Projected Combined Effects of Amendments 13C, 16, and 17A Regulations on south Atlantic Red Snapper Removals

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Introduction

A recent stock assessment of south Atlantic red snapper indicates the stock is undergoing overfishing and is severely overfished (SEDAR 15 2009). The South Atlantic Fishery Management Council (SAFMC) is currently developing Amendment 17A to the Snapper-Grouper Fishery Management Plan (FMP) to address overfishing of red snapper and rebuild this stock (SAFMC 2009). Assuming very high recruitment and an $F_{40\%SPR}$ proxy for F_{MSY}, an 83 percent reduction in total removals of red snapper is needed to end overfishing.

Amendment 13C to the Snapper-Grouper FMP reduced harvest and established commercial quotas and/or trip limits for snowy grouper, golden tilefish, black sea bass, red porgy, and vermilion snapper (VS). Amendment 16 to the Snapper-Grouper FMP closes the recreational fishery for VS in the South Atlantic during November through March of each year. Amendment 16 also closes both the recreational and commercial shallow-water grouper (SWG) fisheries during January through April of each year. These regulatory actions may indirectly affect red snapper removals (e.g. landings and dead discards) if trips targeting other regulated species no longer occur due to closed seasons, quota reductions, or trip limits. Additionally, red snapper removals will be directly impacted by the alternatives under consideration in Amendment 17A, which 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, with limited exceptions for black sea bass pots and spearfishing gears.

Four reports were completed by Southeast Regional Office personnel analyzing the effects of South Atlantic Fishery Management Council (SAFMC) Amendments 13C, 16, and 17A on red snapper removals (SERO 2009a-d). Additionally, an interactive Excel spreadsheet (see Figures A1-2) was developed to model projected reductions under a variety of input assumptions. This report is an updated synthesis of those four reports and Excel model, and estimates overall reductions in red snapper removals across all three fishery sectors – commercial, recreational private/charter, and headboat. To provide a full range of alternatives, this report compares projected removal rates under scenarios with/without: (1) elimination of directed and/or targeted trips due to regulations, (2) changes in overall release mortality, (3) distinct inshore release mortality rates, and (4) varying compliance rates.

Methods

Projected reductions were computed from baseline 2005-2007 data compiled from commercial logbook, Marine Recreational Fisheries Statistics Survey (MRFSS), and headboat logbook data for the U.S. south Atlantic (Figure 1). Baseline removals were reduced due to trip elimination, spatial and bathymetric closures, and changes in release mortality. Sensitivity of the projections to these input factors and noncompliance rate was investigated.

Trip Elimination due to Management Regulations

Recent and currently proposed management regulations may reduce the number of trips taken in the future that would impact the red snapper stock. This may occur due to economic unprofitability on a trip level or a company permanently going out of business. In these projections, outcomes are provided considering indirect red snapper harvest reductions due to elimination or retention of directed and/or targeted trips for species regulated by Amendment 13C (commercial sector only), Amendment 16 (all sectors), and Amendment 17A (all sectors). Methods for eliminating directed and/or targeted trips are described in previous reports (SERO 2009a-d).

Spatial and Bathymetric Distribution of the Red Snapper Stock

To compute the impacts of bathymetric closures, it was necessary to determine the percent of red snapper stock contained within the closed depths, by statistical area. Three datasets were analyzed with the hopes of obtaining a useful proxy for this relationship, under the assumption of no movement across depth contours: (1) Marine Resources Monitoring, Assessment, and Prediction (MARMAP), (2) Headboat, and (3) Commercial logbook.

The MARMAP project collects data on the abundance and biomass of fish species off the coast of the southeastern United States (Cape Fear, NC to Cape Canaveral, FL) using traps, hook and line, and trawl gears. MARMAP fishery-independent red snapper collection data from 1978-2008 was evaluated for gears landing at least one red snapper over the 31 year time series. MARMAP data are reported to a very fine spatial resolution, and the total number of red snapper collected inside vs. outside the bathymetric closure by statistical area was computed. To boost sample size for regression modeling of percent area protected vs. percent stock protected, logbook statistical areas were divided into four subgrids each for this analysis.

Headboat logbook data are reported by headboat operators and verified by port samplers. Headboats are large, for-hire vessels that typically accommodate 20 or more anglers on half- or full-day trips. Headboat records contain trip-level information on number of anglers, trip duration, date, area fished, and landings (number fish) of each species. Area fished was aggregated at the most common reporting level (1° latitude by 1° longitude). Headboat landings of red snapper (2005-2007) were plotted in GIS relative to bathymetric closure boundaries. Headboat records of red snapper landings were summarized by statistical area for total pounds landed inside and outside the proposed closure depths.

Commercial logbook data are reported by commercial fishermen with South Atlantic Snapper-Grouper Permits. Logbook records summarize landings on a trip level, with information for each species encountered, including landings (in lbs), primary gear used, and primary area and depth of capture. Depth of capture is only available in logbook records from 2005 onward. Logbook records of red snapper landings (2005-2008) were summarized by statistical area for total pounds landed inside and outside the proposed closure depths.

Release Mortality

Mortality of discarded red snapper has been estimated at 40% for the recreational sector and 90% for the commercial sector (SEDAR 15 2009). A significant component of this difference in discard mortality rate between recreational and commercial sectors results from commercial fishermen generally fishing in deeper water, although longer handling time (longer surface interval) in the commercial fishery can also increase discard mortality rate (SEDAR 15 2009).

As discussed in SEDAR 15, Burns et al. (2004) estimated a red snapper release mortality of 64% following a study on headboats off Florida in the Atlantic and Gulf of Mexico. The majority of acute mortalities in this study (capture depth of 9–42 m) were attributed to hooking (49%), whereas barotrauma accounted for 13.5%. Burns et al. (2002) estimated J-hook mortality at 56% in a similar study. Using barometric chambers, Burns et al. (2004) estimated barometric mortality at 0% for depths of <20, 25, and 30 m; barotrauma-induced mortality increased to 40% at 45 m and 45% at 60 m. A mark-recapture study by Patterson et al. (2001b) in the Gulf of Mexico estimated a discard mortality of 9% at 21 m, 14% at 27 m, and 18% at 32 m. SEDAR 15 (2009) reports mean minimum depth in the recreational (charter boat) fishery was 43 m (range 20 to 183 m); the mean maximum depth was 58 m (24 to 274 m).

Several proposed closure alternatives may result in commercial and recreational fishermen moving into shallower water to fish, potentially decreasing discard mortality rates by reducing barotraumas (Figure 2, red lines). Additionally, the complete closure of the red snapper fishery should reduce handling time, as fishermen will no longer need to measure fish to determine if they are of legal size. Finally, several studies (Gitschlag & Renaud 1994, Burns et al. 2002, Burns et al. 2004, Rummer 2007, Diamond & Campbell unpubl. data) have found release mortalities ≤20% in waters <20 m. Under all currently proposed Amendment 17A alternatives, four inshore cells (3379, 2981, 3081, and 3181) with no depths <20 m would remain open to fishing, and might also be recipients of some effort shifting from closed areas. Consequently, the projection model was designed to account for reduced inshore release mortality in these cells, in addition to changes in release mortality rates across all other cells. It should be noted that the mean depth of fishing is >40 m for both the recreational and commercial fisheries in the South Atlantic (SEDAR 15 2009). Referring to Figure 2 (blue lines), this results in a delayed mortality estimate of around 60%, which is higher than the SEDAR 15 estimated release mortality for the recreational sector.

