# S61-WP-19: Model-estimated conversion factors for calibrating Coastal Household Telephone Survey (CHTS) charterboat catch and effort estimates with For Hire Survey (FHS) estimates in the Atlantic and Gulf of Mexico with application to red grouper and greater amberjack

Kyle Dettloff and Vivian Matter

SEDAR62-RD-06

March 2019

# Model-estimated conversion factors for calibrating Coastal Household Telephone Survey (CHTS) charterboat catch and effort estimates with For Hire Survey (FHS) estimates in the Atlantic and Gulf of Mexico with application to red grouper and greater amberjack

Kyle Dettloff and Vivian Matter

SEDAR61-WP-19

21 February 2019

SOUTHEAST Data, Assessment & Review

*This information is distributed solely for the purpose of pre-dissemination peer review. It does not represent and should not be construed to represent any agency determination or policy.*

Please cite this document as:

Dettloff, K. and Vivian Matter. 2019. Model-estimated conversion factors for calibrating Coastal Household Telephone Survey (CHTS) charterboat catch and effort estimates with For Hire Survey (FHS) estimates in the Atlantic and Gulf of Mexico with application to red grouper and greater amberjack. SEDAR61-WP-19. SEDAR, North Charleston, SC. 17 pp.

# Model-estimated conversion factors for calibrating Coastal Household Telephone Survey (CHTS) charterboat catch and effort estimates with For Hire Survey (FHS) estimates in the Atlantic and Gulf of Mexico with application to red grouper and greater amberjack

by

Kyle Dettloff and Vivian Matter

National Marine Fisheries Service
Southeast Fisheries Science Center

Fisheries Statistics Division
75 Virginia Beach Drive
Miami, FL 33149

October 2018

## INTRODUCTION

The Marine Recreational Information Program (MRIP), formerly the Marine Recreational Fishery Statistics Survey (MRFSS), was implemented in 1981 to provide regional based catch and effort estimates of marine finfish in United States recreational fisheries. Fishing pressure (effort) data are collected through a telephone survey of households in coastal counties (the Coastal Household Telephone Survey, CHTS) and by interviewing anglers at fishing access sites. NOAA Fisheries acknowledged that effort estimation in the charterboat sector is difficult due to the low occurrence of this fishing mode among households contacted in the telephone survey.

To improve charterboat effort estimation, NOAA Fisheries began testing a new survey protocol, the For Hire Survey (FHS), in 1995. To implement the new design, charterboat vessel directories were created by NMFS and participating state agencies which are maintained by the Gulf States Marine Fisheries Commission (GSMFC). Approximately 10% of the charterboat operators in the directory are randomly contacted by phone and asked relevant information regarding their fishing activities (e.g., number of trips and anglers, area of fishing, etc.). NOAA Fisheries concluded that the FHS produced significantly "more efficient, precise, and credible charter angler effort estimates than the traditional MRFSS method" (https://www.st.nmfs.noaa.gov/st1/recreational/queries/charter_method_test.html). Official FHS estimates are available for the Gulf of Mexico and East Florida beginning in 2000 and for the rest of the Atlantic coast beginning in 2004.

***Previous Calibration Analyses***

Conversion factors were previously calculated to calibrate the traditional CHTS charterboat estimates with FHS estimates in the Gulf of Mexico (Diaz and Phares, 2004) and South Atlantic (Sminkey, 2008). For years 1986 and later, the methods used in each region are consistent and are based on effort calibrations. Years 1981-1985 could not be calibrated with the same ratios developed for 1986+ because the survey estimated catch for charterboat and headboat modes as a single combined mode in both regions during that time period. Thus, in order to properly calibrate the estimates from 1981-1985, headboat data from the Southeast Region Headboat Survey (SRHS) must be included in the analysis. In the Gulf of Mexico, the calibration analysis for 1981-1985 was based on combined effort estimates from both surveys (SRHS and MRIP), and assumed that angler trips and angler days are equivalent (Diaz and Phares, 2004). In the South Atlantic, a different approach was used based on combined landings estimates by species (Sminkey, 2008), resulting in species-specific calibration factors. Calibrations were later calculated for 1981-1985 in the Gulf of Mexico and South Atlantic at the aggregate level of state, wave, and area based on equivalent effort units, for a consistent methodology across sub-regions (Matter et al., 2012).

In July 2018, NOAA Fisheries released new recreational catch estimates for all species and all modes, including charter mode estimates. As a result, the SEFSC conducted another analysis using the newly released data to correct for this change to the FHS. The present analysis uses a statistically sound, consistent methodology to provide improved calibrations for estimating FHS charterboat effort and landings with associated uncertainties from CHTS estimates. Estimates based on these calibrations are calculated for all sub-regions and years in which only CHTS estimates are available, producing a consistent time series of FHS estimates across all years of recreational data collection.

## METHODS

Charterboat calibrations based on estimated effort were calculated for years 1981-1999 in the Gulf of Mexico and 1981-2003 in the South Atlantic, years prior to the implementation of the FHS. Due to the availability of only combined charter/headboat estimates from 1981-1985, calibrations for these years were modeled separately using combined estimates as described in Matter et al. 2012. Likewise, combined charter/headboat calibrations were calculated for years 1981-2003 in the North and Mid Atlantic. Effort estimates are available for each sub-region to the level of year, wave, state, and area fished. See table 1 below for a description of the years with overlapping FHS/CHTS estimates that were used to construct the calibration models for each sub-region.

