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Recreational sector is the dominant source of fishing mortality for oceanic fishes in the Southeast United States Atlantic Ocean

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Abstract

Recreational fishing is increasingly recognised as an important source of mortality for marine fish populations. In the United States, estimates of marine recreational catch and effort were recently revised for the time period 1981 and beyond, and for many species, the revised estimates were substantially higher than the original values. Here, the proportion of total landings that came from the recreational sector in the Southeast US Atlantic was quantified. The proportions for 22 oceanic species and for all species combined were computed, using a full time series of landings (1981–2016) and a more recent time series (1999–2016). For the full and recent time series, landings of most species (15/22 and 17/22, respectively) were dominated by the recreational sector. For all species combined, 71% of landings in the full time series were from the recreational sector, and 76% in the recent time series. Trend analysis indicated that most species had a stable or increasing proportion of landings from the recreational sector. In addition, stock assessments were conducted on four species, and the catch revisions increased the estimated scale of abundance and, in some cases, affected stock or fishery status. This work underscores the importance of recreational fishing for marine resource management.

KEYWORDS

fishing effort, marine fish populations, recreational fishing, stock assessment

1 | INTRODUCTION

The effects of exploitation on marine fish populations are well documented (Hilborn et al., 2003; Jackson et al., 2001). Historically, commercial fishing has been considered the dominant source of exploitation on marine fishes. Increasingly, however, recreational fishing is also recognised as an important source of mortality in many systems (Brownscombe et al., 2019; Cooke & Cowx, 2004, 2006; Lewin, Arlinghaus & Mehner, 2006), including fisheries in Australia (McPhee, Leadbitter & Skilleter, 2002), Canada (Post et al., 2002), Europe (Hyder et al., 2018; Pawson, Glenn & Padda, 2008), and the United States (Coleman, Figueira, Ueland & Crowder, 2004; Ihde, Wilber, Loewensteiner, Secor & Miller, 2011; Schroeder & Love, 2002).

Coleman et al. (2004) investigated recreational and commercial landings in the United States (US) using a 22-year time series (1981–2002). After excluding large industrial fisheries, they found that 10% of landings nationwide were due to the recreational sector. However, that percentage varied regionally, and was highest in the Southeast US. Among species of concern (i.e. listed as overfished or experiencing overfishing), Coleman et al. (2004) found that 64% of landings in the US Gulf of Mexico and 38% in the Southeast US Atlantic were due to the recreational sector.

In the Southeast US Atlantic, federally managed fish stocks fall under the purview of the South Atlantic Fishery Management Council (SAFMC), whose jurisdiction includes coastal waters off North Carolina, South Carolina, Georgia and the east coast of Florida. Hook gear is the primary fishing method used by both recreational and commercial sectors in this region. To manage fishing effort on each species or group of species, the SAFMC uses a combination of input controls, such as size limits and bag limits, and output controls, such as allowable biological catch (ABC). The annual ABC is divided between the recreational and commercial sectors, such that each has its own total allowable catch (TAC), and the fishery is closed for the remainder of the year if the TAC is met or projected to be met. Typically, allocations to each sector are based on recent proportions of total landings.

For marine fish stocks in the United States, recreational catch and effort has been monitored since 1981 by the Marine Recreational Information Program (MRIP). In 2018, MRIP revised the estimation of recreational effort, transitioning from a telephone-based survey to a mail-based survey to correct for known sampling biases that were due to under-coverage, non-response and measurement error (National Academies of Sciences, Engineering, and Medicine 2017; National Research Council 2006). This revision resulted in approximately a two- to sixfold increase in estimates of recreational catch and effort, and the entire time series was recalibrated. One implication of this revision is that the data available to Coleman et al. (2004), as well as for previous stock assessments, substantially under-represented the importance of the recreational sector. A second implication is that the previous proportions used for setting TACs potentially underestimated the ratio of recreational to commercial landings.

In this paper, the role of marine recreational fishing in the Southeast US Atlantic was revisited using revised estimates from the new MRIP survey methodology. The objectives are to present the proportion of total landings attributable to the recreational sector for a suite of federally managed species, and to quantify temporal trends in those proportions. In addition, the effects of revised recreational estimates on the results of stock assessments are examined, focusing on four recent assessments as case studies. Using the revised estimates, the need for a shift in how the role of recreational fisheries in the Southeast US Atlantic, from being important but secondary to the commercial sector (Coleman et al., 2004), to being the dominant source of fishing mortality is demonstrated, with implications for sector allocations and for the perceived status of stock and fishery explored.

2 | METHODS

2.1 | Fishing effort and landings

Recreational and commercial landings data were acquired for a suite of stocks that are managed by the SAFMC under three different Fishery Management Plans (FMPs): the Coastal Migratory FMP (mackerels and cobia), the Dolphin/Wahoo FMP and the Snapper Grouper FMP. The Snapper Grouper FMP contains 55 species, many of which are rare and do not have reliable estimates of landings; thus only those species from this FMP for which stock assessments had been conducted or that were on the schedule for future assessment were chosen. This resulted in a list of 22 species for the analysis that collectively represent the preponderance of total finfish landings in the region of study (Table 1).

