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CPUE Expansion Estimation for Total Discards of Gulf of Mexico Vermilion Snapper

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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) and Gulf of Mexico gray triggerfish in SEDAR Working Paper 62-07 (Smith et al. 2019) to Gulf of Mexico vermilion snapper. This application required several species-specific modifications to the estimation procedure: (i) fish weight correction for low catch trips; (ii) stratification by trip catch level; (iii) and accounting for changing minimum size regulations over the analysis time period (1993-2017).

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 vermilion snapper discard estimation, complete calendars years 2007-2017 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 vermilion snapper discard estimation, complete calendar years 1993-2017 were used.

Relevant Management History of GOM Vermilion Snapper

Two management changes to the commercial GOM vermilion snapper fishery are relevant to this analysis: (1) minimum size was increased in July 2005 from 8 inches total length (182 mm fork length) to 11 inches total length (250 mm fork length), and (2) minimum size was subsequently reduced in February 2008 to 10 inches total length (227 mm fork length).

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 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 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):

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

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

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

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 $\hat{C}$ was estimated using

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

Standard error of total catch was calculated as

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

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

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

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

Spatial Strata

Following methods in SEDAR 45, the GOM was divided into East and West spatial strata for discard estimation of vermilion snapper, with statistical zones 1-12 defined as East, and zones 13-21 defined as West (**Fig. 1**).

Gear

In the coastal observer data, vermilion snapper was rarely observed on bottom longline trips. Thus, discard estimation was conducted exclusively for vertical line gear.

Hindcast Procedures

The hindcast discard estimation procedures for "Trending CPUE" described in Smith et al. (2019) were applied to vermilion snapper. 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. (2019). 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 changes in regulations for GOM vermilion snapper. Verification compared total landed catch from logbook data with the estimated total catch $\hat{C}$ and standard error from observer data for the hindcast time period.

Modifications for GOM Vermilion Snapper

Several species-specific modifications were made to the general discard calculation methodology described in SEDAR Working Papers 61-15 (Smith et al. 2018) and 62-07 (Smith

et al. 2019): (i) fish weight correction for low catch trips; (ii) stratification by trip catch level; and (iii) accounting for changing minimum size regulations during the pre-observer time period (years prior to 2007).

Fish Weight Correction for Low-Catch Trips

Logbook catches are recorded as integers; thus, the lowest recorded catch for a given species was 1 lb. Observers, in contrast, record weights to fractions of a pound. For vermilion snapper, the corresponding average weight of a single fish at the current minimum legal size (10") was 0.44 lbs. There was thus a general mismatch between logbook and observer catch for low-catch trips. The ratio of observer to logbook mean catch for vermilion snapper trips <20 lbs. was used to correct logbook catches to better match the more precisely recorded observer catches.

Stratification by Trip Catch Level

Computations of mean CPUE, total catch, and associated standard errors were generalized to include strata for trip catch level of vermilion snapper. This enabled accurate estimation of total catch (and discards) in cases where observer sampling was not proportional to the fleet with respect to trip catch levels of vermilion snapper, e.g., observers sampled fewer or more low-catch trips with respect to logbook low-catch trips, etc. Comparisons of observer vs. logbook frequency distributions for trip-level catch, effort, and CPUE were used to delineate strata for trip catch levels (e.g., low, moderate, high, etc.).

Accounting for Changing Minimum Size Regulations

The observer time period mostly encompassed the management regime for 10" TL minimum size for vermilion snapper (≥2008). The pre-observer time period included management regimes for 11" TL minimum size (2005-2007) and 8" TL minimum size (≤2004). Initial inspection of observer length frequency data showed that discards of vermilion snapper were mostly fish smaller than the minimum legal size (**Fig. 2)**. Methods for hindcasting vermilion snapper catch and discards were modified to approximate the 11" TL and 8" TL management regimes. Key steps were:

(i) The disposition for individual fish recorded by observers was re-assigned according to the associated minimum legal size, with fish smaller than the minimum size assigned as discards, and fish at or above the minimum size assigned as kept. Fish recorded without lengths were assigned their original disposition. Standard procedures were then carried out to create an observer trip-level catch-effort dataset for a given management regime.

(ii) Standard computational formulae were used to compute observer mean CPUE and variance, and the proportions of observer trips and effort with kept fish, for each management regime.

(iii) The ratio of observer catch for a historical management regime to the current regime, i.e., $C_{11"}/C_{10"}$ and $C_{8"}/C_{10"}$, was used to: (a) adjust the annual reported logbook catch during the observer time period for a historical regime; and (b) adjust the catch level strata boundaries for logbook trips in a historical regime time period.

(iv) Computations of discards for the hindcasting time period were carried out following the procedures for the Trending CPUE method.

Results and Discussion

The observer database included 1,187 vertical line trips with corresponding trip and set information. Observer sampling effort is summarized in **Table 1**, distinguishing all trips from the subset of trips that captured vermilion snapper.

For the observer time period, 2007-2017, the disposition (kept or discarded) of GOM vermilion snapper corresponded with the respective minimum size limit, 11" TL (250 mm FL) in 2007 and 10" TL (227 mm FL) during 2008-2017 (**Fig. 2**). Discards were mostly fish near or below the minimum size limit, and kept fish were mostly above the minimum size limit.

Inspection of the annual nominal CPUE (catch in whole pounds per hour) from logbook trips reporting vermilion snapper in both the East and West spatial strata showed distinct trends over time (**Fig. 3**). In the East stratum, logbook CPUE was relatively stable prior to 2006, doubled from 2006 to 2009, declined through 2013 to levels below those at the start of the time-series, and then was relatively stable through 2017 (**Fig. 3A**). In the West stratum, logbook CPUE also was stable prior to 2006, doubled from 2006 to 2009, declined somewhat in 2010, and then was stable with minor fluctuations through 2017 (**Fig. 3B)**. Stable CPUE time periods that occurred within both the observer time period and the current 10" TL management regime were identified for each spatial stratum, 2013-2017 in the East (**Fig. 3A**, gray dashed line) and 2010-2017 in the West (**Fig. 3B**, gray dashed line).