As effort is a strictly-positive continuous variable, generalized linear models with a Gamma response structure and log-link were fit to non-missing FHS estimated trips, with CHTS estimated trips as a predictor in the regression. Outliers were handled by fitting linear models to FHS trips against CHTS trips and excluding observations with a Cook's distance greater than one. This resulted in the removal of four total points that would have otherwise had a high influence on the model coefficients. Wave, state, and fishing area plus interactions were used as other potential covariates, with area fished excluded from years 1981-1985 as it was unavailable in the headboat survey. Models were fit separately for each sub-region due to variation in the available years with overlapping data and to better capture spatial differences in the relationship between FHS and CHTS. In order to prevent erroneous predictions outside the range of the available data, CHTS trip estimates were left uncorrected (ratio set to 1) if they exceeded the maximum value of that available to be modeled for each sub-region. All combinations of covariates and interactions were considered for inclusion, with the final models selected according to lowest BIC values (see table 1).

| | Calibrated Years | Overlap Years | Covariates Selected |
|---|---|---|---|
| Gulf of Mexico | 1986-1999 | 2000-2004 | *t, w, s, a, w:s, w:a, s:a* |
| | 1981-1985* | 1986-1990 | *t, w, s, w:s* |
| South Atlantic | 1986-2003** | 2004-2007 | *t, w, s, a, w:s, w:a, s:a* |
| | 1981-1985* | 1986-1990 | *t, w, s, w:s* |
| Mid Atlantic | 1981-2003 | 2004-2006 | *t, w, s, s:a* |
| North Atlantic | 1981-2003 | 2004-2006 | *t, w, s, a, t:a, s:a* |

*Table 1: Years in which CHTS units were adjusted to FHS units (calibrated years) and years of overlapping survey methods from which calibration models were constructed (overlap years). Terms selected for final models by minimizing BIC. t=CHTS trips, w=wave, s=state, a=area fished; colons represent interactions. *Combined charterboat/headboat effort (overlap years use estimated FHS effort). **Florida east coast calibrated 1986-1999 as official FHS estimates are available beginning in 2000 (overlap years include 2000-2003).*

FHS effort estimates for each sub-region were obtained by generating model predicted values using CHTS effort at each level of the stratification variables (year, wave, state, area fished):

$$\widehat{FHS_{eff}}_{hijk} = f\left(CHTS_{eff_{hijk}}\right) \{eq. 1\}$$

$$where\ h = year, i = wave, j = state, k = area\ fished$$

Calibration ratios were calculated by dividing the model-predicted FHS effort values by estimated CHTS trips:

$$\hat{R}_{ijk} = \frac{\widehat{FHS_{eff}}_{hijk}}{CHTS_{eff_{hijk}}} \{\text{eq. } 2\}$$

These empirical ratios were then applied to catch estimates (claim, harvest, release, AB1-C, AB1-H) for each species (n=822) by multiplying the estimated CHTS catch by the calibration ratio at each stratification level:

$$\widehat{FHS_{cat}}_{hijkl} = \hat{R}_{ijk}\ CHTS_{cat_{hijkl}} \{\text{eq. } 3\}$$

$$where\ l = species$$

Approximate variances of the ratios were calculated using the delta-method:

$$v\left(\hat{R}_{hijk}\right) = \left(CHTS_{eff_{hijk}} e^{CHTS_{eff_{hijk}} \hat{\beta}_1}\right)^2 v\left(\hat{\beta}_1\right) \{\text{eq. } 4\}$$

$$where\ \hat{\beta}_1 = model\ estimated\ CHTS\ coefficient$$

As the variance of a Gamma random variable is proportional to the square of the mean, calibrated variances for new FHS estimates were calculated as follows:

$$v\left(\widehat{FHS}_{hijk(l)}\right) = \hat{R}^2{}_{ijk}\, v\left(CHTS_{hijk(l)}\right) \{\text{eq. }5\}$$

Adjusted calibrated variances incorporating the uncertainty from the model estimated ratios were calculated with the following equation:

$$v_{adj}\left(\widehat{FHS}_{hijk(l)}\right) = \widehat{FHS}^2{}_{hijk(l)}\, v\left(\hat{R}_{hijk}\right) + \hat{R}^2\, v\left(\widehat{FHS}_{hijk(l)}\right) - v\left(\hat{R}_{hijk}\right) v\left(\widehat{FHS}_{hijk(l)}\right) \{\text{eq. }6\}$$

To reduce the effect of corrections for extreme ratios on the total variance when summing within a stratum, as well as to eliminate the possibility of negative estimated variances, the median of the positive ratio adjusted standard errors to the calibrated standard errors was used as a constant correction factor within each sub-region:

$$adj_g = median\left(\left(\frac{v_{adj}\left(\widehat{FHS}_{hijk}\right) > 0}{v\left(\widehat{FHS}_{hijk}\right)}\right)^{-2}\right)_g \{\text{eq. }7\}$$

$$where\ g = subregion$$

Thus, each calibrated variance estimate was multiplied by this correction factor as an approximation of the magnitude by which the model estimated ratios contributed to the total FHS variance estimates:

$$v_{adj}\left(\widehat{FHS}_{ghijk(l)}\right) = adj_g * v\left(\widehat{FHS}_{ghijk(l)}\right) \{\text{eq. }8\}$$

Model outputs are provided in Appendix 2.