For each species, effort and landings information (1981–2016) was queried from databases made publically available by the US National Marine Fisheries Service (NMFS). In the Southeast US, the recreational sector comprises four primary fleets (or, modes): shore, charter boats (typically ≤ 6 passengers), private boats and headboats (typically > 6 passengers) (Figueira & Coleman, 2010). Information on landings by species and total fishing effort (all species) for the first three fleets was obtained through the NMFS Marine Recreational Information Program (MRIP, https://www.fisheries.noaa.gov/topic/recreational-fishing-data/). The headboat fleet is sampled separately by the NMFS Southeast Region Headboat Survey (SRHS; Fitzpatrick et al., 2017), and estimates of headboat landings by species were obtained from the NMFS Southeast Fisheries Science Center. Landings by species from the commercial sector were obtained from the NMFS Office of Science and Technology (https://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/). For direct comparison across sectors, all landings estimates were queried in units of weight (pounds).

Three species in the analysis were not identified to species in the commercial database, and in those cases, an aggregate category for commercial landings was used. Grey triggerfish was represented by a “triggerfishes” category; king mackerel by a “king + cero” category; and white grunt by a “grunts” category. For each, the aggregate landings were believed to be predominantly from the target species (D. Gloeckner, NMFS, pers. comm.), but because they contain some mixture of congeners, commercial landings of these three species are likely to be overestimated.

For each species and for all species combined, the proportion of total landings from the recreational sector was computed using data from the full time series (1981–2016) and from the latter half of the time series (1999–2016). The intent was to evaluate proportions in the long term (full time series), as well as those from more recent years (latter half) that may be of greater interest from a management perspective. For both time periods, the median proportion of total landings that were from the recreational sector across years were used as a robust estimate of the central tendency. Several species were missing from at least 1 year of recreational or commercial estimates, almost exclusively from the first half of the time series. If estimates from both sectors were not available for a given year, that year was omitted from computation of the median proportions. To evaluate trends in proportions within the same time periods, the slope estimated from beta regression was used, which is appropriate for analysis when the response variable assumes values over the interval (0,1). Analyses were performed in R (Cribari-Neto & Zeileis, 2010; R Core Team, 2017).

2.2 | Stock assessments

Time series of landings are crucial input for most stock assessments. Given the newly revised estimates of recreational landings in the

TABLE 1 Species from the Southeast US Atlantic included in this study

Common name	Scientific name	Recreational	Commercial	Sum	Rank
Black Grouper	*Mycteroperca bonaci*	136	20	156	22
Black Sea Bass	*Centropristis striata*	1,266	852	2,118	4
Blueline Tilefish	*Caulolatilus microps*	28	139	167	21
Cobia	*Rachycentron canadum*	1,382	99	1,481	6
Dolphin	*Coryphaena hippurus*	10,377	512	10,889	1
Gag	*Mycteroperca microlepis*	627	598	1,225	9
Golden Tilefish	*Lopholatilus chamaeleonticeps*	16	478	494	15
Grey Triggerfish	*Balistes capriscus*	407	249	656	11
Greater Amberjack	*Seriola dumerili*	1,300	486	1,786	5
Hogfish	*Lachnolaimus maximus*	140	29	169	20
King Mackerel	*Scomberomorus cavalla*	6,796	3,149	9,945	2
Mutton Snapper	*Lutjanus analis*	524	57	581	12
Red Grouper	*Epinephelus morio*	211	150	361	17
Red Porgy	*Pagrus pagrus*	159	165	324	18
Red Snapper	*Lutjanus campechanus*	406	153	559	14
Scamp	*Mycteroperca phenax*	105	278	383	16
Snowy Grouper	*Hyporthodus niveatus*	25	245	270	19
Spanish Mackerel	*Scomberomorus maculatus*	3,324	3,456	6,780	3
Vermilion Snapper	*Rhomboplites aurorubens*	579	902	1,481	7
Wahoo	*Acanthocybium solandri*	1,210	46	1,256	8
White Grunt	*Haemulon plumierii*	558	154	712	10
Yellowtail Snapper	*Ocyurus chrysurus*	464	107	571	13

Note: Values shown are medians of annual landings estimates (1000 lb) from the time period 1981–2016. Ranks are based on the sums.

Southeast US Atlantic, the importance of these revisions was examined for stock assessment results. These analyses focused on four stocks: black sea bass, blueline tilefish, red grouper and vermilion snapper. These stocks were selected because their assessments had recently been completed, they span a range of results in terms of stock status, and because they differ in their importance to the recreational sector.

