CPUE Expansion Estimation for Commercial Discards of Gulf of Mexico Red Grouper (*Epinephelus morio*)

Sarina Atkinson & Kevin Thompson

SEDAR88-WP-04

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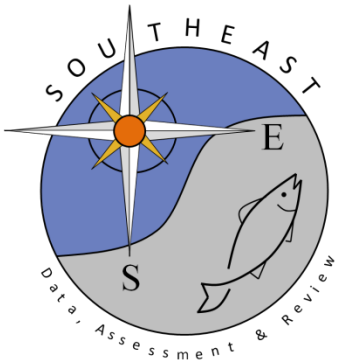

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CPUE Expansion Estimation for Commercial Discards of Gulf of Mexico Red Grouper (*Epinephelus morio*)

Sarina Atkinson* & Kevin Thompson

SEDAR88-WP-04

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National Marine Fisheries Service, Southeast Fisheries Science Center, Miami Laboratory, 75 Virginia Beach Drive, Miami, FL 33149

*Corresponding author: sarina.atkinson@noaa.gov

†Updated submission includes a change to the discard length composition methodology. Previously, length compositions were pooled using the management regimes as discard estimation, however annual length compositions with number of trips and fish sampled each year are needed as inputs for the assessment. Therefore, annual weighted discard length compositions were provided.

Introduction

The general approach for estimating discards for the commercial reef fish fleet 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. 2019a), and Gulf of Mexico Vermilion Snapper in SEDAR Working Paper 67-12 (Smith et al. 2019b) to Gulf of Mexico Red Grouper for SEDAR 88.

Methods

Data Sources

Catch per unit effort was determined from the coastal Reef Fish Observer Program in which scientific observers on commercial fishing vessels recorded detailed information on catch and effort for a subset of trips (Atkinson et al. 2021a, Scott-Denton et al. 2011). The program targeted two principal gears for the Gulf of Mexico (GOM) reef fishery, bottom longline and vertical lines (e.g., handlines, electric and hydraulic reels aka bandit reels). Catch by species was recorded according to disposition category: kept (landed), released alive, released dead, released undetermined, and used for bait. Length and either whole or gutted weight were recorded for a subsample of individual fish. The coastal Reef Fish Observer Program began in July 2006; for GOM Red Grouper discard estimation, complete calendars years 2007-2022 were used. 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. 2021b). The coastal logbook program began in 1990 for a subset of vessels in the Gulf of Mexico, and expanded to all vessels in 1993; for GOM Red Grouper discard estimation, complete calendar years 1993-2022 were considered.

Relevant Management History of GOM Red Grouper

There were key management changes relevant to discard estimation: (1) The establishment of a minimum size in late 1990 (20” TL) and a subsequent update in 2009 (18” TL); (2) seasonal closures in the winter beginning in 2000 and ending in 2009; and (3) the implementation in 2010 of an Individual Fisheries Quota for GOM Red Grouper. It was these management actions as well as sample size information that were used to determine how to pool data when necessary.

Gear

In the Gulf of Mexico observer data Red Grouper were observed on both vertical line and bottom longline trips. Discard estimation was conducted for each gear separately.

Spatial Domain

Given low landings and no observer data in the west GOM, discard estimates were only analyzed and prepared for the eastern GOM and as such all subsequent results shown here are restricted to that area (zones 1-12; Fig. 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). All length and weight information converted to fork length and whole weight using the SEDAR 42 meristic regressions (SEDAR 42 2015; Table 2.14).

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 $\hat{X}$, the proportion of observer trips that discarded only the target species was calculated and applied to the summed logbook trip effort by gear. Logbook total trips N were calculated in a similar manner.

Mean CPUE was estimated by

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

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

$$\bar{y} = \frac{1}{n}\Sigma_i y_i,$$

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

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

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

$$var\left[\hat{C}\right] = var[C\bar{P}UE] * \widehat{X^2}$$

where the variance of mean CPUE is

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

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

$$s^2(y|x) = \frac{\Sigma_i(y_i - C\bar{P}UEx_i)^2}{n-1}.$$

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, management regulations and length compositions were considered. 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 weighted length frequency distribution for discards was computed in the following manner. Average discard CPUE in stratum h was scaled to stratum total effort $\widehat{Y_h}$.

$$\hat{Y}_h = C\bar{P}UE_h * \hat{X}_h$$

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

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

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,

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

Annual weighted discard length compositions differ from nominal discard length compositions when additional trip catch or effort stratification is applied to a given management regime.

Results and Discussion

Vertical Line

The observer database included 874 vertical line trips with corresponding trip and set information. Observer sampling effort is summarized in Table 1, distinguishing all trips from the subset of trips that captured red grouper.

For the pre-IFQ period 2007-2009, the disposition (kept or discarded) of GOM Red Grouper corresponded with the minimum size limit of 20" TL (487.6 mm FL) until the switch in 2009 to 18" TL (439.4 mm FL; Fig. 2). Discards were mostly fish near or below the minimum size limit for trips that had kept and discarded Red Grouper. Kept fish were mostly above the minimum size limit. For the IFQ period, 2010-2022, discards included more fish below and above the minimum size limit. In addition, legal-sized fish were discarded on some of the same trips that kept legal-sized fish.

Inspection of the annual nominal CPUE (catch in whole pounds per hour) from logbook trips reporting Red Grouper showed a generally increasing average CPUE from 1998 through 2012 with some year-to-year variation. Trends after 2012 are more variable overall with some very low years in 2018 and 2019 in this fishery (Fig. 3). Catch-effort data for observer trips catching Red Grouper were pooled across years for the pre-IFQ period but then were estimated annually for all years except 2018-2021 which was combined into two management regimes (2018-2019 and 2020-2021). Additionally, during the pre-IFQ management regime, observer trips were pooled by open and closed season. 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 each management regime.

Observer and logbook frequency distributions of trip-level catch, effort, and CPUE were similar for most years, suggesting that observer sampling of Red Grouper trips was representative of the commercial fleet. For years 2007-2009 (pre-IFQ open season), and 2011 initial catch verification between observer and logbook data showed an under-estimate, with an over-estimate for 2012. For the pre-IFQ management regime, further analysis showed that observers sampled a slightly lower proportion of low catch (< 67 lb) and moderate (67-288 lb) Red Grouper trips and a slightly higher proportion of high catch (>288 lb) trips relative to the commercial fleet (Table 2). To account for this discrepancy, observer and logbook trips were grouped into strata according to low (L), moderate (M), and high (H) catches for subsequent analysis and estimation. Data for 2011 were stratified into low ($\leq$ 174 lb) and high (> 174 lb) catch trips. Catch in 2012 was stratified to three levels; low (<82 lb), moderate (82-321 lb), and high (> 321 lb; Table 2).

The proportions of observer trips and associated effort encountering Red Grouper that had kept fish are given in Table 3 by management regime and catch level strata. 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 discard CPUEs for the pre-IFQ management regime (2007-2009) by open and closed season were the basis for hindcasting discards during 1993-2006.

CPUE expansion estimates of annual total landed catch of GOM Red Grouper compared favorably with reported logbook landings for 1993-2022 (Fig. 4). Therefore, CPUE expansion estimates for annual discards in numbers and weight of GOM Red Grouper are provided in Table 6. Estimated discards in number ranged from 83,000 to 184,000 fish during the pre-IFQ management regime 1993-2009, and averaged about 123,000 fish during the pre-IFQ

management regime (Fig. 5A). IFQ management regime discards had a maximum over 200,000 fish in 2011 and decreased to only ~32,000 in the terminal year of 2022. Discards in weight accounted for about 20-25% of the total catch (kept + discards) during 1993-2012 then significantly dropped in the subsequent years with some variability but generally remaining below 15%, with some years approaching 20% again (Fig. 5B). Estimated discards for SEDAR 88 were compared to SEDAR 61 which was the first time this discard estimation methodology using observer data was proposed (Fig. 6). Since SEDAR 61, several improvements were made to the methodology including the hindcasting procedure. In the previous assessment, to hindcast 1993-2006, the average observer CPUE was applied to the total annual logbook effort which assumed a stable CPUE overtime. This method was improved for SEDAR 62 to account for trends in CPUE by calculating an annual average CPUE between observer and logbook data before applying an expansion. Differences in the annual estimates of discards between SEDAR 61 and 88 are due to these methodological changes (Fig. 6). Annual weighted discard length frequencies were provided in 2 cm fork length bins using the catch and effort strata by management regime. Figure 7 shows the subtle differences between the weighted and nominal discard length compositions.