Catch-effort data for observer trips catching vermilion snapper were pooled across years for the respective stable CPUE periods in the East and West spatial strata. Logbook catch-effort data for vermilion snapper 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 current management regime (10" TL) and the historical regimes (11" TL, 8" TL).

Observer and logbook frequency distributions of trip-level catch, effort, and CPUE were similar for the West spatial stratum for the stable CPUE time period (2010-2017), suggesting that observer sampling of vermilion snapper trips was representative of the commercial fleet. This was not the case for the East spatial stratum for years 2013-2017 (stable CPUE period). Further analysis showed that observers sampled a higher proportion of low catch (<20 lbs.) vermilion snapper trips and a lower proportion of moderate (20-100 lbs.) and high catch (>100 lbs) trips relative to the commercial fleet (**Table 2**). To account for this discrepancy, observer and logbook trips were grouped into strata according to low (L), moderate (M), and high (H) catches for subsequent analysis and estimation for the East spatial stratum. The weight correction factor for logbook low-catch trips, 0.7746, was computed from the ratio of observer to logbook mean catch per trip for vermilion snapper trips <20 lbs.

The proportions of observer trips and effort encountering vermilion snapper that had kept fish are given in **Table 3** by management regime, catch level strata, and spatial strata. These proportions were used to adjust annual logbook total vermilion snapper trips and effort (**Table 4**) to account for logbook trips that only had discarded fish. Estimates of logbook and observer mean CPUE by management regime, catch level strata, and spatial strata are given in **Table 5.** These CPUEs were the basis for expansion estimates of vermilion snapper catch and discards. Ratios of observer catch for a historical management regime to the current regime (**Table 3**) were used to adjust logbook catches and CPUE estimates (**Table 5**) for hindcasting for historical management regimes.

CPUE expansion estimates of annual total landed catch of GOM vermilion snapper compared favorably with reported logbook landings for 1993-2017 (**Fig. 4**). CPUE expansion estimates for annual discards of GOM vermilion snapper for 1993-2017 are shown in **Fig. 5** for numbers and weight. The time-series of discard estimates is also provided in **Table 6**. Estimated discards were low during the 8" TL management regime (1993-2004) and high during the 11" TL management regime (2005-2007) compared to the current 10" TL management regime (2008-2017).

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Table 1. Number of total and Vermilion Snapper coastal observer vertical line trips by year for (**A**) East and (**B**) West spatial strata in GOM.

(A) East

Year	Total Trips	Vermilion Snapper Trips
2007	71	42
2008	32	12
2009	37	21
2010	48	21
2011	77	48
2012	206	129
2013	110	58
2014	89	51
2015	164	95
2016	114	63
2017	55	36

(B) West

Year	Total Trips	Vermilion Snapper Trips
2007	16	10
2008	12	6
2009	7	3
2010	4	2
2011	9	8
2012	34	21
2013	12	3
2014	18	13
2015	35	21
2016	25	16
2017	12	6

Table 2. Definition of trip catch level strata for GOM Vermilion Snapper, and corresponding percentages of logbook and observer trips in the East spatial stratum during 2013-2017.

Trip Catch Level	Stratum Code	% Trips	
		Logbook	Observer
Low, catch < 20 lbs.	L	28.7	44.9
Moderate, 20≤ catch <100 lbs.	M	21.7	16.3
High, catch ≥ 100 lbs.	H	49.7	38.8

Table 3. Vermilion Snapper effort and catch adjustment factors by management regime and catch level strata for (**A**) East and (**B**) West spatial strata in GOM. Computations for each management regime used observer data for the respective stable CPUE periods in the East and West spatial strata (Fig. 3); for historical management regimes (11", 8"), the disposition of individual fish (kept or discarded) was re-assigned according to the associated minimum legal size. The proportions of observer trips and effort with kept Vermilion Snapper were used to respectively adjust annual logbook total Vermilion Snapper trips and effort (Table 4) to account for logbook trips that only had discarded fish. Ratios of observer catch for a historical management regime to the current regime were used to adjust logbook catches and CPUE estimates (Table 5) for hindcasting for historical management regimes.

(A) East

Management Regime	Catch Level	Number of Observer Trips (n)	Proportion of Observer Data with Kept Vermilion Snapper		Observer Catch Data Ratios for Hindcasting	
			Trips	Effort	Catch Ratio	Kept
2008-2017, 10" TL	L	153	0.8235	0.7837	$C_{10"}/C_{10"}$	1.0
	M	50	1.0	1.0	$C_{10"}/C_{10"}$	1.0
	H	100	1.0	1.0	$C_{10"}/C_{10"}$	1.0
2005-2007, 11" TL	L	160	0.8250	0.8014	$C_{11"}/C_{10"}$	1.0441
	M	48	1.0	1.0	$C_{11"}/C_{10"}$	1.001
	H	95	1.0	1.0	$C_{11"}/C_{10"}$	0.7686
1993-2004, 8" TL	L	143	0.9580	0.9454	$C_{8"}/C_{10"}$	1.1324
	M	58	1.0	1.0	$C_{8"}/C_{10"}$	1.1149
	H	102	1.0	1.0	$C_{8"}/C_{10"}$	1.1234

(B) West

Management Regime	Catch Level	Number of Observer Trips (n)	Proportion of Observer Data with Kept Vermilion Snapper		Observer Catch Data Ratios for Hindcasting	
			Trips	Effort	Catch Ratio	Kept
2008-2017, 10" TL	All	90	0.9778	0.9955	$C_{10"}/C_{10"}$	1.0
2005-2007, 11" TL	All	90	0.9889	0.9976	$C_{11"}/C_{10"}$	0.9245
1993-2004, 8" TL	All	90	0.9889	0.9976	$C_{8"}/C_{10"}$	1.0220

Table 4. Annual time-series of logbook trips (number) and effort (hours) by catch level strata for GOM Vermilion Snapper in the (**A**) East and (**B**) West spatial strata.