Compliance

Most of the fisheries benefits of spatial closures are dependent on compliance with no-take regulations (Fogarty et al. 2000). Although published data exists to estimate rates of non-compliance (Ward et al. 2001), numerous modeling efforts and case studies have shown that even relatively low levels of poaching can rapidly erode the fisheries benefits of reserves (Tegner 1993, Attwood et al. 1997, Gribble & Robertson 1998, Guzman & Jacome 1998, Murray et al. 1999, Rogers-Bennett et al. 2000; however, see Jennings et al. 1996). As such, the projection model was designed to account for reduced compliance rates. Compliance rate was treated as a scalar multiplier, uniformly distributed across closed cells. For example, if a cell with 1000 lbs of removals were closed with 90% compliance, 100 lbs of removals would still occur in that cell.

Results

To evaluate MARMAP sampling (1977-2008) with gears landing at least 1 red snapper, south Atlantic statistical areas intersecting proposed closure bathymetry (98-240 ft) were subdivided into 4 equal parts to enhance statistical robustness of analysis. Upon first glance, sampling across domain appeared somewhat robust, although sampling was biased towards South Carolina and inshore of the 240 ft bathymetric contour. However, closer examination indicated that sampling was spatially biased by gear, and sampling using gears with higher CPUE (e.g., hook and line, snapper reel) for red snapper was limited. Of the 16,566 total fishery-independent samples by MARMAP during this 31-yr time period, only 1.3% (218) of these samples landed red snapper.

MARMAP sampling is conducted primarily with gears that are not particularly effective at capturing red snapper (e.g. Chevron traps, Blackfish traps, and Florida 'Antillean' Traps). Although hook and line and snapper reel gears were only deployed at 9% of the MARMAP sampling sites, they accounted for 30% of the sites landing red snapper; whereas only 2% of Chevron trap sets landed red snapper, 5% of snapper reel sets, and 8% of hook and line sets landed at least one. Spatial and temporal differences in where these gears were deployed may have influenced these catch rates. Chevron traps especially were deployed in many areas where red snapper do not occur, which would reduce their proportional effectiveness relative to other, more strategically deployed gears.

MARMAP data (1977-2008) appeared inappropriate to determine the distribution of the red snapper stock because: (1) sampling was heavily biased towards inshore waters off South Carolina and might not adequately reflect the distribution of the south Atlantic stock (Figure 3), and (2) sampling was strongly biased within the 98-240 ft depth contour, which limited the utility of any regression models derived from the data.

Of the 14,543 total headboat trips (2005-2007), 27% (3,371) landed red snapper. An examination of the spatial data (confidential) indicated a complete lack of reporting off Georgia, biasing any analyses to trends observed off of north Florida and South Carolina. Headboat 'sampling' off north Florida and South Carolina was spatially well-distributed. A regression model of percent stock protected vs. percent area protected for headboat data suggested a homogeneous distribution of the stock (e.g. slope ~ 1, intercept ~ 0); however, headboat landings were deemed inappropriate for this analysis because depth is not reported, and spatial landing locations are reported on a subgrid level (e.g. each statistical area is divided into 36 parts), which is too coarse to adequately evaluate whether landings occurred inside or outside the proposed bathymetric closure.

Of the 55,643 total commercial trips (2005-2008) for managed south Atlantic species, 10% (5,540) landed red snapper, and 91% (5,035) of these had complete depth records (Table 1). Of trips landing red snapper with complete depth records, 93% (4,703) landed red snapper between 66-240 ft, 79% (3,952) landed red snapper between 98-240 feet, and 81% (4,079) landed red snapper between 98-300 ft. There were recorded landings both inside and outside the bathymetric closures for all closures currently proposed in Amendment 17A alternatives; therefore, the percent stock protected by a bathymetric closure was computed as the landings of red snapper within the closed area divided by the total landings in the cell (Table 2).

Projected reductions under a variety of scenarios by alternative are presented in Table 3 and discussed below. The projected reductions are extremely sensitive to changes in recreational release mortality rate, as the recreational sectors (private, charter and headboat) account for the majority of removals, but the influence of this parameter is reduced as encounters with red snapper are minimized through spatial closures. For example, with no closed cells assuming 100% compliance, no trip elimination, and 40% recreational and 90% commercial overall release mortality, the anticipated reduction is 39%; whereas increasing the recreational release mortality to 60% cuts this projected reduction to 18% (a 21% difference). Under the same input assumptions but given closure 4A, at 40% recreational release mortality, the projected reduction is 86%; given 60% release mortality, the projected reduction is 82% (a 4% difference). The projected reductions are also extremely sensitive to the estimated compliance rate. For example, under Alternative 3A closures assuming no trip elimination, 40% recreational release mortality, 90% commercial release mortality, and 100% compliance, the projected reduction is 81%; given 80% compliance, the projected reduction is cut to 72% (a 9% difference). Under the same suite of assumptions for Alternative 4A closures, 100% compliance generates a projected reduction of 86%; 80% compliance generates a projected reduction of 77% (a 9% difference). The projected reductions due to trip elimination range from approximately 4-13%, with the influence of the trip eliminations decreasing as the scale of closures increases, because trips that would be eliminated economically become prohibited by management instead. Reducing inshore mortality to 20% provides an additional 2-3% reduction in projected removals.

Table 1. Availability and reliability of reported depth of capture for red snapper trips in south Atlantic.

Year	Available Depth	Unavailable Depth	Percent Unavailable	Unrealistic Depth	Percent Unrealistic
2005	1009	333	25%	70	5%
2006	1081	73	6%	66	6%
2007	1326	0	0%	111	8%
2008	1619	1	0%	59	4%

Source: SEFSC commercial logbook (Accessed Aug 2009)

Table 2. Percent of total red snapper landings (2005-2008) occurring within bathymetric closures proposed in Amendment 17A

	Pct. Stock in Bathymetry		
Cell	66-240 ft	98-240 ft	98-300 ft
2880	90%	56%	57%
2980	94%	82%	83%
3080	98%	94%	94%
3179	92%	92%	94%
3180	97%	95%	97%
3279	80%	78%	79%
3278	85%	69%	69%

Source: SEFSC commercial logbook (Accessed Aug 2009)

Table 3. Projected reductions in red snapper removals following implementation of various alternatives proposed by Amendment 17A. Various scenarios illustrate sensitivity of projection model to input parameters.