Bottom Longline

The observer database included 697 bottom longline trips with corresponding trip and set information. Observer sampling effort is summarized in Table 7, distinguishing all trips from the subset of trips that captured Red Grouper.

For the pre-IFQ period 2007-2009, the disposition (kept or discarded) of GOM Red Grouper corresponded with the minimum size limit of 20" TL (487.6 mm FL) (Fig. 8). Discards were mostly fish near or below the minimum size limit, and kept fish were mostly above the minimum size limit. Once the IFQ program was implemented in 2010, discards included fish below and above the minimum size limit.

Inspection of the annual nominal CPUE (catch in whole pounds per hour) from logbook trips reporting Red Grouper showed relatively stable CPUE prior to IFQ (1993-2009). During the IFQ management regime, there was an increasing CPUE until 2012 followed by a decrease until 2019. Since 2019, CPUE has been generally increasing (Fig. 9). Given the availability of observer data and trends in annual nominal CPUE, catch-effort data for observer trips catching Red Grouper were pooled annually except for 2007-2008 and 2017-2022. There were insufficient data to separate out trips that fished during the open and closed seasons during the pre-IFQ time period. 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.

Observer and logbook frequency distributions of trip-level catch, effort, and CPUE were comparable for most years, suggesting that observer sampling of Red Grouper trips was representative of the commercial fleet. This was not the case for years 2012-2015 where observers disproportionately sampled high or low catch trips in those years (Table 8). For example, in 2012, observers sampled a higher proportion of high catch (> 6,971 lb) Red Grouper

trips and a lower proportion of low catch (< 6,971 lb) trips relative to the commercial fleet. To account for this discrepancy, observer and logbook trips were grouped into strata according to low (L) and high (H) catches for subsequent analysis and estimation. A similar catch stratification was necessary for years 2013, 2014, and 2015.

The proportions of observer trips and associated effort encountering Red Grouper that had kept fish are given in Table 9 by management regime and catch level strata. These proportions were used to adjust annual logbook total Red Grouper trips and effort (Table 10) 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 11. These CPUEs were the basis for expansion estimates of Red Grouper catch and discards. Observer discard CPUEs for the pre-IFQ management regime with a 20" TL minimum size limit (2007-2008) were the basis for hindcasting discards during 1993-2006.

CPUE expansion estimates of annual total landed catch of GOM Red Grouper compared favorably with reported logbook landings for the entire time series (Fig. 10). CPUE expansion estimates for annual discards in numbers and weight of GOM Red Grouper for 1993-2022 are provided in Table 12. Estimated discards in number averaged about 373,896 fish from 1993-2022 with more Red Grouper discards prior to IFQ implementation (Fig. 11A). Discards in weight accounted for about 30% of the total catch (kept + discards) during pre-IFQ time period (1993-2006) and between 15-25% of the total catch during the IFQ management regime (Fig. 11B). A comparison of estimated discards for SEDAR 88 to SEDAR 61 are shown in Fig. 12. As mentioned for vertical line, the largest difference can be attributed to a different hindcast methodology for SEDAR 61 that is no longer considered the standard method. Weighted annual discard length frequencies for the bottom longline fishery were provided in 2 cm fork length bins using the catch and effort strata by management regime (Fig. 13).

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Table 1. Number of total and Red Grouper coastal observer vertical line trips by year for the GOM.

	East Zone		West Zone	
Year	Total Observer Trips	Red Grouper Observer Trips	Total Observer Trips	Red Grouper Observer Trips
2007	62	61	0	0
2008	34	34	0	0
2009	33	33	0	0
2010	35	35	0	0
2011	74	74	0	0
2012	181	180	1	1
2013	76	76	0	0
2014	67	66	0	0
2015	113	111	0	0
2016	76	75	0	0
2017	35	35	0	0
2018	19	19	0	0
2019	12	12	0	0
2020	8	8	0	0
2021	21	20	0	0
2022	28	27	0	0

Table 2. Definition of trip catch level strata for GOM Red Grouper, and corresponding percentages of logbook and observer vertical line trips for only selected management regimes and seasons. Some management regimes did not require additional trip catch level stratification because the observer and logbook catch distributions were comparable.

Management Regime	Season	Strata Level	% Trips		
			Stratum Code	Logbook	Observer
First 2007-2009	Open	Low, Catch <= 67 lb	L	23.7	29.6
First 2007-2009	Open	Moderate, 67< Catch <= 288 lb	M	28.6	25.2
First 2007-2009	Open	High, Catch > 288 lb	H	47.6	45.2
Third 2011	Open	Low, Catch <= 174 lb	L	46.5	41.9
Third 2011	Open	High, Catch > 174 lb	H	53.5	58.1
Fourth 2012	Open	Low, Catch <= 82 lb	L	28.2	25.6
Fourth 2012	Open	Moderate, 82< Catch <= 321 lb	M	23.6	23.3
Fourth 2012	Open	High, Catch > 321 lb	H	48.1	51.1

Table 3. GOM Red Grouper vertical line trip and effort adjustment factors by management regime and catch level strata. Catch level strata are defined in Table 2; catch level stratum 'All' is all levels (i.e., no stratification) for the management regime. 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.

					Proportion of Observer Data with Kept Red Grouper	
Management Regime	Season	Strata Type	Strata Level	Number of Observer Trips (n)	Trips	Effort
First 2007-2009	Closed	All	A	13	0.923	0.993
First 2007-2009	Open	Catch	L	34	0.824	0.87
First 2007-2009	Open	Catch	M	29	1	1
First 2007-2009	Open	Catch	H	52	1	1
Second 2010	Open	All	A	35	0.971	0.999
Third 2011	Open	Catch	L	31	0.71	0.832
Third 2011	Open	Catch	H	43	1	1
Fourth 2012	Open	Catch	L	46	0.826	0.834
Fourth 2012	Open	Catch	M	42	1	1
Fourth 2012	Open	Catch	H	92	1	1
Fifth 2013	Open	All	A	76	0.961	0.971
Sixth 2014	Open	All	A	66	0.97	0.993
Seventh 2015	Open	All	A	111	0.973	0.997
Eight 2016	Open	All	A	75	0.92	0.979
Ninth 2017	Open	All	A	35	0.886	0.97
Tenth 2018-2019	Open	All	A	31	0.871	0.866
Eleventh 2020-2021	Open	All	A	28	0.929	0.981
Twelve 2022	Open	All	A	27	0.963	0.93

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

				Logbook Trips		Logbook Effort	
Year	Season	Strata Type	Strata Level	Reported	Adjusted (N)	Reported	Adjusted ($\hat{X}$)
1993	Open	Catch	L	1,491	1,810	28,472	32,743
1993	Open	Catch	M	863	863	29,560	29,560
1993	Open	Catch	H	916	916	59,030	59,030
1994	Open	Catch	L	1,714	2,081	33,355	38,358
1994	Open	Catch	M	1,135	1,135	37,493	37,493
1994	Open	Catch	H	1,040	1,040	59,706	59,706
1995	Open	Catch	L	1,582	1,921	32,987	37,935
1995	Open	Catch	M	1,237	1,237	39,177	39,177
1995	Open	Catch	H	1,055	1,055	62,493	62,493
1996	Open	Catch	L	1,580	1,919	31,801	36,571
1996	Open	Catch	M	1,115	1,115	40,782	40,782
1996	Open	Catch	H	980	980	65,375	65,375
1997	Open	Catch	L	1,614	1,960	32,720	37,628
1997	Open	Catch	M	1,157	1,157	39,050	39,050
1997	Open	Catch	H	1,049	1,049	72,146	72,146
1998	Open	Catch	L	1,918	2,329	35,074	40,335
1998	Open	Catch	M	1,097	1,097	39,540	39,540
1998	Open	Catch	H	893	893	60,883	60,883
1999	Open	Catch	L	1,868	2,268	35,271	40,561
1999	Open	Catch	M	1,382	1,382	39,220	39,220
1999	Open	Catch	H	1,237	1,237	72,276	72,276
2000	Closed	All	A	372	403	11,722	11,806
2000	Open	Catch	L	1,573	1,910	27,030	31,085
2000	Open	Catch	M	1,473	1,473	36,401	36,401
2000	Open	Catch	H	1,379	1,379	68,064	68,064
2001	Closed	All	A	276	299	8,840	8,904
2001	Open	Catch	L	1,362	1,654	22,522	25,901
2001	Open	Catch	M	1,602	1,602	39,942	39,942
2001	Open	Catch	H	1,599	1,599	82,085	82,085
2002	Closed	All	A	241	261	7,113	7,164
2002	Open	Catch	L	1,390	1,688	25,264	29,053
2002	Open	Catch	M	1,752	1,752	42,888	42,888
2002	Open	Catch	H	1,650	1,650	82,434	82,434

