Evaluating the Effects of Amendment 13C, Amendment 16, and Amendment 17 Regulations on Red Snapper Removals by South Atlantic Commercial Fisheries

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Introduction/Background

A recent stock assessment of red snapper off the south Atlantic coast of the United States indicates the stock is undergoing overfishing and is severely overfished (SEDAR15 2009). Red snapper fishing mortality during 2006 was 7.67 times higher than the fishing mortality rate associated with F_{MSY} (=$F_{40\%SPR}$) and spawning stock biomass (SSB) was 2 percent of the SSB at maximum sustainable yield (SEFSC 2009). The south Atlantic Fishery Management Council (SAFMC) is currently developing Amendment 17 to the Snapper-Grouper Fishery Management Plan to address overfishing of red snapper and rebuild this stock (SAFMC 2009). Alternatives under consideration include a year-round prohibition on red snapper harvest, possession, and retention in the south Atlantic EEZ, as well as year-round spatial area closures for all snapper-grouper harvest and possession, (except with spearfishing equipment). The overall size and extent of these area closures is contingent on bycatch mortality outside the closed areas and the overall percent reduction in fishing mortality needed to end overfishing. Based on an F_{MSY} = $F_{40\%SPR}$, an 87 percent reduction in red snapper fishing mortality is needed to end overfishing.

In October 2006, the SAFMC implemented Snapper-Grouper Amendment 13C. This amendment was developed, in part, to address overfishing of snowy grouper, golden tilefish, and black sea bass through quota reductions and alterations to allowable gear configurations. In September 2008, the SAFMC approved Snapper-Grouper Amendment 16. This amendment was developed to address overfishing of gag and vermilion snapper in the south Atlantic. NOAA Fisheries Service partially approved this amendment in March 2009. If implemented through final rule, Amendment 16 would establish a four month commercial and recreational closed season (January-April) for shallow-water grouper, establish a five-month recreational closed season for vermilion snapper (November-March), modify gag and vermilion snapper commercial quotas, and reduce bag limits for vermilion snapper, gag, and other groupers.

The intent of this analysis is to evaluate potential changes in red snapper commercial harvest and discards associated with Amendment 13C and Amendment 16 regulatory changes, and to evaluate the cumulative effects of these regulations in conjunction with the regulations proposed by Amendment 17.

Methods

Baseline

To determine baseline landings for red snapper, landings reported in the commercial logbook (provided by Kevin McCarthy, SEFSC, on April 6, 2009) were summarized by statistical area for 2005 – 2007 using custom software written in SAS (SAS Institute Inc., Cary, NC). To maintain confidentiality, some landings were aggregated across grids. Year was assigned using the date the fish were landed. South Atlantic red snapper landings were considered any landings reported in statistical areas 2400 through 3700. Additionally, the number of unique trips and vessels were summarized by year and area. Because the commercial logbook does not account for all commercial landings (e.g. sales made on state permits), landings were scaled up to account for this missing data. Percent scalars for 2005 and 2006 logbook landings were determined using commercial landings estimates reported in SEDAR 15 (2009; see Table 4, p. 19). The percent scalar for 2007 logbook landings was determined using commercial landings estimates derived using identical methods to SEDAR15 (D. Gloeckner, NMFS Beaufort Lab, pers. comm.). Logbook landings for 2005, 2006, and 2007 were scaled up by the respective SEDAR and Beaufort Lab scalars to create baseline commercial landings for these years. Next, an average of 2005 – 2007 landings was computed for each area. These scaled landings represent the baseline total commercial landings by area.

Reliability of Depth Records

To determine the utility of partitioning commercial landings by area and depth, the accuracy of reported fishing depth in the commercial logbook was investigated. Digitized bathymetric maps (www.nauticalcharts.noaa.gov) for the south Atlantic were projected in ArcGIS (ESRI, Redlands, CA) and overlaid with commercial logbook grids. The maximum and minimum depths in fathoms within each grid cell were visually identified, then converted to feet. To establish a buffer for measurement uncertainty, 50 feet was subtracted from minimum depths and added to maximum depths. Next, depth records for red snapper landings reported in the commercial logbook were compared to the valid range of depths for the relevant logbook grid area. Unrealistic reported depth values were flagged.

Economic Trip Reduction Model

To predict the impacts of regulations associated with Amendments 13C and 16 upon commercial trips that had previously encountered red snapper, and project associated reductions in take, an economic trip reduction model was developed (Waters 2008). The model hypothetically imposed proposed regulations on individual fishing trips as reported to the logbook database. Each reported trip was examined with regard to a combination of regulations implemented in Amendment 13C as well as proposed rules in Amendment 16, and the various proposed alternatives in Amendment 17. The effects of the rules on trip catches, revenues and costs were calculated from a model run using an opportunity cost of $52 per person. Opportunity cost expresses the surplus revenue per person per day relative to cost of the trip required for the trip to occur. A three-year average was used to estimate the expected effects of proposed regulations so that anomalies that may have affected fishing success in any one year would be averaged out. Logbook data for the three year period, 2005 – 2007, were used to simulate the fishery. A comprehensive description of the model may be found in Appendix A.

Evaluating Impacts of Management Alternatives

Outputs from the economic trip reduction model were summarized to quantify landings, trips, and discards by area and by management action for simulations based on 2005, 2006, and 2007 logbook records. The impacts of Amendment 13C (A16_NO_ACTION), Amendment 16 (A17_NO_ACTION), and various alternatives of Amendment 17 (A17_ALT2, A17_ALT3, A17_ALT4, A17_ALT5, A17_ALT6) were evaluated (Table 1). Red snapper landings (A13C_NO_ACTION, A16_NO_ACTION, A17_NO_ACTION) and discards attributable to proposed red snapper fishery closures (A17_ALT2, A17_ALT3, A17_ALT4, A17_ALT5, A17_ALT6) were computed by area for 2005, 2006, and 2007. Discards were assumed to be zero for fish harvested with spearfishing gear.

Projected annual landings and new management discard estimates were then scaled up to represent all commercial fishing activities using the scalars described previously. Next, three-year average removals were computed for each management scenario. Note that these removals do not account for baseline discard rates, which will be discussed later.

Because the baseline case for the economic trip reduction model (A13C_NO_ACTION) eliminates unprofitable trips, outputs for all model runs underestimate landings. Projected cumulative reductions in total removals by area were computed by calculating percent reductions in removals by area for each management scenario relative to the baseline model, then multiplying this percentage by the baseline landings by area.

Total Removals

Total removals by the commercial fishery must account for discards. In August 2001, the Southeast Fisheries Science Center (SEFSC) initiated a program to collect information regarding the numbers of fish that were being discarded in Gulf of Mexico and south Atlantic fisheries. To collect this information, the SEFSC developed a form that supplements the existing vessel coastal logbook forms that are currently mandatory for those fisheries (Poffenberger and McCarthy, 2004). A 20% random sample of the vessels with south Atlantic snapper-grouper, king mackerel, Spanish mackerel or shark permits were selected to report the number of animals discarded by species. To assure that the sample was representative of the total universe of vessels with these Federal permits, the universe of permitted vessels was stratified and a random sample selected, without replacement, from each stratum (SEDAR15 2009).

A general linear modeling approach was applied to these data to derive estimates of red snapper discards (expressed as thousands of fish) in the south Atlantic (SEDAR15 2009). Values for 2005 - 2007 were generated from the same program used to produce the SEDAR 15 estimates (SEDAR15 2009), but differed slightly from the SEDAR 15 estimates due to additional quality control on the logbook data (K. McCarthy, NMFS SEFSC Miami, FL, pers. comm.).

Discard estimates in numbers were converted to discard estimates in weight using the mean (2007 – 2009) ratio of discards in weight to discards in numbers from red snapper stock assessment projection scenario H1 ($F = F_{current}$) in SEFSC (2009). Discard estimates in weight for each year (2005 – 2007) were converted to dead discards by multiplying by the commercial release mortality for red snapper, estimated at 90% (SEDAR15 2009). These baseline dead discards were assumed to occur spatially in proportion to landings by grid. A mean dead discard estimate for 2005 – 2007 was computed and added to mean annual (e.g. 'baseline') landings to obtain an estimate for baseline removals.

To compute reductions in red snapper mortality due to management actions, projected landings under scenarios permitting red snapper harvest (A13C_NO_ACTION, A16_NO_ACTION, A17_NO_ACTION) and projected new discards attributable to proposed red snapper fishery closures (A17_ALT2, A17_ALT3, A17_ALT4, A17_ALT5, A17_ALT6) were treated as proxies for the commercial fishery's rate of interaction with the red snapper stock. Percent reductions in this 'rate of interaction' from the baseline model (e.g. A13C_NO_ACTION) were computed and applied to baseline dead discards to compute a new overall dead discard weight across the spatial domain. These baseline dead discards were assumed to occur spatially in proportion to reductions in landings and were distributed accordingly. Projected red snapper landings and additional dead discards resulting from new management regulations were added to generate an estimate of total removals for each scenario. Distributing total removals spatially facilitated the evaluation of additional reductions in red snapper removals that might be obtained via spatial closures of statistical areas to all fishing resulting in red snapper discards.

Results

Baseline

Logbook reported landings of red snapper, in thousand pounds whole weight (TP), for red snapper by area were highest in grid 3080 in 2007 (38 TP), and ranged annually between 81 – 117 TP for the entire south Atlantic (Table 2). Annual scalars to account for unreported commercial landings ranged from 3 – 6% (Table 3). Baseline scaled landings by area are reported in Table 4.

Red snapper commercial landings occur predominantly off the northeast coast of Florida (Figure 1). Based on a three-year average (2005 – 2007), over 32 TP (30% of the fishery) per year were landed in cell 3080, and the majority of other landings occur in bordering areas (2880, 2980, 3081, 3180, and 3179). A large portion of commercial red snapper landings also occur off the coast of South Carolina (Areas 3278, 3279, and 3378). Similarly, the majority of trips occur off the northeast coast of Florida and off the coast of South Carolina (Figure 2).

Reliability of Depth Records

Depth was determined to be an unreliable field in the commercial logbook, as depth records were often unavailable (Table 5). Reporting of depth improved through time, with no missing 'depth' records in 2007. However, a significant percentage of reported depths each year were well outside the range of depths available within the reported fishing statistical area. Some landings of red snapper were reported in cells with minimum depths beyond 1000 ft, but these cases only represented 1.43% of total landings.

Economic Trip Reduction Model

Table 6 lists projected commercial removals of red snapper, not including baseline discards, under various management scenarios derived by applying economic trip reduction model percent reductions in landings from baseline A13C_NO_ACTION model to baseline commercial landings. Numbers for Amendment 13C, Amendment 16, and Amendment 17: No Action represent projected landings. As all other Amendment 17 actions prohibit the harvest of south Atlantic red snapper, numbers for other Amendment 17 actions represent new discards.

Figure 3 illustrates projected commercial landings of south Atlantic red snapper by area, based on economic trip reduction model scenario A17_NO_ACTION, which incorporates anticipated reductions in landings given implementation of Amendment 13C and Amendment 16. The largest percent reductions from baseline landings tend to occur in the areas previously described as the core of the red snapper fishery.

Total Removals

The mean (2007 – 2009) ratio of discards in weight to discards in numbers from the south Atlantic red snapper stock assessment projection scenario H1 ($F = F_{current;}$ SEFSC 2009) was 1.49 ± 0.05 lbs/fish (mean ± SD). Using this ratio, the mean (2005 – 2007) baseline discard estimate in weight was computed as 25.62 ± 2.99 $TP{\cdot}yr^{-1}$ (Table 7).

As the economic trip reduction model predicted significantly reduced rates of fishery interactions with red snapper, the discard rate was also expected to decline. Table 8 lists projected commercial discards (TP) under various management scenarios. Projected discards (excluding discards due to new management regulations) range from 25.6 TP at baseline to 7.4 TP (29% of baseline) under Amendment 17, Alternative 6. Projected total removals by area were computed by applying the commercial release mortality rate of 90% (SEDAR15 2009) and adding landings and new management dead discards (Table 9). Overall removals were projected to decline from 130.8 TP at baseline to 34.7 TP (a 73.5% reduction) under Amendment 17, Alternative 6. Amendment 13C was projected to provide little reduction in red snapper removals (1.2% reduction); whereas Amendment 16 regulations were projected to reduce total removals by 16.5% from baseline removals.

