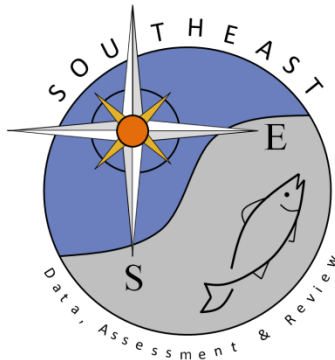# CPUE Expansion Estimation for Total Commercial Discards of Gulf of Mexico Greater Amberjack

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SEDAR 70 Working Paper

**CPUE Expansion Estimation for Total Commercial Discards of
Gulf of Mexico Greater Amberjack**

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Introduction

The general approach for estimating discards for the commercial reef fish fleet in the Gulf of Mexico 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,

total Catch = CPUE x total Effort   .

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 greater amberjack. This application required no additional species-specific modifications to the estimation procedure.

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 (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 weight were recorded for a subsample of individual fish. The coastal reef fish observer program began in July 2006; for GOM greater amberjack discard estimation, complete calendars years 2007-2018 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 logbook program in which fishers reported basic information on effort and catch by species for every trip. The reef logbook program began in 1990 for a subset of vessels in the GOM, and expanded to all vessels in 1993; for GOM greater amberjack discard estimation, complete calendar years 1993-2018 were used.

Relevant Management History of GOM Greater Amberjack

The key management changes during 1993-2018 relevant to this analysis were: (1) establishment of a closed season for GOM Greater Amberjack during March-May beginning in 1998 and continuing to the present; and (2) additional closed months beginning in 2009 based on annual catch limits. Closed months by year are listed in **Table 1**. A month was considered open or closed if the date of closure occurred before or after the 15th day, respectively. For years 2010 and prior, the fishery was closed for less than 6 months of the year; for 2011 and later, the fishery was closed more than 6 months of the year. Three management regimes were thus defined: Open (1993-1997), Mostly Open (1998-2010), and Mostly Closed (2011-2018).

Gear
    In the coastal observer data, greater amberjack were observed on both vertical line and bottom longline trips. Discard estimation was conducted separately for the two gears.

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):

$$\hat{C} = \overline{CPUE} \times \hat{X} \ ,$$

where $\overline{CPUE}$ 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 per trip i,

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

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

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

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

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

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

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

Variance of $\hat{C}$ was estimated using

$$var[\hat{C}] = var[\overline{CPUE}] \times \hat{X}^2 \quad .$$

Standard error of total catch was calculated as

$$SE[\hat{C}] = \sqrt{var[\hat{C}]} \quad .$$

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

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

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

Spatial Domain

Per recommendation of the stock assessment analysts, discard estimates were conducted for the GOM, defined as statistical zones 1-21 (**Fig. 1**).

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 greater amberjack. 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 length compositions for kept and discarded fish from observer sampling were evaluated with respect to Mostly Open (2007-2010) and Mostly Closed (2011-2018) management regimes. Verification compared total landed catch from logbook data with the estimated total kept catch $\hat{C}$ and standard error from observer data for the hindcast time period.

Results and Discussion

Vertical Line

The observer database included 1,058 vertical line trips with corresponding trip and set information. Observer sampling effort is summarized in **Table 2**, distinguishing all trips from the subset of trips that captured greater amberjack, and further distinguishing greater amberjack trips within open and closed seasons.

For the observer time period, 2007-2018, kept fish were mostly above the minimum size limit of 36" FL (914 mm FL) during the Mostly Open and Mostly Closed management regimes (**Fig. 2**). As shown in **Fig. 3**, discards were mostly fish near or below the minimum size limit during the Mostly Open period (2007-2010), but included more legal-sized fish during the Mostly Closed period (2011-2018). Discard estimation was conducted separately within each management regime to account for potential changes in the discard CPUE indicated by differences in the discard length frequencies.

Catch-effort data for observer trips catching greater amberjack were pooled across years for the respective management regimes for open and closed seasons. Annual logbook catch-effort data for greater amberjack trips were stratified by season and management regime. 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 effort were similar for the Mostly Open management regime (2007-2010), suggesting that observer sampling of greater amberjack trips was representative of the commercial fleet. This was not the case for the Mostly Closed management regime (2011-2018). Further analysis showed that observers sampled a larger proportion of high effort (>32.9 hours) greater amberjack trips and a smaller proportion of low effort (≤32.9 hours) trips relative to the commercial fleet (**Table 3**). To account for this discrepancy, observer and logbook trips were grouped into strata according to low (L) and high (H) effort for subsequent analysis and estimation for the Mostly Closed time period.

The proportions of observer trips and effort encountering greater amberjack that had kept fish are given in **Table 4** by management regime, season, and effort level strata. These proportions were used to adjust annual logbook total greater amberjack trips and effort (**Table 5**) to account for logbook trips that only had discarded fish. Estimates of logbook and observer mean discard CPUE by management regime, season, and effort level strata are given in **Table 6.** Observer discard CPUEs for the Mostly Open period (2007-2010) were the basis for hindcasting discards during 1993-2006 by season.

CPUE expansion estimates of annual total landed catch of GOM greater amberjack compared favorably with reported logbook landings for 1993-2018 (**Fig. 4**). CPUE expansion estimates for annual discards of GOM greater amberjack for 1993-2018 in numbers and weight are provided in **Table 7**. Estimated discards in number ranged from 30,000 to 40,000 fish during 1993-2004, declined between 2005 and 2010, and have ranged from 10,000 to 15,000 fish during 2010-2018 (**Fig. 5A**). Discards in weight accounted for about 40% of the total catch (kept + discards) during 1993-2009 and 30% of the total catch during 2010-2018 (**Fig. 5B**).

Bottom Longline

The observer database included 401 bottom longline trips with corresponding trip and set information. Observer sampling effort is summarized in **Table 8**, distinguishing all trips from the subset of trips that captured greater amberjack, and further distinguishing greater amberjack trips within open and closed seasons.

For the observer time period, 2007-2018, kept fish were generally above the minimum size limit of 36" FL (914 mm FL) during the Mostly Open and Mostly Closed management regimes (**Fig. 6**). As shown in **Fig. 7**, discards included fish below and above the minimum size limit in both management regimes, but comprised proportionally more legal-sized fish during the Mostly Closed period (2011-2018). Discard estimation was conducted separately within each management regime to account for potential changes in the discard CPUE indicated by differences in the discard length frequencies.

Catch-effort data for observer trips catching greater amberjack were pooled across years for the respective management regimes for open and closed seasons. Annual logbook catch-effort data for greater amberjack trips were stratified by season and management regime. 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 effort were similar for both management regimes, suggesting that observer sampling of greater amberjack trips was representative of the commercial fleet.

The proportions of observer trips and effort encountering greater amberjack that had kept fish are given in **Table 9** by management regime and season strata. These proportions were used to adjust annual logbook total greater amberjack trips and effort (**Table 10**) to account for logbook trips that only had discarded fish. Estimates of logbook and observer mean discard CPUE by management regime and season strata are given in **Table 11.** Observer discard CPUEs for the Mostly Open period (2007-2010) were the basis for hindcasting discards during 1993-2006 by season.

