2014 Gulf of Mexico Red Snapper Recreational Slot Limit Analysis

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Introduction

On October 1, 2013, NOAA Fisheries published a final rule (78 FR 57314) implementing an 11 million pound whole weight (mp ww) total allowable catch for Gulf of Mexico (Gulf) red snapper. This catch level was the highest ever for red snapper and was allocated 51% to the commercial sector (5.61 mp ww) and 49% to the recreational sector (5.39 mp ww). The catch level is expected to remain at 11 mp through the 2014 season, but will be updated following the next stock assessment, which is scheduled for completion in late 2014.

The rebuilding of red snapper has, somewhat counterintuitively, led to progressively shorter recreational fishing seasons. In 2006, the season was 194 days. In 2013, it was just 42 days. Accounting for landings from extended state seasons with regulations that differ from federal regulations (**Table 1**), the increased catch rates observed by the newly-implemented Marine Recreational Information Program (MRIP) in 2013, and incorporating a 20% buffer between the annual catch limit (ACL) and annual catch target (ACT) in 2014, NOAA Fisheries projected the 2014 red snapper federal season would last only 9 days (SERO-LAPP-2014-02).

Recreational fishing regulations are becoming more and more restrictive as the red snapper population increases because, on average, the fish are bigger and easier to catch. In 2014, recreational fishermen are projected to land fish at over four times the rate they did in 2007—over 26,600 fish per day in 2014 as compared to 6,000 fish per day in 2007 (SERO-LAPP-2014-02). At the same time, the fish are getting bigger. The mean weight of recreationally landed red snapper has increased from around 3.5 pounds per fish to over 7 pounds per fish over the past decade (SERO-LAPP-2013-10, SERO-LAPP-2014-02). Consequently, although catch limits have nearly doubled since 2007, recreational landings (lbs) per day have increased greater than 9X (i.e., from 23,223 lbs/day in 2007 to 219,489 lbs/day projected in 2014). Thus, although managers have been able to raise the catch limit each year since 2010, they have had to progressively shorten the recreational fishing season to stay within the increasing catch limits (SERO-LAPP-2013-10, SERO-LAPP-2014-02).

This analysis examines the utility of a recreational slot limit for Gulf red snapper to extend the recreational fishing season by reducing the average weight of a landed fish and to promote rebuilding by increasing survivorship of larger, more fecund fish. Outputs include percent impacts on total removals, changes in recreational season length, and impacts on stock egg production.

Methods

Model Framework

The Gulf red snapper Southeast Data, Assessment and Review (SEDAR-31) benchmark assessment was completed in 2013. The base run of the assessment used to generate management advice and status determination criteria was implemented using Stock Synthesis 3 (SS3). SS3 provides a statistical framework for calibration of a population dynamics model using a diversity of fishery and survey data. It is designed to accommodate both age and size structure in the population from multiple stock sub-areas. The assessment for red snapper sub-divided the Gulf of Mexico into Eastern (Florida, Alabama, and Mississippi) and Western (Louisiana and Texas) areas, which were combined to generate management advice.

The slot limit analysis was implemented in Microsoft Excel, with separate tabs for each simulated slot limit combination. To simulate the impacts of a slot limit, the SS3 retention function was modified to simulate minimum retention sizes from 13-16 inches total length ("), and maximum retention sizes from 24-30". No minimum size limit with maximum size limits of 24-30" was also simulated. The SS3 assessment model contained length data in 2 cm bins; these were converted to inches and rounded to assign bins to slot limits. As the SS3 base run simulated retention as a asymptotic distribution with some retention below the minimum size limit, this distribution was retained for slot limit analyses by shifting the undersized retention downward for smaller minimum size limits. Similarly, if a maximum size limit is imposed, some retention above the maximum size limit is expected to occur. The lower tail of the retention function for undersized fish was mirrored for the upper tail and used as a proxy to simulate retention of fish above the maximum size limit, rather than assuming knife-edged retention.

Management Target

As some slot limit alternatives reduce average landed weight sufficiently to allow for an extension of the recreational season, the management target became an important consideration. The current 51% commercial/49% recreational allocation (and all revised allocations currently considered under Reef Fish Amendment 40) is based on landed catch, with dead discards accounted for in the stock assessment and deducted from projected yield levels before setting landings-only catch limits. The current management targets for quota closures are specified in landed catch, as ACLs and ACTs. Determining the length of the recreational season based on total removals rather than when landings reach the ACT accounts for increased dead discards outside the slot limit that are not inherently accounted for in current stock assessment yield projections.

To simplify comparisons under different slot limits, all comparisons were done relative to a baseline (i.e., 'status quo') run under the SS3-modeled 16" TL minimum size limit. Managing towards 100% of status quo landings would result in longer seasons than managing towards 100% of status quo removals; however, the failure to account for increased dead discards might slow rebuilding, resulting in lower future quotas and reduced future stock productivity. At their January 2014 meeting, the Gulf Council's Scientific and Statistical Committee (SSC) received a presentation discussing the tradeoffs of managing towards a slot limit target of 100% landings vs. 100% status quo removals. All analyses presented herein achieve a management target of 100% status quo removals, which was recommended by several SSC members.

Landings and Removals

For each slot limit run, total landings and removals in numbers and weight were summed for the Eastern and Western Gulf of Mexico. The Eastern and Western Gulf outputs were summed to determine the Gulfwide impacts. All comparisons were made relative to a base run at the status quo federal minimum size limit of 16". All analyses assumed the slot limit would apply to all recreational red snapper landings in the Gulf. This implicitly assumed that all states would adopt slot limit regulations consistent with federal regulations, and that other state regulations would be consistent with 2012, when only Texas had regulations inconsistent with federal regulations.

The slot limit analysis was implemented in steps, using initialization values from the midpoint of the final year of input data (i.e., 2012) from the SEDAR-31 (2013) SS3 base run. Numbers-at-age from SS3 were converted to numbers-at-length based on proportions of fish sizes at each age from the SEDAR-31 (2013) base run (**Figure 1**). Landed catch in numbers was computed as the product of fleet-specific selectivity at age ($S_{age,\ fleet}$), the percent of fish at age by length ($P_{age|length}$), the number at length (N_{length}), the fleet-specific fishing mortality rate (F_{fleet}), and the fleet-specific retention at length ($R_{length,\ fleet}$), summed across lengths and fleets:

$$Landings_N = \sum_{length=0}^{l_\infty} \sum_{fleet=1}^{n} \left(S_{fleet}^{age} \times P_{age|length} \times N_{length} \times F_{fleet} \times R_{fleet}^{length} \right) \qquad (1)$$

Landed catch in weight was computed by converting numbers-at-length (N_{length}) to biomass-at-length (B_{length}) using the conversion equation from SEDAR-31 (2013):

$$Whole\ Weight_{lb} = \ 2.20462\ lb/kg\ \times (1.67 \times 10^{-5} \times TL_{cm}^{2.953}) \qquad (2)$$

where TL_{cm} is the total length, in cm. Biomass-at-length was then summed across the fleets to determine landed catch in weight.

Removals in numbers were computed as the sum of landings in numbers and dead discards, across lengths and fleets:

$$Removals_N = \ Landings_N + \rho \left[\sum_{length=0}^{l_\infty} \sum_{fleet=1}^{n} \left(S_{fleet}^{age} \times P_{age|length} \times N_{length} \times F_{fleet} \times \left(1 - R_{fleet}^{length}\right) \right) \right] \qquad (3)$$

where ρ denotes the release mortality rate. Removals in weight were computed by applying equation 2 to removals in numbers, by length. SEDAR-31 (2013) assumed ρ = 10%, based on observations from 2008-2011, during which time there was a venting tool requirement in place for the recreational fishery. This requirement was removed in January 2014; thus, a sensitivity run was performed at ρ = 22%, the recreational release mortality rate applied by SEDAR-31 (2013) when venting tools were not required. It should be noted that simulated changes in release mortality rate were also applied to the status quo scenario used as a benchmark for analytical comparison, as the analysis is not assuming that the implementation of the slot limit is the causative factor for the change in release mortality rate.

Changes in Season Length

Changes to the recreational season length relative to status quo were presented in two ways. The first approach was to evaluate the ratio of removals (in weight) from the slot limit scenario relative to status quo, prior to altering the season to allow 100% of status quo removals (in weight) to be achieved. Under this approach, altering the season is identical to scaling the fleet-specific fishing mortality rates as follows:

$$\frac{F_{fleet}^{slot\ limit}}{F_{fleet}^{status\ quo}} = \frac{Season_{days}^{slot\ limit}}{Season_{days}^{status\ quo}} = \frac{Removals_{lbs}^{slot\ limit\ @\ status\ quo\ F}}{Removals_{lbs}^{status\ quo}} \tag{4}$$

This approach to computing the slot limit's impacts on recreational fishing season length assumes that anglers are not currently constrained by the bag limit of two fish per angler per day.

If it is not possible for anglers to increase their daily catch rates, then the change in recreational season length would be driven exclusively by changes in the number of landed fish:

$$\frac{Season_{days}^{slot\ limit}}{Season_{days}^{status\ quo}} = \frac{Landings_{N}^{slot\ limit}}{Landings_{N}^{status\ quo}} \tag{5}$$

This second approach to computing the change in recreational fishing season length assumes that the current two fish bag limit constrains angler daily catch rates. Previous analytical work has indicated that most recreational anglers catch the 2-fish red snapper bag limit, indicating the second approach for calculating the season length is more likely (see SERO-LAPP-2012-11).

Keeping One Fish over the Limit

The impacts of a slot limit where each angler would be allowed to keep one fish over the slot limit (i.e., a 'trophy' fish) were analyzed and compared to a strict slot limit. For a non-constraining bag limit, the proportional increase in landings relative to a strict slot limit for each slot limit scenario was computed by adding 50% (i.e., one fish out of the two-fish bag limit) times the ratio of mean number of fish landed under status quo conditions above the proposed slot limit and the mean number of fish landed under strict slot conditions within the proposed slot limit:

$$\frac{Landings_N^{keep\ 1\ over\ limit}}{Landings_N^{status\ quo}} = \frac{Landings_N^{strict\ slot}}{Landings_N^{status\ quo}} + 50\% \times \frac{\sum_{l=maxSL}^{l\infty} Landings_{length} \Big/ \sum_{l=max}^{l\infty} n}{\sum_{l=minSL}^{maxSL} Landings_{length} \Big/ \sum_{l=minSL}^{maxSL} n} \qquad (6)$$

This formulation expressed the increase in landings relative to the status quo, for ease of comparison with strict slot limit outputs. The scalar of 50% was applied because the current bag limit is two fish per angler; thus, the formulation assumed all anglers would keep one fish over the limit, if they caught one. The probability of catching a fish over the limit was modeled as a function of the selectivity, and declined as the maximum slot size was increased. This formulation thus accounted for differences in selectivity, numbers of fish at size, and weight of fish at size between the slot limit and above it.

For a fully-constraining bag limit, the impact of allowing retention of one fish over the limit was modeled by multiplying each fleet's retention function by 50% above the maximum size limit, and adding this to the percent kept at length. The season was then scaled toward the management target (e.g., 100% status quo removals in weight) and the change in season length was expressed as the ratio of landed fish as shown in equation 5, above.

Observed 2013 Selectivity

Most model runs applied the SS3 base model estimated selectivity; however, because the mean weight of a landed fish has increased substantially since the rebuilding plan was implemented in 2007 (SERO-LAPP-2014-02), sensitivity runs were also performed using the length-frequency composition of 2013 recreational catches, by fleet (**Figure 2**).

