# CPUE Expansion Estimation for Total Commercial Discards of Gulf of Mexico Cobia Using Reef Fish Observer Data, and Adjustments to Discard Logbook Estimates for Florida East Coast

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# CPUE Expansion Estimation for Total Commercial Discards of Gulf of Mexico Cobia Using Reef Fish Observer Data, and Adjustments to Discard Logbook Estimates for Florida East Coast

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**Abstract**

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. For discard estimation, CPUE is computed for total discards, including fish released alive, released dead, released in unknown condition, and used for bait. The principal focus of this study was to apply recently developed discard estimation methods for Gulf of Mexico red grouper, gray triggerfish, and vermilion snapper to Gulf of Mexico cobia. Discard estimation was conducted separately for two gears, vertical line and bottom longline. A verification step compared annual total landed catch from logbook data with the estimated observer annual total landed catch. Once verified, cobia annual total discards in weight and number were estimated for the observer data period 2007-2018, and then hindcasted for the period 1993-2006. For vertical line gear, estimated discards in number ranged from 1,000 to 1,500 fish per year during 1993-2004, declined between 2004 and 2007, and have remained at about 500 fish per year during 2007-2018. Discards in weight accounted for about 19% of the total catch (kept + discards) during 1993-2018. For bottom longline gear, estimated discards in number were about 400 to 500 fish per year prior to 2009, declining to about 200 to 400 fish per year after 2009. Discards in weight accounted for about 20% of the total catch (kept + discards) during 1993-2018.

A bias correction method was developed to adjust vertical line discard estimates derived from discard logbooks for the Florida East Coast region using vertical line discard estimates from the reef fish observer program in the Gulf of Mexico. Adjusted estimates of cobia discards for the Florida East Coast region ranged from 100 to 150 fish per year during 1993-2004, declining to about 50 fish per year during 2005-2018.

## Part 1: Gulf of Mexico

### 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 cobia. 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 cobia 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 cobia discard estimation, complete calendar years 1993-2018 were used.

*Gear*

In the coastal observer data, cobia 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*,

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

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

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

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

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

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

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

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 (landed) 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 cobia. 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). Verification compared total landed catch from logbook data with the estimated total kept (landed) catch $\hat{C}$ and standard error from observer data for the hindcast time period.

**Results and Discussion**

*Vertical Line*

The observer database included 1,222 vertical line trips with corresponding trip and set information during 2007-2018. Observer sampling effort is summarized in **Table 2**, distinguishing all trips from the subset of trips that captured cobia. For the observer time period, 2007-2018, kept fish were mostly above the minimum size limit of 33" FL (838 mm FL), and discards were mostly fish near or below the minimum size limit (**Fig. 2**).

Inspection of the annual nominal CPUE (catch in whole pounds per hour) from logbook trips reporting cobia showed distinct trends over time (**Fig. 3**). Logbook CPUE was comparatively high during the pre-observer time period (prior to 2007), declined to lower values in 2007-2009, and increased to moderate levels from 2010-2018. A stable CPUE time period that occurred

within the observer time period was identified as 2010-2018. Catch-effort data for observer trips catching cobia were pooled across years for the stable CPUE period to accommodate low annual observer sample sizes for cobia trips (**Table 2**). Logbook catch-effort data for cobia 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 observer time period (2007-2018) and pre-observer time period (1993-2006).

Observer and logbook frequency distributions of trip-level catch and effort were similar for the pooled CPUE period, suggesting that observer sampling of cobia trips was representative of the commercial fleet. The proportions of observer trips and effort encountering cobia that had kept fish are given in **Table 2**. These proportions were used to adjust annual logbook total cobia trips and effort (**Table 3**) to account for logbook trips that only had discarded fish. Estimates of observer mean kept and discard CPUE are given in **Table 4.** Observer discard CPUE was the basis for hindcasting discards during 1993-2006.

CPUE expansion estimates of annual total landed catch of GOM cobia compared favorably with reported logbook landings for 1993-2018 (**Fig. 4**). CPUE expansion estimates for annual discards of GOM cobia for 1993-2018 in numbers and weight are provided in **Table 5**. Estimated discards in number ranged from 1,000 to 1,500 fish during 1993-2004, declined between 2004 and 2007, and have remained at about 500 fish during 2007-2018 (**Fig. 5A**). Discards in weight accounted for about 19% of the total catch (kept + discards) during 1993-2018 (**Fig. 5B**).

*Bottom Longline*

The observer database included 401 bottom longline trips with corresponding trip and set information during 2007-2018. Observer sampling effort is summarized in **Table 6**, distinguishing all trips from the subset of trips that captured cobia. For the observer time period, 2007-2018, kept fish were mostly above the minimum size limit of 33" FL (838 mm FL), and discards were mostly fish near or below the minimum size limit (**Fig. 6**).

Inspection of the annual nominal CPUE (catch in whole pounds per hour) from logbook trips reporting cobia showed distinct trends over time (**Fig. 7**). Logbook CPUE gradually increased during 1993-2005, and gradually declined during 2006-2018. A stable CPUE time period that occurred within the observer time period was identified as 2009-2015. Catch-effort data for observer trips catching cobia were pooled across years for the stable CPUE period to accommodate low annual observer sample sizes for cobia trips (**Table 6**). Logbook catch-effort data for cobia 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 observer time period (2007-2018) and pre-observer time period (1993-2006).

Observer and logbook frequency distributions of trip-level catch for the stable CPUE period (2009-2015) differed somewhat, suggesting that observer sampling of cobia trips may not have been representative of the commercial fleet. Further analysis showed that observers sampled a higher proportion of low catch (<41 lbs.) cobia trips and a lower proportion of high catch (>41 lbs.) trips relative to the commercial fleet (**Table 7**). 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.

The proportions of observer trips and effort encountering cobia that had kept fish are given in **Table 8** by catch level strata. These proportions were used to adjust annual logbook total cobia trips and effort (**Table 9**) to account for logbook trips that only had discarded fish. Estimates of observer mean kept and discard CPUE by catch level strata are given in **Table 10.** Observer discard CPUE was the basis for hindcasting discards during 1993-2006.

CPUE expansion estimates of annual total landed catch of GOM cobia compared favorably with reported logbook landings for 1993-2018 (**Fig. 8**). CPUE expansion estimates for annual discards of GOM cobia for 1993-2018 in numbers and weight are provided in **Table 11**. Estimated discards in number were about 400 to 500 fish per year prior to 2009, declining to about 200 to 400 fish per year after 2009 (**Fig. 9A**). Discards in weight accounted for about 20% of the total catch (kept + discards) during 1993-2018 (**Fig. 9B**).