				Logbook Trips		Logbook Effort	
Year	Season	Strata Type	Strata Level	Reported	Adjusted (N)	Reported	Adjusted ($\hat{X}$)
2003	Closed	All	A	321	348	11,837	11,922
2003	Open	Catch	L	1,910	2,319	40,528	46,607
2003	Open	Catch	M	1,722	1,722	48,092	48,092
2003	Open	Catch	H	1,196	1,196	66,444	66,444
2004	Closed	All	A	505	547	16,282	16,399
2004	Open	Catch	L	1,633	1,983	34,126	39,245
2004	Open	Catch	M	1,576	1,576	41,510	41,510
2004	Open	Catch	H	1,384	1,384	66,850	66,850
2005	Closed	All	A	455	493	15,490	15,601
2005	Open	Catch	L	952	1,156	17,637	20,282
2005	Open	Catch	M	1,292	1,292	35,444	35,444
2005	Open	Catch	H	1,433	1,433	70,515	70,515
2006	Closed	All	A	162	176	4,893	4,928
2006	Open	Catch	L	1,057	1,284	26,615	30,607
2006	Open	Catch	M	1,260	1,260	37,931	37,931
2006	Open	Catch	H	1,526	1,526	82,049	82,049
2007	Closed	All	A	185	200	6,961	7,011
2007	Open	Catch	L	907	1,101	27,759	31,923
2007	Open	Catch	M	1,099	1,099	34,476	34,476
2007	Open	Catch	H	1,553	1,553	80,505	80,505
2008	Closed	All	A	231	250	8,424	8,485
2008	Open	Catch	L	768	933	21,996	25,295
2008	Open	Catch	M	1,035	1,035	28,973	28,973
2008	Open	Catch	H	1,751	1,751	88,336	88,336
2009	Closed	All	A	185	200	7,384	7,437
2009	Open	Catch	L	938	1,139	31,352	36,055
2009	Open	Catch	M	1,017	1,017	29,402	29,402
2009	Open	Catch	H	1,940	1,940	112,751	112,751
2010	Open	All	A	2,759	2,840	118,124	118,300
2011	Open	Catch	L	1,354	1,908	41,448	49,791
2011	Open	Catch	H	1,557	1,557	83,188	83,188
2012	Open	Catch	L	852	1,031	25,060	30,057
2012	Open	Catch	M	713	713	24,842	24,842
2012	Open	Catch	H	1,451	1,451	81,582	81,582
2013	Open	All	A	2,894	3,013	122,746	126,354

				Logbook Trips		Logbook Effort	
Year	Season	Strata Type	Strata Level	Reported	Adjusted (N)	Reported	Adjusted ($\hat{X}$)
2014	Open	All	A	3,013	3,107	124,150	125,024
2015	Open	All	A	2,925	3,006	114,570	114,934
2016	Open	All	A	2,840	3,087	114,501	116,942
2017	Open	All	A	2,650	2,992	104,197	107,453
2018	Open	All	A	2,426	2,785	88,185	101,826
2019	Open	All	A	2,363	2,713	79,100	91,335
2020	Open	All	A	2,226	2,397	73,663	75,074
2021	Open	All	A	2,176	2,343	75,622	77,071
2022	Open	All	A	1,704	1,770	62,042	66,715

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

					Observer CPUE		
Management Regime	Season	Strata Type	Strata Level	Logbook CPUE	Kept	Discard (lb)	Discard (number)
First 2007-2009	Closed	All	A	7.914	5.926	1.265	0.4109
First 2007-2009	Open	Catch	L	0.777	0.797	0.700	0.2617
First 2007-2009	Open	Catch	M	5.430	5.073	2.426	0.9378
First 2007-2009	Open	Catch	H	16.959	13.391	3.494	1.2803
Second 2010	Open	All	A	9.733	7.116	3.126	1.4570
Third 2011	Open	Catch	L	1.651	1.448	0.823	0.3525
Third 2011	Open	Catch	H	17.569	20.259	5.511	2.2128
Fourth 2012	Open	Catch	L	0.855	0.847	0.661	0.2035
Fourth 2012	Open	Catch	M	5.323	5.334	1.598	0.7034
Fourth 2012	Open	Catch	H	21.179	24.191	4.089	1.5925
Fifth 2013	Open	All	A	10.720	12.517	1.744	0.7303
Sixth 2014	Open	All	A	12.793	11.962	0.984	0.4268
Seventh 2015	Open	All	A	13.315	12.817	1.626	0.7112
Eight 2016	Open	All	A	8.965	10.322	1.524	0.7553
Ninth 2017	Open	All	A	8.867	8.252	1.126	0.6383
Tenth 2018-2019	Open	All	A	6.197	5.335	1.437	0.6783
Eleventh 2020-2021	Open	All	A	10.965	9.512	1.891	0.7214
Twelve 2022	Open	All	A	11.049	9.687	1.228	0.4833

Table 6. Time-series of CPUE expansion estimates for GOM Red Grouper vertical line discards in whole weight (lb) 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	225,246	17,872	83,940	6,147
1994	265,317	20,498	99,040	7,069
1995	271,981	20,964	101,625	7,242
1996	248,190	19,086	92,714	6,590
1997	267,176	20,858	99,735	7,193
1998	238,561	17,674	89,242	6,119
1999	316,133	24,590	118,027	8,482
2000	357,369	27,855	132,828	9,593
2001	388,798	30,813	144,545	10,613
2002	408,193	32,276	151,885	11,127
2003	329,279	23,598	122,886	8,209
2004	355,684	26,251	132,082	9,070
2005	339,970	26,410	125,725	9,084
2006	339,072	27,990	126,092	9,622
2007	396,162	47,047	146,641	16,199
2008	407,403	48,382	150,377	16,611
2009	499,968	59,375	184,424	20,372
2010	369,850	95,930	172,362	42,687
2011	499,387	63,722	201,629	26,279
2012	393,122	44,512	153,513	16,175
2013	220,398	39,352	92,270	16,508
2014	123,046	20,678	53,355	9,506
2015	186,935	33,442	81,745	14,414
2016	178,178	38,025	88,329	19,775
2017	120,960	26,892	68,589	17,515
2018	146,345	31,210	69,066	15,113
2019	131,268	27,995	61,951	13,556
2020	141,992	50,509	54,158	18,604
2021	145,769	51,852	55,598	19,099
2022	81,898	21,932	32,242	8,600

Table 7. Number of total and Red Grouper coastal observer bottom longline trips by year for the GOM.

	East Zone		West Zone	
Year	Total Observer Trips	Red Grouper Observer Trips	Total Observer Trips	Red Grouper Observer Trips
2007	15	15	0	0
2008	2	2	0	0
2009	23	23	1	1
2010	54	54	0	0
2011	81	81	0	0
2012	33	33	0	0
2013	70	70	0	0
2014	21	21	0	0
2015	21	21	0	0
2016	46	46	0	0
2017	15	15	1	1
2018	5	5	0	0
2019	6	6	0	0
2021	6	6	0	0
2022	23	23	0	0

Table 8. Definition of trip catch level strata for GOM Red Grouper, and corresponding percentages of logbook and observer bottom longline trips for each zone and management regime.