The assessment methods are detailed elsewhere (SEDAR-50, 2017; SEDAR-53, 2017; SEDAR-55, 2018; SEDAR-56, 2018), so they are only summarised here. The assessment of blueline tilefish applied a surplus-production model (Prager, 1994); the assessments of black sea bass, red grouper and vermilion snapper applied an integrated, age-structured model (Williams & Shertzer, 2015). For each species, time series of recreational and commercial landings, as well as discards, were included in the assessment as data input. These inputs were the same as those used in the original assessments, but revised recreational time series were additionally constructed, adjusting the previous values by MRIP's annual calibration factors. To evaluate the importance of the recreational sector on assessment results, each assessment model was run twice, first using the previous estimates of recreational landings and discards, and then using the revised estimates. All other data inputs and aspects of model configuration remained the same.

Three primary stock assessment outputs were used to quantify the effect of recreational landings and discards on model results: estimated time series of biomass, stock status and fishery status. Stock status was computed as spawning biomass (S) relative to the minimum stock size threshold (MSST), and fishery status was computed as fishing mortality rate (F) relative to that at maximum sustainable yield (F_{MSY}). Time series of S and F, as well as thresholds MSST and F_{MSY}, were computed for each assessment run, such that revised recreational values could result in changes to both the numerator and denominator of status indicators. By convention in US fishery management, spawning biomass lower than MSST indicates that the stock is overfished, and fishing mortality rate above F_{MSY} indicates that overfishing is occurring.

3 | RESULTS

3.1 | Fishing effort and landings

The recent adjustments made by MRIP increased the estimates of recreational fishing effort in the Southeast US Atlantic. Across the full time period, effort by the private boat fleet was adjusted upward by a mean (minimum, maximum) factor of 2.24 (1.74, 3.00), effort by the shore mode was adjusted upward by a mean factor of 5.58 (4.35, 7.70), and effort by the charter mode was unaffected

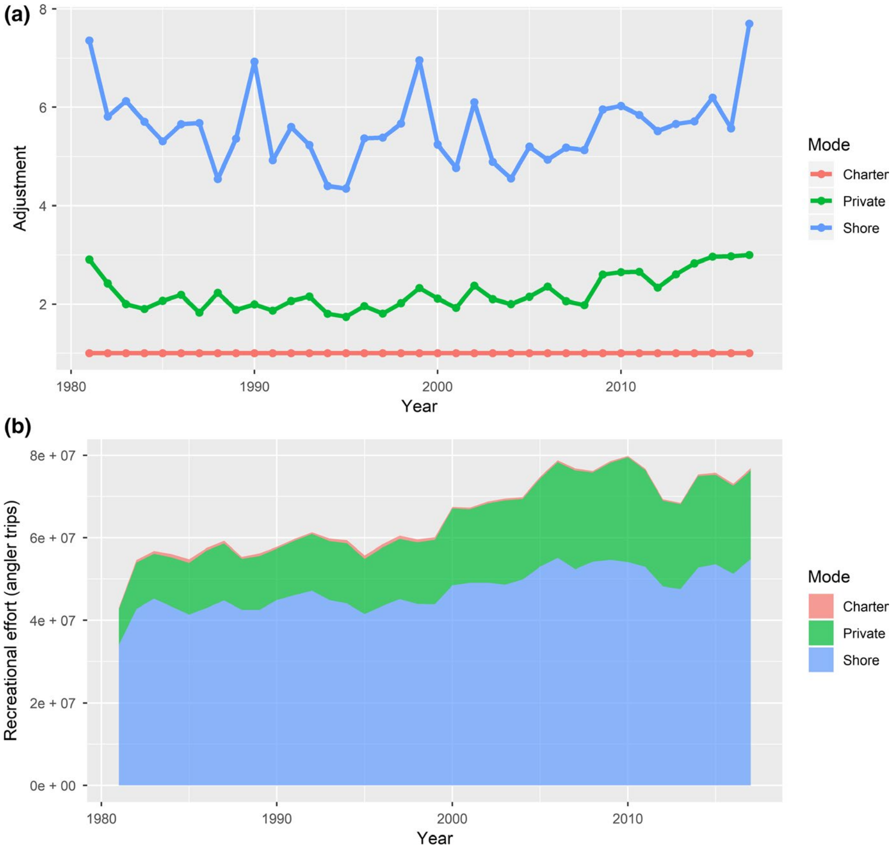

FIGURE 1 Proportional adjustment (a) in recreational effort resulting from the revised survey methodology and total recreational effort (b), apportioned by charter boats, private boats and shore modes in the Southeast US Atlantic, as estimated by the Marine Recreational Information Program [Colour figure can be viewed at wileyonlinelibrary.com]

(Figure 1a). These adjustments resulted in total recreational effort that ranged approximately between 60,000,000 and 80,000,000 angler trips per year, with a generally increasing trend (Figure 1b). As most species in the analysis are caught primarily offshore, the data analysed were primarily affected by adjustments to the private boat fleet.

