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MANAGEMENT BRIEF

Using Common Age Units to Communicate the Relative Catch of Red Snapper in Recreational, Commercial, and Shrimp Fisheries in the Gulf of Mexico

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Abstract
The natural mortality rates and fecundity of Red Snapper *Lutjanus campechanus* vary substantially by age, so the age composition of catch is an important consideration when quantifying the relative effects of catch on the Red Snapper population across different fisheries. For example, the shrimp fishery catches many (but younger) Red Snapper, whereas directed commercial and recreational fisheries catch fewer (but older) individuals. We propose a simple approach for comparing catch across sectors. Fish that are caught can be scaled to a common age by multiplying or dividing by natural mortality rates so that the catch data can then be reported in "common age units." Applying this approach to the catch data from the 2018 Red Snapper stock assessment, we showed that the shrimp-trawl bycatch typically accounts for <10% of the relative catch, the commercial sectors account for ~32%, and the recreational sectors are responsible for ~59%. We believe that the effective management of Red Snapper requires regulation and oversight of each fishery that is proportional to its effect on the population. Given the apparently large influence of recreational fisheries on Red Snapper populations, recent management changes that delegate state-by-state control over important aspects of the recreational fishery (Amendment 50) should be accompanied by efforts to improve the understanding of this sector's interactions with Red Snapper.

The management of the Red Snapper *Lutjanus campechanus* stock in the Gulf of Mexico has been contentious. Large numbers of young Red Snapper are taken as bycatch in the shrimp fishery, and subadult and adult fish are taken in both recreational and commercial fisheries. The stock in the Gulf of Mexico has been in an overfished condition for the past three decades (Goodyear 1994; SEDAR 2018). For many years, the cornerstone of the Gulf of Mexico Fishery Management Council's (GMFMC) rebuilding plan for Red Snapper has been the reduction of Red Snapper bycatch in shrimp trawls. Because the numbers of Red Snapper that were taken in shrimp trawls greatly exceeded the numbers of adults that were harvested, reducing the bycatch mortality was believed to be adequate to recover the fishery while maintaining historical levels of adult harvest (for a review see Gallaway et al. 2017).

The use of bycatch reduction devices (BRDs) in shrimp trawls was mandated in 1998 and continues to be required. Additionally, a shrimp effort reduction target was established in Shrimp Amendment 14 (NMFS 2008). The Southeast Data Assessment and Review (SEDAR) 7 stock assessment also determined that bycatch levels in *both* the directed Red Snapper and shrimp fisheries were likely to jeopardize the success of the Red Snapper rebuilding plan that was implemented in 2005 (SEDAR 2005). The SEDAR 7 stock assessment indicated the need for a 74% reduction in the bycatch mortality of Red Snapper, with the levels of effort and mortality that were attributed to shrimp trawls during the 2001 to 2003 period used as a baseline. Essentially, the action was to cap shrimp fishing effort in statistical zones 10–21 in 10–30-fathom water depths, which is where most of the Red Snapper mortality had occurred. The threshold reduction was lowered to 67% in 2011, as is outlined in Amendment

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14. Finally, Amendment 14 noted that the target reduction goal should decrease to 60% by 2032. The Gulf shrimp fishery has not exceeded the effort caps from 2008 to the present. The number of boats in the shrimp fishery has been greatly reduced from historical levels. Furthermore, a shrimp permit moratorium was established in 2006 and has since been extended (NMFS 2016). This ensures that shrimp fishery participation, and thus effort, will remain at or near present levels.

The National Marine Fisheries Service ([NMFS] 2008) complemented Shrimp Amendment 14 by reducing the harvest for the directed fishery from 4.14 to 2.95 million kilograms (mkg) in 2007 and to 2.27 mkg in 2008 and 2009. As noted by Gallaway et al. (2017), this was the beginning of real change in the rebuilding strategy for Red Snapper in that the harvest of adults was curtailed in addition to the shrimp-trawl bycatch reduction requirements. The stock exhibited remarkable growth in biomass from 2008 forward and exceeded 45.36 mkg by 2012. This growth enabled steady increases in the catch quotas for the directed fishery, which were maintained at 3.18 and 3.67 mkg between 2010 and 2012, set at 4.99 mkg in 2013 and 2014, close to 6.35 mkg over the period of 2016 to 2018, and at 6.85 mkg for 2019 (GMFMC 2019a, 2019b).

In 2018, it was determined that the Red Snapper fishery was no longer overfished or undergoing overfishing, although the stock is still rebuilding, consistent with the rebuilding plan (SEDAR 2018). Also, recent research indicated that the effects of the shrimp fishery on Red Snapper are much less than previously thought (Gallaway et al. 2017). Given this new information, the GMFMC requested that the NMFS Southeast Fishery Science Center conduct an analysis to determine whether effort in shrimp fisheries could increase (i.e., could the reduction target be further reduced to 60%) without affecting the Red Snapper rebuilding plan.

