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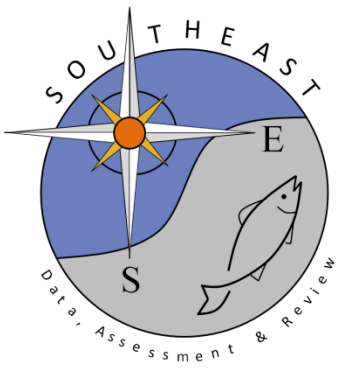
SEDAR86-WP09

Received: 9/1/23



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Please cite this document as:

Atkinson, Sarina. CPUE Expansion Estimation for commercial Discards of South Atlantic Red Grouper. SEDAR82-AW09. SEDAR, North Charleston, SC. 20 pp.

SEDAR 86 Working Paper

CPUE Expansion Estimation for Commercial Discards of South Atlantic Red Grouper

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August 2023

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Introduction

The general approach for estimating discards for the commercial reef fish fleet in the South Atlantic utilizes catch-per-unit-effort (CPUE) from the coastal reef fish observer program and total fishing effort from the commercial reef logbook program to estimate total catch,

$$totalCatch = CPUE * totalEffort.$$

For discard estimation, CPUE is computed for total discards, including fish released alive, released dead, released in unknown condition, and used for bait. The primary metric for the coastal observer program is CPUE by species and gear. The principal focus of this study was to apply the discard estimation methods developed for Gulf of Mexico red grouper in SEDAR Working Paper 61-15 (Smith et al. 2018), Gulf of Mexico gray triggerfish in SEDAR Working Paper 62-07 (Smith et al. 2019), and Gulf of Mexico vermilion snapper in SEDAR Working Paper 67-12 (Smith et al. 2019) to South Atlantic Red Grouper. This method was first applied in the South Atlantic for SEDAR 82 Gray Triggerfish (McCarthy et al. 2023).

Methods

Data Sources

Vertical line observer data collected by the Gulf and South Atlantic Fisheries Foundation (GSAFF) from 2007-2016 and SEFSC Panama City Laboratory (SAVLOP) from 2014-2021 were considered for estimating discards of South Atlantic Red Grouper. For both observer programs, scientific observers on commercial fishing vessels record detailed information on catch and effort for a subset of trips. Catch by species was recorded according to the disposition category: kept (landed), released alive, released dead, released undetermined, and used for bait. Length and weight were recorded for a subsample of individual fish. Time periods for the methodology can be defined in terms of the observer program, with the pre-observer time period representing years prior to 2007, and the observer time period representing years 2007 and beyond.

Total effort was determined from the commercial Coastal Fisheries Logbook Program in which fishers reported basic information on effort and catch by species for every trip (Atkinson et al. 2021). The coastal logbook program began in 1990 for a subset of vessels in the South Atlantic, and expanded to all vessels in 1993; for South Atlantic Red Grouper discard estimation, complete calendar years 1993-2021 were considered.

Relevant Management History of South Atlantic Red Grouper

There are two key management changes relevant to discard estimation: (1) the establishment of a minimum size limit in 1992 (20” TL) and (2) commercial shallow water grouper spawning closure from January to April in 2009. Based these management regulations, observer sample size, and trends in annual coastal logbook CPUE, three management regimes were defined. During the observer time period, the management regimes were first (2007-2009), second (2010-2012), and third (2013-2021).

Gear

In the South Atlantic observer data, only vertical line trips are sampled. Therefore, discard estimation for Red Grouper was conducted for only this gear.

Spatial Domain

Similar to the previous SEDAR, discard estimates were conducted for the South Atlantic as a single stock (Figure 1).

Trip-Level Catch for Observer Data

Observers collected catch data at a sub-trip level (e.g., a specific set and line for vertical line gear), but it was not feasible to sample every set, line, etc., for every trip. Gear-specific procedures were applied to estimate the trip-level landed catch from the observer data (Smith et al. 2018).

Trip-Level Effort for Observer and Logbook Data

For observer data, trip-level effort for vertical lines was computed as the cumulative daily fishing time (hours) from first hook in to last hook out; this time metric included the active fishing time as well as transit time between fishing locations during a given trip day. This effort variable generally matched trip fishing time reported in vessel logbook data (Smith et al. 2018). For bottom longlines, trip-level effort was the number of sets fished; this effort variable matched the number of sets reported in vessel logbook data (Smith et al. 2018).

Catch Expansion Procedures and Verification

Observer CPUE was calculated using trip-level nominal effort and catch for a given time period. Statistical estimation of total catch $\hat{C}$ and associated variance followed procedures for a (Horvitz-Thompson) survey design ratio estimator (Jones et al. 1995; Lohr 2010):

$$\hat{C} = \bar{CPUE} * \hat{X},$$

where $\bar{CPUE}$ is observer mean CPUE and $\hat{X}$ is total logbook nominal effort. Species- and gear-specific logbook total effort $\hat{X}$ was calculated in two steps. First, logbook trip effort by gear was summed over trips reporting landings of the target species. Second, to obtain $\hat{X}$, logbook trip effort was adjusted by the proportion of observer trip effort that reported only discards of the target species. Logbook total trips N were calculated in a similar manner.