## RESULTS AND DISCUSSION

The following table (2) provides mean estimated ratios and standard error correction factors to convert CHTS effort and standard errors to FHS units at each level of stratification:

| REGION | WAVE | STATE | AREA | RATIO | SE ADJ |
|---|---|---|---|---|---|
| GOM | 1 | AL | Inshore | 0.58 | 0.94 |
| GOM | 1 | AL | Ocean<=3mi | 1.96 | 4.89 |
| GOM | 1 | AL | Ocean>3mi | 1.41 | 3.28 |
| GOM | 1 | FLW | Inshore | 18.56 | 88.88 |
| GOM | 1 | FLW | Ocean<=10mi | 0.89 | 1.75 |
| GOM | 1 | FLW | Ocean>10mi | 1.08 | 1.94 |
| GOM | 1 | LA | Inshore | 1.27 | 3.1 |
| GOM | 1 | LA | Ocean<=3mi | 1.96 | 4.6 |
| GOM | 1 | LA | Ocean>3mi | 1.5 | 4.25 |
| GOM | 1 | MS | Inshore | 0.21 | 0.4 |
| GOM | 1 | MS | Ocean<=3mi | 1.07 | 2.03 |
| GOM | 1 | MS | Ocean>3mi | 0.22 | 0.4 |
| GOM | 2 | AL | Inshore | 1.24 | 2.34 |
| GOM | 2 | AL | Ocean<=3mi | 0.8 | 1.52 |
| GOM | 2 | AL | Ocean>3mi | 3.96 | 19.42 |
| GOM | 2 | FLW | Inshore | 9.13 | 42.4 |
| GOM | 2 | FLW | Ocean<=10mi | 1.79 | 3.52 |
| GOM | 2 | FLW | Ocean>10mi | 1.17 | 1.96 |
| GOM | 2 | LA | Inshore | 5.16 | 15.98 |
| GOM | 2 | LA | Ocean<=3mi | 2.41 | 6.32 |
| GOM | 2 | LA | Ocean>3mi | 14.41 | 67.96 |
| GOM | 2 | MS | Inshore | 1.96 | 5.58 |

| REGION | WAVE | STATE | AREA | RATIO | SE ADJ |
|---|---|---|---|---|---|
| GOM | 2 | MS | Ocean<=3mi | 1.51 | 5.1 |
| GOM | 2 | MS | Ocean>3mi | 2.3 | 7.61 |
| GOM | 3 | AL | Inshore | 1.02 | 1.8 |
| GOM | 3 | AL | Ocean<=3mi | 1.44 | 2.61 |
| GOM | 3 | AL | Ocean>3mi | 1.87 | 3.9 |
| GOM | 3 | FLW | Inshore | 5.66 | 20.35 |
| GOM | 3 | FLW | Ocean<=10mi | 1.55 | 2.59 |
| GOM | 3 | FLW | Ocean>10mi | 1.21 | 2.06 |
| GOM | 3 | LA | Inshore | 10.75 | 43.52 |
| GOM | 3 | LA | Ocean<=3mi | 3.16 | 7.78 |
| GOM | 3 | LA | Ocean>3mi | 2.85 | 6.54 |
| GOM | 3 | MS | Inshore | 2.56 | 7.46 |
| GOM | 3 | MS | Ocean<=3mi | 1.93 | 3.71 |
| GOM | 3 | MS | Ocean>3mi | 2.01 | 3.79 |
| GOM | 4 | AL | Inshore | 1.65 | 3.04 |
| GOM | 4 | AL | Ocean<=3mi | 1.25 | 2.24 |
| GOM | 4 | AL | Ocean>3mi | 1.39 | 2.4 |
| GOM | 4 | FLW | Inshore | 17.37 | 87.16 |
| GOM | 4 | FLW | Ocean<=10mi | 1.81 | 3.73 |
| GOM | 4 | FLW | Ocean>10mi | 1.12 | 1.93 |
| GOM | 4 | LA | Inshore | 6.26 | 15.04 |
| GOM | 4 | LA | Ocean<=3mi | 2.07 | 4.97 |