Alternative	Closed Cells	Closed Depths	Area Closed (1000 km^2)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
2	None	None	0	29%	39%	52%	55%	60%	60%
3A	2880, 2980, 3080, 3180	All	38	72%	72%	83%	83%	87%	90%
3B	2880, 2980, 3080, 3180	66-240 ft	27	69%	70%	81%	81%	85%	88%
3C	2880, 2980, 3080, 3180	98-240 ft	15	63%	65%	76%	77%	81%	84%
3D	2880, 2980, 3080, 3180	98-300 ft	16	63%	66%	76%	77%	81%	84%
4A	2880, 2980, 3080, 3180, 3179, 3278, 3279	All	67	76%	77%	86%	86%	89%	93%
4B	2880, 2980, 3080, 3180, 3179, 3278, 3279	66-240 ft	39	73%	74%	83%	84%	87%	91%
4C	2880, 2980, 3080, 3180, 3179, 3278, 3279	98-240 ft	24	66%	69%	78%	80%	83%	86%
4D	2880, 2980, 3080, 3180, 3179, 3278, 3279	98-300 ft	25	67%	69%	79%	80%	83%	86%

Scenario 1: No impacts A13C, A16; A17A eliminates targeted trips only; 80% compliance; 60%/60% offshore release mortality; 20%/20% inshore release mortality.

Scenario 2: No impacts A13C, A16; A17A eliminates targeted trips only; 80% compliance; 40%/90% offshore release mortality, 40%/90% inshore release mortality.

Scenario 3: No impacts A13C, A16; A17A eliminates targeted trips only; 85% compliance; 40%/40% offshore release mortality, 20%/20% inshore release mortality.

Scenario 4: Directed and targeted trips eliminated by A13C, A16, A17A; 85% compliance; 40%/90% offshore release mortality; 20%/20% inshore release mortality.

Scenario 5: Directed and targeted trips eliminated by A13C, A16, A17A; 87% compliance; 40%/40% offshore release mortality; 20%/20% inshore release mortality.

Scenario 6: Directed and targeted trips eliminated by A13C, A16, A17A; 100% compliance; 40%/40% offshore release mortality; 20%/20% inshore release mortality.

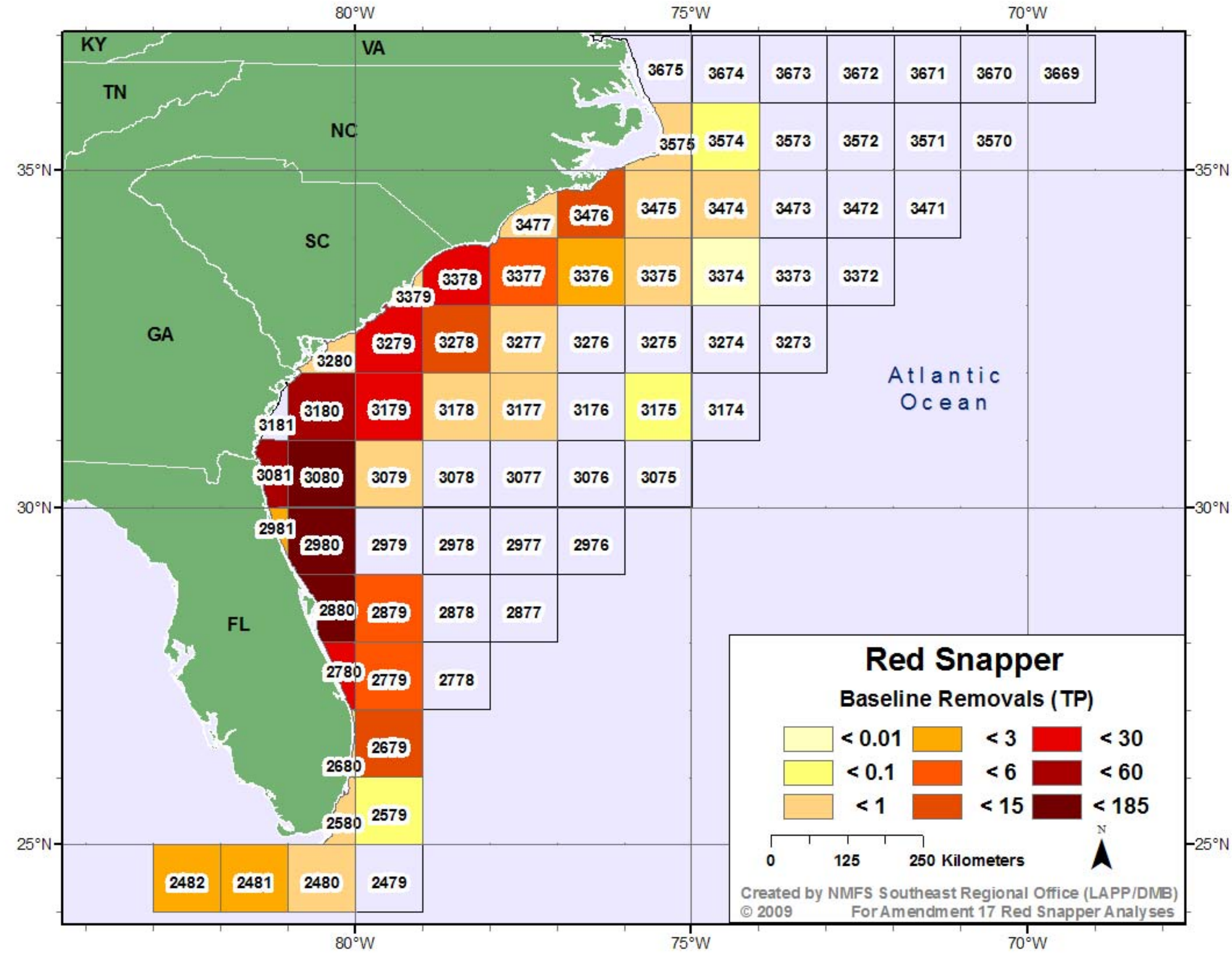

Figure 1. Baseline removals of South Atlantic red snapper by logbook grid, 2005-2007. Removals include landings and dead discards from the commercial, headboat and private/charterboat sectors.