Over the full time period, landings from the recreational sector exceed those of the commercial sector for the majority of species (15/22) (Figure 2). Over the second half of the time period, that majority was larger (17/22), adding Spanish mackerel and red porgy. Three of the species (blueline tilefish, golden tilefish and snowy grouper) caught predominately by the commercial sector are considered to be deep-water animals, although the proportion harvested by the recreational sector increased for these three species as well.

For all species combined, 71% of landings came from the recreational sector during the full time period, and 76% during the second half of the time series (Figure 2). These percentages were larger than those based on the previous telephone-based methodology (60% for the full time series and 64% for the second half). For species in the Coastal Migratory FMP (cobia, king mackerel, and Spanish mackerel), 63% were from recreational fisheries during the full time period and 67% during more recent years, and for those in the Dolphin/Wahoo FMP (dolphin and wahoo), 96% were from recreational fisheries during both time periods. For species in the Snapper Grouper FMP, not including the three deep-water species (blueline tilefish, golden tilefish and snowy grouper), 65% of landings came from the recreational sector during the full time period, and 68% during the more recent years. For the deep-water species, those percentages were 11% and 21%, respectively.

Most species (21/22) showed an increasing or stable trend over the full time period in the proportion of total landings contributed by the recreational sector (Figure 3a). Dolphin was the only species that showed a decreasing trend over the full time period (Figure 3a), although its landings remained heavily dominated by the recreational sector (~96%) in the more recent period (Figure 2). Over the second half of the time period, most species (19/22) still showed an increasing or stable trend (Figure 3b), with the three exceptions being dolphin, gag and Spanish mackerel. In all three cases, the majority of landings were again from the recreational sector (Figure 2). For all species combined, the general trends were towards an increasing proportion of landings from the recreational sector over the full time period, but a stable proportion over the second half of the time period (Figures 3,4). The most substantial increase in proportion occurred over the last 5 years, which was driven by both an increase in recreational landings and a simultaneous decrease in commercial landings (Figure 4).

3.2 | Stock assessments

For stock assessments, the primary influence of increased recreational removals was larger estimated standing biomass (Figure 5). This was particularly true for black sea bass and red grouper, the two species with the highest proportion of total landings attributable to the recreational sector. For blueline tilefish, a species with landings dominated by the commercial sector, the estimated time