Long-Term Changes in Age Structure, Egg Production, and Season Length

To evaluate changes in age structure, egg production, and recreational fishing season length through time, the Gulf of Mexico red snapper population was forward-projected for five years assuming constant commercial and bycatch fishing mortality, constant natural mortality, and SS3-projected recruitment. Commercial and bycatch fishing mortality were distributed to lengths as described for recreational fleets above; although selectivity and retention were held constant for these fleets, their mortality was dependent upon the numbers of fish at size, which varied for different slot limit scenarios. SS3-input instantaneous age-specific natural mortality was converted to age-specific fractional natural mortality, or expectation of a natural death at age (*v*) for the Eastern and Western Gulf, computed as the difference between the fractional annual mortality rate at age (A_{age}) and the exploitation rate at age (u_{age}) as follows:

$$v_{age} = A_{age} - u_{age}$$
$$A_{age} = \left(1 - e^{-\left(\left(\sum_{fleet=1}^{n} F_{fleet,age}\right) + M_{age}\right)}\right) \qquad (7)$$

$$u_{age} = \left(\left(\sum_{fleet=1}^{n} F_{fleet,age}\right) * A_{age}\right) \Big/ \left(\left(\sum_{fleet=1}^{n} F_{fleet,age}\right) + M_{age}\right)$$

Percent at length, by age ($P_{age|length}$) was computed, and initial numbers at length and age ($N_{length \cdot age}$) were determined based on the number at age partitioned into lengths using the SS3 age-length key. Next, the number of fish at length surviving harvest was partitioned by age using the percent at age, by length ($P_{length|age}$) as computed from $N_{length \cdot age}$. Egg production was computed for the survivors, ages were incrementally advanced, numbers at length were recomputed from the age-length key, recruits were introduced, and cohorts were reduced by age-specific natural mortality. Recruitment projected from SS3 was nearly constant for 2013-2018, averaging around 54,679,000 recruits in the Eastern Gulf and 106,567,000 recruits in the Western Gulf.

Fecundity was expressed as total egg production, and was computed as the product of percent fish at age by length ($P_{age|length}$), the egg production at age (E_{age}), and the number at age by length after harvest ($N_{age|length}$), summed across lengths:

$$Egg\ Production = \sum_{length=0}^{l_\infty} \left(P_{age|length} \times N_{age|length}^{after\ harvest} \times E_{age}\right) \tag{8}$$

Egg production relative to status quo for the Eastern and Western Gulf was computed for several illustrative slot limit scenarios.

Results

Management Targets

The impacts of two different management targets (i.e., 100% status quo landings vs. 100% status quo removals) at different release mortality rates for a 16-24” strict slot limit were evaluated. The rate of increase in removals when managing for landings was more rapid than the rate of decline in landings when managing for removals (**Figure 3**: top). Hence, managing towards removals is more risk averse. Projected season length when managing for 100% status quo landings would be insensitive to changes in release mortality rate, because dead discards would be ignored under this management target. Realized season length over time would be sensitive to this assumption, as it would result in increased removals relative to the projected rebuilding plan. No information for changes in removals in weight relative to status quo are presented because this was the management target for the analysis; hence, there were no changes in removals in weight, and the season for the slot limit was allowed to proceed until the removals target was met.

Landings and Removals

All slot limit scenarios evaluated resulted in increased landings in numbers relative to status quo (**Table 2**, **Figure 4**). Eliminating the minimum size limit resulted in substantial increases in landings in numbers (**Table 2**, **Figure 4**). A 16-30" slot limit resulted in landings in numbers very similar to status quo (**Table 2**), because few fish are harvested above 30" currently (see **Figure 2**). A 16-24" slot limit resulted in a 1-9% increase in landings in numbers, depending on assumptions regarding release mortality rate (**Table 2**).

Only slot limit scenarios with no minimum size and relatively high maximum size limits resulted in increased landings in pounds, whole weight (**Table 3**, **Figure 5**). The smallest maximum size limits evaluated resulted in the largest decreases in landings in pounds, whole weight (**Table 3**). Higher release mortality rates resulted in more pronounced changes in landings (**Table 3**). A 16-24" slot limit resulted in a 9-16% decrease in landed weight, depending on assumptions regarding release mortality rate (**Table 3**).

All slot limit scenarios evaluated generated increased removals in numbers relative to status quo (**Table 4**, **Figure 6**). Elimination of the minimum size limit resulted in substantial increases in total fish killed (**Table 4**). A 16-24" slot limit resulted in a 12-16% increase in total removals in numbers, dependent on assumptions regarding release mortality rate (**Table 3**).
Narrow slot limits resulted in increased dead discards (in weight); broad slot limits resulted in decreased dead discards (in weight) (**Table 5**, **Figure 7**). Elimination of the minimum size limit resulted in decreased dead discards (in weight) under all maximum size limits considered (**Table 5**). A 16-24" slot limit resulted in between a 30-41% increase in dead discards (in weight), depending on assumptions regarding release mortality rate (**Table 5**).

All slot limit scenarios resulted in decreased average weight of landed fish compared to current regulations (**Table 6**, **Figure 8**). Lower minimum and maximum size limits resulted in lower average weights (**Table 6**). A 16-24" slot limit resulted in a 17% reduction in average weight under all release mortality rate scenarios (**Table 6**).

Changes in Season Length

Assuming the current two-fish bag limit does not constrain recreational catch rates, reducing the minimum size limit while maintaining a relatively high maximum size limit resulted in reduced fishing seasons relative to the status quo (**Table 7A-B**, **Figure 9**). The reduction in season length is due to assumed increases in daily landings rate of recreational fisherman. Relatively narrow slot limits provided some increases to the season length (**Table 7**). A 16-24" slot limit provided an 18-25% increase to the fishing season length, depending on assumptions regarding release mortality rate (**Table 7A-B**, **Figure 9A, D**). The increase in season length occurs due to a predicted decrease in the daily landings rate of recreational fisherman.

Assuming no high-grading occurs and that the current two-fish bag limit constrains daily recreational catch rates, reducing the minimum size limit resulted in increased fishing seasons relative to the status quo (**Table 7C-D, Figure 9B, E**). A 13-24" slot limit would provide a 14-18%

increase in recreational fishing season length assuming no bag limit constraints, but a much larger (23-29%) increase assuming the bag limit fully constrains catch rates. A 16-24” slot limit would provide a 1-25% increase in recreational fishing season length depending upon assumptions regarding release mortality rate and bag limit constraints. Lower release mortality rates result in more effective slot limits under all assumptions (**Table 7; Figure 10**).

Keeping One Fish over the Limit

Assuming the two-fish bag limit is not constraining recreational catch rates, allowing anglers to retain one fish above the slot limit (i.e., a ‘trophy’ fish) reduced benefits of the slot limit (as compared to a strict slot limit) for extending the fishing seasons presented in **Table 7A-B** by around 10%. Assuming the two-fish bag limit is fully constraining recreational catch rates, allowing anglers to retain one fish above the slot limit would provide some benefits relative to the status quo, but would increase average weights and truncate extensions to the recreational season length presented in **Table 7C-D**. Allowing retention of one fish above the maximum size limit with a fully-constraining bag limit has little impact on season length at maximum sizes >24 inches TL. Relaxing the slot limit to allow retention of a trophy fish above 24” results in around 5000 additional fish landed, which impacts the season length by <1%. Under a very tight slot limit (16-20”), the impacts of allowing retention of a trophy fish upon season length are slightly higher than 1%. The impacts of allowing retention of a trophy fish decreases as the maximum size limit increases, because there is a diminishing probability of encountering a fish above the maximum size.

Observed 2013 Selectivity

Assuming the two-fish bag limit is not constraining recreational catch rates, applying estimated 2013 selectivity within the slot limit modeling framework resulted in longer season lengths than if selectivity from the stock assessment was used(**Table 8A-B**, **Figure 9C**). Under these assumptions, narrow slot limits extended the season by around 12%, whereas eliminating the minimum size limit reduced the season by nearly 30% (**Figure 9F**). A slot limit of 14-24” appeared to be the turning point; minimum sizes below 14” resulted in seasons shorter than status quo.

Assuming 2013 observed selectivity, no high-grading, and catch rates fully constrained by the two-fish bag limit, reducing the minimum size limit resulted in increased fishing seasons relative to the status quo (**Table 8C-D**). Increases were dramatic for decreases in the minimum size limit under these assumptions, and were heavily impacted by assumptions about the release mortality rate.

Long-Term Changes in Age Structure, Egg Production, and Season Length

Forward projection of various slot limits revealed several interesting trends. **Figure 11** shows that slot limits tended to reduce abundance of fish in the younger (ages 3-9) age classes and increase abundance of fish in the older age classes (ten years and older). Narrower slot limits resulted in greater changes to population age structure. Restrictive slot limits provided some gains in egg production in the Eastern Gulf, but often at the expense of Western Gulf egg production (**Figure 12**). Most slot limits evaluated allow longer seasons by reducing average weight landed (primarily in the Eastern Gulf), which allows for increased landings in the Western Gulf, reducing Western Gulf egg production below status quo in some cases. Some slot limits lead to increased egg production for a few years followed by reduced egg production further into the time series as the cohorts hit more heavily by the fishery under a slot limit advance into peak egg producing ages. Forward projections suggested that assuming a non-constraining bag limit, reducing the maximum size provided the longest recreational seasons; assuming a fully-constraining bag limit, reducing the minimum size limit would provide the longest recreational fishing seasons (**Figure 13**).

In summary, there were only minor differences in the impacts of the slot limit between the Eastern and Western Gulf of Mexico (**Figure 14**). Under a 16-24" strict slot limit, the Western Gulf had slightly larger gains in landings in numbers, season length, and dead discards in weight. The Eastern Gulf had slightly greater losses in landings in weight and average weight in the catch. The Eastern Gulf also had greater gains in egg production. Assuming the bag limit does not constrain catch rates, a 16-24" strict slot limit was the most effective for extending the recreational fishing season and reducing the average weights of landed fish. Assuming the bag limit fully constrains catch rates, a 13-24" strict slot limit was the most effective for extending the recreational fishing season by greatly reducing the average weights of landed fish and improving the odds that anglers rapidly filled their daily bag limit. Reducing the minimum size limit resulted in substantial increases in the landings in numbers; reducing the maximum size limit resulted in substantial decreases in landed biomass. Under SS3-modeled selectivity, slot limits above 27" had little impact, as few fish were caught above that size. When compared to the same slot limits under lower release mortality rates, increased release mortality rates led to smaller gains in landings and removals in numbers, smaller but still substantial gains in season length, and greater losses in landings in pounds. Assuming a non-constraining bag limit, allowing anglers to retain one fish above the slot limit would lead to increased landings in numbers and weight, which would substantially reduce the season length at lower maximum sizes relative to a strict slot limit. Assuming a fully-constraining bag limit, allowing anglers to retain one fish above the slot limit had little impact on season length.

Discussion

A recreational slot limit for Gulf red snapper was modeled assuming that a consistent level of removals relative to status quo management would be maintained. If managers attempted to maintain a level of landings consistent with the recreational ACL without considering the increases in total removals resultant from imposing a maximum size limit, the short-term benefits of the slot limit would be amplified; however, there could be long-term consequences for the rate of population rebuilding. The current assessment projections (SEDAR-31 2013) do not account for a slot limit with associated increases in landings of smaller fish and dead discards of larger fish. Management towards a target of 100% status quo removals ensures that the population remains at or above the targeted rebuilding path. Management towards a target of 100% status quo landings requires the slot limit to be explicitly incorporated into the assessment model projections and corresponding landings-only yield outputs. Incorporation of slot limit management options into the Stock Synthesis assessment model is planned prior to the next red snapper stock assessment, scheduled for completion in late 2014 (J. Tetzlaff, SEFSC, pers. comm.).