Figures 4 – 11 illustrate the spatial distribution and projected weight of removals under various management scenarios. For the baseline scenario, assuming no impacts of Amendment 13C or Amendment 16, red snapper removals were concentrated in Northeast Florida and coastal South Carolina, with the majority occurring in grids 3080, 2980, 2880, 3279, 3378, and 3278 (Figure 4). Amendment 13C had little impact on the level or spatial distribution of removals (Figure 5). Amendment 16 was projected to reduce removals in the core of the fishery between 10 – 40%, with the most significant reductions off the coast of South Carolina (Figure 6). Amendment 17, Alternative 2 was projected to generate substantial reductions (10 – 90%) in the core of the fishery, with some reductions along the fringes (Figure 7). Amendment 17, Alternative 3 was projected to substantially reduce removals (>50%) in the core of the Northeast Florida fishery, with less substantial reductions off South Carolina (Figure 8). Amendment 17, Alternative 4 was projected to substantially reduce removals (>50%) off both Northeast Florida and South Carolina (Figure 9). Amendment 17, Alternative 5 was projected to reduce removals even more than Alternative 4 off Northeast Florida, but less off South Carolina (Figure 10). Amendment 17, Alternative 6 was projected to reduce removals throughout the fishery, with removals remaining above 3 TP in only 3 statistical areas: 3180, 3179, and 3378 (Figure 11).

Closures of logbook grid areas to all snapper – grouper fishing may provide substantial additional reductions in red snapper removals. If none of the current alternatives from Amendment 17 are implemented, and Amendment 13C and Amendment 16 have no effect, an 87% reduction in red snapper removals by the commercial fishery might be obtained through closure of ten grid cells to all snapper – grouper fishing (Table 10). If Amendment 13C and Amendment 16 have the effects predicted by the economic trip reduction model, an 87% reduction in red snapper removals by the commercial fishery might be obtained through closure of nine grid cells to all fishing resulting in red snapper discards (Table 11). If Amendment 13C, Amendment 16, and Amendment 17, Alternative 4 are all implemented and have the effects predicted by the economic trip reduction model, an 87% reduction in red snapper removals by the commercial fishery might be obtained through closure of five grid cells (3378, 3080, 3279, 3476, 3081) to all fishing resulting in red snapper discards (Table 12), in addition to the partial closures proposed by Amendment 17, Alternative 4 (see Table 1). For Amendment 17, Alternative 6, an 87% cumulative reduction in commercial fishing removals could be obtained through closure of four grid cells (3378, 3179, 3180, and 3476) to all fishing resulting in red snapper discards (Table 13), in addition to the partial closures proposed by Amendment 17, Alternative 6 (see Table 1). It should be noted that two of these cells would be partially closed under Alternatives 4 and 6 (3080 and 3279), but discards still exist due to depth and gear exceptions present in the proposed regulations.

Discussion

In this report, baseline landings for south Atlantic red snapper were computed as a three-year average of logbook reported landings adjusted up for underreporting. Baseline removals of red snapper were computed by adding a baseline discard weight derived from a generalized linear model of observer reported red snapper discards on commercial vessels (SEDAR15 2009) and a stock production model's projected relationship between red snapper discard numbers and weight (SEFSC 2009). The impacts of various management regulatory measures implemented in Amendment 13C and proposed in Amendments 16 and 17 upon red snapper interaction rates (e.g. landings and discards) were simulated using an economic trip reduction model described in Waters (2008). Model outputs suggested minimal reductions (< 2%) in red snapper removals from Amendment 13C, slight reductions (16%) from Amendment 16, and substantial reductions from the various management alternatives proposed in Amendment 17 (48 – 73%). Under all scenarios, area closures in addition to those currently proposed in Amendment 17 would be necessary to achieve the 87% reduction in red snapper removals necessary to end overfishing based on an $F_{MSY} = F_{40\%SPR}$.

As with any fishery-dependent dataset, the commercial logbook data upon which the majority of these analyses are based has its limitations. As a trip-level reporting form, the coastal logbook datasheet only allows for reporting of one area and one depth fished per species, although the species reported as landed on the form may have been caught in several different areas at several different depths over the length of a single fishing trip. Over the 2005 – 2007 period, 'depth' was either unavailable or unrealistic in 8 – 30% of reported records. As such, 'depth' was not considered in these analyses.

The distribution of red snapper landings based on reported 'area fished' corresponded with anecdotal information that the bulk of the south Atlantic red snapper fishery occurs off the coast of Northeast Florida, with an additional fishery off the coast of South Carolina. There were probably some inaccuracies in this field, given that a small percentage of red snapper landings were reported in cells with depths beyond 1000 ft. These are likely trips that were targeting a deep water species that landed red snapper in transit.

Discards of red snapper were computed using a generalized linear model applied to observed discards on commercial vessels (SEDAR15 2009). The number of trips reporting red snapper in the south Atlantic was very low and the number of individual fish reported as discarded was also low. Stratification of the available data was limited because of the small sample sizes and, therefore, likely does not capture much of the variation in numbers of discards within the red snapper fisheries. How that may affect the number of calculated discards (over or under estimate) is unknown (SEDAR15 2009). Dead discards were added to landings to obtain total removals. Assuming no redistribution of effort and no impacts of Amendments 13C or 16, an 87% reduction in red snapper removals might be achieved by closing ten grid cells to all snapper – grouper fishing.

The impacts of Amendments 13C, 16, and 17 were simulated using an economic trip reduction model that hypothetically imposed proposed regulations on individual fishing trips as reported to the logbook database (Waters 2008). Each reported trip was then examined with regard to a combination of rules proposed in Amendments 13C, 16, and 17. The effects of the rules on trip catches, revenues and costs were calculated. Trips that were deemed unprofitable were eliminated and the impacts on red snapper interactions were calculated (Waters 2008).

The following discussion of the economic trip reduction model is taken from Waters (2008): *The logbook data used in this analysis reflected the full range of harvesting activities and outcomes for trips in the commercial snapper-grouper fishery, from targeted to incidental capture of various species, and included differences in species composition and fishing activities by area, gear, duration of trip, crew size, good luck and bad luck, and so forth. In this sense, this analysis was more realistic than conventional bioeconomic models, which specify homogeneous fishing activity within a few discrete fishing classes defined by vessel size, gear type, area fished, or scale of operation.*

The economic trip reduction model accounted for behavioral responses by fishermen to new regulations by eliminating currently observed trips that likely would become unprofitable. However, the simulation model did not account for more complex behavioral responses such as a redirection of fishing effort among different types of fishing as fishermen react to minimize the adverse effects of management. Conversely, fishing effort in the snapper-grouper fishery may increase with time if proposed regulations are successful in increasing the long-term abundance of economically important species. This analysis did not account for potential changes in fishing effort with time, and additional econometric analysis is needed to model this type of behavioral response to changes in resource abundance and regulation.

Analyses using the economic trip reduction model suggested that regulations associated with Amendments 13C and 16 might reduce overall red snapper removals in the commercial fishery by 16%, and would require major area closures or some combination of area closures and regulations proposed in Amendment 17 to reduce overall red snapper removals by the commercial fishery to 87%. Of the proposed alternatives, Alternatives 4 and 6 came closest to achieving the 87% reduction, but each would require additional area closures. For example, Amendment 17, Alternative 6 would prohibit commercial and recreational harvest, possession, and retention of species in the snapper grouper FMU year-round in an area that includes commercial logbook grids 2880, 2980, 3080, 3179, 3180, 3278, and 3279. These analyses suggest the provisions in this alternative allowing the harvest of black sea bass and golden tilefish result in significant red snapper discards, especially in cells 3080 and 3179. The complete closure of these two cells and two additional grid cells (3378, 3476) to all fishing resulting in red snapper discards would reduce red snapper harvest by greater than 87% overall for the commercial fishery. Similar patterns were observed for Amendment 17 Alternatives 4 and 6. This is not surprising, given that the area closures are identical between the two alternatives except that Alternative 4 provides for some open depths within each cell where red snapper occur in less abundance.

Further investigations into the sensitivity of these model predictions and the actions required to reduce red snapper removals in the recreational fisheries will be required to fully ascertain the impacts of previously implemented and currently proposed Amendments. Additional investigations of the impacts of proposed regulations on deep water species also found in Amendment 17 may also be prudent, although their effects on red snapper discard rates are expected to be minimal.

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Table 1. Proposed or implemented regulations under various management actions integrated into economic trip reduction simulation model.

Model	Status	Management Actions*
A13C_NO_ACTION	Implemented (Oct 2006)	Decrease commercial quota for snowy grouper from 151 TP gw in 2006 to 118 TP gw in 2007, and decrease trip limit from 275 lbs gw in 2006 to 175 lbs gw in 2007. Reduce golden tilefish commercial quota to 295 TP wg, reduce trip limit to 4 TP gw, reduce trip limit to 300 lbs gw if 75% quota taken by 1 Sept. Establish 1.1 MP gw quota for vermilion snapper. Reduce black sea bass quota from 477 TP gw (June 1, 2006 - May 31, 2007) to 423 TP gw (June 1, 2007 - May 31, 2008), require use of ≥2 inch mesh for entire back panel of pots, remove pots from water when quota is met. Increase trip limit for red porgy to 120 fish (May - December), establish quota of 127 TP gw.
A16_NO_ACTION	Proposed (Public Comment)	Establish closed season from January to April for all shallow water grouper. Establish 352,940 lbs gw quota for gag. Reduce vermilion snapper quota to 315,523 lbs gw (January - June) and 302,523 lbs gw (July - December).
A17_NO_ACTION	Proposed	Continue the 20 inch size limit (commercial & recreational).
A17_ALT2	Proposed	Prohibit all commercial and recreational harvest, possession, and retention of red snapper year-round in the south Atlantic EEZ.

A17_ALT3	Proposed	Prohibit commercial and recreational harvest, possession, and retention of species in the snapper grouper FMU year-round in an area that includes commercial logbook grids 2880, 2980, 3080, and 3180 between a depth of 98 feet (16 fathoms; 30 m) to 240 feet (40 fathoms; 73 m). Allow black sea bass harvest, possession, and retention in the closed area if fish were harvested with black sea bass pots with endorsements. Allow golden tilefish harvest, possession, and retention in the closed area. Allow harvest, possession, and retention of snapper grouper species in the closed area if fish were harvested with spearfishing gear. Prohibit all commercial and recreational harvest, possession, and retention of red snapper year-round in the south Atlantic EEZ.
A17_ALT4	Proposed	Prohibit commercial and recreational harvest, possession, and retention of species in the snapper grouper FMU year-round in an area that includes commercial logbook grids 2880, 2980, 3080, 3179, 3180, 3278, and 3279 between a depth of 98 feet (16 fathoms; 30 m) to 240 feet (40 fathoms; 73 m). Allow black sea bass harvest, possession, and retention in the closed area if fish were harvested with black sea bass pots with endorsements. Allow golden tilefish harvest, possession, and retention in the closed area. Allow harvest, possession, and retention of snapper grouper species in the closed area if fish were harvested with spearfishing gear. Prohibit all commercial and recreational harvest, possession, and retention of red snapper year-round in the south Atlantic EEZ

A17_ALT5	Proposed		Prohibit commercial and recreational harvest, possession, and retention of species in the snapper grouper FMU year-round in an area that includes commercial logbook grids 2880, 2980, 3080, and 3180. Allow black sea bass harvest, possession, and retention in the closed area if fish were harvested with black sea bass pots with endorsements. Allow golden tilefish harvest, possession, and retention in the closed area. Allow harvest, possession, and retention of snapper grouper species in the closed area if fish were harvested with spearfishing gear. Prohibit all commercial and recreational harvest, possession, and retention of red snapper year-round in the south Atlantic EEZ
A17_ALT6	Proposed		Prohibit commercial and recreational harvest, possession, and retention of species in the snapper grouper FMU year-round in an area that includes commercial logbook grids 2880, 2980, 3080, 3179, 3180, 3278, and 3279. Allow black sea bass harvest, possession, and retention in the closed area if fish were harvested with black sea bass pots with endorsements. Allow golden tilefish harvest, possession, and retention in the closed area. Allow harvest, possession, and retention of snapper grouper species in the closed area if fish were harvested with spearfishing gear. Prohibit all commercial and recreational harvest, possession, and retention of red snapper year-round in the south Atlantic EEZ

*impacting commercial fisheries

Table 2. Logbook reported landings (thousand lbs, whole weight) for south Atlantic red snapper, 2005 – 2007, by area.

