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DRAFT

TO: Gulf of Mexico Fishery Management Council (GMFMC)

FROM: David Eggleston, Independent Reviewer

DATE: March 28, 2021

RE: Peer Review of "The Great Red Snapper Count: Estimating the Absolute Abundance of Red Snapper in the U.S Gulf of Mexico"

This document represents my review of the report "The Great Red Snapper Count: Estimating the Absolute Abundance of Age-2+ Red Snapper (*Lutjanus campechanus*) in the U.S. Gulf of Mexico", by Stunz et al. 2021. I was tasked by the GMFMC to determine if the absolute abundance estimate of 2+ red snapper (and its variance) are reliable and consistent with data and population characteristics by addressing three specific terms of reference (TOR): (1) Study design and sampling approaches, (2) Statistics and data analyses, and (3) Results. In addition to addressing the specific terms of reference, general comments and suggestions are provided to help make estimates more precise, as well as enhance our understanding of snapper distribution and abundance patterns, and application to enhance Stock Synthesis Models.

I am a Marine Ecologist, with experience in the behavior, habitat use, recruitment, demographic rates, and metapopulation dynamics of exploited marine species. I am not a trained statistician, nor stock assessment scientist, however, I consistently use basic to advanced statistical models in my research, and my research results are sometimes integrated into stock assessment models. Thus, my report focuses on the first TOR, and I added comments and suggestions for TORs 2 & 3 where I felt they might add value to feedback from Drs. Cadrin and Christman.

Summary of Findings. -- This report describes the results from an impressive team of fishery ecologists, sampling design experts, and stock assessment scientists (PI plus 36 co-PIs) to estimate the absolute abundance of Age 2+ red snapper in U.S. waters of the northern Gulf of Mexico. This is an unprecedented spatial scale for such a field survey. It was clear that the team tried to minimize and account for bias and uncertainty that would affect the robustness of the abundance estimates. The two-phased approach attempted to address gear efficiency issues by first determining best (or near best) methods for making estimates of age 2+ red snapper density, and then scaling-up to sampling and making inferences among 4 geographic regions and 3 depth zones. The team clearly recognized and tried to address potential sources of bias, such as: (i) departures from the original stratified sampling design to address regional differences in methods to detect red snapper (e.g., Remotely Operated Vehicle (ROV) versus Hydroacoustics), (ii) the potential to double-count age 2+ red snapper on reefs with high abundances using the ROV (e.g., AL), and (iii) meeting assumptions of depletion methods in various habitats (AL/MS), among others**. I agree with the key finding of the study, that the absolute abundance of age 2+ red snapper is <u>on the order of</u> 110 million fish, and**

that this value is likely an underestimate. I also conclude that the variation around this estimate of absolute abundance is larger than reported. Despite variances in abundance estimates that may be larger than reported, I am hopeful that this absolute abundance estimate and its variance can help refine the current Stock Synthesis Assessment model for red snapper in the Gulf of Mexico. A key finding was identification of the relative importance of Uncharacterized Bottom (UCB), which is analogous to the concept of Effective Juvenile Nursery Habitat (Dahlgren et al. 2006). Moreover, important advances were made by the Educational Outreach program in terms of identifying what modes of communication were most effective, and making stakeholders feel that they were a part of the assessment process. I appreciated the team's identification of (1) Sampling Biases, (2) Management integration, (3) Future research recommendations, and (4) Overall collaborative tone with respect to informing stock assessment models and not superseding them. Lastly, it would help the general reader to place age 2+ red snapper in the context of the broader life cycle of red snapper by adding a Life History diagram (e.g., typical circular life history schematic) to the report—the diagram could depict spawning locations and times, settlement habitats, and ontogenetic habitat shifts of juveniles to the age 2+ red snapper targeted in this study.