Management Regime	Season	Strata Level	% Trips		
			Stratum Code	Logbook	Observer
Fifth 2012	Open	Low, Catch <= 6,971 lb	L	65.9	48.5
Fifth 2012	Open	High, Catch > 6,971 lb	H	34.1	51.5
Sixth 2013	Open	Low, Catch <= 4,453 lb	L	39.1	54.3
Sixth 2013	Open	High, Catch > 4,453 lb	H	60.9	45.7
Seventh 2014	Open	Low, Catch <= 8,484 lb	L	80.7	57.1
Seventh 2014	Open	High, Catch > 8,484 lb	H	19.3	42.9
Eight 2015	Open	Low, Catch <= 3,164 lb	L	34.6	47.6
Eight 2015	Open	High, Catch > 3,164 lb	H	65.4	52.4

Table 9. Red Grouper bottom longline trip and effort adjustment factors by management regime and catch level strata in the GOM. Catch level strata are defined in Table 8; catch level stratum 'All' is all levels (i.e., no stratification) for the management regime. 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 10) to account for logbook trips that only had discarded fish.

Zone (East)

Management Regime	Season	Strata Type	Strata Level	Number of Observer Trips (n)	Proportion of Observer Data with Kept Red Grouper	
					Trips	Effort
First 2007-2008	Open	All	A	17	1	1
Second 2009	Open	All	A	23	0.957	0.963
Third 2010	Open	All	A	54	1	1
Fourth 2011	Open	All	A	81	1	1
Fifth 2012	Open	Catch	L	16	1	1

Management Regime	Season	Strata Type	Strata Level	Number of Observer Trips (n)	Proportion of Observer Data with Kept Red Grouper	
					Trips	Effort
Fifth 2012	Open	Catch	H	17	1	1
Sixth 2013	Open	Catch	L	38	1	1
Sixth 2013	Open	Catch	H	32	1	1
Seventh 2014	Open	Catch	L	12	1	1
Seventh 2014	Open	Catch	H	9	1	1
Eight 2015	Open	Catch	L	10	1	1
Eight 2015	Open	Catch	H	11	1	1
Ninth 2016	Open	All	A	46	1	1
Tenth 2017-2022	Open	All	A	55	1	1

Table 10. Annual time-series of bottom longline logbook trips (number) and effort (hours) by catch level strata for GOM Red Grouper.

Zone (East)

				Logbook Trips		Logbook Effort	
Year	Season	Strata Type	Strata Level	Reported	Adjusted (N)	Reported	Adjusted ($\hat{X}$)
1993	Open	All	A	994	994	29,386	29,386
1994	Open	All	A	1,254	1,254	34,130	34,130
1995	Open	All	A	1,193	1,193	28,318	28,318
1996	Open	All	A	1,294	1,294	31,577	31,577
1997	Open	All	A	1,341	1,341	35,686	35,686
1998	Open	All	A	1,245	1,245	31,778	31,778
1999	Open	All	A	1,248	1,248	32,684	32,684
2000	Open	All	A	1,134	1,134	28,526	28,526
2001	Open	All	A	1,229	1,229	30,792	30,792
2002	Open	All	A	1,165	1,165	27,474	27,474
2003	Open	All	A	1,266	1,266	28,290	28,290
2004	Open	All	A	1,293	1,293	27,390	27,390
2005	Open	All	A	1,148	1,148	20,972	20,972
2006	Open	All	A	1,257	1,257	24,219	24,219
2007	Open	All	A	917	917	19,766	19,766
2008	Open	All	A	957	957	21,757	21,757
2009	Open	All	A	402	420	9,997	10,382
2010	Open	All	A	329	329	9,579	9,579
2011	Open	All	A	523	523	15,355	15,355
2012	Open	Catch	L	313	313	7,195	7,195
2012	Open	Catch	H	162	162	5,335	5,335
2013	Open	Catch	L	204	204	4,575	4,575
2013	Open	Catch	H	318	318	10,387	10,387
2014	Open	Catch	L	444	444	12,832	12,832
2014	Open	Catch	H	106	106	4,174	4,174
2015	Open	Catch	L	189	189	4,719	4,719
2015	Open	Catch	H	358	358	12,921	12,921
2016	Open	All	A	636	636	19,730	19,730
2017	Open	All	A	593	593	19,536	19,536
2018	Open	All	A	521	521	17,190	17,190
2019	Open	All	A	508	508	16,211	16,211
2020	Open	All	A	546	546	14,745	14,745

				Logbook Trips		Logbook Effort	
Year	Season	Strata Type	Strata Level	Reported	Adjusted (N)	Reported	Adjusted ($\hat{X}$)
2021	Open	All	A	532	532	13,912	13,912
2022	Open	All	A	498	498	11,694	11,694

Table 11. Estimated observer mean CPUE in weight by management regime and catch level strata for expansion estimates of bottom longline GOM Red Grouper catch and discards.

					Observer CPUE		
Management Regime	Season	Strata Type	Strata Level	Logbook CPUE	Kept	Discard (lb)	Discard (number)
First 2007-2008	Open	All	A	115.035	100.689	53.738	18.764
Second 2009	Open	All	A	104.544	106.040	45.321	16.935
Third 2010	Open	All	A	129.717	119.804	34.761	15.989
Fourth 2011	Open	All	A	177.812	176.043	54.542	22.213
Fifth 2012	Open	Catch	L	161.313	169.615	57.497	20.418
Fifth 2012	Open	Catch	H	265.732	255.224	78.630	31.293
Sixth 2013	Open	Catch	L	107.569	110.533	24.946	9.157
Sixth 2013	Open	Catch	H	221.926	206.198	40.380	15.849
Seventh 2014	Open	Catch	L	160.706	164.076	30.873	11.157
Seventh 2014	Open	Catch	H	248.722	249.518	59.439	22.753
Eight 2015	Open	Catch	L	63.472	69.636	7.421	3.000
Eight 2015	Open	Catch	H	180.026	160.445	35.100	14.833
Ninth 2016	Open	All	A	148.871	160.601	25.992	11.942
Tenth 2017-2022	Open	All	A	107.473	113.223	36.206	16.099

Table 12. Time-series of CPUE expansion estimates for GOM Red Grouper bottom longline discards in whole weight (lb) 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	1,437,382	201,262	501,888	77,213
1994	1,148,649	160,834	401,072	61,703
1995	1,064,259	149,018	371,606	57,170
1996	1,391,463	194,833	485,855	74,746
1997	1,488,645	208,440	519,787	79,967
1998	1,426,382	199,722	498,047	76,622
1999	1,786,046	250,082	623,631	95,942
2000	1,350,141	189,047	471,426	72,527
2001	1,655,138	231,753	577,922	88,910
2002	1,502,785	210,420	524,725	80,726
2003	1,450,823	203,144	506,581	77,935
2004	1,589,888	222,616	555,139	85,405
2005	1,459,203	204,318	509,507	78,385
2006	1,485,578	208,011	518,717	79,802
2007	1,062,187	148,728	370,882	57,058
2008	1,169,180	163,709	408,240	62,806
2009	470,531	106,250	175,821	37,265
2010	332,972	37,751	153,157	17,613
2011	837,500	62,051	341,082	22,361
2012	833,182	120,949	313,854	43,051
2013	533,552	57,585	206,516	23,491
2014	644,257	121,343	238,140	43,061
2015	488,540	86,620	205,810	35,977
2016	512,815	60,476	235,615	29,032
2017	707,323	81,009	314,514	35,703
2018	622,383	71,281	276,746	31,416
2019	586,937	67,221	260,985	29,626
2020	533,859	61,142	237,383	26,947
2021	503,699	57,688	223,972	25,425
2022	423,394	48,491	188,264	21,371

Figure 1. Map of fishing areas.