(A) East

		Logbook Trips		Logbook Effort	
Year	Catch Level	Reported	Adjusted (*N*)	Reported	Adjusted $(\hat{X})$
1993	L	496	566	15,368	18,052
	M	460	457	13,385	12,771
	H	796	759	36,464	35,422
1994	L	630	731	18,707	21,729
	M	530	495	14,274	13,452
	H	951	919	40,103	39,177
1995	L	489	564	13,353	15,425
	M	513	489	14,285	13,719
	H	1,017	992	45,089	44,455
1996	L	499	567	15,498	17,675
	M	498	505	15,651	16,423
	H	1,022	971	44,580	42,596
1997	L	456	521	15,225	17,659
	M	463	465	15,845	15,772
	H	844	799	36,270	34,873
1998	L	532	602	15,131	17,718
	M	422	399	13,344	12,717
	H	739	717	33,413	32,426
1999	L	554	638	15,643	18,547
	M	445	420	14,552	13,480
	H	1,055	1,023	42,604	41,784
2000	L	517	581	12,611	14,753
	M	417	408	12,856	12,431
	H	746	715	34,856	33,944
2001	L	504	571	14,527	16,504
	M	416	412	11,798	12,101
	H	809	770	35,108	33,728
2002	L	536	598	14,276	15,897
	M	468	472	12,743	13,266
	H	972	931	38,376	37,099
2003	L	529	600	15,071	17,113
	M	454	442	12,364	12,141
	H	1,121	1,087	44,571	43,685
2004	L	607	686	18,421	20,740
	M	472	447	11,726	11,080
	H	849	824	38,075	37,533
2005	L	596	732	17,210	21,822
	M	435	360	13,503	11,050
	H	809	877	35,060	37,240
2006	L	472	576	16,492	20,732
	M	362	302	12,755	10,515
	H	830	887	40,510	42,627
2007	L	277	339	11,434	14,559

	M	205	166	8,481	6,747
	H	899	935	44,754	46,254
2008	L	359	436	15,928	20,323
	M	214	214	8,474	8,474
	H	1,073	1,073	50,275	50,275
2009	L	446	542	20,843	26,594
	M	257	257	9,047	9,047
	H	1,423	1,423	69,535	69,535
2010	L	307	378	11,855	15,126
	M	265	265	9,529	9,529
	H	1,014	1,014	48,535	48,535
2011	L	306	372	13,189	16,828
	M	276	276	8,967	8,967
	H	1,530	1,530	74,747	74,747
2012	L	384	466	14,037	17,910
	M	366	366	13,104	13,104
	H	1,467	1,467	75,187	75,187
2013	L	396	481	15,648	19,966
	M	359	359	14,167	14,167
	H	1,041	1,041	52,461	52,461
2014	L	482	585	16,758	21,382
	M	370	370	11,565	11,565
	H	1,037	1,037	55,717	55,717
2015	L	539	655	18,059	23,042
	M	456	456	16,258	16,258
	H	815	815	40,413	40,413
2016	L	606	736	22,871	29,182
	M	415	415	16,943	16,943
	H	866	866	44,766	44,766
2017	L	681	827	22,131	28,238
	M	471	471	17,034	17,034
	H	1,015	1,015	49,237	49,237

(B) West

		Logbook Trips		Logbook Effort	
Year	Catch Level	Reported	Adjusted (N)	Reported	Adjusted $(\hat{X})$
1993	All	1,207	1,221	39,569	39,663
1994	All	1,253	1,267	44,482	44,588
1995	All	1,152	1,165	32,756	32,834
1996	All	1,663	1,682	36,903	36,991
1997	All	1,958	1,980	48,728	48,843
1998	All	1,780	1,800	45,739	45,848
1999	All	1,721	1,740	53,002	53,128
2000	All	1,472	1,489	44,947	45,054
2001	All	1,523	1,540	45,883	45,992
2002	All	1,691	1,710	51,115	51,236
2003	All	1,898	1,919	57,829	57,966
2004	All	1,879	1,900	59,753	59,894

2005	All	1,397	1,413	48,289	48,403
2006	All	1,332	1,347	43,315	43,418
2007	All	604	611	36,558	36,645
2008	All	471	482	27,631	27,755
2009	All	384	393	22,924	23,027
2010	All	365	373	22,004	22,103
2011	All	376	385	21,568	21,665
2012	All	409	418	25,211	25,325
2013	All	424	434	20,816	20,910
2014	All	511	523	19,831	19,920
2015	All	592	605	23,363	23,468
2016	All	654	669	26,069	26,186
2017	All	584	597	22,998	23,101

Table 5. Estimated logbook and observer mean CPUE by management regime and catch level strata for expansion estimates of Vermilion Snapper catch and discards for (**A**) East and (**B**) West spatial strata. Computations for each management regime used data for the respective stable CPUE periods in the East and West spatial strata (Fig. 3) and adjustment factors from Table 3.

(A) East

Management Regime	Catch Level	Logbook CPUE	Observer CPUE	
			Kept	Discard
2008-2017, 10” TL	L	0.1193	0.1246	0.0279
	M	1.3799	1.3747	0.0535
	H	13.9587	11.9193	0.5699
2005-2007, 11” TL	L	0.1244	0.1244	0.0404
	M	1.3681	1.4430	0.1656
	H	10.7944	10.8669	2.0299
1993-2004, 8” TL	L	0.1349	0.1398	0.0008
	M	1.5234	1.1246	0.0034
	H	15.7762	12.0259	0.0233

(B) West

Management Regime	Catch Level	Logbook CPUE	Observer CPUE	
			Kept	Discard
2008-2017, 10” TL	All	24.5254	23.4232	0.1566
2005-2007, 11” TL	All	22.7381	22.0766	0.9421
1993-2004, 8” TL	All	25.1365	22.9785	0.0109