AREA	2005	2006	2007	Grand Total	Average 2005 - 2007	Percent of Total
3080	29.3	24.5	37.7	91.5	30.5	29.59%
2980	13.7	7.5	15.2	36.4	12.1	11.76%
3279	15.5	6.1	7.5	29.0	9.7	9.38%
2880	7.9	5.5	9.5	22.8	7.6	7.36%
3278	9.4	5.8	6.6	21.7	7.2	7.01%
3378	9.3	6.0	6.0	21.3	7.1	6.89%
3179	9.6	3.3	2.9	15.8	5.3	5.12%
3081	2.6	4.9	7.3	14.8	4.9	4.79%
3180	3.5	2.6	3.8	9.9	3.3	3.21%
3476	3.0	2.6	2.1	7.7	2.6	2.50%
3377	1.9	2.4	1.0	5.2	1.7	1.68%
2879	0.5	1.7	1.8	4.0	1.3	1.29%
3376	0.3	0.1	3.5	3.9	1.3	1.26%
2482	1.7	2.0	0.0	3.7	1.2	1.19%
2481	1.3	1.0	0.3	2.5	0.9	0.82%
2480	0.7	0.9	0.7	2.3	0.8	0.73%
2780	0.8	0.3	0.5	1.6	0.5	0.53%
3477	0.5	0.6	0.5	1.5	0.5	0.49%
2981	0.3	0.6	0.3	1.2	0.4	0.39%
3474	0.4	0.5	0.2	1.1	0.4	0.36%
3277	0.0	0.3	0.7	1.0	0.4	0.33%
3079	0.6	0.2	0.2	1.0	0.3	0.31%
2580	0.5	0.2	0.0	0.8	0.3	0.25%
3379	0.1	0.5	0.2	0.8	0.3	0.26%
2679	0.0	0.5	0.1	0.6	0.2	0.19%
3178	0.4	0.1	0.1	0.6	0.2	0.18%
2779	0.1	0.1	0.2	0.4	0.1	0.14%
3280	0.2	0.1	0.1	0.4	0.1	0.13%
3575	0.0	0.1	0.1	0.1	0.1	0.06%
Other*	2.9	0.0	0.1	3.0	1.8	0.0178
Grand Total	**117.1**	**80.9**	**108.9**	**306.8**	**103.1**	

Source: Commercial Logbook database, SEFSC, accessed April 6, 2009.
*Landings from areas with fewer than 3 vessels per year are aggregated into this 'Other' category.

Table 3. Annual scalars accounting for commercial landings (thousands of pounds, whole weight) unreported in commercial logbook.

	2005	2006	2007
Logbook	117.1	80.9	108.8
All Comm Landings	124.4*	83.2*	115.7†
Lbs Difference	7.3	2.3	6.8
%Difference	6.24%	2.83%	6.28%

*Source: SEDAR 15: south Atlantic Red Snapper (SEDAR15 2009).
†Source: D. Gloeckner, NMFS Beaufort Lab, NC.

Table 4. Commercial landings (thousand lbs, whole weight) for south Atlantic red snapper, 2005 – 2007, by area, with baseline average (2005 – 2007) used for subsequent commercial landings comparisons.

AREA	2005	2006	2007	Grand Total	Average	Pct of Total
3080	31.2	25.2	40.1	96.4	**32.1**	29.83%
2980	14.6	7.7	16.1	38.4	**12.8**	11.89%
3279	16.5	6.2	7.9	30.6	**10.2**	9.48%
2880	8.4	5.6	10	24	**8**	7.43%
3278	10	6	7	22.9	**7.6**	7.07%
3378	9.9	6.2	6.3	22.4	**7.5**	6.94%
3179	10.2	3.4	3	16.7	**5.6**	5.17%
3081	2.8	5.1	7.7	15.6	**5.2**	4.82%
3180	3.7	2.7	4.1	10.5	**3.5**	3.23%
3476	3.2	2.7	2.3	8.1	**2.7**	2.51%
3377	2	2.4	1	5.4	**1.8**	1.68%
2879	0.5	1.7	2	4.2	**1.4**	1.30%
3376	0.3	0.1	3.7	4.2	**1.4**	1.28%
2482	1.8	2	0	3.9	**1.3**	1.19%
2481	1.4	1	0.3	2.7	**0.9**	0.83%
2480	0.8	0.9	0.7	2.4	**0.8**	0.73%
2780	0.9	0.3	0.6	1.7	**0.6**	0.53%
3477	0.5	0.6	0.6	1.6	**0.5**	0.49%
2981	0.4	0.6	0.3	1.3	**0.4**	0.39%
3277	0	0.3	0.7	1.1	**0.4**	0.34%
3474	0.5	0.5	0.2	1.2	**0.4**	0.36%
2580	0.6	0.2	0	0.8	**0.3**	0.25%
3079	0.6	0.2	0.2	1	**0.3**	0.31%
3379	0.1	0.6	0.2	0.8	**0.3**	0.26%
2679	0	0.5	0.1	0.6	**0.2**	0.19%
2779	0.1	0.1	0.2	0.5	**0.2**	0.14%
3178	0.4	0.1	0.1	0.6	**0.2**	0.18%
3280	0.2	0.1	0.1	0.4	**0.1**	0.13%
3575	0	0.1	0.1	0.1	**0**	0.04%
Other*	3	0	0	3.1	**1**	0.98%
Grand Total	**124.4**	**83.2**	**115.7**	**323.3**	**107.8**	

*Landings from areas with fewer than 3 vessels per year are aggregated into this 'Other' category.

Table 5. Reliability of depth records in commercial logbook, as indicated by percentage of records missing depth information, and percentage of reported depths falling outside the bounds of available depths within reported fishing area (i.e. 'unrealistic').

Year	Rows	Unavailable Depth	%Unavailable	Unrealistic Depth	%Unrealistic
2005	1342	333	24.8%	70	5.2%
2006	1154	73	6.3%	66	5.7%
2007	1326	0	0.0%	111	8.4%

Source: Commercial Logbook database, SEFSC, accessed April 6, 2009.

Table 6. Projected commercial removals of red snapper (thousands of pounds, whole weight), not including baseline discards, given implementation of Amendment 13C (A13C), Amendment 16 (A16), and various management alternatives proposed in Amendment 17 (A17).

	Landings			Amendment 17 New Discards				
	A13C	**A16**	**A17 No Action**	**ALT2**	**ALT3**	**ALT4**	**ALT5**	**ALT6**
3080	32.1	32.0	28.6	15.7	3.6	3.7	1.0	1.0
2980	12.8	12.3	11.3	4.1	2.2	2.2	0.9	0.9
3279	10.2	10.0	7.4	6.4	6.8	2.6	6.9	0.0
2880	8.0	8.0	7.5	1.9	1.2	1.2	1.0	1.0
3278	7.6	7.6	6.1	5.2	5.6	1.9	5.7	0.4
3378	7.5	7.5	5.6	4.8	5.3	5.8	5.4	5.8
3179	5.6	5.4	3.8	3.3	4.0	0.4	4.1	5.6
3081	5.2	5.2	4.3	1.5	1.9	2.2	1.9	2.2
3180	3.5	3.5	2.7	1.8	0.3	0.3	3.5	3.5
3476	2.7	2.6	2.3	2.2	2.3	2.5	2.3	2.5
3377	1.8	1.8	1.4	1.3	1.4	1.5	1.4	1.5
2879	1.4	1.4	0.9	0.3	0.8	1.4	0.8	1.4
3376	1.4	1.4	1.1	0.2	0.4	0.9	0.4	0.9
2482	1.3	1.2	1.2	0.5	0.6	0.6	0.6	0.6
2481	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3
2480	0.8	0.8	0.8	0.4	0.4	0.4	0.4	0.4
2780	0.6	0.6	0.5	0.3	0.3	0.3	0.3	0.3
3477	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.5
2981	0.4	0.4	0.4	0.1	0.1	0.1	0.1	0.1
3474	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
3277	0.4	0.3	0.2	0.2	0.3	0.3	0.3	0.3
3079	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
2580	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0
3379	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1
2679	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0
3178	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.2
2779	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0
3280	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Other*	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0
Total	**107.8**	**106.4**	**89.8**	**53.2**	**40.4**	**31.0**	**36.4**	**21.9**
%Baseline	**100.0%**	**98.8%**	**83.4%**	**49.4%**	**37.5%**	**28.8%**	**33.8%**	**20.3%**

*Landings from areas with fewer than 3 vessels per year are aggregated into this 'Other' category. Statistical areas with less than 50 lbs landings omitted from table.

Table 7. Baseline commercial discards, in thousands of fish and thousands of pounds (whole weight), for south Atlantic red snapper, for 2005 – 2007. Estimates of discards in numbers generated by K. McCarthy, NMFS SEFSC Miami. Conversion to discards in weight performed using mean 2007 – 2009 ratio of discard in numbers to discard in lbs from projection scenario H1 (SEFSC 2009).

Year	D(1000)	D(1000 lb)
2005	15.25	22.67
2006	17.18	25.53
2007	19.28	28.65
Mean	**17.24**	**25.62**

Table 8. Estimated baseline commercial discards (thousands of pounds, whole weight) given implementation of Amendment 13C (A13C), Amendment 16 (A16), and various management alternatives proposed in Amendment 17 (A17).

			Amendment 17					
	A13C No Action	**A16 No Action**	**No Action**	**ALT2**	**ALT3**	**ALT4**	**ALT5**	**ALT6**
3080	7.6	7.6	6.8	3.7	0.9	0.9	0.2	0.2
2980	3	2.9	2.7	1	0.5	0.5	0.2	0.2
3279	2.4	2.4	1.8	1.5	1.6	0.6	1.6	0
2880	1.9	1.9	1.8	0.4	0.3	0.3	0.2	0.2
3278	1.8	1.8	1.4	1.2	1.3	0.5	1.4	0.1
3378	1.8	1.8	1.3	1.1	1.3	1.4	1.3	1.4
3179	1.3	1.3	0.9	0.8	1	0.1	1	1.3
3081	1.2	1.2	1	0.4	0.4	0.5	0.4	0.5
3180	0.8	0.8	0.6	0.4	0.1	0.1	0.8	0.8
3476	0.6	0.6	0.5	0.5	0.6	0.6	0.6	0.6
3377	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3
2482	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1
2879	0.3	0.3	0.2	0.1	0.2	0.3	0.2	0.3
3376	0.3	0.3	0.3	0	0.1	0.2	0.1	0.2
2480	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
2481	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
2580	0.1	0.1	0.1	0	0	0	0	0
2780	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2981	0.1	0.1	0.1	0	0	0	0	0
3079	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3277	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3379	0.1	0.1	0	0	0	0	0	0
3474	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3477	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Other*	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
DISCARDS	**25.6**	**25.3**	**21.4**	**12.6**	**9.6**	**7.4**	**9.4**	**7.4**

*Landings from areas with fewer than 3 vessels per year are aggregated into this 'Other' category. Statistical areas with less than 50 lbs landings omitted from table.

Table 9. Total estimated removals of south Atlantic red snapper by area (thousands of lbs, whole weight) given implementation of Amendment 13C (A13C), Amendment 16 (A16), and various management alternatives proposed in Amendment 17 (A17).

				Amendment 17				
Area	**Baseline**	**A16**	**No Action**	**ALT2**	**ALT3**	**ALT4**	**ALT5**	**ALT6**
3080	39	38.8	34.7	17.5	4.1	4.1	1.2	1.2
2980	15.5	14.9	13.7	4.6	2.4	2.4	1	1
3279	12.4	12.2	8.9	7.2	7.6	2.9	7.7	0
2880	9.7	9.7	9.1	2.1	1.4	1.4	1.1	1.1
3278	9.3	9.2	7.4	5.8	6.3	2.2	6.3	0.4
3378	9.1	9.1	6.8	5.4	5.9	6.4	6	6.4
3179	6.8	6.6	4.6	3.7	4.5	0.5	4.5	6.2
3081	6.3	6.3	5.2	1.7	2.1	2.5	2.1	2.5
3180	4.2	4.2	3.2	2	0.3	0.3	3.9	3.9
3476	3.3	3.2	2.8	2.4	2.6	2.7	2.6	2.7
3377	2.2	2.2	1.6	1.5	1.5	1.6	1.6	1.6
2879	1.7	1.7	1.1	0.3	0.9	1.5	0.9	1.5
3376	1.7	1.7	1.3	0.2	0.5	1	0.5	1
2482	1.6	1.5	1.5	0.6	0.6	0.6	0.6	0.6
2481	1.1	1.1	1.1	0.4	0.4	0.4	0.4	0.4
2480	1	1	0.9	0.4	0.4	0.4	0.4	0.4
2780	0.7	0.7	0.6	0.3	0.3	0.4	0.3	0.4
3477	0.6	0.6	0.5	0.4	0.4	0.5	0.4	0.5
2981	0.5	0.5	0.5	0.1	0.1	0.1	0.1	0.1
3474	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4
3079	0.4	0.4	0.3	0.3	0.4	0.4	0.4	0.4
3277	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3
2580	0.3	0.3	0.3	0	0	0	0	0
3379	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.1
2679	0.2	0.2	0.2	0	0	0	0	0
2779	0.2	0.2	0.1	0	0	0	0	0
3178	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
3280	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
3575	0.1	0	0	0	0	0	0	0
Other*	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1
TOTAL	**130.8**	**129.2**	**109.2**	**59.1**	**44.8**	**34.6**	**44.1**	**34.7**
%Baseline	**100.0%**	**98.8%**	**83.5%**	**45.2%**	**34.2%**	**26.5%**	**33.7%**	**26.5%**

Note: 90% release mortality is applied to new management discards and baseline discards for A17 alternatives 2 - 6.

*Landings from areas with fewer than 3 vessels per year are aggregated into this 'Other' category. Statistical areas with less than 50 lbs landings omitted from table.