The analysis also assumed that all the Gulf states would adopt consistent slot limit regulations. In 2013 and 2014, several of the Gulf states adopted regulations inconsistent with federal regulations, resulting in a shortening of the federal fishing season. If the Gulf states implement less-restrictive regulations inconsistent with the slot limit scenarios explored in this report, the potential benefits of a slot limit could be greatly reduced. The impacts of inconsistent regulations would be highest for states with high state water harvests or extended state seasons.

Model outputs suggested a recreational slot limit for the Gulf red snapper sector could provide substantial gains in season length associated with reductions in average weight of landed fish. The impacts of slot limits upon the season length were heavily dependent upon assumptions regarding the impacts of the current two-fish recreational bag limit. Assuming the current two-fish bag limit does not constrain catches, narrow slot limits provided the greatest gains, and reductions in the minimum size limit reduced the season extension. The narrow slot limits extend the season by reducing the daily landings rate. However, a narrow slot limit also leads to increased discarding relative to the status quo. A recent bag limit analysis (SERO-LAPP-2012-11) indicated that red snapper catches are effectively constrained by the two-fish bag limit. Under the assumption that the two fish bag limit is constraining catch rates, reductions in the minimum size limit provide the greatest extension of the federal fishing season relative to status quo, because the probability of encountering fish at smaller sizes—filling the daily bag limit quickly—is high. The actual impacts of a slot limit are probably somewhere between the outputs for these two assumptions, but likely closer to the assumption of a fully-restrictive bag limit, assuming high-grading does not take place.

The analysis of the impacts of allowing retention of one fish per angler above the maximum size limit assumed all anglers would retain a fish above the maximum size if they encountered one. Assuming a non-constraining bag limit, allowing anglers to retain a fish above the slot limit undermined the utility of the slot limit; the more narrow the slot limit, the bigger the impact of this exception. Assuming a fully-constraining bag limit, allowing anglers to retain one fish above the maximum size had little impact upon the length of the fishing season – it allowed anglers to fill their bag limit slightly faster. Allowing anglers to retain a trophy fish might reduce the impacts of a slot limit for decreasing fishing mortality of larger fish; a reasonable compromise to retain the effectiveness of the slot limit might be to allow anglers to retain a rarely encountered size (e.g., above 27”). The ability of anglers to retain one fish above the slot limit was expressed as a 50% scalar to the retention function above the maximum size limit. Modification of the value of 50% to some value between 0% and 50% would simulate the impacts of retaining one fish per vessel over the slot limit. For example, if it were known that a fleet had, on average, two anglers per vessel, then a scalar of 25% would be appropriate to model the impacts of a one fish per vessel limit for that fleet. Similarly, a scalar of 16.7% would be appropriate if there were, on average, three anglers per vessel. Computationally, the implementation of a vessel limit would have less effect on the relative impacts of a slot limit than allowing each angler to retain one fish above the slot limit.

Several studies have suggested that larger fish produce more and healthier eggs, so allowing the landing of trophy fish might have some undesirable impacts on population recovery (Baskett et al. 2005, Jørgensen et al. 2007, Coltman 2008, Fenberg & Roy 2008). Most slot limit scenarios increased egg production in the Eastern Gulf but reduced egg production in the Western Gulf. In SEDAR-31 (2013), no spawner-recruit relationship was found at observed population sizes and steepness was fixed at 0.99. Thus, although changes to population egg production under a slot limit may be desirable, the steepness value selected for the base run of SEDAR-31 (2013) suggests these projected changes in egg production would have no impact on recruitment for the red snapper population in the Gulf of Mexico.

The model assumes no changes in fisher behavior or selectivity due to implementation of slot limit. It is possible effort would increase in some areas, especially if the minimum size limit were reduced, due to an increased incentive for nearshore fishing. Additionally, implementation of a slot limit might result in high-grading within the slot, as anglers attempt to retain fish close to the maximum size limit. Similarly, an increase in recreational hook sizes required might shift selectivity closer to the maximum size limit. These changes in selectivity were not modeled, but their impacts are obvious. A change in hook size to promote the catch of larger fish would shift selectivity upwards, increasing the average weight of landed fish relative to the currently modeled selectivity, which would reduce the benefits of the slot limit. If recreational hook sizes were required that made it more difficult to capture fish near the maximum size limit, the slot limit could be even more effective. It should be noted that it would be difficult to enforce a red snapper hook size in a multispecies fishery, and even with full compliance by anglers, there would likely be high levels of red snapper bycatch during trips targeting other species. If anglers high-grade within a slot limit, this would shift the retention function upwards, and the impacts of that slot limit might, in reality, be closer to status quo conditions due to increased discarding of smaller fish within the slot. Reductions in the minimum size limit might increase the frequency of high-grading; the impacts of a 13-24" slot limit might be very similar to those of a 16-24" slot limit if high-grading is common. High-grading is more likely if the minimum size limit is reduced from the 16" status quo.

There have been signs that recreational selectivity is higher at the edges of the size distribution than projected by the SS3 base run (see **Figure 2**). Higher recreational selectivity near or below the minimum size and near or above the maximum size increased the impacts of a slot limit, as anglers more frequently encountered and discarded fish above the maximum size, and used up their quota landing smaller size fish (see **Figure 9D**). It is unknown whether these selectivity patterns observed in 2013 would persist under slot limit regulations.

The SS3 base run assumed a 10% release mortality rate during the time period that circle hooks and venting were required for the recreational red snapper sector (SEDAR-31 2013). The Gulf

Council recently removed the venting requirement; therefore, sensitivity runs were conducted using the 22% release mortality rate assumed during the time period when venting was not required (SEDAR-31 2013). Release mortality rates of 22% reduced the benefits of the slot limit, but were not high enough to eliminate its benefits. Sensitivity runs indicated the increase in recreational season length relative to status quo assuming no bag limit effects dropped below 10% at recreational release mortality rates above 45%. No seasonal or size-related considerations were incorporated into the simulation of recreational release mortality rates. Some unpublished studies have suggested that smaller red snapper have lower release mortality, and that release mortality rates are higher during the summer months of the recreational red snapper season (G. Stunz, Harte Research Institute, unpublished data). The percentage of smaller fish being released relative to status quo would decrease under most slot limit scenarios, meaning the releases would be composed of a higher-than-status-quo percentage of larger fish. If more larger fish are being released at a higher release mortality rate, this would reduce the benefits of the slot limit. Higher summer release mortality rates would not impact the relative benefits of the slot limit, as the status quo fishing season is also a summer season.

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TABLES

Table 1. Gulf state water recreational red snapper regulations for 2014. Cells highlighted in gray indicate regulations incompatible with 2014 federal regulations.

State	Size Limit	Bag Limit	Season	Days Open
Florida*	16" TL	2-fish		52
Alabama	16" TL	2-fish	Same as federal season	Same as federal season
Mississippi	16" TL	2-fish	Same as federal season	Same as federal season
Louisiana	16" TL	2-fish		286
Texas				365

Table 2. Percent change from status quo landings in numbers under various slot limits. Assumes management towards 100% status quo removals (weight) with A) a 10% release mortality rate and B) a 22% release mortality rate.

A)

Min. Size	Max. Size 24	25	26	27	28	29	30
None	83%	72%	68%	65%	62%	61%	60%
13	29%	24%	22%	20%	18%	17%	17%
14	22%	18%	16%	14%	12%	12%	11%
15	16%	12%	10%	8%	7%	6%	6%
16	9%	6%	4%	3%	1%	1%	1%

B)

Min. Size	Max. Size 24	25	26	27	28	29	30
None	77%	71%	69%	67%	65%	65%	64%
13	23%	22%	21%	20%	19%	19%	19%
14	15%	15%	14%	14%	13%	13%	12%
15	8%	8%	8%	8%	7%	7%	6%
16	1%	2%	2%	1%	1%	1%	0%

Table 3. Percent change from status quo landings in pounds, whole weight, under various slot limits. Assumes management towards 100% status quo removals (weight) with A) a 10% release mortality rate and B) a 22% release mortality rate.

A)

Min. Size \ Max. Size	24	25	26	27	28	29	30
None	-4%	0%	1%	2%	2%	3%	3%
13	-6%	-2%	-1%	0%	1%	1%	1%
14	-7%	-3%	-1%	0%	1%	1%	1%
15	-8%	-3%	-2%	-1%	0%	0%	0%
16	-9%	-4%	-3%	-2%	-1%	0%	0%

B)

Min. Size \ Max. Size	24	25	26	27	28	29	30
None	-7%	-1%	2%	3%	5%	5%	5%
13	-11%	-4%	-1%	0%	2%	2%	3%
14	-13%	-5%	-2%	-1%	1%	2%	2%
15	-14%	-6%	-4%	-2%	0%	0%	1%
16	-16%	-8%	-5%	-3%	-1%	-1%	-1%

Table 4. Percent change from status quo removals in numbers under various slot limits. Assumes management towards 100% status quo removals (weight) with A) a 10% release mortality rate and B) a 22% release mortality rate.

A)

Min. Size \ Max. Size	24	25	26	27	28	29	30
None	62%	50%	46%	43%	40%	39%	39%
13	27%	19%	16%	14%	11%	11%	10%
14	23%	15%	12%	10%	8%	7%	7%
15	20%	12%	9%	7%	5%	4%	4%
16	16%	9%	6%	4%	2%	1%	1%

B)

Min. Size \ Max. Size	24	25	26	27	28	29	30
None	42%	34%	32%	30%	28%	27%	27%
13	19%	13%	11%	9%	8%	7%	7%
14	16%	11%	9%	7%	5%	5%	5%
15	14%	9%	6%	5%	3%	3%	3%
16	12%	7%	5%	3%	1%	1%	1%

Table 5. Percent change from status quo dead discards (in weight) under various slot limits. Assumes management towards 100% status quo removals (weight) with A) a 10% release mortality rate and B) a 22% release mortality rate.

A)

Min. Size	Max. Size: 24	25	26	27	28	29	30
None	-10%	-24%	-28%	-30%	-33%	-34%	-34%
13	20%	1%	-4%	-8%	-11%	-12%	-13%
14	26%	6%	1%	-3%	-7%	-8%	-9%
15	33%	12%	6%	2%	-2%	-3%	-4%
16	41%	18%	12%	7%	3%	2%	1%

B)

Min. Size	Max. Size: 24	25	26	27	28	29	30
None	-13%	-24%	-27%	-29%	-32%	-32%	-33%
13	13%	0%	-5%	-8%	-11%	-11%	-12%
14	18%	4%	0%	-3%	-7%	-7%	-8%
15	24%	9%	4%	1%	-2%	-3%	-4%
16	30%	14%	9%	6%	2%	1%	1%

Table 6. Percent change from status quo average weight (pounds/fish) under various slot limits. Assumes management towards 100% status quo removals (weight) with A) a 10% release mortality rate and B) a 22% release mortality rate.