CPUE expansion estimates of annual total landed catch of GOM greater amberjack compared favorably with reported logbook landings for 1993-2018 (**Fig. 8**). CPUE expansion estimates for annual discards of GOM greater amberjack for 1993-2018 in numbers and weight are provided in **Table 12**. Estimated discards in number were below 1,000 fish during 1993-1997, increased to 2,000 to 3,000 fish during 1998-2006, and then declined over several years to a stable 1,000 or so fish during 2010-2018 (**Fig. 9A**). Discards in weight accounted for just under 30% of the total catch (kept + discards) during 1993-1997, fluctuated between 30% and 60% of the total catch during 1998-2010, and ranged between 55% and 65% of the total catch during 2011-2018 (**Fig. 9B**).

Relation to Discard Estimates for SEDAR 33 and SEDAR 33 Update

Discard estimates for GOM greater amberjack for SEDAR 33, conducted in 2013-2014, and the subsequent update in 2016, relied on information from the discard logbook program (DLP), conducted by NOAA's Southeast Fisheries Science Center, and the reef fish observer program (RFOP) described above (SEDAR 2014). Discard logbook data were used for the pre-observer time period (prior to 2007), and RFOP data were used in conjunction with discard logbook data

for the observer time period (2007 and later). The general discard estimation approach was the same for both data sources: discard CPUE was multiplied by total effort from the commercial logbook program to produce total discards. However, there were data reliability and estimation issues with these earlier discard estimates on both accounts. The DLP data have reporting issues. More than 50% of trips per year report no discards of any species, whereas the RFOP data show <3% of trips per year with no discards of any species. In addition, the DLP estimation procedures have no method for validation (e.g., **Fig. 4**). The initial discard estimation procedures using the RFOP data for SEDAR 33 had issues with (i) scaling sub-trip level catch data collected by observers (e.g., catch per reel, catch per set) to the trip-level, and (ii) developing an effort variable for the observer data that matched the effort reported in commercial logbooks; consequently, attempts to accurately estimate the logbook reported catch as a validation step (e.g., **Fig. 4**) were unsuccessful. These estimation issues concerning the RFOP data were resolved for red grouper for SEDAR 61 (Smith et al. 2018). The RFOP discard estimation procedures were further refined with respect to hindcasting to the pre-observer period (prior to 2007) for subsequent SEDARs for gray triggerfish (SEDAR 62) and vermilion snapper (SEDAR 67).

Another difference between the current approach and previous approaches concerns the statistical estimator for discard CPUE. The current approach employs a Horvitz-Thompson survey design estimator for CPUE (see Methods, *Catch Expansion Procedures and Verification*, above), whereas the previous approaches employed a general linear model (GLM) estimator. The underlying sampling assumptions are the same for the survey design and GLM estimators: the sample catch and effort data (observer or discard logbook) are presumed to be a representative sample of the commercial fishing fleet catch and effort. However, this assumption is not always met, as illustrated for greater amberjack vertical lines several biases are known (**Table 3**): observers disproportionately sampled a lower number of low effort trips and a higher number of high effort trips compared to the logbook-reported effort for the commercial fleet. The survey design estimation approach facilitated reconciling this issue via adding a stratification variable for trip effort level.

The current, improved RFOP approach applied in this study for greater amberjack has a key validation step: CPUE of kept fish is used to estimate total landed catch, which is then compared with the reported catch from commercial logbooks. For greater amberjack, there was good correspondence between estimated catches from RFOP and catches reported from the commercial logbook program (**Fig. 4**, **Fig. 8**). Applications to GOM red grouper (Smith et al. 2018), gray triggerfish (Smith et al. 2019a), and vermilion snapper (Smith et al. 2019b) have also shown good correspondence between estimated catches from RFOP and catches reported from the commercial logbook program. This has resulted in fairly high confidence in estimation of discards from the RFOP approach. Thus, the discard estimates for greater amberjack provided in **Table 7** for vertical lines and **Table 12** for bottom longlines supersede and supplant previously reported estimates for SEDAR 33 and SEDAR 33 Update.

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Table 1. Commercial fishery time closures for Greater Amberjack in the Gulf of Mexico. For discard analysis, months were considered closed if the date of closure occurred before the 15th, and were considered open if the closure occurred after the 15th.

Year	Greater Amberjack Time Closures	
	Number of Months	Description
1993	0	
1994	0	
1995	0	
1996	0	
1997	0	
1998	3	Mar-May
1999	3	Mar-May
2000	3	Mar-May
2001	3	Mar-May
2002	3	Mar-May
2003	3	Mar-May
2004	3	Mar-May
2005	3	Mar-May
2006	3	Mar-May
2007	3	Mar-May
2008	3	Mar-May
2009	5	Mar-May, Nov-Dec
2010	5	Mar-May, Nov-Dec
2011	7	Mar-May, Jul-Aug, Nov-Dec
2012	10	Mar-Dec
2013	9	Mar-May, Jul-Dec
2014	7	Mar-May, Sep-Dec
2015	8	Mar-May, Aug-Dec
2016	8	Mar-May, Aug-Dec
2017	9	Mar-May, Jul-Dec
2018	10	Mar-Dec

Table 2. Number of total and Greater Amberjack coastal observer vertical line trips by year for the GOM, denoting trips during open and closed seasons.

		Greater Amberjack Trips		
Year	Total Trips	Total	Open	Closed
2007	73	31	25	6
2008	37	20	16	4
2009	36	14	6	8
2010	48	11	5	6
2011	90	21	9	12
2012	213	89	20	69
2013	112	40	8	32
2014	89	40	20	20
2015	162	59	24	35
2016	113	48	26	22
2017	55	16	2	14
2018	30	11	3	8

Table 3. Definition of effort level strata for GOM Greater Amberjack by open and closed seasons, and corresponding percentages of logbook and observer vertical line trips during the 2011-2018 management regime.

	Stratum	% Trips	
Trip Effort Level	Code	Logbook	Observer
Open Season			
Low, effort ≤ 32.9 hours	L	58.0	35.7
High, effort > 32.9 hours	H	42.0	64.3
Closed Season			
Low, effort ≤ 32.9 hours	L	46.0	29.7
High, effort > 32.9 hours	H	54.0	70.3

Table 4. Greater Amberjack vertical line effort and catch adjustment factors by management regime, season (OP=open, CL=closed), and effort level strata in GOM. Effort level strata for the Mostly Closed 2011-2018 management regime are defined in Table 3 (low L≤ 32.9 hours, high H > 32.9 hours) ; effort level stratum 'A' is all levels (i.e., no stratification) for the Mostly Open 2007-2010 management regime. The proportions of Greater Amberjack observer trips and effort with kept Greater Amberjack were used to respectively adjust annual logbook total trips and effort (Table 5) to account for logbook trips that only had discarded fish.