Table 10. Percent reduction in commercial fishery removals (R), in thousands of lbs (TP), whole weight, of south Atlantic red snapper given closures to all snapper – grouper fishing in specific logbook grid cells, assuming no impacts of Amendment 13C or Amendment 16.

Area	Baseline	Pct of Removals	Cum Pct Reduction* if Closed
3080	39	29.80%	29.80%
2980	15.5	11.90%	41.70%
3279	12.4	9.50%	51.20%
2880	9.7	7.40%	58.70%
3278	9.3	7.10%	65.70%
3378	9.1	6.90%	72.70%
3179	6.8	5.20%	77.80%
3081	6.3	4.80%	82.70%
3180	4.2	3.20%	85.90%
3476	3.3	2.50%	88.40%
3377	2.2	1.70%	90.10%
2879	1.7	1.30%	91.40%
3376	1.7	1.30%	92.70%
2482	1.6	1.20%	93.90%
2481	1.1	0.80%	94.70%

*from baseline total of 130.81 thousand lbs, assuming no redistribution of fishing pressure onto other spatial locations with red snapper.

Table 11. Cumulative percent reductions in projected commercial fishery removals (R) relative to baseline removals of 130.8 thousands lbs (TP), whole weight, of south Atlantic red snapper, given additional spatial closures to all fishing resulting in red snapper discards in specific logbook grid cells, given implementation of Amendments 13C and 16.

Potential closed area	R(TP)	Cum Pct Reduction* if Closed
Overall reduction due to A13C & A16	**21.6**	**16.53%**
3080	34.7	43.07%
2980	13.7	53.55%
2880	9.1	60.52%
3279	8.9	67.35%
3278	7.4	72.98%
3378	6.8	78.16%
3081	5.2	82.11%
3179	4.6	85.63%
3180	3.2	88.11%
3476	2.8	90.24%
3377	1.6	91.49%
2482	1.5	92.61%
3376	1.3	93.62%
2879	1.1	94.45%
2481	1.1	95.27%

*from baseline total of 130.81 thousand lbs, assuming no redistribution of fishing pressure onto other spatial locations with red snapper.

Table 12. Cumulative percent reductions in projected commercial fishery removals (R) relative to baseline removals of 130.8 thousands lbs (TP), whole weight, of south Atlantic red snapper, given additional spatial closures to all fishing resulting in red snapper discards in specific logbook grid cells, given implementation of Amendments 13C, 16, and 17 Alt. 4.

Potential closed area	R(TP)	Cum Pct Reduction* if Closed
Overall reduction due to A13C, A16, & A17 (Alt. 4)	**34.6**	**73.52%**
3378	6.4	78.42%
3080	4.1	81.57%
3279	2.9	83.80%
3476	2.7	85.89%
3081	2.5	87.77%
2980	2.4	89.63%
3278	2.2	91.28%
3377	1.6	92.53%
2879	1.5	93.68%
2880	1.4	94.74%
3376	1.0	95.52%

*from baseline total of 130.81 thousand lbs, assuming no redistribution of fishing pressure onto other spatial locations with red snapper.

Table 13. Cumulative percent reductions in projected commercial fishery removals (R) relative to baseline removals of 130.8 thousands lbs (TP), whole weight, of south Atlantic red snapper, given additional spatial closures to all fishing resulting in red snapper discards in specific logbook grid cells, given implementation of Amendments 13C, 16, and 17 Alt. 6.

Potential closed area	R(TP)	Cum Pct Reduction* if Closed
Overall reduction due to A13C, A16, & A17 (Alt. 6)	**34.7**	**73.50%**
3378	6.4	78.40%
3179	6.2	83.15%
3180	3.9	86.12%
3476	2.7	88.21%
3081	2.5	90.09%
3377	1.6	91.33%
2879	1.5	92.48%
3080	1.2	93.37%
2880	1.1	94.24%
3376	1	95.02%
2980	1	95.78%

*from baseline total of 130.81 thousand lbs, assuming no redistribution of fishing pressure onto other spatial locations with red snapper.

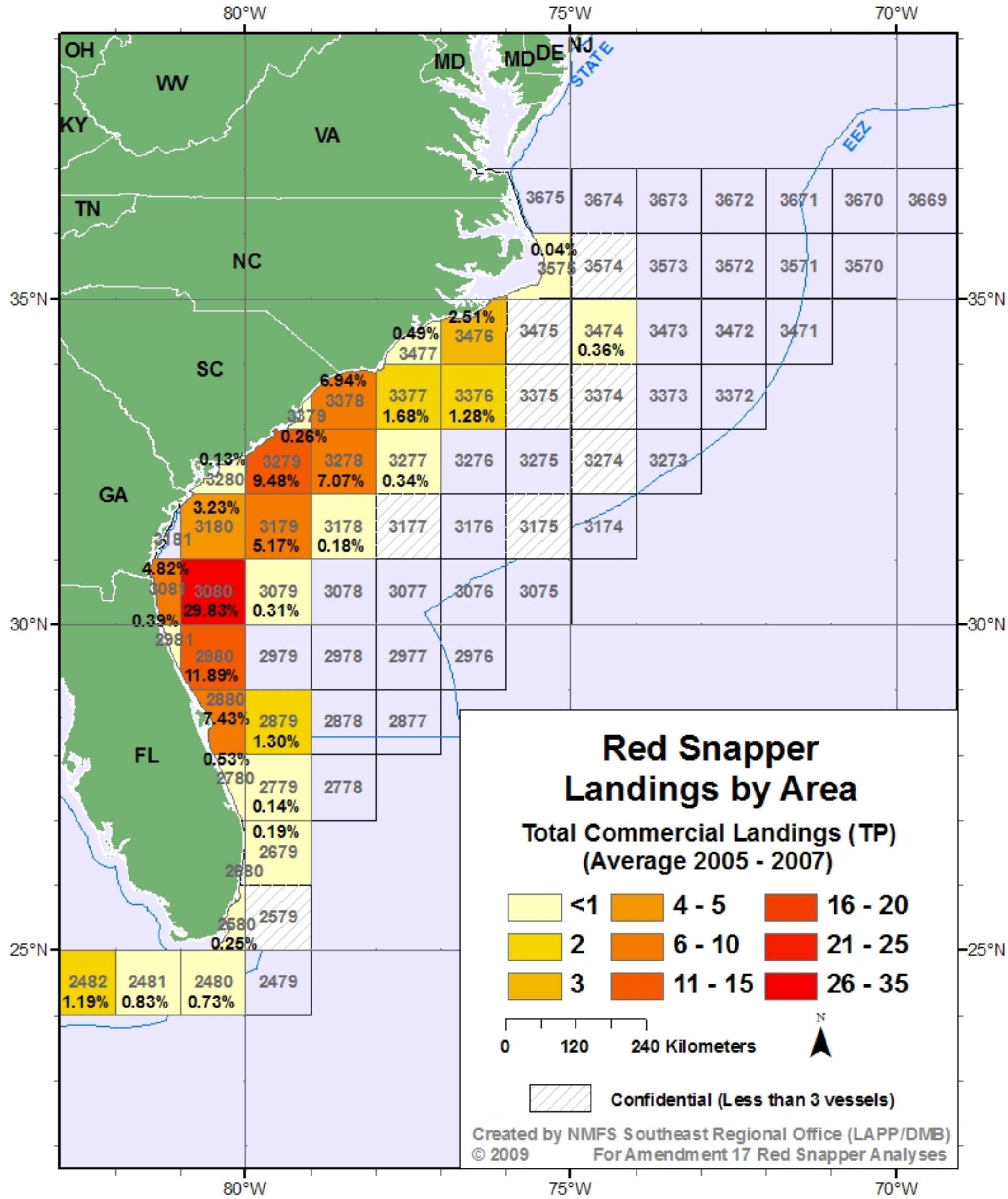

Figure 1. Total commercial landings of south Atlantic red snapper by area, based on scaled 2005 – 2007 average. Color scale denotes landings in thousands of pounds whole weight, and percentage of overall landings is indicated for each grid cell.

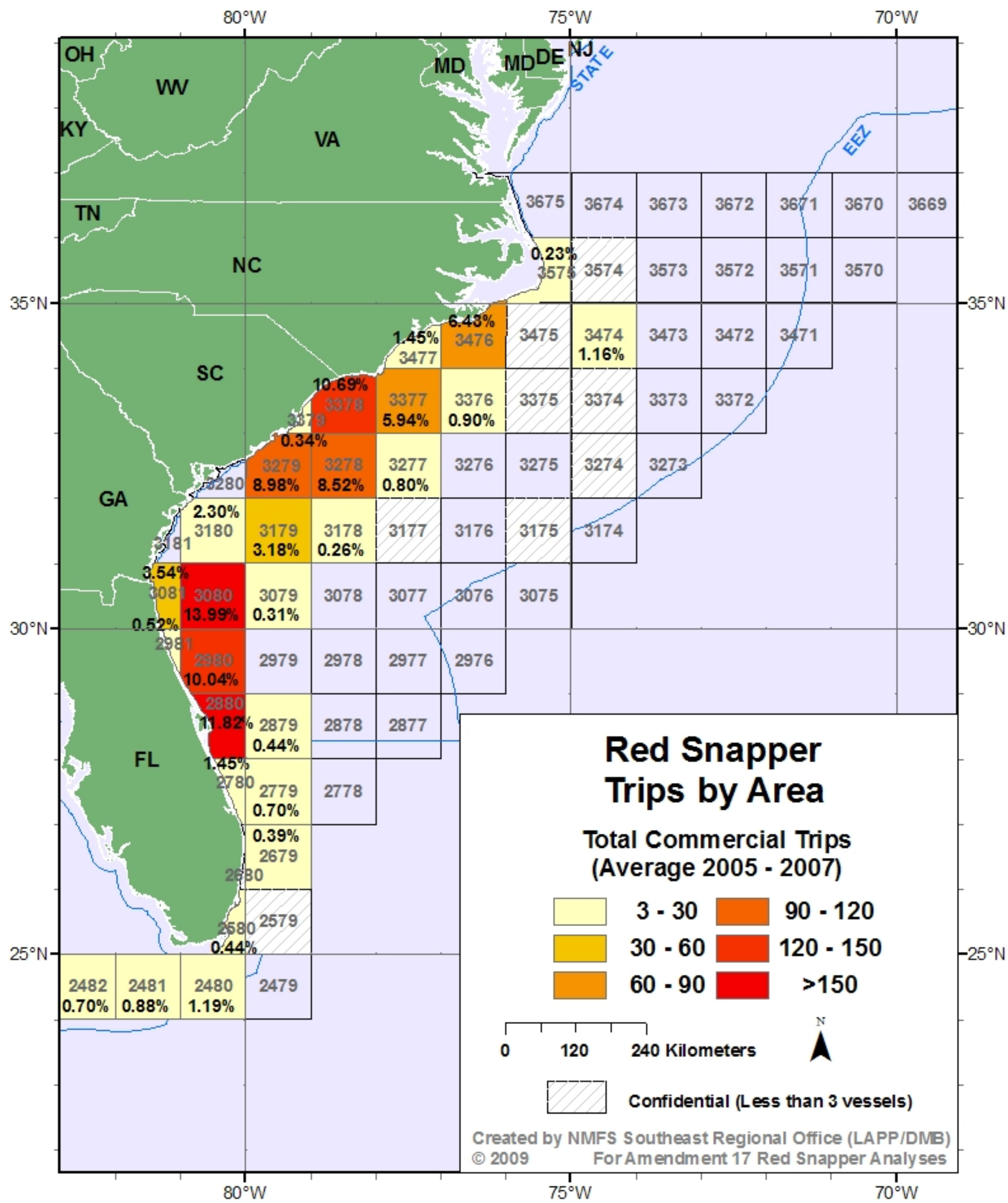

Figure 2. Total commercial trips landing south Atlantic red snapper by area, based on scaled 2005 – 2007 average. Color scale denotes number of trips, and percentage of overall trips is indicated for each grid cell.