A)

Min. Size	Max. Size: 24	25	26	27	28	29	30
None	-48%	-42%	-40%	-38%	-37%	-36%	-36%
13	-28%	-21%	-18%	-17%	-14%	-14%	-13%
14	-24%	-17%	-15%	-13%	-10%	-10%	-9%
15	-20%	-13%	-11%	-9%	-6%	-6%	-5%
16	-17%	-9%	-7%	-5%	-2%	-1%	-1%

B)

Min. Size	Max. Size: 24	25	26	27	28	29	30
None	-48%	-42%	-40%	-38%	-37%	-36%	-36%
13	-28%	-21%	-18%	-17%	-14%	-14%	-13%
14	-24%	-17%	-15%	-13%	-10%	-10%	-9%
15	-20%	-13%	-11%	-9%	-6%	-6%	-5%
16	-17%	-9%	-7%	-5%	-2%	-1%	-1%

Table 7. Percent change from status quo season length under various slot limits. Assumes management towards 100% status quo removals (weight) with the two fish bag limit not constraining catch rates at A) a 10% release mortality rate and B) a 22% release mortality rate and with the two fish bag limit fully constraining catch rates at C) a 10% release mortality rate and D) a 22% release mortality rate. All scenarios assume no high-grading.

A)		**Max. Size**						
		24	**25**	**26**	**27**	**28**	**29**	**30**
Min. Size	**None**	12%	1%	-3%	-6%	-10%	-11%	-11%
	13	18%	7%	3%	-1%	-4%	-5%	-5%
	14	20%	9%	4%	1%	-2%	-3%	-4%
	15	22%	11%	6%	3%	0%	-1%	-1%
	16	25%	13%	9%	6%	2%	2%	1%

B)		**Max. Size**						
		24	**25**	**26**	**27**	**28**	**29**	**30**
Min. Size	**None**	9%	1%	-2%	-5%	-7%	-8%	-8%
	13	14%	5%	2%	0%	-3%	-4%	-4%
	14	15%	6%	3%	1%	-2%	-2%	-3%
	15	17%	8%	5%	3%	0%	-1%	-1%
	16	18%	10%	7%	4%	2%	1%	1%

C)		**Max. Size**						
		24	**25**	**26**	**27**	**28**	**29**	**30**
Min. Size	**None**	83%	72%	68%	65%	62%	61%	60%
	13	29%	24%	22%	20%	18%	17%	17%
	14	22%	18%	16%	14%	12%	12%	11%
	15	16%	12%	10%	8%	7%	6%	6%
	16	9%	6%	4%	3%	1%	1%	1%

D)		**Max. Size**						
		24	**25**	**26**	**27**	**28**	**29**	**30**
Min. Size	**None**	77%	71%	69%	67%	65%	65%	64%
	13	23%	22%	21%	20%	19%	19%	19%
	14	15%	15%	14%	14%	13%	13%	12%
	15	8%	8%	8%	8%	7%	7%	6%
	16	1%	2%	2%	1%	1%	1%	0%

Table 8. Percent change from status quo season length under various slot limits, assuming 2013 observed selectivity. Assumes management towards 100% status quo removals (weight) with the two fish bag limit not constraining catch rates at A) a 10% release mortality rate and B) a 22% release mortality rate, and assuming the two fish bag limit fully constraining catch rates at C) a 10% release mortality rate and D) a 22% release mortality rate. All scenarios assume no high-grading.

A)		**Max. Size**						
		24	**25**	**26**	**27**	**28**	**29**	**30**
Min. Size	**None**	-14%	-26%	-32%	-36%	-42%	-43%	-44%
	13	-6%	-18%	-24%	-28%	-34%	-35%	-36%
	14	6%	-5%	-11%	-15%	-21%	-23%	-23%
	15	20%	9%	3%	-1%	-7%	-8%	-9%
	16	30%	18%	12%	8%	2%	1%	1%

B)		**Max. Size**						
		24	**25**	**26**	**27**	**28**	**29**	**30**
Min. Size	**None**	-10%	-19%	-23%	-26%	-30%	-31%	-32%
	13	-5%	-13%	-17%	-20%	-25%	-25%	-26%
	14	4%	-4%	-8%	-11%	-16%	-16%	-17%
	15	15%	7%	2%	-1%	-5%	-6%	-6%
	16	22%	13%	9%	6%	2%	1%	0%

C)		**Max. Size**						
		24	**25**	**26**	**27**	**28**	**29**	**30**
Min. Size	**None**	124%	112%	105%	101%	95%	94%	94%
	13	106%	94%	88%	85%	79%	78%	77%
	14	78%	68%	62%	59%	54%	53%	53%
	15	40%	33%	29%	27%	23%	22%	22%
	16	12%	8%	6%	4%	1%	1%	0%

D)		**Max. Size**						
		24	**25**	**26**	**27**	**28**	**29**	**30**
Min. Size	**None**	132%	124%	120%	117%	112%	112%	111%
	13	109%	103%	99%	96%	92%	91%	91%
	14	75%	70%	67%	65%	62%	61%	61%
	15	31%	29%	28%	27%	25%	25%	24%
	16	0%	2%	2%	1%	1%	0%	0%

FIGURES

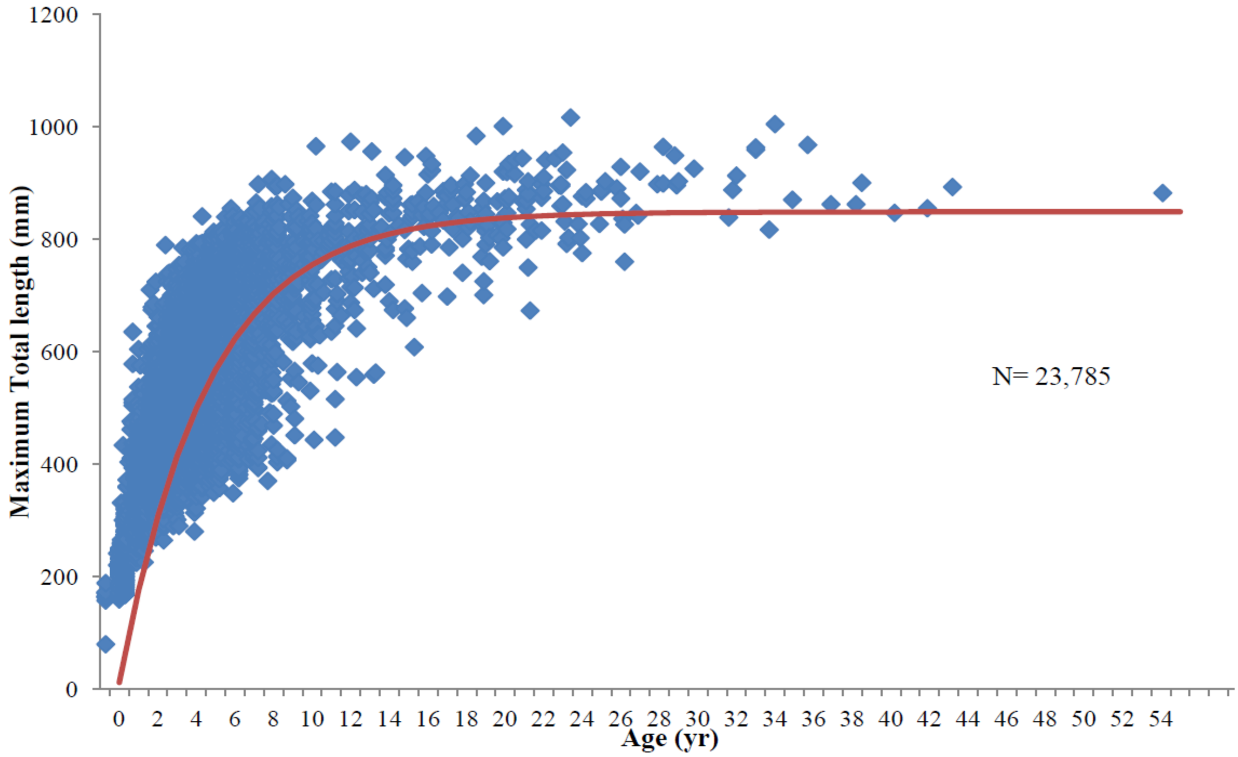

Figure 1. Relationship between Gulf of Mexico red snapper age and total length, from SEDAR-31 (2013).

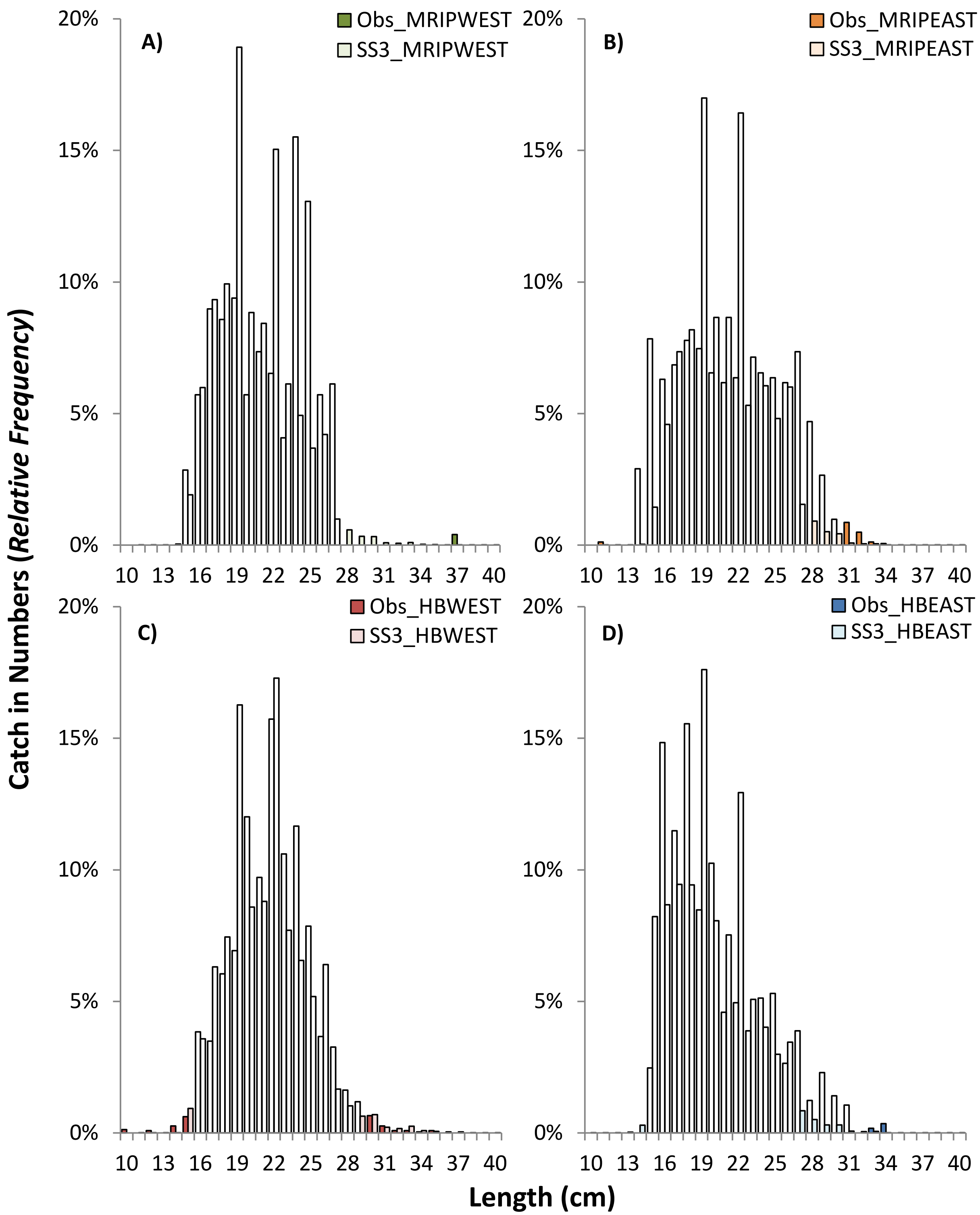

Figure 2. Length-frequency distribution for recreationally-landed red snapper in the Eastern (top) and Western (bottom) Gulf of Mexico, as observed in 2013 (dark fill) and as predicted (light fill) by Stock Synthesis 3 (SS3) assessment model base run projections for A) Private/charter anglers in the Western Gulf, B) Private/charter anglers in the Eastern Gulf, C) Headboat anglers in the Western Gulf, and D) Headboat anglers in the Eastern Gulf.