| REGION | WAVE | STATE | AREA | RATIO | SE ADJ |
|---|---|---|---|---|---|
| GOM | 4 | LA | Ocean>3mi | 2.89 | 6.13 |
| GOM | 4 | MS | Inshore | 1.47 | 2.63 |
| GOM | 4 | MS | Ocean<=3mi | 3.02 | 5.56 |
| GOM | 4 | MS | Ocean>3mi | 2.45 | 5.69 |
| GOM | 5 | AL | Inshore | 1.06 | 2.14 |
| GOM | 5 | AL | Ocean<=3mi | 0.44 | 0.9 |
| GOM | 5 | AL | Ocean>3mi | 0.66 | 1.16 |
| GOM | 5 | FLW | Inshore | 2.48 | 5.29 |
| GOM | 5 | FLW | Ocean<=10mi | 0.74 | 1.35 |
| GOM | 5 | FLW | Ocean>10mi | 0.85 | 1.4 |
| GOM | 5 | LA | Inshore | 5.99 | 16.92 |
| GOM | 5 | LA | Ocean<=3mi | 0.7 | 1.46 |
| GOM | 5 | LA | Ocean>3mi | 1.58 | 3.5 |
| GOM | 5 | MS | Inshore | 2.48 | 5.36 |
| GOM | 5 | MS | Ocean<=3mi | 1.5 | 3.6 |
| GOM | 5 | MS | Ocean>3mi | 1.16 | 3.08 |
| GOM | 6 | AL | Inshore | 0.49 | 0.93 |
| GOM | 6 | AL | Ocean<=3mi | 0.17 | 0.37 |
| GOM | 6 | AL | Ocean>3mi | 0.29 | 0.76 |
| GOM | 6 | FLW | Inshore | 1.51 | 2.81 |
| GOM | 6 | FLW | Ocean<=10mi | 0.81 | 1.38 |
| GOM | 6 | FLW | Ocean>10mi | 0.81 | 1.42 |
| GOM | 6 | LA | Inshore | 2.55 | 5.89 |
| GOM | 6 | LA | Ocean<=3mi | 1.28 | 3.35 |
| GOM | 6 | LA | Ocean>3mi | 1.27 | 4.74 |
| GOM | 6 | MS | Inshore | 0.72 | 1.62 |
| GOM | 6 | MS | Ocean<=3mi | 0.22 | 0.44 |
| GOM | 6 | MS | Ocean>3mi | 0.3 | 0.72 |
| **GOM** | **Median** | | | **1.5** | **3.32** |
| MA | 2 | DE | Inshore | 49.81 | 273.13 |
| MA | 2 | DE | Ocean<=3mi | 5.48 | 12.99 |
| MA | 2 | DE | Ocean>3mi | 0.53 | 1.34 |
| MA | 2 | MD | Inshore | 18 | 67.78 |
| MA | 2 | MD | Ocean<=3mi | 6.58 | 21.21 |
| MA | 2 | MD | Ocean>3mi | 0.23 | 0.46 |
| MA | 2 | NJ | Inshore | 0.21 | 0.42 |
| MA | 2 | NJ | Ocean<=3mi | 1.93 | 7.59 |
| MA | 2 | NJ | Ocean>3mi | 0.73 | 1.58 |
| MA | 2 | NY | Inshore | 0.24 | 0.53 |
| MA | 2 | NY | Ocean<=3mi | 2.95 | 9.16 |
| MA | 2 | NY | Ocean>3mi | 0.86 | 2.46 |
| MA | 2 | VA | Inshore | 2.46 | 6.4 |
| MA | 2 | VA | Ocean<=3mi | 0.2 | 0.56 |
| MA | 2 | VA | Ocean>3mi | 0.08 | 0.2 |
| MA | 3 | DE | Inshore | 2.81 | 15.28 |
| MA | 3 | DE | Ocean<=3mi | 9.93 | 22.36 |
| MA | 3 | DE | Ocean>3mi | 0.89 | 2.59 |
| MA | 3 | MD | Inshore | 3.28 | 7.22 |
| MA | 3 | MD | Ocean<=3mi | 54.83 | 225.18 |
| MA | 3 | MD | Ocean>3mi | 0.58 | 1.32 |
| MA | 3 | NJ | Inshore | 1.85 | 11.12 |
| MA | 3 | NJ | Ocean<=3mi | 1.34 | 3.4 |
| MA | 3 | NJ | Ocean>3mi | 1.14 | 1.99 |
| MA | 3 | NY | Inshore | 0.78 | 1.49 |
| MA | 3 | NY | Ocean<=3mi | 1.67 | 5.54 |
| MA | 3 | NY | Ocean>3mi | 3.75 | 9.31 |
| MA | 3 | VA | Inshore | 1.04 | 2.83 |
| MA | 3 | VA | Ocean<=3mi | 0.98 | 4.01 |
| MA | 3 | VA | Ocean>3mi | 0.3 | 1.01 |
| MA | 4 | DE | Inshore | 0.95 | 2.26 |
| MA | 4 | DE | Ocean<=3mi | 23.51 | 79.62 |