Table 6. Time-series of CPUE expansion estimates for GOM Vermilion Snapper discards in weight and number (with associated standard errors) for (**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
1993	1293.3	19.3	5957.5	132.1
1994	1756.1	26.3	8079.9	179.1
1995	1741.9	26.1	8010.7	177.6
1996	1457.5	21.8	6712.6	148.8
1997	1278.8	19.1	5892.1	130.6
1998	1140.5	17.1	5254.0	116.5
1999	1275.5	19.1	5874.9	130.2
2000	985.4	14.7	4545.6	100.8
2001	1027.2	15.4	4736.9	105.0
2002	1270.7	19.0	5854.6	129.8
2003	1485.9	22.2	6837.4	151.6
2004	1086.6	16.3	5013.4	111.1
2005	140145.5	64249.7	304815.7	115031.8
2006	163448.6	74933.0	355441.9	134137.2
2007	193272.9	88605.9	420247.4	158593.6
2008	62013.4	8918.0	166220.1	24027.7
2009	96846.2	13927.2	259654.6	37534.1
2010	44810.4	6444.1	119993.3	17345.5
2011	79177.0	11386.2	212240.4	30680.2
2012	53645.3	7714.6	143600.2	20758.0
2013	31213.3	4488.7	83355.8	12049.4
2014	32969.1	4741.2	88119.8	12738.1
2015	24544.9	3529.7	65389.0	9452.2
2016	27233.7	3916.4	72555.6	10488.2
2017	29760.0	4279.7	79341.0	11469.0

(B) West

Year	Estimated Discards in Weight	SE of Estimated Discards in Weight	Estimated Discards in Number	SE of Estimated Discards in Number
1993	249.9	5.2	1273.3	42.3
1994	275.3	5.8	1402.8	46.6
1995	209.9	4.4	1069.7	35.6
1996	216.7	4.5	1104.6	36.7
1997	418.8	8.8	2134.1	70.9
1998	348.2	7.3	1774.6	59.0

1999	394.1	8.3	2008.3	66.8
2000	249.8	5.2	1272.9	42.3
2001	314.5	6.6	1602.6	53.3
2002	363.2	7.6	1851.1	61.5
2003	468.8	9.8	2389.5	79.4
2004	471.7	9.9	2403.9	79.9
2005	29525.8	31811.7	59342.9	45350.1
2006	22418.4	24154.0	45058.0	34433.5
2007	41533.8	44749.2	83477.3	63793.6
2008	5523.7	1131.2	16614.1	3966.1
2009	5093.7	1043.1	15320.9	3657.4
2010	3461.8	708.9	10412.3	2485.6
2011	3393.3	694.9	10206.2	2436.4
2012	3966.4	812.3	11930.1	2847.9
2013	3274.9	670.7	9850.3	2351.5
2014	3120.0	638.9	9384.2	2240.2
2015	3675.6	752.7	11055.3	2639.1
2016	4101.4	839.9	12336.1	2944.9
2017	3618.2	741.0	10882.7	2597.9