The NMFS Southeast Fishery Science Center conducted the analyses by using several different scenarios of increasing shrimp effort Gulf-wide (i.e., not just the area that is monitored for bycatch of juvenile Red Snapper; Goethel and Smith 2018, revised 2019). The results suggested that increasing the shrimp effort to the level that is outlined in Amendment 14 (60% below the baseline years of 2001–2003 in statistical zones 10–21 from 10–30 fathoms deep) was unlikely to affect the rebuilding timeline for Red Snapper, and it would have little effect on yearly Red Snapper annual catch limit projections.

Goethel and Smith (2019) observed that mortality due to Red Snapper discards from the recreational fleets during closed seasons (especially in the eastern region) is now much higher than that from shrimp trawl bycatch. The increase in recreational closed-season discards over the last decade has acted to diminish the effect of shrimp trawl bycatch levels on total allowable catches and rebuilding schedules. Furthermore, compared with assessments prior to SEDAR 31 (Cass-Calay et al. 2015), the relatively high natural mortality values that are now assumed for age-0 and 1 fish (i.e., the ages that are primarily caught as bycatch in shrimp trawls) further reduces the effect of shrimp bycatch on rebuilding schedules. Because a higher proportion of these juvenile fish are likely to die from natural causes, shrimp bycatch has a lower long-term effect on the resource and moderate increases in shrimping effort are unlikely to greatly decrease the allowable catch levels.

Goethel and Smith (2019) conducted peer-reviewed analyses that were accepted by the Scientific and Statistical Committee of the GMFMC. At its April 2019 meeting, the GMFMC took final action on Shrimp Amendment 18, which reduced the shrimp effort threshold to 60% below the baseline years in the area that is monitored for Red Snapper bycatch.

Despite findings to the contrary, some still believe that (1) shrimp trawl bycatch is the primary threat to rebuilding the Red Snapper population, (2) bycatch reduction has been the one management action that can be directly tied to the remarkable recovery of Red Snapper in the Gulf of Mexico, and (3) this action is being eroded by the GMFMC (Venker 2019). We believe that these misconceptions are primarily based on looking at the numbers of Red Snapper that are caught in shrimp trawls versus the numbers that are caught in the directed fisheries without taking into account the age composition of the catch and the natural mortality rates of the various ages (Figure 1). For example, the estimates of shrimp trawl bycatch for Red Snapper in 2014 and 2015 as described in SEDAR 52 (SEDAR 2018) were roughly 20 million individuals in 2014 and 18 million individuals in 2015. Of these, about 80% were age-0 fish and 20% were age-1 fish. In contrast, the combined directed fisheries harvested fewer than 7 million fish but these were from 2 to 10+ years of age ("+" refers to fish that are 10 years of age and older), mostly between 2 and 5 years old (Figure 1). Simply stating that juvenile fish have higher natural mortality rates than older fish do fails to immediately convey the magnitude of differences or foster communication among stakeholders.

The purpose of this article is to compare the catch rates for Red Snapper across fisheries by using a currency that expresses total catch and discards in common age units. We first discuss why weighting catch by fish age is needed and present a simple approach that makes as few assumptions about the biology of Red Snapper (fecundity, sex ratios, etc.) as possible. We then apply this approach to the catch and demographic data that are presented in the most recent stock assessment of Red Snapper (SEDAR 2018). We discuss areas of uncertainty and potential bias in this analysis (and thus also in the stock assessment of Red Snapper) and highlight the importance of resolving those issues given the recent management change that instituted state-by-state

