Spatial Analyses of Commercial and Recreational Catch (2019) Compared to Biomass Derived from the "Great Red Snapper Count"

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Abstract

This paper builds upon Gardner et al. 2022 which assigned commercial red snapper catch and effort to 1) assign recreational catch and effort in space, 2) sum commercial and recreational landings spatially, 3) overlay extractions with estimates of biomass from the "Great Red Snapper Count" (GRSC); 4) calculate exploitation (catch/abundance) rates from three scenarios of fishery yield. The degree of exploitation was highly heterogeneous with several localized hotspots on natural reefs along the continental shelf break, offshore areas of the Northeast Gulf of Mexico, the Florida Panhandle, and the Alabama Artificial Reef Zone. Regarding a major decision before the SSC in terms of what fraction of the total biomass might be accessible to the fishery, we draw the following conclusions: much of the biomass in the uncharacterized bottom (UCB) is not currently fished according to the 2019 spatial pattern of fishing effort and 'all structure' alone underestimates the existing footprint, indicating that some fraction of the UCB is currently fished. Assuming a similar pattern of spatial exploitation as in 2019 supports the all structure + an additional allocation of available biomass. This indicates that, if the spatial footprint of fishing effort remained the same as in 2019 and there is a desire to retain similar exploitation rates to 2019 estimates but assume abundances as estimated by the GRSC, this would support the catch recommendations from all structure plus an additional allocation. However, exploitation is not equal across the Gulf and given the high estimated exploitation rates in the Florida Panhandle and Alabama/MS these areas would experience increases in exploitation relative to other regions, if the spatial allocation of effort did not shift. This could result in high localized depletion in these regions. The exploitation maps developed here can directly aid fisheries managers by highlighting specific habitats and locations that should be carefully monitored as catch limits continue to increase.

Introduction

Understanding population rebuilding rates and potential sustainable exploitation levels is hindered by basic knowledge gaps regarding both the dynamics of red snapper and the behavior of the fleets targeting the species. New information on red snapper abundance from the GRSC (i.e., population estimates that are three-fold higher than from recent stock assessments; Stunz et al., 2021) raises the question in relation to potential future increases in red snapper quotas due to these increased abundance estimates, as a large component of the total biomass estimated in the GRSC study is on the uncharacterized bottom (UCB) and in areas that may not currently be fished by recreational or commercial fishermen. Here we use the same definition of uncharacterized bottom (UCB) as Stunz et al. (2021) which comprises habitat that is not differentiated as known artificial or natural structure. In the Florida part of the GRSC study, both known and unknown structure was retained within the UCB component, whereas in other states, known natural reef was separately identified. Two major uncertainties regarding the potential impacts of increases in quotas are 1) where might increased effort be concentrated, and 2) how might localized fishing effort impact the red snapper resource if fishing does not reallocate to other spatial locations.

High fishing pressure on known reefs could potentially increase production by reducing density and competition, thereby opening further habitat suitable for recruitment. This is consistent with population dynamics theory where fishery yields are maximized at intermediate biomass levels.

Conversely, density reduction on known reefs may attract fish from unstructured bottom, where they are currently inaccessible to exploitation, resulting in increased exploitation on the entire population.

The first step to beginning to understand the dynamics of exploitation and of the population is to identify the proportion of landings being extracted spatially by the commercial and recreational fishery. This would enable a better assessment of the ecosystem while also ascertaining the likelihood of localized depletion due to fishing hotspots. Gardner et al. 2022 used vessel monitoring system data to assign reef handline effort in space and time and logbook reports to assign catch to the fishing locations. This paper builds upon Gardner et al. 2022 to 1) assign recreational catch and effort in space, 2) sum commercial and recreational landings spatially, 3) overlay extractions with estimates of biomass from the "Great Red Snapper Count" (GRSC); 4) calculate exploitation (catch/abundance) rates from three scenarios of fishery yield.

Methods

Spatial Assignment of Commercial Catch

To spatially allocate commercial landings data, Vessel Monitoring System (VMS) data (mandated on all commercial fishing vessels in the Gulf of Mexico since 2007) from commercial reef fish vessels was linked to Trip Interview Program (TIP) landings in which data are collected by port agents with a mandate to obtain representative samples from federally managed species and provides detailed information from a subset of commercially permitted vessels, including weight of catch landed and a random subset of lengths and ages at the trip level (Saari, 2013).

The VMS-TIP linked data allows for broad coverage across the fisheries, while providing high spatial resolution, albeit necessitating a number of assumptions to fill data gaps. The first step in the filtering process was to identify trips that landed red snapper based on the TIP data. Using the VMS filtering methods outlined in O'Farrell et al. (2017), VMS data were subset to only GPS locations classified as actively "fishing" based on algorithms developed from patterns in fishing behavior using a feature engineering approach to differentiate fishing and steaming locations. The resultant filtered VMS data provided accurate estimates of latitude, longitude, time, and date of fishing locations. After the landings data for trips that targeted red snapper were collated from the TIP database, these trips were linked to the VMS data using the unique trip identifiers. This allowed filtering VMS trips (i.e., defined as an individual vessel departing and returning to port after fishing where a trip could span a single or multiple days) to those targeting red snapper and for which landings data were available. The combined VMS-TIP data set thus had trips associated with identified fishing locations targeting red snapper along with the associated landings in weight from these trips.

Most trips were composed of multiple fishing activities or locations (as determined by the analysis of VMS data), yet only total landings from the entire trip were recorded dockside (in the TIP database). Thus, an assumption about the percentage of landings occurring during each identified fishing event within a given trip was necessary. Due to lack of more refined data to assess the weight of red snapper landed during each fishing event, it was assumed that each event resulted in equivalent landings. The associated TIP landings from a given trip were thus equally allocated to all fishing locations from a trip, then the percent of landings from each habitat was calculated based on the number of habitat-linked fishing events and associated assigned landings.

The weighted average (i.e., by landings) of the proportion of catch in 2019 from each 10 x 10 km cell associated with a given state was then taken to develop a state-specific data set. The total Gulf extrapolated data set took the weighted average by state of the catch proportions by spatial cell and multiplied this by the total Gulf of Mexico commercial red snapper landings, which provided a general depiction of how landings were distributed across the entire management area (Figure 1). For the state and Gulf-wide extrapolated data sets, the states of Alabama and Mississippi were combined to retain consistency with NOAA reporting of Gulf-wide red snapper landings (SERO, 2020). For full details, see methods in Gardner et al. 2022.

