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SEDAR 62 Working Paper

Proposed CPUE Expansion Estimation for Total Discards of Gulf of Mexico Gray Triggerfish

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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, and released in unknown condition. 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) to Gulf of Mexico gray triggerfish, with several species-specific modifications: (i) inclusion of spatial strata; (ii) exclusion of bottom longline gear; (iii) accounting for changing stock CPUE during the pre-observer time period (years prior to 2007); and (iv) refinement of standard error calculations for the pre-observer time period.

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 (GMFMC 2005). 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 gray triggerfish discard estimation, complete calendars years 2007-2017 were utilized. 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 gray triggerfish discard estimation, complete calendar years 2000-2017 were utilized.

Relevant Management History of GOM Gray Triggerfish

Three management changes to the commercial GOM gray triggerfish fishery are relevant to this analysis. Minimum size increased in July 2008 from 12 inches total length (270 mm fork length) to 14 inches fork length (356 mm). Beginning in 2010, a seasonal closure went into effect for all areas during the months of June and July. In 2012, an Annual Catch Limit (ACL) was enacted for GOM gray triggerfish, resulting in closures in 2012 (July 1, 2012 – Dec. 31, 2012) and 2017 (Nov. 17, 2017 – Dec. 31, 2017). Additionally, in 2013 a trip limit of 12 fish per boat per day went into effect.

Trip-Level Catch for Observer Data

Observers collected catch data at a sub-trip level (e.g., a specific longline set or a specific 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 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).

Catch Expansion Procedures and Verification

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

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

where $\overline{CPUE}$ is observer mean CPUE and $\hat{X}$ is total logbook nominal effort. Mean CPUE was estimated by

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

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

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

$\bar{x}$ 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

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

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 $\hat{C}$ can also be represented as

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

Standard error of total catch was calculated as

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

Species- and gear-specific logbook annual 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.

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

Modifications for GOM Gray Triggerfish

Several species-specific modifications were made to the general discard calculation methodology described in SEDAR Working Paper 61-15 (Smith et al. 2018): (i) inclusion of spatial strata; (ii) exclusion of bottom longline gear; and (iii) refinement of procedures for hindcasting estimates of catch and discards for the pre-observer time period (years prior to 2007) using data from the observer time period (2007-2017).

Spatial Strata

Following methods in SEDAR 43, the GOM was divided into East and West spatial strata for discard estimation of gray triggerfish, with statistical zones 1-12 defined as East, and zones 13-21 defined as West (**Fig. 1**).

Gear

For the period 2007 – 2017, vertical line gear accounted for 91% of the reported logbook catch of GOM gray triggerfish, bottom longline gear accounted for 6%, and other gears (spears, etc.) accounted for 3%. In the coastal observer data, gray triggerfish were rarely observed on bottom longline trips. Thus, discard estimation was conducted exclusively for vertical line gear.

Hindcast Procedures

The hindcast discard estimation procedures of Smith et al. (2018) assumed a stable CPUE over the full analysis time period (pre-observer and observer). An alternate method was developed for species exhibiting trends in CPUE over the analysis time frame. An initial evaluation of logbook CPUE time-series by strata for potential trends was conducted to guide selection of the appropriate hindcast method. Annual estimates of logbook CPUE were computed as the sum of annual catch in pounds whole weight over all trips divided by the sum of effort in fishing time over all trips. The two hindcast methods were:

Stable CPUE Hindcast Method—The average observer CPUE in number and weight for the observer time period was used to hindcast the respective total annual landed catch and discards in number and weight using logbook effort for the pre-observer time period.

Trending CPUE Hindcast Method—The average annual ratio of observer CPUE in weight to logbook CPUE was computed for the observer time period. This ratio was then multiplied by the annual logbook CPUE for the pre-observer time period to produce an estimated annual observer CPUE. Then, following the stable CPUE hindcast method, the annual observer CPUE was multiplied by 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.

An important aspect for either hindcast method was selection of the specific years within the observer time period (2007-2017) that best matched the conditions of the pre-observer time period with respect to landed catch and discards. For GOM gray triggerfish, management changes in size limits, catch limits, etc., likely impacted the number of annual discarded fish. To guide selection of appropriate time frames for hindcasting, time-series of annual length compositions for kept and discarded fish from observer sampling were evaluated with respect to changes in regulations for GOM gray triggerfish.

Methods described in SEDAR Working Paper 61-15 for estimating standard errors for the hindcast period were also refined. The ratio of the standard error to the mean, i.e., the coefficient of variation (CV), was used for the hindcast procedure for both the stable and trending methods. This approach made use of the following property,

$$CV\left[\hat{C}\right] = \frac{SE[\hat{C}]}{\hat{C}} = \frac{\sqrt{var[\overline{CPUE}]\times\hat{X}^2}}{\overline{CPUE}\times\hat{X}} = \frac{SE[\overline{CPUE}]}{\overline{CPUE}} = CV[\overline{CPUE}]$$

i.e., that the CV of total catch $\hat{C}$ is identical to the CV of mean CPUE (Cochran 1977). Estimation was carried out in two steps: (i) the average annual CV of observer CPUE was computed for the target quantity (landed catch or discards in numbers or weight) for the observer time period; (ii) this average CV was multiplied by the respective annual total (catch or discards in number or weight) for each year in the pre-observer period to estimate the annual standard error.

Verification for each method 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. The appropriate hindcast method was then used to calculate discards in weight and number.

Results and Discussion

The observer database included 1,189 vertical line trips with corresponding trip and set information. Observer sampling effort is summarized in **Table 1**, distinguishing all trips from trips that captured gray triggerfish. The proportions of observer trips and effort encountering gray triggerfish that had kept fish are given in **Table 2** by year and spatial strata. These proportions were used to adjust the logbook total gray triggerfish trips and effort to account for logbook trips that only had discarded fish.

Inspection of the annual CPUE (catch in whole pounds per hour) from logbook trips reporting gray triggerfish in both the East and West spatial strata showed distinct trends over time (**Fig. 2**). In the East stratum, logbook CPUE doubled from 2000 to 2003, declined through 2009 to levels below those at the start of the time-series, and then was stable with minor

fluctuations through 2017 (**Fig. 2A**). In the West stratum, logbook CPUE declined steadily from 2000 through 2013, and then remained at low levels through 2017 (**Fig. 2B)**.