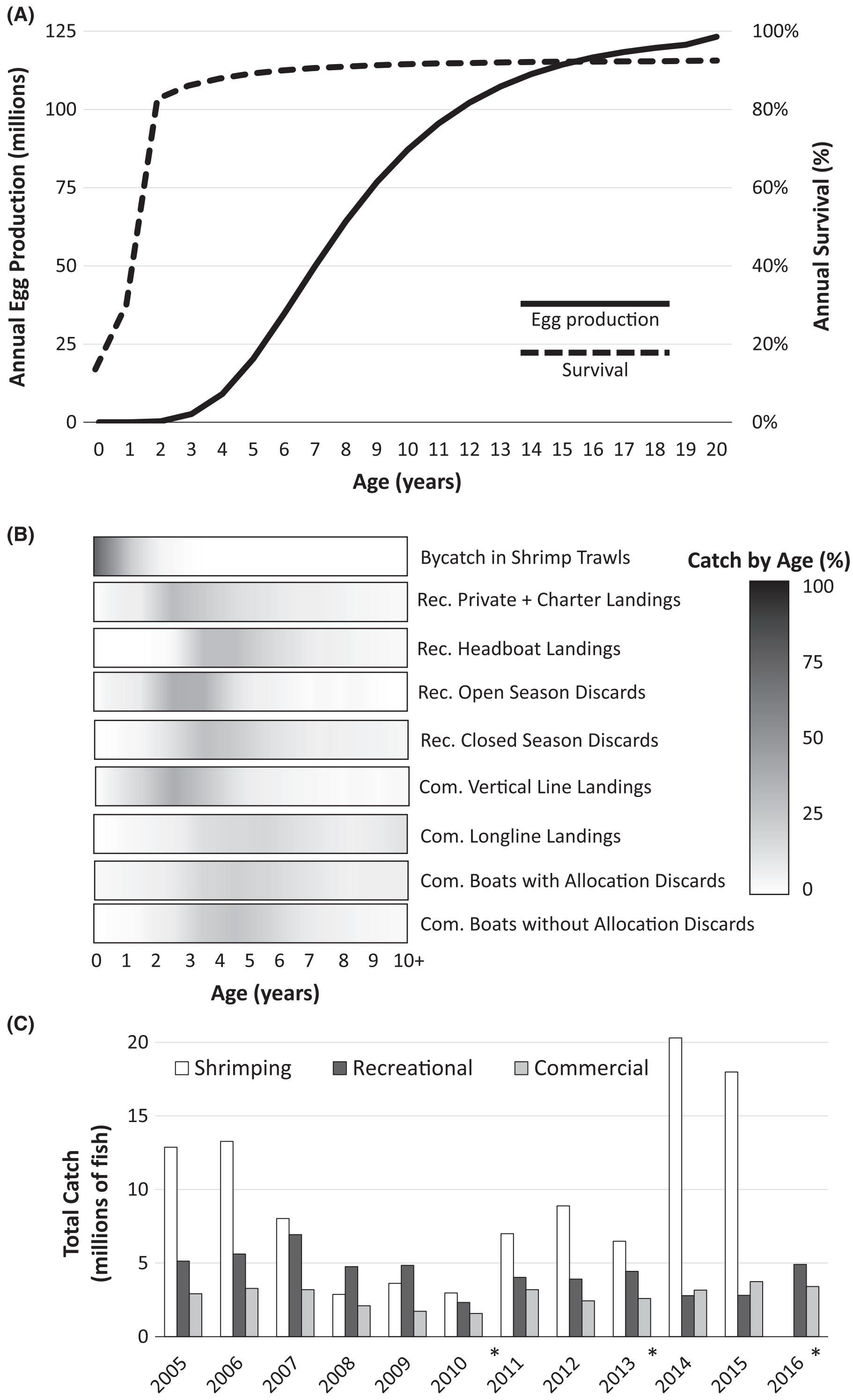

FIGURE 1. **(A)** Red Snapper annual egg production (solid) and annual probability of survival (dashed) by age. **(B)** Mean proportion of catch by age in different fisheries between 2005 and 2015; "Rec" = recreational and "Com" = commercial. **(C)** Gulf-wide estimates of total annual catch (landings and discards) by the shrimp, recreational, and commercial fisheries. The data were obtained from the SEDAR 52 Red Snapper stock assessment. The data for commercial sector discards were only fully reported for 2010, 2013, and 2016 (each marked with an asterisk) and were not reported prior to 2007. Shrimp trawl bycatch was not reported for 2016. Due to ontogenetic shifts in habitat, the susceptibility of Red Snapper to different fisheries changes over their life span. Older fish have higher natural survival and fecundity and are more valuable to the population. Therefore, the effect of fisheries on the Red Snapper population depends in large part on the age of fish that are caught.

control over important aspects of the recreational fishery for Red Snapper (Amendment 50) (GMFMC 2019c). We believe that this simple way to view catch among fisheries will improve communication among stakeholders from different sectors and encourage these groups to accept regulations that are proportional to their effect on the Red Snapper population in the Gulf of Mexico.

Red Snapper Life-Cycle and the Need to Scale Catch to Common Age Units

Spawning occurs during April through September across the continental shelf, with a peak between June and August from the mid-shelf to the continental slope (100–200-m depth). The eggs are buoyant and float to the surface, hatch within ~1 d, remain pelagic for ~28 d, and settle closer to shore over the next ~38 d (Gallaway et al. 2009). Initially, these young fish preferentially inhabit low-relief, relic shell habitat. After the age of ~18 months, they recruit to higher-relief habitat, to which they show high site fidelity. Although mortality rates over these periods are not well documented, each ontogenetic shift likely introduces a large loss to the cohort. A particularly severe bottleneck is likely to occur during the shift from low- to high-relief habitat because higher-relief habitat (e.g., natural rock outcrops, sunken ships, or petroleum platforms) covers a substantially smaller portion of the seafloor than low-relief habitat does (e.g., relic oyster beds and shell ridges) and the presence of larger Red Snapper on high-relief habitat precludes the recruitment of smaller fish (Bailey et al. 2001; Workman et al. 2002). Given that this ontogenetic shift appears to be related to the increasing body size of Red Snapper precluding them from sheltering in shell rubble, the snapper that do not recruit to high-relief habitats are likely subject to predation. Red Snapper become reproductively mature between 2 and 8 years of age, with apparent individual variation through time and across regions (Kulaw et al. 2017). During this period, Red Snapper continue to occupy high-relief habitat, spanning the width of the continental shelf, with larger individuals shifting to reefs with increasing vertical height and complexity. Red Snapper may live up to 50 years, and the larger individuals (beginning around age 8) may expand their range to include open bottom habitats, as their large body size protects them from most predators (Gallaway et al. 2009; Karnauskas et al. 2017).