Spatial Assignment of Recreational Catch

Estimates of 2019 recreational landings were derived from multiple federal and state specific datasets, using the same units (e.g. MRIP-CHTS) used in the previous red snapper stock assessment (SEDAR 52) by the NOAA SEFSC Sustainable Fisheries Division (V. Matter, NMFS personal communication). This rationale was so that we could divide 2019 landings by the SEDAR 52 stock assessment biomass in similar units. The estimates did not have the spatial resolution of the commercial landings, but did have estimates that could be tied to several covariates such as region, depth, distance to port, etc that could then be used to make estimates within the spatial framework. Reported landings in 2019 were then linked to the 10 x 10 km grid cells consistent with the Karnauskas et al. 2017 and the Gardner et al. 2022 studies to derive recreational landings, commercial landings, and biomass distribution all on the same spatial scale (Figures 2 and 3). We note that discards were not considered here.

State Specific Allocation

Spatial allocation of Florida recreational spatial landings were derived from two surveys of the recreational fishery; observer data from charter vessels and private vessel dockside interviews (B. Sauls, FWRI personal communication). These data include the reported number of anglers, CPUE, and location (Latitude/Longitude for observer points, approximately 10x10 nm blocks for private vessels). Data were collected on ~2500 private trips accounting for ~22000 red snapper caught and ~4000 retained. Observers on for-hire vessels collected data from~1750 trips accounting for ~26000 red snapper. The data were divided into three regions, the FL Panhandle, Cape San Blas to 28° N latitude (mid-FL) and S of 28° (S FL). The for-hire (charter boat observer data) and private surveys were treated as separate fleets with the proportion of total landings reported for each. Proportion catch per region was calculated as well as the proportion of catch from Gulf access points within each region for each fleet. These proportions were then allocated among the cells meeting each criteria for region and distance to pass. Reported 2019 landings (V. Matter, NMFS personal communication) were converted to kilograms and allocated according to the proportions in each grid cell.

Alabama landings were spatially allocated according to depth via proportions reported in Snapper Check (J. Mareska, AL DCNR personal communication). Reporting is mandatory for recreational anglers in Alabama and includes data such as number of anglers, time fishing, depth fished, fish landed, fish discarded (Outdoor Alabama, 2022). These data reported ~62,000 red snapper targeted trips between 2016-2018 landing an estimated 631,000 fish. Data were partitioned by proportion of total landings per depth strata then applied to 2019 reported landings (V. Matter, NMFS personal communication) to all cells meeting the criteria for depth. Because of the relatively short Alabama coastline and limited number of ports, cells within the same depth zone were allocated equally.

Spatial allocation of Mississippi recreational landings were applied to the same depth framework as Alabama then allocated according to reported 2019 recreational landings (V. Matter, NMFS personal communication).

Spatial allocation of Louisiana recreational landings were derived from voluntary dockside interviews collected between 2018-2021 by the Louisiana Department of Wildlife and Fisheries in which information was gathered from approximately 2400 private and charter trips. Data gathered included depth fished, primary target species, Bureau of Ocean Energy Management (BOEM) grid/lease location (BOEM 2022), and natural or artificial habitat (J. Adriance, LDWF, personal communication). From these data, proportion of trips targeting/landing red snapper were applied to the reported 2019 landings (V. Matter, NMFS personal communication) and allocated into the 10x10 km blocks of which the centroid of the 10 x 10 km blocks coincided with the BOEM grid and depth attributes.

Spatial allocation of Texas recreational landings were estimated by using iSnapper data (iSnapper, 2022; G. Stunz, TAMUCC, personal communication). The data analyzed were collected between 2017-2020 as part of a voluntary self-reporting application (Harte Research Institute, 2022) in which fishers reported locations fished (Latitude, Longitude) as well as number of fishermen and total red snapper landed. Data were filtered to remove erroneous points (on land, in estuaries, deeper than 200m) leaving approximately 800 fishing trips landing ~7000 red snapper. Proportion of catch were allocated by distance from port and applied to the 10x10 km blocks meeting those criteria.

The resultant overlaid spatially explicit data provided estimates of recreational landings were combined with commercial estimates at the same spatial resolution, as well as varying levels of red snapper biomass We then calculated an index of relative red snapper exploitation by dividing landings in each 10 × 10 km cell by the relative biomass in each cell (two levels of biomass x two distributions).

Biomass Distributions

At present, one of the most comprehensive, high resolution spatial maps of red snapper distribution currently available in the Gulf of Mexico is a Gulf-wide statistical model providing predictions at a 10 × 10 km cell resolution (i.e., matching the cell grid used here to extrapolate landings; Karnauskas et al. 2017; Figure 4). The Karnauskas et al. (2017) analysis used extensive synoptic sampling from the 2011 Congressional Supplemental Sampling Program, and has previously been recognized as the best scientific information available for determining red snapper distribution across the Gulf of Mexico (GMFMC, 2019). It also explicitly places fish on known natural and artificial structure which likely gives more precise spatial allocation of distribution particularly within a region. The static spatial distributions of red snapper from Karnauskas et al. (2017) were scaled in two distributions to assign biomass values to each cell. The first used the Karnauskas et al. 2017 distribution scaled to each states values for the GRSC, while the second scaled the Karnauskas et al. 2017 distribution to GRSC values for state, region, and depth.

Numbers of age 2+ red snapper per state from the "Great Red Snapper Count" (GRSC) (Stunz et al., 2021) were converted to biomass using region specific average weights from the SEDAR 52 stock assessment (SEDAR, 2018) and allocated according to four estimates of biomass distribution. These included: 1) the GRSC value of 96.7M fish to a version of the Karnauskas et al. 2017 distribution with individual state values allocated 2) the GRSC value of 96.7M fish distributed to state, regional, and depth strata scaled to regional values of the Karnauskas et al. 2017 3) the post-stratification estimate of 94.3M fish in which FL was divided into four depth zones (10-25m, 25-40m, 40-100m, 100m+) applied to the Karnauskas et al. 2017 with individual state values and 4) the post-stratification estimate of 94.3M fish applied to the state, regional, and depth strata scaled to regional values of the Karnauskas et al. 2017 (Figures 5-8). The first distribution assumes that Karnauskas et al 2017 is the best spatial allocation of the overall GRSC biomass, (2) assumes the state, regional, and depth strata as estimated by the GRSC but distributed by Karnauskas et al within a state, region and depth, (3) and (4) do the same but with the depth-post-stratified GRSC values.

The four biomass distributions showed a number of key differences, particularly with the more recent GRSC state and region allocations indicating higher biomass in the East relative to the West, and the post-stratification according to depth placing more of the GRSC biomass in the 25-40 m depth ranges and the GRSC not estimating a hotspot of biomass distribution north of the Dry Tortugas as does Karnauskas et al. 2017. Nonetheless, the biomass distributions are broadly similar and when we report overall exploitation rates by state and region we average across them.