## Part 2: Florida East Coast

### Introduction

The coastal reef fish observer program (RFOP), described above, primarily collects data in the Gulf of Mexico. The discard logbook program (DLP), conducted by NOAA's Southeast Fisheries Science Center, collects data from both the GOM and South Atlantic, including the Florida East Coast (FEC) region. As described above, the RFOP approach estimates CPUE of both discards and kept fish from observer data, and produces subsequent expansion estimates of total discards using total effort from the commercial logbook program. Similarly, as described in McCarthy and Diaz (2020), the DLP approach estimates CPUE of discards from discard logbook data, and produces subsequent expansion estimates of total discards using total effort from the commercial logbook program. Cobia discard estimates for vertical line gear in GOM were generally higher using the DLP approach compared to the RFOP approach (**Table 12**).

The RFOP approach 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 cobia, 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. In contrast, 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. A method was developed to adjust the DLP discard estimates for the FEC region using DLP and RFOP estimates for the GOM region.

### Methods

Although the RFOP and DLP approaches produce different estimates of discards, it was assumed that the ratio of discards for FEC:GOM would be similar for each approach:

$$\frac{FEC\ Discards\ RFOP}{GOM\ Discards\ RFOP} = \frac{FEC\ Discards\ DLP}{GOM\ Discards\ DLP}$$

The FEC Discards that would have been estimated by the RFOP are then approximated by:

$$FEC\ Discards\ RFOP = GOM\ Discards\ RFOP \times \frac{FEC\ Discards\ DLP}{GOM\ Discards\ DLP}$$

The associated FEC discard standard errors (SE) are derived from the DLP estimates,

SE(RFOP) = CV(DLP) x mean estimate(RFOP),

where CV(DLP) is the DLP standard error divided by the DLP mean estimate (i.e., coefficient of variation for the mean estimate). Thus, the method adjusts the mean value of the discard estimates but does not affect the uncertainty.

**Results and Discussion**

The adjusted annual estimates for cobia vertical line discards in the FEC region during 1993-2018 are provided in **Table 13**. Adjusted estimates of cobia discards ranged from 100 to 150 fish per year during 1993-2004, declining to about 50 fish per year during 2005-2018. The adjustment method should be only be considered as an interim bias correction. Improved, reliable discard estimates in the future for FEC and the South Atlantic will be possible when the reef fish observer program is expanded to these areas.

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

| Year | Total Trips | Cobia Trips |
|---|---|---|
| 2007 | 87 | 10 |
| 2008 | 44 | 2 |
| 2009 | 44 | 2 |
| 2010 | 52 | 2 |
| 2011 | 87 | 10 |
| 2012 | 238 | 12 |
| 2013 | 122 | 12 |
| 2014 | 107 | 6 |
| 2015 | 199 | 14 |
| 2016 | 138 | 9 |
| 2017 | 67 | 8 |
| 2018 | 37 | 2 |

**Table 2.** Cobia vertical line effort and catch adjustment factors for the stable CPUE period 2010-2018 (see Fig. 2) in GOM. The proportions of Cobia observer trips and effort with kept Cobia were used to respectively adjust annual logbook total trips and effort (Table 3) to account for logbook trips that only had discarded fish.

| Stable CPUE Period | Number of Observer Trips (n) | Proportion of Observer Data with Kept Cobia | |
|---|---|---|---|
| | | Trips | Effort |
| 2010-2018 | 75 | 0.6667 | 0.6861 |

**Table 3.** Annual time-series of vertical line logbook trips (number) and effort (hours) for GOM Cobia.

| | Logbook Trips | | Logbook Effort | |
|---|---|---|---|---|
| Year | Reported | Adjusted ($N$) | Reported | Adjusted ($\hat{X}$) |
| 1993 | 736 | 1,104 | 26,049 | 37,966 |
| 1994 | 764 | 1,146 | 27,661 | 40,315 |
| 1995 | 782 | 1,173 | 29,631 | 43,187 |
| 1996 | 972 | 1,458 | 26,803 | 39,065 |
| 1997 | 1,022 | 1,533 | 28,166 | 41,052 |
| 1998 | 949 | 1,424 | 25,323 | 36,908 |
| 1999 | 1,102 | 1,653 | 30,956 | 45,118 |
| 2000 | 1,017 | 1,526 | 28,521 | 41,569 |
| 2001 | 891 | 1,337 | 24,739 | 36,056 |
| 2002 | 1,035 | 1,553 | 28,703 | 41,834 |
| 2003 | 820 | 1,230 | 23,132 | 33,714 |
| 2004 | 817 | 1,226 | 22,905 | 33,384 |
| 2005 | 617 | 926 | 18,937 | 27,601 |
| 2006 | 646 | 969 | 18,611 | 27,125 |
| 2007 | 405 | 608 | 19,306 | 28,138 |
| 2008 | 456 | 684 | 20,009 | 29,163 |
| 2009 | 483 | 725 | 23,227 | 33,853 |
| 2010 | 265 | 398 | 10,851 | 15,815 |
| 2011 | 381 | 572 | 14,088 | 20,533 |
| 2012 | 390 | 585 | 14,735 | 21,476 |
| 2013 | 419 | 629 | 16,666 | 24,291 |
| 2014 | 480 | 720 | 16,755 | 24,420 |
| 2015 | 464 | 696 | 18,097 | 26,376 |
| 2016 | 517 | 776 | 15,700 | 22,883 |
| 2017 | 457 | 686 | 13,915 | 20,281 |
| 2018 | 338 | 507 | 10,195 | 14,859 |

**Table 4.** Estimated observer mean kept and discard CPUE in weight (lbs.) and numbers for expansion estimates of vertical line GOM Cobia discards.

| Stable CPUE Period | Observer Kept CPUE | | Observer Discard CPUE | |
|---|---|---|---|---|
| | Pounds per hour | Number per hour | Pounds per hour | Number per hour |
| 2010-2018 | 0.71741 | 0.02981 | 0.17796 | 0.02261 |