The changes in body size and habitat as Red Snapper age result in changes in their key demographic parameters and susceptibility to interactions with fisheries. At the population level, growth, survival, and fecundity rapidly increase with age. Natural survival rates are estimated to increase from 14% at age 0 to 30% at age 1 and to >83% at age 2 years and over (Figure 1A). Fecundity, as measured by the number of eggs that are produced per year, increases from 350,000 at age 2 (the first year that Red Snapper become mature) to 20.3 million at age 5 to >100 million by age 12+ (Figure 1A). Fisheries interactions with Red Snapper begin at approximately 67 d posthatch when they settle onto mid-shelf habitats where they are susceptible to bycatch in shrimp trawls (Gallaway et al. 2009). After recruiting to higher-relief habitat (at ~2 years old), they are infrequently caught in shrimp trawls but enter directed commercial (vertical line, longline) and recreational (headboats, charter, and private anglers) fisheries that harvest them throughout the remainder of their life span (SEDAR 2018). The different fisheries often operate in separate areas, so they catch Red Snapper of different ages (Figure 1B). Given that Red Snapper of different ages have very different survival rates and fecundity, the reproductive value of the fish that are caught in each fishery differs substantially (Figure 1A). Therefore, the effect of each fishing sector on the Red Snapper population is likely different and the potential for regulating those sectors to rebuild or maintain it likely differ as well.

METHODS

Approach for scaling catch to common age units.— Despite the differences in the reproductive value of fish by age, fishery catches are typically reported as the total number of fish that are caught, potentially leading to erroneous assumptions of the relative effects of different fisheries (Figure 1). To assess the effects of catches across fisheries based on the numbers that are caught, a "common currency" is needed. First, for each fishery the number of fish that are caught at each age must be computed:

$$C_a = C \times P_a, \tag{1}$$

where C is the total catch (landings, discards, or bycatch) for a given year, P_a is the proportion of the catch at a particular age (a), which gives C_a, the number of fish that are caught at a particular age.

With this information, one can then scale the number of fish that are caught in each fishery to a common age by using the annual probability of survival to the target age (down-weighting younger fish because they have lower survival and up-weighting older fish because they have higher survival). For fish that are younger than the target age of comparison, this can be achieved by multiplying the number of fish of a given age-class by the probability of survival up to the target age:

$$C_{ca} = C_a \times S_a \times S_{a+1} \ldots S_{t-1}, \tag{2}$$

where C_a is the number of fish that are caught at age a, S_a is the annual probability of survival for fish at age a,

S_{a+1} is the annual probability of survival for fish the following year, and so on up until the year prior to the target age, S_{t-1}, which yields C_{ca}, the catch of age-class a scaled in common age units.

For fish that are older than the target age of comparison, one need only multiply the number of fish by the inverse of the probability of survival from a given age-class to the target age.

$$C_{ca} = C_a \times S_a{}^{-1} \times S_{a-1}^{-1} \ldots S_t^{-1}, \tag{3}$$

where C_a is the number of fish that are caught at age a, S_a is the annual probability of survival for fish at age a, S_{a-1} is the annual probability of survival for fish the previous year, and so on through the year of the target age (S_t), and C_{ca} is the catch of age-class a scaled in common age units.

With the catch for each age-class scaled to common age units, these values can then be summed for a given year:

$$C_{ct} = C_{c0} + C_{c1} + C_{c2} + \ldots C_{cn}, \tag{4}$$

where C_{ct} is the total catch, scaled in common age units; C_{c0} is the number of fish that are caught at age-0, scaled to common age units; C_{c1} is the number of fish that are caught at age-1, scaled to common age units; C_{c2} is the number of fish that are caught at age-2, scaled to common age units; and so on up to C_{cn}, the maximum age of the fish that are caught in the fishery.

Although the values for C_{ct} will differ depending on the target age that is chosen (a lower target age will result in larger values, an older target age will result in smaller values), the results will allow a direct comparison across fisheries that catch fish at different ages and the relative differences among them do not vary based on the target age that is chosen.