Management Regime	Season	Effort Level	Number of Observer Trips (n)	Proportion of Observer Data with Kept Greater Amberjack	
				Trips	Effort
Mostly Open, 2007-2010	OP	A	52	0.4038	0.5164
	CL	A	24	0.0417	0.0526
Mostly Closed, 2011-2018	OP	L	40	0.3000	0.2614
	OP	H	72	0.5417	0.5613
	CL	L	63	0.0476	0.0256
	CL	H	149	0.1477	0.1508

Table 5. Annual time-series of vertical line logbook trips (number) and effort (hours) by season and effort level strata for GOM Greater Amberjack. See Table 4 for season and effort level definitions.

Year	Season	Effort Level	Logbook Trips		Logbook Effort	
			Reported	Adjusted (N)	Reported	Adjusted ($\hat{X}$)
1993	OP	A	1,558	3,858	68,373	132,405
1994	OP	A	1,729	4,281	75,222	145,669
1995	OP	A	1,705	4,222	71,189	137,859
1996	OP	A	1,936	4,794	74,983	145,205
1997	OP	A	1,978	4,898	81,733	158,278
1998	OP	A	1,210	2,996	50,265	97,340
	CL	A	99	2,376	3,499	66,548
1999	OP	A	1,243	3,078	54,709	105,946
	CL	A	126	3,024	4,116	78,283
2000	OP	A	1,091	2,702	46,141	89,352
	CL	A	96	2,304	3,809	72,444
2001	OP	A	1,181	2,924	49,390	95,645
	CL	A	67	1,608	2,349	44,667
2002	OP	A	1,486	3,680	57,686	111,709
	CL	A	58	1,392	1,739	33,075
2003	OP	A	1,527	3,781	59,608	115,432
	CL	A	47	1,128	1,308	24,877
2004	OP	A	1,471	3,642	57,578	111,501
	CL	A	46	1,104	1,236	23,508
2005	OP	A	1,125	2,786	49,168	95,215
	CL	A	51	1,224	1,255	23,869

2006	OP	A	907	2,246	42,288	81,892
	CL	A	28	672	953	18,125
2007	OP	A	740	1,832	42,704	82,697
	CL	A	30	720	1,227	23,337
2008	OP	A	804	1,991	40,118	77,689
	CL	A	20	480	712	13,542
2009	OP	A	832	2,060	42,600	82,496
	CL	A	51	1,224	1,927	36,650
2010	OP	A	419	1,038	19,899	38,535
	CL	A	25	600	1,118	21,264
2011	OP	L	159	530	2,413	9,231
	OP	H	178	329	10,412	18,549
	CL	L	35	735	392	15,328
	CL	H	18	122	1,011	6,703
2012	OP	L	79	263	1,394	5,333
	OP	H	116	214	7,363	13,117
	CL	L	18	378	303	11,848
	CL	H	29	196	1,284	8,513
2013	OP	L	184	613	2,823	10,799
	OP	H	197	364	12,649	22,534
	CL	L	10	210	155	6,061
	CL	H	20	135	1,158	7,677
2014	OP	L	304	1,013	4,665	17,844
	OP	H	237	438	14,841	26,439
	CL	L	9	189	141	5,514
	CL	H	11	75	657	4,356
2015	OP	L	235	783	3,408	13,037
	OP	H	166	306	10,258	18,274
	CL	L	12	252	188	7,351
	CL	H	7	47	374	2,480
2016	OP	L	339	1,130	5,117	19,575
	OP	H	193	356	11,315	20,157
	CL	L	13	273	240	9,385
	CL	H	11	75	566	3,752
2017	OP	L	349	1,163	4,941	18,900
	OP	H	163	301	9,614	17,127
	CL	L	7	147	127	4,966
	CL	H	21	142	958	6,351
2018	OP	L	197	657	3,112	11,903
	OP	H	85	157	4,642	8,270
	CL	L	5	105	63	2,463
	CL	H	11	75	676	4,482

Table 6. Estimated observer mean discard CPUE in weight and numbers by management regime, season, and effort level strata for expansion estimates of vertical line GOM Greater Amberjack discards. See Table 4 for season and effort level definitions.

Management Regime	Season	Effort Level	Observer Discard CPUE	
			Pounds per hour	Number per hour
Mostly Open,	OP	A	2.5675	0.2331
2007-2010	CL	A	0.8605	0.1055
Mostly Closed,	OP	L	4.5446	0.4153
2011-2018	OP	H	2.1386	0.2278
	CL	L	1.7288	0.3979
	CL	H	2.0935	0.1687

Table 7. Time-series of CPUE expansion estimates for GOM Greater Amberjack vertical line discards in weight (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	332,312.7	96,193.7	30,176.4	5,954.4
1994	337,263.8	97,626.8	30,626.0	6,043.1
1995	412,439.9	119,387.9	37,452.5	7,390.1
1996	427,830.4	123,842.9	38,850.1	7,665.8
1997	420,826.8	121,815.6	38,214.1	7,540.3
1998	332,672.6	96,297.9	32,712.3	6,454.7
1999	407,920.8	118,079.7	42,348.7	8,356.2
2000	340,515.5	98,568.1	33,293.6	6,569.5
2001	358,407.0	103,747.1	36,398.0	7,182.0
2002	331,300.7	95,900.7	31,648.1	6,244.8
2003	377,137.8	109,169.1	35,688.8	7,042.1
2004	377,639.4	109,314.3	36,324.8	7,167.6
2005	286,412.1	82,906.9	27,016.4	5,330.8
2006	234,669.5	67,929.1	22,089.7	4,358.7
2007	232,404.1	67,273.4	21,743.7	4,290.4
2008	211,118.4	61,111.9	19,542.3	3,856.1
2009	243,342.8	70,439.8	23,101.9	4,558.4
2010	117,234.1	33,935.4	11,228.6	2,215.6
2011	122,149.0	39,518.1	15,288.3	3,722.7
2012	90,590.3	29,308.1	11,352.9	2,764.4
2013	123,819.4	40,058.6	13,324.5	3,244.5
2014	156,283.9	50,561.6	16,361.1	3,983.9
2015	116,228.8	37,602.8	12,920.0	3,146.0
2016	156,147.0	50,517.3	17,087.7	4,160.8
2017	144,400.1	46,716.9	14,797.4	3,603.1
2018	85,420.1	27,635.5	8,563.0	2,085.1

Table 8. Number of total and Greater Amberjack coastal observer bottom longline trips by year for the GOM, denoting trips during open and closed seasons.

		Greater Amberjack Trips		
Year	Total Trips	Total	Open	Closed
2007	10	7	6	1
2008	5	5	5	0
2009	32	20	10	10
2010	51	34	15	19
2011	78	44	18	26
2012	19	16	2	14
2013	81	47	6	41
2014	27	21	14	7
2015	26	18	7	11
2016	55	39	12	27
2017	13	11	2	9
2018	4	4	0	4

Table 9. Greater Amberjack bottom longline effort and catch adjustment factors by management regime, season (OP=open, CL=closed). The proportions of Greater Amberjack observer trips and effort with kept Greater Amberjack were used to respectively adjust annual logbook total trips and effort (Table 10) to account for logbook trips that only had discarded fish.