Exploitable Biomass Calculations

Exploitation rates and proportion of biomass overlapping with current fishing were calculated for each of the biomass distributions listed above. Exploitation rate was simply derived from dividing the total landings (2019) in a 10 x 10 km block (commercial plus recreational) by the estimated biomass per each distribution. When removals exceeded biomass, the index value was capped at 1.0. Additionally, we assumed that landings were primarily age-2+ to match the biomass estimates, which is generally reasonable given that there are effectively no landings of age-1 fish in either fishery (Figure 9).

To identify the fraction of 'fished' biomass, we explored various levels of exploitation ranging from 0.0001 to 0.1 at each of the aforementioned biomass distributions. This yielded the fraction of biomass available to the fishery (i.e. the biomass at or above the defined level of exploitation) as well as estimates of catch in unallocated areas. For demonstration purposes, we designated fishing as an exploitation rate ≥ .01, corresponding to greater than or equal to 1% of the biomass in the grid square being removed annually. For context, using commercial catch rate data this was usually greater than 500 lbs of red snapper removed from a 10 x 10 km block. This value yielded a proportion of biomass available to exploitation between 43.6-45.9% while accounting for 90-96% of the landings. A summary of values of biomass available and unallocated catch per distribution are available in Tables 1-2 and an example of the exploitation/unallocated catch curves is available in Figure 10.

Catch analyses

The SSC recently requested catch analyses based on two estimates, the 96.7 million fish with and without post stratification at three levels of yield (the All structure model, All Structure + 10% UCB and All Structure +15% UCB) (GMFMC, 2022). Additionally, these analyses have been performed on the two biomass distributions described above (Karnauskas et al scaled to state GRSC numbers and Karnauskas et al scaled to state, depth, and regional GRSC numbers). Total yield of the three scenarios was provided by the NOAA SEFSC Sustainable Fisheries Division at values of 19.52 million pounds (All Structure), 22.11 million pounds (All Structure + 10% UCB), and 23.41 million pounds (All Structure +15% UCB) (M. Smith, NMFS, 2022 personal communication). Weight values were converted to kg then exploitation rates calculated for each of the biomass estimates and distributions (e.g. 2 biomass scenarios x 2 distributions x 3 yield) estimates) (Figures 11-13).

Additionally, calculations are provided for proportion biomass above a defined exploitation rate (.122, .3, and .5) for each of the scenarios biomass, distribution, and yield level (All Structure, All Structure +10% UCB, All Structure +15% UCB) to highlight areas that could be susceptible to localized depletion (Tables 3-5). The exploitation level of 0.122 was derived from a draft value for F_{MSY} as approximated by a spawner potential ratio, SPR, of 26% in the interim catch advice for the Gulf of Mexico Red Snapper Stock (NMFS, 2021). Exploitation levels of .3 and .5 are for demonstration purposes only.

To determine which level of exploitation was closest to previous stock assessment (SEDAR, 2018), overall exploitation levels were calculated for estimates of biomass of age 2+ from SEDAR52 distributed according to the GRSC state, regional, and depth patterns. We note that the biomass estimates were from the terminal year (2016) of SEDAR52 so the exploitation rates should be considered relative rather than absolutes. The overall exploitation rates were capped at 1.0 in areas where landings exceeded biomass estimates and compared to similarly derived estimates from the GRSC estimates.

Overall, the SEDAR52 estimates of biomass distributed according to the GRSC values had an exploitation rate of 0.148 for 2019 (Table 6). The mean population exploitation rates for the various distribution and yield scenarios were: "all structure"- 0.102, "all structure + 10% UCB"- 0.112, and "all structure +15% UCB"- 0.116. An overview of the various distributions are available in Table 6.

To summarize the 2019 estimated exploitation rates we averaged over the four biomass distributions to obtain mean exploitation rates (Figure 14) according to four different catch scenarios: baseline 2019 exploitation rates (see Figure 9), All structure, All Structure + 10% UCB and All Structure + 15% UCB averaged across the four spatial biomass allocation scenarios outlined in Figures 5-8. The Alabama/Mississippi and NW-FL regions both were estimated to experience relatively high exploitation in 2019 with fairly substantial increases under each catch scenario. In contrast other regions experience much lesser increases. This is based on assuming the 2019 spatial pattern of exploitation rates for both commercial and recreational fisheries.

As with any analysis of this magnitude there are many assumptions inherent here, particularly regarding the spatial allocation of catch and effort, which is well characterized for the commercial fishery but less characterized for the recreational fishery. Second it requires assumptions about where the red snapper biomass is distributed, of which we provide four possibilities; in each case they use the GRSC state allocations but distribute fish according to depth and regional allocations, using the Karnauskas et al. 2017 mapping for further partitioning with a depth or region, as noted. The other main assumption inherent in Figure 14 is that the spatial pattern of fishing remains similar to 2019. While there may be spatial reallocation of fishing within a region, which would not affect the estimates in Figure 14, it remains to be seen whether substantial reallocation across regions could be achieved. Futhermore, as we use SEDAR 52 biomass estimates with a terminal year of 2016 divided by 2019 catch, so the exploitation rates estimated for SEDAR 52 should be taken as relative and approximate and may not reflect overall values from SEDAR52. Lastly we note that this is only a first step in answering the question of how local exploitation may affect population dynamics of red snapper.

Conclusions

We conducted this analysis to assist the SSC in consideration of revised GRSC catch advice. Two key uncertainties exist regarding what the impacts of increased quotas might be on the red snapper population: how the fleets might reallocate spatially and, if they do not, what might be the impacts of locally higher exploitation? The spatial maps of exploitation rate give some indications of how local exploitation rates might increase with increased catches and with various assumptions regarding the spatial distribution of red snapper and the commercial and recreational fishery.

From the standpoint of the major decision before the SSC in terms of what fraction of the total biomass might be accessible to the fishery, we can draw the following conclusions from the analyses in this paper:

- majority of biomass in the UCB is very lightly exploited according to recent (2019) spatial pattern of fishing effort
- ‘all structure’ alone underestimates the existing footprint, indicating that some fraction of the UCB is currently fished.
- Assuming similar pattern of spatial exploitation as in 2019 supports some fraction of UCB for allocation of available biomass for catch advice

- Exploitation is not equal across Gulf; NW_FL and AL/MS experience higher exploitation and would experience increases in exploitation relative to other regions, if the spatial allocation of effort did not shift.

This indicates, that, if the spatial footprint of fishing effort remained the same as in 2019 and there is a desire to retain similar spatial exploitation rates to 2019 estimates, but assume abundances as estimated by the GRSC, existing, locally high exploitation rates may increase.

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Tables:

Table 1: Proportion biomass available to the fishery at or above each level of exploitation per each of the distributions explored.