The length distributions of kept and discarded fish from observer data changed over the observer time frame (2007-2017), generally corresponding with management changes (**Fig. 3**). For 2007-2008, discards of GOM gray triggerfish were mostly fish near or below the minimum size limit of 12 inches total length (271 mm fork length), and kept fish were mostly above the minimum size limit. This was also the case for 2009-2011, the years following the increase in minimum size to 14 inches fork length (356 mm), with a corresponding increase in the size range of discarded fish. The length distributions of discarded fish were similar between trips with kept fish and trips with no kept fish in 2010-2011 following implementation of a seasonal closure (June-July) for GOM gray triggerfish in 2010. For the years 2012-2017, discards included fish below and above the minimum size limit corresponding with catch limit closures (annual catch limit closure in 2012 and 2017, trip catch limits 2013-2017).

Viewing the data of **Fig. 3** in light of the management history for gray triggerfish, the observer time period was divided into four management regimes:

I. 2007-2008, pre-management changes.

II. 2009-2011, increased minimum size, implementation of closed seasons.

III. 2012, implementation of annual catch limit resulting in fishery closure for half the year.

IV. 2013-2017, implementation of trip catch limits.

The fishery conditions for kept and discarded fish were considered to be more or less similar within a management regime, and substantially different among regimes.

CPUE expansion estimates of annual total landed catch of GOM gray triggerfish compared favorably with reported logbook landings for the observer period (2007-2017) (**Fig. 4**). For hindcasting total landed catch, observer CPUE data for years 2007-2008, the pre-management change time frame, were used to carry out the expansion estimates for the stable CPUE method. In contrast, the trending CPUE method for hindcasting total landed catch utilized data from the full observer period 2007-2017, since the ratio of observer CPUE to logbook CPUE of landed fish in a given year should not be affected by changes in annual CPUE due to changes in stock abundance or fishery regulations. As suggested by **Fig. 2**, the trending CPUE method for hindcasting total landed catch provided a better match with the historical logbook reported catch compared to the stable CPUE method (**Fig. 5**).

Low observer sampling effort for gray triggerfish trips may have affected expansion estimates during the observer period. In particular, fewer than 3 trips were sampled in the West stratum in 2009 and 2010 (**Table 1B**). Catch estimates were very low for these two years (**Fig. 4B**, open squares). Imputation of catch estimates for these years using the trending CPUE hindcast method compared more favorably with the logbook reported catch.

The trending CPUE method was selected for hindcasting discard estimates for the pre-observer period, as well as for imputing discard estimates for years with low sampling effort during the observer period. The CPUE of discarded fish in weight was higher in 2009 and later years compared to 2007-2008 (**Fig. 6**), corresponding with management changes (size limits, seasonal closures, catch limits) and changes in length composition of discards (**Fig. 3**). Data from the pre-management change regime (2007-2008) appeared to be the most representative of discard conditions during the pre-observer period, and were thus used for hindcasting. For the

observer period, imputation methods were applied for years with either low sample size (n<3) or no sampling during fishery closures (**Table 1**, shaded values). The time frame for imputation was restricted to the corresponding management regime.

CPUE expansion estimates for annual discards of GOM gray triggerfish for 2000-2017 are shown in **Fig. 7** for numbers and weight. The time-series of discard estimates is also provided in Table 3. These results suggest very low discards of GOM gray triggerfish during 2000-2008, prior to management changes of 2009 and later.

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Table 1. Number of GOM total and gray triggerfish coastal observer vertical line trips by year for (**A**) East and (**B**) West spatial strata. Fishery closures (season, catch limit) began in 2010. Shaded values denote low observer sampling effort for gray triggerfish trips.

(A) East

	Total Trips		Gray Triggerfish Trips	
Year	Open	Closed	Open	Closed
2007	71	-	36	-
2008	32	-	7	-
2009	37	-	11	-
2010	38	11	16	3
2011	70	7	33	5
2012	174	32	99	14
2013	86	24	44	7
2014	78	11	37	2
2015	131	33	62	11
2016	90	24	45	11
2017	40	15	21	8

(B) West

	Total Trips		Gray Triggerfish Trips	
Year	Open	Closed	Open	Closed
2007	16	-	8	-
2008	12	-	4	-
2009	7	-	1	-
2010	3	1	1	1
2011	10		9	0
2012	28	6	14	1
2013	5	7	2	2
2014	15	3	5	0
2015	26	9	18	7
2016	21	4	11	1
2017	8	4	3	0

Table 2. Summary of observer and logbook trips (number) and effort (hours) for GOM gray triggerfish in the (**A**) East and (**B**) West spatial strata.

(A) East

Year	Number of Observer Trips (n)	Proportion of Observer Data with Kept Gray Triggerfish		Logbook Trips		Logbook Effort	
		Trips	Effort	Reported	Adjusted (N)	Reported	Adjusted $(\hat{X})$
2007	36	0.8611	0.9164	1102	1279.7	46533	50776.1
2008	7	0.8571	0.7888	1130	1318.3	45965.5	58273.8
2009	11	0.7273	0.8282	1387	1907.1	65167	78687.1
2010	18	0.8333	0.7884	1135	1362	48217	61154.4
2011	38	0.9474	0.9552	1413	1491.5	63541	66523.3
2012	113	0.5398	0.5716	843	1561.6	39801	69632.3
2013	51	0.7255	0.7596	1036	1428	46313	60972
2014	39	0.8462	0.8616	973	1149.9	44034.5	51109.3
2015	73	0.6301	0.7211	1058	1679	39510	54788.3
2016	56	0.6964	0.8148	1168	1677.1	49413	60646
2017	29	0.4828	0.4472	1127	2334.5	43682	97684.1