**Table 5.** Time-series of CPUE expansion estimates for GOM Cobia 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 | 8,165.1 | 1,705.5 | 1,037.5 | 199.4 |
| 1994 | 8,453.9 | 1,765.9 | 1,074.2 | 206.5 |
| 1995 | 9,051.3 | 1,890.6 | 1,150.1 | 221.0 |
| 1996 | 11,060.6 | 2,310.3 | 1,405.4 | 270.1 |
| 1997 | 10,947.4 | 2,286.7 | 1,391.1 | 267.4 |
| 1998 | 10,622.9 | 2,218.9 | 1,349.8 | 259.4 |
| 1999 | 12,135.3 | 2,534.8 | 1,542.0 | 296.4 |
| 2000 | 11,895.3 | 2,484.7 | 1,511.5 | 290.5 |
| 2001 | 9,029.2 | 1,886.0 | 1,147.3 | 220.5 |
| 2002 | 10,856.9 | 2,267.8 | 1,379.6 | 265.1 |
| 2003 | 8,392.8 | 1,753.1 | 1,066.4 | 205.0 |
| 2004 | 8,056.8 | 1,682.9 | 1,023.8 | 196.8 |
| 2005 | 5,785.1 | 1,208.4 | 735.1 | 141.3 |
| 2006 | 5,857.0 | 1,223.4 | 744.2 | 143.0 |
| 2007 | 3,700.9 | 773.1 | 470.3 | 90.4 |
| 2008 | 4,187.3 | 874.7 | 532.1 | 102.3 |
| 2009 | 4,221.7 | 881.8 | 536.4 | 103.1 |
| 2010 | 2,814.5 | 587.9 | 357.6 | 68.7 |
| 2011 | 3,654.1 | 763.3 | 464.3 | 89.2 |
| 2012 | 3,821.9 | 798.3 | 485.6 | 93.3 |
| 2013 | 4,322.8 | 902.9 | 549.3 | 105.6 |
| 2014 | 4,345.7 | 907.7 | 552.2 | 106.1 |
| 2015 | 4,693.8 | 980.4 | 596.4 | 114.6 |
| 2016 | 4,072.2 | 850.6 | 517.4 | 99.5 |
| 2017 | 3,609.2 | 753.9 | 458.6 | 88.1 |
| 2018 | 2,644.2 | 552.3 | 336.0 | 64.6 |

**Table 6.** Number of total and Cobia coastal observer bottom longline trips by year for the GOM.

| Year | Total Trips | Cobia Trips |
|---|---|---|
| 2007 | 10 | 3 |
| 2008 | 5 | 2 |
| 2009 | 32 | 11 |
| 2010 | 51 | 12 |
| 2011 | 78 | 18 |
| 2012 | 19 | 7 |
| 2013 | 81 | 30 |
| 2014 | 27 | 16 |
| 2015 | 26 | 15 |
| 2016 | 55 | 28 |
| 2017 | 13 | 4 |
| 2018 | 4 | 3 |

**Table 7.** Definition of trip catch level strata for GOM Cobia, and corresponding percentages of logbook and observer bottom longline trips during 2009-2015 (stable CPUE period, see Fig. 7).

| | Stratum | % Trips | |
|---|---|---|---|
| Trip Catch Level | Code | Logbook | Observer |
| Low, catch ≤ 41 lbs. | L | 49.4 | 61.4 |
| High, catch > 41 lbs. | H | 50.6 | 38.6 |

**Table 8.** Cobia bottom longline effort and catch adjustment factors by catch level strata for the stable CPUE period 2009-2015 (see Fig. 7) in GOM. The proportions of Cobia observer trips and effort with kept Cobia were used to respectively adjust annual logbook total trips and effort (Table 9) to account for logbook trips that only had discarded fish. See Table 7 for definitions of catch level strata.

| Stable CPUE Period | Catch Level | Number of Observer Trips (n) | Proportion of Observer Data with Kept Cobia | |
|---|---|---|---|---|
| | | | Trips | Effort |
| 2009-2015 | L | 77 | 0.6623 | 0.6789 |
| | H | 32 | 1.0000 | 1.000 |

**Table 9.** Annual time-series of bottom longline logbook trips (number) and effort (sets) by catch level for GOM Cobia. See Table 7 for definitions of catch level strata.

| | | Logbook Trips | | Logbook Effort | |
|---|---|---|---|---|---|
| Year | Catch Level | Reported | Adjusted ($N$) | Reported | Adjusted ($\hat{X}$) |
| 1993 | L | 115 | 174 | 3,474 | 5,117 |
| | H | 77 | 77 | 2,378 | 2,378 |
| 1994 | L | 135 | 204 | 4,054 | 5,972 |
| | H | 150 | 150 | 4,853 | 4,853 |
| 1995 | L | 139 | 210 | 3,849 | 5,670 |
| | H | 127 | 127 | 3,159 | 3,159 |
| 1996 | L | 182 | 275 | 5,005 | 7,373 |
| | H | 186 | 186 | 4,282 | 4,282 |
| 1997 | L | 165 | 249 | 5,212 | 7,678 |
| | H | 175 | 175 | 5,545 | 5,545 |
| 1998 | L | 131 | 198 | 3,852 | 5,674 |
| | H | 169 | 169 | 5,125 | 5,125 |
| 1999 | L | 127 | 192 | 3,431 | 5,054 |
| | H | 205 | 205 | 6,386 | 6,386 |
| 2000 | L | 114 | 172 | 3,082 | 4,540 |
| | H | 171 | 171 | 5,028 | 5,028 |
| 2001 | L | 125 | 189 | 3,508 | 5,168 |
| | H | 145 | 145 | 3,804 | 3,804 |
| 2002 | L | 159 | 240 | 4,080 | 6,009 |
| | H | 178 | 178 | 5,103 | 5,103 |
| 2003 | L | 194 | 293 | 5,042 | 7,427 |
| | H | 235 | 235 | 5,743 | 5,743 |
| 2004 | L | 163 | 246 | 3,580 | 5,274 |
| | H | 224 | 224 | 5,204 | 5,204 |
| 2005 | L | 142 | 214 | 2,817 | 4,150 |
| | H | 172 | 172 | 3,653 | 3,653 |
| 2006 | L | 187 | 282 | 3,530 | 5,200 |
| | H | 215 | 215 | 5,040 | 5,040 |
| 2007 | L | 157 | 237 | 3,689 | 5,434 |
| | H | 135 | 135 | 3,644 | 3,644 |
| 2008 | L | 165 | 249 | 4,015 | 5,914 |
| | H | 165 | 165 | 4,427 | 4,427 |
| 2009 | L | 81 | 122 | 2,314 | 3,409 |
| | H | 84 | 84 | 2,371 | 2,371 |
| 2010 | L | 53 | 80 | 1,686 | 2,484 |
| | H | 40 | 40 | 1,261 | 1,261 |
| 2011 | L | 85 | 128 | 2,437 | 3,590 |
| | H | 81 | 81 | 2,511 | 2,511 |
| 2012 | L | 64 | 97 | 1,915 | 2,821 |
| | H | 93 | 93 | 2,952 | 2,952 |
| 2013 | L | 78 | 118 | 2,350 | 3,462 |
| | H | 108 | 108 | 3,353 | 3,353 |
| 2014 | L | 110 | 166 | 3,681 | 5,422 |
| | H | 123 | 123 | 4,332 | 4,332 |

| | | | | | |
|---|---|---|---|---|---|
| 2015 | L | 119 | 180 | 4,547 | 6,698 |
| | H | 145 | 145 | 5,312 | 5,312 |
| 2016 | L | 133 | 201 | 5,166 | 7,610 |
| | H | 138 | 138 | 4,963 | 4,963 |
| 2017 | L | 118 | 178 | 4,408 | 6,493 |
| | H | 104 | 104 | 4,097 | 4,097 |
| 2018 | L | 91 | 137 | 3,207 | 4,724 |
| | H | 58 | 58 | 2,578 | 2,578 |