Mean CPUE was estimated by

$$\overline{CPUE} = \frac{\bar{y}}{\bar{x}}$$

where $\bar{y}$ is average catch and y_i is observed catch per trip *i*,

$$\bar{y} = \frac{1}{n}\sum_i y_i$$

$\bar{x}$ is average effort and x_i is observed effort per trip *i*,

$$\bar{x} = \frac{1}{n}\sum_i x_i,$$

and *n* is the number of observer trips. Variance of total catch was estimated using

$$var\left[\hat{C}\right] = var[\overline{CPUE}] \times \hat{X}^2\,,$$

where the variance of mean CPUE is

$$var[\overline{CPUE}] = \left(1 - \frac{n}{N}\right)\frac{s^2(y|x)}{n\bar{x}^2},$$

N is the total number of logbook trips, and sample variance is

$$s^2(y|x) = \frac{\sum_i (y_i - \overline{CPUE}x_i)^2}{n-1}.$$

Standard error of total catch was calculated as

$$SE\left[\hat{C}\right] = \sqrt{var\left[\hat{C}\right]}\,.$$

The CV of total catch $\hat{C}$ was estimated by

$$CV\left[\hat{C}\right] = \frac{SE\left[\hat{C}\right]}{\hat{C}}.$$

A verification step compared annual total landed catch from logbook data with the estimated observer annual total catch $\hat{C}$. Once verified, the catch expansion procedure was used to estimate annual total discards in weight and number.

Stratification by Trip Catch or Effort Level

Computations of mean CPUE, total catch, and associated standard errors were generalized to include strata for trip catch and/or effort levels of Red Grouper. This enabled accurate estimation of total catch (and discards) in cases where observer sampling was not proportional to the fleet with respect to trip catch or effort (Smith et al. 2019a), e.g., observers sampled fewer or more

low-catch trips with respect to logbook low-catch trips, etc. Comparisons of observer vs. logbook frequency distributions for trip-level catch, effort, and CPUE were used to delineate strata for trip catch and/or effort levels (e.g., low, moderate, high, etc.).

Hindcast Procedures

For years prior to 2007, before observer data were collected, hindcast discard estimation procedures for "Trending CPUE" described in Smith et al. (2019a) were applied to Red Grouper. For this method, the ratio of observer CPUE in weight to logbook CPUE was computed for the observer time period, and then multiplied by the annual logbook CPUE for the hindcast time period to produce an estimated annual observer CPUE. Then, the annual observer CPUE was multiplied by annual logbook effort for the pre-observer time period to estimate total catch $\hat{C}$ in weight. An additional step computed the ratio of the observer CPUE in number to observer CPUE in weight. This ratio was then used to compute the observer estimated discards in number from the discards in weight for the hindcast period. Standard errors for the hindcast period were estimated using the respective CVs of total estimated catch $\hat{C}$ kept and discarded as described in Smith et al. (2019a). To guide selection of appropriate time periods for hindcasting, time-series of annual logbook CPUE were evaluated with respect to the 1993-2006 hindcast time period. Verification compared total landed catch from logbook data with the estimated total catch $\hat{C}$ and standard error from observer data for the hindcast time period.

Discard Length Composition

The length frequency distribution for discards for a given management time frame was computed in the following manner. Average discard CPUE in stratum h was scaled to stratum total effort $\widehat{Y_h}$.

$$\widehat{Y_h} = \overline{CPUE}_h * \hat{X}_h$$

and multiplied by stratum proportion of length L to obtain the stratum total discards $\widehat{Y_h}$ at length L,

$$\hat{Y}(L)_h = \widehat{Y_h} * p(L)_h.$$

These were summed over all strata to obtain the survey frame total $\hat{Y}$ at length L

$$\hat{Y}(L)_{st} = \Sigma_h \hat{Y}(L)_h,$$

and then converted to relative proportion of length L,

$$p(L)_{st} = \frac{\hat{Y}(L)_{st}}{\Sigma_h \widehat{Y_h}} (1)$$

Annual discards-at-length were computed by multiplying eq. (1) and annual estimates of total discards.

Results and Discussion

The observer database included 61 vertical line trips with corresponding trip and set information for Red Grouper. Of those 61 trips, 55 trips were observed by GSAFF and only 6 trips were sampled under the SAVLOP. For this reason, both observer programs were included in this analysis and there was insufficient data during the years of overlap to assess for differences in sampling protocols. Annual observer sampling effort is summarized in Table 1, distinguishing all trips from the subset of trips that captured Red Grouper. Sampling effort is split into two fishing regions: areas south of 37° latitude and north of 32° latitude (NC-SC) and areas in the South Atlantic south of 32° latitude (GA-FL) (Figure 1). For subsequent analyses, discards were estimated for the entire South Atlantic region as single stock.

For the first time period (2007-2009), the disposition (kept or discarded) of South Atlantic Red Grouper corresponded with the minimum size limit of 20" TL (Figure 2). Discards were mostly fish near or below the minimum size limit, and kept fish were mostly above the minimum size limit. During the second (2010-2012) and third (2013-2021) management regimes, discards included fish below and above the minimum size limit. Due to limited data, discard CPUE could not be calculated for open and closed seasons separately.