(B) West

Year	Number of Observer Trips (n)	Proportion of Observer Data with Kept Gray Triggerfish		Logbook Trips		Logbook Effort	
		Trips	Effort	Reported	Adjusted (N)	Reported	Adjusted $(\hat{X})$
2007	8	1.0000	1.0000	496	496	29534	29534
2008	4	1.0000	1.0000	356	356	19915	19915
2009	1	Insufficient number of observer trips					
2010	2	Insufficient number of observer trips					
2011	9	0.8889	0.9821	220	247.5	11685	11898.1
2012	15	0.6000	0.4094	143	238.3	7937.3	19389.5
2013	4	0.2500	0.6758	135	540	7174	10615.8
2014	5	0.6000	0.7132	109	181.7	5474	7675.4
2015	25	0.4000	0.4824	121	302.5	6173	12795.3
2016	12	0.5000	0.8170	151	302	7280	8910.8
2017	3	1.0000	1.0000	101	101	5011	5011

Table 3. Observer CPUE-expansion estimates of GOM gray triggerfish annual discards (±SE) in number and weight for 2000-2017 for the (**A**) East and (**B**) West spatial strata.

(A) East

Year	Estimated Discards in Weight	SE of Estimated Discards in Weight	Estimated Discards in Number	SE of Estimated Discards in Number
2000	599.6	277.8	647.6	326.0
2001	974.1	451.3	1052.2	529.6
2002	1404.4	650.6	1516.9	763.5
2003	1794.3	831.3	1938.1	975.5
2004	1322.9	612.9	1428.9	719.2
2005	1136.0	526.3	1227.0	617.6
2006	603.9	279.8	652.3	328.3
2007	833.6	247.2	763.7	235.6
2008	272.3	171.6	338.8	236.5
2009	33656.0	31267.2	16417.3	15056.0
2010	13707.2	7031.6	7990.0	3801.2
2011	32935.6	13829.2	18618.2	8147.4
2012	51784.5	8921.4	21535.9	4373.3
2013	18810.4	4562.5	8764.8	2379.8
2014	15854.3	6462.0	6932.3	2857.4
2015	18052.5	4019.8	7084.5	1314.4
2016	41457.0	15450.2	15781.3	5386.1
2017	73856.5	21629.3	23839.4	7086.9

Table 3 (cont.)

(B) West

Year	Estimated Discards in Weight	SE of Estimated Discards in Weight	Estimated Discards in Number	SE of Estimated Discards in Number
2000	368.1	233.5	303.6	192.5
2001	284.0	180.1	234.2	148.5
2002	388.4	246.3	320.3	203.2
2003	352.1	223.3	290.4	184.2
2004	343.8	218.1	283.6	179.8
2005	178.2	113.0	147.0	93.2
2006	151.1	95.9	124.6	79.0
2007	0.0	0.0	0.0	0.0
2008	223.9	284.1	184.7	234.3
2009	2754.7	1863.0	1111.8	754.7
2010	1505.8	1018.4	607.8	412.5
2011	2020.8	1366.6	815.6	553.6
2012	16666.2	5393.4	4541.5	1603.7
2013	4208.7	5140.8	1459.0	1775.0
2014	3303.1	2224.8	1462.4	947.7
2015	6801.0	1503.2	2116.2	517.8
2016	4032.4	1733.5	1110.2	467.0
2017	2741.2	1846.3	1213.6	786.5

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

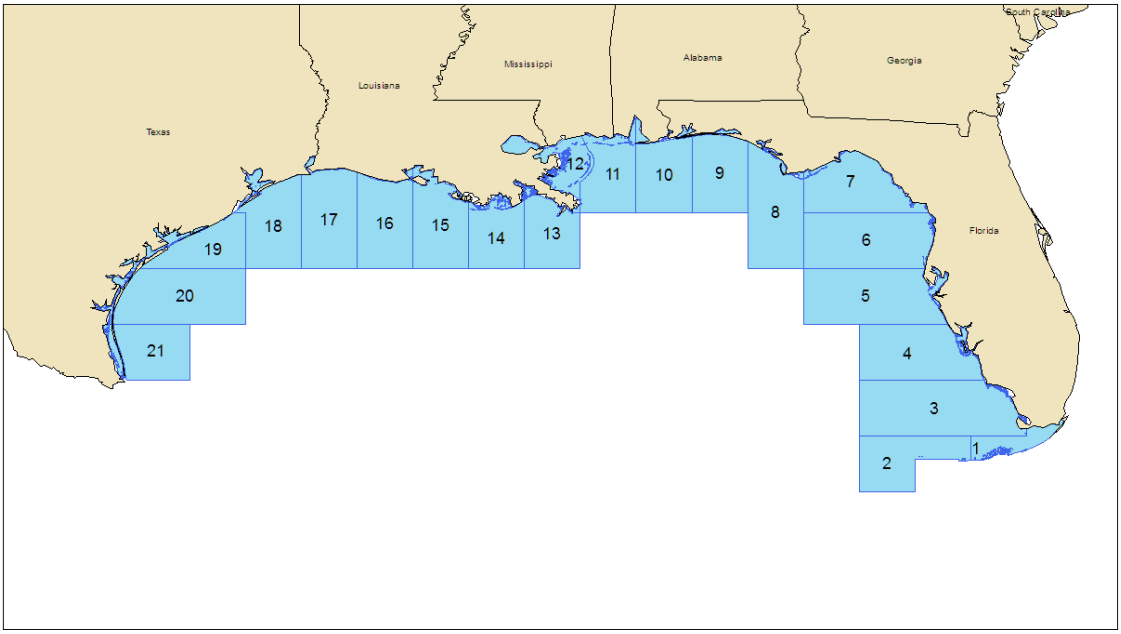


Figure 2. CPUE (catch in whole pounds per hour) time-series for logbook data from 2000 – 2017 for trips landing GOM gray triggerfish in the (**A**) East and (**B**) West spatial strata.