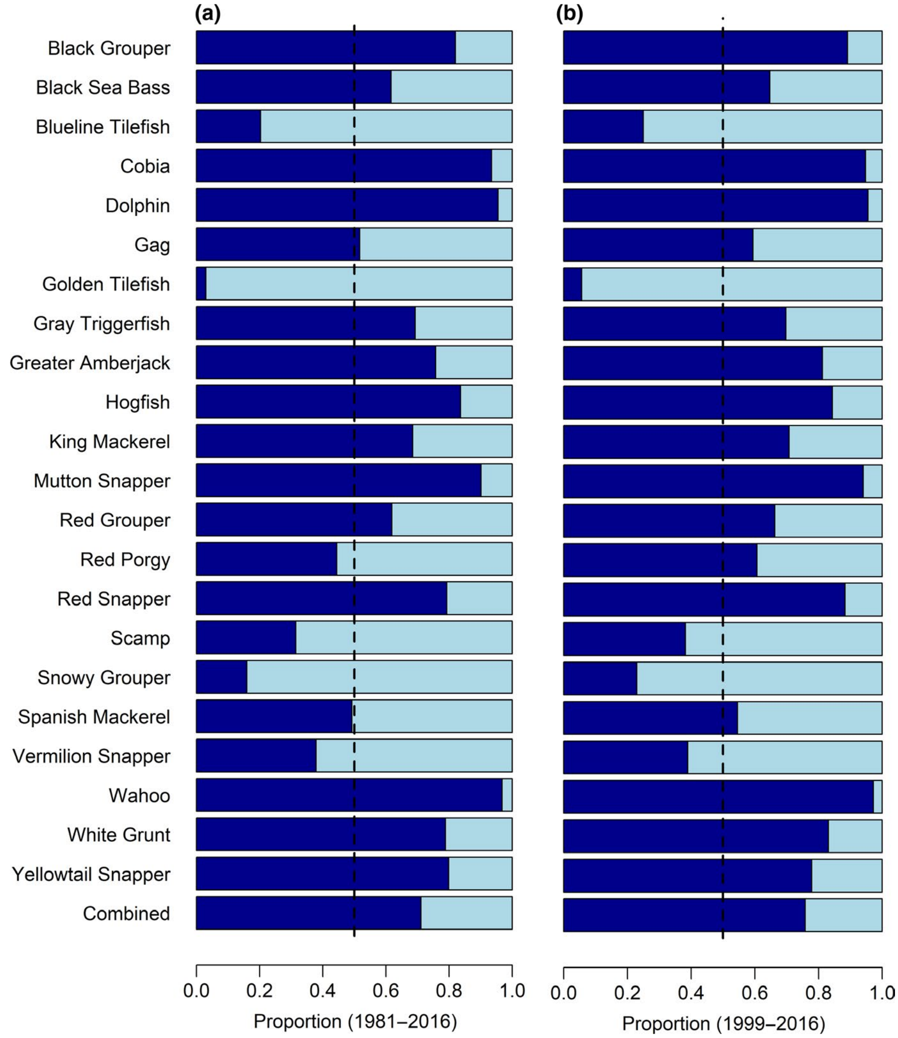

FIGURE 2 Proportion of harvest landed by the recreational sector (dark blue) for the full time series ([a], 1981–2016) and for the second half of the time series ([b], 1999–2016). Values shown are medians of the annual proportions, and vertical dashed line indicates 0.5 [Colour figure can be viewed at wileyonlinelibrary.com]

series of standing biomass was generally similar across the two assessments (Figure 5). However, the estimates differed substantially in the terminal 2 years, consistent with the trend towards increased recreational significance for this stock (Figure 3).

Estimated time series of spawning biomass relative to the management threshold was similar between the revised and unrevised assessments (Figure 5). This result occurred because the threshold increased along with estimates of spawning biomass, such that the ratio of stock status remained relatively consistent. Nonetheless, for all four species, estimates of stock status with higher recreational landings were lower in the terminal years of the assessment, the time period typically of greatest interest to managers. For one of the four species, black sea bass, the qualitative result in the terminal year changed to an overfished status, in which spawning biomass was lower than its threshold.

Similarly, estimated time series of fishing rate relative to its management threshold was similar between the revised and unrevised assessments (Figure 5). Across all four species, the largest differences in estimated fishery status were in the terminal years. For two of the stocks, black sea bass and vermilion snapper, the qualitative result in the terminal year changed to an overfishing status, in which *F* was higher than its threshold. The fishing rate on blueline tilefish was found to be much closer to its threshold with the increased recreational removals, and that of red grouper was found to be substantially higher than its threshold.

4 | DISCUSSION

Estimates of marine recreational catch and effort in the United States were recently revised to correct for known sampling biases, benefitting from comprehensive peer review of previous and current estimation methodologies (National Research Council 2006; National Academies of Sciences, Engineering, and Medicine 2017; https://www.fisheries.noaa.gov/event/fishing-effort-survey-calibration-model-peer-review). In this study, the recreational sector is shown to be the dominant source of fishing mortality in the Southeast US Atlantic. Landings from the recreational sector exceeded those from the commercial sector for 17 of the 22 species examined in the recent time period (1999–2016). Of the other five species, three (blueline tilefish, golden tilefish and snowy grouper) are considered deep-water species that are less accessible to the recreational