TOR 1. STUDY DESIGN AND SAMPLING APPROACHES

- **Evaluate study design used for developing a composite estimate of absolute abundance by habitat type, depth, region, and age.**

This study quantified spatial variation in abundance of age 2+ red snapper and not temporal variation (at least over scales relevant to snapper life history), thus my comments are related to spatial aspects of the study design and sampling approaches. In reference to "age", I assumed we should assess the classification of age 2+ fish based fish sizes detected with the various sampling methods.

  - **Assess the sufficiency of spatiotemporal sampling by study strata.**

1.A. - Initially, a stratified random sampling design was developed to generate age 2+ red snapper abundance by region, habitat type, and depth. In this design, the GoM was separated into 4 eco-regions that closely mirrored state jurisdictional boundaries. Within each region, zones were defined by depth (10-40m, 40-100m, 100-160m) and habitat type: artificial reefs (small vs large), natural hard bottom, and uncharacterized bottom (UCB), resulting in 48 strata, with sampling site locations in UCB determined from a random forest model that estimated probability of encountering age 2+ red snapper (e.g., Figure 4). The team consisted of top experts in the U.S. on age 2+ red snapper distribution, abundance, and demographics, as well as experience mapping habitat features in the Gulf of Mexico. Thus, I have confidence in the initial delineation of the strata, as well as the methods chosen to sample age 2+ snapper. Both standard and novel sampling methods quantified age 2+ red snapper density across this broad range of habitat types, depths and water visibility. One goal of the study was to advance novel sampling methods. In many cases, the team conducted rigorous cross-validation studies of the various gear types, and advanced the application of these tools to fisheries science. The main tools included ROVs and towed camera arrays for visual surveys, and hydroacoustics (sonar) for areas with low to no visibility (See Section 1.H below).

As the study progressed, it appears the initial stratification scheme for estimating absolute fish abundance and variance included additional strata, such as latitudinal stratifications in Florida, unique artificial reef types in Texas, and Pipelines (Gulf-wide) (Table 7). The resulting sampling design applied the original stratified random sampling approach for some strata (e.g., Alabama Figure 8), depletion sampling on artificial reefs in AL, probability-based sampling in Florida and some of the Uncharacteristic Bottom (UCB), and ship-based linear transects on UCB in Texas. Moreover, sampling of UCB was treated as a random survey, yet we know that the tendency of snapper to aggregate into schools (clusters) adjacent to structure likely increased spatial auto-correlation, which would increase variation in population estimates if not accounted for. Moreover, accounting for spatial-autocorrelation in UCB will provide key insights into snapper distribution and abundance patterns in this important habitat. Each sampling design likely has a relative positive or negative bias on variance estimates, which would likely increase variance around estimates of absolute abundance when summing absolute abundances among strata. Nevertheless, the spatial scale of sampling is truly impressive, and the exact area sampled (km^2) versus number of structures sampled (artificial reefs) should be clearly defined in Table 7 to estimate % of putative age 2+ red snapper habitat sampled (versus available) in the northern GoM.

1.B. – The random forest derived occupancy probabilities (L, M, H) were applied as strata to the UCB, which seems appropriate, however, it seems like it was also applied to hard-bottom areas in FL, but not other regions. While this may make abundance estimates more precise in hard-bottom habitats in FL, it was not applied to other regional hard-bottom habitats, which would inflate variances in those regions versus FL for scaling up to total abundance. Moreover, it was unclear if the probability of occurrence estimates varied between fishery-dependent and –independent sources. Lastly, it would be informative for future surveys to understand how the Occupancy Probabilities increased precision of the abundance estimates over not including these strata.