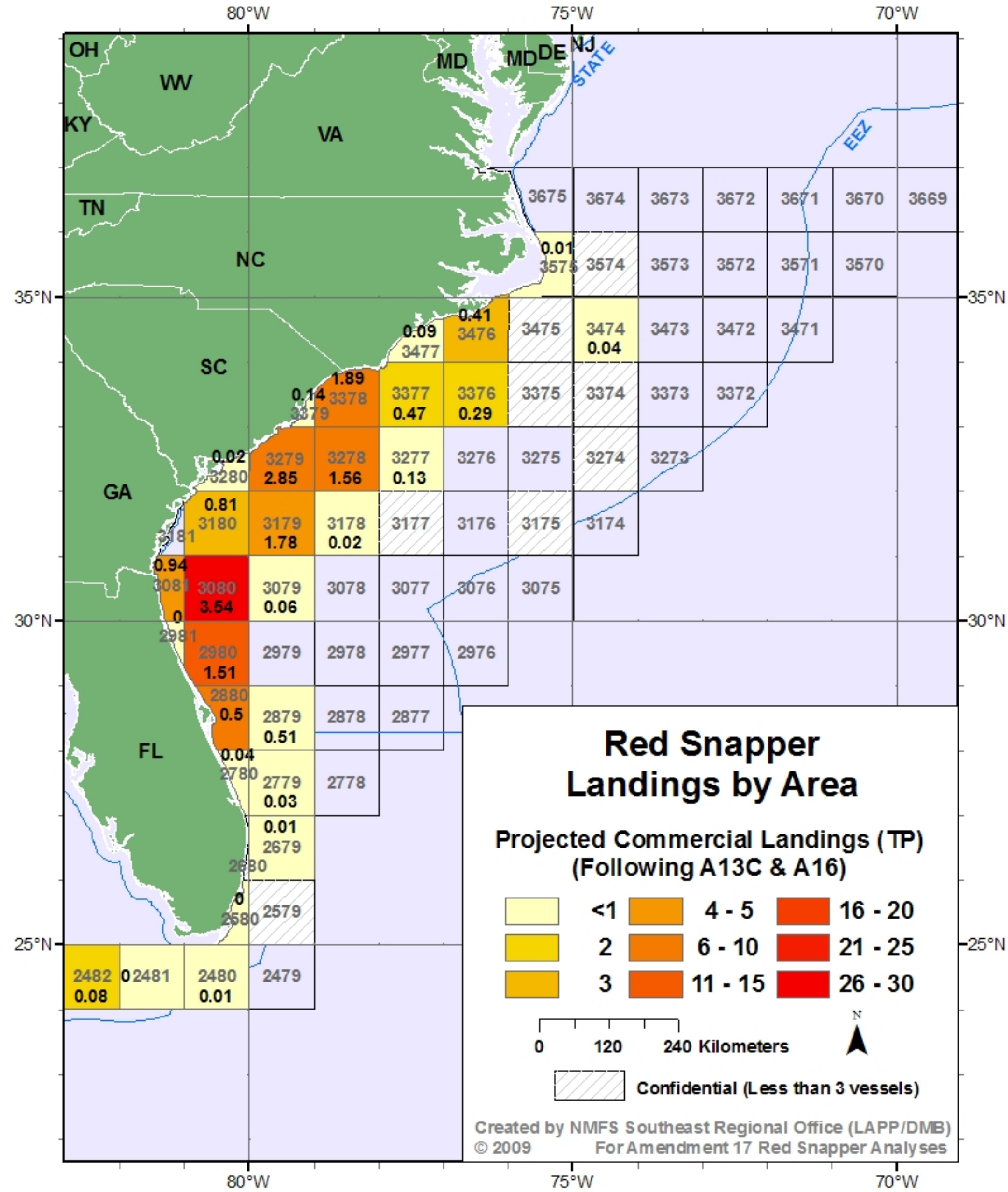

Figure 3. Projected commercial landings of south Atlantic red snapper by area, based on economic trip reduction model scenario A17_NO_ACTION, which incorporates anticipated reductions in landings given implementation of Amendment 13C and Amendment 16. Color scale denotes landings in thousands of pounds (TP) whole weight, and reduction from baseline landings (TP) is given in each cell.

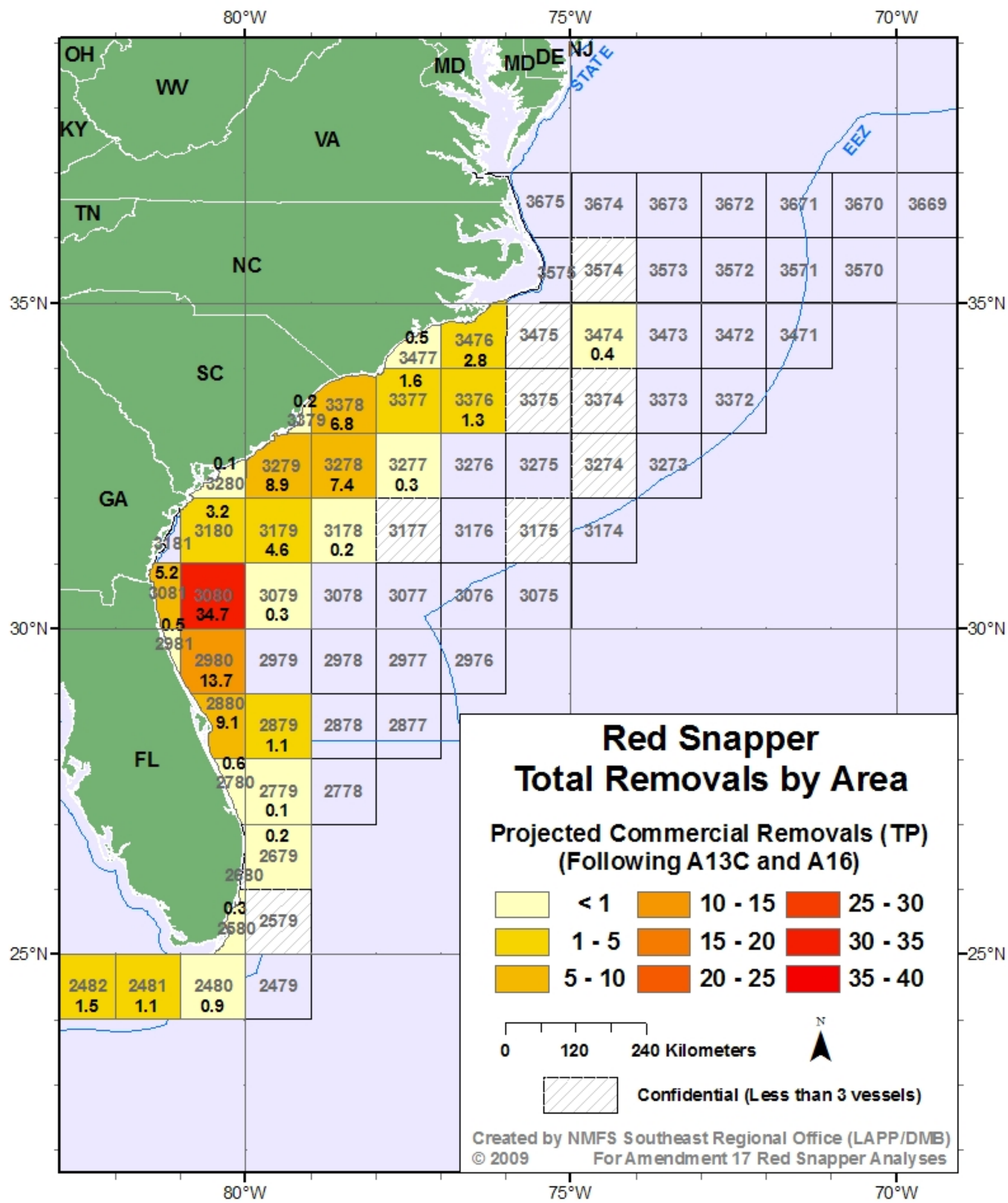

Figure 4. Estimated baseline commercial removals of south Atlantic red snapper by area. Color scale denotes removals in thousands of pounds (TP) whole weight, with value for baseline removals (TP) given in each cell.

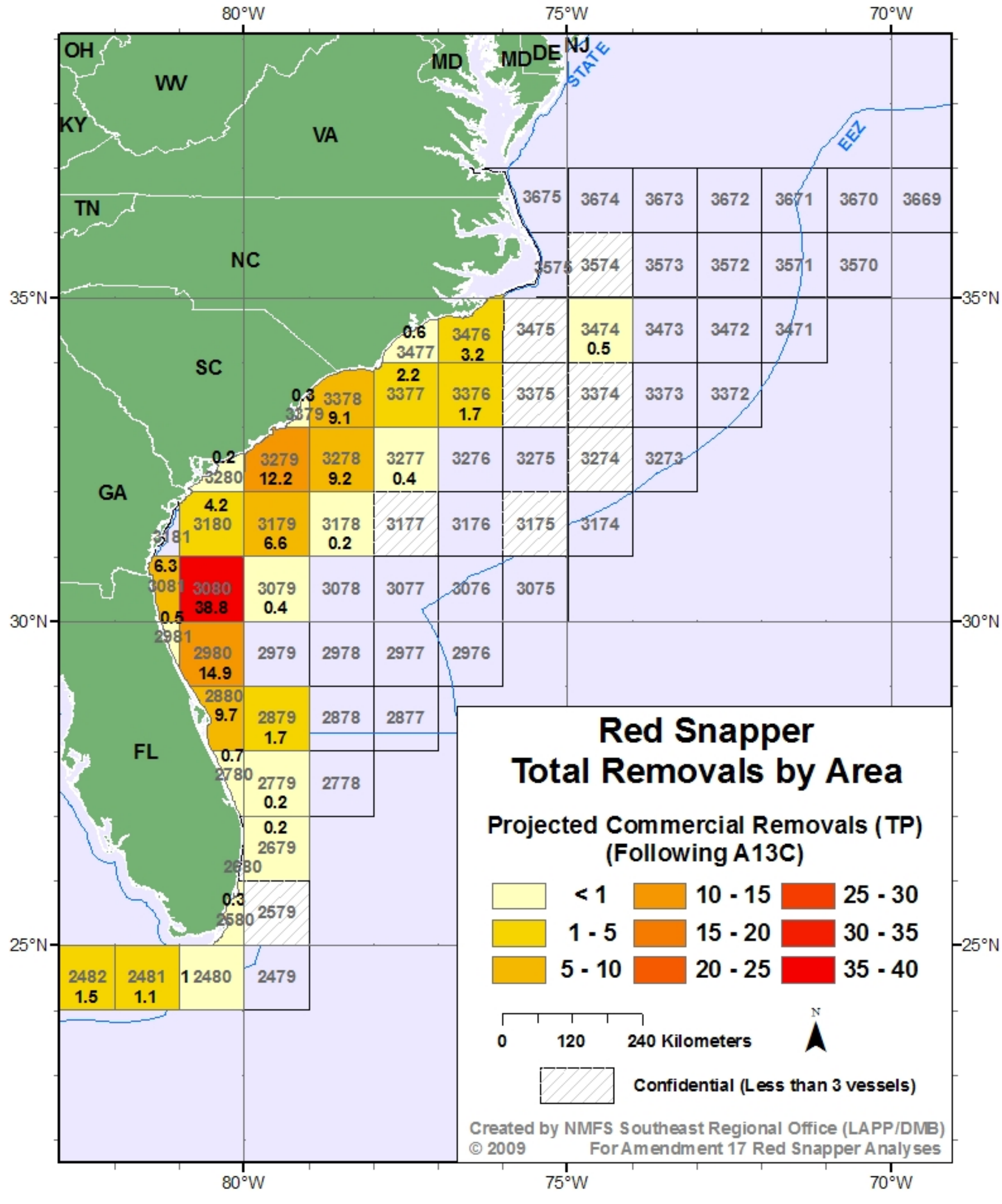

Figure 5. Projected commercial removals of south Atlantic red snapper by area following implementation of Amendment 13C. Color scale denotes removals in thousands of pounds (TP) whole weight, with value for removals (TP) given in each cell.