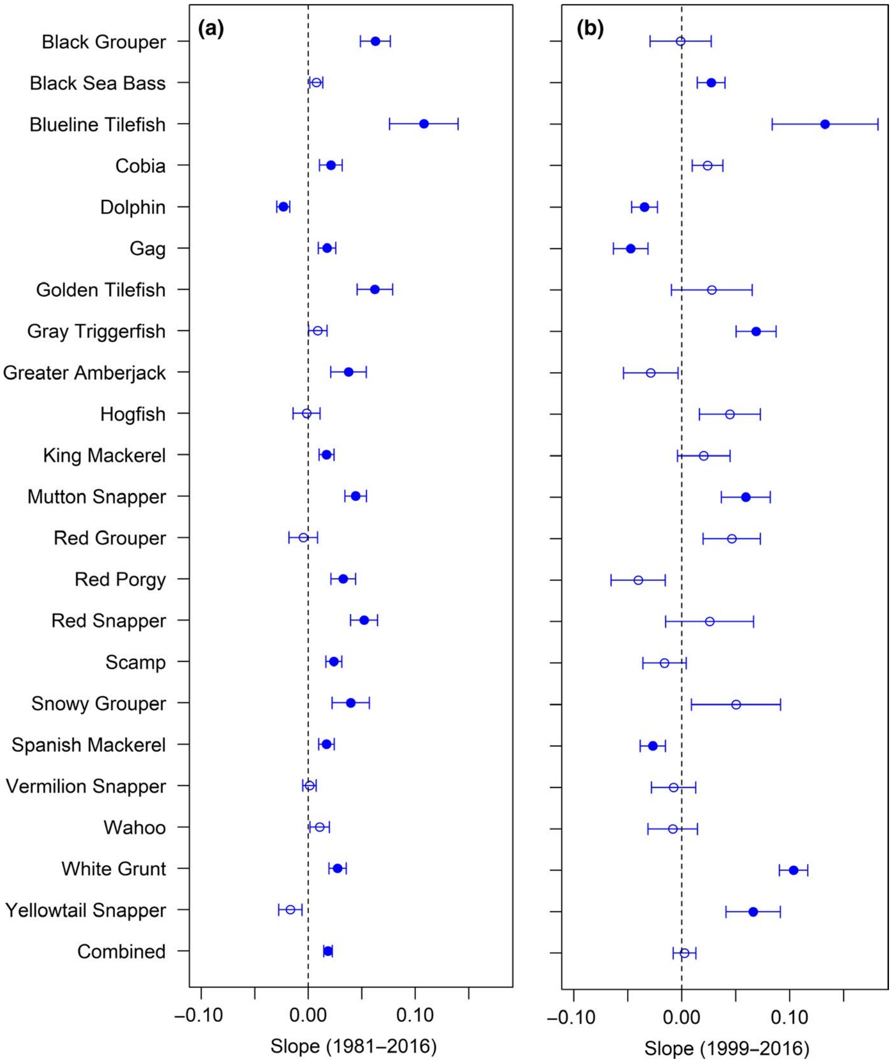

FIGURE 3 Slopes (±1 *SE*) estimated through beta regression of the proportion of total landings contributed by the recreational sector, using either (a) the full time series (1981–2016) or (b) the second half of the time series (1999–2016). Filled circles indicate an estimate with *p*-value < 0.05; open circles indicate otherwise. Vertical dashed line indicates 0.0 [Colour figure can be viewed at wileyonlinelibrary.com]

sector, and two (scamp, vermilion snapper) are caught by the recreational sector in percentages of total landings approaching 40%. For all species combined, 76% of landings were attributable to the recreational sector. This result is consistent with findings that the Southeast US Atlantic contains the two states (North Carolina and Florida) with the highest recreational effort in the nation (National Marine Fisheries Service 2018).

Most species (19/22) showed a stable or increasing trend in the proportion of landings from the recreational sector, as did all species combined. These trends, along with the overall increase in magnitude of the revised recreational catch estimates, affected the stock assessment results in two general ways. First and most notable, the estimated scale of total abundance was larger, to account for the higher catch. Second, although estimates of stock and fishery status were quite similar in most years, the largest differences occurred at the end of the time series, with lower stock sizes and higher fishing rates relative to their thresholds. In most cases, the terminal estimates of status were quantitatively different, but qualitatively unchanged. However, in some cases, terminal estimates were qualitatively reversed, suggesting that the stock was overfished or that overfishing was occurring. Under US fishery regulations, these reversals have management implications, indicating that a rebuilding plan is necessary or that the fishing rate needs to be reduced to address overfishing. Until more species are assessed using the revised recreational estimates, no attempt is made here to infer general effects on stock assessment results.

Although the results demonstrated dominance of the recreational sector, the analyses probably still undervalue recreational importance for three reasons. First, for three species (grey triggerfish, king mackerel and white grunt), estimates of commercial landings were not identified to species, but rather were derived from aggregates. Thus, for these three species, commercial landings were likely overestimated, and the proportion recreational catch underestimated. Second, the landings estimates analysed were in weight, which was necessary because commercial estimates were not available in numbers of fish. For many species in this region, the recreational sector selects younger, smaller fish than the commercial sector. This implies that fish caught by the recreational sector tend to have a smaller average weight, and thus if the analyses were repeated using numbers rather than weight, the proportion of recreational catches would be even larger. This distinction is important, given that mortality acts directly on individual fish, not their weight.