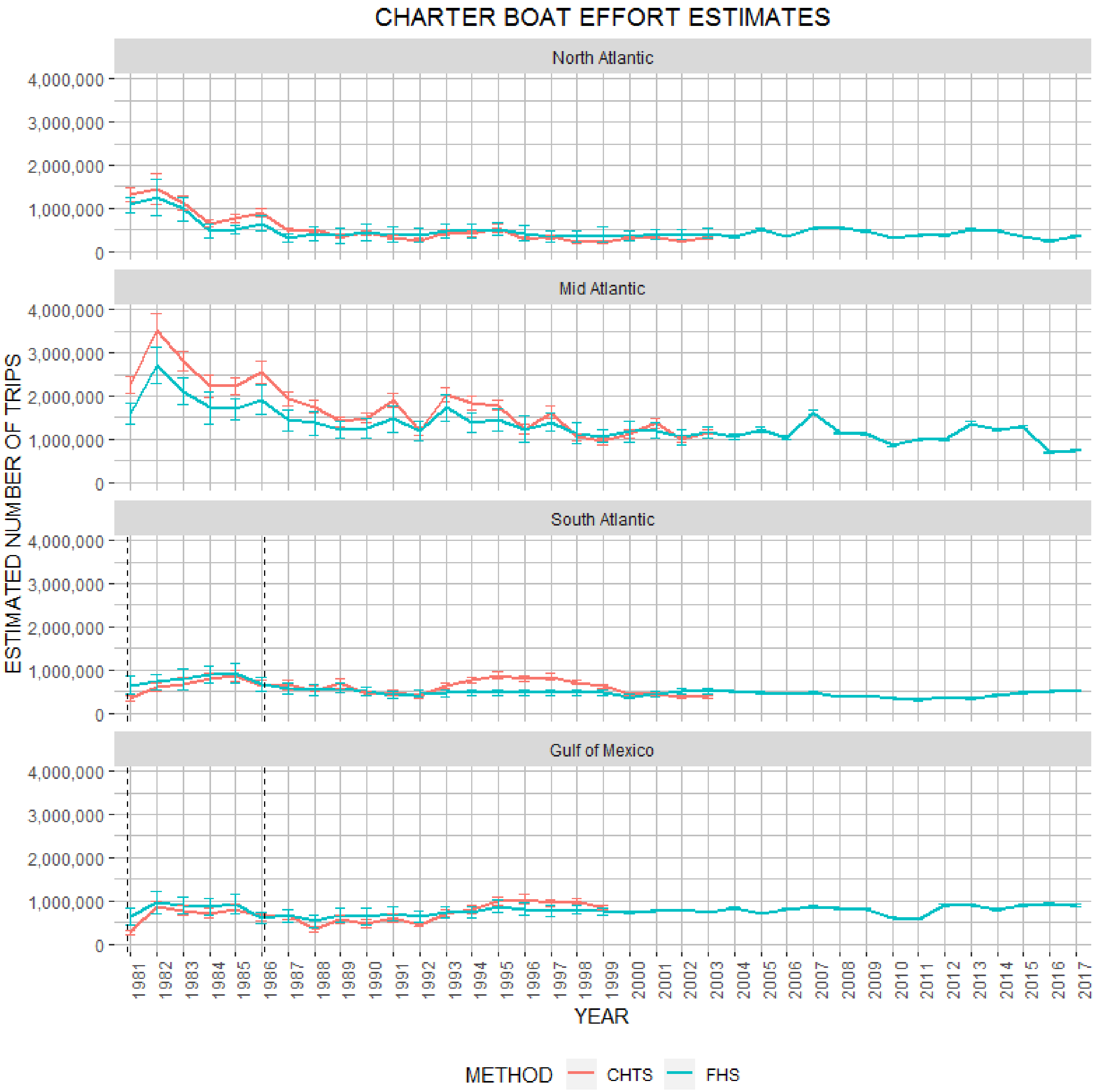
| REGION | WAVE | STATE | AREA | RATIO | SE ADJ |
|---|---|---|---|---|---|
| MA | 4 | DE | Ocean>3mi | 0.77 | 1.74 |
| MA | 4 | MD | Inshore | 3.99 | 9.26 |
| MA | 4 | MD | Ocean<=3mi | 11.21 | 41.71 |
| MA | 4 | MD | Ocean>3mi | 0.36 | 0.69 |
| MA | 4 | NJ | Inshore | 1.72 | 5.01 |
| MA | 4 | NJ | Ocean<=3mi | 2.39 | 6.43 |
| MA | 4 | NJ | Ocean>3mi | 1.56 | 2.89 |
| MA | 4 | NY | Inshore | 1.38 | 2.6 |
| MA | 4 | NY | Ocean<=3mi | 1.17 | 2.47 |
| MA | 4 | NY | Ocean>3mi | 2.01 | 4.35 |
| MA | 4 | VA | Inshore | 1.04 | 2.26 |
| MA | 4 | VA | Ocean<=3mi | 91.41 | 544.32 |
| MA | 4 | VA | Ocean>3mi | 0.36 | 1.19 |
| MA | 5 | DE | Inshore | 0.9 | 2.07 |
| MA | 5 | DE | Ocean<=3mi | 4.43 | 11.01 |
| MA | 5 | DE | Ocean>3mi | 0.65 | 1.72 |
| MA | 5 | MD | Inshore | 1.48 | 3.49 |
| MA | 5 | MD | Ocean<=3mi | 16.99 | 93.93 |
| MA | 5 | MD | Ocean>3mi | 0.2 | 0.39 |
| MA | 5 | NJ | Inshore | 1.04 | 2.32 |
| MA | 5 | NJ | Ocean<=3mi | 0.65 | 1.27 |
| MA | 5 | NJ | Ocean>3mi | 0.77 | 1.39 |
| MA | 5 | NY | Inshore | 1.12 | 3.37 |
| MA | 5 | NY | Ocean<=3mi | 0.44 | 0.84 |
| MA | 5 | NY | Ocean>3mi | 1.25 | 3.19 |
| MA | 5 | VA | Inshore | 1.2 | 5.25 |
| MA | 5 | VA | Ocean<=3mi | 0.27 | 0.75 |
| MA | 5 | VA | Ocean>3mi | 0.23 | 0.66 |
| MA | 6 | DE | Inshore | 1.6 | 4.23 |
| MA | 6 | DE | Ocean<=3mi | 0.94 | 2.48 |
| MA | 6 | DE | Ocean>3mi | 2.12 | 9.12 |
| MA | 6 | MD | Inshore | 3.69 | 12.36 |
| MA | 6 | MD | Ocean<=3mi | 0.72 | 1.35 |
| MA | 6 | MD | Ocean>3mi | 0.49 | 1.11 |
| MA | 6 | NJ | Inshore | 2.04 | 9.28 |
| MA | 6 | NJ | Ocean<=3mi | 2.17 | 15.17 |
| MA | 6 | NJ | Ocean>3mi | 1.91 | 6.93 |
| MA | 6 | NY | Inshore | 0.88 | 1.91 |
| MA | 6 | NY | Ocean<=3mi | 0.67 | 1.7 |
| MA | 6 | NY | Ocean>3mi | 7.28 | 47.15 |
| MA | 6 | VA | Inshore | 1.02 | 2.38 |
| MA | 6 | VA | Ocean<=3mi | 0.37 | 0.9 |
| MA | 6 | VA | Ocean>3mi | 0.46 | 2.57 |
| **MA** | **Median** | | | **1.14** | **2.83** |
| NA | 2 | CT | Inshore | 0.54 | 2.06 |
| NA | 2 | CT | Ocean<=3mi | 0.02 | 0.07 |
| NA | 2 | CT | Ocean>3mi | 0.18 | 0.7 |
| NA | 2 | MA | Inshore | 1.24 | 4.77 |
| NA | 2 | MA | Ocean<=3mi | 13.19 | 87.76 |
| NA | 2 | MA | Ocean>3mi | 0.79 | 4.7 |
| NA | 2 | ME | Ocean<=3mi | 0.56 | 2.01 |
| NA | 2 | ME | Ocean>3mi | 0.39 | 1.31 |
| NA | 2 | NH | Inshore | 124.35 | 373.49 |
| NA | 2 | NH | Ocean<=3mi | 1.23 | 4.84 |
| NA | 2 | NH | Ocean>3mi | 1.79 | 5.57 |
| NA | 2 | RI | Inshore | 5.4 | 16.22 |
| NA | 2 | RI | Ocean<=3mi | 3.71 | 13.4 |
| NA | 2 | RI | Ocean>3mi | 0.35 | 1.56 |
| NA | 3 | CT | Inshore | 1.33 | 6.18 |
| NA | 3 | CT | Ocean<=3mi | 0.79 | 2.66 |
| NA | 3 | CT | Ocean>3mi | 2.75 | 16.1 |