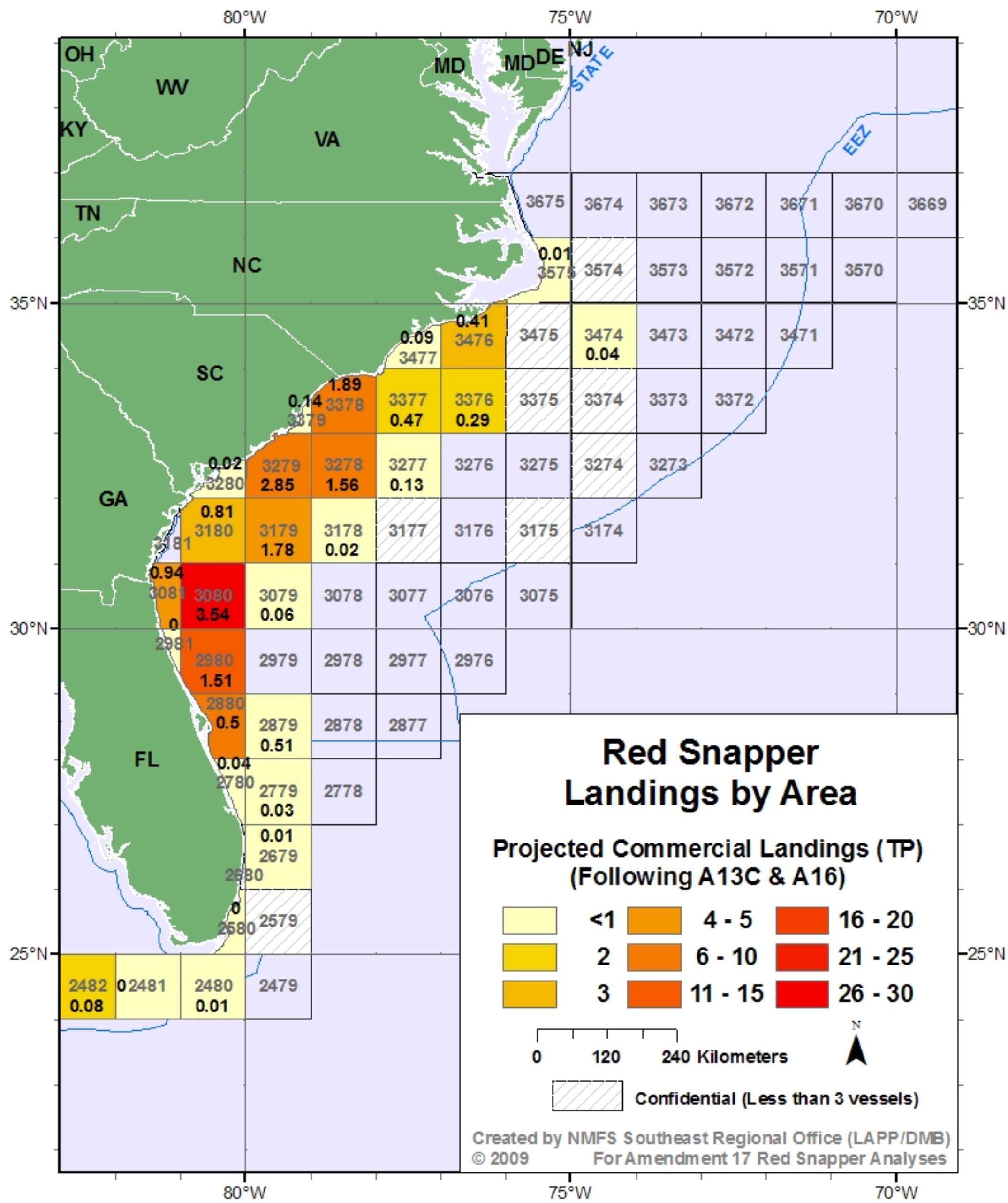

Figure 6. Projected commercial removals of south Atlantic red snapper by area, following implementation of Amendment 13C and Amendment 16. Color scale denotes removals in thousands of pounds (TP) whole weight, with value for removals (TP) given in each cell.

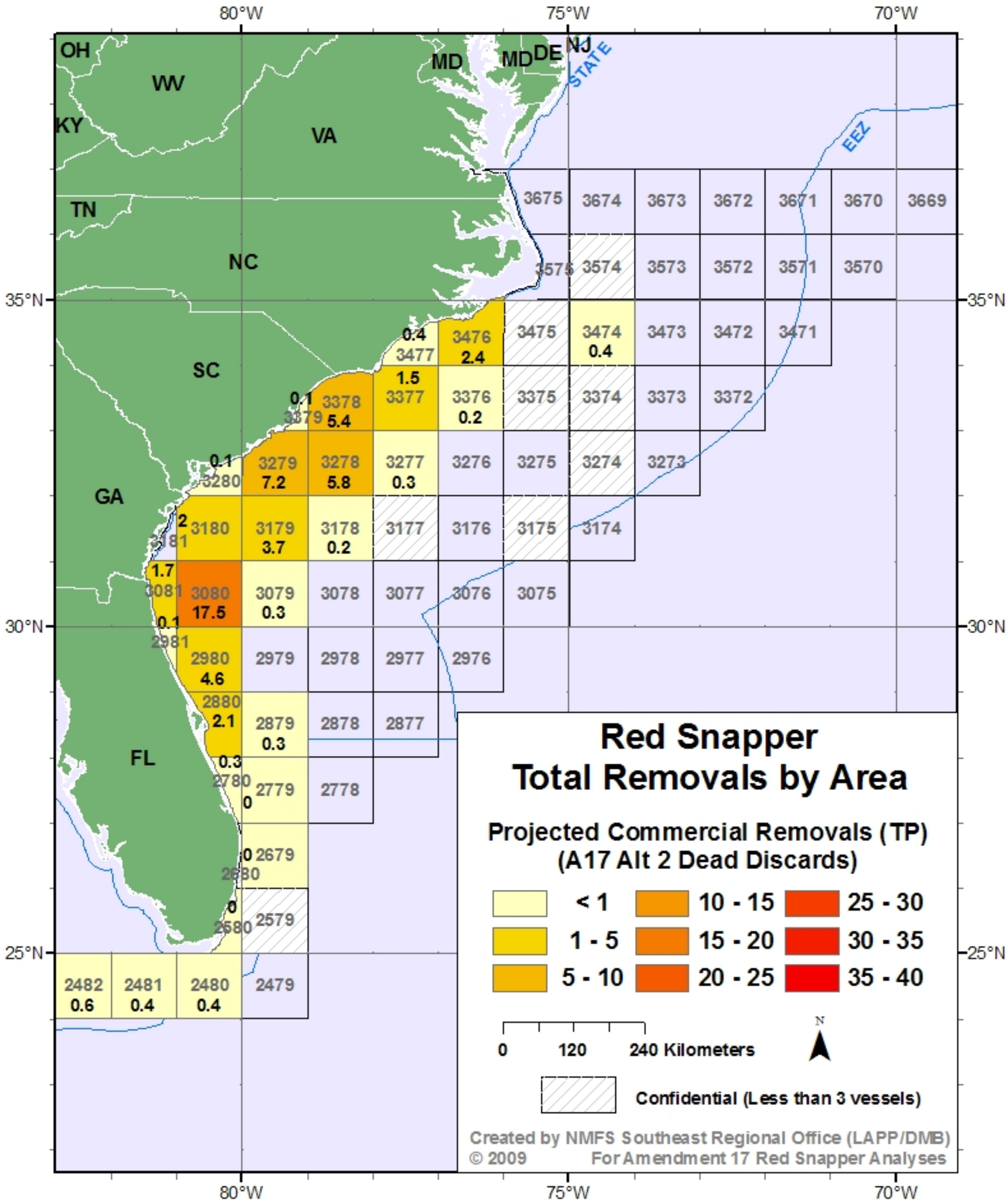

Figure 7. Projected commercial removals of south Atlantic red snapper by area following implementation of Amendment 13C, Amendment 16, and Alternative 2 for Amendment 17. Color scale denotes removals in thousands of pounds (TP) whole weight, with value for removals (TP) given in each cell. Note removals consist entirely of dead discards in this scenario.

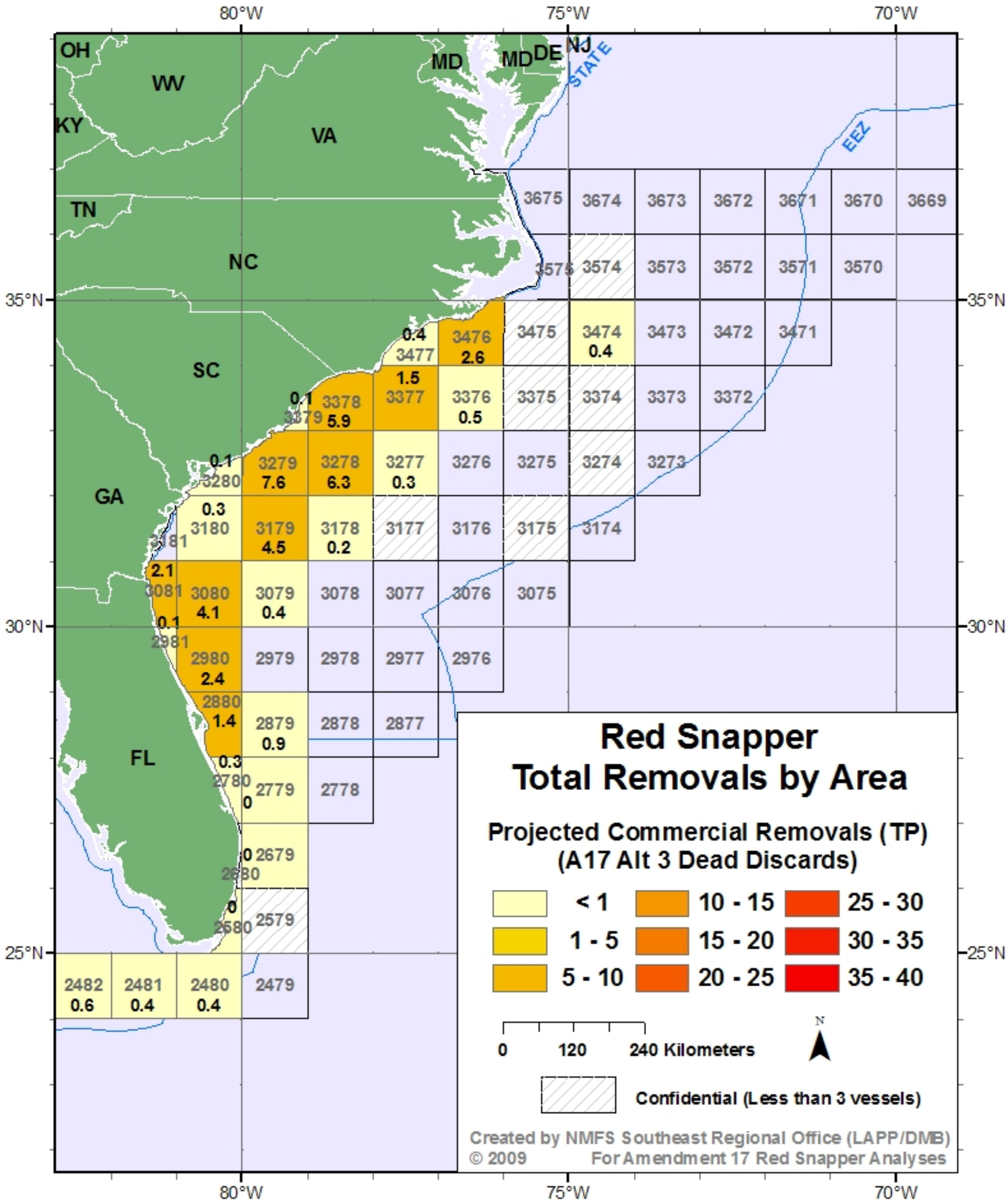

Figure 8. Projected commercial removals of south Atlantic red snapper by area following implementation of Amendment 13C, Amendment 16, and Alternative 3 for Amendment 17. Color scale denotes removals in thousands of pounds (TP) whole weight, with value for removals (TP) given in each cell. Note removals consist entirely of dead discards in this scenario.

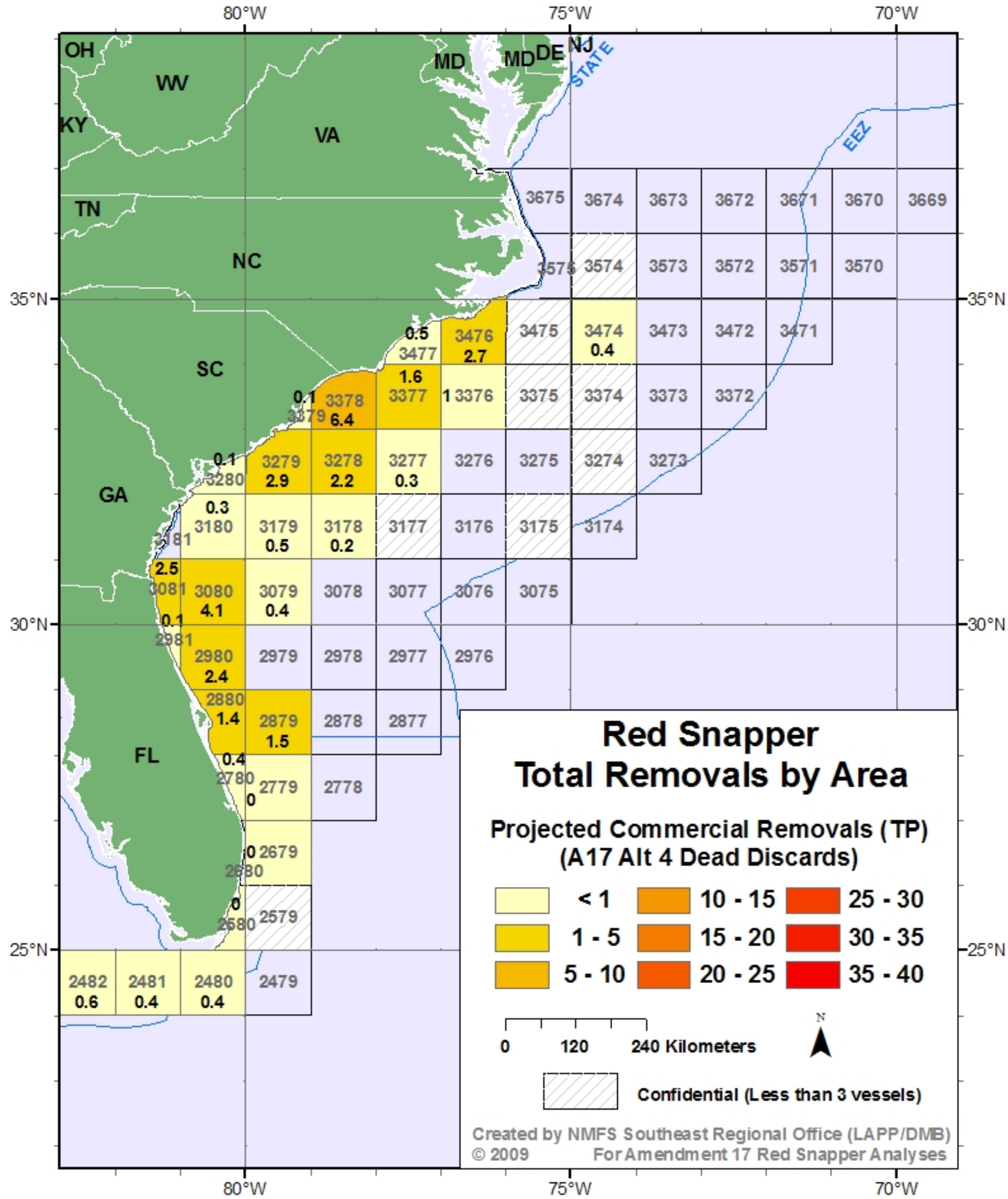

Figure 9. Projected commercial removals of south Atlantic red snapper by area following implementation of Amendment 13C, Amendment 16, and Alternative 4 for Amendment 17. Color scale denotes removals in thousands of pounds (TP) whole weight, with value for removals (TP) given in each cell. Note removals consist entirely of dead discards in this scenario.