1.C. – Was the study design and methods used for developing a composite estimate of absolute abundance for age 2+ fish appropriate? The short answer is YES. The team adopted a conservative approach for estimating age 2+ fish as > 250 mm TL, as set forth in Phase II of the rfp. First, size-at-age was estimated using published von Bertalanffy growth functions, as well as otolith-derived age data. Fish > 250 mm TL have a 60% chance of having an integer age of 2 years old, the age at which they typically recruit to reefs and are exploited by the fishery. Second, given that fish size distribution may be skewed low on reefs in Florida due to the re-building nature of that regional population, the team spent considerable time generating data on size distributions via different sampling methods. For example, the size distribution of age 2+ red snapper was derived from laser scaler or stereo camera (Figure 24) samples to reduce the proportion of fish < 250mm TL that may have been sampled in ROV video and depletion samples collected from FL and AL. Third, because many of the other sampling methods may not have provided accurate length data, the team accessed ancillary data from previous red snapper studies spanning > 10 years and among multiple gear types (ROV laser and stereo camera, vertical long-line, bottom long-line). The goal of this effort was to provide accurate length data by region and habitat type (Table 10), which was generally the case. Interestingly, no ancillary length data was available for Uncharacterized Bottom, again highlighting the need for further research on this expansive habitat mosaic.

- **Does heterogeneity in sampling by strata affect estimates of absolute abundance and variance around that estimate?**

1.D. -- Throughout the report, estimates of means and variances were based on the assumption of a stratified random sampling approach. The *a priori* sampling design could not be implemented across all strata because certain strata were originally misclassified due to inadequate benthic habitat maps, requiring post-stratification of sampling effort (e.g., compare Figures 4 and Table 7). This *a posteriori* change in sampling design is to be expected given that the team had to rely on best available habitat data from a broad range of sources, and were adaptive in their response to spatial patterns in the data as they became available. Nevertheless, variance estimates based on post-stratification, and extrapolation of absolute estimates of age 2+ snapper density to other strata and regions when the sampling design within certain re-classified strata was unclear (e.g., all pipelines, UCB in Texas, etc.), likely added considerable uncertainty to estimates. Some specific examples of reduced precision and inflation of variance estimates are provided below.

- **Evaluate assumptions and biases inherent to the design, and the directionality of those biases.**

1.E. -- The team is aware of the need to scale sample size to the area of a given strata. Without proper scaling, a given sampling method will either under sample or over sample a given strata, which will increase variance in the latter. Without adequate habitat maps, it is impossible to scale sample size appropriately. The only instance I could find where the team scaled sample sizes based on area of a given strata was in Alabama, where grid selection to survey artificial reefs was proportionally allocated to three depth strata based on the bottom area included in each depth. One example of not scaling sampling to the area of a given strata is ROV surveys in Texas, and generally in UCB. This concern is further developed in Section 2.A below.

1.F. -- Another concern relates to spatial auto-correlation in the data. Given the focus on spatial variation in age 2+ snapper abundance, and the fact that the original randomized sampling design could not be applied to the entire project, I expected to see explicit focus on testing spatial auto-correlation, and perhaps integration of this spatial autocorrelation in adaptive sampling. The first mention of spatial autocorrelation in the report was on page 80, in which non-overlapping segments of pipes that were surveyed were used to "sufficiently reduce spatial autocorrelation", however, no results from statistical testing were shown throughout the report (except for reference to one variogram). Given the importance of the UCB strata, it is important to understand spatial variability in age 2+ snapper density in this habitat (e.g., the high biomass on small patch reefs). One approach might be to conduct paired ROV and Sonar surveys (or use the best gear for a given strata), and use an Adaptive Cluster Sampling Design (Thompson and Seber 1996, Salehi and Seber 1997). The report suggests that age 2+ snapper are clustered on a variety of structured habitats within the UCB. The Adaptive Cluster Sampling approach allows one to estimate the spatial coherence on patchy populations, focuses sampling effort on sites with population information, and should lower variation around mean densities. Information on the density and patchiness of age 2+ snapper in UCB could be matched with tag-recapture-based estimates of exploitation to establish a baseline in this novel habitat. Moreover, the mark recapture based estimates in the report are clearly biased high in terms of recreational F since the tag-recapture studies were conducted on high fish density reefs. Thus, inclusion of exploitation rates in relatively low density, yet expansive UCB areas could better define density-dependent exploitation rates by recreational fishers that, in turn, would help define how catch might respond to varying bag limits (e.g., Eggleston et al. 2008).