Data used.— For the analyses in this article, we used data that were obtained from the most recent Red Snapper stock assessment (SEDAR 2018). Landings, discards, and bycatch are often reported separately for the western and eastern Gulf of Mexico; however, for simplicity we combined them into single, Gulf-wide values. Likewise, we combined the data into three major fishing sectors that catch Red Snapper: recreational (comprising private anglers and charter boats and headboats), commercial (comprising vertical line and longline), and shrimping (as bycatch). Prior to combining these data, we computed the number of fish that were caught by age for each component of the fisheries by using equation (1). The natural mortality rates by age (Figure 1A) that were used for scaling the fish to common age units were obtained from SEDAR 2018 Table 2.1. We examined the annual data from 2005 to 2016, as this period had the most consistent data availability across sectors.

In the recreational fisheries, catch was reported in numbers of fish (SEDAR 2018 Table 2.12 provided landings, Tables 2.14 and 2.15 provided discards). The number of fish that were caught by the recreational sector at each age was determined by multiplying the catch values by the age frequencies of landings (SEDAR 2018 Table 2.13) and discards (SEDAR 2018 Table 2.16). For recreational discards, age frequency was only available for headboats during the open fishing season and the year 2008 was missing data. As an estimate for the 2008 age frequencies, we used the mean age frequencies from the 3 years before and after. We assumed that the age frequencies during the open season for private anglers and charter boats were the same as that for headboats. For the closed-season discards, we estimated the age frequencies by averaging the age frequencies of landings and open-season discards for the same years (SEDAR 2018 Tables 2.13 and 2.16).

The commercial fisheries catch was reported in kg of fish landed (SEDAR 2018 Table 2.5) and in numbers of fish discarded (SEDAR 2018 Table 2.7). The number of fish that were caught by the commercial sector at each age was determined by multiplying the catch (in kg) by the age frequencies of landings (SEDAR 2018 Table 2.6) and multiplying by an estimate of weight at age. We used a model-derived weight at age (kg whole weight) for Red Snapper in the Gulf of Mexico, which was calculated within the SEDAR 52 stock assessment model at the mid-point of the calendar year (Matthew Smith, NMFS, personal communication). Thus, we modified equation (1) to the following:

$$C_a = C_w \times P_a \times W_a^{-1}, \tag{5}$$

where C_w is the landings of Red Snapper in kilograms for a given year, P_a is the proportion of the catch at a particular age (a), and W_a is the weight of Red Snapper in kilograms at age a, which gives C_a, the number of fish that were landed at a particular age (a).

Discards were reported as numbers of fish, and we multiplied those values by the age frequencies of the discards (SEDAR 2018 Tables 2.9 and 2.10). However, the age frequencies for the discards were only available starting in 2007 and there was erratic coverage for commercial boats without Red Snapper allocation. The only years with, apparently, complete data on commercial discard numbers and age frequencies were 2010, 2013, and 2016. However, during those years the numbers of fish that were discarded were lower than for some years that lacked complete coverage, so we present the data that were available in the other years together with these for context.

The shrimp trawl bycatch of Red Snapper was reported in number of fish (from SEDAR 2018 Table 2.17) and was multiplied by the age composition of Red Snapper (from SEDAR 2018 Table 2.19) to provide an estimate of the number of Red Snapper caught by age-class. The 2016 data point for Red Snapper bycatch was not reported.

RESULTS

Relative Catch among the Fisheries

Between 2007 and 2015 (the years with data for the three fisheries), the mean annual catch of Red Snapper was estimated to be 8.68 million fish as shrimp trawl bycatch, 4.09 million fish in the recreational sector, and 2.64 million fish in the commercial directed fisheries (SEDAR 2018) (Figure 1C). Without scaling snapper to a common age, over this period it would appear that shrimping is typically responsible for 51.0% of the effect of fisheries on Red Snapper, the recreational sectors are responsible for 30.8% of this effect, and the commercial sectors are responsible for 18.2% of it (Figure 2A). However, after scaling the catch in each fishery to common age units, the relative catch that is shrimp-trawl bycatch drops to 8.9%, that of the recreational sector increases to 59.4%, and that of the commercial sector increases to 31.7% (Figure 2B).

The problems that can potentially arise from the misperception of the relative influence of the three fisheries on the Red Snapper population in the Gulf of Mexico are clear. The centerpiece of the management strategy to rebuild Red Snapper populations from the mid-1990s through the mid-2000s was to reduce shrimp trawl bycatch of Red Snapper by limiting effort and modifying gear, but limits to the commercial harvest of adult Red Snapper remained unchanged. After 10 years of management effort to reduce the effect of bycatch from shrimping, which resulted in no response in Red Snapper biomass, reductions in the total allowable catch for the directed fisheries were required in 2007. An immediate increase in Red Snapper biomass followed. After two more years of population growth, constraints on the directed fisheries were relaxed and allowable catch was increased. In contrast, relaxing constraints on shrimping effort have more slowly been adopted, despite shrimp trawl bycatch being shown to have a relatively minimal effect on the total biomass of Red Snapper for more than a decade (Gazey et al. 2008; Gallaway et al. 2017).