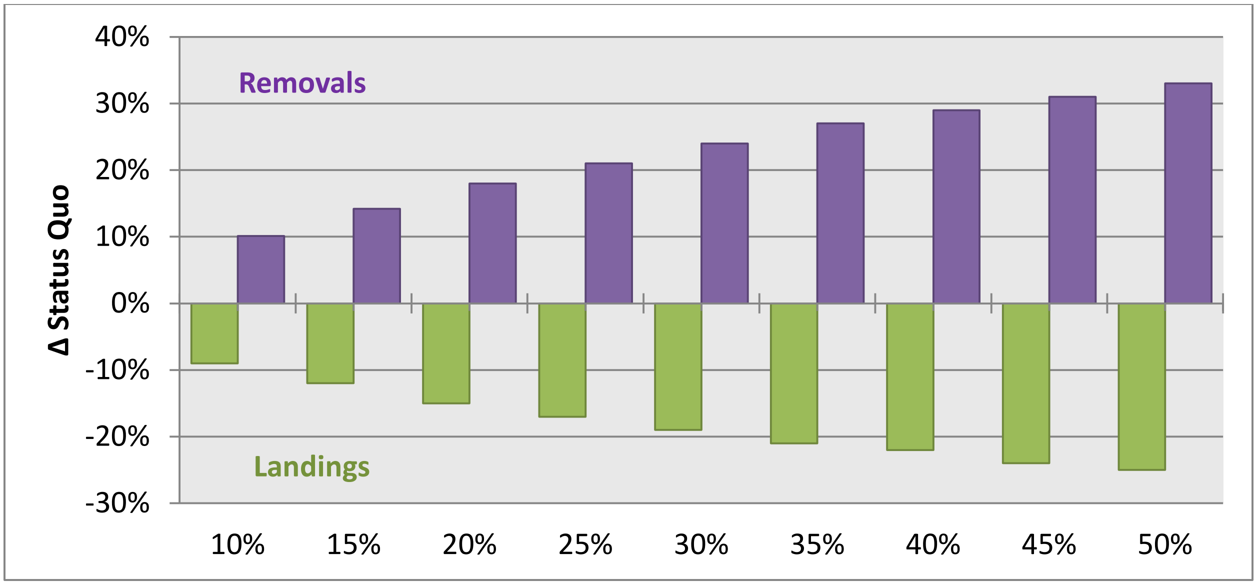

Figure 3. Impacts of management target at different release mortality rates for a 16-24 inch total length strict slot limit. Top figure shows change in total removals if target set at 100% status quo landings (purple bars) and total landings if target set at 100% status quo removals (green bars). Note that the rate of increase in removals when managing for landings is more rapid than the rate of decline in landings when managing for removals.

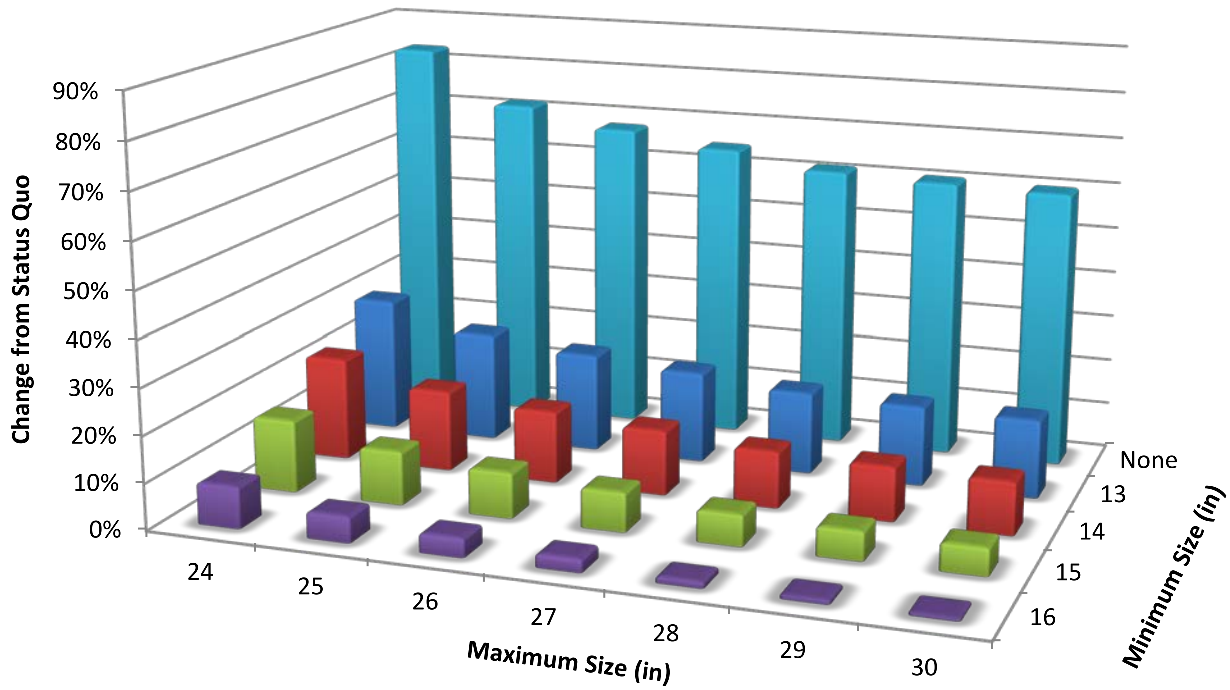

Figure 4. Percent change from status quo landings in numbers under various slot limits. Assumes management towards 100% status quo removals (weight) and a 10% release mortality rate.

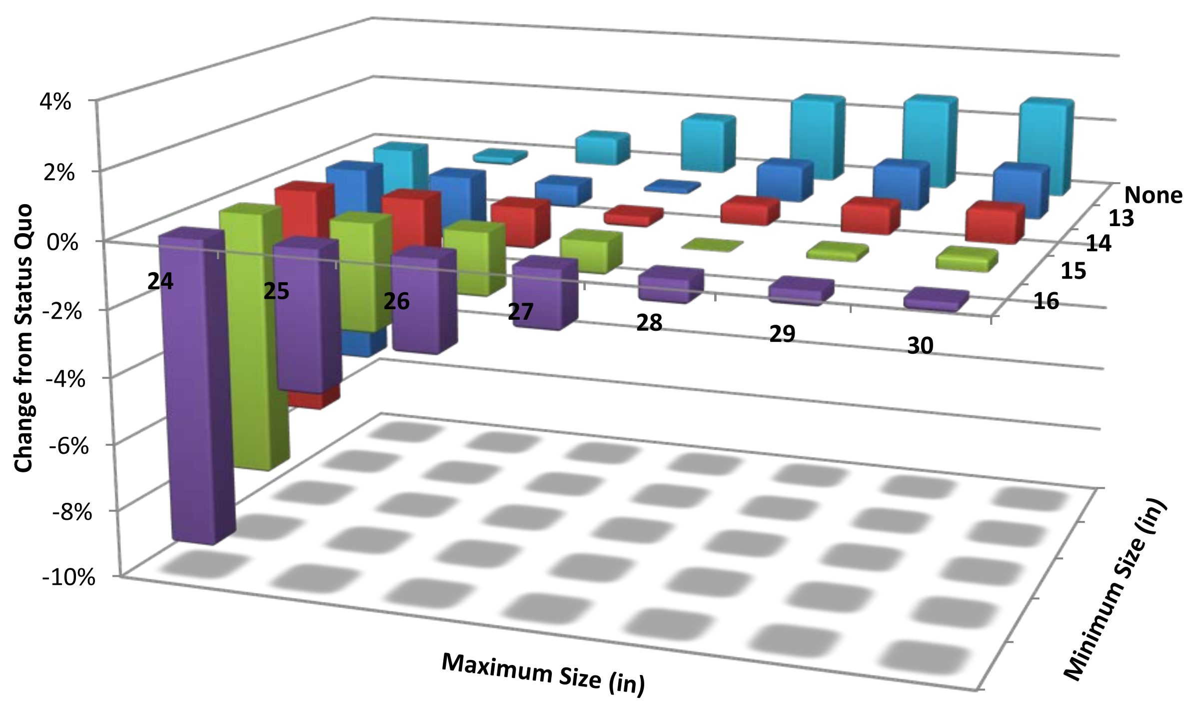

Figure 5. Percent change from status quo landings in weight under various slot limits. Assumes management towards 100% status quo removals (weight) and a 10% release mortality rate.

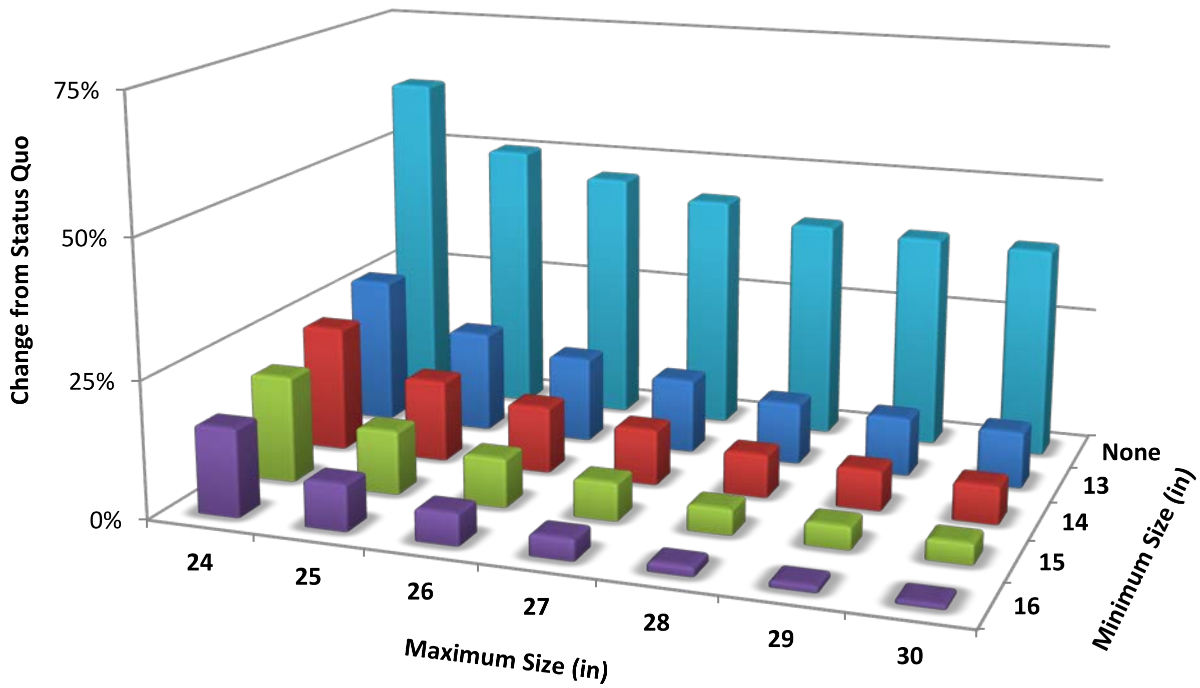

Figure 6. Percent change from status quo removals in numbers under various slot limits. Assumes management towards 100% status quo removals (weight) and a 10% release mortality rate.