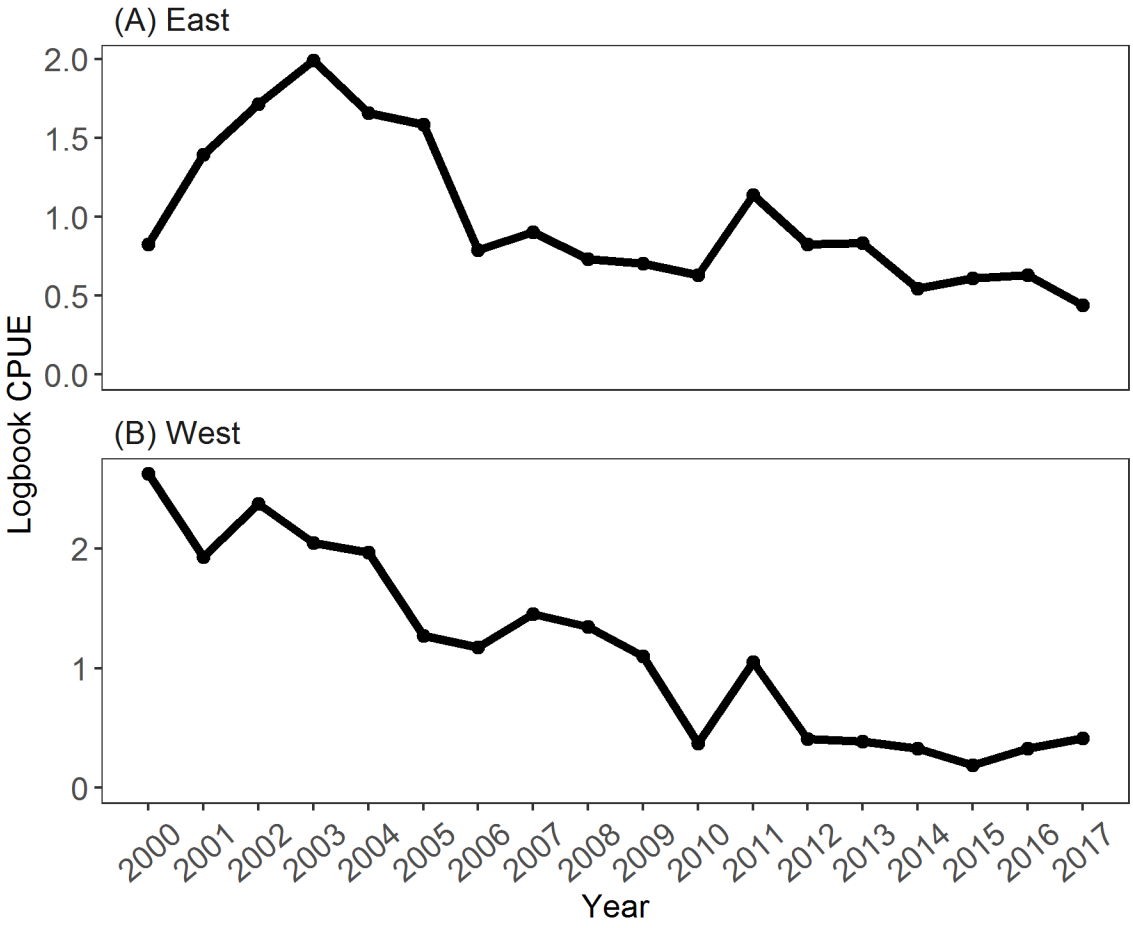


Figure 3. Length-frequency plots of observer GOM gray triggerfish by disposition (Kept or Discard) by year for combined spatial strata. 'Discards Only' were discards from trips with no kept gray triggerfish; 'Discards with Kept' were discards from trips with kept gray triggerfish. Vertical dashed lines denote the minimum size limit in effect for a given year.