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

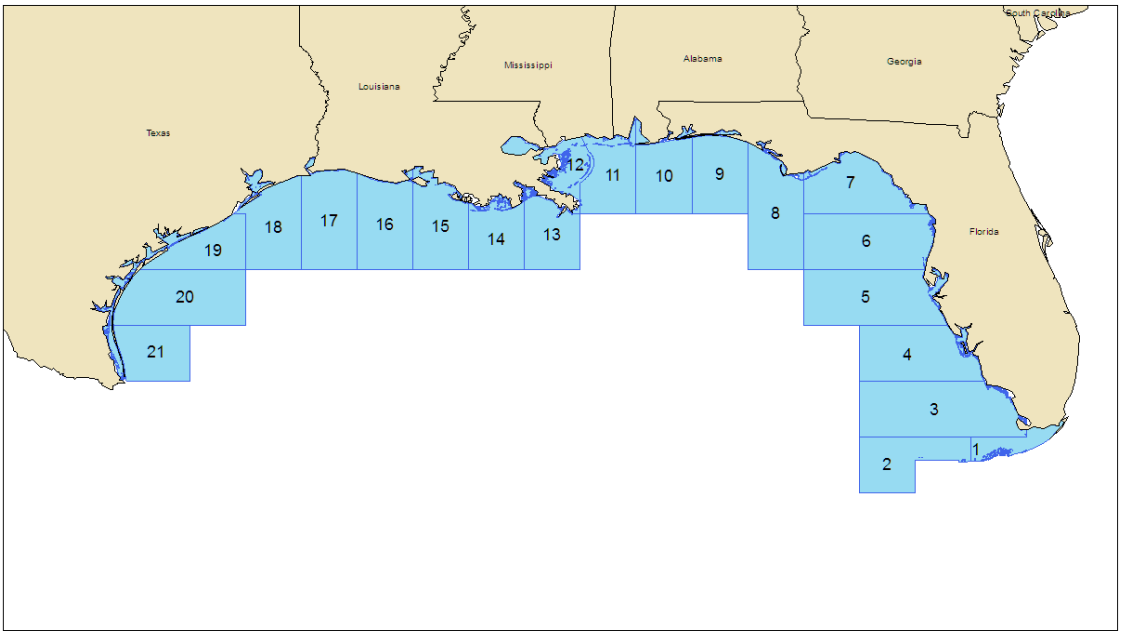