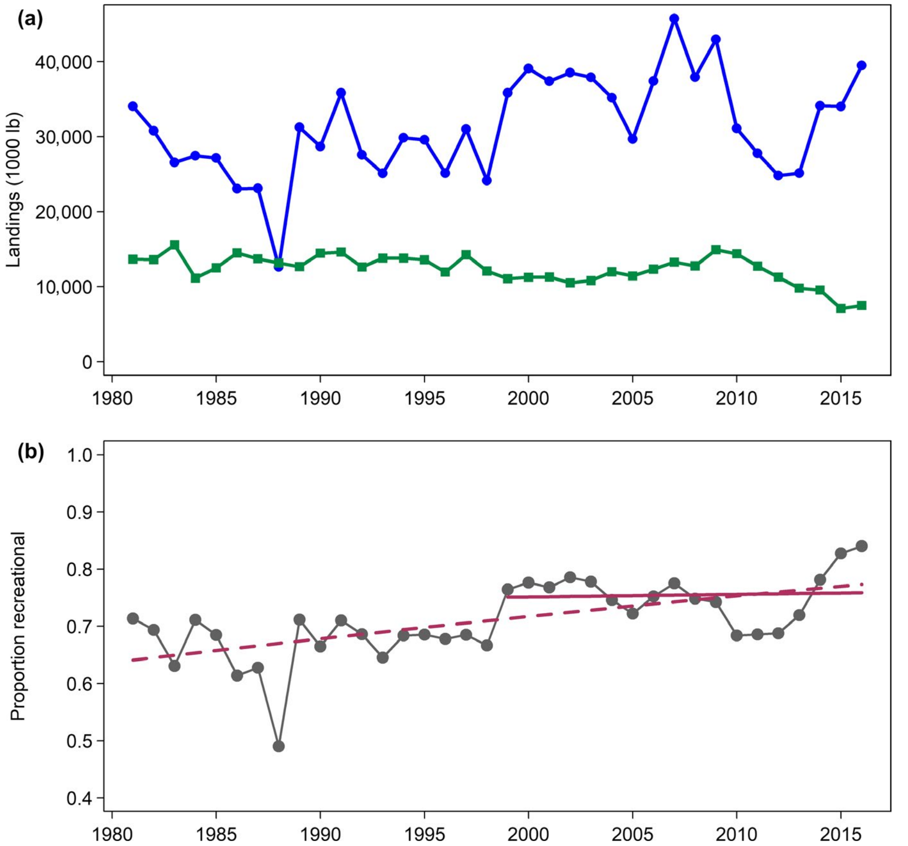

FIGURE 4 Total landings for all species combined. (a) Landings taken by the recreational sector (solid blue, filled circles) and by the commercial sector (solid green, filled squares). (b) Proportion of total landings taken by the recreational sector. Lines represent expected values estimated through beta regression using either the full time series (dashed maroon, 1981–2016) or the second half of the time series (solid maroon, 1999–2016) [Colour figure can be viewed at wileyonlinelibrary.com]

Third, the analysis of sector proportions did not account for discard mortality, because estimates of discards by the commercial sector were not available, nor were estimates of sector-specific discard mortality rates for each species. Multispecies fisheries are typical of this region, such that discarding is common even when regulations prohibit harvest. However, the commercial sector is believed to be more skilful at targeting individual species and, conversely, avoiding species when prohibited. Thus, an analysis that accounted for discards would likely shift proportions of total mortality towards the recreational sector. This trend was observed in the stock assessment examples that did include discard mortality in addition to landings.

Several factors contribute to the higher proportions of recreational catch in the Southeast US Atlantic waters. Since 2011, stocks in this region have been managed under sector-specific TACs (quotas), and the commercial sector is more closely monitored in-season, which reduces the likelihood of exceeding its TACs. In addition, recent declines in commercial landings have occurred along with gentrification of waterfronts. Conversely, the recreational sector has been disproportionately affected by a growing human population on the coast, increases in discretionary income and lack of effort controls (open access fishery). Fishing power has also increased in the recreational sector. Navigation systems have become more affordable and more precise, and they are now standard equipment for recreational fishers, such that anglers can pinpoint productive fishing locations. In addition, the rise of social media and recreational fishing organisations allows anglers to share information, even in real time. In the Southeast US Atlantic, the effects of increased fishing power are concentrated into relatively small, isolated areas of hard-bottom habitat or artificial reefs, the locations of which have become well known and are circulated among recreational anglers.

The current open access recreational fishery has potential to push the limits of resource sustainability as fishing effort and power continue to rise (Cox & Walters, 2002; Thunberg & Milon, 2002). In a multispecies fishery, management measures such as bag limits, size limits and individual species closures may do little to reduce fishing mortality. A considerable proportion of released fish die as a result of hooking injury or barotrauma (Davis, 2002; Rudershausen, Buckel & Williams, 2007). Immediate release mortality can exceed 50% depending on the species and factors such as body size and depth (Pulver, 2017; Stephen & Harris, 2010), and delayed release mortality, which, although difficult to measure, can be substantial (Davis, 2002; Rudershausen et al., 2007). Even when a species is closed to harvest after its TAC has been reached, incidental catch can be prevalent when multispecies fishing effort continues (Harrington, Myers & Rosenberg, 2005). Such catch is unhindered by the predominately non-selective hook gear used in these fisheries, and it is difficult to monitor. In addition, TAC management systems can result in short fishing seasons, for example, the recreational sector is permitted to retain red snapper in the Southeast US Atlantic for only 2 weekends per year. To provide lasting biological or economic benefits, restricted access approaches to management, when feasible to implement, are expected to be generally more effective than open access approaches (Cox & Walters, 2002; Waters, 1991).