Management Regime	Season	Number of Observer Trips (n)	Proportion of Observer Data with Kept Greater Amberjack	
			Trips	Effort
Mostly Open,	OP	36	0.7500	0.7029
2007-2010	CL	30	0.1333	0.1529
Mostly Closed,	OP	61	0.4754	0.5247
2011-2018	CL	139	0.1223	0.1432

Table 10. Annual time-series of bottom longline logbook trips (number) and effort (sets) by season for GOM Greater Amberjack. See Table 9 for season definitions.

Year	Season	Logbook Trips		Logbook Effort	
		Reported	Adjusted (N)	Reported	Adjusted ($\hat{X}$)
1993	OP	270	360	8,554	12,169
1994	OP	336	448	11,408	16,229
1995	OP	325	433	10,199	14,509
1996	OP	353	471	10,841	15,423
1997	OP	412	549	13,172	18,739
1998	OP	297	396	8,726	12,414
	CL	15	113	342	2,237
1999	OP	289	385	8,458	12,033
	CL	23	173	480	3,139
2000	OP	295	393	8,024	11,415
	CL	22	165	480	3,139
2001	OP	298	397	7,941	11,297
	CL	11	83	245	1,602
2002	OP	370	493	9,637	13,710
	CL	9	68	189	1,236
2003	OP	446	595	11,210	15,948
	CL	13	98	268	1,753
2004	OP	335	447	7,483	10,645
	CL	11	83	205	1,341
2005	OP	338	451	5,899	8,392
	CL	8	60	185	1,210
2006	OP	371	495	7,192	10,231
	CL	9	68	150	981
2007	OP	254	339	5,853	8,327
	CL	4	30	94	615
2008	OP	323	431	7,553	10,745
	CL	4	30	125	818
2009	OP	154	205	3,936	5,599
	CL	9	68	265	1,733
2010	OP	79	105	2,393	3,404
	CL	3	23	94	615
2011	OP	55	116	1,553	2,960
	CL	4	33	145	1,013
2012	OP	19	40	734	1,399
	CL	1	8	55	384
2013	OP	41	86	1,339	2,552
	CL	3	25	106	740
2014	OP	63	133	2,193	4,180
	CL	1	8	100	698
2015	OP	63	133	2,415	4,603
	CL	4	33	134	936
2016	OP	66	139	2,222	4,235
	CL	6	49	193	1,348

2017	OP	53	111	2,193	4,180
	CL	3	25	132	922
2018	OP	35	74	1,574	3,000
	CL	1	8	23	161

Table 11. Estimated observer mean discard CPUE in weight and numbers by management regime and season for expansion estimates of bottom longline GOM Greater Amberjack discards. See Table 9 for season definitions.

Management Regime	Season	Observer Discard CPUE	
		Pounds per hour	Number per hour
Mostly Open,	OP	2.3029	0.1312
2007-2010	CL	5.9927	0.2716
Mostly Closed,	OP	4.1725	0.1867
2011-2018	CL	6.0949	0.2288

Table 12. Time-series of CPUE expansion estimates for GOM Greater Amberjack bottom longline
discards in weight (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	10,897.1	2,391.1	621.1	126.4
1994	14,015.8	3,075.4	798.8	162.6
1995	15,524.1	3,406.4	884.8	180.1
1996	15,324.9	3,362.7	873.4	177.8
1997	16,899.5	3,708.2	963.2	196.1
1998	38,602.8	8,470.4	1,937.2	394.4
1999	45,883.0	10,067.9	2,253.5	458.8
2000	59,831.4	13,128.5	2,885.0	587.3
2001	27,371.2	6,005.9	1,404.3	285.9
2002	34,845.8	7,646.0	1,821.9	370.9
2003	50,062.0	10,984.8	2,618.9	533.1
2004	54,658.2	11,993.4	2,745.3	558.9
2005	55,670.9	12,215.6	2,777.0	565.3
2006	39,668.3	8,704.2	2,072.9	422.0
2007	22,859.6	5,016.0	1,259.8	256.5
2008	29,644.1	6,504.6	1,632.3	332.3
2009	23,281.4	5,108.5	1,205.6	245.4
2010	11,524.1	2,528.7	613.8	125.0
2011	18,522.9	4,402.9	784.4	137.8
2012	8,178.5	1,944.0	349.1	61.3
2013	15,160.9	3,603.7	645.9	113.4
2014	21,697.2	5,157.4	940.2	165.1
2015	24,910.0	5,921.1	1,073.5	188.5
2016	25,886.6	6,153.2	1,099.1	193.0
2017	23,059.3	5,481.2	991.3	174.1
2018	13,496.8	3,208.2	596.9	104.8

Figure 1. Map of sampling areas in the Gulf of Mexico (map provided by B. Wrege).
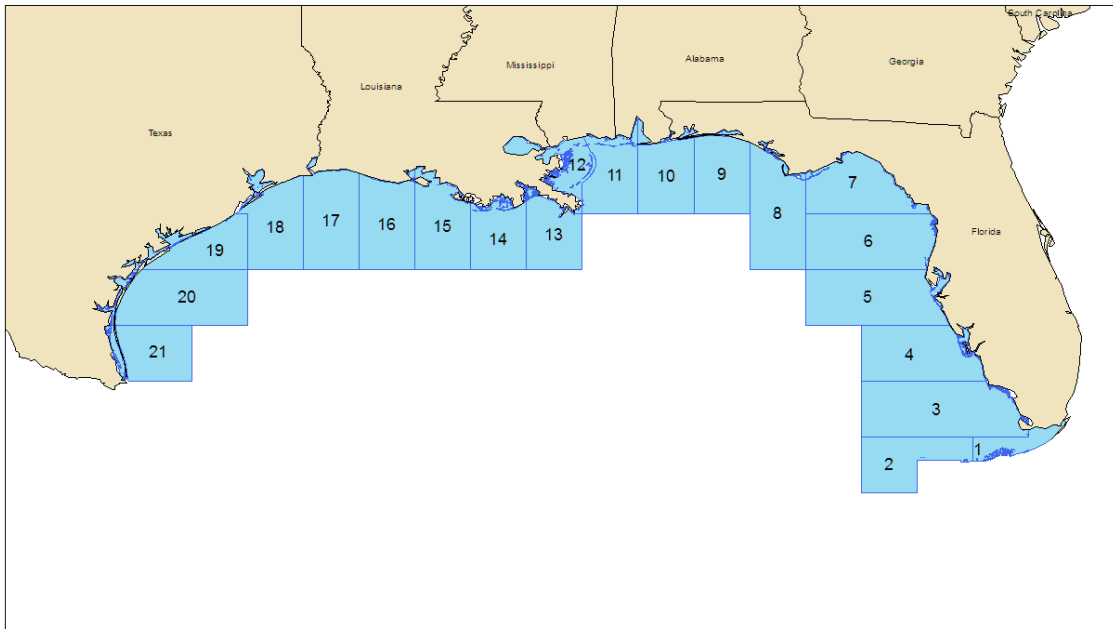
Figure 2. Length-frequency plots of observer vertical line GOM Greater Amberjack for kept fish (landed) by management regime. Vertical dashed lines denote the minimum size limit of 36" FL (914 mm FL); *n* is number of measured fish.