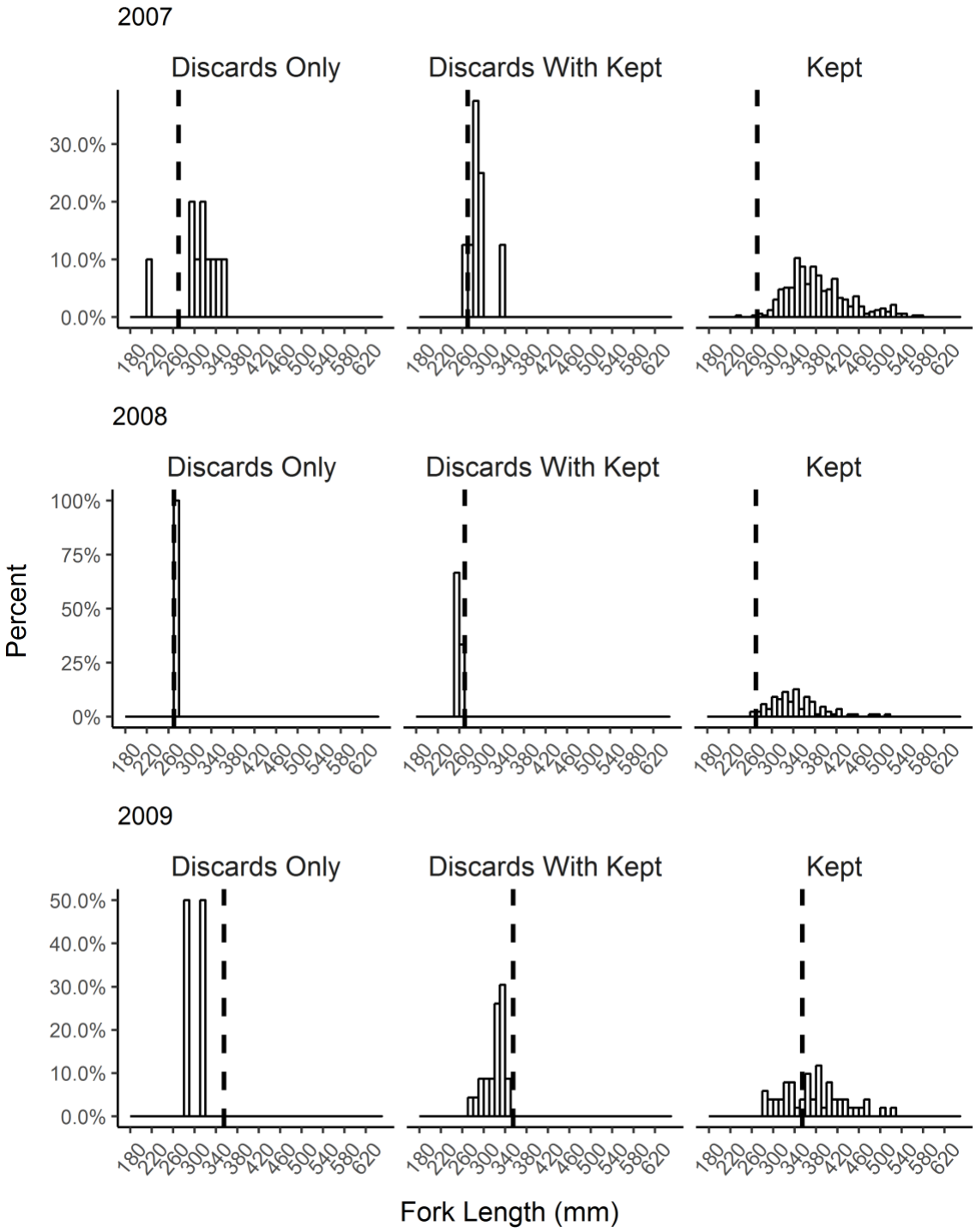


Figure 3 (cont.)

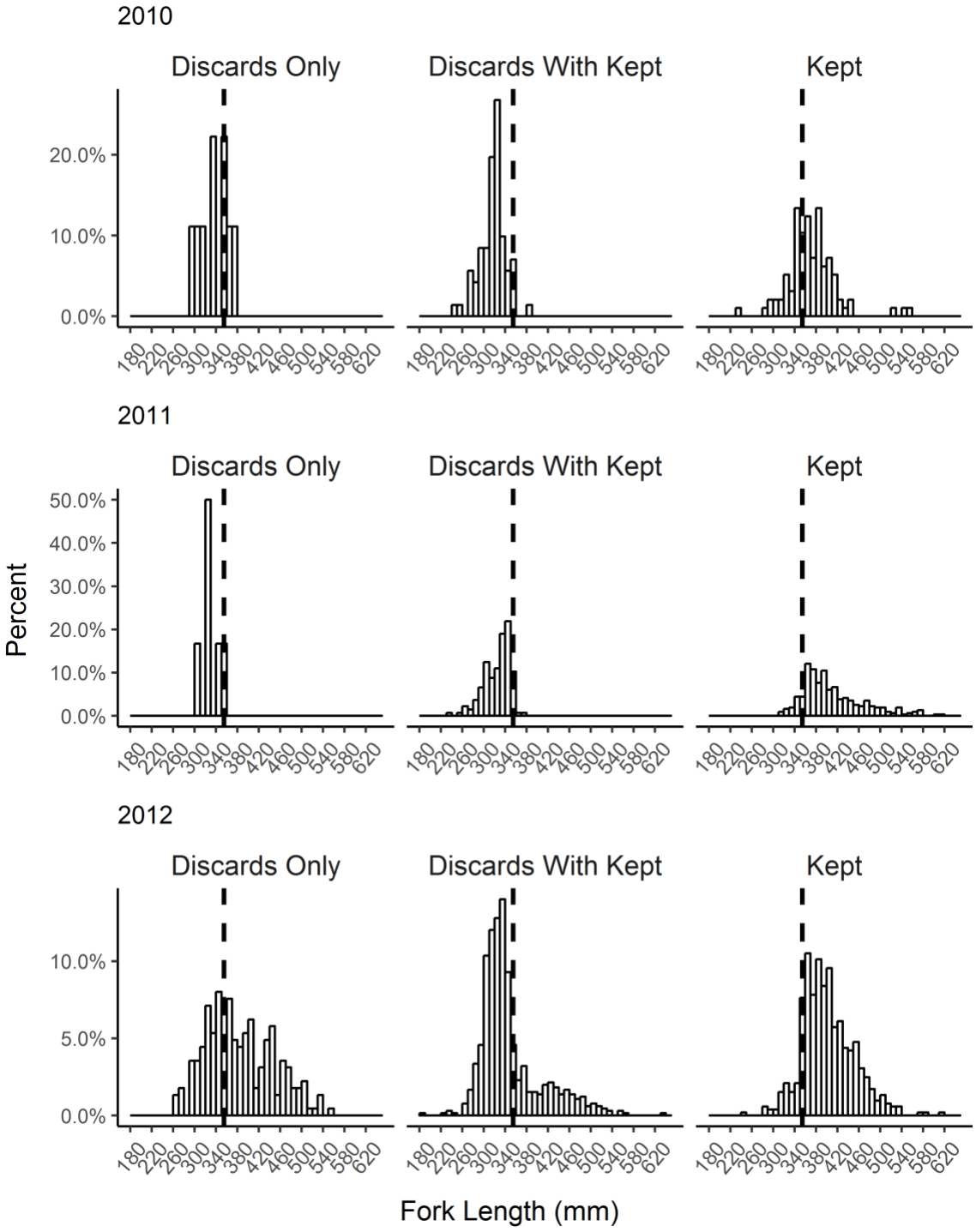
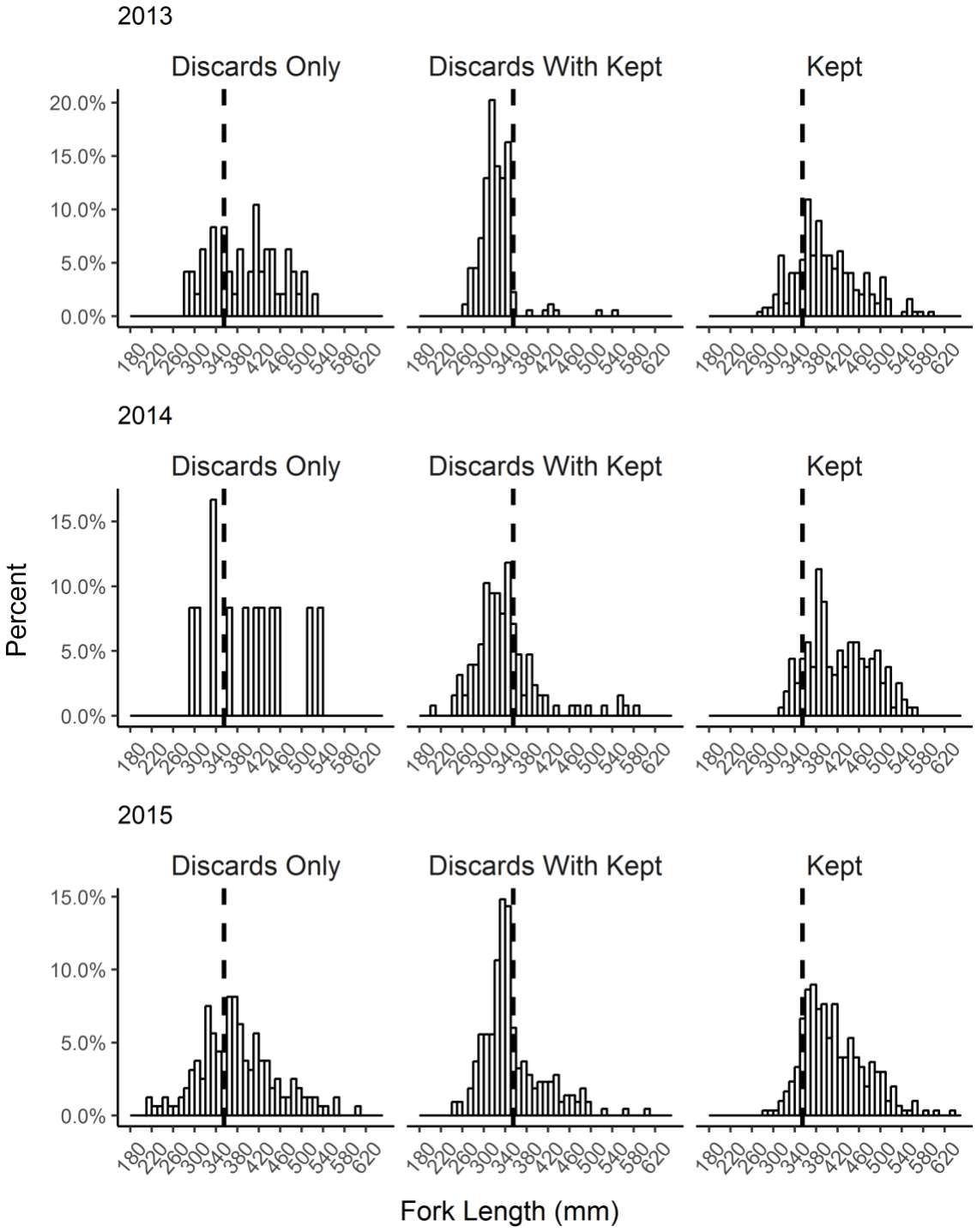