Inspection of the annual nominal CPUE (catch in whole pounds per hour) from logbook trips reporting Red Grouper showed a decrease in average CPUE during the entire observer time period (prior to 2006) (Figure 3). Catch-effort data for observer trips catching Red Grouper were pooled across years for the respective management regimes. Logbook catch-effort data for Red Grouper trips were pooled in the same manner. These observer and logbook datasets were the basis for subsequent analysis and estimation of catch and discards for the first (2007-2009), second (2010-2012), and third (2013-2021) management regimes.

Observer and logbook frequency distributions of trip-level catch, effort, and CPUE for each of the three management regimes suggest that observer sampling of Red Grouper trips was slightly different than the commercial fleet (coastal logbook data). In the first management regime (2007-2009), the observer and logbook trips were stratified into low (L), moderate (M), and high (H) catches. This was because the observers sampled slightly more low (< 16 lbs.) and high (> 42 lbs.) catch trips and less moderate (16-42 lbs.) catch trips relative to the commercial fleet. In the second management regime (2010-2012), the observers sampled an equal proportion of low (< 53 hrs.) and high (> 53 hrs.) effort trips relative to the logbook that had a higher proportion of low effort trips reported. Lastly, in the third management regime (2013-2021), the observers sampled a lower proportion of low (< 60 hrs.) effort trips relative to the commercial fleet. To account for this discrepancy in the second and third management regimes, observer and logbook trips were grouped into strata according to low (L) and high (H) effort trips. This breakdown of catch or effort stratification by management regime are provided in Table 2 and used for subsequent analysis and estimation.

The proportions of observer trips and effort encountering Red Grouper that had kept fish are given in Table 3 by management regime and strata level. These proportions were used to adjust annual logbook total Red Grouper trips and effort (Table 4) to account for logbook trips that only had discarded fish. Estimates of observer mean CPUE by management regime and catch level

strata are given in Table 5. These CPUEs were the basis for expansion estimates of Red Grouper catch and discards. Observer data from the first management regime (2009-2009) were used for hindcasting discards for the pre-observer years 2000-2006 because this was the only time period before the seasonal spawning closures.

CPUE expansion estimates of annual total landed catch of South Atlantic Red Grouper compared favorably with reported logbook landings for 1993-2021 (Figure 4). CPUE expansion estimates for annual discards in numbers and weight (whole) of South Atlantic Red Grouper for 1993-2021 are provided in Table 6. Estimated discards in number averaged 600 fish during the hindcast time period (1993-2006), 1,400 fish during the first management regime (2007-2009), 900 fish during the second management regime (2010-2012), and 400 fish during the third management regime (2013-2021) (Figure 5A). Discards in weight accounted for about 1 to 2% of the total catch (kept + discards) during 1993-2009 and 6 to 9% of the total catch during 2010-2021 after the spawning closure was implemented (Figure 5B). Annual discard length frequencies were provided in 3 cm total length bins using the catch and effort strata by management regime (Figure 6).

The previous SEDAR 53 of South Atlantic Red Grouper commercial discards were estimated using the supplemental discard logbook data. They were calculated using a general linear model which is no longer considered the preferred method for estimating discards using these data. Described further in McCarthy (2015), a standardized discard rate as a model approach is an inappropriate method for discard calculation. Similar to South Atlantic Gray Triggerfish (McCarthy et al. 2023), discards presented in this paper using commercial observer data and provided for this assessment are the recommended estimates. This is because the observer discard approach has a built-in verification procedure which has proven to be reliable in discard estimation in the Gulf of Mexico (Smith et al. 2018).

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Table 1. Number of total and Red Grouper coastal observer vertical line trips by year for the South Atlantic by two subregions. NC-SC indicates trips fishing off the coast of North Carolina and South Carolina. GA-FL indicates trips fishing off the coast of Georgia and the east coast of Florida.

Year	NC-SC		GA-FL	
	Total Trips	Red Grouper Trips	Total Trips	Red Grouper Trips
2007	18	16	10	8
2008	5	5	0	0
2009	4	4	3	2
2010	5	4	1	0
2011	9	5	4	1
2014	7	3	24	0
2015	10	3	15	0
2016	7	2	9	3
2018	10	0	8	2
2019	5	0	7	0
2020	1	0	15	0
2021	6	0	49	3

Table 2. Definition of trip catch or effort level strata for South Atlantic Red Grouper, and corresponding percentages of logbook and observer vertical line trips for each zone and management regime.

Management Regime	Season	Strata Level	Stratum Code	% Trips	
				Logbook	Observer
First 2007-2009	Open	Low, Catch <= 16 lbs	L	16.6	17.1
First 2007-2009	Open	Moderate, 16< Catch <= 42 lbs	M	17.7	14.3
First 2007-2009	Open	High, Catch > 42 lbs	H	65.7	68.6
Second 2010-2012	Open	Low, Effort <= 53 hours	L	76.2	50
Second 2010-2012	Open	High, Effort > 53 hours	H	23.8	50
Third 2013-2021	Open	Low, Effort <= 60 hours	L	88.7	56.2
Third 2013-2021	Open	High, Effort > 60 hours	H	11.3	43.8

Table 3. South Atlantic Red Grouper vertical line trip and effort adjustment factors by management regime and catch or effort level strata. Catch level strata are defined in Table 2. The proportions of Red Grouper observer trips and effort with kept Red Grouper were used to respectively adjust annual logbook total trips and effort (Table 4) to account for logbook trips that only had discarded fish.