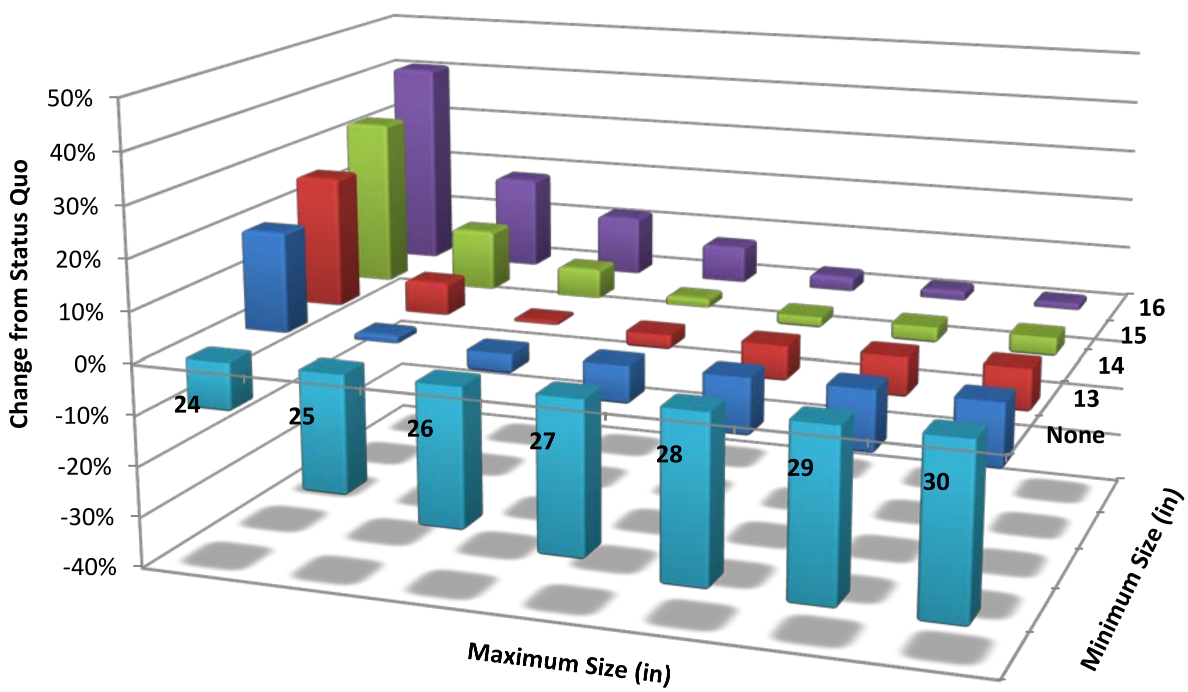

Figure 7. Percent change from status quo dead discards (in weight) under various slot limits. Assumes management towards 100% status quo removals (weight) and a 10% release mortality rate.

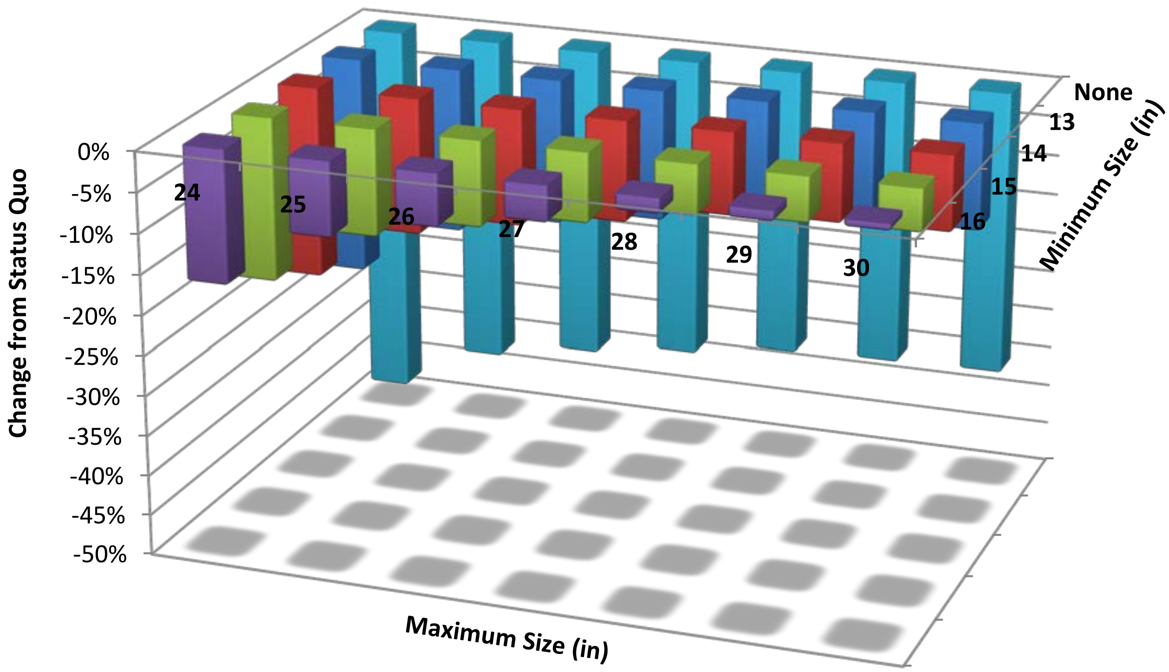

Figure 8. Percent change from status quo average weight under various slot limits. Assumes management towards 100% status quo removals (weight) and a 10% release mortality rate.

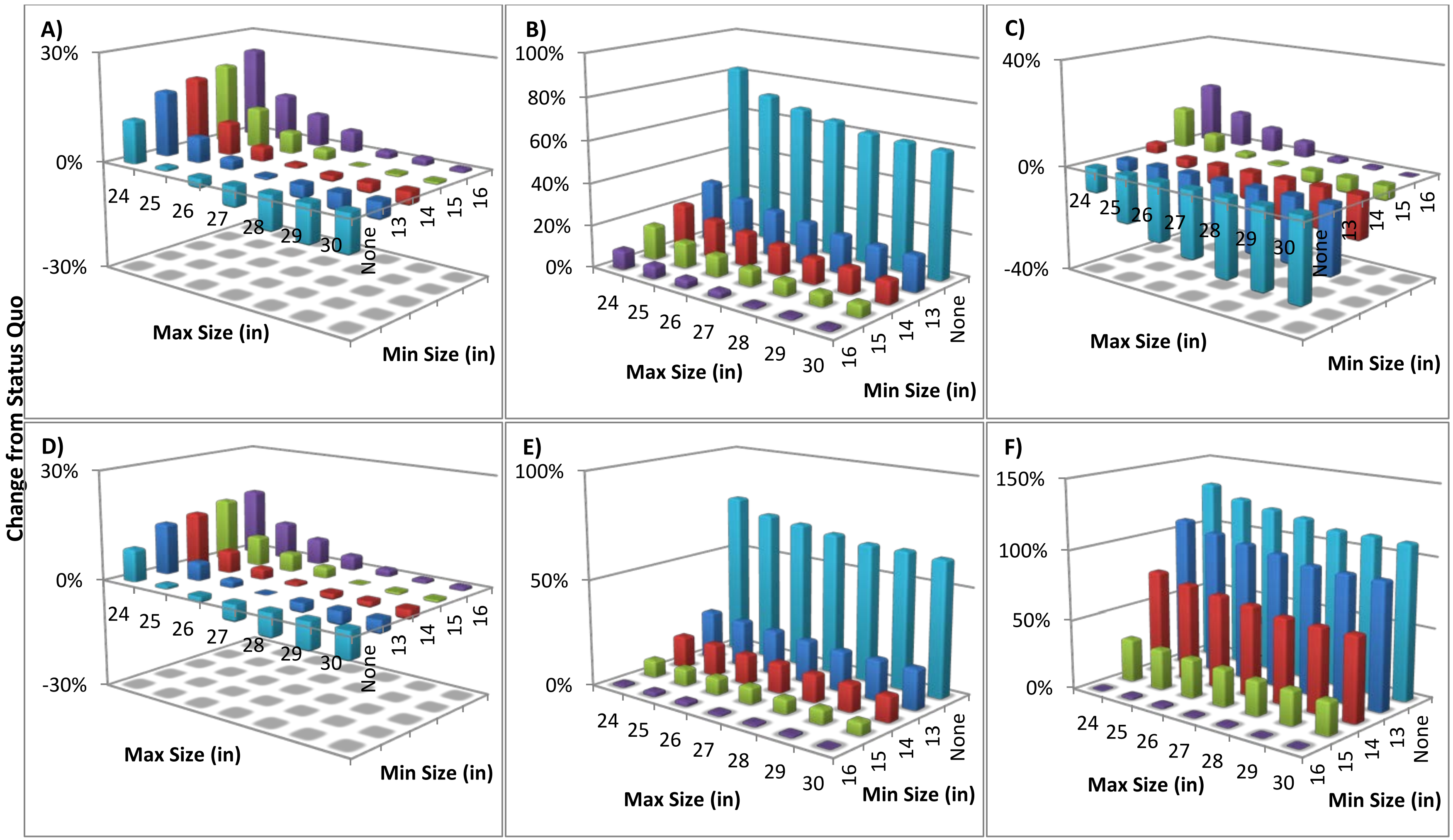

Figure 9. Percent change from status quo season length for various slot limits for A) SS3-based selectivity with non-constraining bag limit at 10% release mortality rate, B) SS3-based selectivity with fully-constraining bag limit at 10% release mortality rate, C) 2013 estimated selectivity with non-constraining bag limit at 22% release mortality rate, D) SS3-based selectivity with non-constraining bag limit at 22% release mortality rate, E) SS3-based selectivity with fully-constraining bag limit at 22% release mortality rate, and F) 2013 estimated selectivity with fully-constraining bag limit at 22% release mortality rate,. All scenarios assume management towards 100% status quo removals (weight).