- **Are sampling approaches collectively appropriate for determining an estimate of absolute abundance for red snapper in the Gulf?**

1.G. -- Estimating Age 2+ snapper abundance with a given gear/method assumes (1) all age 2+ snapper were detected and identified, (2) age 2+ snapper counts were not biased by behavioral responses of fish to the gear, and (3) available habitat is accurately estimated. The report provides a convincing argument that assumption #2 was met. The study also tested detection probabilities of the various gears using cross-validation, and demonstrated that assumption #1 was not met. In some cases, the team was able to correct the biased detection of a given gear, in other cases they went with methods that had low detection probabilities (e.g., hydroacoustics under conditions of high fish densities). For the latter, the team argued that the biased low estimate of abundance was conservative in keeping with the general philosophy of the preferred direction of biases for abundance being conservative. It was also clear that assumption #3 was not met, and the team adapted their sampling design to address this gap. The sections below highlight examples in which the assumptions for a given sampling approach were met or not, and strengths and weaknesses of sampling approaches.

- **Are different sampling techniques effectively calibrated to each other for generating the absolute abundance estimate?**

1.H. – There was a broad range of methods applied in this study and collectively, the sampling methods were appropriate for determining absolute abundance of age 2+ red snapper in the GoM. The sampling techniques were conducted by experts in the field, and there was clear recognition of potential gear biases, and rigorous attempts to address "catch efficiency" of the various gear types via cross-comparisons of gear performance. The methods included: ROV visual surveys, hydro-acoustic surveys, towed camera arrays (TARIS, ARIS, CBASS), Outreach materials, tag-recapture, archived tissue samples for DNA analyses, genetics, age 2+ snapper depletion studies, and stereo-cameras. The challenge was in extrapolating the results from the various techniques across the entire U.S. portion of the Gulf of Mexico (to a depth of 160 m). Extrapolation at this spatial scale and across such heterogeneous habitats increased uncertainty in estimates of age 2+ snapper abundance due to: (1) coarse-scale habitat maps (especially for UCB), (2) differences in gear efficiencies, and the (3) sampling design relative to patchiness of age 2+ snapper in space and, to a much lesser degree, time. To address #1, the team procured the best available maps from a wide range of federal and state agency sources, as well as from their collective research programs. To address #2, the team tried with mixed success to effectively calibrate gear efficiencies. To address #3, the team responded with a somewhat adaptive sampling design as trends emerged related to the patchiness of age 2+ red snapper abundance patterns, and the emerging importance of UCB habitat. The sections below address some representative examples of calibration of gear types.

1.H.1. Comparisons of ROV versus Hydroacoustics (Sonar). – I was holding out hope that there would be a strong correlation between ROV and Hydroacoustic estimates of age 2+ snapper abundance so that Hydroacoustics could confidently be applied across a broad range of strata, especially turbid waters west of the Mississippi. This was not the case as dense aggregations of age 2+ snapper were not adequately sampled by the Hydroacoustics. The reasons for discrepancy in age 2+ snapper density estimates between Hydroacoustics and ROV techniques are somewhat elusive. Several potential explanations that may also explain this discrepancy explored in future efforts were proposed in the report. An additional consideration concerns post-processing of the sonar data, in which it might be helpful to explore the robustness of the algorithm for volume density calculations of the echo-integration and echo-count data used to convert Target Strengths to areal (volume) densities. Both the ROV and Hydroacoustics applied standard methods with appropriate calibration and correction methods. There was also significant pilot research testing the null hypothesis that the presence of the ROV had no effect on fish avoidance or attraction to the gear, and this hypothesis was generally accepted. First, the use of point counts for ROV surveys of reefs (volumetric) and transect surveys of non-reef habitats is appropriate. Second, there was a very large number of paired samples among five regions along the west Florida shelf where both ROV and Hydroacoustic sampling was performed (Figure 5). Although the Target Strength-based estimates of age 2+ snapper abundance at low densities matched estimates from the ROV, the ROV surveys estimated 9-times greater densities of age 2+ snapper than the Hydrocoustics. Further calibration studies demonstrated that Hydroacoustics may underestimate age 2+ red snapper abundance, however, the team did not calibrate for these differences in their abundance estimates, which could bias abundance estimates low and variances high.