Biomass available to fishery				
Exploitation rate	96M Karnauskas	96M GRSC	ReDist94M Karnauskas	ReDist94M GRSC
0.001	0.840	0.885	0.843	0.862
0.005	0.574	0.635	0.579	0.579
0.01	0.454	0.451	0.459	0.436
0.025	0.277	0.271	0.280	0.270
0.05	0.170	0.161	0.172	0.154
0.1	0.095	0.085	0.098	0.081

Table 2: Proportion landings unallocated below each level of exploitation per each of the distributions explored

Unallocated catch				
Exploitation rate	96M Karnauskas	96M GRSC	ReDist94M Karnauskas	ReDist94M GRSC
0.001	0.002	0.004	0.002	0.044

0.005	0.019	0.023	0.019	0.064
0.01	0.040	0.057	0.039	0.090
0.025	0.112	0.131	0.111	0.158
0.05	0.204	0.227	0.201	0.261
0.1	0.339	0.366	0.334	0.386

Table 3: Proportion biomass above exploitation level of 0.122 for each biomass level and distribution, region, and yield scenario.

	Scenario	TX	LA	ALMS	NW_FL	FL_midregion	S_FL	Gulf Wide Total
All Structure	96M Karnauskas	0.059	0.061	0.383	0.527	0.164	0.000	0.103
	96M GRSC	0.059	0.058	0.371	0.819	0.051	0.009	0.092
	ReDist94M_Karnauskas	0.059	0.061	0.383	0.622	0.167	0.000	0.108
	ReDist94M_GRSC	0.059	0.058	0.371	0.590	0.047	0.005	0.086

	Scenario	TX	LA	ALMS	NW_FL	FL_midregion	S_FL	Gulf Wide Total
All Structure + 10% UCB	96M Karnauskas	0.065	0.069	0.419	0.685	0.180	0.001	0.119
	96M GRSC	0.060	0.063	0.413	0.926	0.066	0.010	0.104
	ReDist94M_Karnauskas	0.065	0.069	0.419	0.697	0.185	0.001	0.120
	ReDist94M_GRSC	0.066	0.067	0.420	0.793	0.055	0.008	0.101

	Scenario	TX	LA	ALMS	NW_FL	FL_midregion	S_FL	Gulf Wide Total
All Structure + 15% UCB	96M Karnauskas	0.067	0.070	0.432	0.697	0.185	0.001	0.122
	96M GRSC	0.066	0.067	0.420	0.926	0.077	0.012	0.110
	ReDist94M_Karnauskas	0.067	0.070	0.432	0.729	0.203	0.001	0.125
	ReDist94M_GRSC	0.066	0.067	0.420	0.793	0.055	0.008	0.101

Table 4: Proportion biomass above exploitation level of 0.3 for each biomass level and distribution, region, and yield scenario.

	Scenario	TX	LA	ALMS	NW_FL	FL_midregion	S_FL	Gulf Wide Total
All Structure	96M Karnauskas	0.059	0.061	0.383	0.527	0.164	0.000	0.103
	96M GRSC	0.059	0.058	0.371	0.819	0.051	0.009	0.092
	ReDist94M_Karnauskas	0.059	0.061	0.383	0.622	0.167	0.000	0.108
	ReDist94M_GRSC	0.059	0.058	0.371	0.590	0.047	0.005	0.086

	Scenario	TX	LA	ALMS	NW_FL	FL_midregion	S_FL	Gulf Wide Total
All Structure + 10% UCB	96M Karnauskas	0.065	0.069	0.419	0.685	0.180	0.001	0.119
	96M GRSC	0.060	0.063	0.413	0.926	0.066	0.010	0.104
	ReDist94M_Karnauskas	0.065	0.069	0.419	0.697	0.185	0.001	0.120
	ReDist94M_GRSC	0.060	0.063	0.413	0.714	0.051	0.006	0.095

	Scenario	TX	LA	ALMS	NW_FL	FL_midregion	S_FL	Gulf Wide Total
All Structure + 15% UCB	96M Karnauskas	0.067	0.070	0.432	0.697	0.185	0.001	0.122
	96M GRSC	0.066	0.067	0.420	0.926	0.077	0.012	0.110
	ReDist94M_Karnauskas	0.067	0.070	0.432	0.729	0.203	0.001	0.125
	ReDist94M_GRSC	0.066	0.067	0.420	0.793	0.055	0.008	0.101

Table 5: Proportion of biomass above exploitation level of 0.5 for each biomass level and distribution, region, and yield scenario.

	Scenario	TX	LA	ALMS	NW_FL	FL_midregion	S_FL	Gulf Wide Total
All Structure	96M Karnauskas	0.059	0.061	0.383	0.527	0.164	0.000	0.103
	96M GRSC	0.059	0.058	0.371	0.819	0.051	0.009	0.092
	ReDist94M_Karnauskas	0.059	0.061	0.383	0.622	0.167	0.000	0.108
	ReDist94M_GRSC	0.059	0.058	0.371	0.590	0.047	0.005	0.086

	Scenario	TX	LA	ALMS	NW_FL	FL_midregion	S_FL	Gulf Wide Total
All Structure + 10% UCB	96M Karnauskas	0.065	0.069	0.419	0.685	0.180	0.001	0.119
	96M GRSC	0.060	0.063	0.413	0.926	0.066	0.010	0.104
	ReDist94M_Karnauskas	0.065	0.069	0.419	0.697	0.185	0.001	0.120
	ReDist94M_GRSC	0.060	0.063	0.413	0.714	0.051	0.006	0.095

	Scenario	TX	LA	ALMS	NW_FL	FL_midregion	S_FL	Gulf Wide Total
All Structure + 15% UCB	96M Karnauskas	0.067	0.070	0.432	0.697	0.185	0.001	0.122
	96M GRSC	0.066	0.067	0.420	0.926	0.077	0.012	0.110
	ReDist94M_Karnauskas	0.067	0.070	0.432	0.729	0.203	0.001	0.125
	ReDist94M_GRSC	0.066	0.067	0.420	0.793	0.055	0.008	0.101

Table 6: Exploitation rates per each distribution and SEDAR52 estimates set to each distribution.