**Table 10.** Estimated observer mean kept and discard CPUE in weight (lbs.) and numbers by catch level for expansion estimates of bottom longline GOM Cobia discards. See Table 7 for definitions of catch level strata.

| | | Observer Kept CPUE | | Observer Discard CPUE | |
|---|---|---|---|---|---|
| Stable CPUE Period | Catch Level | Pounds per hour | Number per hour | Pounds per hour | Number per hour |
| 2009-2015 | L | 0.53728 | 0.04363 | 0.27978 | 0.03449 |
| | H | 2.29081 | 0.07137 | 0.45584 | 0.03737 |

**Table 11.** Time-series of CPUE expansion estimates for GOM Cobia 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 | 2,417.9 | 752.2 | 256.4 | 46.7 |
| 1994 | 3,658.8 | 1,138.3 | 372.5 | 67.8 |
| 1995 | 3,661.6 | 1,139.1 | 376.6 | 68.5 |
| 1996 | 5,019.8 | 1,561.7 | 511.0 | 93.0 |
| 1997 | 4,795.9 | 1,492.0 | 484.1 | 88.1 |
| 1998 | 4,184.9 | 1,301.9 | 416.1 | 75.7 |
| 1999 | 4,762.8 | 1,481.7 | 459.1 | 83.5 |
| 2000 | 4,078.2 | 1,268.7 | 398.0 | 72.4 |
| 2001 | 3,446.9 | 1,072.3 | 349.4 | 63.6 |
| 2002 | 4,482.4 | 1,394.5 | 447.6 | 81.5 |
| 2003 | 6,095.4 | 1,896.3 | 607.1 | 110.5 |
| 2004 | 5,738.9 | 1,785.4 | 558.7 | 101.7 |
| 2005 | 4,480.8 | 1,394.0 | 446.6 | 81.3 |
| 2006 | 5,532.0 | 1,721.0 | 552.5 | 100.5 |
| 2007 | 3,825.9 | 1,190.2 | 393.6 | 71.6 |
| 2008 | 4,501.3 | 1,400.4 | 457.5 | 83.3 |
| 2009 | 2,034.5 | 632.9 | 206.2 | 37.5 |
| 2010 | 1,269.7 | 395.0 | 132.8 | 24.2 |
| 2011 | 2,149.0 | 668.5 | 217.6 | 39.6 |
| 2012 | 2,134.9 | 664.2 | 207.6 | 37.8 |
| 2013 | 2,496.9 | 776.8 | 244.7 | 44.5 |
| 2014 | 3,491.7 | 1,086.3 | 348.9 | 63.5 |
| 2015 | 4,295.4 | 1,336.3 | 429.5 | 78.2 |
| 2016 | 3,774.9 | 1,174.4 | 380.2 | 69.2 |
| 2017 | 2,951.9 | 918.3 | 305.8 | 55.7 |
| 2018 | 1,827.1 | 568.4 | 193.5 | 35.2 |

**Table 12.** Comparison of reef fish observer program and discard logbook program estimates for GOM Cobia vertical line discards in number.

| | Estimated Discards in Number | |
|---|---|---|
| Year | Reef Fish Observer Program | Discard Logbook Program |
| 1993 | 1,037.5 | 4,274.9 |
| 1994 | 1,074.2 | 4,677.5 |
| 1995 | 1,150.1 | 4,445.9 |
| 1996 | 1,405.4 | 4,956.6 |
| 1997 | 1,391.1 | 5,553.1 |
| 1998 | 1,349.8 | 4,938.1 |
| 1999 | 1,542.0 | 5,414.0 |
| 2000 | 1,511.5 | 5,151.6 |
| 2001 | 1,147.3 | 5,411.4 |
| 2002 | 1,379.6 | 21,360.9 |
| 2003 | 1,066.4 | 5,266.6 |
| 2004 | 1,023.8 | 2,215.1 |
| 2005 | 735.1 | 3,425.2 |
| 2006 | 744.2 | 824.9 |
| 2007 | 470.3 | 11,392.8 |
| 2008 | 532.1 | 4,676.6 |
| 2009 | 536.4 | 6,697.8 |
| 2010 | 357.6 | 1,205.6 |
| 2011 | 464.3 | 373.6 |
| 2012 | 485.6 | 659.4 |
| 2013 | 549.3 | 1,778.6 |
| 2014 | 552.2 | 1,397.5 |
| 2015 | 596.4 | 592.9 |
| 2016 | 517.4 | 4,913.4 |
| 2017 | 458.6 | 1,856.4 |
| 2018 | 336.0 | 2,822.5 |

**Table 13.** Time-series of adjusted estimates for FEC Cobia vertical line discards in number (with associated standard errors).

| | Adjusted Estimates | |
|---|---|---|
| | Discards in | |
| Year | Number | SE |
| 1993 | 105.1 | 61.8 |
| 1994 | 108.9 | 64.0 |
| 1995 | 116.5 | 68.5 |
| 1996 | 142.4 | 83.7 |
| 1997 | 141.0 | 82.9 |
| 1998 | 136.8 | 80.4 |
| 1999 | 156.3 | 91.9 |
| 2000 | 153.2 | 90.0 |
| 2001 | 116.3 | 68.4 |
| 2002 | 139.8 | 82.2 |
| 2003 | 108.1 | 63.5 |
| 2004 | 103.7 | 61.0 |
| 2005 | 74.5 | 43.8 |
| 2006 | 75.4 | 44.3 |
| 2007 | 47.7 | 28.0 |
| 2008 | 53.9 | 31.7 |
| 2009 | 54.4 | 32.0 |
| 2010 | 36.2 | 21.3 |
| 2011 | 47.1 | 27.7 |
| 2012 | 49.2 | 28.9 |
| 2013 | 55.7 | 32.7 |
| 2014 | 56.0 | 32.9 |
| 2015 | 60.4 | 35.5 |
| 2016 | 52.4 | 30.8 |
| 2017 | 46.5 | 27.3 |
| 2018 | 34.0 | 20.0 |

