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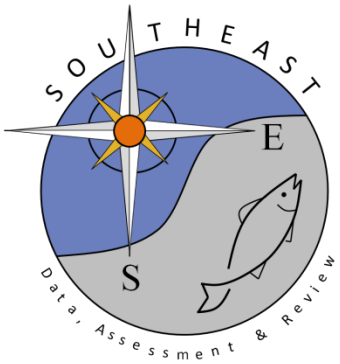

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Proposed CPUE Expansion Estimation for Total Discards of Gulf of Mexico Red Grouper

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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 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 various discard categories, e.g., released alive, released dead, etc. The primary metric for the coastal observer program is CPUE by species and gear; however, the appropriate effort unit (e.g., trip-days, hook-hours, etc.) for computing CPUE was unclear with respect to total catch expansion. The principal focus of this study was to evaluate the suite of effort metrics recorded on commercial logbooks and collected by onboard observers to identify unbiased and consistent effort variables between the two programs for carrying out the catch expansion.

Methods

Data Sources

Catch per unit effort was determined from the coastal 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 reef fishery, bottom longline and vertical lines (e.g., handlines, bandit rigs). 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 observer program began in July 2006; for discard estimation, complete calendars years 2007-2017 were utilized.

Total effort was determined from the commercial reef 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 Gulf of Mexico, and expanded to all vessels in 1993; for discard estimation, complete calendar years 1993-2017 were utilized. Logbook effort metrics were recorded at the trip level, whereas observer effort metrics were recorded at a finer scale (usually individual 'sets' within a trip).

Comparison of Observer and Logbook Effort Variables

Analysis of observer and logbook effort variables was carried out separately for the two major gears, bottom longlines and vertical lines. Our general analysis approach involved three main steps: (i) identification of a subset of logbook trips that were sampled by onboard observers; (ii) calculation of trip-level effort metrics for the observer data that corresponded with logbook effort metrics; and (iii) comparison of the observer and logbook effort metrics for matched trips (paired t-test) to identify potential unbiased variables for carrying out catch expansions.

Computation of Trip-Level Catch for Observer Data

Observers collected catch data at a subtrip 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 developed to: (i) estimate the trip-level landed catch from the observer data; and (ii) compare the observer and logbook catch for matched trips (paired t-test).

Catch Expansion Procedures and Verification

Observer CPUE was calculated using the resulting metrics from the trip-level effort and catch analysis. 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 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 catch per trip,

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

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

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

Standard error of total catch was calculated as

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

A verification step compared total annual landed catch from logbook data with the estimated total catch from observer data for the period 2007-2017. After verification, the average observer CPUE for 2007-2008 (the pre-IFQ time period prior, to change in size limit) was used to hindcast total annual landed catch using logbook effort for 1993-2006. This expansion procedure was then applied to estimate other catch dispositions including discards for the 1993-2017 time period.

Results

Bottom Longline Gear

The observer database included 424 bottom longline trips, of which 396 had corresponding trip and set information. Of these, a matching procedure using the vessel identification and trip start and end dates resulted in 375 matched observer and logbook trips. Effort analysis focused on three directly recorded effort variables from commercial logbooks: (i) the number of sets per trip, (ii) the average hooks per set, and (iii) the average soaktime per set. Soaktime was calculated using various combinations of first hook in, last hook in, first hook out, and last hook out due to discrepancies in the definition of soaktime for the observer and logbook programs. Comparisons of trip effort found that most effort metrics did not correspond well between logbooks and observers (**Table 1**). The number of sets per trip, an unbiased metric (**Fig. 1**), was selected as the longline effort variable for logbook and observer data.

Estimates of trip-level observer catch for red grouper utilized the recorded number of sampled and unsampled sets, resulting in unbiased catches between logbook and observer data (**Fig. 2**). Using unbiased trip-level metrics for observer catch and effort, CPUE expansion estimates of annual total landed catch compared favorably with reported logbook landings for both the analysis time frame (2007-2017) and the hindcast time frame (1993-2006) (**Fig. 3**). The corresponding CPUE expansion estimates for annual discards for 1993-2017 are shown in **Fig. 4** for numbers (**Fig. 4A**) and weight (**Fig. 4B**).