Scenario	96M Karnauskas	96M GRSC	ReDist94M Karnauskas	ReDist94M GRSC
SEDAR52 exploitation rate	0.153	0.148	0.153	0.171
All structure	0.105	0.102	0.107	0.121
All structure + 10% UCB	0.115	0.111	0.117	0.132
All structure + 15% UCB	0.120	0.116	0.122	0.137

Figures:

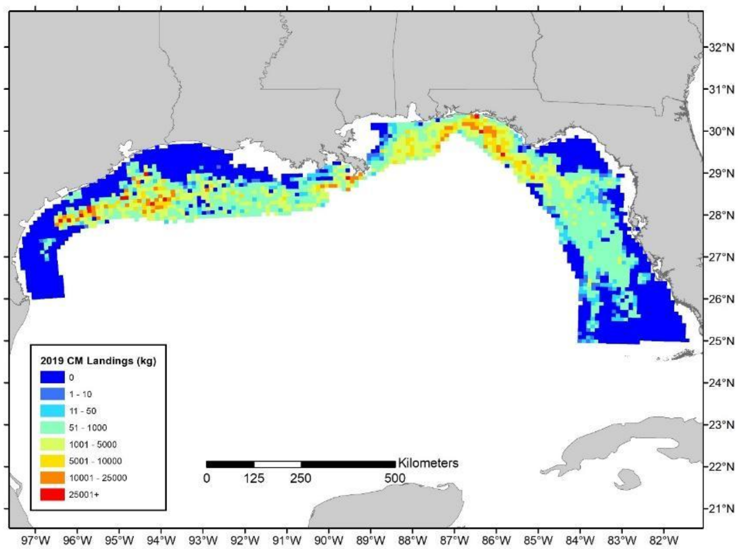

Figure 1: 2019 commercial landings (kg per 10 x 10 km block). Data derived from linking commercial red snapper landings to VMS fishing locations.

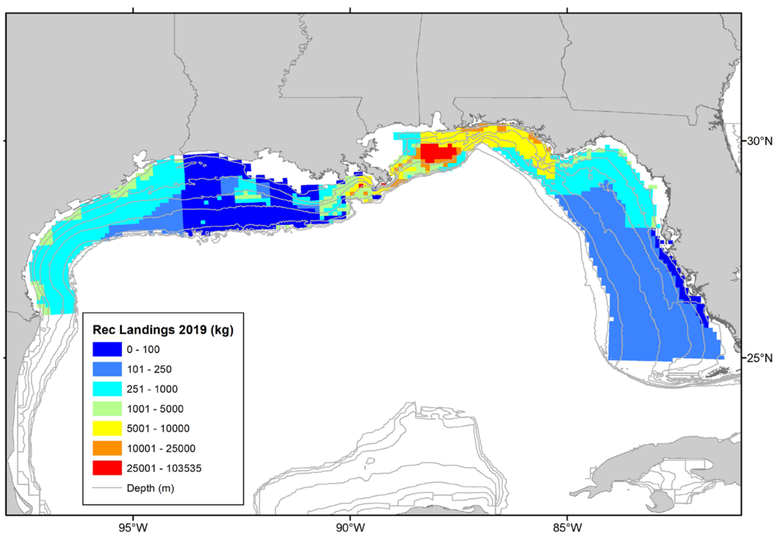

Figure 2: 2019 estimated recreational landings (kg per 10 x 10 km block). Estimated from individual state reporting programs.

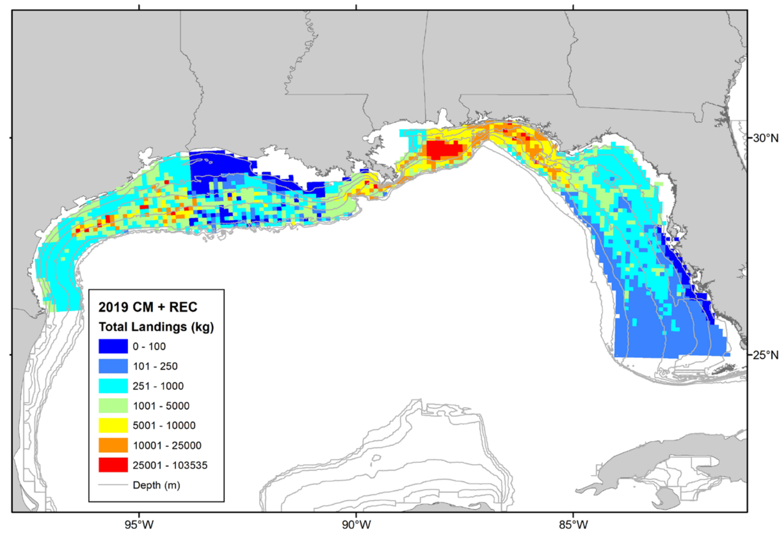

Figure 3: 2019 commercial and estimated recreational landings (kg per 10 x 10 km block).

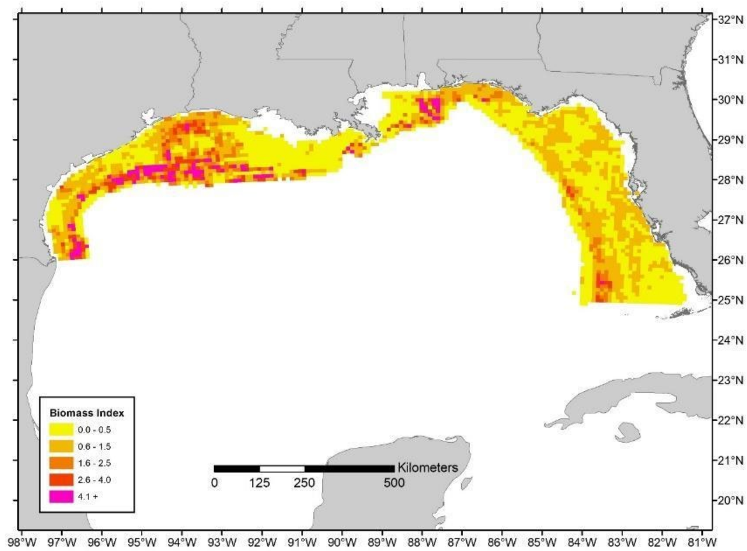

Figure 4: Relative biomass index reproduced from Karnauskas et al. (2017).

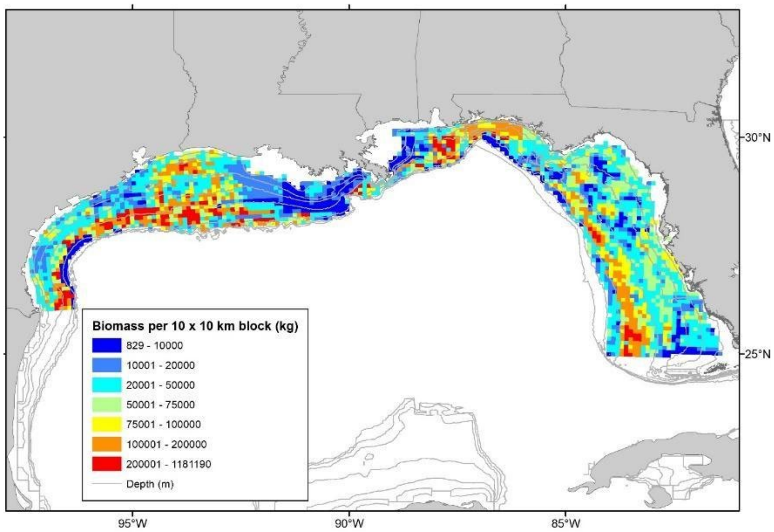

Figure 5: Biomass distribution of 96.7 million red snapper according to state scaled Karnauskas et al. 2017 distribution.