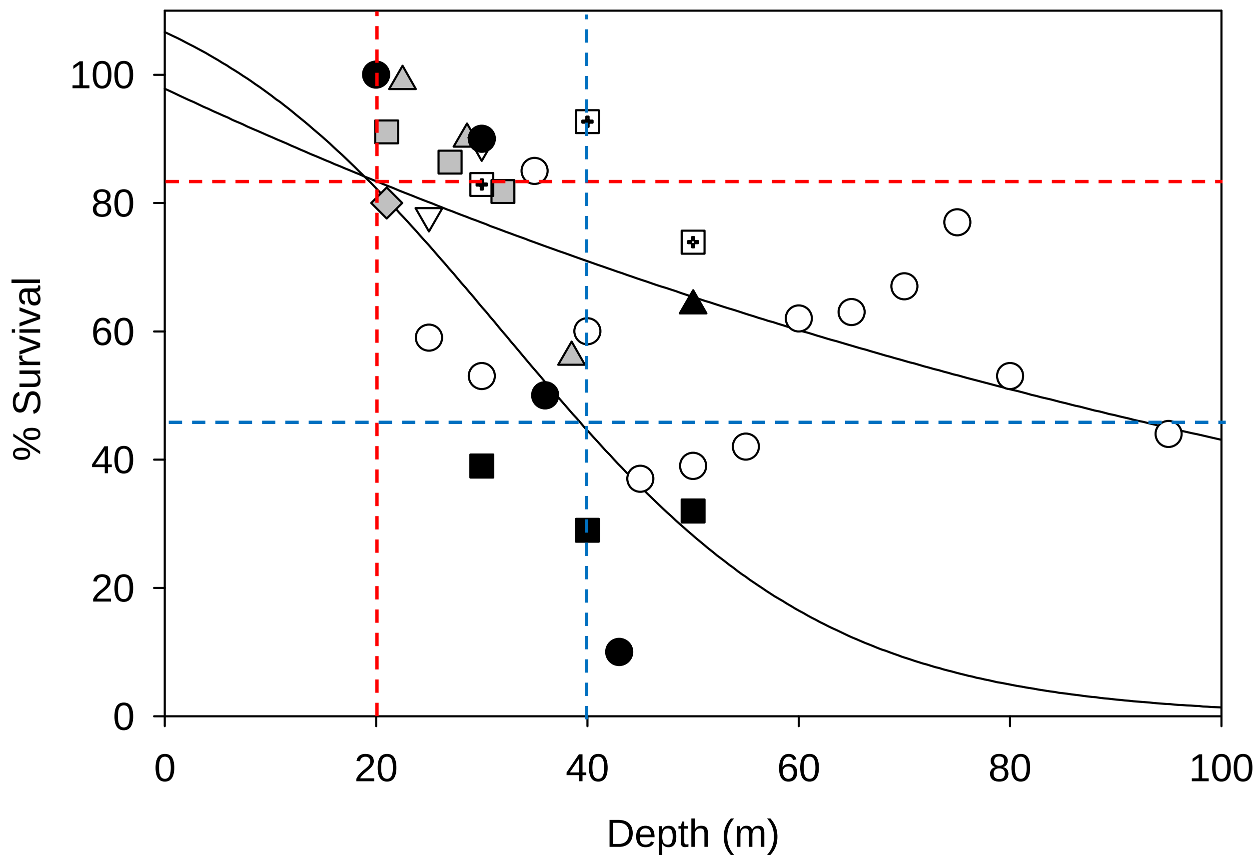

Figure 2: Immediate (open and gray symbols) and delayed (black symbols) survival by depth from literature studies. Immediate mortality estimates are taken from: Dorf (2003, open circles), Gitschlag and Renaud (1994, gray squares), Diamond and Campbell (2009, open crossed squares), Parker (1991, open triangles), Patterson et al. (2002, grey triangles), and Render and Wilson (1994, grey diamonds). Delayed mortality estimates are taken from: Gitschlag and Renaud (1994, black triangles), Diamond and Campbell (2009, black squares), and Burns et al. (2002, black circles). Points are fit to a sigmoidal curve. Immediate mortality is the flatter of the two lines. [reprinted with permission from Diamond et al.; unpublished data].

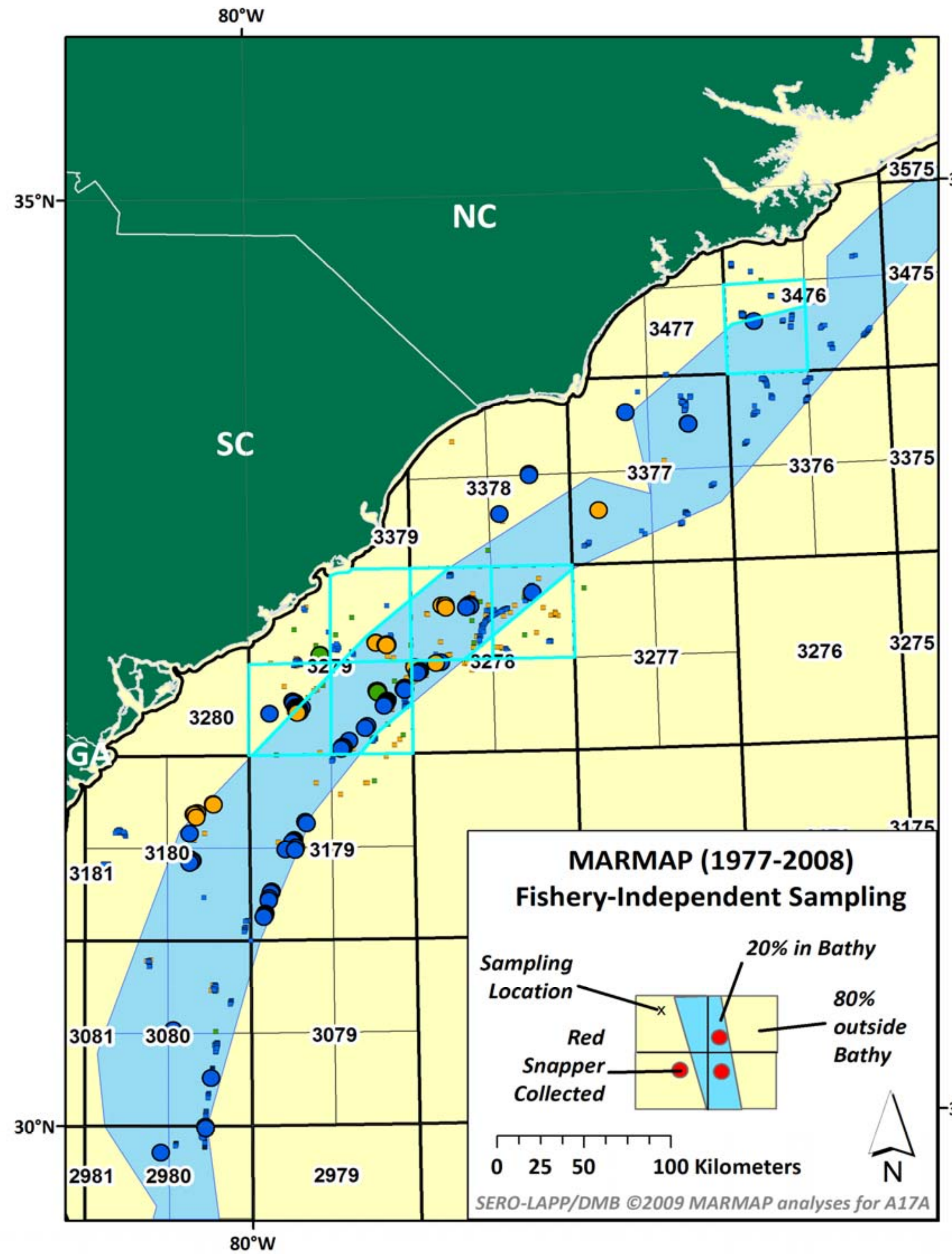

Figure 3. MARMAP sampling 1977-2008 by gear, for gears landing >10 red snapper (e.g., chevron trap, hook and line, snapper reel). Sites with no red snapper collected are indicated with a black 'X'. Selected cells (turquoise) had sampling inside and outside the proposed bathymetric closure (98-240 ft), and thus were appropriate for use in the regression model of percent area protected vs. percent red snapper 'stock' protected.