DISCUSSION

The sustainable harvest of Red Snapper is most likely to be achieved when the amount of oversight and regulation of each fishery is proportional to its long-term influence on the population. When comparing the shrimping, commercial, and recreational sectors with respect to catch in common age units, the recreational fisheries have the largest effect on the Red Snapper population, with average values for annual catches that are 676% greater than those for shrimp trawl bycatch and 101% greater than those for commercial catch (Figure 2B).

Management Implications

Given the apparently large effect of recreational fisheries activities on Red Snapper populations in the Gulf of Mexico, it seems appropriate to focus most resources and attention at managing this sector. Recent changes to the Fishery Management Plan for the Reef Fish Resources of the Gulf of Mexico that instituted state-by-state control over important management aspects of the recreational fishery for Red Snapper (Amendment 50) may be beneficial to this end. This regulatory change delegates authority to states along the U.S. Gulf Coast to set their own catch limits, size limits, and seasons for Red Snapper. Amendment 50 also institutes "payback and carryover provisions" so that individual states that are over or under their allowable catch, which is still set by the NMFS, can add or subtract the difference to (or from) the following year's allowable catch. Finally, each state collects data on fishing effort, catch, and discards for the management of its recreational fishery (GMFMC 2019c).

Prior to Amendment 50, the NMFS burdened these responsibilities, instituting regulations and collecting data uniformly across state lines. National Marine Fisheries Service scientists are currently partnering with Florida, Alabama, Mississippi, and Louisiana (n.b., but not Texas) to ensure that the state sampling programs that collect data on fishing effort, catch rates, discards, and age composition of the catch are compatible with NMFS's Marine Recreational Information Program. Close coordination among states in sample design, implementation, and analysis is important so that data obtained can be compared, aggregated, and used with previously collected data to assess Gulf-wide trends in the Red Snapper population.

Additionally, we believe that this shift in management should be accompanied by efforts to further reduce uncertainty in the recreational fishery and relevant aspects of Red Snapper biology. For the recreational fishery, perhaps the most important area of uncertainty to resolve is that of discard mortality. Discards in the recreational sector are estimated to constitute more than 70% of their total catch (Figure 3). However, in the most recent stock assessment they are treated as a trivial source of mortality, assuming 88.2% survival. That number was derived from a meta-analysis of 11 studies that provided 75 data points over 3 decades that examined postrelease mortality of Red Snapper (Campbell et al. 2014). A common assumption across essentially all of the studies that have examined