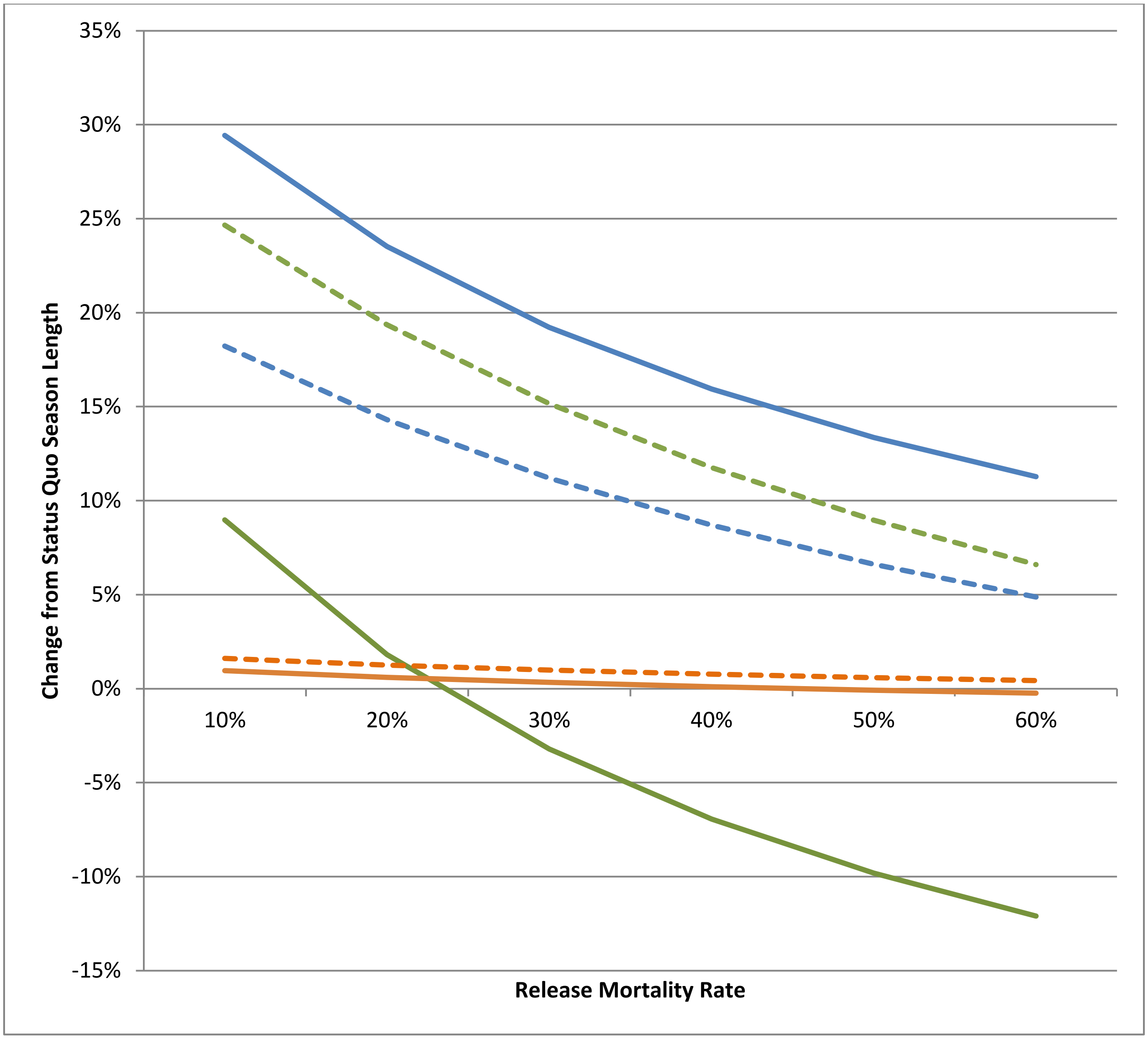

Figure 10. Percent change from status quo season length at different release mortality rates for 13-24” (blue), 16-24” (green), and 16-29” strict slot limits assuming non-constraining bag limit (dashed lines) and fully-constraining bag limit (solid lines). All scenarios assume management towards 100% status quo removals (weight).

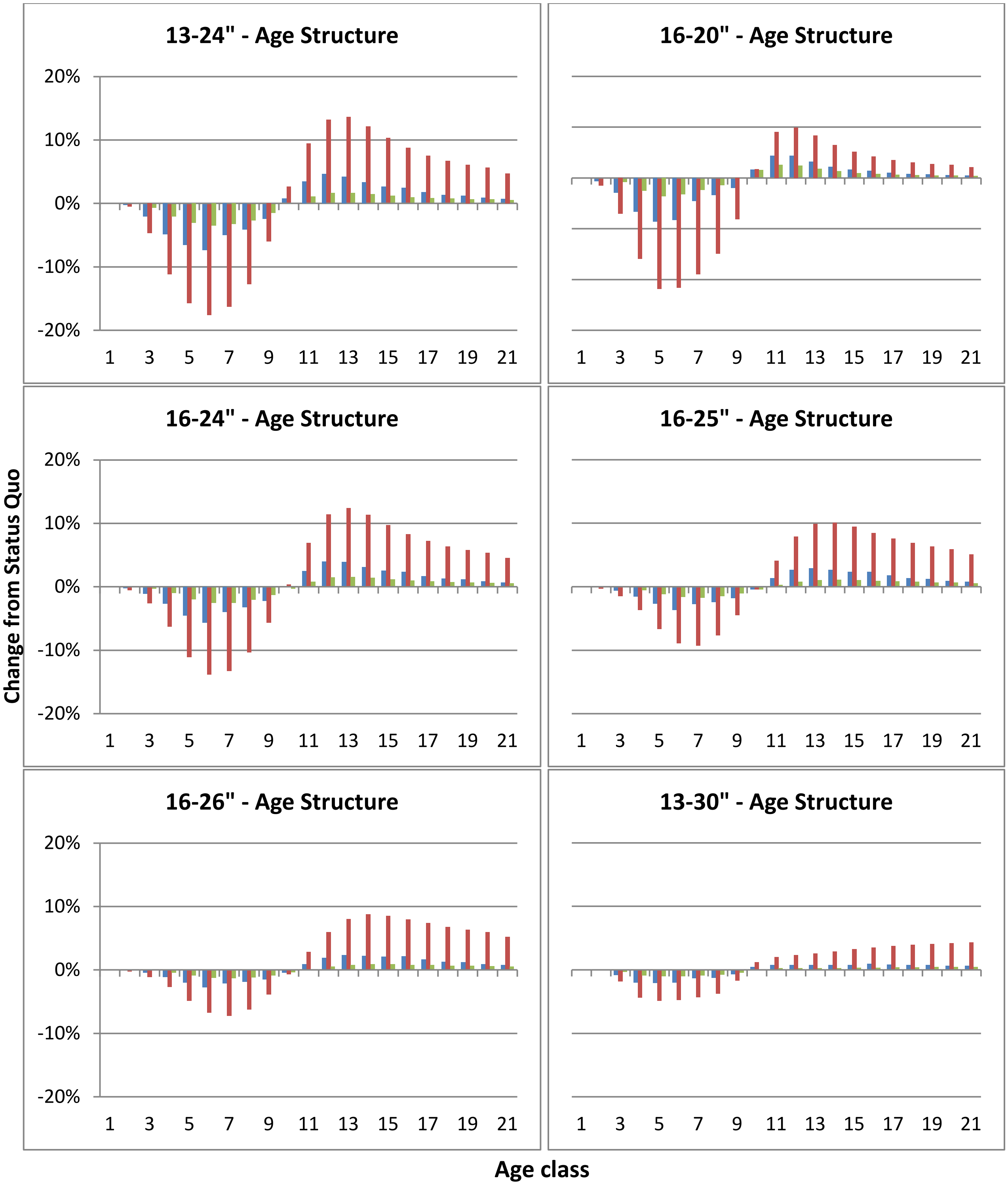

Figure 11. Projected percent change from status quo population age structure after five years under various slot limits for the Eastern (red), Western (green) and entire Gulf of Mexico (blue). All runs assume no high-grading and a 22% release mortality rate.

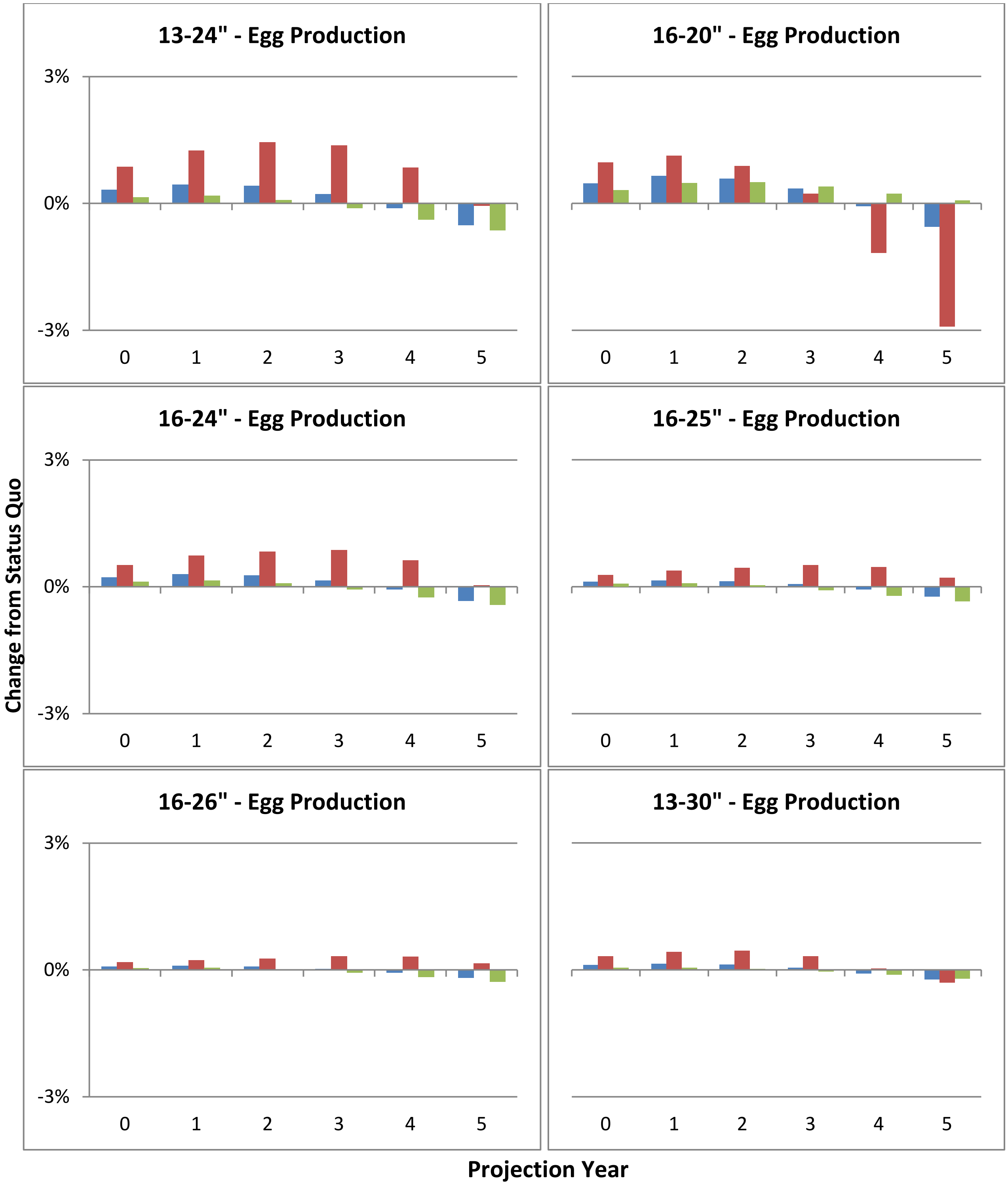

Figure 12. Projected percent change from status quo egg production for five years under various slot limits for the Eastern (red), Western (green) and entire Gulf of Mexico (blue). All runs assume no high-grading and a 22% release mortality rate.