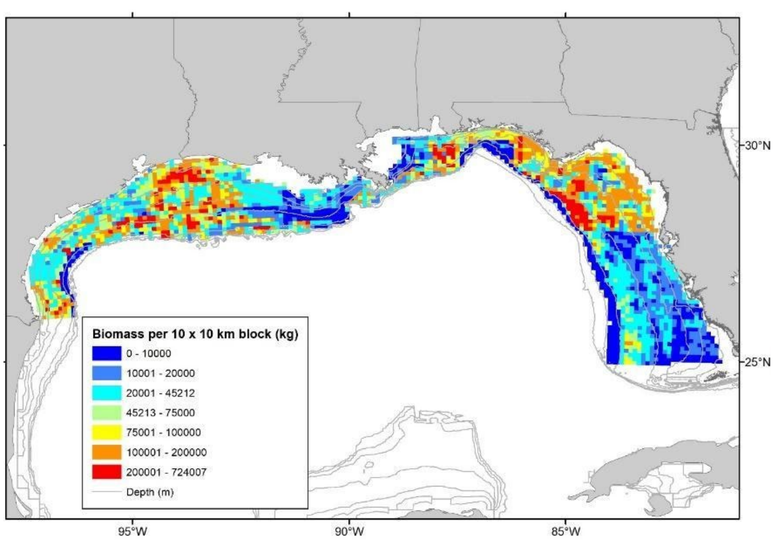

Figure 6: Biomass distribution of 96.7 million red snapper according to state, region, and depth scaled values of the GRSC to Karnauskas et al. 2017.

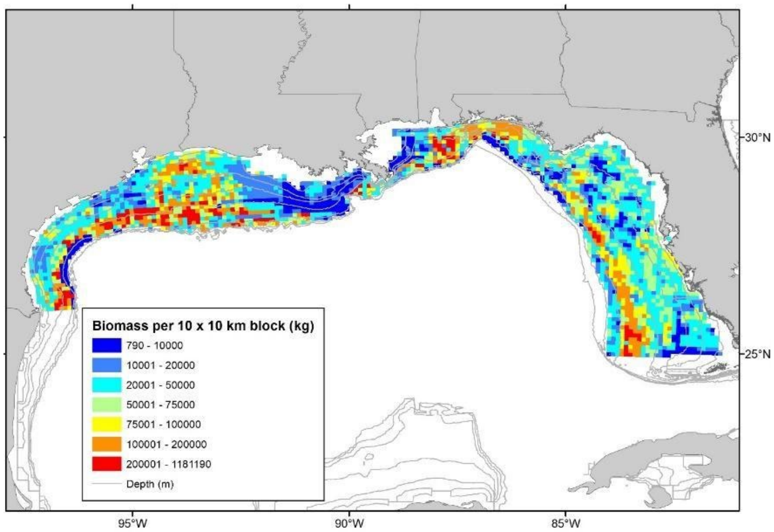

Figure 7: Biomass distribution of the post-stratified GRSC numbers (94.3 M) according to state scaled Karnauskas et al. 2017 distribution.

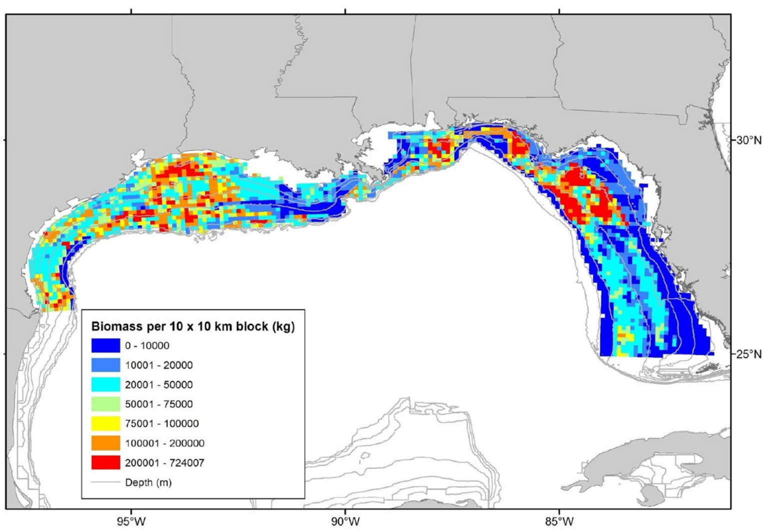

Figure 8: Biomass distribution of the post-stratified GRSC numbers (94.3 M) according to state, region, and depth scaled values of the GRSC to Karnauskas et al. 2017.

Catch Analysis 1:
96.7 M fish
Post-stratification=no

Catch Analysis II:
94.3 M fish
Post-stratification=yes

Karnauskas et al. 2017
State distribution to GRSC #'s

Karnauskas et al. 2017
State/region/depth distribution to GRSC #'s

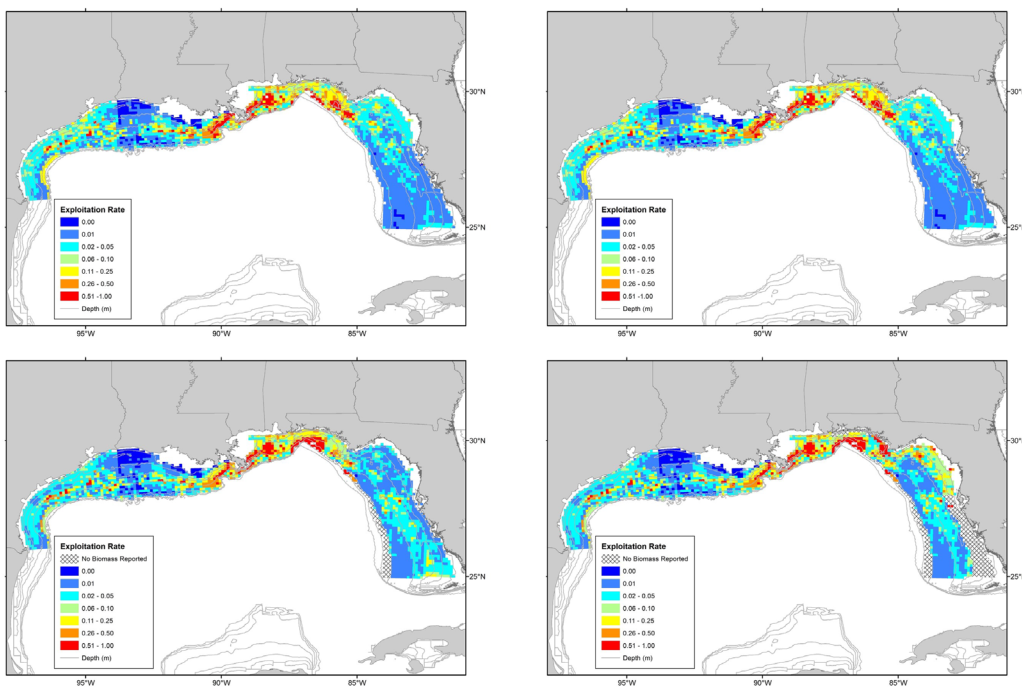

Figure 9: 2019 exploitation rates for commercial and recreational catches combined. Analysis is presented for two distributions and two levels of biomass.