Vertical Line Gear

The observer database included 1,237 vertical line trips, of which 1,210 had corresponding trip and set information. The matching procedure resulted in 1,092 matched observer and logbook trips. Effort analysis focused on three directly recorded effort variables from commercial logbooks: (i) the number of lines per set, (ii) the number of hooks per line, and (iii) the total hours fished. Due to potential ambiguous interpretation of these metrics by fishers, a variety of metrics were analyzed, e.g., average lines per set for a trip, maximum lines fished for a set during a trip, etc. Soaktime was calculated using various combinations of first hook in, last hook in, first hook out, and last hook out due to discrepancies in the definition of soaktime for the observer and logbook programs. Similar to the longline analysis, most trip-level effort metrics for vertical line gear did not correspond well between logbooks and observers (**Table 2**). One unbiased effort metric was identified for logbook and observer data: trip fishing time computed as the cumulative daily fishing time from first hook in to last hook out (**Fig. 5**); this time metric included the active fishing time as well as transit time between fishing locations during a given trip day.

Estimates of trip-level observer catch for red grouper utilized multiple expansions to account for sub-sampling within an individual line within a set, sub-sampling of lines for a set, and sub-sampling of sets within a trip. This procedure produced slightly biased trip-level catches between logbook and observer data, with the observer catch underestimating the logbook catch by an average of 13 pounds per trip; however, the median difference was close to zero pounds (**Fig. 6**).

As with longline data, CPUE expansion estimates of annual total landed catch for vertical line gear compared favorably with reported logbook landings for both the analysis time frame (2007-2017) and the hindcast time frame (1993-2006) (**Fig. 7**). The corresponding CPUE

expansion estimates for annual discards for 1993-2017 are shown in **Fig. 8** for numbers (**Fig. 8A**) and weight (**Fig. 8B**).

Literature Cited

GMFMC. 2005. Amendment 22 to the Reef Fish Management Plan. Gulf Mex. Fish. Manage. Counc., Tampa, FL. (available at http://www.gulfcouncil.org).

Jones, C.M., Robson, D.S., Lakkis, H.D., and Kressel, J. 1995. Properties of catch rates used in analysis of angler surveys. Transactions of the American Fisheries Society 124: 911-928.

Lohr, S. L. 2010. Sampling: design and analysis, 2nd ed. Boston: Brooks/Cole.

Table 1. Comparison of trip-level effort variables for bottom longline gear between observer and logbook data; *n* is the number of matched observer-logbook trips; mean difference (observer value – logbook value) for each metric was evaluated with a paired t-test.

Effort Variable	*n*	Mean Difference	SE Difference	*p*-value
Number of Sets	375	-0.54	0.38	0.1576
Average Hooks per Set	368	293.83	22.53	<0.0001
Average Soak Hours per Set 1 (first hook in, last hook out)	355	2.33	0.08	<0.0001
Average Soak Hours per Set 2 (last hook in, last hook out)	301	1.23	0.08	<0.0001
Average Soak Hours per Set 3 (last hook in, first hook out)	301	-0.29	0.29	0.3185
Average Soak Hours per Set 4 (first hook in, first hook out)	303	0.68	0.29	0.0202

Figure 1. Frequency plot of the difference (observer – logbook) in number of sets per trip for matched bottom longline trips. The mean difference was not significantly different from zero.