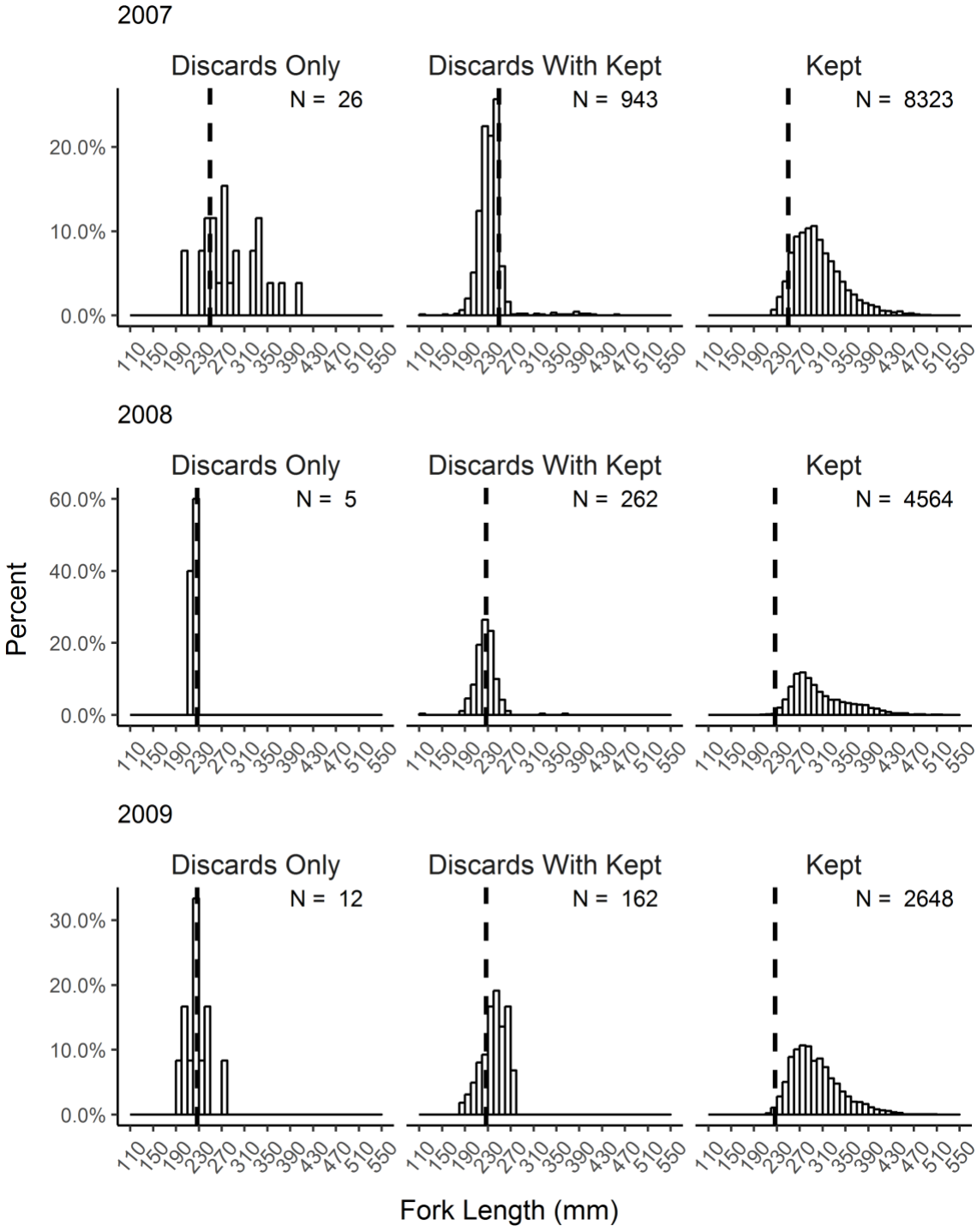
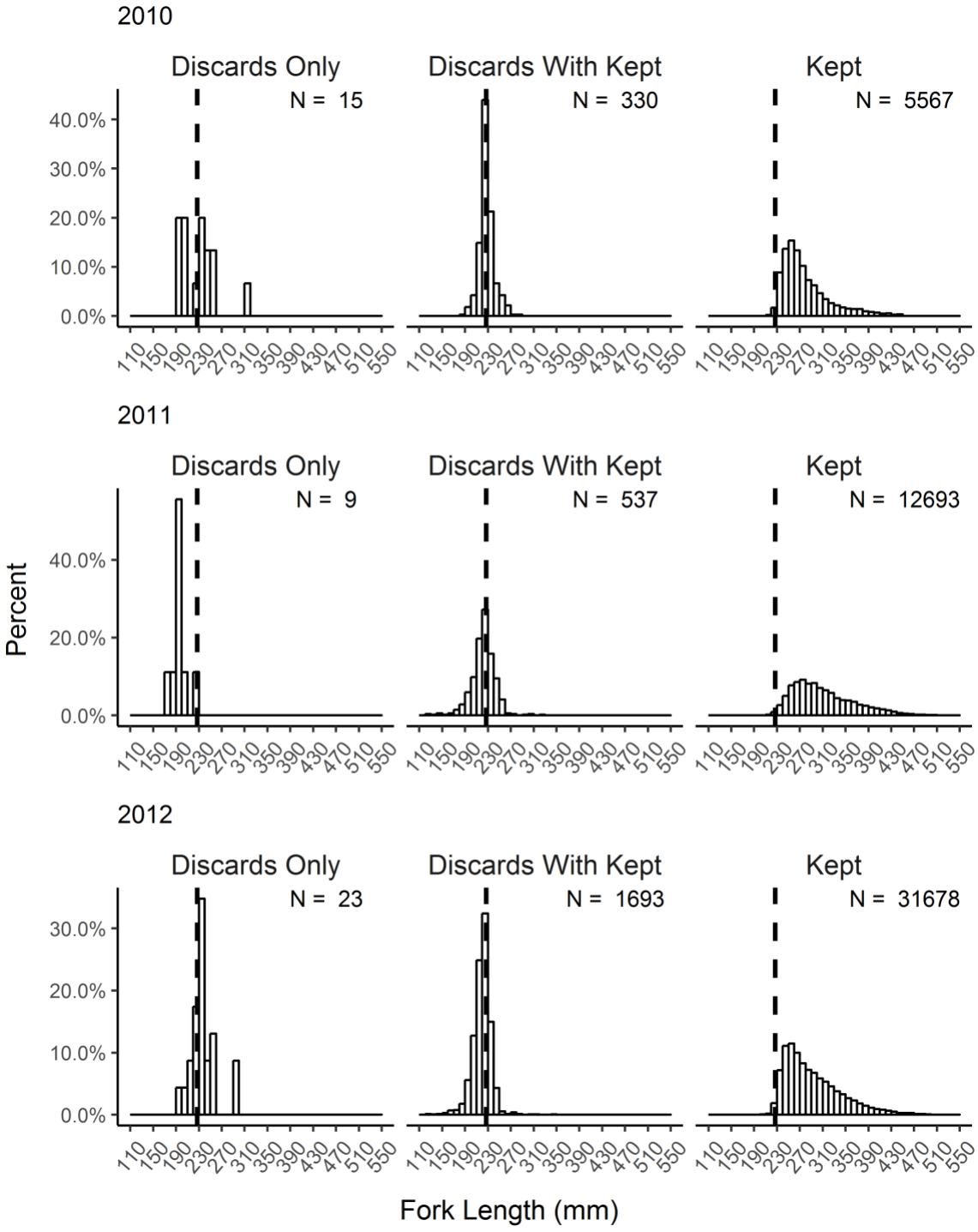
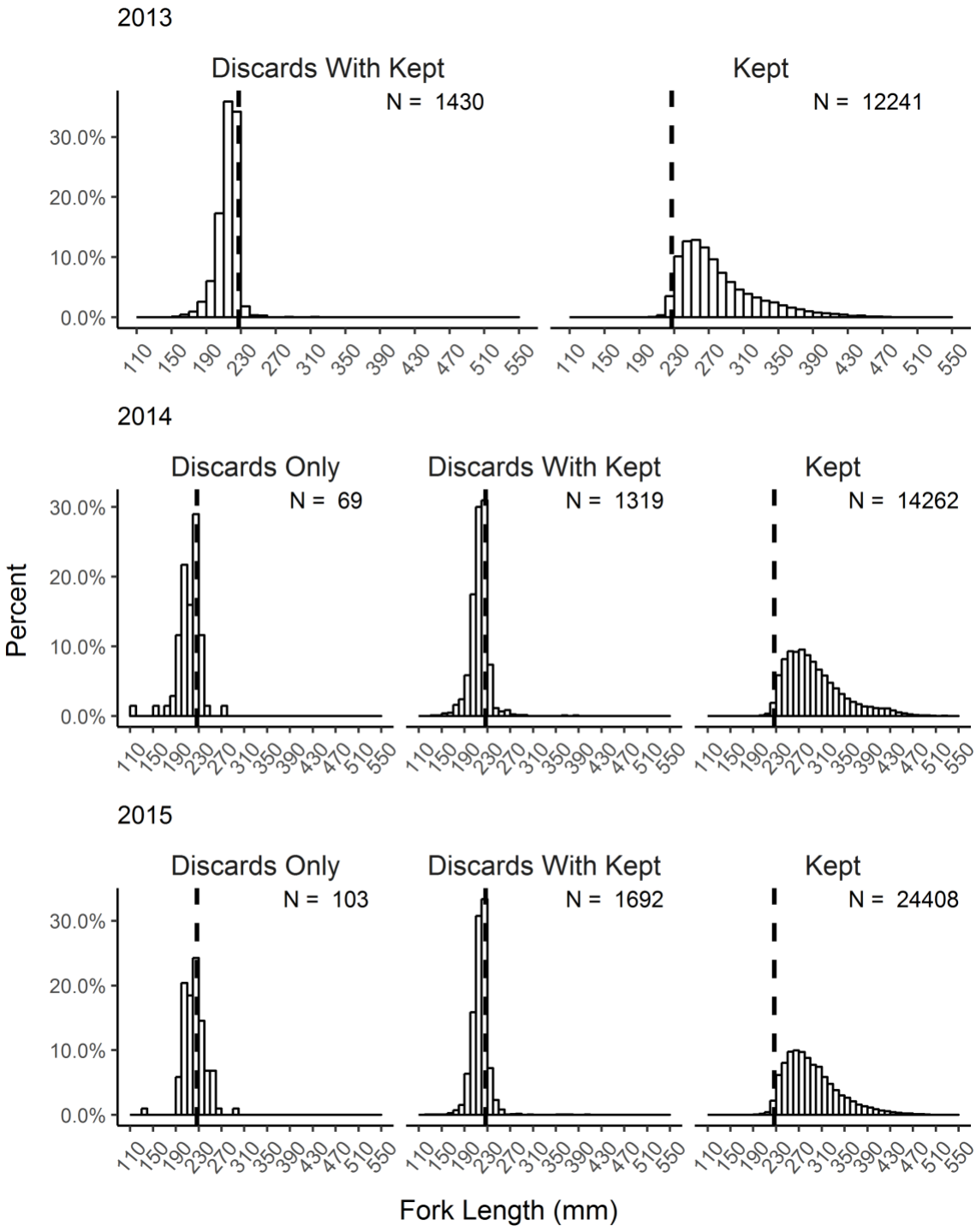