Management Regime	Season	Strata Type	Strata Level	Number of Observer Trips (n)	Proportion of Observer Data with Kept Red Grouper	
					Trips	Effort
First 2007-2009	Open	Catch	L	6	1	1
First 2007-2009	Open	Catch	M	5	1	1
First 2007-2009	Open	Catch	H	24	1	1
Second 2010-2012	Open	Effort	L	5	0.8	0.845
Second 2010-2012	Open	Effort	H	5	1	1
Third 2013-2021	Open	Effort	L	9	0.444	0.744
Third 2013-2021	Open	Effort	H	7	1	1

Table 4. Annual time-series of vertical line logbook trips (number) and effort (hours) by catch or effort level strata for South Atlantic Red Grouper.

				Logbook Trips		Logbook Effort	
Year	Season	Strata Type	Strata Level	Reported	Adjusted (N)	Reported	Adjusted ($\hat{X}$)
1993	Open	Catch	L	620	620	12,787	12,787
1993	Open	Catch	M	383	383	12,015	12,015
1993	Open	Catch	H	473	473	20,581	20,581
1994	Open	Catch	L	777	777	17,504	17,504
1994	Open	Catch	M	507	507	14,547	14,547
1994	Open	Catch	H	624	624	22,338	22,338
1995	Open	Catch	L	804	804	18,050	18,050
1995	Open	Catch	M	553	553	16,082	16,082
1995	Open	Catch	H	967	967	34,344	34,344
1996	Open	Catch	L	1,024	1,024	23,072	23,072
1996	Open	Catch	M	698	698	23,788	23,788
1996	Open	Catch	H	1,004	1,004	44,412	44,412
1997	Open	Catch	L	1,059	1,059	25,127	25,127
1997	Open	Catch	M	784	784	25,722	25,722
1997	Open	Catch	H	1,225	1,225	46,354	46,354
1998	Open	Catch	L	1,067	1,067	20,604	20,604
1998	Open	Catch	M	729	729	20,439	20,439
1998	Open	Catch	H	1,439	1,439	48,694	48,694
1999	Open	Catch	L	635	635	12,578	12,578
1999	Open	Catch	M	617	617	17,096	17,096
1999	Open	Catch	H	1,545	1,545	54,456	54,456
2000	Open	Catch	L	648	648	14,058	14,058
2000	Open	Catch	M	611	611	19,708	19,708
2000	Open	Catch	H	1,239	1,239	43,216	43,216
2001	Open	Catch	L	742	742	15,705	15,705
2001	Open	Catch	M	615	615	21,420	21,420
2001	Open	Catch	H	1,137	1,137	39,387	39,387
2002	Open	Catch	L	735	735	15,360	15,360
2002	Open	Catch	M	667	667	22,014	22,014
2002	Open	Catch	H	1,124	1,124	36,882	36,882
2003	Open	Catch	L	630	630	12,307	12,307
2003	Open	Catch	M	567	567	19,733	19,733
2003	Open	Catch	H	1,060	1,060	41,176	41,176

				Logbook Trips		Logbook Effort	
Year	Season	Strata Type	Strata Level	Reported	Adjusted (N)	Reported	Adjusted ($\hat{X}$)
2004	Open	Catch	L	704	704	14,624	14,624
2004	Open	Catch	M	525	525	16,230	16,230
2004	Open	Catch	H	913	913	33,789	33,789
2005	Open	Catch	L	642	642	15,268	15,268
2005	Open	Catch	M	499	499	16,195	16,195
2005	Open	Catch	H	946	946	37,476	37,476
2006	Open	Catch	L	453	453	13,601	13,601
2006	Open	Catch	M	420	420	16,066	16,066
2006	Open	Catch	H	1,170	1,170	47,709	47,709
2007	Open	Catch	L	424	424	11,035	11,035
2007	Open	Catch	M	422	422	14,157	14,157
2007	Open	Catch	H	1,622	1,622	61,448	61,448
2008	Open	Catch	L	355	355	7,678	7,678
2008	Open	Catch	M	389	389	12,974	12,974
2008	Open	Catch	H	1,610	1,610	63,772	63,772
2009	Open	Catch	L	349	349	9,152	9,152
2009	Open	Catch	M	391	391	14,530	14,530
2009	Open	Catch	H	1,222	1,222	54,523	54,523
2010	Open	Effort	L	857	1,071	18,314	21,663
2010	Open	Effort	H	343	343	28,383	28,383
2011	Open	Effort	L	955	1,194	20,832	24,642
2011	Open	Effort	H	281	281	22,624	22,624
2012	Open	Effort	L	742	928	16,026	18,956
2012	Open	Effort	H	172	172	13,231	13,231
2013	Open	Effort	L	684	1,539	17,504	23,522
2013	Open	Effort	H	114	114	9,366	9,366
2014	Open	Effort	L	683	1,537	14,752	19,823
2014	Open	Effort	H	108	108	8,844	8,844
2015	Open	Effort	L	505	1,136	12,390	16,649
2015	Open	Effort	H	76	76	6,299	6,299
2016	Open	Effort	L	505	1,136	10,126	13,607
2016	Open	Effort	H	65	65	5,282	5,282
2017	Open	Effort	L	533	1,199	9,695	13,028
2017	Open	Effort	H	52	52	4,207	4,207
2018	Open	Effort	L	454	1,022	9,917	13,326