1.H.2. – Similar to the challenges described above for ROV and Hydroacoustics, efficiency of the C-BASS towed camera system was hampered under low visibility conditions. For example, when the C-BASS system sampled UCB off Louisiana, it assumed that (1) all age 2+ red snapper were detected and identified, (2) counts were not biased by gear avoidance, and (3) available pipeline habitat was accurately estimated. We know that assumptions 1 & 3 were not met. When visibility hindered accurate identification of species composition, the mean proportion of age 2+ red snapper was derived from regional surveys. While this was a necessary step, it did add uncertainty in the abundance estimates and, when coupled with lack of accurate maps of pipelines, estimates of abundance were biased low and precision reduced. In general, detectability was not tested for any of the mobile visual surveys gears under low visibility indicative of the western GoM.

- **Are the biases and limitations of each approach effectively addressed?**

I.1. -- Yes and No. As discussed above (Section 1.H.1), there was an impressive number of paired ROV and Sonar surveys conducted off the western shelf of Florida where water visibility was relatively high (Figure 5). For the ROV surveys, the integration of the point count (volume) surveys with the transect surveys seemed appropriate, and the methods for conducting the sonar surveys approach was rigorous in terms of standard calibration and correction methods. Despite the discrepancy in abundance estimates between the two techniques under conditions of high fish densities, the team was left with relying on Hydroacoustics in most strata west of the Mississippi River plume due to turbid conditions that did not allow for general application of ROV and other video techniques. This decision to go with Hydroacoustic estimates of age 2+ snapper density for the western Gulf is consistent with the general goal of erring on the side of conservative density estimates, however, calibration of Hydroacoustic data with ROV methods was not conducted, thereby reducing precision and increasing variance in estimates.

I.2. – The Alabama/Mississippi region presented a somewhat contrasting challenge to the low visibility issues that plagued western GoM sites described above. In this case, artificial reefs have been placed for decades in the AL Artificial Reef zone without clearly marked coordinates, such that only~ 22% of reefs have been mapped. Moreover, previous data indicated extremely high age +2 snapper densities on these reefs, such that there was concern that visual survey methods using ROV would double-count age 2+ red snapper. The general strategy in AL/MS was to use an index of age + 2 snapper depletion on reefs from fishing (longline sets) to estimate a calibration coefficient that would convert the ROV counts into an absolute number of fish. This estimate would then be scaled to the number of reefs in AL/MS to obtain a total population estimate. While the assumptions of a stratified random sampling approach for a given reef are debatable due to non-independence of repeated sampling on the reef, the calibration approach was a novel way to try and increase precision of the ROVs in areas with extremely high fish densities.

TOR 2. STATISTICS AND DATA ANALYSIS

- **Evaluate the statistical methods used to analyze the data, and to construct the absolute abundance estimate and its variance.**

The team performed independent, cross-validation analyses to test the efficacy of their primary estimate of 110 million age 2+ red snapper. The two analyses were performed using the same data, and guidance was not shared between the teams to ensure independence. Descriptions of estimators were provided in the report. The *Substitution* estimator was used in regions or habitats where samples were not available or missing. Thus, total abundance was estimated by substituting missing samples with samples from similar or nearby areas. One way to increase accuracy in this case would have been to use some type of spatial (nearest neighbor) kriging that integrated any known spatial autocorrelation among nearby sites. Also, the *Estimation* procedure (PROC SURVEYMEANS in SAS) assumed the sampling design was stratified random, with simple random samples taken within each region. The preceding discussion for TOR1 already addressed the non-random nature of some of the sampling, and the fact that this assumption of the statistical model in SURVEYMEANS was likely not met.