Figure 2. Length-frequency plots of observer GOM Vermilion Snapper by disposition (Kept or Discard) by year for combined spatial strata. 'Discards Only' were discards from trips with no kept Vermilion Snapper; 'Discards with Kept' were discards from trips with kept Vermilion Snapper. Vertical dashed lines denote the minimum size limit in effect for a given year; N is number of measured fish.




2010
Discards Only
N = 15
Discards With Kept
N = 330
Kept
N = 5567
2011
Discards Only
N = 9
Discards With Kept
N = 537
Kept
N = 12693
2012
Discards Only
N = 23
Discards With Kept
N = 1693
Kept
N = 31678
Percent
0.0%
10.0%
20.0%
30.0%
40.0%
110 150 190 230 270 310 350 390 430 470 510 550
Fork Length (mm)


2013
Discards With Kept
N = 1430
Kept
N = 12241
2014
Discards Only
N = 69
Discards With Kept
N = 1319
Kept
N = 14262
2015
Discards Only
N = 103
Discards With Kept
N = 1692
Kept
N = 24408
Percent
30.0%
20.0%
10.0%
0.0%
110 150 190 230 270 310 350 390 430 470 510 550
Fork Length (mm)

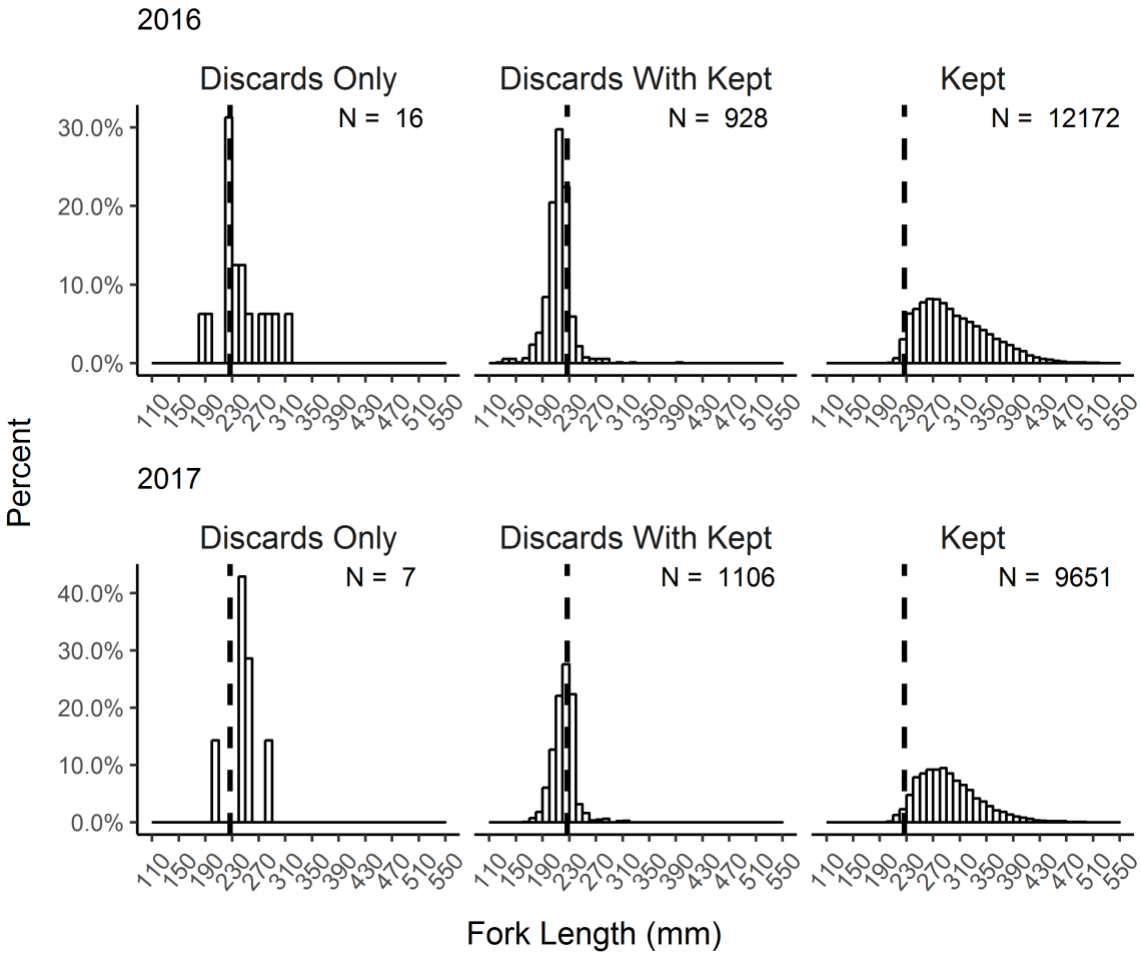

2016
Discards Only
Discards With Kept
Kept
N = 16
N = 928
N = 12172
2017
Discards Only
Discards With Kept
Kept
N = 7
N = 1106
N = 9651
Percent
Fork Length (mm)

Figure 3. CPUE (catch in whole pounds per hour) time-series for logbook data from 1993 – 2017 for trips landing GOM Vermilion Snapper in the (**A**) East and (**B**) West spatial strata. The respective dashed gray lines denote stable CPUE time periods that occurred within both the observer time period (2007-2017) and current 10" TL management regime (2008-2017).