Figure 3 (cont.)



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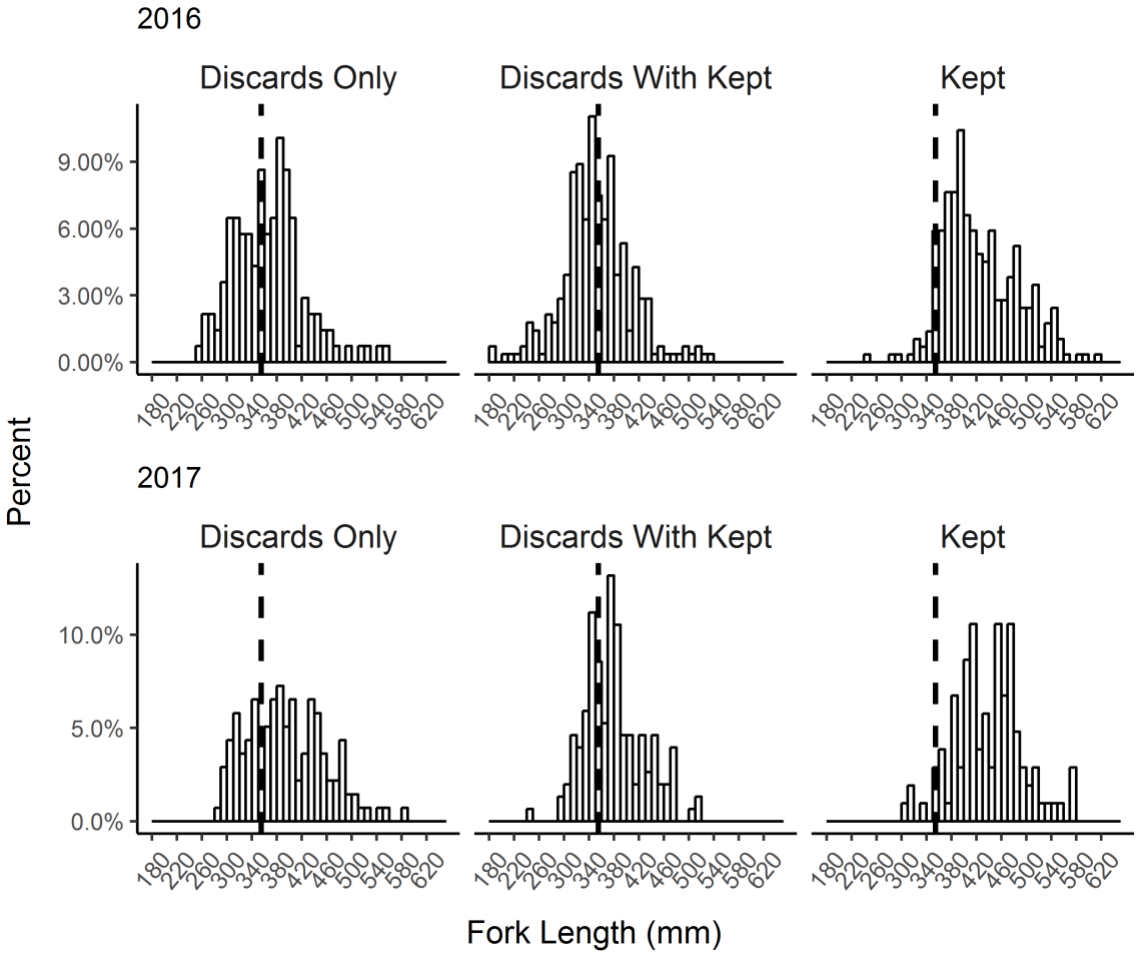

Figure 4. Comparison of annual logbook landings of GOM gray triggerfish (solid line) with CPUE-expansion estimates from observer vertical line data (gray boxes) for 2007 – 2017 for the (A) East and (B) West spatial strata. Error bars (SE) are shown for observer estimates. Open boxes denote observer estimates for years with low sampling effort.