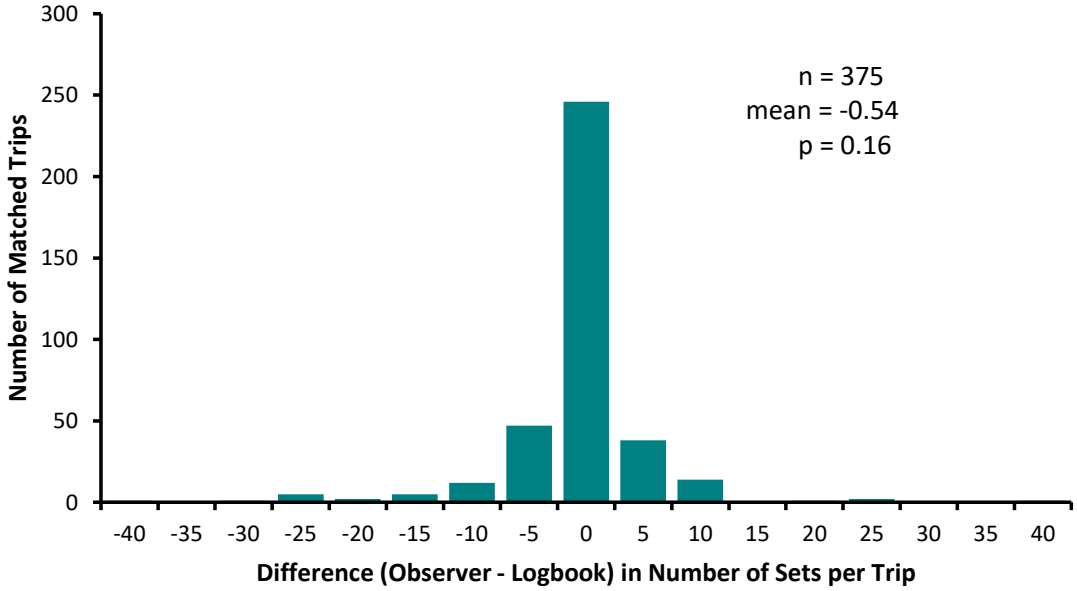


Figure 2. Frequency plot of the difference (observer – logbook) between the estimated observer catch and reported logbook catch of red grouper for matched bottom longline trips. The mean difference was not significantly different from zero.

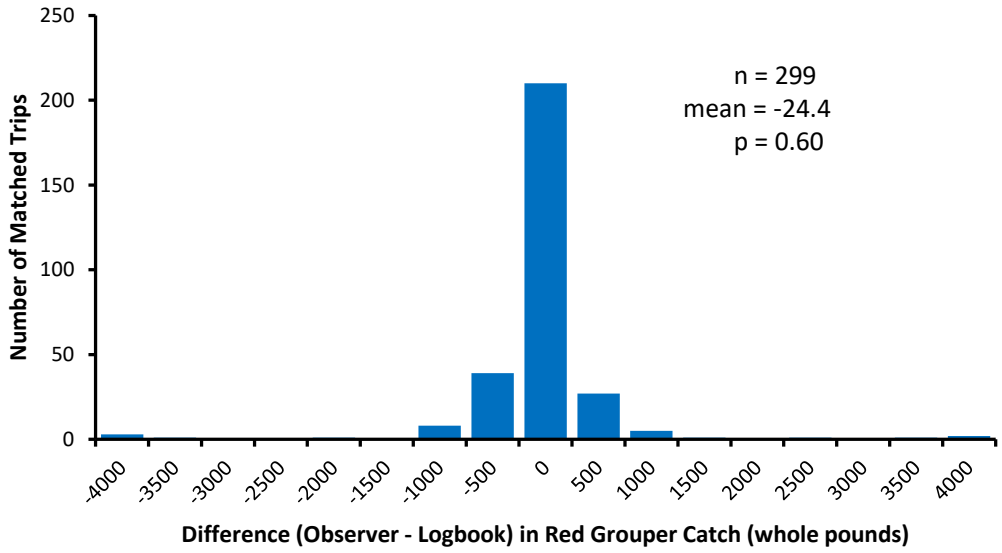


Figure 3. Comparison of annual logbook landings of red grouper with CPUE-expansion estimates from observer longline data. Error bars (SE) are shown for observer estimates for 2007-2017, the time frame of the Gulf of Mexico coastal observer program.