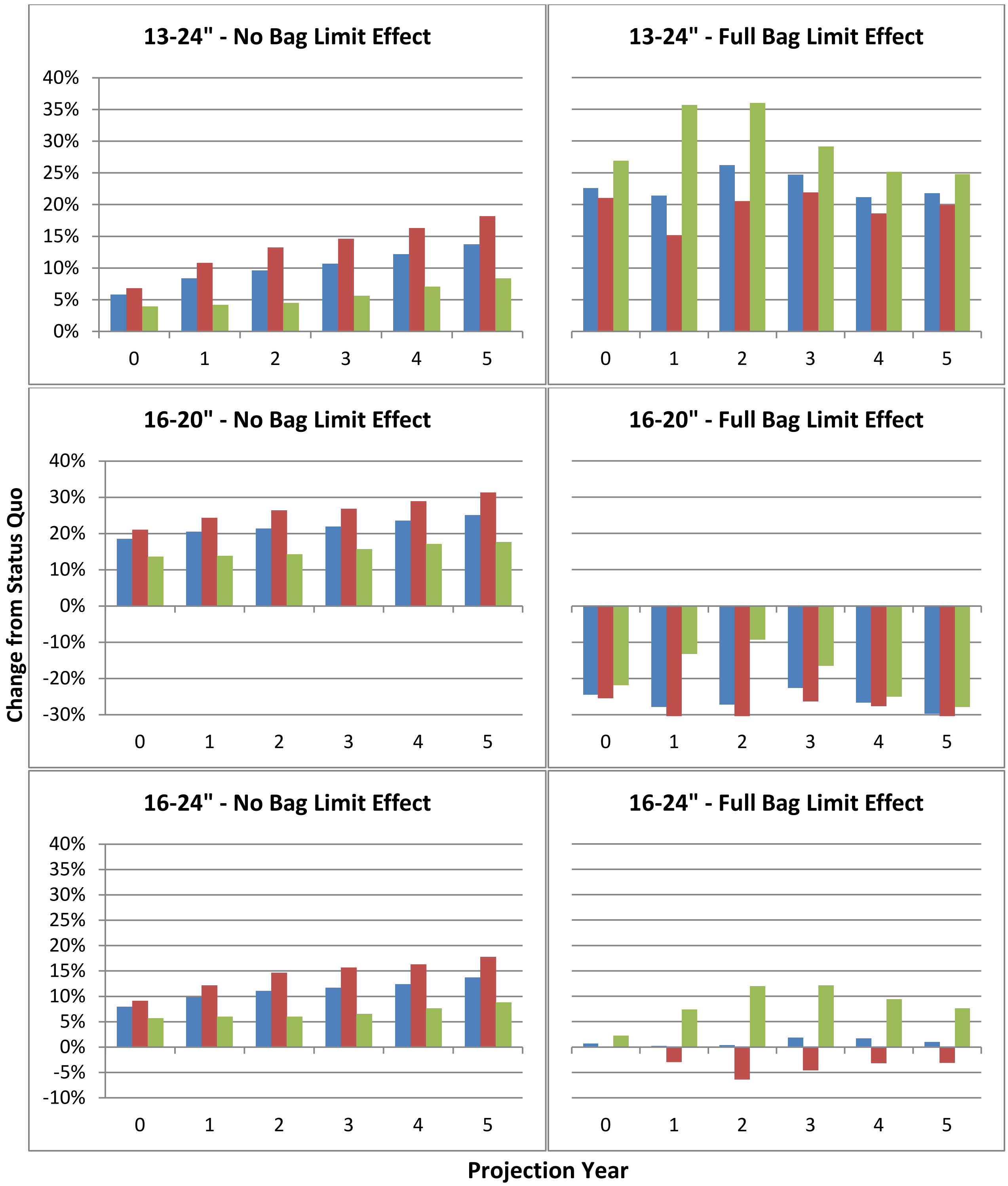

Figure 13. Projected percent change from status quo season length for five years under various slot limits for the Eastern (red), Western (green) and entire Gulf of Mexico (blue) assuming a non-constraining (left) or fully constraining (right) recreational bag limit. All runs assume no high-grading and a 22% release mortality rate.

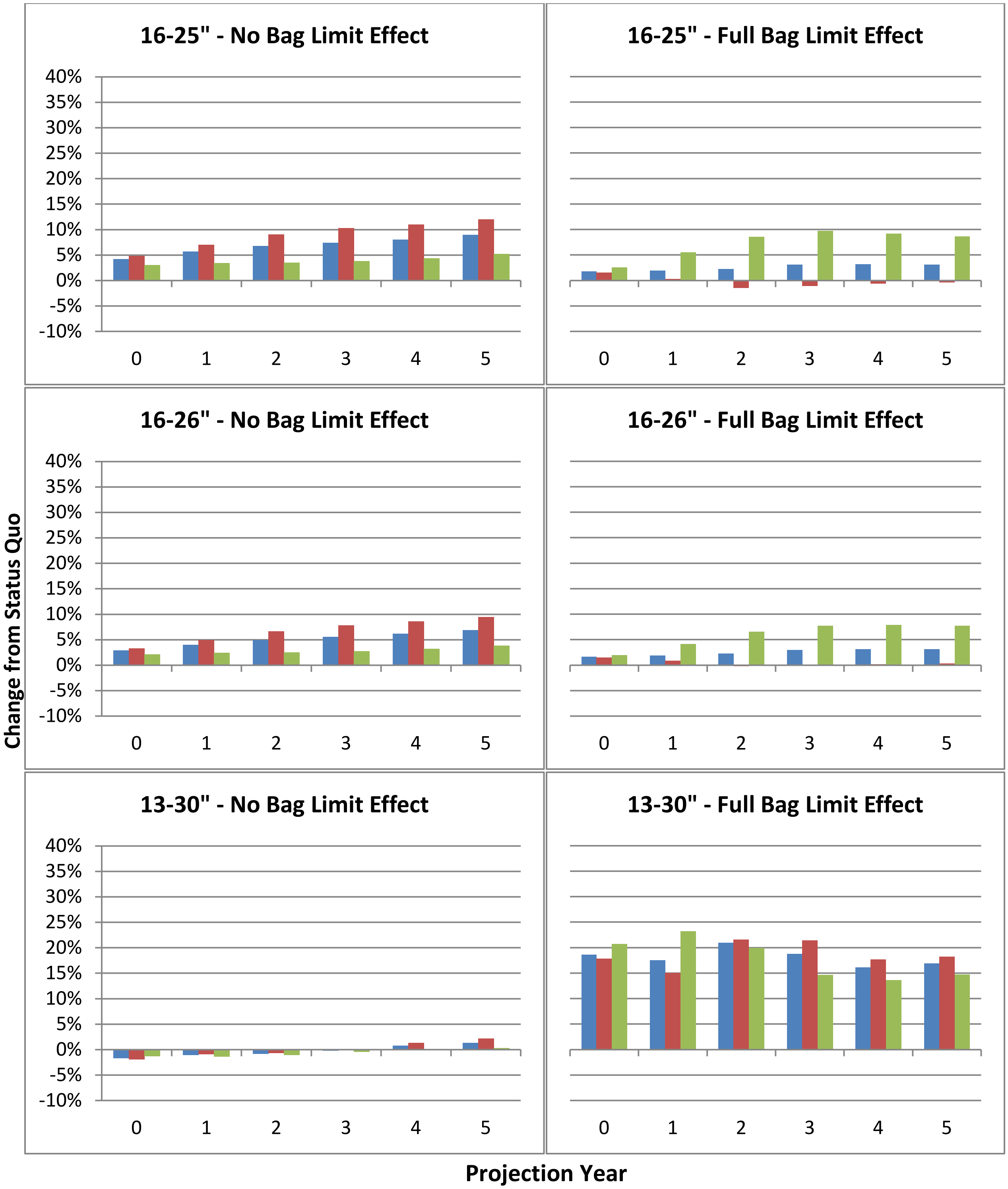

Figure 13 (con't). Projected percent change from status quo season length for five years under various slot limits for the Eastern (red) , Western (green) and entire Gulf of Mexico (blue) assuming a non-constraining (left) or fully constraining (right) recreational bag limit. All runs assume no high-grading and a 22% release mortality rate.

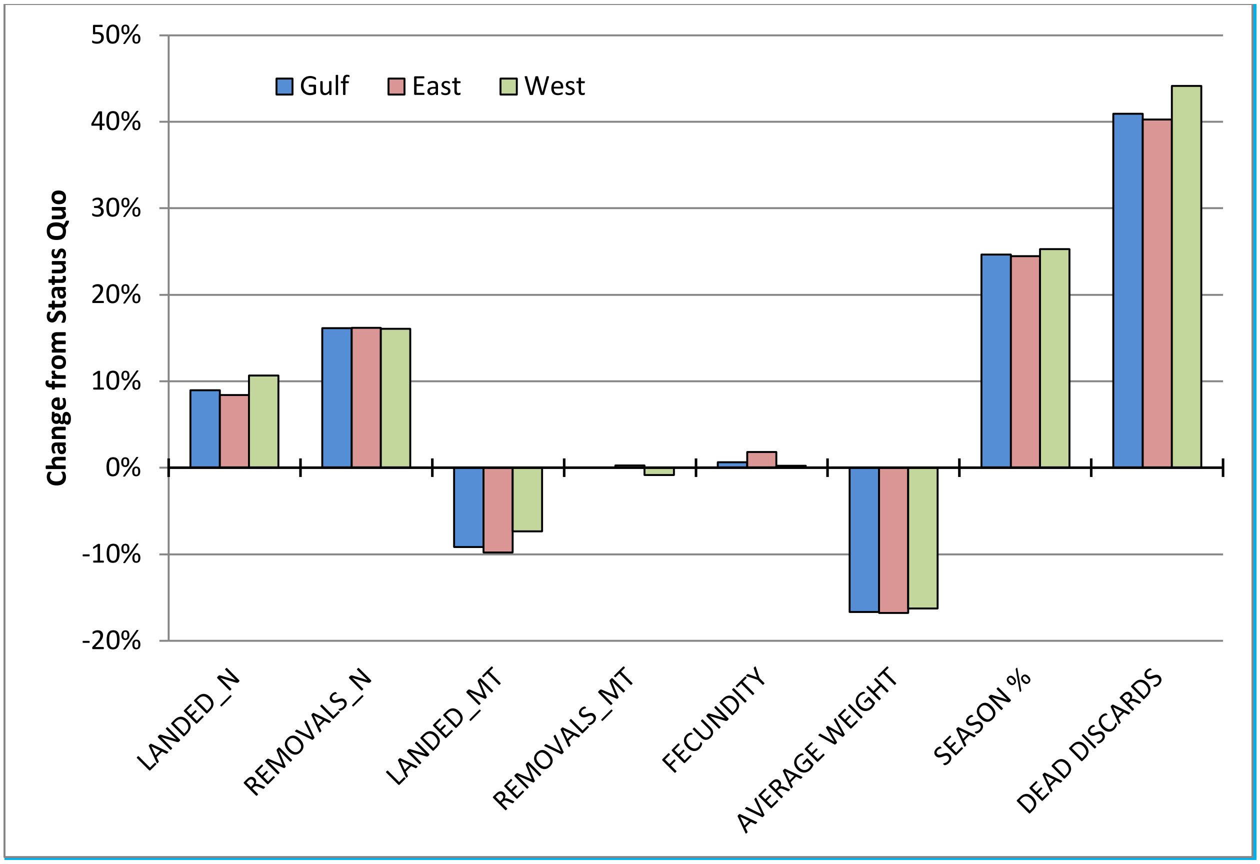

Figure 14. Percent change from status quo season length for a 16-24 inch total length slot limit for the Eastern (red), Western (green) and entire Gulf of Mexico (blue) for landings in numbers (Landed_N), removals in numbers (Removals_N), landings in weight (Landed_MT), removals in weight (Removals_MT), egg production (Fecundity), average weight, season length (Season %) assuming no bag limit effect, and dead discards in weight. Note under a fully-constraining bag limit, the change in season length is assumed proportional to the change in Landed_N.