- **Is the statistical variance appropriate for habitat-specific, regional and Gulf-wide estimates?**

2.A. -- A goal of the study was to generate a Coefficient of Variation of 0.30 or less. Table 6 displays CVs as a function of area or number of structures sampled by State/Region and Habitat type. The CVs range from 5 to 43, with the average being 11%, which meets the stated goal of the study. I assumed there was some type of optimal allocation of sampling effort that integrated the area of a given Habitat type or number of reefs within a given strata, the variance for a given sampling method, and the costs in terms of personnel and funds; however, this was not clear. It would help to provide a very explicit section in the report that takes the reader step-by-step on the sampling units and how sample sizes were allocated. Moreover, as discussed above (Section 1.H.1), the relationship between age 2+ red snapper densities estimated with ROV versus Hydroacoustic surveys was marginally significant with lots of variation. For example, the relatively high CVs in Texas (Table 6) were likely due to the fact that there was no calibration for the differences in the two gear types when applying Hydroacoustics to large strata with low visibility.

- **Are potential sources of uncertainty effectively incorporated into variance estimates?**

2.B. -- Certain very high abundance estimates within a given strata were often eliminated from population estimates because of concerns that these outliers would have a disproportionate effect on overall absolute population estimates. The team that collected these data points felt they were accurate. It would help to have some biologically-based discussion on why the data collection team felt these measurements were accurate (e.g., potential spawning events, aggregations around reefs that were fairly isolated from others, etc.), which could shed light on important life history attributes. Given that these high abundance outliers were not used, thereby biasing absolute estimates low in keeping with the philosophy to generate conservative estimates, it was surprising to see the incredibly high densities in LA on Mid- and Shallow-Artificial Reefs (Table 7). I understand these high density Age +2 snapper aggregations were the reason that the ROV surveys on these reefs were paired with depletion surveys, however, I would urge the authors to re-check these seeming outliers values.

- **Are imputations made for unsampled regions appropriate, and what are the potential implications for the direction of biases in the estimates.**

2.C. -- Although the overall spatial scale of sampling was impressive, there were numerous imputations made for un-sampled regions which, in many cases, were likely due to logistical constraints. Future sampling programs could be informed if the rationale for these imputations were clearly described. Relatively deep > 160m areas in most regions were outside of the spatial sampling frame based on the likely need to cover known areas of age 2+ red snapper occurrence. Yet, the ROV surveys suggest the deep areas contain age +2 red snapper, so there is a biological basis for their exploration as a potential deep-water spawning refuge. Areas of low probability of age +2 snapper occurrence in UCBs in Florida were not sampled, again likely due to logistical constraints. The most prominent strata not sampled inside 160 m was in LA, in which shallow artificial reefs were not sampled, with substitution of the missing estimates from analogous habitats/strata from Texas. It is unclear how the imputations would affect estimates of absolute abundance and variances. For example, sampling of low probability UCBs in FL could produce numerous zeros or low abundance values, and drive the means lower (e.g., see means for FL in Table 6).

2.D. – From a forward-looking perspective, given the non-random nature of sampling UCB, and the patchy nature of age 2+ red snapper in this habitat, the precision of absolute abundance estimates might be enhanced by applying: (1) Bayesian derived occupancy probabilities to inform pre- or post-stratification of the data and surveys, (2) Stratification that incorporates information on the heterogeneity in the population (integrate known structural features), (3) Regression models that account for information correlated with the occupancy probabilities, such as spatial coherence, and (4) Inclusion of aggregated data collected at larger spatial or temporal scales (e.g., among regions).