| REGION | WAVE | STATE | AREA | RATIO | SE ADJ |
|---|---|---|---|---|---|
| NA | 3 | MA | Inshore | 1.01 | 2.98 |
| NA | 3 | MA | Ocean<=3mi | 2.35 | 8.28 |
| NA | 3 | MA | Ocean>3mi | 2.51 | 10.12 |
| NA | 3 | ME | Inshore | 4.45 | 18.32 |
| NA | 3 | ME | Ocean<=3mi | 2.58 | 14.63 |
| NA | 3 | ME | Ocean>3mi | 0.78 | 3.18 |
| NA | 3 | NH | Inshore | 31.39 | 103.66 |
| NA | 3 | NH | Ocean<=3mi | 4.13 | 24.17 |
| NA | 3 | NH | Ocean>3mi | 1.15 | 4.53 |
| NA | 3 | RI | Inshore | 39.96 | 268.61 |
| NA | 3 | RI | Ocean<=3mi | 2.78 | 9.53 |
| NA | 3 | RI | Ocean>3mi | 0.53 | 2.59 |
| NA | 4 | CT | Inshore | 1.58 | 5.75 |
| NA | 4 | CT | Ocean<=3mi | 0.74 | 2.69 |
| NA | 4 | CT | Ocean>3mi | 0.32 | 1.83 |
| NA | 4 | MA | Inshore | 1.65 | 4.96 |
| NA | 4 | MA | Ocean<=3mi | 3.72 | 17.85 |
| NA | 4 | MA | Ocean>3mi | 2.45 | 9.06 |
| NA | 4 | ME | Inshore | 4.6 | 18.58 |
| NA | 4 | ME | Ocean<=3mi | 1.78 | 5.99 |
| NA | 4 | ME | Ocean>3mi | 0.86 | 3.56 |
| NA | 4 | NH | Inshore | 111.95 | 550.67 |
| NA | 4 | NH | Ocean<=3mi | 9.7 | 74.71 |
| NA | 4 | NH | Ocean>3mi | 1.77 | 7.73 |
| NA | 4 | RI | Inshore | 64.59 | 311.43 |
| NA | 4 | RI | Ocean<=3mi | 4.75 | 17.54 |
| NA | 4 | RI | Ocean>3mi | 1.36 | 5.49 |
| NA | 5 | CT | Inshore | 0.56 | 1.6 |
| NA | 5 | CT | Ocean<=3mi | 0.06 | 0.21 |
| NA | 5 | CT | Ocean>3mi | 0.78 | 4.11 |
| NA | 5 | MA | Inshore | 1.51 | 8.03 |
| NA | 5 | MA | Ocean<=3mi | 4.33 | 37.87 |
| NA | 5 | MA | Ocean>3mi | 3.01 | 15.95 |
| NA | 5 | ME | Inshore | 3.43 | 14.34 |
| NA | 5 | ME | Ocean<=3mi | 1.28 | 5.26 |
| NA | 5 | ME | Ocean>3mi | 0.53 | 2.31 |
| NA | 5 | NH | Inshore | 43.84 | 131.68 |
| NA | 5 | NH | Ocean<=3mi | 2.3 | 8.43 |
| NA | 5 | NH | Ocean>3mi | 3.32 | 14.4 |
| NA | 5 | RI | Inshore | 90.29 | 426.86 |
| NA | 5 | RI | Ocean<=3mi | 4.78 | 21.08 |
| NA | 5 | RI | Ocean>3mi | 0.89 | 5.1 |
| NA | 6 | CT | Inshore | 0.51 | 1.7 |
| NA | 6 | CT | Ocean<=3mi | 1.14 | 3.42 |
| NA | 6 | CT | Ocean>3mi | 1.29 | 6.51 |
| NA | 6 | MA | Inshore | 1.4 | 4.87 |
| NA | 6 | MA | Ocean<=3mi | 3.94 | 21.35 |
| NA | 6 | MA | Ocean>3mi | 1.63 | 6.8 |
| NA | 6 | RI | Inshore | 6.12 | 29.14 |
| NA | 6 | RI | Ocean<=3mi | 3.46 | 24.32 |
| NA | 6 | RI | Ocean>3mi | 1.35 | 6.85 |
| **NA** | **Median** | | | **1.71** | **6.83** |
| SA | 1 | FLE | Inshore | 5.21 | 12.7 |
| SA | 1 | FLE | Ocean<=3mi | 1.92 | 5.69 |
| SA | 1 | FLE | Ocean>10mi | 1.24 | 2.24 |
| SA | 1 | FLE | Ocean>3mi | 0.71 | 2.17 |
| SA | 2 | FLE | Inshore | 16.4 | 44.3 |
| SA | 2 | FLE | Ocean<=3mi | 1.39 | 3.23 |