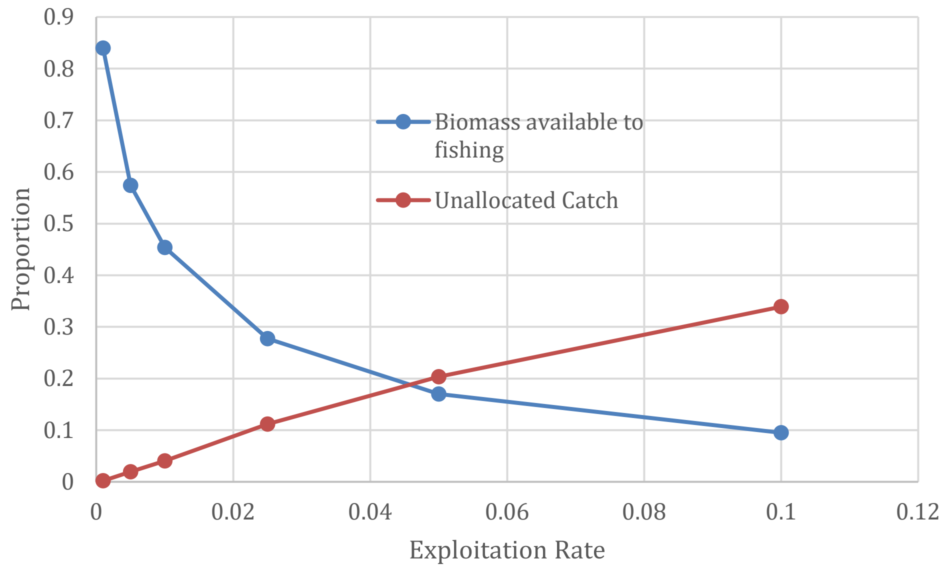

Figure 10. Biomass available to fishery and unallocated catch per exploitation rate. This example is based on the GRSC value of 96.7M fish applied to the Karnauskas et al. distribution of biomass per state.

Catch Analysis 1:
96.7 M fish
Post-stratification=no

Catch Analysis II:
94.3 M fish
Post-stratification=yes

Karnauskas et al. 2017
State distribution to GRSC #'s

Karnauskas et al. 2017
State/region/depth distribution to GRSC #'s

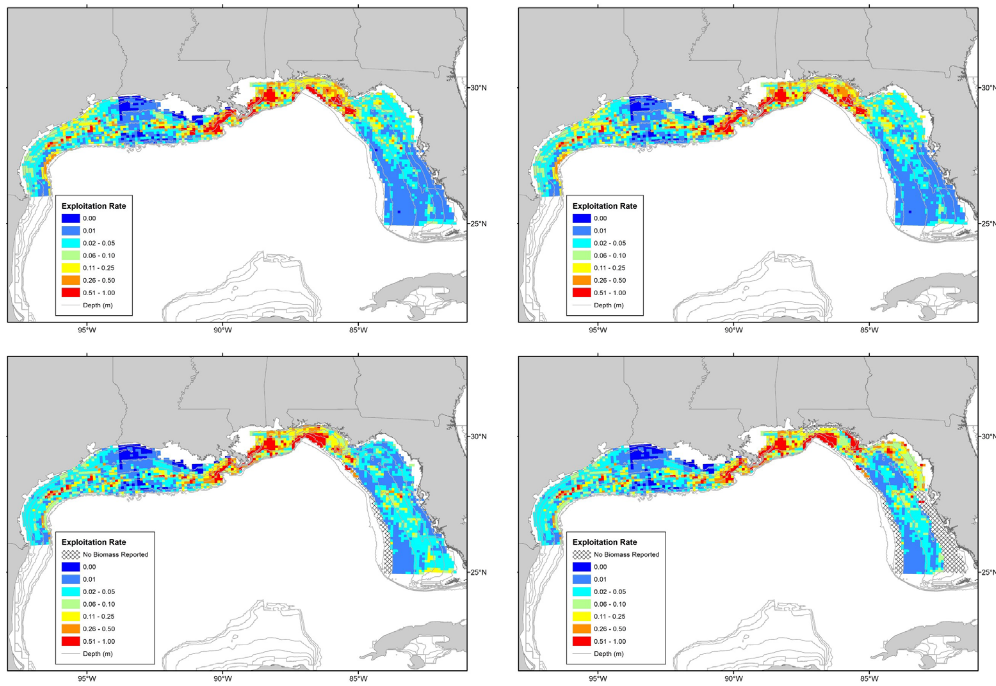

Figure 11: Exploitation rates based "All Structure" yield estimate of 19.52 million pounds. Catch analysis is presented for two distributions and two levels of biomass.

