significant difference in red snapper (P = 0.0005) and King mackerel catch rates among origination areas (P = 0.0327); however, there was no significant difference in catch rates among vermilion snapper (P = 0.0737), gray triggerfish (P = 0.2075), cobia (P = 0.3659), and dolphinfish (P = 0.7249). A Tukey multiple comparison test showed there was a significant difference in red snapper catch rates between lower Laguna Madre and Aransas and Corpus Christi Bays and upper Laguna Madre and Galveston Bay areas. Also, King mackerel catch rates at Galveston Bay was significantly different than King mackerel catch rates at lower Laguna Madre.

Similar to anglers fishing aboard private vessels, charter vessel anglers also mostly caught red snapper, King mackerel, vermilion snapper, gray triggerfish, cobia, and dolphinfish during 2003 through 2007. In general, the mean cumulative (all primary species and years) catch rates were lowest (0.01 fish per hour) from trips originating from lower Laguna Madre and highest (0.07 fish per hour) from Matagorda and San Antonio Bays. Although red snapper rates were not as high as those reported for private vessels, red snapper catches were the highest and cobia and gray triggerfish were the lowest. Catch rates for anglers fishing aboard charter vessels varied by origination area. The lowest mean annual catch rate (0.07 fish per hour) for red snapper was for trips originating from Aransas and Corpus Christi Bays and upper Laguna Madre and highest (0.32 fish per hour) from Matagorda and San Antonio Bays. King mackerel annual catch rates were lowest (0.003 fish per hour) for trips originating from lower Laguna Madre and highest (0.14 fish per hour) from Aransas and Corpus Christi Bays and upper Laguna Madre. In general, annual catch rates for the primary species did not display any consistent patterns. In most areas, annual catch rates for red snapper were higher than the other species with the exception for trips originating from Aransas and Corpus Christi Bays and upper Laguna Madre where King mackerel and dolphinfish catch rates were high during 2003 through 2006. A Kruskal-Wallis test showed there was a significant difference in catch rates among species for trips originating from Galveston Bay (P = 0.0007) and Matagorda and San Antonio Bays (P = 0.0008); however, there was no significant difference in catch rates among species for trips originating from Sabine Lake (P = 0.1303), Aransas and Corpus Christi Bays and upper Laguna Madre (P = 0.1901), and lower Laguna Madre (P = 0.5308). A Tukey multiple comparison test showed that there were significant differences between red snapper and vermilion snapper, and cobia catch rates for trips originating from Galveston Bay and Matagorda and San Antonio Bays.

Further analysis showed that there was a significant difference in catch rates by specific species among origination area. A Kruskal-Wallis test showed there was a significant difference in red snapper (P = 0.0221), vermilion snapper (P = 0.0099), gray triggerfish (P = 0.005), and dolphinfish (P = 0.0148) catch rates among origination areas; however, there was no significant difference in King mackerel (P = 0.0945) or cobia (P = 0.2067) catch rates. A Tukey multiple comparison test showed there was a significant difference in the red snapper catch rate between trips originating from Matagorda and San Antonio Bays, and Aransas and Corpus Christi Bays and upper Laguna Madre areas as well as the vermilion snapper catch rate between trips originating from Matagorda and San Antonio Bays and Aransas and Corpus Christi Bays and upper Laguna Madre, lower Laguna Madre, Sabine Lake, and Galveston Bay. The gray triggerfish catch rate originating from Galveston Bay was significantly different than the catch rate for trips originating from Sabine Lake, Aransas and Corpus Christi Bays and upper Laguna Madre, and lower Laguna Madre. In addition, findings showed the dolphinfish catch rate for trips originating from Matagorda and San Antonio Bays, Galveston Bay, and Aransas and Corpus Christi Bays and upper Laguna Madre was significantly different than catch rates for trips originating from Sabine Lake and lower Laguna Madre.