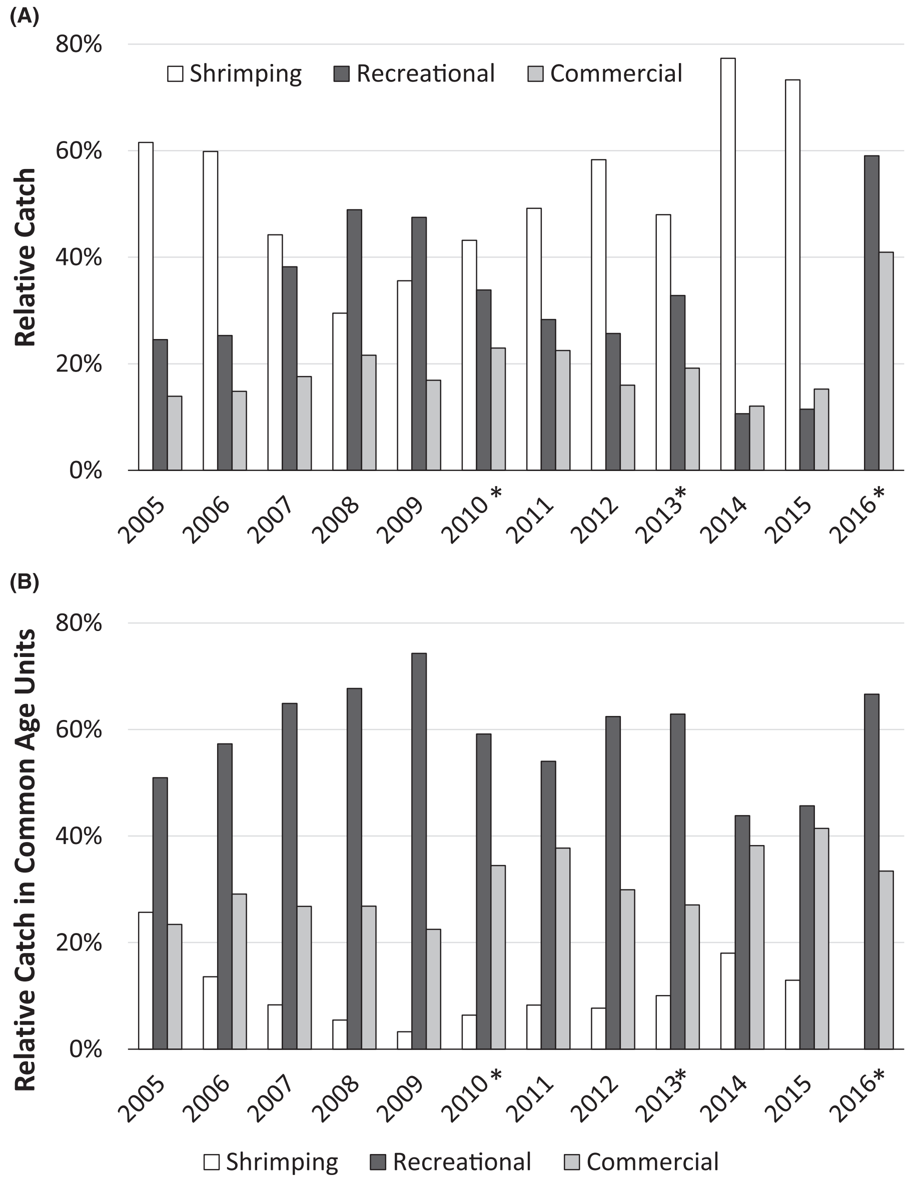

FIGURE 2. **(A)** Percentage of the total numerical abundance caught by shrimp (white), recreational (dark gray), and commercial (light gray) fisheries. **(B)** Taking into account age frequencies of catch and natural mortality, the estimates of annual catch are scaled to common age units prior to computing the percentage of Red Snapper caught by the three fisheries. The data for commercial sector discards were only fully reported for 2010, 2013, and 2016 (each marked with an asterisk) and were not reported prior to 2007.

discard mortality of Red Snapper is that fish that are caught in deeper water are less likely to survive (Campbell et al. 2014). The value of 11.8% mortality (88.2% survival) is the model-derived estimate for fish that are caught at a depth of 25 m, based on estimates of where the bulk of recreational effort is located.

Close examination of these data suggest that recreational discard mortality could be substantially underestimated. For comparison, a meta-analysis of mortality associated with bass fishing tournaments, in which considerable care is taken to keep the fish alive and barotrauma is of less concern, showed 28% mortality (Wilde 1998). In the analysis for Red Snapper by Campbell et al. (2014), each estimate of mortality was weighted by its sample sizes. Surface-release studies were the most common method that was employed to assess mortality (and these studies tend to use sample sizes of fish that are greater than those that are used for tagging or cage studies), which necessarily biases the overall estimate to reflect that method. Surface-release studies do not account for delayed mortality, and they assume that submergence ability is a proxy for mortality (Campbell et al. 2014). Measured