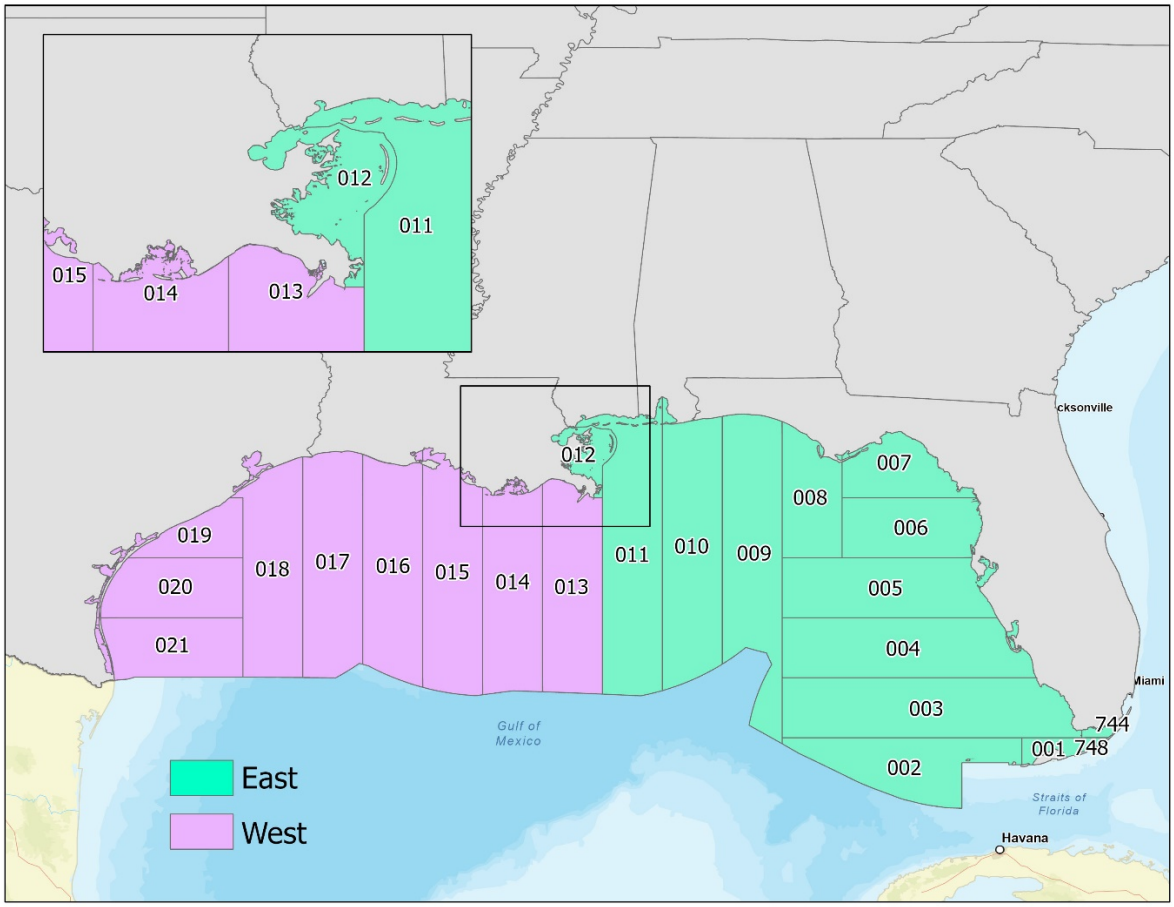


Figure 2. Length-frequency plots of observer vertical line GOM Red Grouper by disposition (Kept or Discard) and management regime. “Discarded Only” were discards from trips with no kept Red Grouper; “Discarded with Kept” were discards from trips with kept Red Grouper. Vertical dashed lines denote the minimum size limit over time (19.2 in. fork length from 2007-2008 and 17.3 in. fork length from 2009-2022); N is the number of measured fish.

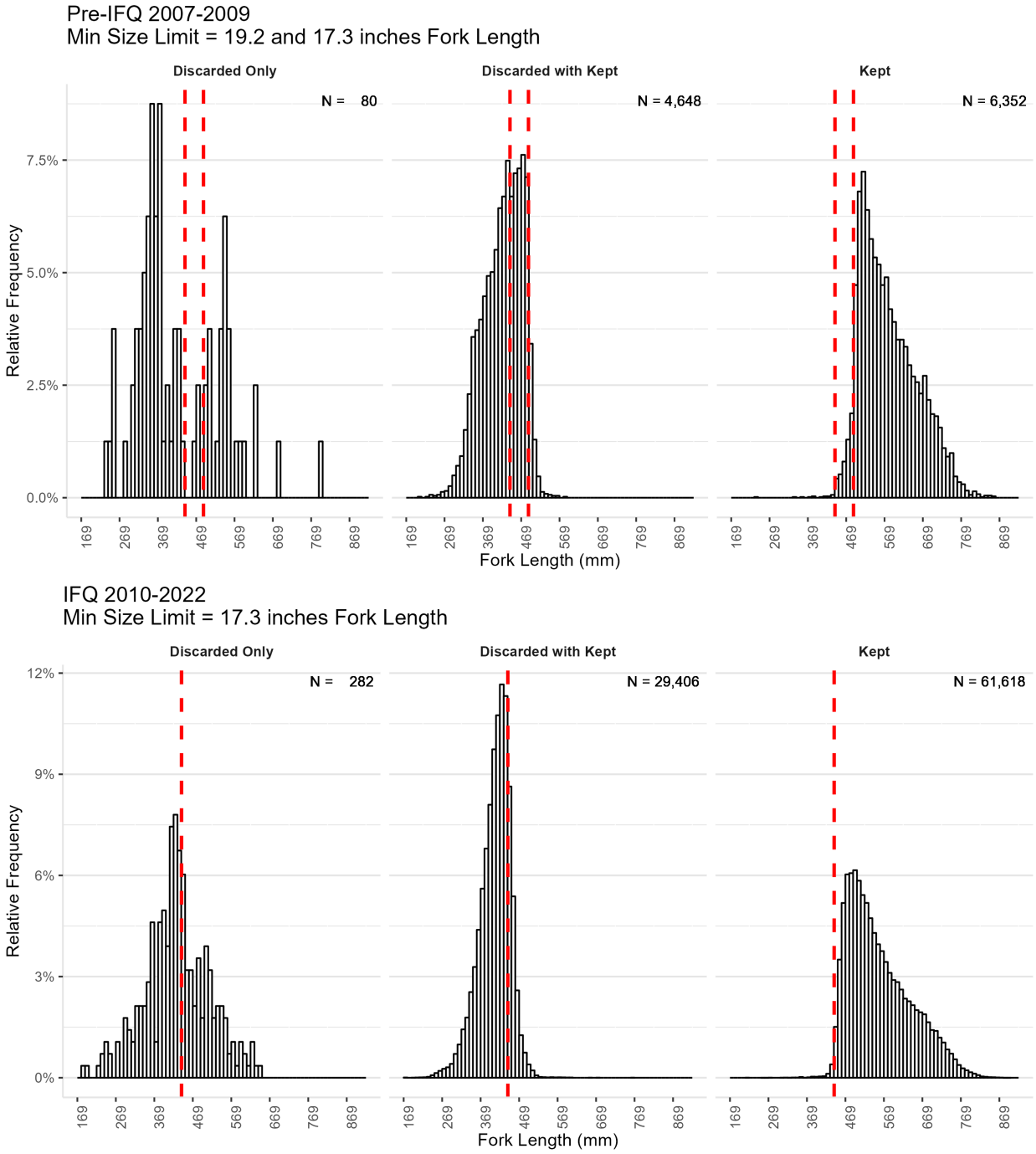


Figure 3. CPUE (catch in whole pounds per hour) time-series for logbook data from 1993 - 2022 for vertical line trips landing GOM Red Grouper.

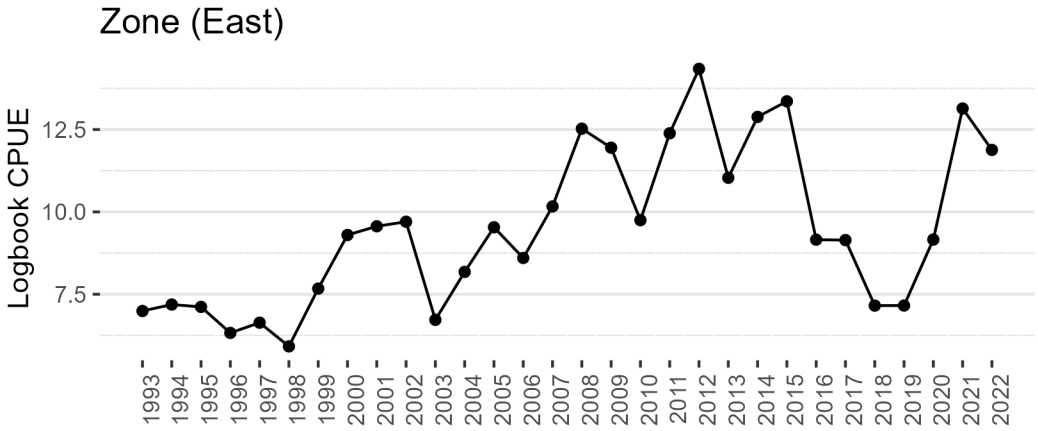


Figure 4. Comparison of vertical line reported annual logbook landings of GOM Red Grouper (solid black line) with CPUE expansion estimates from observer data (open squares). Error bars (SE) are shown for observer estimates.