Discussion

Marine sanctuary resource managers are charged with providing lasting protection for part or all of the natural and cultural resource areas designated as MPAs. As such, resource managers of the FGBNMS are considering establishing "special" areas (no-take) that prohibit all fishing activities within the sanctuary. Despite the lack of explicit spatial recreational fisheries data for the FGBNMS, this characterization of the recreational fisheries did identify catch composition, and pointed out various trends in total landings, fishing effort, and catch rates for the primary species taken within the vicinity of the sanctuary. This assessment of the recreational fisheries associated with the FGBNMS was the first attempt to assemble available datasets to investigate and identify trends in recreational fishing landings, fishing effort, and catch rates for the primary fish landed by recreational anglers.

Catch Characteristics

Red snapper and vermilion snapper were the primary species taken by recreational anglers aboard private, charter, and headboat vessels fishing near the FGBNMS. Previous studies have also demonstrated that snappers are not only among the most important recreational species, but snappers are also an economically valuable species of the commercial fishery in the Gulf of Mexico [29, 30]. Interestingly, Coleman *et al*. [29] found that red snapper recreational landings actually exceeded commercial landings in the Gulf of Mexico. Besides reef-fish (snappers and Atlantic spadefish), the findings of this present study also showed that recreational anglers landed a significant number of small coastal sharks (i.e., Atlantic sharpnose sharks) and coastal pelagic species (cobia, dolphinfish, and King mackerel), which were probably taken closer to shore. Coastal pelagic species, and King mackerel in particular, are highly south-after gamefish in the Gulf of Mexico that are landed by recreational anglers in large numbers. According to NMFS [31], recreational anglers landed about 4,809 mt of coastal pelagic species in the Gulf of Mexico in 2006, which was above the Maximum Sustainable Yield estimate (4,702 mt).

Findings showed there were more reef-fish taken in Area 25 than Area 26, and more inshore and coastal pelagic species taken in Area 26 than Area 25. Based on these results, the catch characteristics suggested that anglers in Area 25 (i.e., the area nearest to the FGBNMS) were targeting reef-fish on the banks within or vicinity of the FGBNMS, while anglers in Area 26 were fishing closer to shore and away from the sanctuary reef-system. Given the distance (204–222 km from shore) to the FGBNMS, interviews with anglers indicated that many anglers usually anchored their vessels and targeted bottom reef-fish at the sanctuary instead of trolling for coastal pelagic species; however, anglers did state they sometimes trolled lures and baits to and from the FGBNMS to target coastal (e.g., dolphinfish and wahoo) and highly (tuna) migratory species.

Similar to other areas of the Gulf of Mexico, the largest percentage of fish landed by recreational anglers occurred from late-spring to late-summer, which was the most popular season to fish offshore since the weather was better [31]. The findings also showed there were more red snapper, vermillion snapper, and gray triggerfish landed in May, which was not surprising since it is common local knowledge that snappers usually spawn in aggregations during early summer (May and June) in the Gulf of Mexico [32]. In general, both commercial fishermen and recreational anglers plan fishing trips according to the species, month, geographical location, and local environmental conditions, such as water temperature or current. With time, anglers usually develop gear and techniques that make them proficient at catching sought after species, especially for those species that aggregate during spawning [33]; anglers targeting spawning aggregation sites can significantly impact populations, aggregation behavior, courtship, and even fertilization success.

The annual number of vermilion snapper and gray triggerfish landed was stable during 1986 through 2006; however, as with past assessments, red snapper catch declined over time. The red snapper resource is among the most economically valuable, but it has been overexploited for many years causing catches to decline in both the commercial and recreational sectors [34]. Today, the red snapper stock in the Gulf of Mexico is classified as overfished and overfishing (i.e., fishing mortality is above the threshold) is occurring [35]. Despite the findings of this present study suggesting that catches of gray triggerfish was stable during 1986 through 2006, NMFS [35] recently classified the stock as overfished and overfishing (i.e., fishing mortality is above the threshold) is occurring. However, these findings agreed with the recent assessment for vermilion snapper, which indicated the stock was stable and not approaching an overfished condition [35].