				Logbook Trips		Logbook Effort	
Year	Season	Strata Type	Strata Level	Reported	Adjusted (N)	Reported	Adjusted ($\hat{X}$)
2018	Open	Effort	H	58	58	4,882	4,882
2019	Open	Effort	L	435	979	9,302	12,500
2019	Open	Effort	H	30	30	2,280	2,280
2020	Open	Effort	L	357	803	8,019	10,776
2020	Open	Effort	H	34	34	2,756	2,756
2021	Open	Effort	L	298	670	7,170	9,635
2021	Open	Effort	H	33	33	2,764	2,764

Table 5. Estimated observer mean CPUE in weight by management regime and catch or effort level strata for expansion estimates of vertical line South Atlantic Red Grouper catch and discards.

					Observer CPUE	
Management Regime	Season	Strata Type	Strata Level	Logbook CPUE	Kept	Discard
First 2007-2009	Open	Catch	L	0.394	0.173	0.000
First 2007-2009	Open	Catch	M	0.795	0.353	0.000
First 2007-2009	Open	Catch	H	5.970	5.940	0.097
Second 2010-2012	Open	Effort	L	5.263	4.943	0.457
Second 2010-2012	Open	Effort	H	2.386	0.920	0.019
Third 2013-2021	Open	Effort	L	1.908	0.668	0.179
Third 2013-2021	Open	Effort	H	1.229	0.846	0.000

Table 6. Time-series of CPUE expansion estimates for South Atlantic Red Grouper vertical line discards in weight (whole lbs.) and number (with associated standard errors).

Year	Estimated Discards in Weight	SE of Estimated Discards in Weight	Estimated Discards in Number	SE of Estimated Discards in Number
1993	1,010	539	246	126
1994	1,239	660	302	155
1995	2,256	1,203	550	282
1996	2,190	1,168	534	274
1997	2,767	1,476	674	346
1998	3,523	1,879	859	441
1999	3,761	2,006	917	471
2000	3,255	1,736	793	407
2001	2,751	1,467	670	344
2002	2,904	1,549	708	364
2003	2,821	1,504	687	353
2004	2,306	1,230	562	289
2005	2,193	1,169	534	274
2006	3,280	1,749	799	411
2007	5,961	3,179	1,453	746
2008	6,186	3,299	1,508	774
2009	5,289	2,821	1,289	662
2010	10,445	7,394	913	502
2011	11,695	8,279	986	542
2012	8,916	6,312	735	404
2013	4,202	2,662	631	376
2014	3,541	2,243	532	317
2015	2,974	1,884	447	266
2016	2,431	1,540	365	217
2017	2,328	1,474	349	208
2018	2,381	1,508	357	213
2019	2,233	1,415	335	200
2020	1,925	1,219	289	172
2021	1,721	1,090	258	154

Figure 1. Coastal logbook fishing areas in the South Atlantic.