**Figure 1.** Map of sampling areas in the Gulf of Mexico (map provided by B. Wrege).

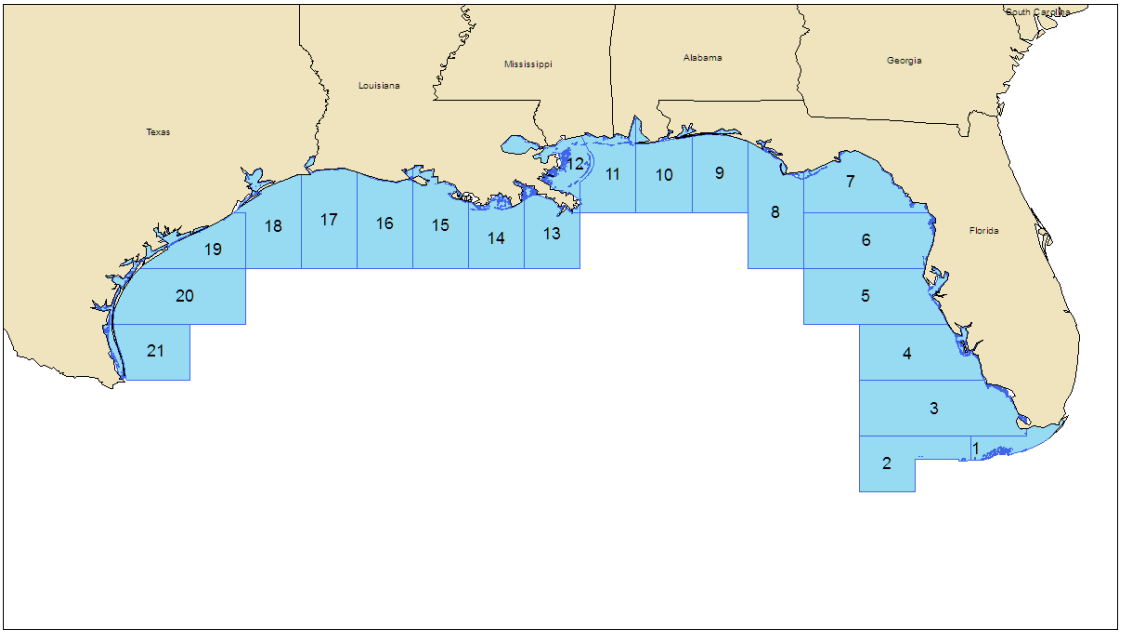


**Figure 2.** Length-frequency plots of observer vertical line GOM Cobia for kept (landed) and discarded fish. Discard plots are shown for trips with no kept Cobia and for trips with kept Cobia. Vertical dashed lines denote the minimum size limit of 33" FL (838 mm FL); *n* is number of measured fish.

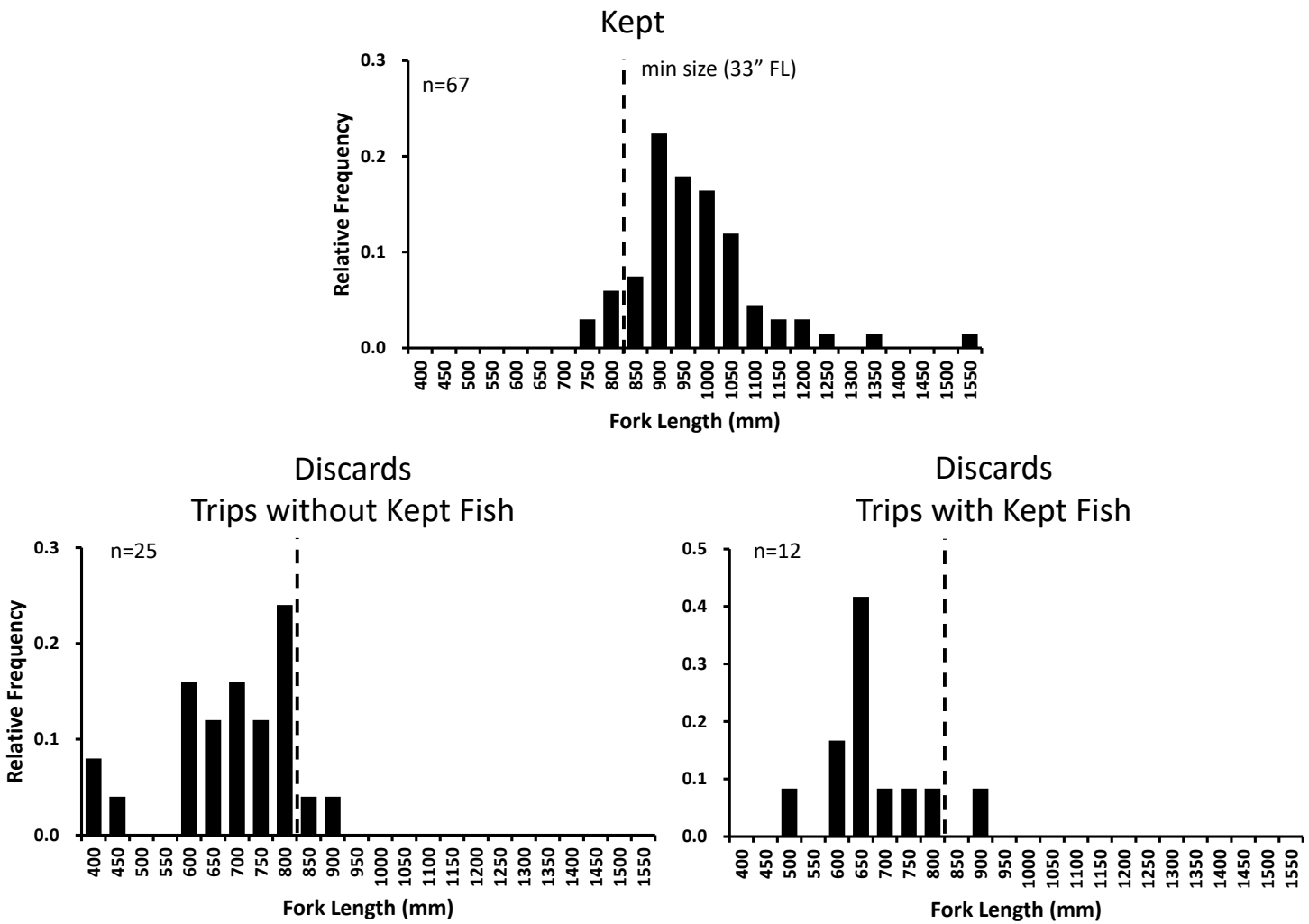


**Figure 3.** CPUE (catch in whole pounds per hour) time-series for logbook data from 1993 – 2018 for vertical line trips landing GOM Cobia, showing the observer time period (2007-2018) and the stable CPUE period within the observer time period (2010-2018).