Understanding the length or weight-frequency distribution of an exploited stock is an important factor for determining how a population stock is being affected by anthropogenic activities, such as commercial and recreational fishing; these types of data evaluations are often used in population assessment models and to impose or develop size restrictions [36, 37]. In general, the results from this present study agreed with previous examinations of weight-distribution trends for red snapper, vermilion snapper, and gray triggerfish. The findings for this study showed that the estimated annual mean weight of gray triggerfish was stable over the 21-year time period, but the estimated mean weight of red and vermilion snapper had declined. Although these findings also supported the trend observed for red snapper catch (decline in numbers over time), they did not support vermilion snapper and gray triggerfish catch observations, which indicated that recreational anglers have landed less numbers of fish over time, but heavier fish. This observation could be the result of anglers targeting larger fish or it could be from technological advancements (GPS and bottom depth instruments) that have improved overall catch efficiency. Given the distance and fuel cost associated with traveling to and from the Flower Garden Banks, there is an incentive for anglers to retain the largest or heaviest fish (anonymous, personal communication).

This study found that anglers aboard headboats landed heavier vermilion snapper than red snapper or gray triggerfish. Based on this observation, it is possible that anglers may prefer to retain vermilion snapper over the other primary fish in the future since they were larger and heavier; anglers typically retain the largest edible fish (personal observation). In the Gulf of Mexico, previous studies have also shown red snapper mean weights in the recreational fishery have declined over time. Hester [37] conducted an independent assessment of the red snapper stock in the South Atlantic and found that the average weight of red snapper in the recreational fishery had declined from 2.47 kg (5.44 lbs) in 1960 to 2.04 kg (4.5 lbs) in 1970. However, updated information showed that the average weight of a red snapper landed by anglers in the Gulf of Mexico has increased from 1.51 kg (3.32 lb) in 2007 to 2.29 kg (5.04 lb) in 2009 [31]. Interestingly, the study also demonstrated there was a noticeable decline in the average weight of red snapper landed from 2005 through 2007, which the NMFS speculated was due to recreational anglers shifting effort from federal to state waters where average lengths and weights of red snapper may be smaller [31].

Overall, NMFS [31] reported there was a 29 percent increase in the average weight of red snapper landed between 2007 and 2008, and a 17 percent increase between 2008 and 2009. Based on this new report, the agency is hopeful that the average weight of red snapper should continue to increase as the stock rebuilds and the number of older, larger fish in the population increases [31]. The decline in mean weight for vermilion snapper landed by headboat anglers also agreed with those reported by Manooch *et al*. [36] for some geographical areas of the southeast region. Manooch *et al*. [36] indicated the mean weight of vermilion snapper landed in North Carolina continued to decline until 1979, but remained stable from 1986 to 1996. Overall, the average weight declined between 1 and 1.4 kg (2–3 lb) from 1976 to 1982, and 0.45 kg (1 lb) from 1985 to 1996.

In South Carolina, a similar annual size pattern for vermilion snapper was reported, except that the mean weight of South Carolina fish increased from 1992 to 1996 [35]. Historical changes in the vermillion snapper stock structure between the eastern and western Gulf of Mexico was reported by Hood and Johnson [38]. Based on their findings, Hood and Johnson [38] speculated that the decrease in average size of vermilion snapper in the commercial fishery was due to an increase in fishing pressure, which likely also explains the findings from this present study. Lastly, finding for gray triggerfish also agreed with a recent stock assessment that showed the weigh-frequency distribution, and mean weight for gray triggerfish has remained stable through time [39]. The study also showed that the weight-frequency distribution was slightly skewed toward small fish, but the percentage of larger fish landed had increased in the last few years, which could be due to new fishing restrictions [39].

Fishing Effort

Estimating the overall recreational fishing effort associated with the FGBNMS was challenging given the type of information that was available. Nonetheless, the findings of this study showed various trends in overall monthly and annual recreational landings that probably explained the distribution of fishing effort for the FGBNMS, but it is feasible that these findings did not accurately reflect the magnitude of the recreational fishing effort and total landings specifically for the sanctuary for various reasons. For example, unlike commercial fisheries data, state and federal fishery collection programs were not designed to be used for extracting fine-scale spatial resolution information for areas, such as the FGBNMS. Also, interviews with anglers revealed that the FGBNMS was only accessible to recreational anglers with larger fishing vessels (> 9.1 meters [30 ft]); these data were not stratified by vessel size since this type of information was not included under the interview process. Despite these data limitations, some fishing effort information was able to be extracted from the charter vessel and creel survey datasets.