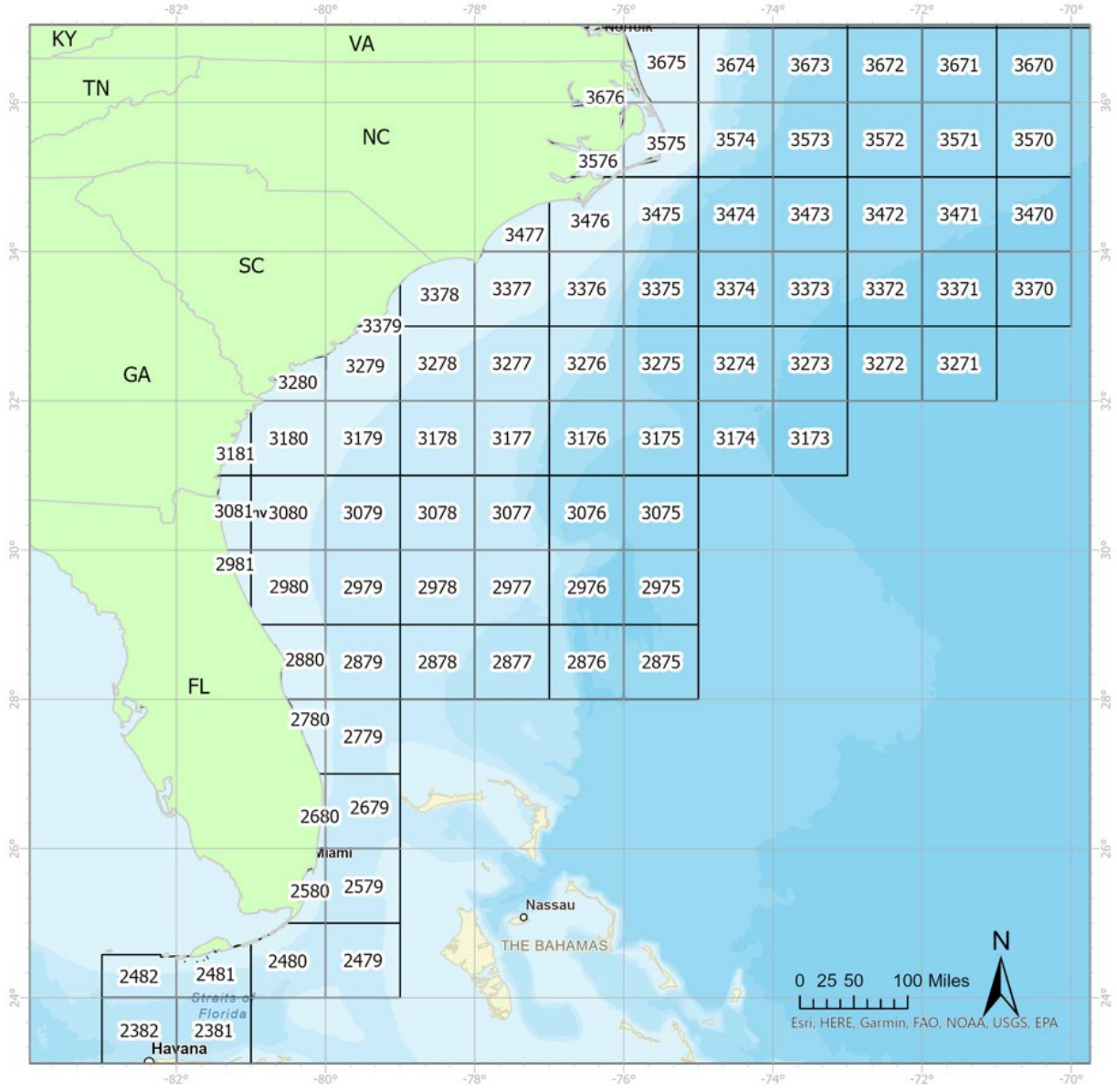
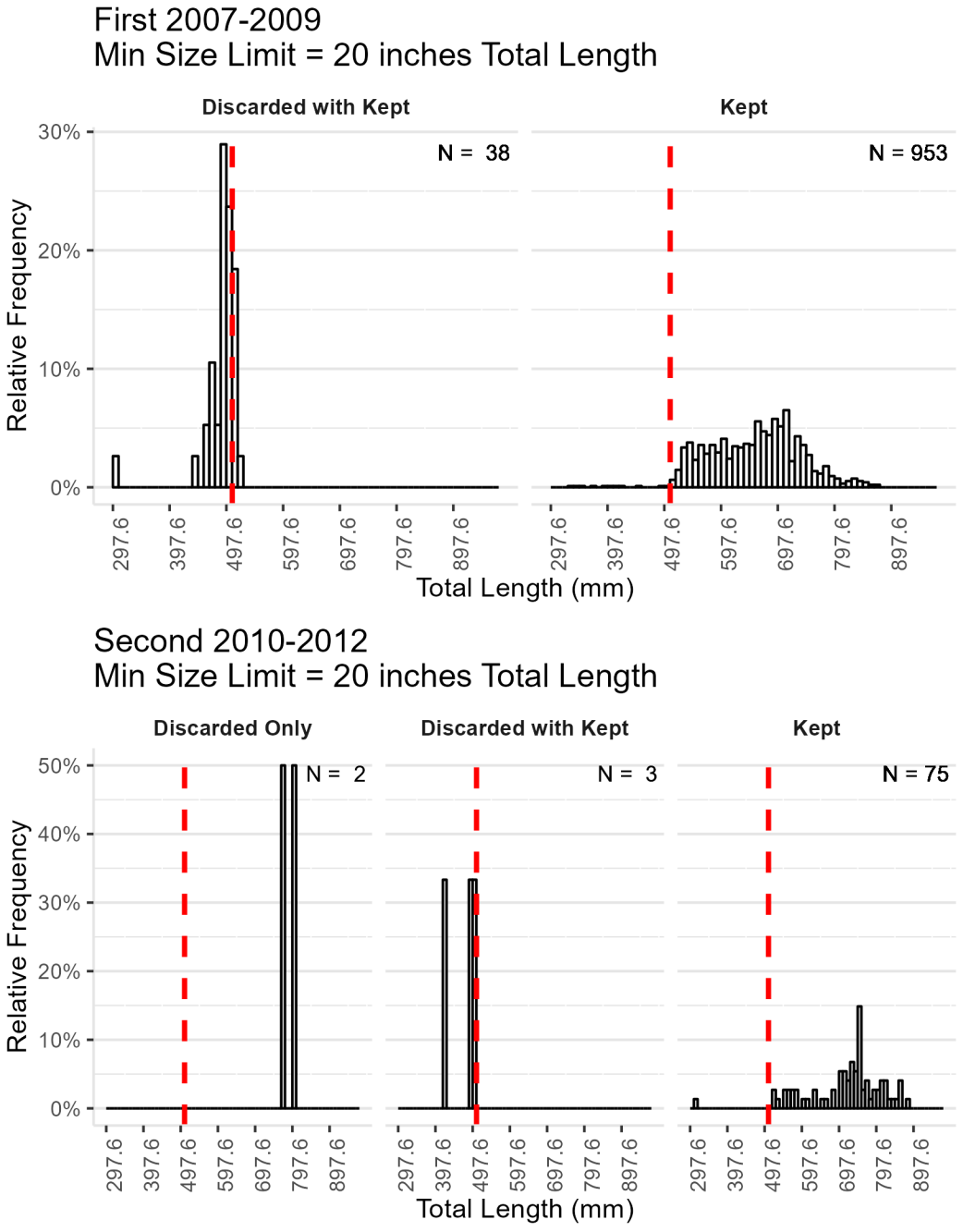