3. RESULTS

- **Is the estimate and its variance reliable, consistent with input data and population biological characteristics, and useful as an estimate of absolute abundance of age 2+ red snapper?**

As described above in TORs 1 & 2, there is strong evidence that the estimate of absolute abundance of age 2+ red snapper is biased low, and the variance biased higher than proposed (e.g, > 11%). Conventional fishery-independent surveys provide relative abundance indices, which are scaled by catchability to get the total abundance. Since catchability is typically unknown, it is often estimated as a parameter in the assessment model. In the case of age 2+ red snapper, we have an absolute abundance estimate, as well as an estimate of confidence (CV) in the estimate. If there was confidence in the overall CV of 11%, then a stock synthesis model could fit to the estimate of CV, as well as other data such as relative indices, size/age composition, magnitude of fishery catch, etc. to predict total abundance. Given the uncertainty in the overall CV of 11%, it makes sense to try and refine the precision of the CVs, or see if the stock assessment models can be tuned to the regional numbers of age 2+ red snapper shown in Table 6 to assess the fit of predicted versus observed abundances. Lastly, federal landings statistics from the recreational fishery were not designed to estimate catch and effort during short (< 20 days) fishing seasons. A Before-After-Control-Impact design pairing experimental tag-recapture and depletion surveys (Before & After) with Recreational landings could help tune both indices over large spatial scales.

- **Assumptions and biases inherent to the methods:**
    - **Are assumptions made appropriate, given study design considerations?**

No, throughout the report, the sampling design is referred to as simple random or stratified random, when that was clearly not the case in certain regions and strata. For example, certain regions such as FL appear to have more robust estimates than other regions (e.g., LA), likely due to increased water clarity and greater sampling effort. Interestingly, FL had some of the lowest age + 2 snapper densities, which may reflect low recruitment or survival, or simply provide a more reliable set of population estimates based on the large sampling frame and high water clarity. Thus, the regional estimates may not be comparable for simply summing estimates across regions and habitats.

- - **Describe the magnitude and directionality of any biases.**

In general, the directionality of the biases in variance are high and precision low based on the differences in sampling efficiencies among habitat types and regions. For example, the need for extrapolation from strata that were either not sampled (e.g., artificial reefs in LA) or relatively under-sampled (e.g., UCB) will result in low precision of estimates. Regarding the magnitude of the biases, it is hard to determine without a better understanding of the sample sizes and calibrated gear efficiencies for hydroacoustics in the western portion of the GoM, as well as other factors. For example, despite the low capture efficiency of hydroacoustic gear, age +2 snapper densities west of the Mississippi River are ~ an order of magnitude greater than in the east (Table 6), which suggests that the magnitude of the bias (underestimate) could be quite high.

4. CONCLUSIONS

In conclusion, this is a VERY impressive team of some of the best fisheries ecologists, modelers and field personnel that could have been assembled for such an ambitious project. The type of field sampling in the open waters of the GoM can be extremely challenging. Just as challenging, is the coordination of this massive sampling effort, the sharing of information as trends began to emerge, and the need for flexible and coordinated responses. Moreover, the knowledge gained regarding age 2+ red snapper distribution and abundance patterns, refinements of novel and traditional sampling methods, and potential refinements to the results of stock assessment models will advance the field of marine fisheries science. I agree with many of the Sampling Biases already identified by the team in terms of direction, uncertainty and validity of the abundance estimates. Although I have confidence that the general magnitude of the absolute abundance estimate is true, I am feel the overall variance estimate is likely higher than 11%. Moreover, there appears to be interesting spatial structure to the variance and density estimates that could be explored further via sensitivity analyses and simulation modeling. I also agree with many of the future research recommendations, with improved maps of UCB and understanding of age 2+ red snapper spatial dynamics as key needs. Funding should be provided to work up the tissue samples from the individual fish, and perhaps begin a pilot study of the efficacy of eDNA as a means to assess presence/absence. Lastly, positive engagement with the public, especially snapper fishermen, and identification of best communication methods to reach the public, will positively translate to related studies in the Gulf and beyond.

5. LITERATURE CITED

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