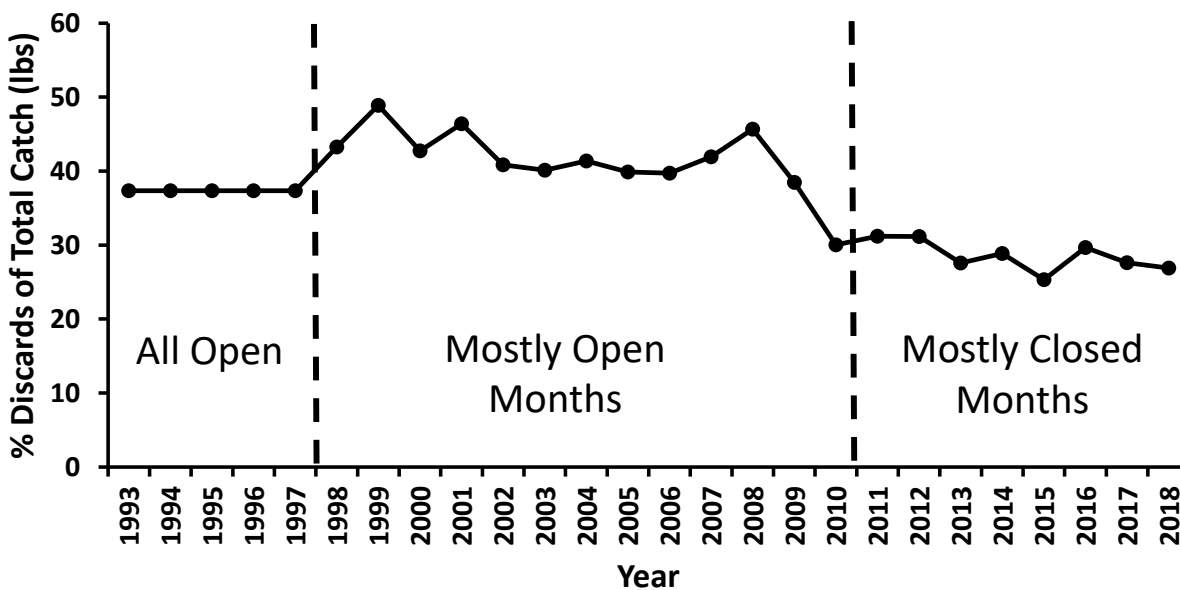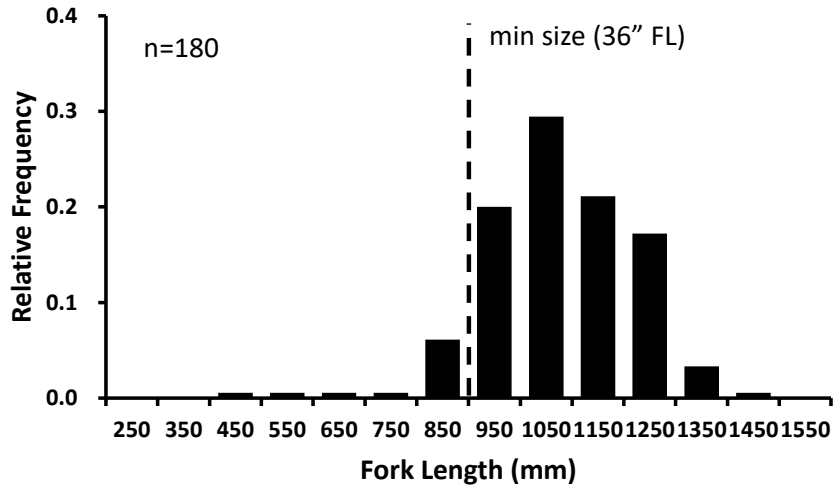Mostly Open (2007-2010)
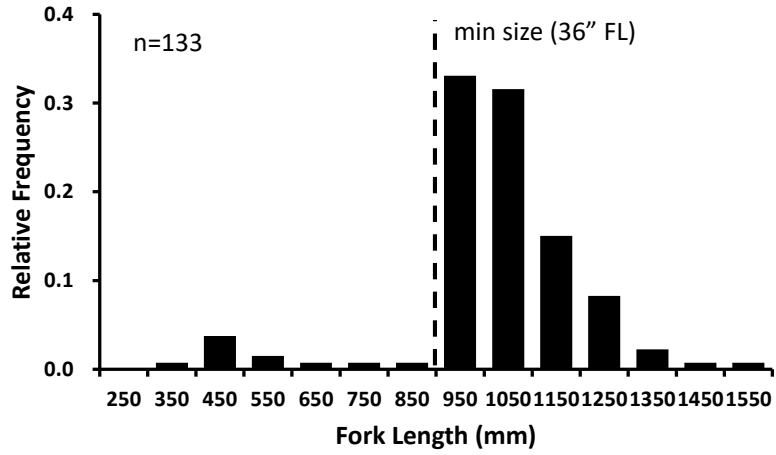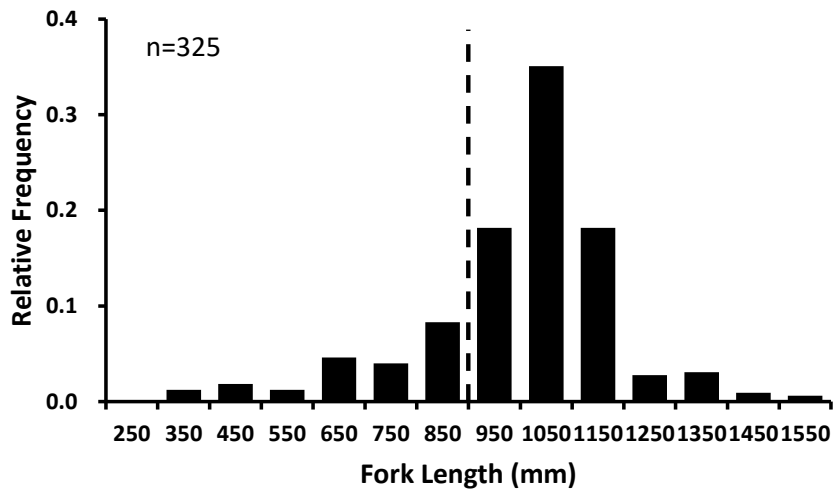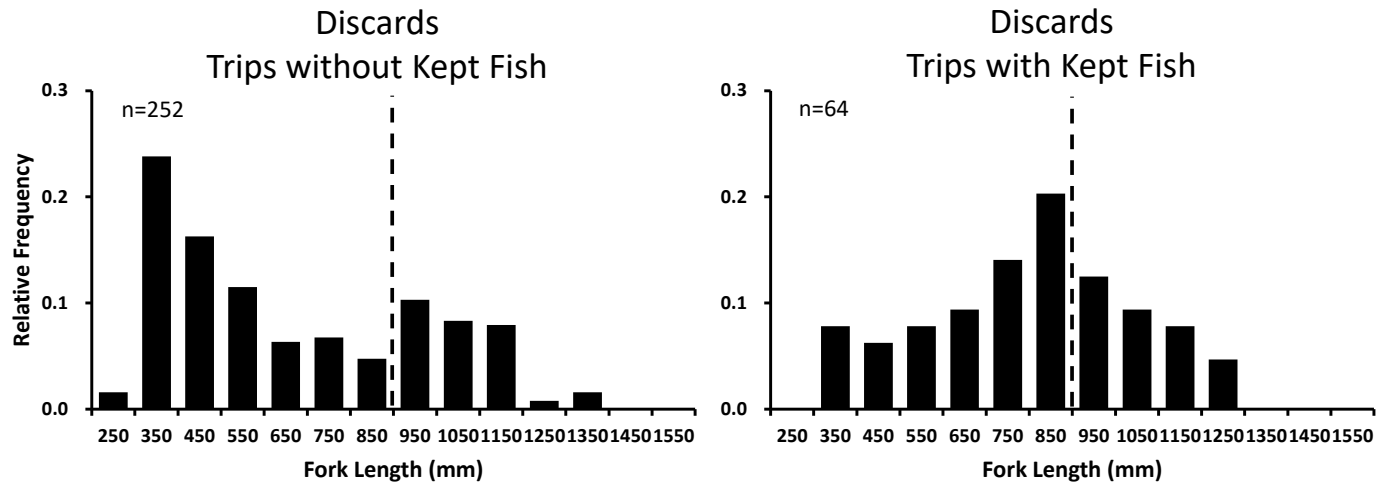