Discussion

At least an 83% reduction in removals of red snapper (based on an $F_{MSY} = F_{40\%SPR}$) is needed to achieve Congressional mandates to end overfishing and rebuild the red snapper stock in the south Atlantic region. Amendment 17A, Alternative 2 proposes the closure of the red snapper fishery in the south Atlantic. Our analyses suggest that without additional regulations, this closure will provide reductions in the range of 29-60% (see Table 3), and will be inadequate to achieve the reduction in red snapper removals necessary to end overfishing. This is due to the high rate of encounter with red snapper during other snapper-grouper fishing operations as well as the high release mortality of red snapper. To achieve an 83% reduction, the interaction rate of south Atlantic fisheries with red snapper must be reduced through the closure of specific areas to harvest of all members of the snapper/grouper fishery management unit (FMU), in addition to a general closure of the red snapper fishery. As shown in Table 3, under assumptions that directed and targeted trips will be eliminated by Amendments 13C; 16; and 17A, with a 40% offshore release mortality and 20% inshore release mortality for all sectors, an 87% compliance rate would be required to achieve the necessary 83% reduction under the South Atlantic Council's current preferred alternative 4D.

Alternatives 3 and 4 close four and seven nearshore statistical areas to all snapper-grouper fishing within depth ranges specified by subalternatives A-D, respectively. An examination of Table 2 shows little difference between subalternatives C and D, primarily because there is minimal additional area closed by extending the eastern boundary of the closure from 240 ft out to 300 ft, due to the extreme decline of the coastal bathymetry near the Gulf Stream. Due to a relative lack of fishery-independent data concerning the distribution of the red snapper stock, projected reductions associated with bathymetric closures are uncertain and should be considered with caution.

In these analyses, the percent stock protected by the bathymetric closures proposed in Alternatives 3 and 4 was based on commercial logbook data, which introduces several potential biases into the computations. First, this data is expressed in pounds, rather than numbers, meaning it is a biomass-based percentage estimate which does not necessarily correspond to encounter rates with actual individual fish. Second, depth of capture in the logbook records is not always available or reliable (Table 1), although reporting has improved through time. Finally, basing the impacts of the bathymetric closure upon commercial logbook observations of stock distribution may not be appropriate for recreational and headboat fisheries, as commercial fisheries may operate in deeper waters. Recreational vessels tend to fish closer to shore and are more likely to fish in shallower water since most are making day trips. An unpublished examination of confidential headboat fishing effort suggests a substantial number of red snappers occur inshore of 98 ft, an observation supported by the logbook as well. The projected reductions associated with a 66-240 ft closure are 2-7% higher than those associated with a 98-240 ft closure under the scenarios explored in Table 3. It should also be noted that the additional area covered by extending the closure inshore to 66 ft provides far more comprehensive coverage of red snapper spawning locations identified by Moe (1963) and MARMAP (1977-2008), as illustrated in Figure A3.

This report considered scenarios with changes in release mortality. Some level of effort shifting into shallower water, for both the recreational and commercial fisheries, may be expected following implementation of areal closures. Although a variety of factors contribute to discard mortality (e.g., fishing depth, surface interval, hook location, predation, water temperature), depth of capture is an important consideration (GMFMC 2007). This is because a substantial component of the mortality experienced by red snapper following capture and release is due to barotrauma (Campbell 2008) and is therefore directly related to depth of capture (Burns et al. 2004, Rummer 2007). Rummer (2007) estimates that discard mortality may be as low as 20% if the fish is caught in waters < 20 m. If red snapper fishing activity does move closer to shore (particularly into areas 2981, 3081, and 3181) as areas farther offshore are closed (see Figures 3 and 4), then reductions in depth-related discard mortality should be realized. It is difficult to predict exactly what those reductions will be, both because the level and pattern of effort shifting is unknown and because higher discard mortality rates will continue to be experienced in areas of the south Atlantic where areal closures are not implemented.

If the recreational and commercial fisheries move shoreward, a decrease in discard mortality can be expected in those areas where effort shifts. The implications of decreased discard mortality are most profound for the commercial fishery, where discard mortality is currently estimated at 90% (SEDAR 2009). However, the shoreward movement of the fishery is not well-supported by commercial logbook data, which suggests the average depth of fishing for red snapper may actually be deeper for the fishery overall following implementation of the closures proposed in Alternative 4A (SERO 2009a). A recent meta-analysis of delayed mortality studies (Diamond et al. unpubl. data; see Figure 2) suggests that recreational release mortality may actually be higher than the 40% recommended by SEDAR 15.

As with most statistical analyses, assumptions can limit the applicability of results and conclusions of these projected reductions. Assumptions in this analysis included: 1) the spatial distribution of discards is proportional to the spatial distribution of landings, 2) if effort shifting from closed areas occurs, it is adequately captured via manipulation of the compliance rate, 3) headboat landings are reasonable spatial proxies for private and charter boat landings, 4) movement of fish across reserve boundaries does not increase red snapper encounter rates in adjacent areas above baseline (2005-2007) levels, 5) no disproportionate redistribution of fishing effort along reserve boundaries, and 6) historical trends (2005-2007) are reasonable proxies for future trends (2010).

If discards do not occur proportionally to landings, the overall reductions generated by spatial closures in Alternatives 3-4 would be different than presented herein. If fishermen relocate their effort to open areas rather than eliminating trips, reductions would be less than presented herein. If fishermen go out of business due to the stringency of proposed regulations, overall reductions might be greater than those presented herein.

Most of the positive benefits of spatial closures, including projected reductions in red snapper, are dependent on compliance with no-take regulations (Fogarty et al. 2000). Numerous modeling efforts and case studies have shown that even relatively low levels of poaching can rapidly erode the fisheries benefits of no-take areas (Tegner 1993, Attwood et al. 1997, Gribble & Robertson 1998, Guzman & Jacome 1998, Murray et al. 1999, Rogers-Bennett et al. 2000; however, see Jennings et al. 1996), an observation that is borne out in this modeling approach. Little published data exists to estimate rates of non-compliance (Ward et al. 2001), but a multi-year study by Gribble & Robertson (1998) reported high levels of intrusion into a no-take zone of the Great Barrier Reef Marine Park. If compliance is less than 100% or effort shifting occurs, then reductions in red snapper removals might be substantially less than those estimated in this report.

In order to remain economically viable in the face of substantial spatial closures such as those proposed by Amendment 17A, fishermen may be forced to shift fishing effort from closed areas into areas that remain open. The directionality and extent of this effort shifting is difficult to predict; however, its impacts upon projected reductions in red snapper landings can be approximated through modification of the compliance rate. Given that the proposed spatial closures render the core of the red snapper stock inaccessible to fishing, any effort shifting from closed areas to open areas would have a lower proportional encounter rate with red snapper (e.g., a lower catch-per-unit-effort). Additionally, regulations imposed by Amendment 17B (approved by SAFMC in December 2009 for submission to the Secretary of Commerce for final review and approval) would prohibit the harvest of deepwater species (snowy grouper, blueline tilefish, yellowedge grouper, warsaw grouper, speckled hind, misty grouper, queen snapper, and silk snapper) beyond 73 m depth and would implement ACLs for gag, red, and black grouper. In light of these new regulations, it stands to reason that effort from Amendment 17A closures would mostly shift inshore. As previously discussed, red snapper landed inshore might be subject to lower release mortality rates than those recommended by SEDAR 15. As such, it is perhaps safe to assume that noncompliance has a far greater proportional impact on red snapper removals than a similar level of effort shifting (e.g., 10% effort shift ~ ≤5% noncompliance). Functionally, this implies that under Scenario 5, the current preferred alternative (Alternative 4D) could only achieve an 83% reduction if compliance and effort shifting combined amounted to the equivalent of 87% compliance. That is, the impacts of effort shifting and non-compliance would have to be the equivalent of 13% of the baseline removals still occurring in the closed cells.