Figure 2. Length-frequency plots of commercial observer vertical line South Atlantic Red Grouper by disposition (Kept or Discard) and management regime. "Discarded Only" were discards from trips with no kept Red Grouper; "Discarded with Kept" were discards from trips with kept Red Grouper. Vertical dashed line denotes the minimum size limit in total length (TL); N is the number of measured fish.



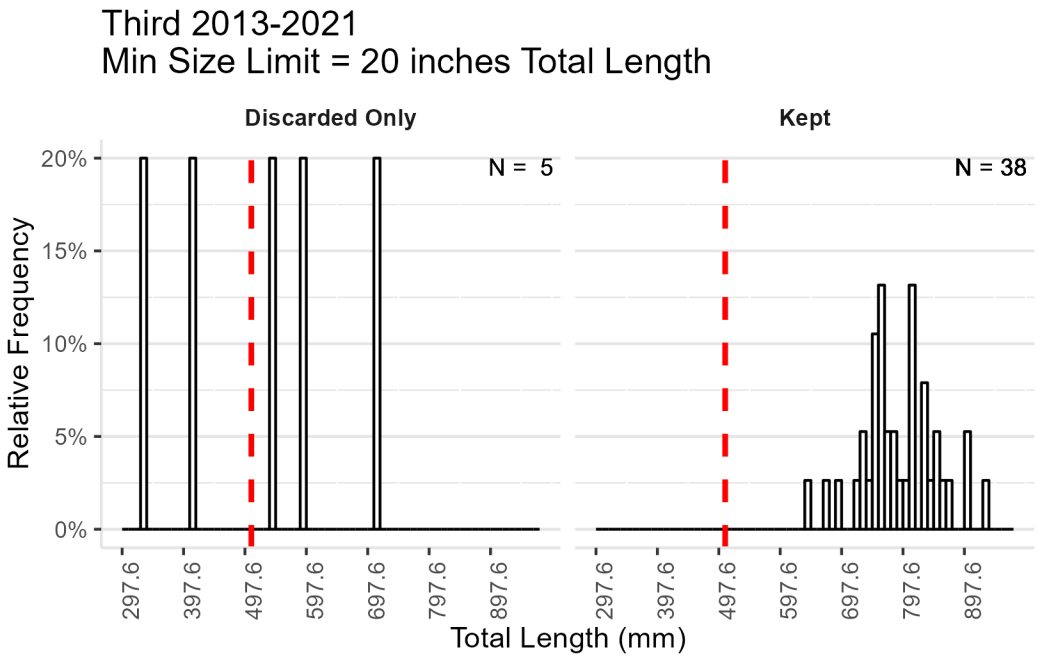


Figure 3. CPUE (catch in whole pounds per hour) time-series for commercial logbook data from 1993 - 2021 for vertical line trips landing South Atlantic Red Grouper. The observer time period is from 2007 - 2021.

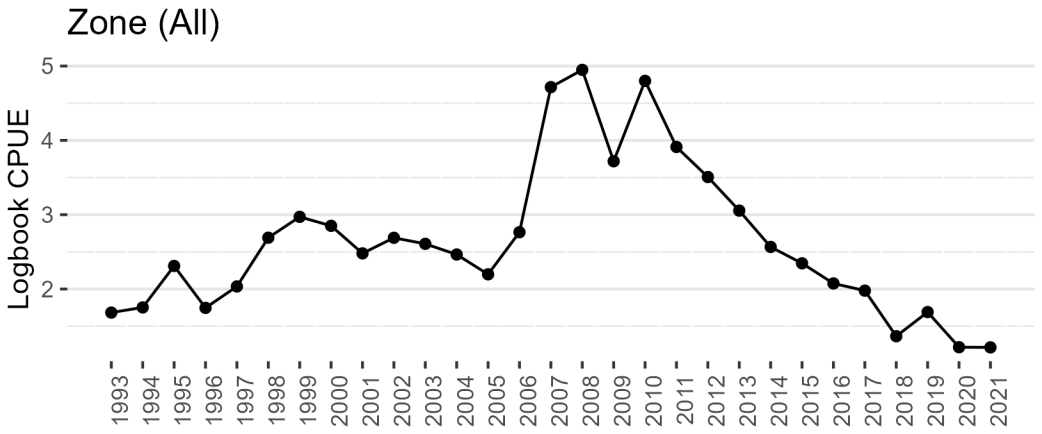


Figure 4. Comparison of vertical line reported annual logbook landings of South Atlantic Red Grouper (solid black line) with CPUE expansion estimates from observer data (open squares). Error bars (SE) are shown for observer estimates.