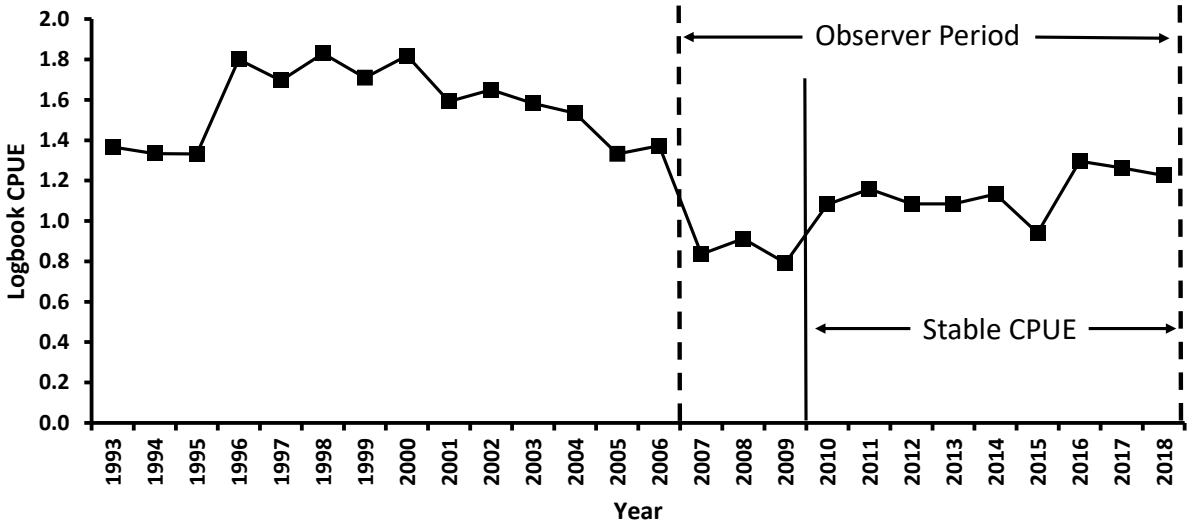



**Figure 4.** Comparison of vertical line reported annual logbook landings of GOM Cobia (solid black line) with CPUE expansion estimates from observer data (open squares). Error bars (SE) are shown for observer estimates.

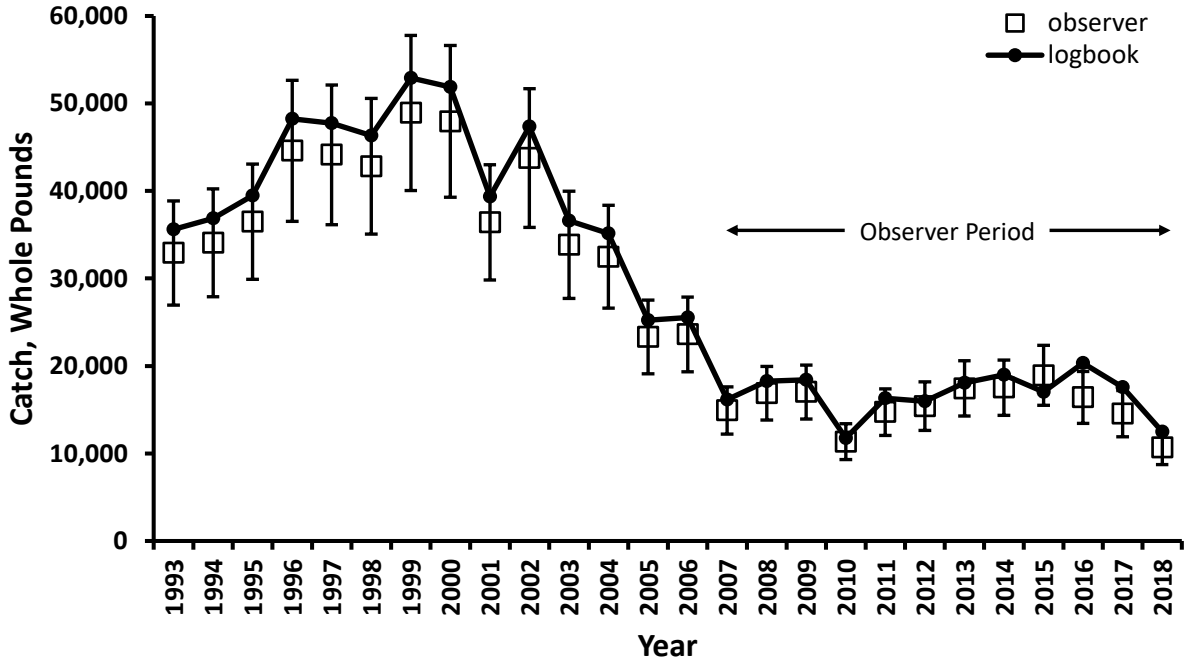
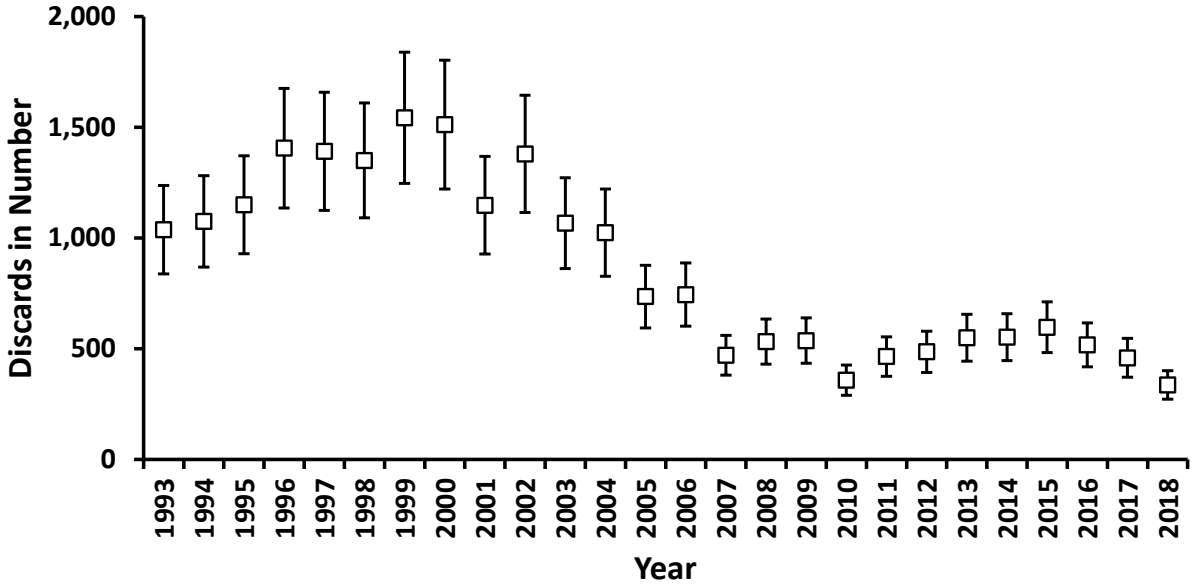


**Figure 5.** Observer CPUE expansion estimates of GOM Cobia vertical line annual discards (±SE) in (A) number and (B) weight expressed as percentage of total catch (kept + discards) for 1993-2018.