Catch Analysis 1:
96.7 M fish
Post-stratification=no

Catch Analysis II:
94.3 M fish
Post-stratification=yes

Karnauskas et al. 2017
State distribution to GRSC #'s

Karnauskas et al. 2017
State/region/depth distribution to GRSC #'s

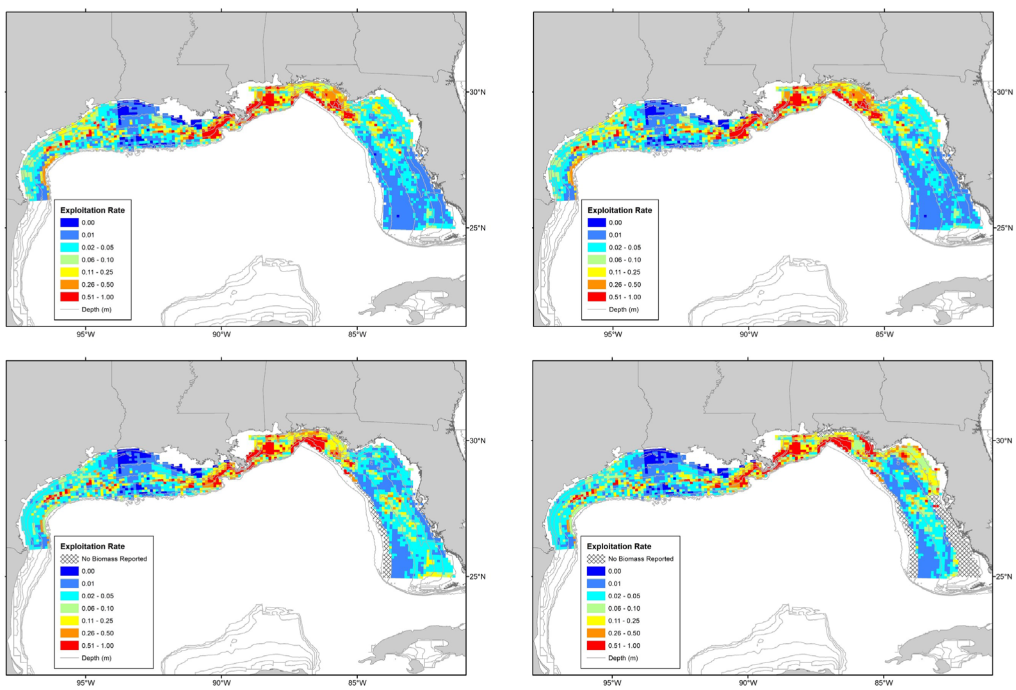

Figure 12: Exploitation rates based "All Structure + 10% UCB" yield estimate of 22.11 million pounds. Catch analysis is presented for two distributions and two levels of biomass.

Catch Analysis 1:
96.7 M fish
Post-stratification=no

Catch Analysis II:
94.3 M fish
Post-stratification=yes

Karnauskas et al. 2017
State distribution to GRSC #'s

Karnauskas et al. 2017
State/region/depth distribution to GRSC #'s

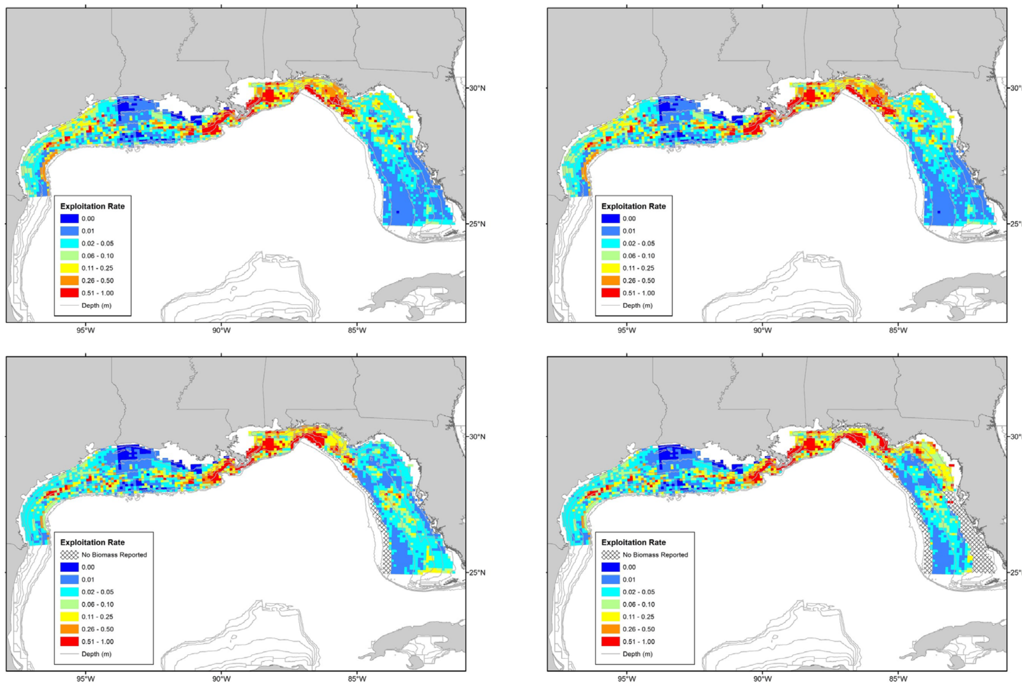

Figure 13: Exploitation rates based "All Structure + 15% UCB" yield estimate of 23.41 million pounds. Catch analysis is presented for two distributions and two levels of biomass.

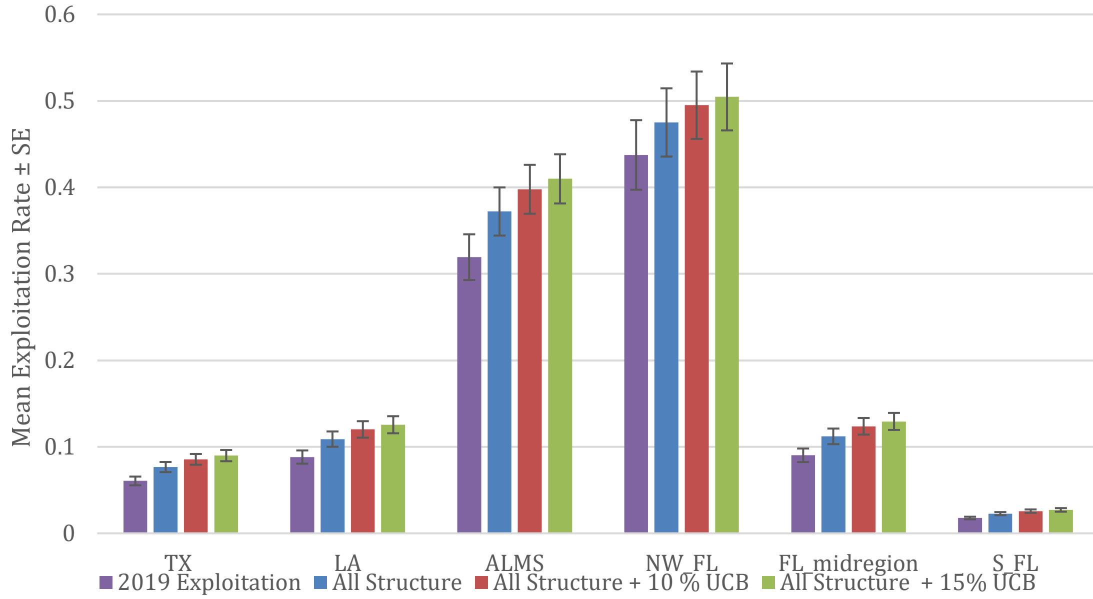

Figure 14. Exploitation rates by region according to four different catch scenarios: baseline 2019 exploitation rates (see Figure 9), All structure, All Structure + 10% UCB and All Structure + 15% UCB averaged across the four spatial biomass allocation scenarios outlined in Figures 5-8.