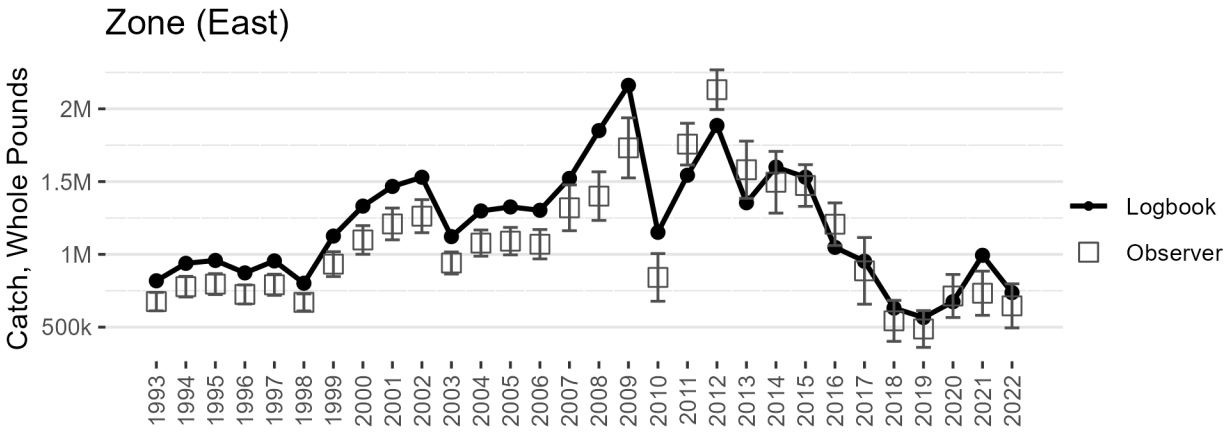
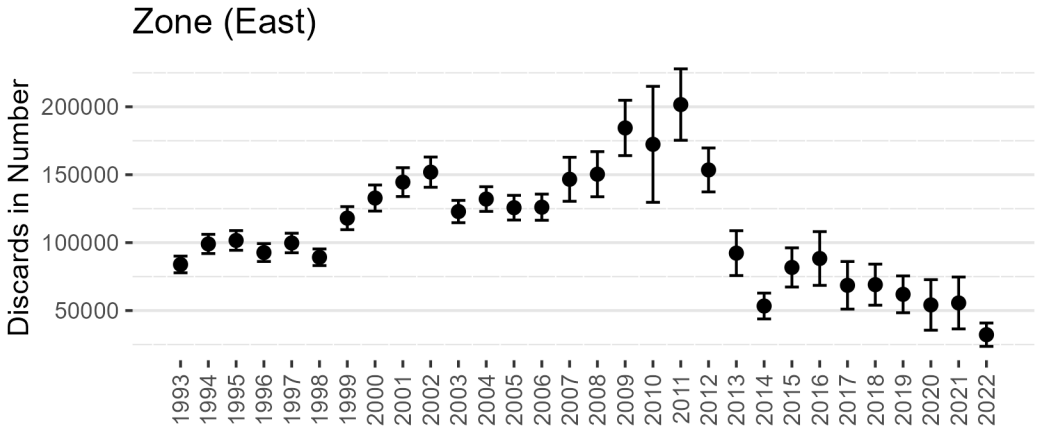


Figure 5. Observer CPUE expansion estimates of GOM Red Grouper commercial vertical line annual discards (+/-SE) in (A) number and (B) weight expressed as percentage of total catch (kept + discards) for 1993 - 2022.

(A) Discards in Number



(B) Discards in Weight, Percentage of Total Catch

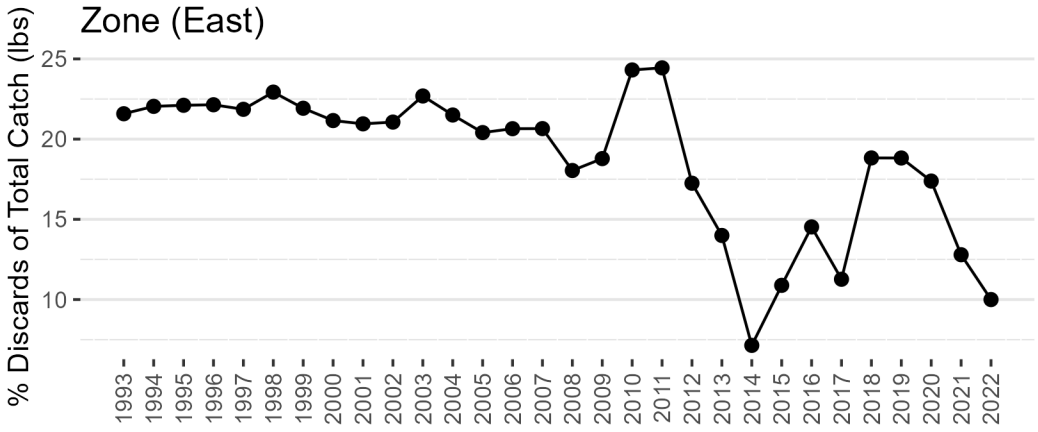


Figure 6. Commercial vertical line discard estimates of Red Grouper for SEDAR 88 compared to SEDAR 61.

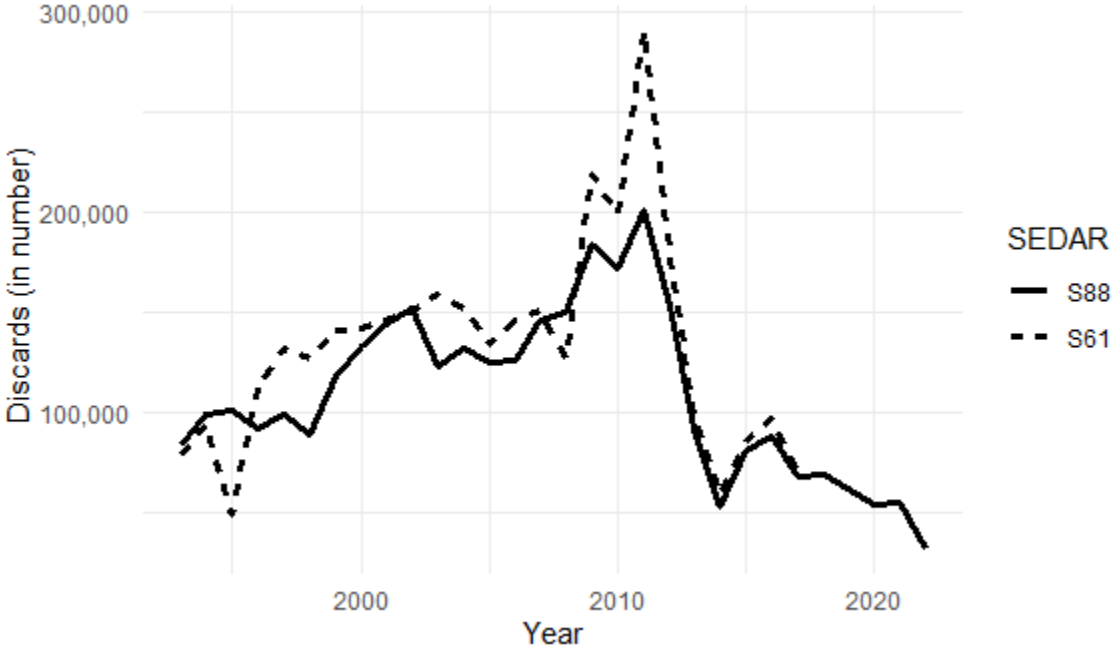


Figure 7. Annual commercial vertical line weighted and nominal discard length compositions for GOM Red Grouper, where the weighted frequencies are accounting for catch and effort level stratification by management period.