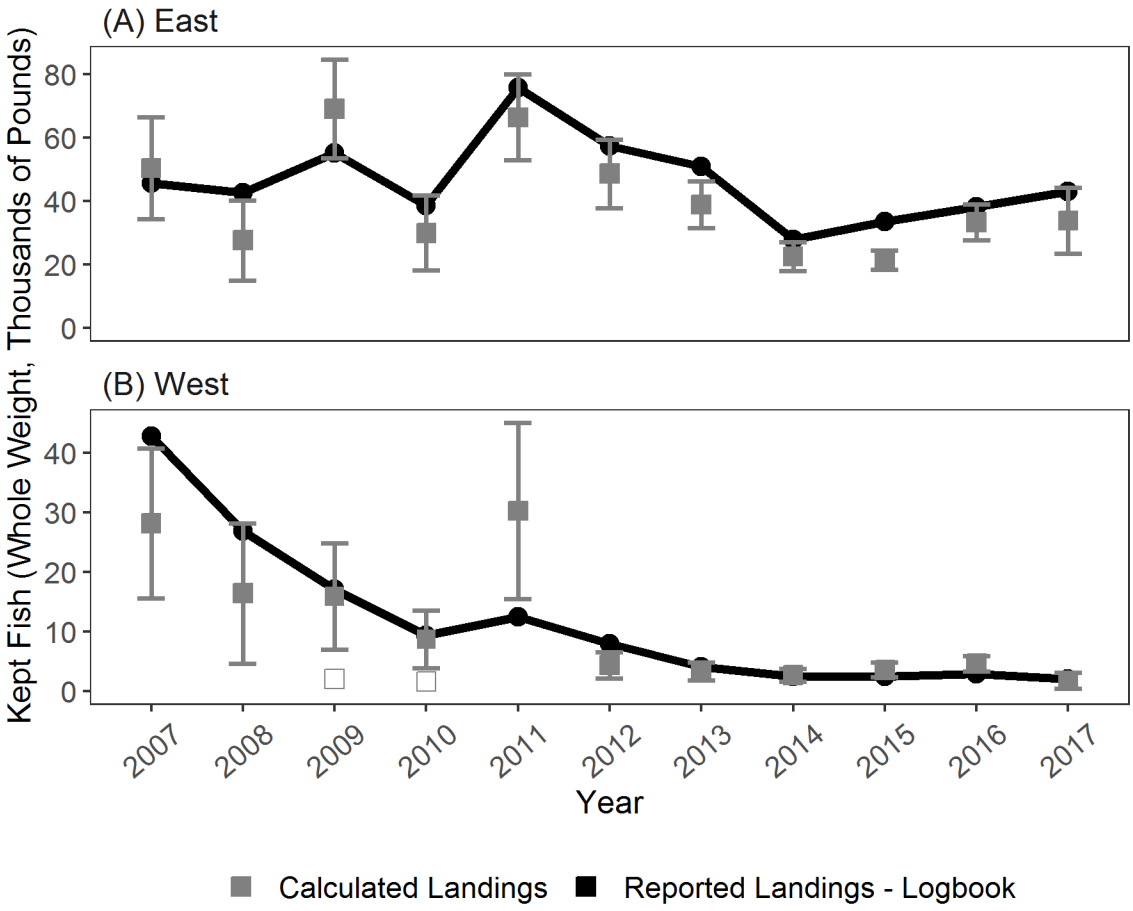

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Figure 5. Comparison of annual logbook landings of GOM gray triggerfish (solid black line) with CPUE-expansion estimates from observer data for the (**A**) East and (**B**) West spatial strata. Error bars (SE) are shown for observer estimates. Hindcast data for the pre-observer time period are calculated for both the stable CPUE method (light gray) and the trending CPUE method (dark gray).