| SA | 2 | FLE | Ocean>3mi | 1.14 | 2.49 |
| SA | 2 | GA | Inshore | 1.02 | 2.14 |
| SA | 2 | GA | Ocean<=3mi | 1.32 | 3.17 |
| SA | 2 | GA | Ocean>3mi | 4.39 | 16.27 |
| SA | 2 | NC | Inshore | 0.72 | 1.6 |
| SA | 2 | NC | Ocean<=3mi | 1.38 | 2.98 |
| SA | 2 | NC | Ocean>3mi | 0.8 | 1.79 |
| SA | 2 | SC | Inshore | 0.64 | 1.47 |
| SA | 2 | SC | Ocean<=3mi | 0.45 | 0.97 |
| SA | 2 | SC | Ocean>3mi | 1.21 | 2.92 |
| SA | 3 | FLE | Inshore | 2.42 | 5.41 |
| SA | 3 | FLE | Ocean<=3mi | 6.86 | 44.3 |
| SA | 3 | FLE | Ocean>3mi | 0.58 | 1.16 |
| SA | 3 | GA | Inshore | 1.1 | 2.17 |
| SA | 3 | GA | Ocean<=3mi | 2.62 | 5.13 |
| SA | 3 | GA | Ocean>3mi | 3.45 | 7.14 |
| SA | 3 | NC | Inshore | 1.73 | 4.44 |
| SA | 3 | NC | Ocean<=3mi | 1.99 | 5.02 |
| SA | 3 | NC | Ocean>3mi | 1.75 | 3.51 |
| SA | 3 | SC | Inshore | 0.69 | 1.63 |
| SA | 3 | SC | Ocean<=3mi | 0.7 | 1.61 |
| SA | 3 | SC | Ocean>3mi | 1.13 | 2.31 |
| SA | 4 | FLE | Inshore | 3.35 | 7.4 |
| SA | 4 | FLE | Ocean<=3mi | 1.14 | 2.59 |
| SA | 4 | FLE | Ocean>3mi | 0.69 | 1.55 |
| SA | 4 | GA | Inshore | 3.6 | 8.49 |
| SA | 4 | GA | Ocean<=3mi | 4.74 | 12.12 |
| SA | 4 | GA | Ocean>3mi | 7.86 | 20.35 |
| SA | 4 | NC | Inshore | 3 | 7.03 |
| SA | 4 | NC | Ocean<=3mi | 2.53 | 6.53 |
| SA | 4 | NC | Ocean>3mi | 2.37 | 5.6 |
| SA | 4 | SC | Inshore | 1.31 | 4.04 |
| SA | 4 | SC | Ocean<=3mi | 1.48 | 4.26 |
| SA | 4 | SC | Ocean>3mi | 2.69 | 7.05 |
| SA | 5 | FLE | Inshore | 3.49 | 9.64 |
| SA | 5 | FLE | Ocean<=3mi | 1.3 | 4.43 |
| SA | 5 | FLE | Ocean>3mi | 0.97 | 2.84 |
| SA | 5 | GA | Inshore | 1.08 | 2.66 |
| SA | 5 | GA | Ocean<=3mi | 1.26 | 2.8 |
| SA | 5 | GA | Ocean>3mi | 2.25 | 6.06 |
| SA | 5 | NC | Inshore | 4.57 | 12.74 |
| SA | 5 | NC | Ocean<=3mi | 1.29 | 2.7 |
| SA | 5 | NC | Ocean>3mi | 1.34 | 2.7 |
| SA | 5 | SC | Inshore | 0.52 | 1.23 |
| SA | 5 | SC | Ocean<=3mi | 0.27 | 0.81 |
| SA | 5 | SC | Ocean>3mi | 1.5 | 5.54 |
| SA | 6 | FLE | Inshore | 8.88 | 20.8 |
| SA | 6 | FLE | Ocean<=3mi | 0.93 | 2.19 |
| SA | 6 | FLE | Ocean>3mi | 0.61 | 1.56 |
| SA | 6 | GA | Inshore | 1.26 | 3.11 |
| SA | 6 | GA | Ocean<=3mi | 2.68 | 5.88 |
| SA | 6 | GA | Ocean>3mi | 2.21 | 5.43 |
| SA | 6 | NC | Inshore | 1.83 | 3.6 |
| SA | 6 | NC | Ocean<=3mi | 4.16 | 13.83 |
| SA | 6 | NC | Ocean>3mi | 4.27 | 18.54 |
| SA | 6 | SC | Inshore | 0.68 | 2.41 |
| SA | 6 | SC | Ocean<=3mi | 0.18 | 0.44 |
| SA | 6 | SC | Ocean>3mi | 1.59 | 7.13 |
| **SA** | **Median** | | | **1.39** | **3.56** |
| **ALL** | **Median** | | | **1.44** | **4.12** |