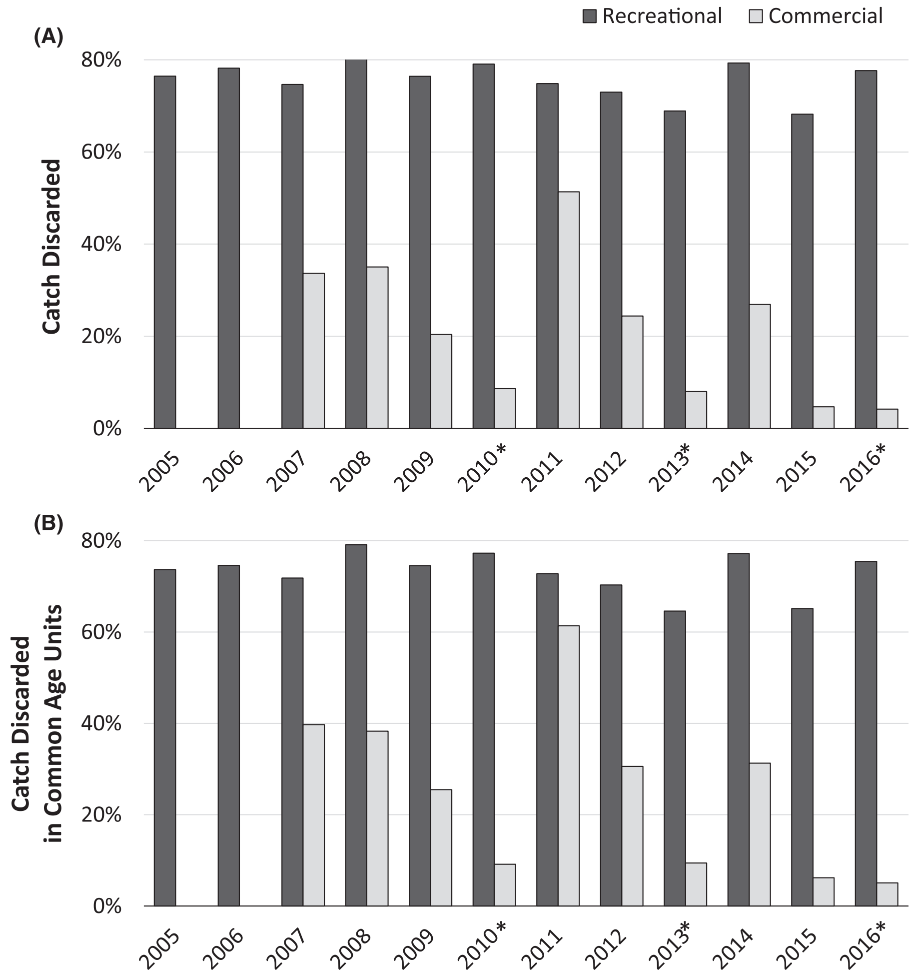

FIGURE 3. **(A)** Gulf-wide estimates of the percentage of total Red Snapper catch that was discarded by recreational (dark gray) and commercial (light gray) fisheries. **(B)** The percentage of discarded Red Snapper catch after first scaling the fish to common age units. The data for commercial sector discards were only fully reported for 2010, 2013, and 2016 (each marked with an asterisk) and were not reported prior to 2007. Discards are a particularly large portion of the recreational fisheries catch of Red Snapper (>70%, whether or not the samples are scaled to common age units). Thus, estimates of mortality are critical to assessing their effect on the population. In contrast, commercial discards are relatively small. Despite much higher estimates of discard mortality in commercial fisheries (currently 55–81% mortality compared to an assumed 11.8% mortality in the recreational fishery), the potential influence on the Red Snapper population is lower and the uncertainty that they introduce to stock assessments is much lower.

mortality rates ≤11.8% (survival of ≥88.2%) were only observed in studies that used surface-release methods (n = 10). Delayed mortality that is associated with fishery discards is likely to be considerably higher, as was indicated in a cage study that showed ~50% mortality of Red Snapper that were caught in July and September in 300-m-deep water (Diamond and Campbell 2009). Moreover, the effect of predation is poorly known at present. It is excluded from cage studies, and it is probably underestimated in surface-release studies (as only immediate predation events are recorded). Were predation explicitly accounted for (e.g., through tagging studies), increases to the estimates of fishing-related mortality would be likely (Curtis et al. 2015) and the inferred effect of the recreational fishery would likewise increase. Given these unresolved issues, we echo the recommendation by Campbell et al. (2014) that tagging studies that are designed to characterize immediate and latent mortality of discarded Red Snapper should be prioritized.

CONCLUSIONS

Ultimately, the purpose of scaling the catch of Red Snapper to common age units is to account for the important role of age in the fitness of individual fish (Figure 1A). Of course, the potential for a fish to contribute offspring to the population is influenced by many other factors including genetics, sex, body condition, parasite load, aerobic capacity, ability to navigate, habitat preference, the surrounding environment, and so on. Incorporating such variables into more complex analyses than we have presented here could help refine estimates of the "relative catch" across fisheries, but is unlikely to alter the primary finding that the recreational sectors have a disproportionately large effect on the Red Snapper population. For example, there are indications that young Red Snapper that recruit to high-relief natural reefs and artificial structures have greater survival rates than those that settle on low-relief habitat do (Szedlmayer and Schroepfer 2005; Jaxion-Harm and Szedlmayer 2015). Therefore, fish that are caught over structure might have higher fitness and be more valuable to the Red Snapper population than are fish of the same age that are caught over low-relief habitat. Shrimp trawls do not target natural reefs or artificial structures, but recreational fishers routinely do. By not accounting for such differences in *where* fish are caught, our approach may have overestimated the effect of shrimping and underestimated the effect of recreational fisheries.

Many areas of research could aid in the management of Red Snapper, such as improving understanding of the genetic and demographic connectivity of Red Snapper (Gold et al. 2001; Topping and Szedlmayer 2011; Gomes et al. 2012), their natural mortality rates (Szedlmayer and Schroepfer 2005; Jaxion-Harm and Szedlmayer 2015), and the use of artificial structures to enhance habitat (Karnauskas et al. 2017). However, our analyses point to the importance of addressing questions that are related to the recreational fishery (such as discard mortality) because this sector has the highest relative catch of Red Snapper in the Gulf of Mexico. We believe that Amendment 50 of the Fishery Management Plan for the Reef Fish Resources of the Gulf of Mexico can be a useful step toward that need. Nonetheless, changes in management for one fishing sector have the potential to affect others, so all sectors should advocate for robust, science-based decisions. We hope that presenting catch data in "common age units" will improve communication among the diverse stakeholders that interact with Red Snapper so that differing views can be discussed in a scientifically meaningful way.

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