Mostly Closed (2011-2018)
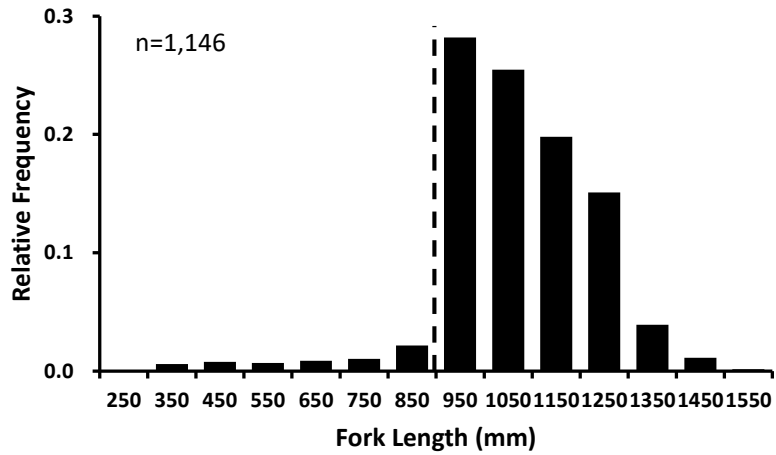
Figure 3. Length-frequency plots of observer vertical line GOM Greater Amberjack for discarded fish by management regime. 'Discards Only' were discards from trips with no kept Greater Amberjack; 'Discards with Kept' were discards from trips with kept Greater Amberjack. Vertical dashed lines denote the minimum size limit of 36" FL (914 mm FL); *n* is number of measured fish.