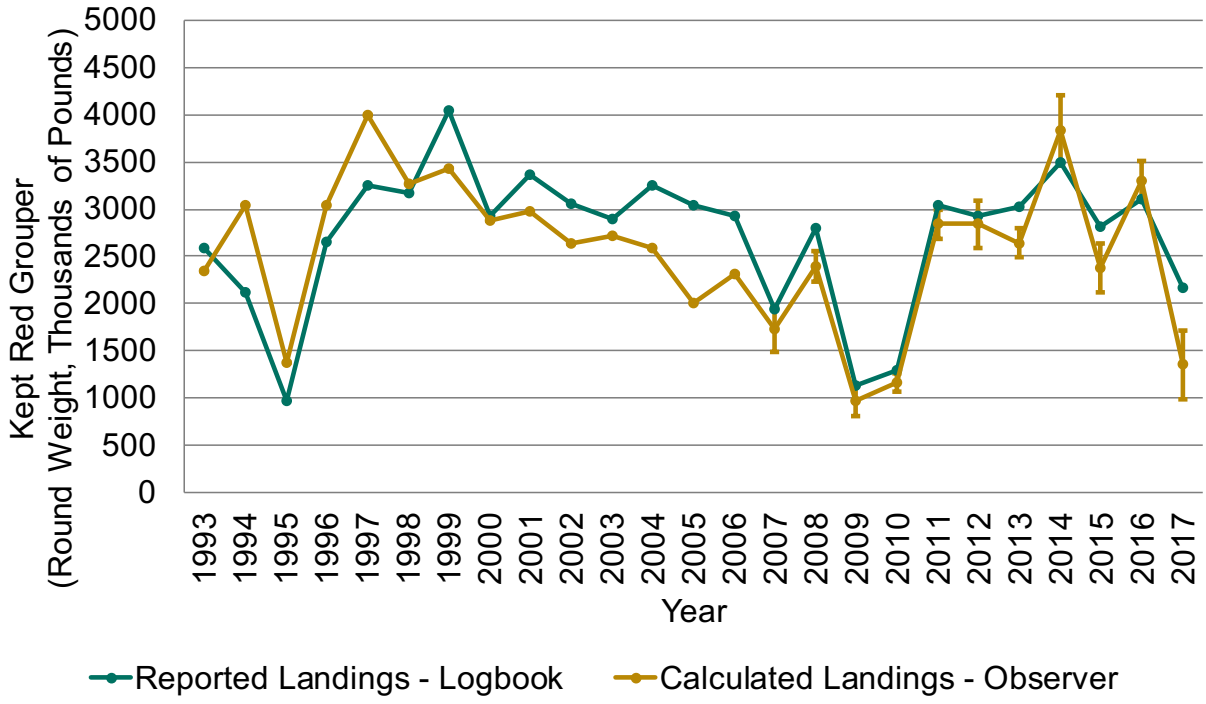
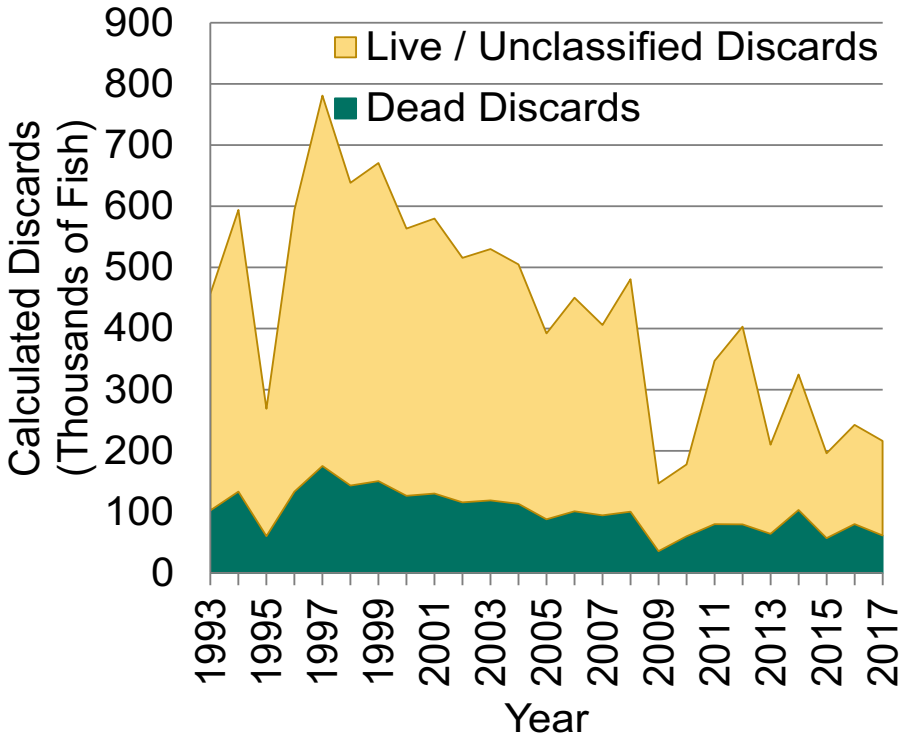


Figure 4. Observer CPUE-expansion estimates of Red Grouper annual discards in **(A)** number and **(B)** weight for bottom longline gear for 1993-2017, denoting live/unclassified and dead discards.