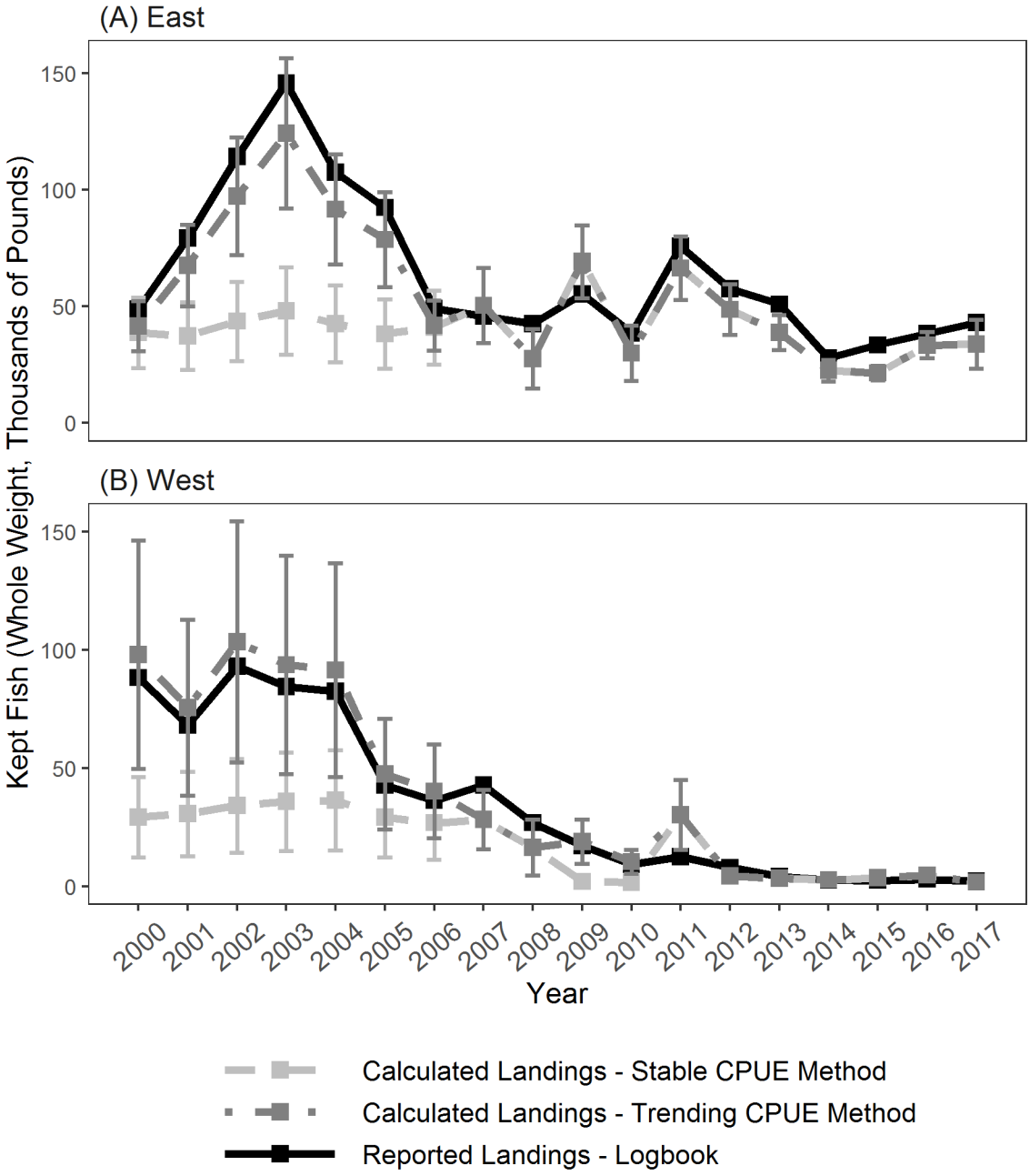

Figure 6. Observer discard CPUE (±SE) (catch per hour) time-series from 2007 – 2017 for trips landing GOM gray triggerfish in the (**A**) East and (**B**) West spatial strata. Open boxes denote observer estimates for years with low sampling effort.

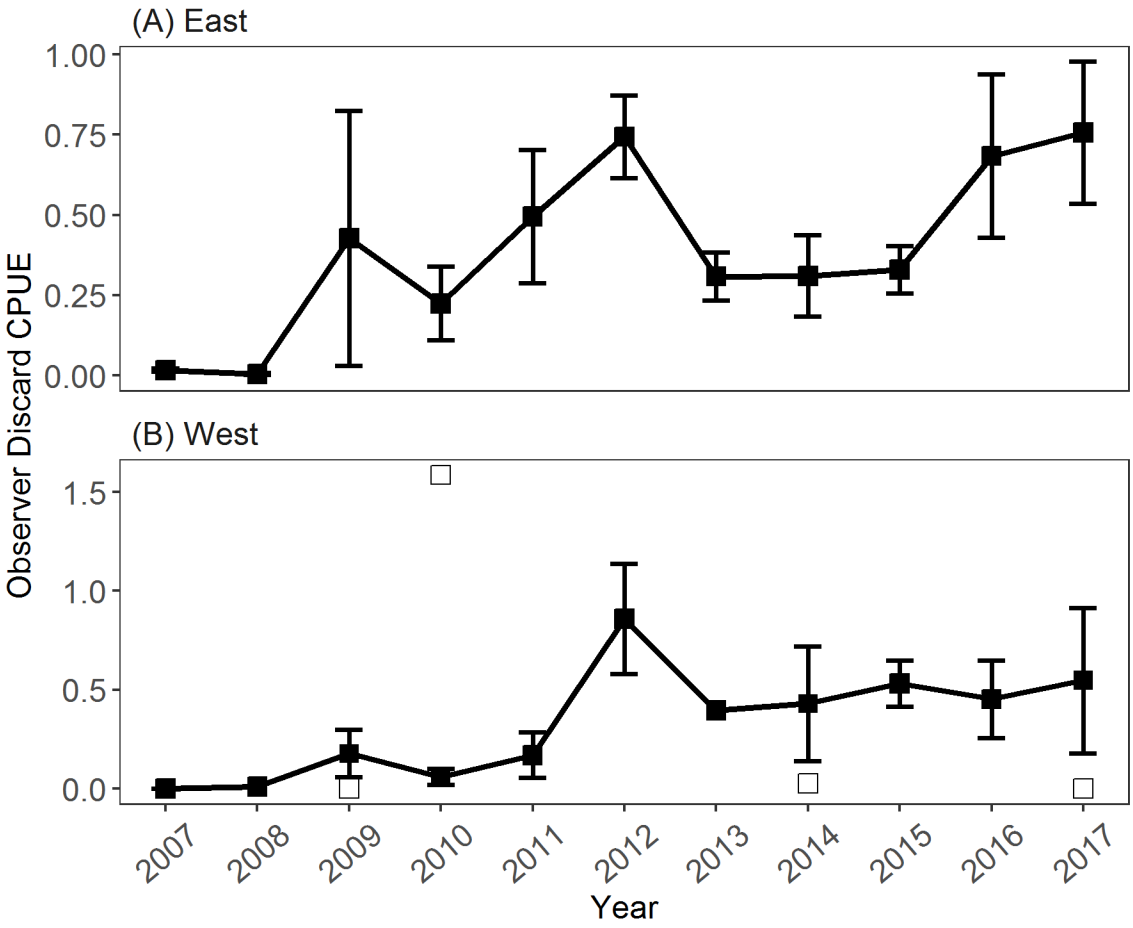

Figure 7. Observer CPUE-expansion estimates of GOM gray triggerfish annual discards (±SE) in number (gray) and weight (black) for 2000-2017 for the (**A**) East and (**B**) West spatial strata.