Mostly Open (2007-2010)
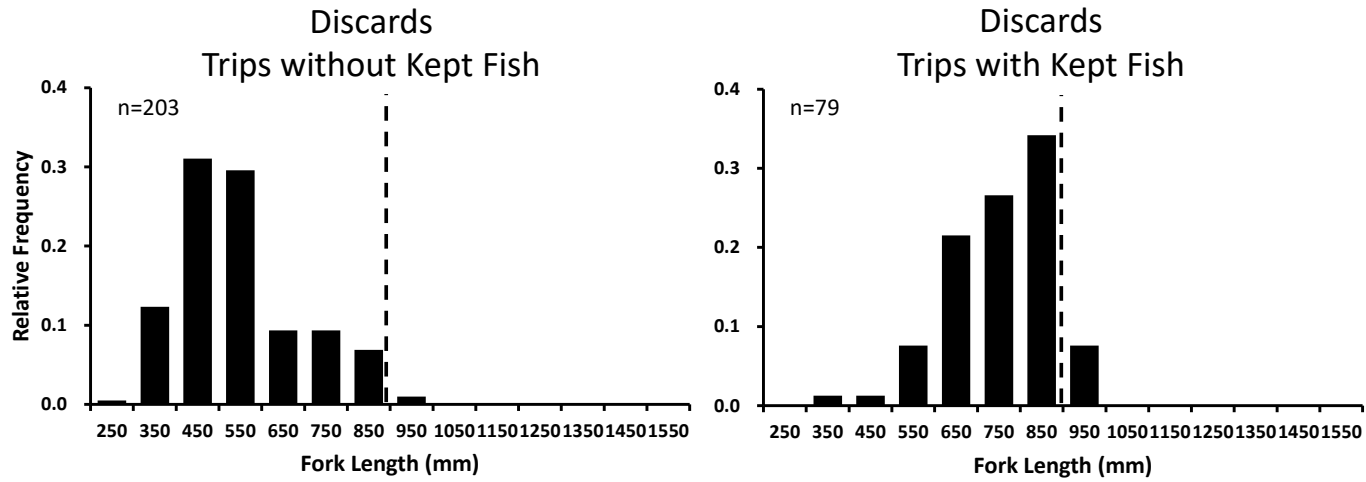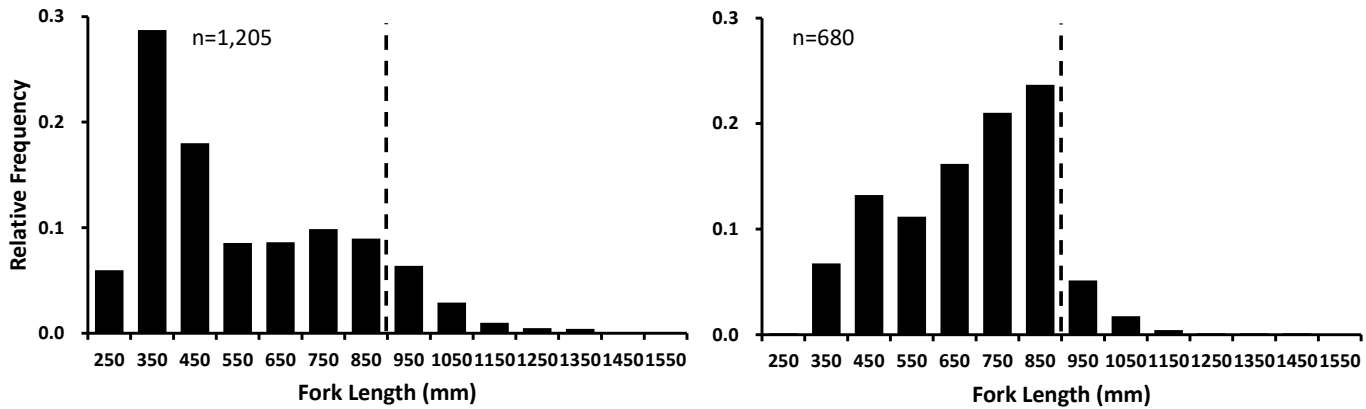
Figure 4. Comparison of vertical line reported annual logbook landings of GOM Greater Amberjack (solid black line) with CPUE expansion estimates from observer data (open squares). Error bars (SE) are shown for observer estimates.
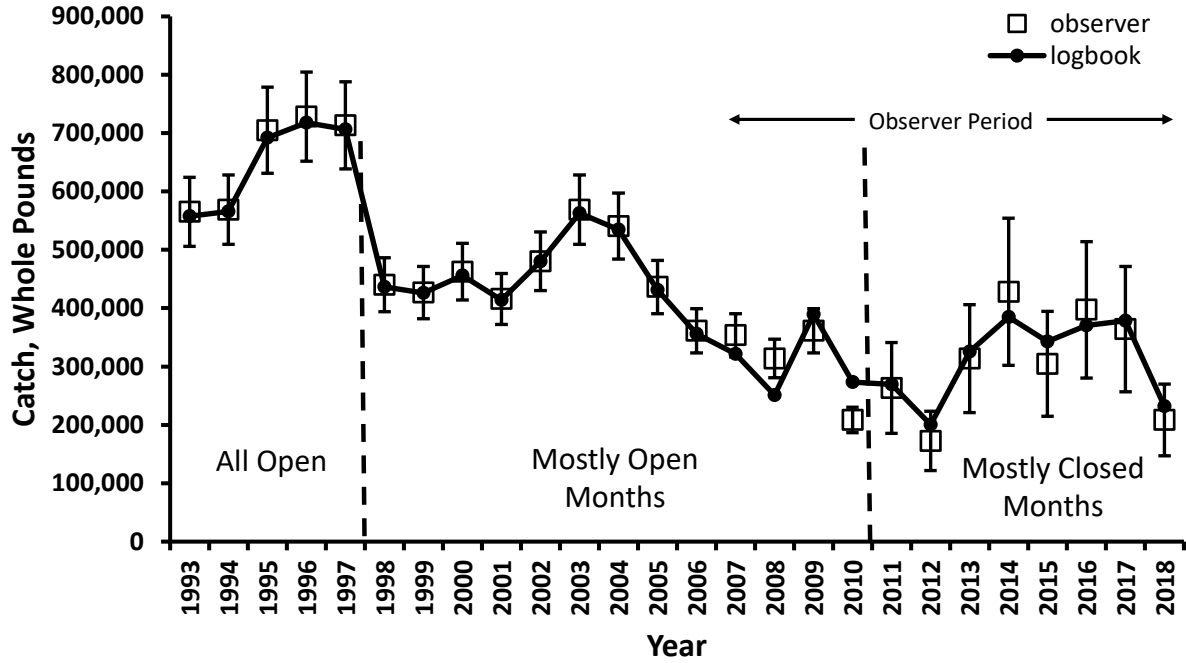
Figure 5. Observer CPUE expansion estimates of GOM Greater Amberjack vertical line annual discards (±SE) in (A) number and (B) weight expressed as percentage of total catch (kept + discards) for 1993-2018.

(A) Discards in Number
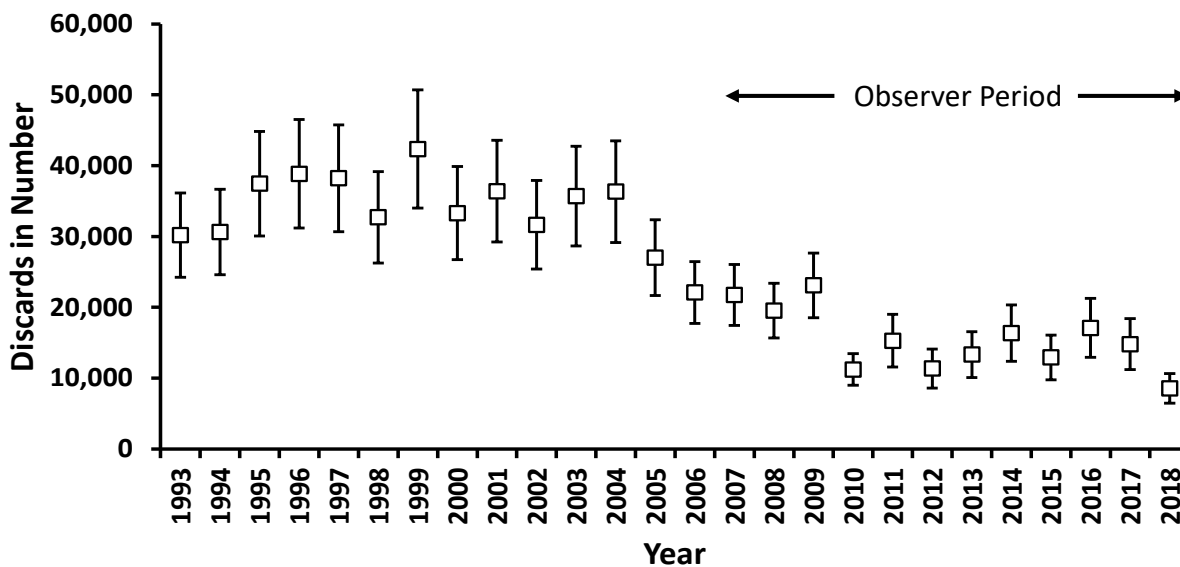
(B) Discards in Weight, Percentage of Total Catch

Figure 6. Length-frequency plots of observer bottom longline GOM Greater Amberjack for kept fish (landed) by management regime. Vertical dashed lines denote the minimum size limit of 36" FL (914 mm FL); *n* is number of measured fish.