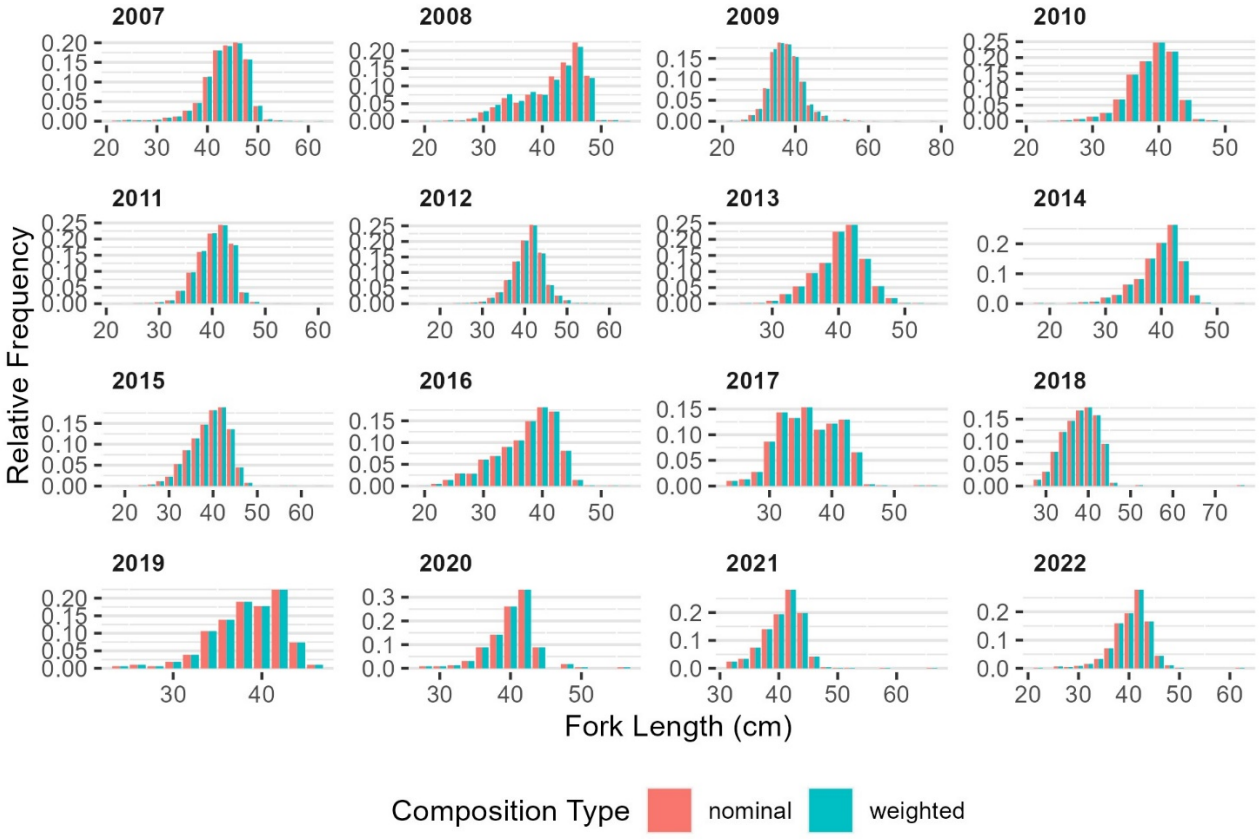


Figure 8. Length-frequency plots of observer bottom longline GOM Red Grouper by disposition (Kept or Discard) and management regime. "Discarded Only" were discards from trips with no kept Red Grouper; "Discarded with Kept" were discards from trips with kept Red Grouper. Vertical dashed lines denote the minimum size limit over time (19.2 in. fork length from 2007-2008 and 17.3 in. fork length from 2009-2022); N is the number of measured fish.

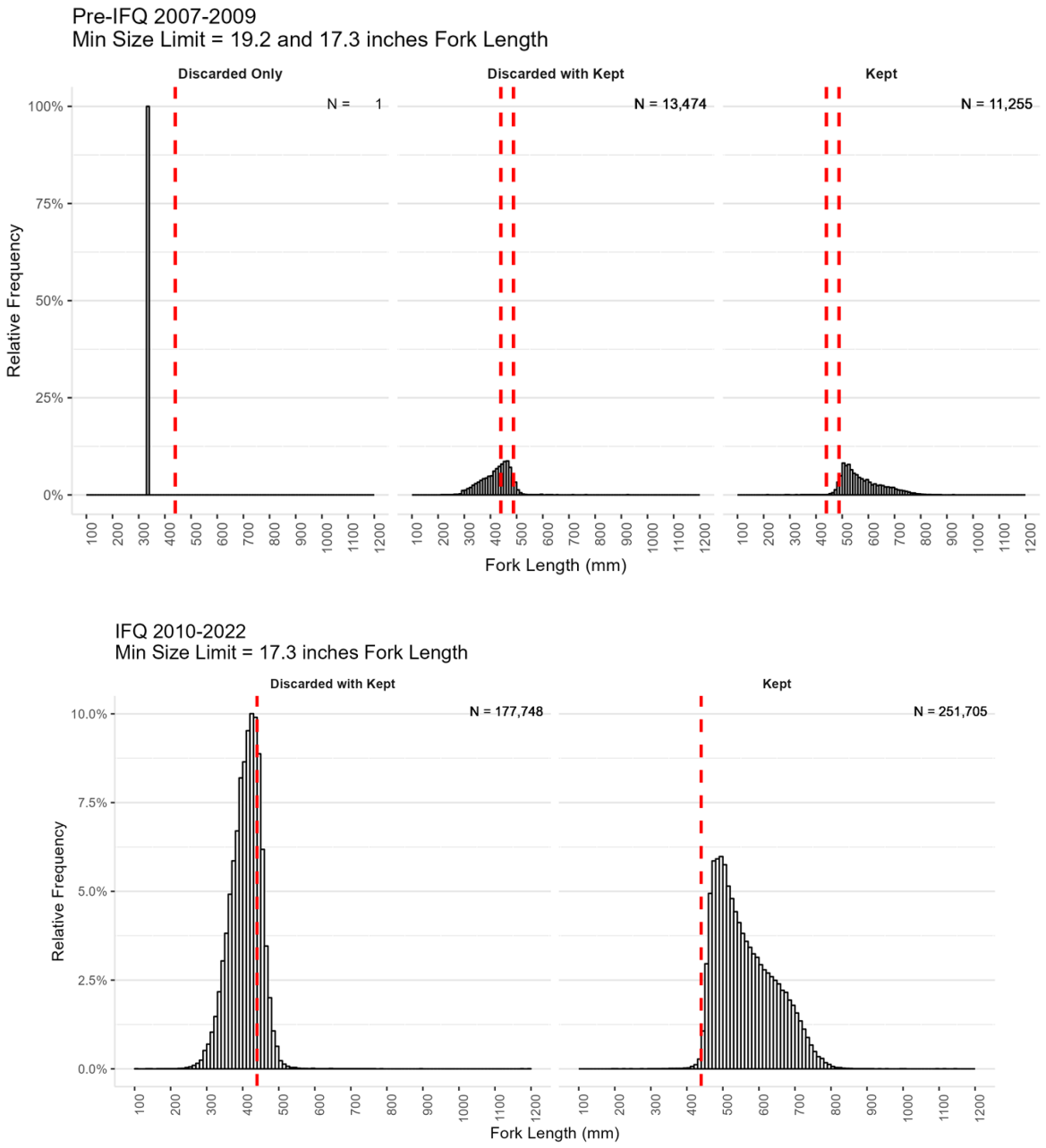


Figure 9. CPUE (catch in whole pounds per hour) time-series for logbook data from 1993 - 2022 for bottom longline trips landing GOM Red Grouper.

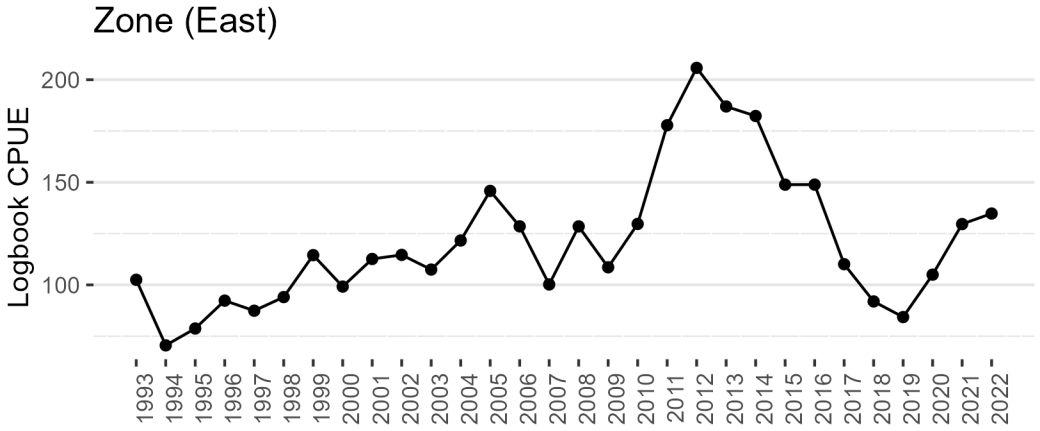


Figure 10. Comparison of bottom longline reported annual logbook landings of GOM Red Grouper (solid black line) with CPUE expansion estimates from observer data (open squares). Error bars (SE) are shown for observer estimates.