The use of headboat landings locations as spatial proxies for private and charter boat landings is discussed in SERO (2009c). A comparison of post-stratified aggregated landings showed similar patterns in red snapper removals, although MRFSS reports higher relative landings off Northeast Florida and lower relative landings off South Carolina (SERO 2009c). Given the large size of the statistical areas involved in the spatial portioning of landings and the locations of major population centers, it seems reasonable to assume that broad-scale landings patterns between these fisheries might be similar. If charter boat and private recreational landings patterns are not reasonably approximated by the headboat fishery, then overall reductions might be greater or lower than those projected by these analyses.

Movements of exploited fish species across no-take zone boundaries can help maintain fisheries yields but also reduce the ability of the no-take zone to protect spawning stock biomass (Farmer 2009). Fishermen may take advantage of these movements by redistributing fishing effort along reserve boundaries (review in Gell & Roberts 2003), further reducing the no-take zone's ability to control fishing pressure on the stock. Modeling efforts suggest larger no-take zones such as those proposed in Amendment 17A provide a buffer, reducing the impacts of 'fishing-the-line' upon the core population (Fogarty 1999, Bohnsack 2000, Crowder et al. 2000, Walters 2000, Farmer 2009). Regardless, a combination of fish movement across reserve boundaries and a redistribution of fishing effort along boundaries might substantially reduce the protections afforded by the closures proposed in Amendment 17A for the red snapper stock.

Literature Cited

Attwood, C.G., J.M. Harris and A.J. Williams. 1997. International experience of marine protected areas and their relevance to South Africa. South African Journal of Marine Science 18: 311–332.

Bohnsack, J.A. 2000. A comparison of the short-term impacts of no-take marine reserves and minimum size limits. Bulletin of Marine Science, 66(3): 635-650.

Burns, K.M, C.C. Koenig, and F.C. Coleman. 2002. Evaluation of multiple factors involved in release mortality of undersized red grouper, gag, red snapper, and vermilion snapper. Mote Marine Laboratory Technical Report No. 814. (MARFIN grant #NA87FF0421)

Burns, K. M., R. R. Wilson, and N. F. Parnell. 2004. Partitioning release mortality in the undersized red snapper bycatch: comparison of depth vs. hooking effects. Mote Marine Laboratory Tech. Rept. No. 932 funded by NOAA under MARFIN Grant #NA97FF0349.

Campbell, M.D. 2008. Characterization of the stress response of red snapper: connecting individual responses to population dynamics. Ph.D. Dissertation, Texas Tech University, Lubbock, TX. 111 pp.

Crowder, L.B., Lyman, S.J., Figueira, W.F., and J. Priddy. 2000. Source-sink population dynamics and the problem of siting marine reserves. Bulletin of Marine Science, 66(3): 799-820.

Dorf, B.A., 2003. Red snapper discards in Texas coastal waters - a fishery dependent onboard survey of recreational headboat discards and landings. American Fisheries Society Symposium 36, 155-166.

Farmer, N.A. 2009. Reef fish movements and marine reserve designs. Ph.D. Dissertation, University of Miami, Miami, FL. 216 pp.

Fogarty, M.J. 1999. Essential habitat, marine reserves and fishery management. Trends in Ecology & Evolution, 14(4): 133-134.

Fogarty, M.J., J.A. Bohnsack and P.K. Dayton. 2000. Marine reserves and resource management. In: *Seas at the Millenium: An Environmental Evaluation. Volume III Global Issues and Processes*. C.R.C. Sheppard (Editor). Pergamon, Elsevier Science, New York. p. 375–392.

Gell, F. R. and C.M. Roberts. 2003. The fishery effects of marine reserves and fishery closures Washington, DC: WWF-US.

Gitschlag, G.R. and M.L. Renaud. 1994. Field experiments on survival rates of caged and released red snapper. North American Journal of Fisheries Management, 14: 131-136.

GMFMC. 2007. Final, Amendment 27 to the Reef Fish Fishery Management Plan and Amendment 14 to the Shrimp Fishery Management Plan (Including Supplemental Environmental Impact Statement, Regulatory Impact Review, and Regulatory Flexibility Act Analysis). Gulf of Mexico Fishery Management Council, Tampa, FL. 380 pp. + appenices.

Gribble, N.A. and J.W.A. Robertson. 1998. Fishing effort in the far northern section cross shelf closure area of the Great Barrier Reef Marine Park: the effectiveness of area-closures. *Journal of Environmental Management* 52: 53–67.

Guzman, H.M. and G. Jacome. 1998. Artisan fishery of Cayos Cochinos Biological Reserve, Honduras. *Revista de Biologia Tropical* 46: 151–163.

Jennings, S., S.S. Marshall and N.V.C. Polunin. 1996. Seychelles' marine protected areas: comparative structure and status of reef fish communities. *Biological Conservation* 75: 201–209.

Moe, M.A. 1963. A survey of offshore fishing in Florida. Florida State Board of Conservation, Marine Laboratory, Maritime Base (St. Petersburg, FL). Professional papers series, no. 4. 117 pp.

Murray, S.N., T. Gibson Denis, J.S. Kido and J.R. Smith. 1999. Human visitation and the frequency and potential effects of collecting on rocky intertidal populations in Southern California marine reserves. *California Cooperative Oceanic Fisheries Investigation Report* 40: 100–106.

Parker, R.O. 1991. Survival of released fish—A summary of available data. Progress report to South Atlantic and Gulf of Mexico Fisheries Management Councils, Charleston, South Carolina, and Tampa, Florida.

Patterson, W. F. III, J.C. Watterson, R.L. Shipp, and J.H. Cowan, Jr. 2001. Movement of tagged red snapper in the northern Gulf of Mexico. Transactions of the American Fisheries Society 130:533-545.

Rogers-Bennett, L., Bennett, W. A., Fastenau, H. C. and C. M. Dewees. 1995. Spatial variation in red sea urchin reproduction and morphology: implications for harvest refugia. *Ecological Applications* 5: 1171–1180.

Rummer, J.L. 2007. Factors affecting catch and release (CAR) mortality in fish: Insight into CAR mortality in red snapper and the influence of catastrophic decompression. Pages 123-144 *in* W.F. Patterson, III, J.H. Cowan, Jr., G.R. Fitzhugh, and D.L. Nieland, editors. Red snapper ecology and fisheries in the U.S. Gulf of Mexico. American Fisheries Society, Symposium 60, Bethesda, Maryland.