Interviews with anglers pointed out that recreational fishing opportunities at the FGBNMS was weather dependent (summer fishing effort), which was supported by the data; the data showed that around 88 percent of the fishing effort (number of fishing trips and anglers) was in late-spring through summer. Based on angler interviews, the FGBNMS is a fishing "hot spot" for some anglers; however, the sanctuary is probably more important to anglers who fish off charter vessels than private vessels because of its remote location. Again, it is difficult to guess the magnitude (e.g., number of fishing trips per year) of fishing effort at the sanctuary, but it is highly probable that the FGBNMS does not receive as much fishing pressure as some of the other areas in the Gulf of Mexico because of the distance from the shore. In fact, NMFS headboat data showed that only a few vessels (19.7% or n = 16) reported catch within the vicinity (Areas 25 and 26) of the FGBNMS during 1986 through 2006. Information from charter vessel captains indicated that the number of fishing trips per year was around 94.3 (0−8 fishing trips per month). In general, there was no other available information about the fishing effort specifically for the FGBNMS, but information did indicate that recreational fishing effort for the primary species landed (red snapper, vermillion snapper, and gray triggerfish) continues to increase each year throughout the Gulf of Mexico. This is problematic for struggling stocks, such as red snapper and gray triggerfish stocks given the ongoing directed commercial fishery effort and the bycatch issues associated with the shrimp fishery [34, 39, 40].

Because of the current regulatory scheme, management of the recreational fishing effort focuses only on controlling the landings of individual anglers and not the number of individuals that are allowed to fish [29]. Coleman *et al*. [29] stated that this management approach has caused an increase in bycatch (i.e., discards) and fishing mortality. Historically, fishing effort in the Gulf of Mexico reef fishery was controlled by a permit system for commercial fisheries, and an allocated quota system for commercial and recreational sectors. Today, commercial red snapper fishing effort is managed through an Individual Fishing Quota (IFQ) program and quota system, which began in 2007 to reduce overcapacity and mitigate derby fishing conditions. The IFQ has reduced some fishing effort (number of participants) in the commercial fishery, but this program does not apply to recreational fisheries; red snapper recreational landings generally exceed commercial landings [29]. Despite these efforts, red snapper and other important recreational reef fish are classified as overfished [35]. Because of the present regulatory situation (i.e., lack of methods to regulate recreational fisheries), one of the only ways to control recreational fishing effort in the United States at environmentally sensitive areas is to establish MPAs and implement regulations that prohibit all fishing activities or some types of fishing methods (e.g., bottom fishing).

Catch Trends

Monthly catch rates (number of fish taken per angler) by anglers aboard charter vessels varied by month with the lowest catch rates occurring from April to October, and the highest catch rates occurred in November (2006), March (2007), and February (2008). Monthly catch rates ranged from 0 in January and December to 14.27 fish per angler in February (2007) with mean of 4.42 fish per angler. This observation was interesting because it was the opposite pattern observed for fishing effort, which indicated that as the fishing pressure increased (summer months) the number of fish landed decreased. It is difficult to explain why offshore fishing improved during the winter, but one explanation could be that targeted fish (red snapper, vermilion snapper, and triggerfish) either aggregated at particular sites where anglers could concentrate fishing effort, or there was less prey available during the winter so fish were more apt to take an angler's bait. Another explanation could be that perhaps only the skilled or experienced anglers target offshore species during the winter.