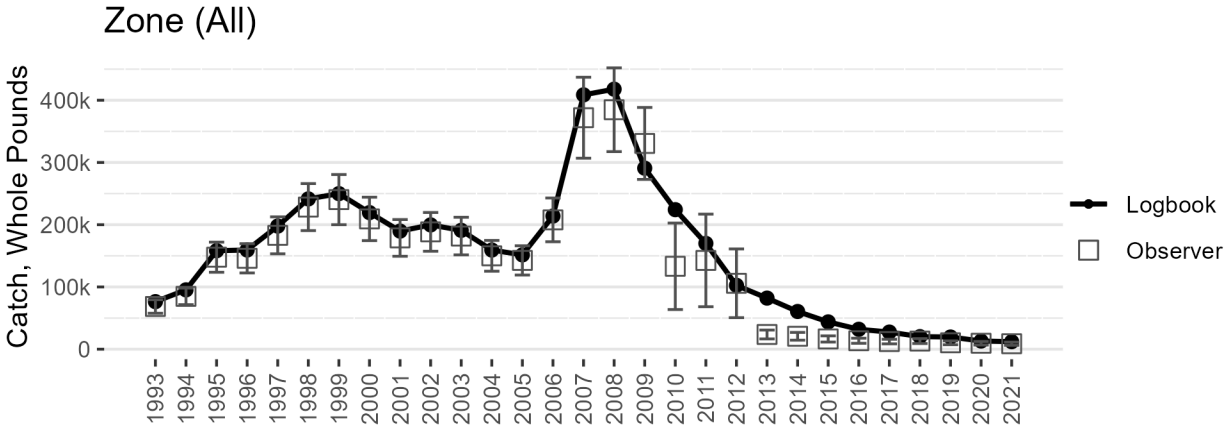
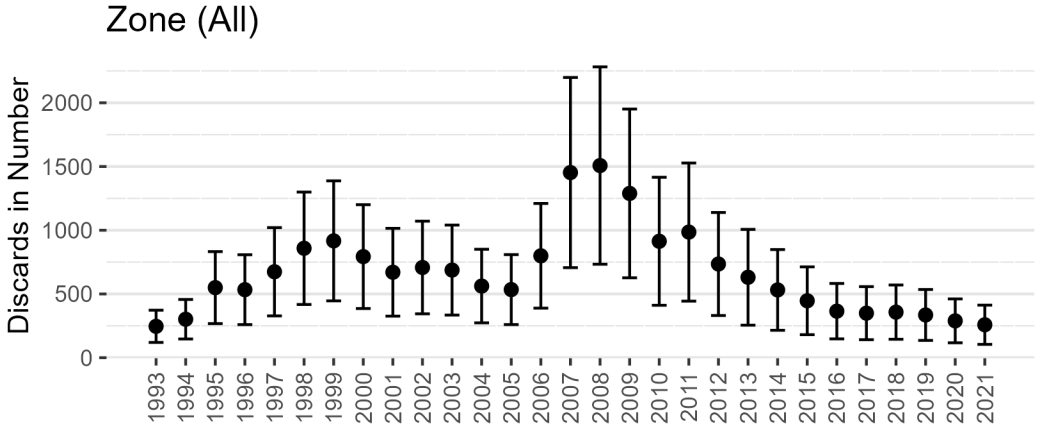


Figure 5. Observer CPUE expansion estimates of commercial South Atlantic Red Grouper vertical line annual discards (+/-SE) in (A) number and (B) weight expressed as percentage of total catch (kept + discards) for 1993 - 2021.

(A) Discards in Number



(B) Discards in Weight, Percentage of Total Catch

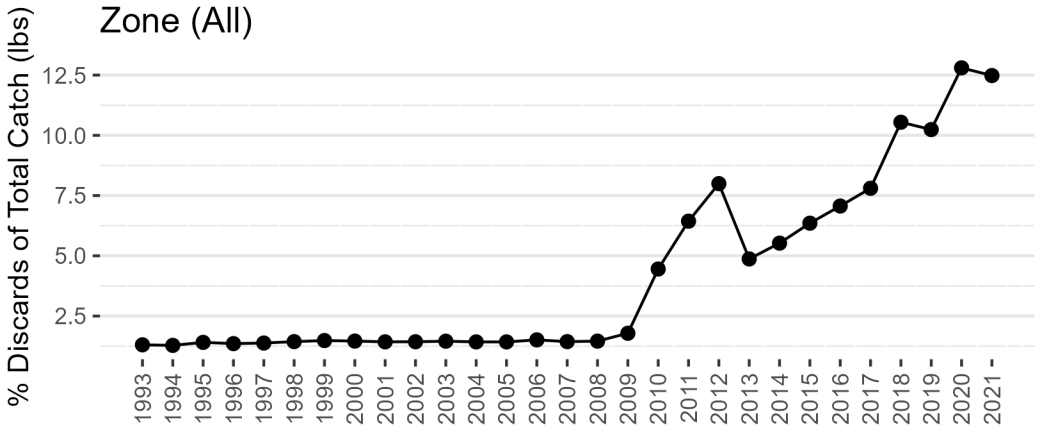


Figure 6. Commercial annual discard length compositions in 3 cm bins for South Atlantic Red Grouper, accounting for catch and effort level stratification by management period.