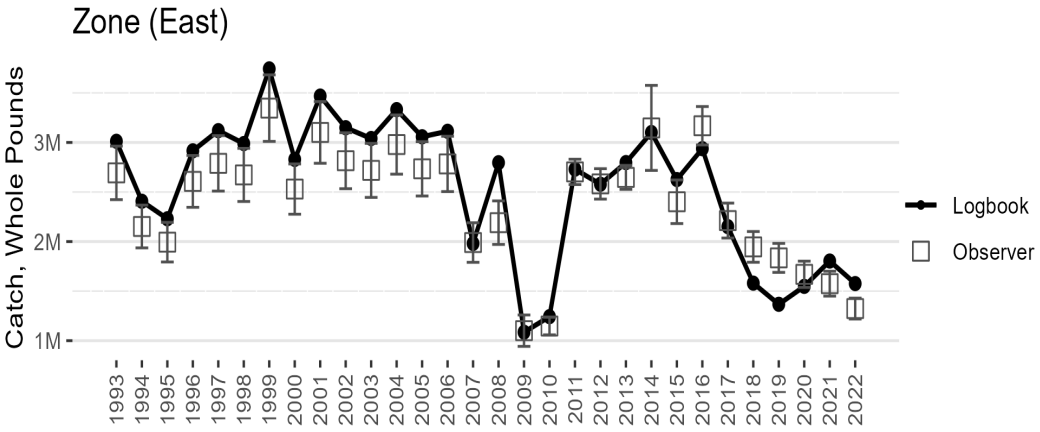
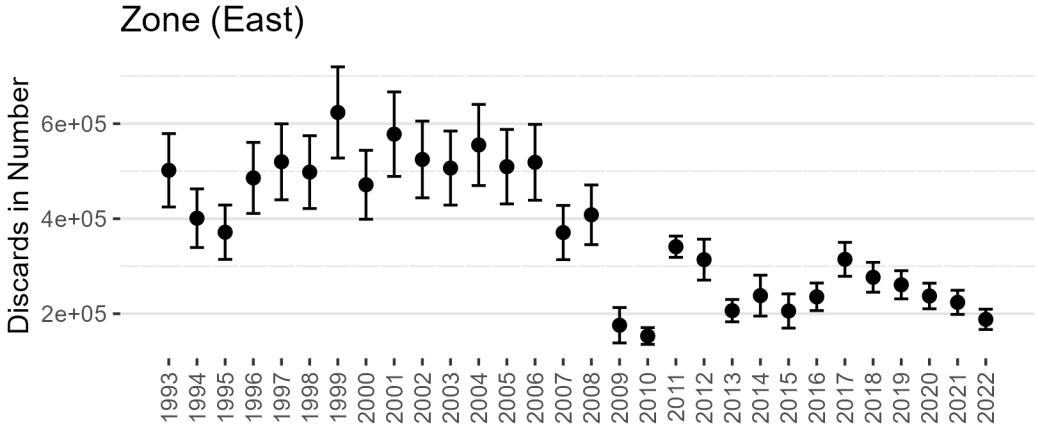


Figure 11. Observer CPUE expansion estimates of GOM Red Grouper bottom longline annual discards (+/-SE) in (A) number and (B) weight expressed as percentage of total catch (kept + discards) for 1993 - 2022.

(A) Discards in Number



(B) Discards in Weight, Percentage of Total Catch

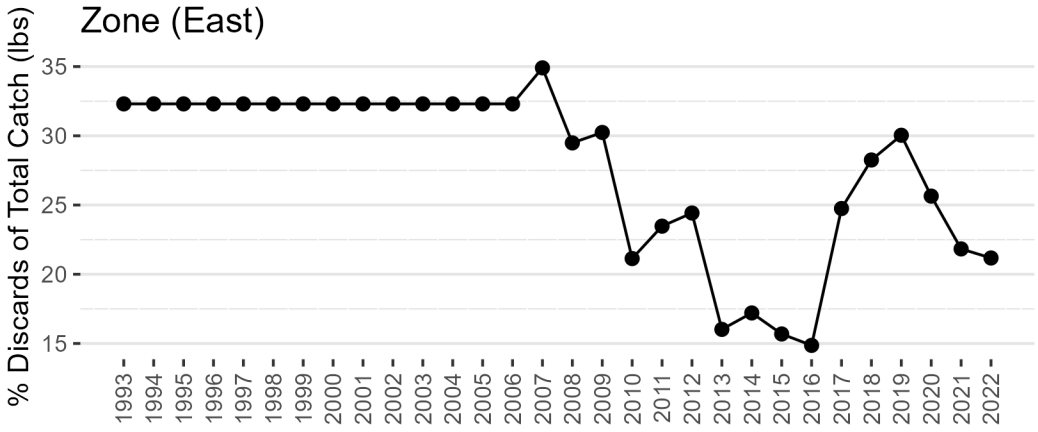


Figure 12. Commercial bottom longline discard estimates of Red Grouper for SEDAR 88 compared to SEDAR 61.

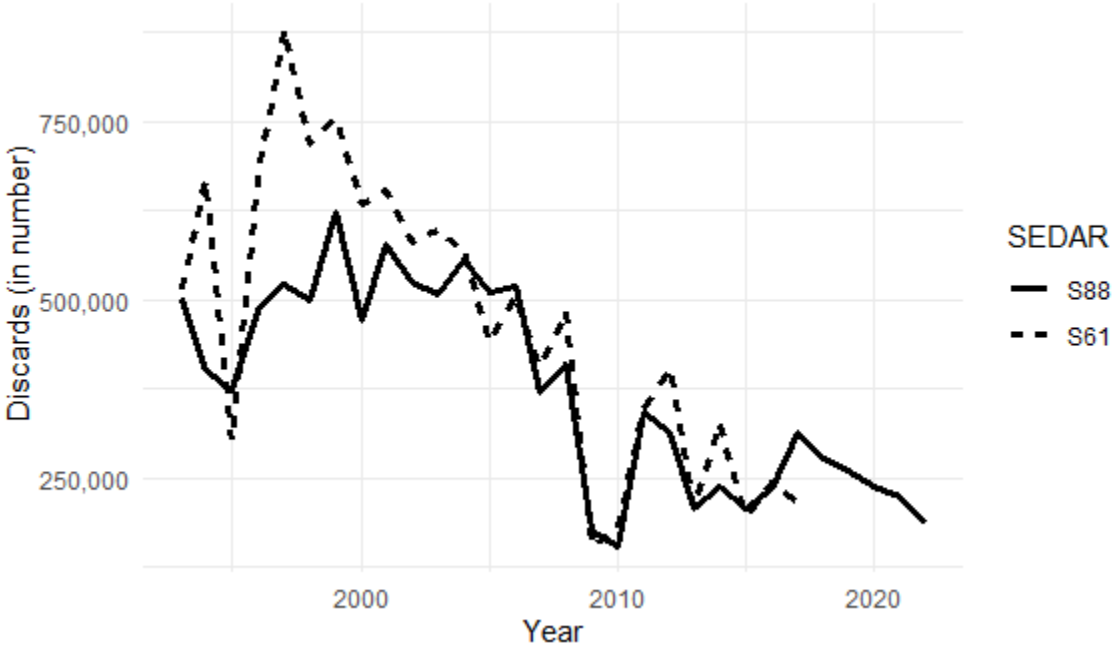


Figure 13. Annual commercial bottom longline weighted and annual discard length compositions for GOM Red Grouper, where weighted frequencies are accounting for catch and effort level stratification by management period.