(A)



(B)

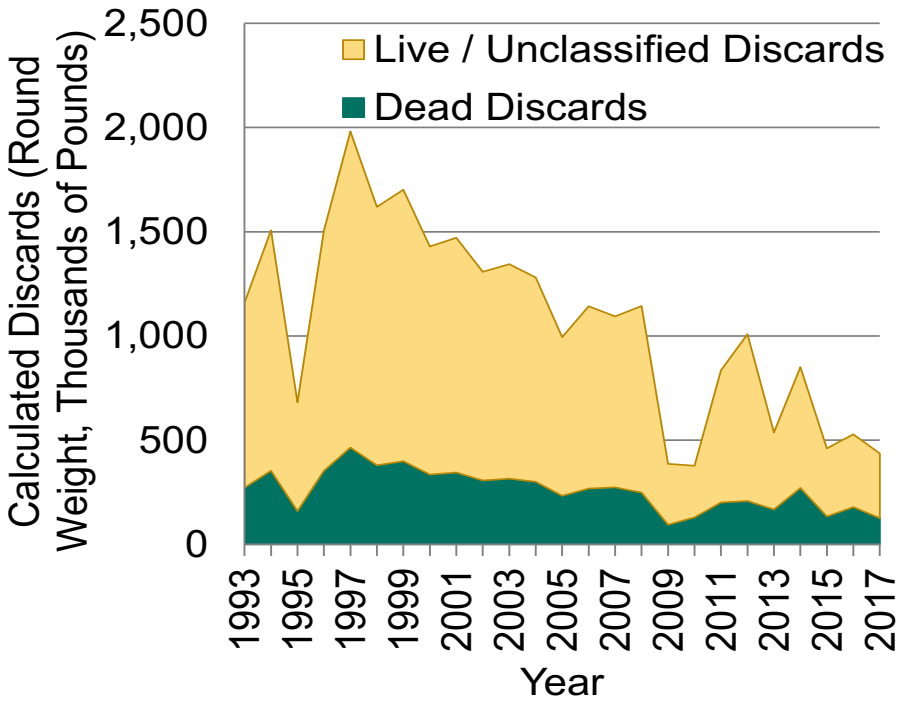


Table 2. Comparison of trip-level effort variables for vertical line gear between observer and logbook data; *n* is the number of matched observer-logbook trips; mean difference (observer value – logbook value) for each metric was evaluated with a paired t-test.

Effort Variable	*n*	Mean Difference	SE Difference	*p*-value
Set Time (hrs)	916	-16.21	0.74	<0.0001
Fishing Day (hrs)	916	0.11	0.73	0.8831
Average Lines per Set	916	-0.310	0.039	<0.0001
Max Lines per Set	916	0.356	0.046	<0.0001
Average Hooks per Line 1 (gear configurations)	916	-0.95	0.17	<0.0001
Average Hooks per Line 2 (sampled lines/sets)	916	-0.36	0.16	0.0226

Figure 5. Frequency plot of the difference (observer – logbook) in fishing day hours for matched vertical line trips. The mean difference was not significantly different from zero.