**(A) Discards in Number**




**(B) Discards in Weight, Percentage of Total Catch**

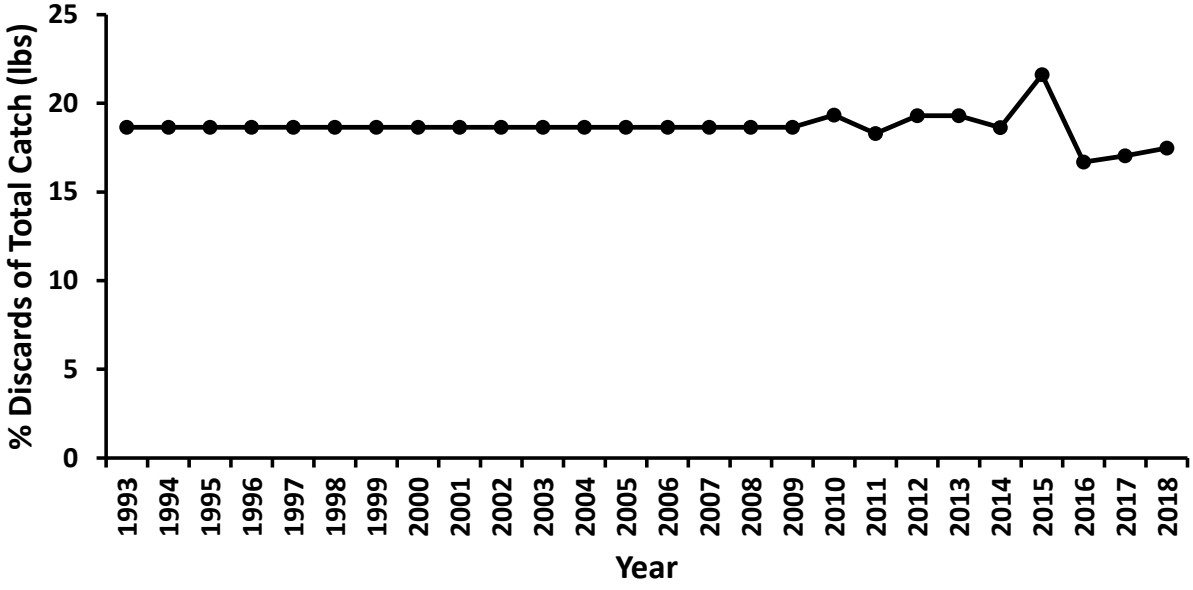


**Figure 6.** Length-frequency plots of observer bottom longline GOM Cobia for kept (landed) and discarded fish. Discard plots are shown for trips with no kept Cobia and for trips with kept Cobia. Vertical dashed lines denote the minimum size limit of 33" FL (838 mm FL); *n* is number of measured fish.

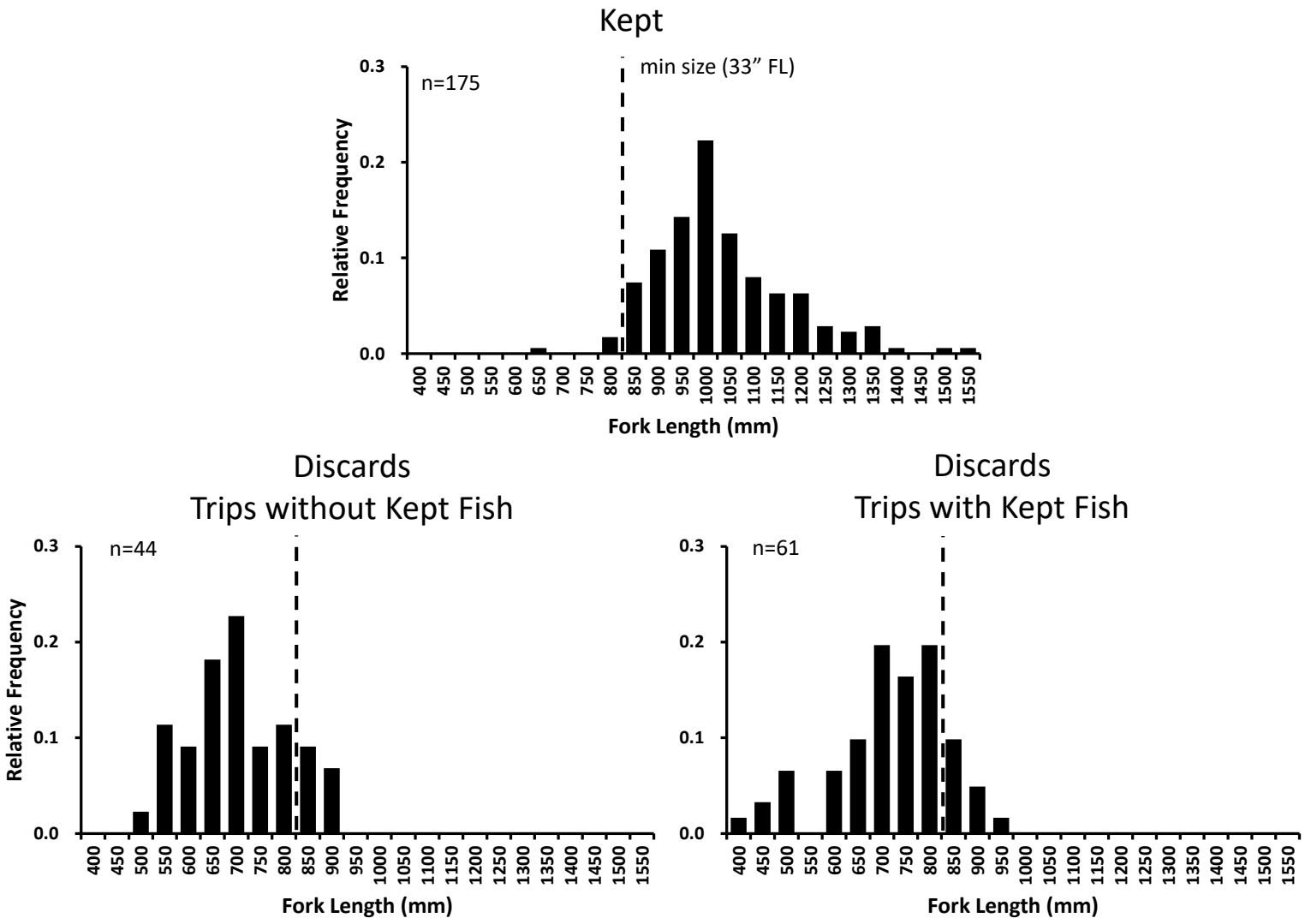


**Figure 7.** CPUE (catch in whole pounds per hour) time-series for logbook data from 1993 – 2018 for bottom longline trips landing GOM Cobia, showing the observer time period (2007-2018) and the stable CPUE period within the observer time period (2009-2015).