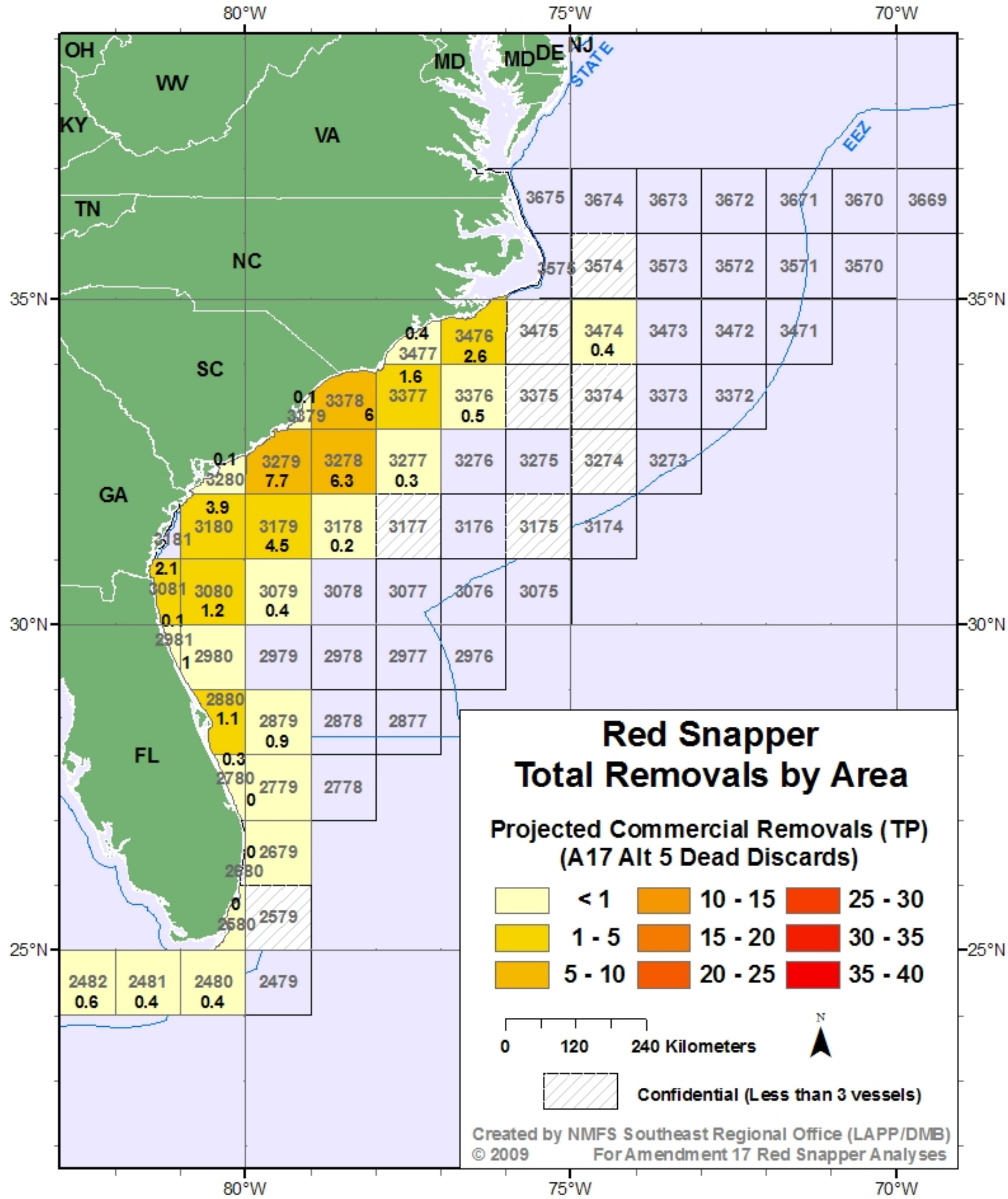

Figure 10. Projected commercial removals of south Atlantic red snapper by area following implementation of Amendment 13C, Amendment 16, and Alternative 5 for Amendment 17. Color scale denotes removals in thousands of pounds (TP) whole weight, with value for removals (TP) given in each cell. Note removals consist entirely of dead discards in this scenario.

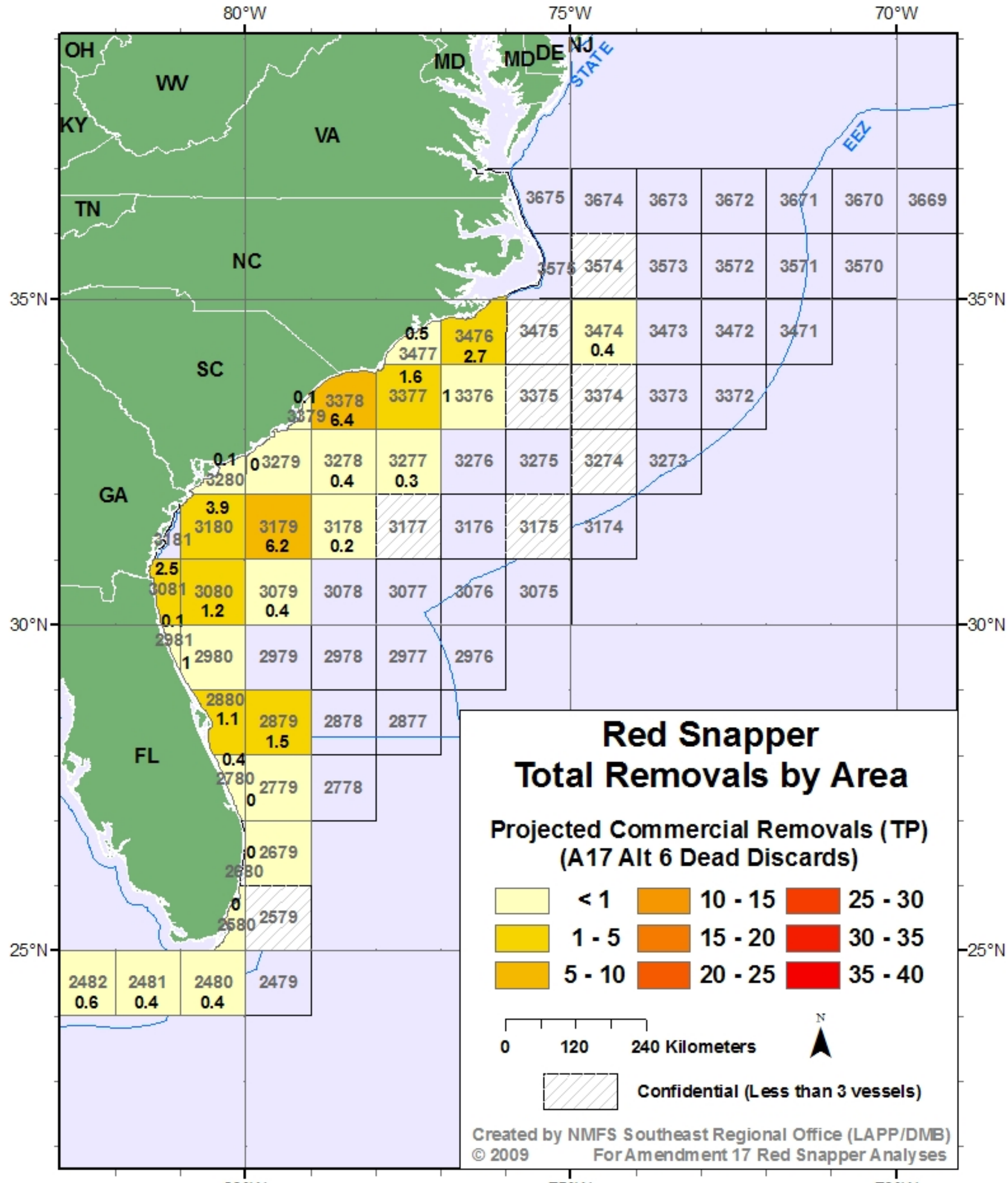

Figure 11. Projected commercial removals of south Atlantic red snapper by area following implementation of Amendment 13C, Amendment 16, and Alternative 6 for Amendment 17. Color scale denotes removals in thousands of pounds (TP) whole weight, with value for removals (TP) given in each cell. Note removals consist entirely of dead discards in this scenario.

Appendix A

Description of Economic Trip Reduction Model

The following description of the model is drawn from Amendment 16: An Economic Model to Analyze Management Alternatives Proposed for the Commercial Fishery in Amendment 16 to the Atlantic Snapper-Grouper Fishery Management Plan (Waters 2008).

Logbook trip reports include information about landings by species, but do not include information about trip revenues. Therefore, average monthly prices were calculated from the NMFS Accumulated Landings System and merged with logbook trip reports by year, month, species and state. Trip revenues for each species were calculated as the product of average monthly prices and reported pounds per trip.

Information about trip costs was obtained from a sample of snapper-grouper boats that was required to report trip costs in 2002-2003 in conjunction with their normal logbook reporting requirements. Data that were collected included their costs per trip for major variable inputs such as fuel, bait, ice, food and other disposable supplies. Trip costs were estimated for each major gear type as a function of pounds landed, days per trip away from port, crew size and other trip characteristics, with the explanatory variables chosen to match the types of information reported for each trip in the logbook database (Perruso and Waters 2005).[1] Then, the estimated coefficients from the trip cost equations were used to calculate expected trip costs for each trip in the logbook database for 2005-2007. The expected trip costs were adjusted to constant 2007 dollars with the producer price index for #2 diesel fuel.[2]

Net operating revenues for trip *j* in year *t* were calculated as trip revenues from all species *s*, $TR_{j,t} = \sum R_{s,j,t}$, minus predicted trip costs, $TC_{j,t}$, which include fuel, oil, bait, ice, and other supplies, and exclude fixed costs and labor costs. Fixed costs were not deducted because data are not available with which to determine the fraction of each boat's fixed costs that should be allocated to red snapper fishing relative to its other fishing activities. Therefore, net operating revenues represent the return to fixed factors of production, labor (including crew) and boat owner. Net operating revenues

[1] Perruso, Lawrence A., and James R. Waters. 2005. Trip level cost function estimation for the south Atlantic snapper-grouper commercial fishery. Social Science Research Group Working Paper SEFSC SSRG 9, National Marine Fisheries Service, Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami FL 33149.

[2] The producer price index for #2 diesel fuel can be found at http://data.bls.gov. See series WPU057303.

were adjusted to constant 2007 dollars with the consumer price index for all items and all urban consumers.[3]

Fishermen were presumed willing to embark on a trip if net operating revenues exceeded an opportunity cost of labor defined as $50 per person per day fished in 2005. Opportunity cost does not measure actual payments to labor. Rather, it is used in the model as a proxy for the unknown minimum amount that fishermen would be willing to accept for each trip, and is used in the model to determine if trips are still worth taking after accounting for the effects of regulation. The proxy value of $52 per person per day fished is slightly more than the current minimum wage rate of $5.85 per hour for an 8-hour work day, which is the minimum that could be earned in less risky land-based employments. Opportunity cost was adjusted annually for changes in the cost of living between 2005 and 2007 with the consumer price index for all items and all urban consumers and a base year of 2007.