This present study generated catch rates for specific areas using data obtained from anglers aboard private and charter vessels based out of Texas. In general, the geographical area with the highest catch rates for reef fish and coastal pelagic species were from the southernmost (Laguna Madre) and northernmost (Galveston) origination ports, respectively. These findings suggest that anglers in the northernmost areas (closest to the FGBNMS) may not be making long journey fishing trips to the sanctuary to target reef fish, but instead are trolling for coastal pelagic species, such as King mackerel along coastal beaches or nearshore structures. It is difficult to speculate how these findings should be interpreted given no other previous studies have evaluated recreational fisheries associated with the FGBNMS. As such, further investigation may be warranted.

Specific annual cumulative catch rates were not generated or standardized in this present study, but they were inferred from the total number of fish landed over time, which showed that vermilion snapper and triggerfish catches were stable and red snapper catch had declined. These findings agree with recent stock assessment models for red snapper, vermilion snapper, and gray triggerfish which showed that red snapper and gray triggerfish catch rates have declined over time and met the overfished criteria [39, 40]. Based on projections of the current fishing mortality rates for red snapper and triggerfish, the exploitation rate continues to increase at a level that is unsustainable to the population [39, 40]. Nevertheless, the red snapper stock assessment pointed out the stock would recover by the year 2032 if there was a 40−50 percent reduction in bycatch of the shrimp fishery, and the total allowable catch was reduced by 907,185 to 1,360,777 kg (2 to 3 million lbs) per year. Similarly, Valle *et al*. [39] concluded that the gray triggerfish fish mortality rate was also unsustainable for the estimated population size.

Conclusions and Management Implications

One method that has been used for conserving biodiversity in the marine environment is the establishment of MPAs [41]. Depending on the political and social situation, sanctuary resource managers can either designate restrictive or multiple-use MPAs. One reason to employ a multiple-use MPA is that the conservation "precautionary" approach can still be applied without eliminating all of the public's right to use the area. This type of management approach has been applied successfully at the Florida Keys NMS [2, 15]. Before establishing a MPA or making any modifications to any existing MPA regulations, Meester *et al*. [2] recommended that policymakers should consider shape and compactness (i.e., size) along with designing specific goals (e.g., protecting X% of the stock biomass, or minimal fleet displacement, X% coral reef area) for measuring success. Another important factor that the researchers highlighted was having information that described the spatial and temporal dynamics of fisheries [16, 19].

Resource managers at the FGBNMS will have to make difficult and controversial decisions whether to permanently or temporarily close the entire sanctuary to all fishing activities or to authorize some fishing activity or specific fishing techniques (e.g., trolling). Regardless of the final decision, the establishment and expansion of MPAs have generally benefited fisheries in terms of size and biomass over the long-term [42, 43]. Still, it is important to document fisheries before and after a MPA is established or new restrictions are imposed so managers can gauge effectiveness. For these reasons, the FGBNMS is considering establishing a research area where these hypotheses can be tested.

The FGBNMS is one of the most important natural resources in the Gulf of Mexico. Because of its biological uniqueness (topography and oceanic conditions), the FGBNMS provides habitat for many important commercial and recreational species [44]. Accurate estimates of recreational fishing effort explicitly for the FGBNMS was unable to be generated from this study because of the lack of spatial data, but it is probable that any expansion of the FGBNMS or restrictions on recreational fishing activities, will reduce some recreational fishing effort by eliminating available productive fishing grounds. Lynch [16] asked the dialectic question "Why close areas to fishing that are not heavily or are only lightly fished?" In another study, Lynch [19] later explained that one reason fishery policymakers sometimes prohibit recreational fishing in areas that receive low fishing pressure is to meet conservation goals without causing much political controversy, which the author termed "the worthless sea hypothesis." Given that most fishing "hot spots" often become discovered with time, another reason policymakers sometimes choose to prohibit fishing in areas that have low fishing pressure is to protect resources that are not currently being overexploited [19]. Sanctuary manages need to consider all of their options during the decision making process and establish objectives for the sanctuary that can be quantified and scientifically tested. However, if fishing effort is being concentrated onto breeding aggregations for rapidly declining stocks of fish, such as red and vermilion snapper, then these sites should be identified and an adequate proportion closely considered for reservation.

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