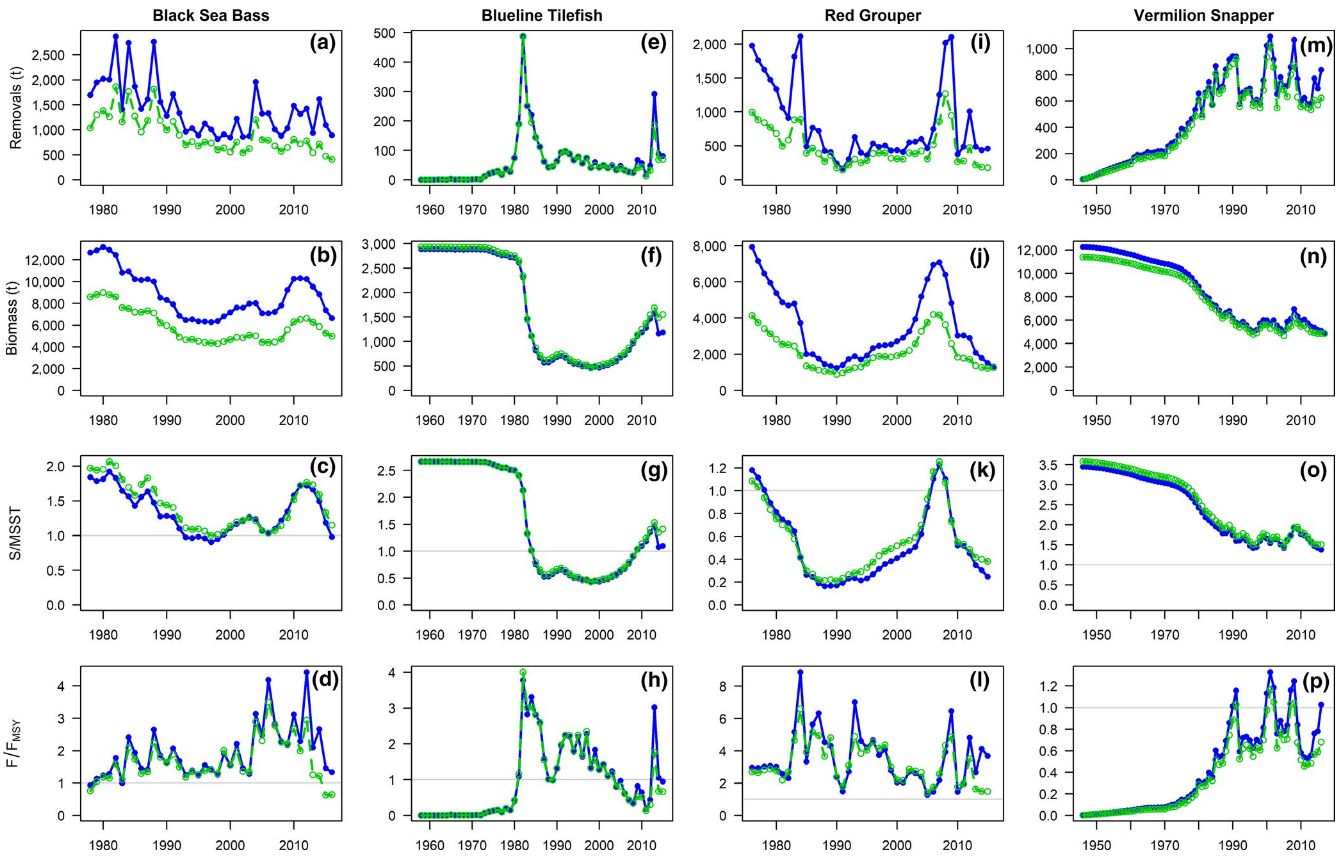

FIGURE 5 Stock assessment results with (blue line, filled circles) and without (green line, open circles) the adjustment to recreational landings and discards. Each column represents a different species, as indicated. Top row of panels shows estimated total removals (landings and dead discards from commercial and recreational sectors in units of tonnes, t), second row shows estimated biomass (t), third row shows spawning biomass (S) relative to its management threshold (MSST), and bottom row shows fishing mortality rate (F) relative to its threshold (F_{MSY}). Note, the ranges of *x*- and *y*-axes differ across panels [Colour figure can be viewed at wileyonlinelibrary.com]

Federal fishing regulations in the United States were initially developed with a focus on commercial fishing, prior to an understanding about the importance of marine recreational fishing. Such regulations often rely on the concept of maximum sustainable yield (MSY), with the implicit acknowledgement that commercial fishermen make rational decisions about expending effort based on maximising their profits. However, the values and motivations of recreational fishermen are different from those of their commercial counterparts. This raises the important question of what is the optimal approach for managing fisheries dominated by the recreational sector (Ihde et al., 2011). Rather than MSY, management strategies geared towards the recreational sector should address qualities of angler satisfaction as well as population sustainability (e.g. Miller et al., 2010).

Recreational fishing is increasingly recognised as an important source of mortality for marine fish populations in the Southeast US Atlantic and elsewhere around the world. As human populations continue to grow, particularly along coastal areas, it seems safe to forecast a concomitant rise in recreational fishing effort. To address this, fishery managers may need to restrict recreational access to the resource, if they hope to achieve their goals for harvest and sustainability. In addition, the development of management strategies that simultaneously account for the varied interests of different stakeholders, including commercial and recreational sectors, is encouraged.

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