Mostly Open (2007-2010)


Mostly Closed (2011-2018)

Figure 7. Length-frequency plots of observer bottom longline GOM Greater Amberjack for discarded fish by management regime. 'Discards Only' were discards from trips with no kept Greater Amberjack; 'Discards with Kept' were discards from trips with kept Greater Amberjack. Vertical dashed lines denote the minimum size limit of 36" FL (914 mm FL); *n* is number of measured fish.
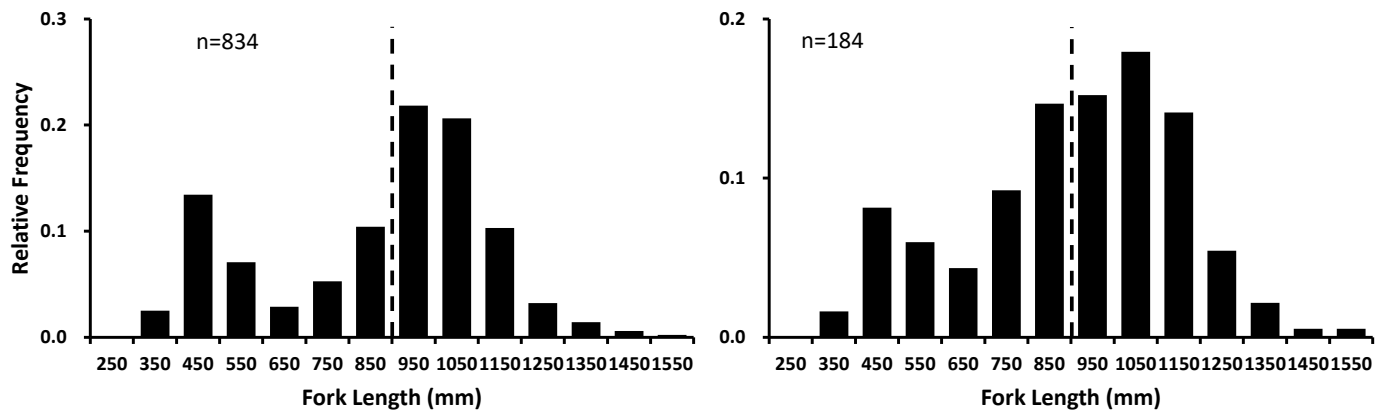
Figure 8. Comparison of bottom longline reported annual logbook landings of GOM Greater Amberjack (solid black line) with CPUE expansion estimates from observer data (open squares). Error bars (SE) are shown for observer estimates.
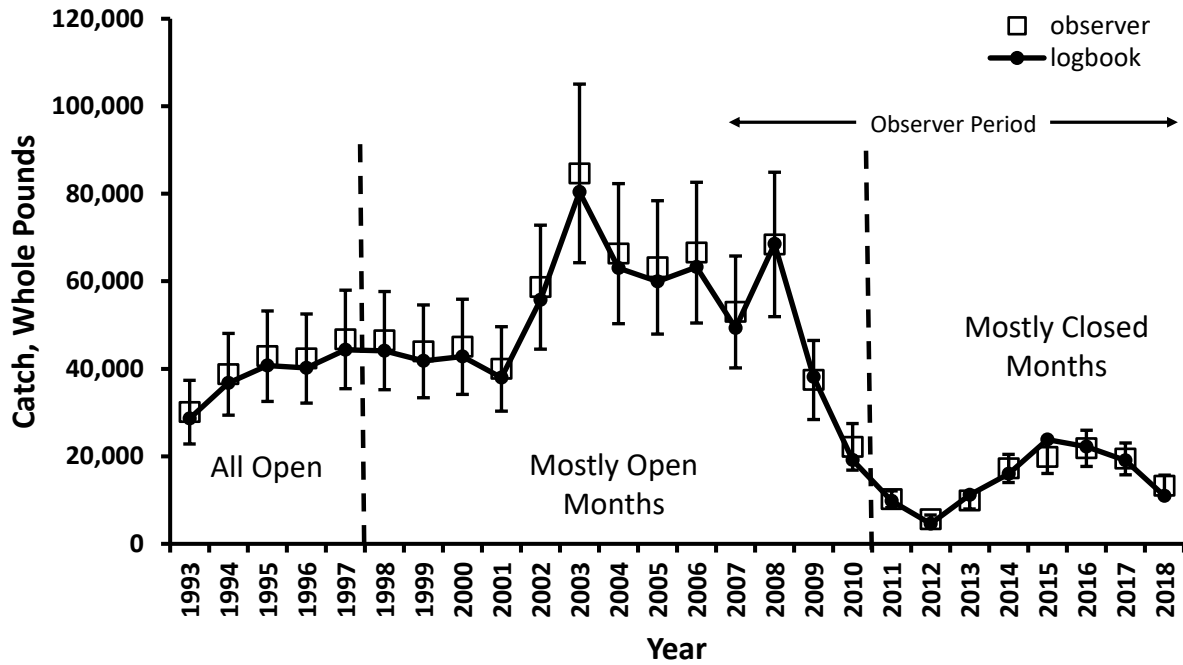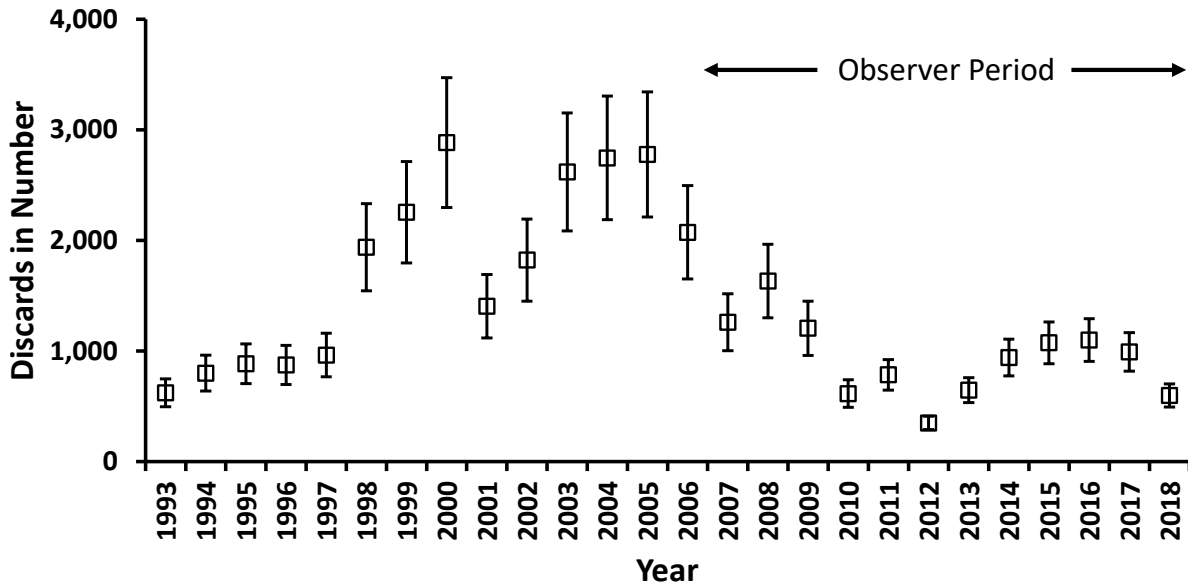
Figure 9. Observer CPUE expansion estimates of GOM Greater Amberjack bottom longline annual
discards (±SE) in (A) number and (B) weight expressed as percentage of total catch (kept + discards)
for 1993-2018.

(A) Discards in Number

(B) Discards in Weight, Percentage of Total Catch