SEDAR 15. 2009. Stock Assessment Report 1 (SAR 1) South Atlantic red snapper. Southeast Data, Assessment, and Review, Charleston, SC. 511 pp.

SERO. 2009a. Evaluating the Effects of Amendment 13C, Amendment 16, and Amendment 17A Regulations on Red Snapper Removals by South Atlantic Commercial Fisheries. SERO-LAPP-2009-03, NMFS, SERO, St. Petersburg, FL. 41 pp.

SERO. 2009b. Evaluating the Effects of Amendment 16 Regulations on 2005-2007 South Atlantic Red Snapper Headboat Removals. SERO-LAPP-2009-04, NMFS, SERO, St. Petersburg, FL. 10 pp.

SERO. 2009c. Evaluating the Effects of Amendment 16 Regulations on 2005-2007 South Atlantic Red Snapper Private and Charterboat Removals. SERO-LAPP-2009-05, NMFS, SERO, St. Petersburg, FL. xx pp.

SERO. 2009d. Evaluating the Effects of Amendment 17A Regulations on 2005-2007 South Atlantic Red Snapper Headboat Removals. SERO-LAPP-2009-06, NMFS, SERO, St. Petersburg, FL. 13 pp.

Tegner, M.J. 1993. Southern California abalones: can stocks be rebuilt using marine harvest refugia? *Canadian Journal of Fisheries and Aquatic Sciences* 50: 2010–2018.

Walters, C.J. 2000. Impacts of dispersal, ecological interactions, and fishing effort dynamics on efficacy of marine protected areas: How large should protected areas be? Bulletin of Marine Science, 66(3): 745-757.

Ward, T.J., Heinemann, D., and N. Evans. 2001. The role of marine reserves as fisheries management tools: A review of concepts, evidence, and international experience. Australia Bureau of Rural Sciences: Agriculture, Fisheries, and Forestry, 105 pp.

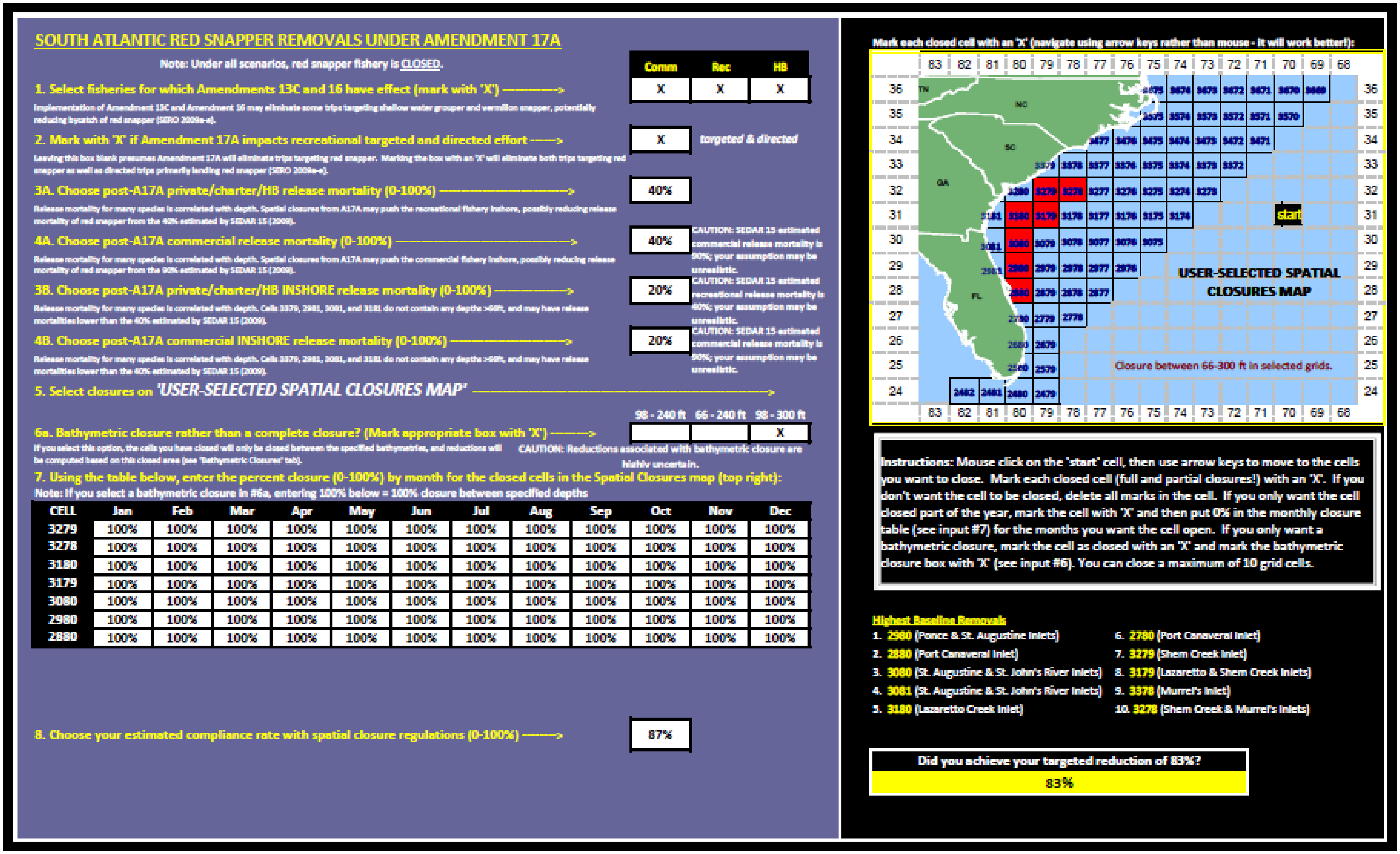

Figure A1. Screenshot of input screen for Excel-based projected reductions model. Note flexibility in user-input specifications for management-induced trip elimination (inputs #1-2), offshore and inshore sector-specific release mortality (inputs #3-4), locations of spatial closures (input #5), bathymetric scope of closures (input #6), partial openings during user-specified months (input #7), and compliance rate (input #8). Note warnings given when input parameters are outside recommended tolerance levels.

REGULATIONS

Amendments 13C and 16 have effect for:	Comm, Rec, HB	
Closed Statistical Areas:	3279, 3278, 3180, 3179, 3080, 2980, 2880	(NEW ALTERNATIVE)
Total Closed Statistical Areas:	7	
Any Partial Closures:	NO	
Partially Closed Cells:	n/a	
Type of Closures:	Bathymetric closure (66-300 ft) assuming heterogeneous distribution [Logbook]	

BASELINE REMOVALS

FISHERY	L(1000)	D(1000)	R(1000)
Comm	107.8	25.6	130.8
Rec	258.0	351.7	398.7
HB	45.9	68.8	73.4
TOTAL	411.6	446.2	602.9

L(1000) = landings (thousand lbs)
D(1000) = discards (thousand lbs)
R(1000) = removals (thousand lbs)

AMENDMENT 17A REMOVALS

FISHERY	R(1000)	PCT REDUCTION
Comm	11.7	91%
Rec	75.7	81%
HB	16.8	77%
TOTAL	104.2	83%

Note: Commercial reductions are larger than those projected in SERO (2009a) report due to new assumption of no discards in closed cells

TARGETED REDUCTIONS

Reduction in total removals (landings plus dead discards) needed to end overfishing. Non-shaded areas determined by comparing actual landings from 2005-2007 with allowable removals in 2010. Shaded areas are estimated by interpolation.