If trip revenues exceeded trip costs plus opportunity cost after accounting for the likely effects of proposed restrictions on trip-level harvests, then short-term economic losses were measured as the resulting reduction in trip revenues. Conversely, if the combination of proposed alternatives would cause trip revenues to fall below the sum of trip costs and opportunity cost, then the trip was recorded as not taken, and losses were measured as a reduction in net operating revenues, which included the loss in revenues from all species minus the savings of trip costs not incurred.

Net operating revenues for the combination of proposed rules denoted by *a* in rebuilding year *t*, $NOR_{a,t}$, were totaled for all trips within each logbook year, *k*, from 2005-2007, with annual totals averaged across all three years.

$$NOR_{a,t} = \frac{\sum_{k=2005}^{k=2007} \sum_{j=trips} (TR_{a,j,k} - TC_{a,j,k})}{3}$$

The three-year average is interpreted as the expected annual economic effect of the proposed combination of rules on industry net operating revenues in rebuilding year *t*, $NOR_{a,t}$. Each analysis was conducted for a single rebuilding year, t = 2009.

This approach is interpreted as follows. If 2009 is similar to fishing conditions that existed in 2006, then the analysis of proposed regulations with logbook data from 2006 would represent the predicted outcome of proposed regulations for 2009. However, if 2009 turns out to be similar to fishing conditions that existed in 2005, then the analysis of proposed regulations with data from 2005 would represent the predicted outcome

[3] The consumer price index for all urban consumers can be found at http://data.bls.gov. See series CUUR0000SAO, which was adjusted to a 2005 base period for this study.

for 2009. We do not know exactly what conditions will prevail in 2009; therefore we construct an average predicted outcome based on the three most recent years for which data are available.

The predicted outcome for rule-combination *a* is compared to the predicted outcome for no-action (*i.e.*, no additional management) to determine if the proposed alternatives are expected to generate net benefits or losses to commercial fishermen. Net benefits are expected to accrue to the fishery if the predicted outcome for rule combination *a* exceeds the predicted outcome without additional regulation. A net loss would accrue if the predicted outcome for rule combination *a* is less than the predicted outcome for no additional management. Because the analysis is short-term for rebuilding year 2009 only, we expect it to estimate the short-term losses associated with implementation of rules proposed in Amendments 13C, 16, and 17.

Modeling Management Alternatives

This section describes the method of modeling the effects of management actions on the commercial snapper-grouper fishery. Management alternatives implemented or proposed by Amendments 13C, 16, and 17 include minimum size limits, limits on catch per trip, seasonal closures, quotas, and limits on the numbers of black sea bass pots fished per trip. Each type of regulation was modeled by restricting the ability to catch and/or keep fish that were reported on logbook trip reports.

Minimum size limits:

Larger minimum size limits were modeled by assuming that an additional (when compared to the baseline) percentage, ρ_s^{msl}, of species *s* on each trip are undersized and must be culled from the catch and discarded.

$$q_{s,j,t} = h_{s,j,t}\,(1-\rho_s^{msl})$$

Variable $h_{s,j,t}$ represents quantity of species *s* caught on trip *j* in year *t*, and $q_{s,j,t}$ denotes quantity kept after accounting for the effects of the larger minimum size limit. Each trip is assumed to catch the same quantity of species *s* as without the size limit, but that undersized fish would be discarded and subject to release mortality. Revenues for species *s* on trip *j*, $R_{s,j,t} = p_{s,j,t}\ q_{s,j,t}$, are based on quantities kept, $q_{s,j,t}$, and price per pound, $p_{s,j,t}$. The harvest of other species on trip *j*, $h_{sp,j,t}$ for $sp \neq s$, is assumed not to be affected by the proposed minimum size limit for species *s*. If trip revenues exceeded trip costs after accounting for the proposed minimum size limit and other jointly-proposed rules, then the expected losses for trip *j* due to a minimum size limit were calculated as a reduction in trip revenues for species *s*, $p_{s,j,t}\ (q_{s,j,t} - h_{s,j,t})$. However, if the trip became unprofitable with the proposed combination of rules, then losses were measured as a reduction in net operating revenues, which included the loss in revenues from all species minus the savings of trip costs not incurred because the trip would not be taken, $\sum_s p_{s,j,t}\ h_{s,j,t} - TC_{j,t}$.

In the simulation model, trip costs are a function of total catch, including discards, and are not changed by the minimum size limit. Data were not available with which to estimate the potential additional costs of culling and discarding undersized fish.

The percentages that define the additional undersized fish associated with each proposed minimum size limit were held constant throughout the analysis and regardless of the alternatives proposed for other species in the fishery. When effective biologically, minimum size limits gradually change the age and size distribution of the resource and the percentage of undersized fish landed. However, this analysis does not include a biological component with which to endogenously determine changes in the proportion of undersized fish that would be landed each year.
These percentages refer to numbers of fish smaller than the proposed minimum size limits. However, the simulation model works with quantities of each species landed as reported on logbook trips rather than numbers of fish. Hence, this method of simulating the effect of minimum size limits is an approximation for the preferred method that would use numbers of fish, and is likely to overestimate the effect of the minimum size limit when the average weight per fish for species *s* exceeds 1 pound.

Mesh regulations for black sea bass pots:
Mesh regulations were implemented in Amendment 13C and affect the proportion of small fish that would be retained by fish pots. Hence, they were modeled in a similar way as minimum size limits by specifying the additional percentage, ρ^{mesh}, of fish on each trip that would be too small to be retained in fish pots. The primary difference between mesh regulations and minimum size limits is that mesh regulations affect catches and revenues from all species caught in pots, whereas the effects of minimum size limits are specific to species *s*. Although black sea bass constitute the bulk of catches in fish pots, mesh regulations are modeled to reduce the catch of all species that were landed with fish pots.

$$q_{s,j,t} = h_{s,j,t}(1-\rho^{mesh}) \qquad for\ all\ s$$

If trip revenues exceeded trip costs after accounting for larger mesh and other jointly-proposed rules, then losses were measured as a reduction in trip revenues for all species caught on trip *j* in year *t*, $\sum p_{s,j,t}\,(q_{s,j,t} - h_{s,j,t})$. Fish that would not be retained due to the larger mesh were assumed to have never been caught, and hence would not be subject to release mortality. Therefore, trip costs could change due to implementation of mesh regulations if empirical evidence suggests that trip costs are a function of total quantity harvested.

Some combinations of management alternatives would implement larger mesh regulations and larger minimum size limits. Since mesh regulations and minimum size limits both act to reduce the catch of smaller fish, the combined percentage, ρ_s^C, of species *s* that would be lost due to mesh and size limit regulations would be the greater of the two effects.

$$\rho_s^C = \max[\rho_s^{msl},\ \rho^{mesh}]$$

where ρ^{mesh} pertains to all species caught with pot gear on trip *j* and ρ_s^{msl} pertains only to species *s* for which the minimum size limit applies. The combined effects of mesh regulations and minimum size limits were modeled as:

$$q_{s,j,t} = h_{s,j,t}\,(1-\rho_s^C)$$

Variable $\rho^{mesh} > 0$ only for pot gear. Otherwise, $\rho^{mesh} = 0$, and $\rho_s^C = \rho_s^{msl}$. If neither minimum size limits nor mesh regulations are proposed, then $\rho_s^C = 0$.

Limit on number of pots fished per trip:

A limit on the number of pots that may be fished per trip is modeled by restricting the number of pots to the pot limit, and reducing catch per trip proportionally. If $P_{j,t}$ denotes the number of pots reported for trip *j* in year *t*, and *PL* represents the pot limit, then

$$q_{s,j,t} = h_{s,j,t}\,\frac{PL}{P_{j,t}} \qquad for\ P_{j,t} > PL$$

$$q_{s,j,t} = h_{s,j,t} \qquad for\ P_{j,t} \le PL$$

Pot limits affect the ability to catch fish of all species on trips using pots. Hence, potential reductions in catch due to pot limits are considered in the model to occur prior to the effects of other kinds of management rules, such as minimum size limits and trip limits, that restrict the ability of fishermen to keep their catches.

Trip limits:

Trip limits for species *s* impose a maximum allowable catch per trip, and trips with catches of species *s* in excess of the trip limit, TL_s, were modeled by restricting their catches to the trip limit. Some management actions combine trip limits and minimum size limits and/or mesh regulations. In this event, the simulation model reduced catches according to the percentage, ρ_s^C, of undersized fish on trip *j* before determining if the trip limit would be restrictive.

$$q_{s,j,t} = TL_s \qquad when\ h_{s,j,t}\,(1-\rho_s^C) \ge TL_s$$

Losses attributable to the trip limit were measured as the value of the difference between catches for species *s* that would have occurred with and without the trip limit, $p_{s,j,t}\,[TL_s - h_{s,j,t}\,(1 - \rho_s^C)]$. Please note that losses due to the trip limit would be equal to the difference between the trip limit and reported catches, $p_{s,j,t}\,[TL_s - h_{s,j,t}]$, only when there were no proposed minimum size limits or mesh regulations. The portion of the overall loss measured by $[p_{s,j,t}\,h_{s,j,t}\,\rho_s^C]$ is attributable to the minimum size limit and/or mesh regulation rather than the trip limit. The quantity of species *s* in excess of the trip limit, after accounting for the effects of minimum size limits and mesh regulations, is assumed to have been caught, discarded, and subject to release mortality because the trip would continue in search of other species. In this event, trip costs would not change due to implementation of trip limits.

Trips with catches less than the trip limit, after accounting for the effects of minimum size limits and mesh regulations, would not incur additional losses due to the trip limit.

$$q_{s,j,t} = h_{s,j,t}(1-\rho_s^C) \qquad when\ h_{s,j,t}(1-\rho_s^C) < TL_s$$

The simulation model includes a behavioral assumption about the effect of trip limits on the duration of trips and the cost of fishing. Trips are modeled to terminate after the trip limit is filled if the regulated species is the primary source of revenue on the trip. In this event, trip costs are reduced due to the shorter trip duration and smaller quantity harvested. However, if the regulated species is not the primary source of revenue, then the trip is modeled to continue even if the trip limit is filled. In this event, fish caught in excess of the trip limit are presumed to be caught and discarded. Trip costs would not change. Trip limits create an incentive for fishermen to take shorter, but more frequent fishing trips. However, this behavioral response has not been modeled for this analysis.

Seasonal closures:

Seasonal closures for species *s* were modeled by defining variable $open_s$ = 0 when the season is closed for species *s* and $open_s$ = 1 when it is open, and then multiplying by the reported catch of species *s* on trip *j*. Therefore, catch of species *s* would be affected by a seasonal closure policy only during the closed season; *i.e.*, $q_{s,j,t}$ = 0 only when $open_s$ = 0.

$$q_{s,j,t} = h_{s,j,t}(1-\rho_s^C)\ open_s \qquad when\ h_{s,j,t}(1-\rho_s^C) < TL_s$$

$$q_{s,j,t} = TL_s\ open_s \qquad when\ h_{s,j,t}(1-\rho_s^C) \geq TL_s$$

Seasonal closures create an incentive for boats to re-schedule trips to minimize the likely effect of the closure. However, the model does not accommodate this type of behavioral adaptation to regulation. Logbook data record the month and day landed for each reported trip, and the duration of each trip so that start dates could be calculated. The model uses landed date to identify the trips that would be subject to the closure.

Quotas:

Fishery-wide quotas were modeled in a similar way as seasonal closures. The primary difference between seasonal closures and quotas is that seasonal closures have fixed beginning and ending dates, whereas quotas may or may not result in fishery closures. When quotas are filled, the closure dates vary annually depending on the speed at which the fishery lands its quota for species *s*. The closure extends through the end of the fishing year once the quota is filled.

The equations that describe the short-term economic effects of quotas are the same as already presented for seasonal closures. The model sets variable $open_s$ = 0 to reflect a no-harvest rule resulting from seasonal closures or fishery closures after the quota is filled. Otherwise, it sets $open_s$ = 1 to indicate that the fishery for species *s* is open and that trips are unaffected by either quota or seasonal closure.

The model compares the accumulated fishery landings of species *s* with its quota to determine if and when the fishery would be closed. This is accomplished by sorting logbook trip reports by year, month and day landed, and then performing a chronological trip-by-trip accumulation of landings that likely would occur given the selected combination of proposed management alternatives. The model sets $open_s = 1$ at the beginning of each fishing year, and sets $open_s = 0$ as soon as accumulated landings exceed the quota for species *s*.

Quotas tend to promote a race for fish as fishermen compete to maximize their shares of the overall catch before the fishery is closed. The model does not include the possibility that fishermen might accelerate their trips in anticipation of a fishery closure, or that dockside prices might fall if market gluts occur due to the accelerated harvesting activity. More work is needed on these issues since they are two of the primary outcomes of quota management.