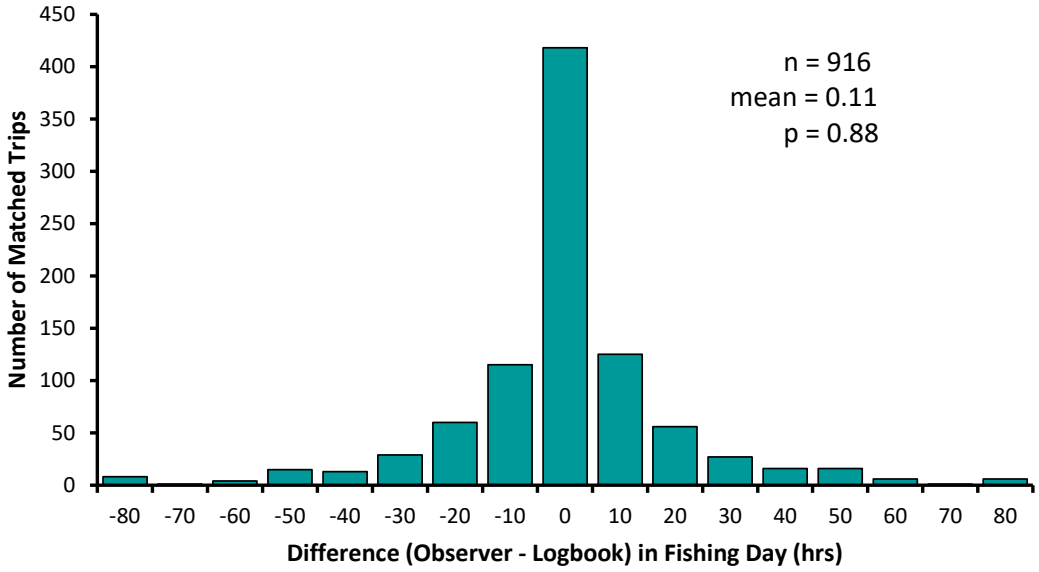


Figure 6. Frequency plot of the difference (observer – logbook) between the estimated observer catch and reported logbook catch of red grouper for matched vertical line trips. The mean difference was significantly different from zero; however, the median difference was approximately zero.

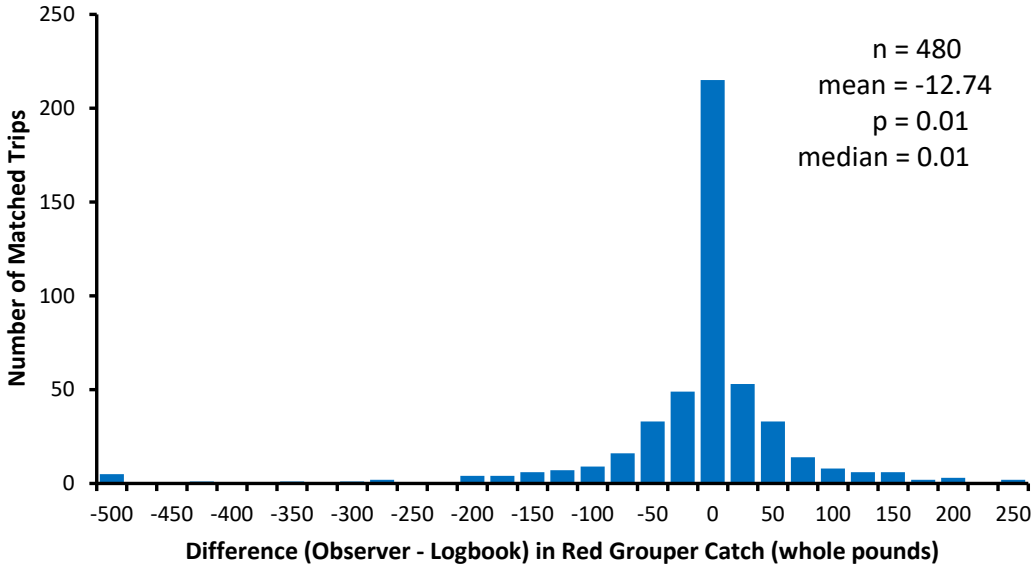


Figure 7. Comparison of annual logbook landings of red grouper with CPUE-expansion estimates from observer vertical line data. Error bars (SE) are shown for observer estimates for 2007-2017, the time frame of the Gulf of Mexico coastal observer program.