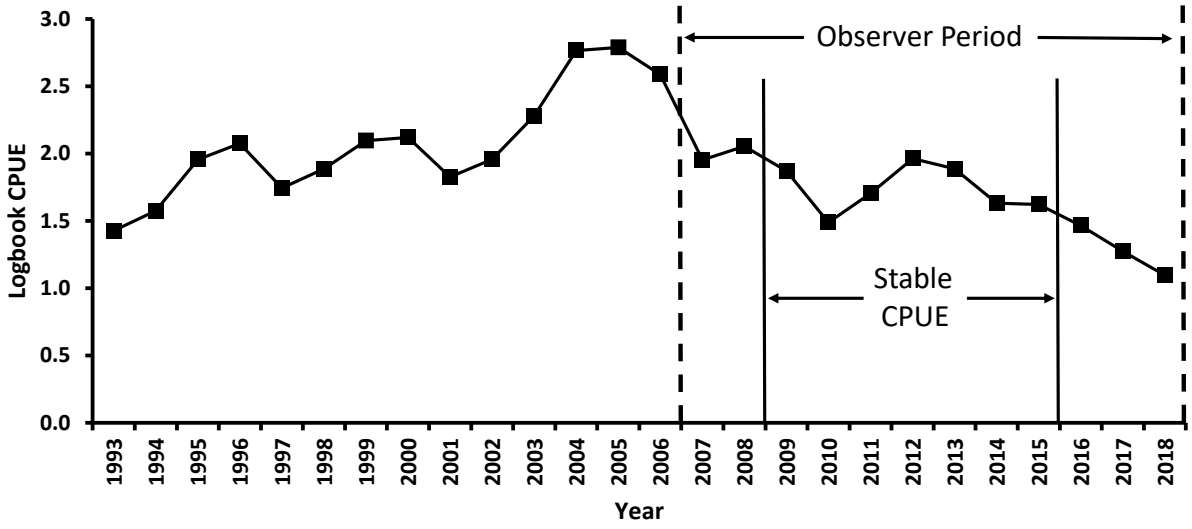



**Figure 8.** Comparison of bottom longline reported annual logbook landings of GOM Cobia (solid black line) with CPUE expansion estimates from observer data (open squares). Error bars (SE) are shown for observer estimates.

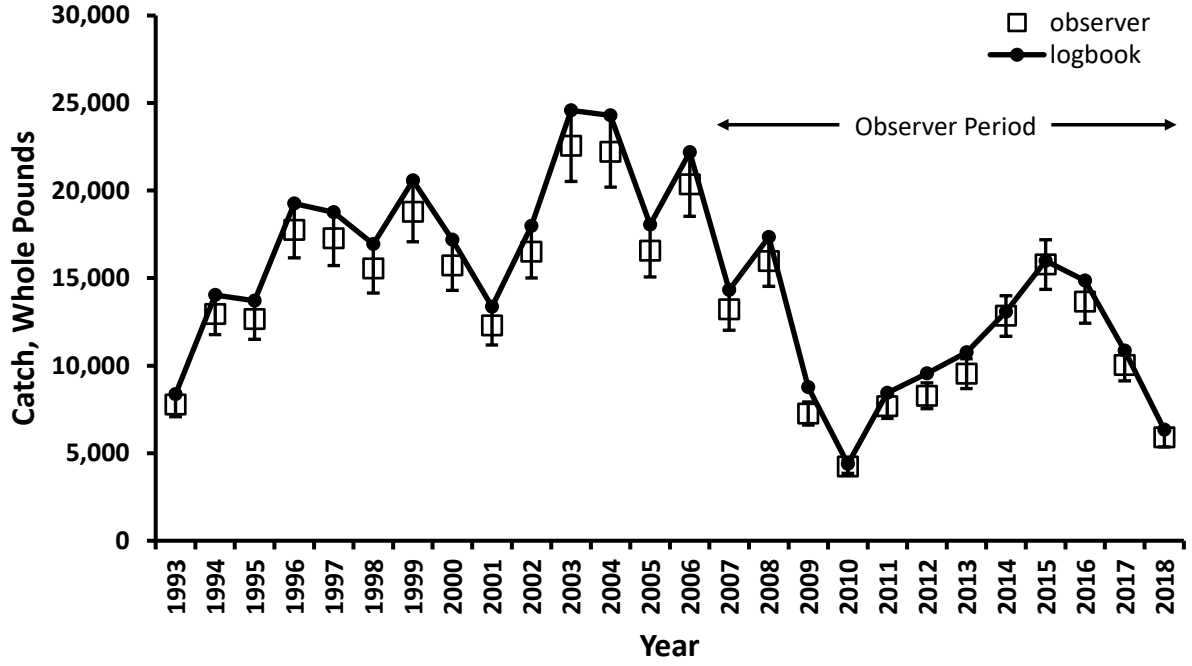
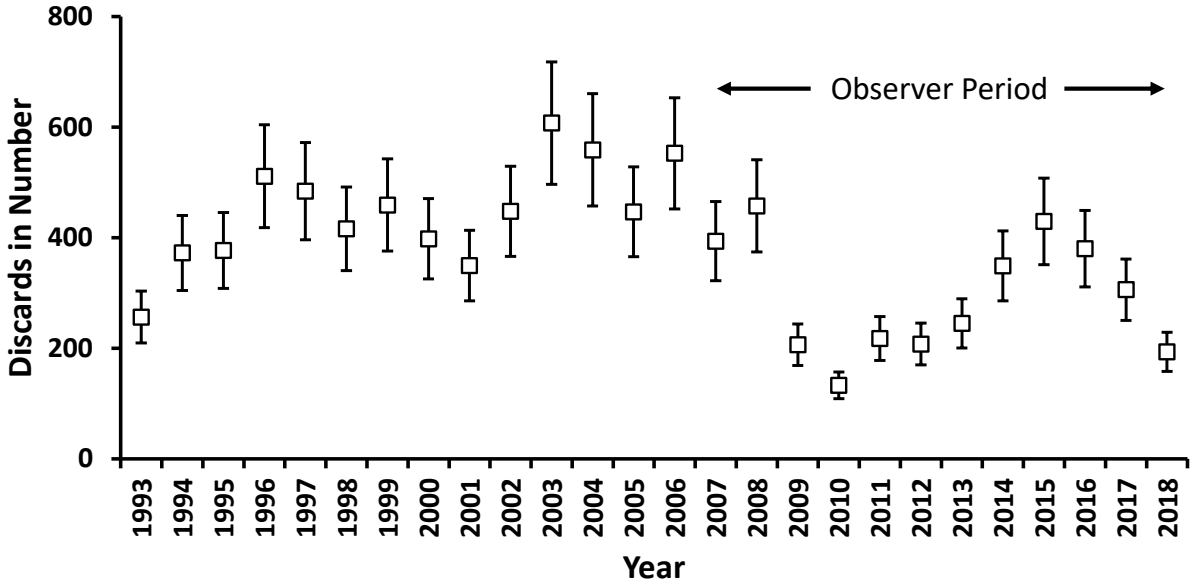


**Figure 9.** Observer CPUE expansion estimates of GOM Cobia bottom longline annual discards (±SE) in (A) number and (B) weight expressed as percentage of total catch (kept + discards) for 1993-2018.

**(A) Discards in Number**




**(B) Discards in Weight, Percentage of Total Catch**