Fmsy proxy	F40% proxy				F30% proxy			
Recruitment	Base Estimated	High	Very High	Extremely High	Base Estimated	High	Very High	Extremely High
Alternative 2 (FMSY)	86%	86%	83%	81%	81%	80%	78%	76%
Alternative 3 (85% FMSY)	89%	88%	85%	83%	84%	83%	81%	79%
Alternative 4 (75% FMSY)	90%	89%	87%	85%	86%	85%	83%	81%
Alternative 5 (65% FMSY)	91%	90%	89%	86%	88%	87%	85%	83%
Alternative 6 (Frebuild)	87%	86%	83%	82%	82%	81%	79%	77%

Desired reduction achieved under current suite of user-selected parameters?

Fmsy proxy	F40% proxy				F30% proxy			
Recruitment	Base Estimated	High	Very High	Extremely High	Base Estimated	High	Very High	Extremely High
Alternative 2 (FMSY)	NO	NO	NO	YES	YES	YES	YES	YES
Alternative 3 (85% FMSY)	NO	NO	NO	NO	NO	NO	YES	YES
Alternative 4 (75% FMSY)	NO	NO	NO	NO	NO	NO	NO	YES
Alternative 5 (65% FMSY)	NO	NO	NO	NO	NO	NO	NO	YES
Alternative 6 (Frebuild)	NO	NO	NO	YES	YES	YES	YES	YES

NOTE: Council's preferred alternative (Sept 2009) is indicated in red.

Potential input errors:

CAUTION: SEDAR 15 estimated commercial release mortality is 90%; your assumption may be unrealistic. CAUTION: Reductions associated with bathymetric closure are highly uncertain. CAUTION: SEDAR 15 estimated recreational release mortality is 40%; your assumption may be unrealistic. CAUTION: SEDAR 15 estimated commercial release mortality is 90%; your assumption may be unrealistic.

Additional assumptions:

Additional assumptions in this analysis include: 1) discards occur in same proportion as landings, 2) no effort shifting from closed areas occurs, 3) headboat landings are reasonable spatial proxies for private and charter boat landings, 4) no movement of fish across spatial closure boundaries, 5) no disproportionate redistribution of fishing effort along spatial closure boundaries, 6) historical trends are reasonable proxies for future trends. It should also be noted that some uncertainty exists in baseline data (especially for discards)

Figure A2. Screenshot of output screen for Excel-based projected reductions model. Note summary of input parameters, baseline versus projected removals, and color-coded achievement of certain management targets. Note also potential input errors resulting from users deviating from recommended parameters, as well as list of input assumptions potentially introducing bias or error into projections.

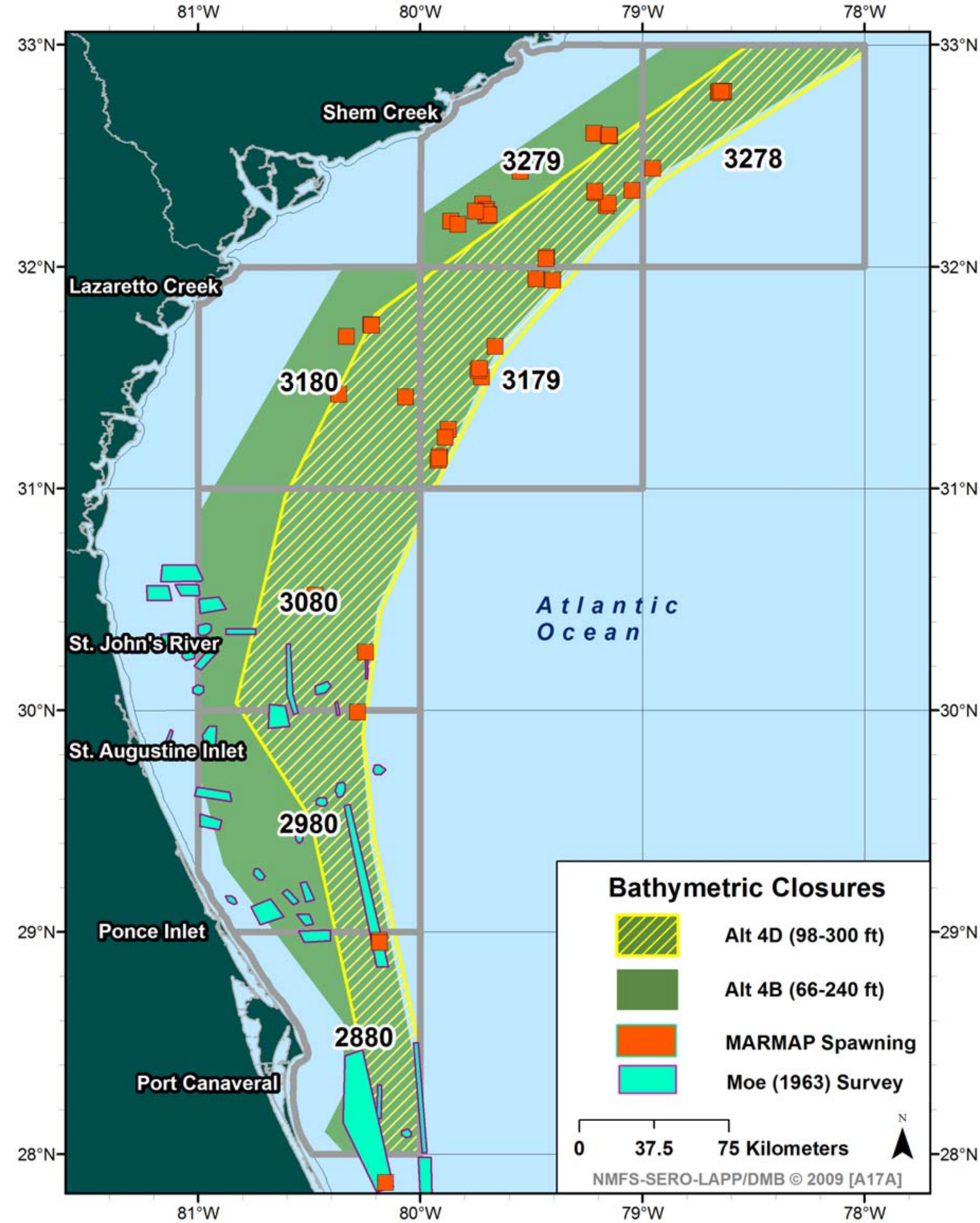

Figure A3. Overlay of Amendment 17A Alternatives 4B and 4D with spawning locations observed by Moe (1963) and MARMAP (1977-2008). Note scale of 4B closure relative to 4D and far greater coverage of spawning locations.