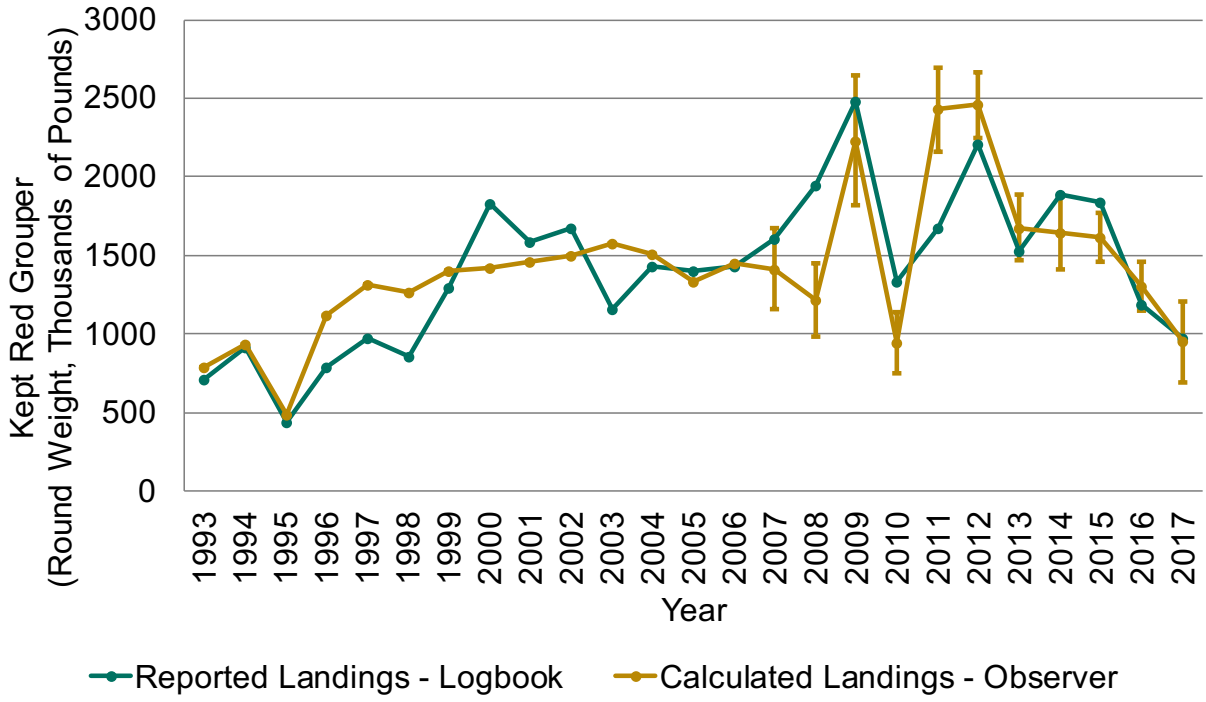
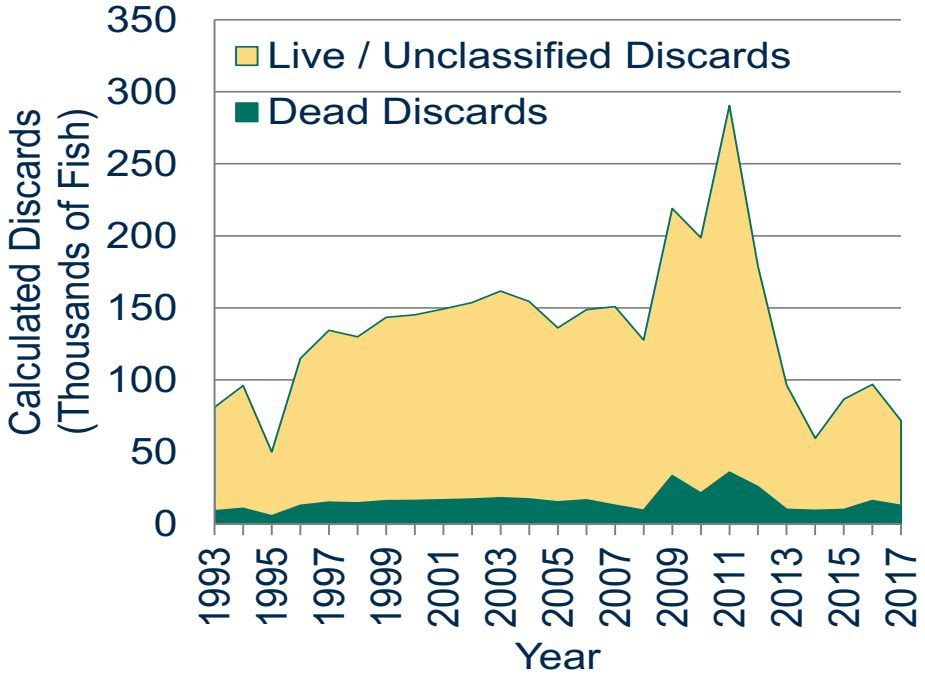


Figure 8. Observer CPUE-expansion estimates of Red Grouper annual discards in **(A)** number and **(B)** weight for vertical line gear for 1993-2017, denoting live/unclassified and dead discards.

(A)



(B)