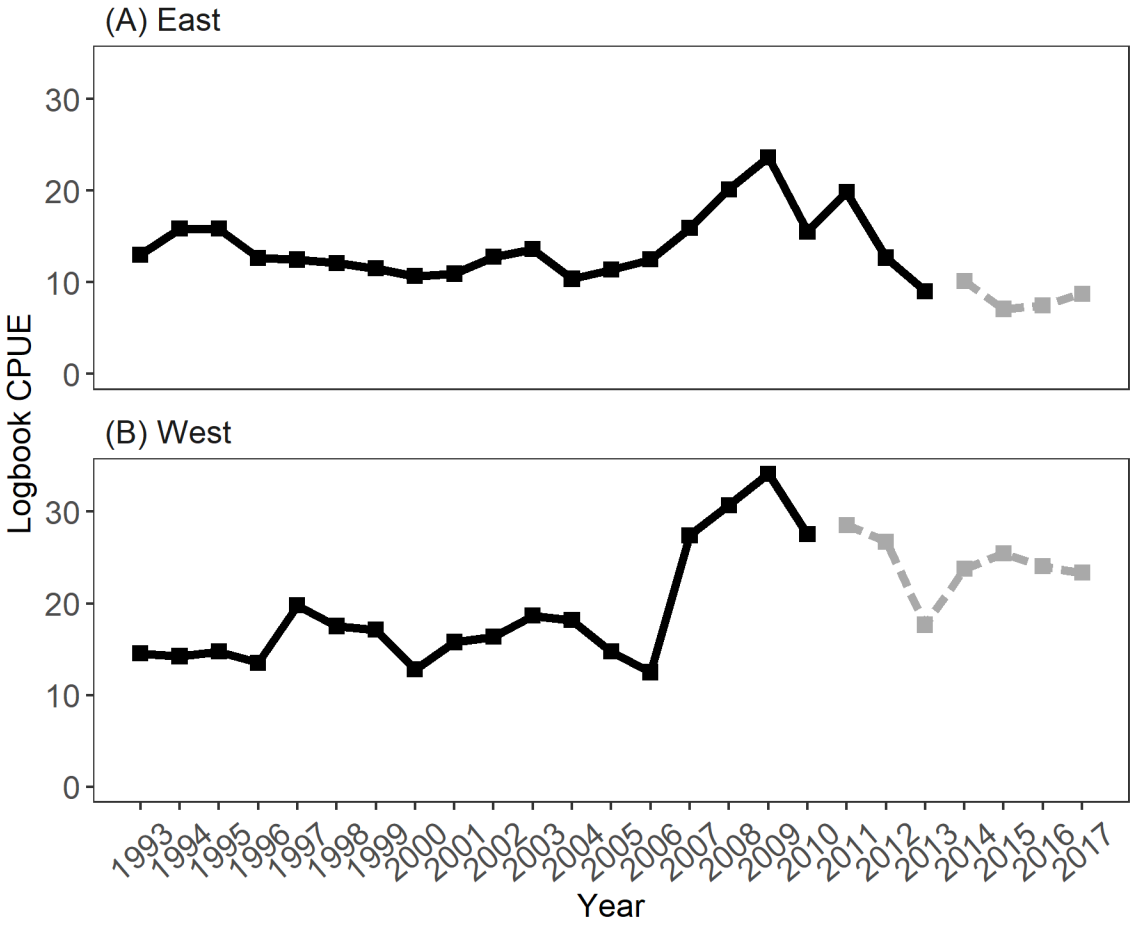


Figure 4. Comparison of reported annual logbook landings of GOM Vermilion Snapper (solid black line) with CPUE expansion estimates from observer data (gray squares) for the (**A**) East and (**B**) West spatial strata. Error bars (SE) are shown for observer estimates.

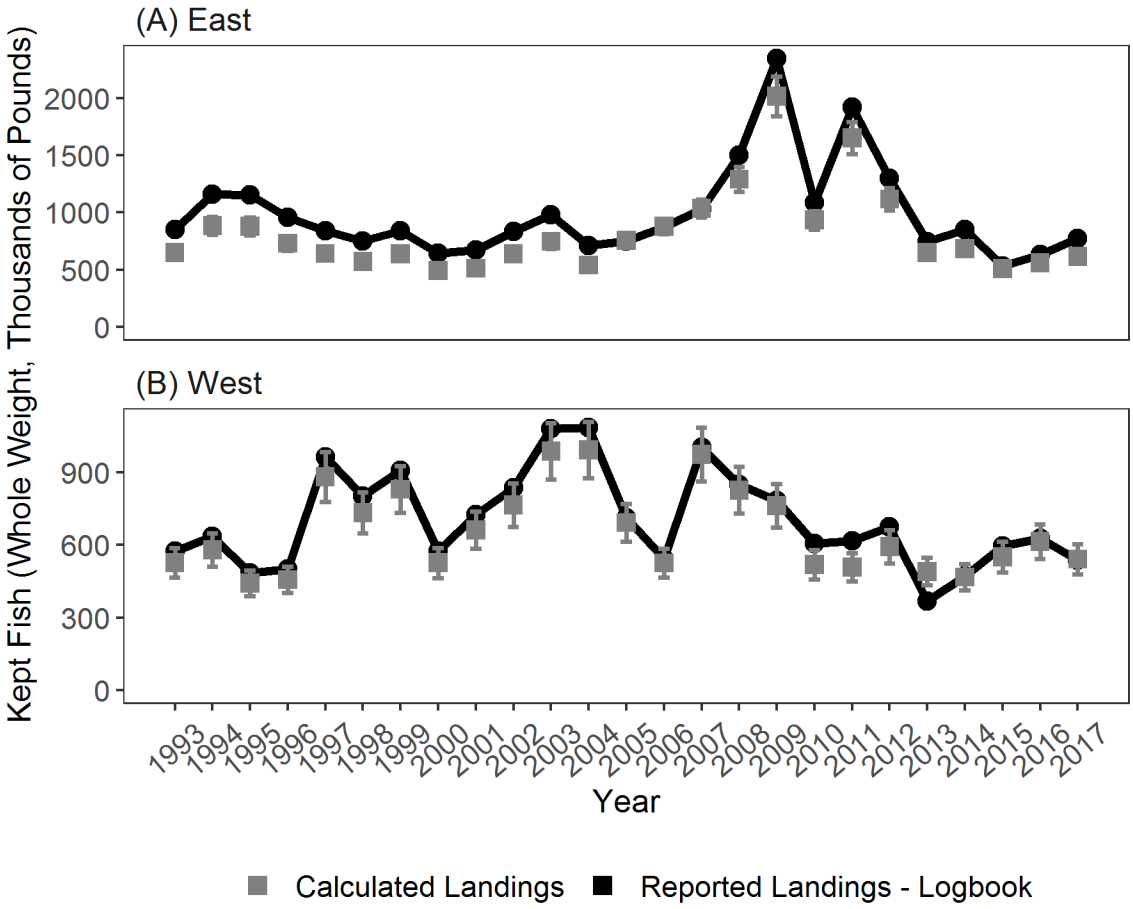


Figure 5. Observer CPUE expansion estimates of GOM Vermilion Snapper annual discards (±SE) in number (gray) and weight (black) for 1993-2017 for the (**A**) East and (**B**) West spatial strata. Discards were low during the 8" TL management regime (1993-2004) and high during the 11" TL management regime (2005-2007) compared to the current 10" TL management regime (2008-2017).