*Table 2: Estimated CHTS to FHS conversion factors.*

Figure 1: Relationship between model-estimated FHS trips and CHTS trips, color coded by sub-region with a 1:1 reference line.

Figure 2: Annual time series of aggregated FHS and CHTS charterboat effort estimates (with standard errors) by sub-region. Values in years between dashed vertical lines represent combined charter/headboat effort (all values in North and Mid Atlantic represent combined effort).



Note that within a given stratum, overall FHS effort (and thus catch) estimates are estimated to be greater than CHTS estimates (median ratio > 1). However, as seen in figure 2, this varies from year to year and sub-region to sub-region when estimates are aggregated on an annual level. Estimates from each method in the North Atlantic are relatively similar across time, while CHTS seemed to overestimate effort in the Mid Atlantic in earlier years. In contrast, in the Gulf of Mexico and South Atlantic, CHTS effort appears to have been slightly underestimated in earlier years and slightly overestimated in later years. Some ratios may lack robustness on an individual level due to lack of data in given stratum, and those with large standard error adjustments should be applied cautiously. This approach is preferable to previous methods in which data were aggregated before the estimation of calibration factors, leading to the loss of spatial and temporal variability. Potential relationships across space and time are now preserved, and a unified methodology now allows for a fair comparison of estimates across years and sub-regions. It is also possible to apply these ratios to smaller spatial units (e.g., domains) under the assumption that the relationship between estimates is constant across the level at which the ratio was calculated.

## REFERENCES

Diaz, G.A, and P. Phares. 2004. Estimated conversion factors for calibrating MRFSS charterboat landings and effort estimates for the Gulf of Mexico in 1981-1997 with For Hire Survey estimates with application to red snapper landings. Sustainable Fisheries Division Contribution No SFD-2004-036. Miami, FL. SEDAR7-AW-03.

Matter, V., N. Cummings, J. Isely, K. Brennan, and K. Fitzpatrick. 2012. Estimated conversion factors for calibrating MRFSS charterboat landings and effort estimates for the South Atlantic and Gulf of Mexico in 1981-1985 with For Hire Survey estimates with application to Spanish mackerel and cobia landings. Sustainable Fisheries Division Contribution No SFD-2012-003. Miami, FL. SEDAR 28-DW-12.

Sminkey, T. 2008. Estimated conversion factors for calibrating MRFSS charterboat landings and effort estimates from the Southeastern US (North Carolina to Florida-east coast) in 1981-2003 with For-Hire Survey estimates with application to King Mackerel landings. Silver Spring, MD. SEDAR 16-DW-15.

**APPENDIX 1: GOM red grouper and SA greater amberjack**

Table 3: FHS vs. CHTS total catch estimates and standard errors (lbs.) for Gulf of Mexico red grouper by year and state.

| YEAR | ST | CHTS | FHS | SE CHTS | SE FHS |
|---|---|---|---|---|---|
| 1981 | FLW | 363,673 | 510,314 | 242,969 | 511,851 |
| 1982 | FLW | 126,361 | 135,185 | 42,131 | 72,029 |
| 1983 | FLW | 104,388 | 110,497 | 27,963 | 42,565 |
| 1984 | AL | 91 | 65 | 105 | 116 |
| 1984 | FLW | 576,684 | 644,827 | 241,060 | 378,460 |
| 1985 | FLW | 740,949 | 796,397 | 412,123 | 702,280 |
| 1986 | FLW | 291,429 | 226,476 | 67,338 | 73,792 |
| 1987 | FLW | 139,396 | 121,858 | 38,337 | 45,728 |
| 1988 | FLW | 100,410 | 127,891 | 31,352 | 57,038 |
| 1989 | FLW | 318,997 | 240,474 | 100,911 | 113,438 |
| 1990 | AL | 270 | 116 | 270 | 181 |
| 1990 | FLW | 280,962 | 289,768 | 135,189 | 200,979 |
| 1991 | FLW | 349,796 | 261,127 | 299,924 | 329,672 |
| 1991 | FLW | 35 | 33 | 24 | 35 |
| 1992 | FLW | 227,020 | 281,258 | 58,949 | 114,065 |
| 1993 | FLW | 107,470 | 113,240 | 49,342 | 78,706 |
| 1994 | FLW | 222,611 | 189,067 | 97,615 | 135,512 |
| 1995 | AL | 147 | 5 | 166 | 9 |
| 1995 | FLW | 439,978 | 312,006 | 143,841 | 159,248 |
| 1996 | AL | 163 | 150 | 193 | 274 |
| 1996 | FLW | 233,841 | 152,131 | 100,623 | 100,764 |
| 1997 | FLW | 201,671 | 150,604 | 49,077 | 62,267 |
| 1998 | FLW | 367,184 | 230,890 | 67,375 | 65,076 |
| 1999 | AL | 164 | 74 | 112 | 78 |
| 1999 | FLW | 556,087 | 411,423 | 87,216 | 113,825 |
| **Total** | | **5,749,777** | **5,305,872** | **689,750** | **1,082,731** |

Figure 4: Gulf of Mexico red grouper annual estimates for FHS calibrated years (error bars represent ±1 SE).

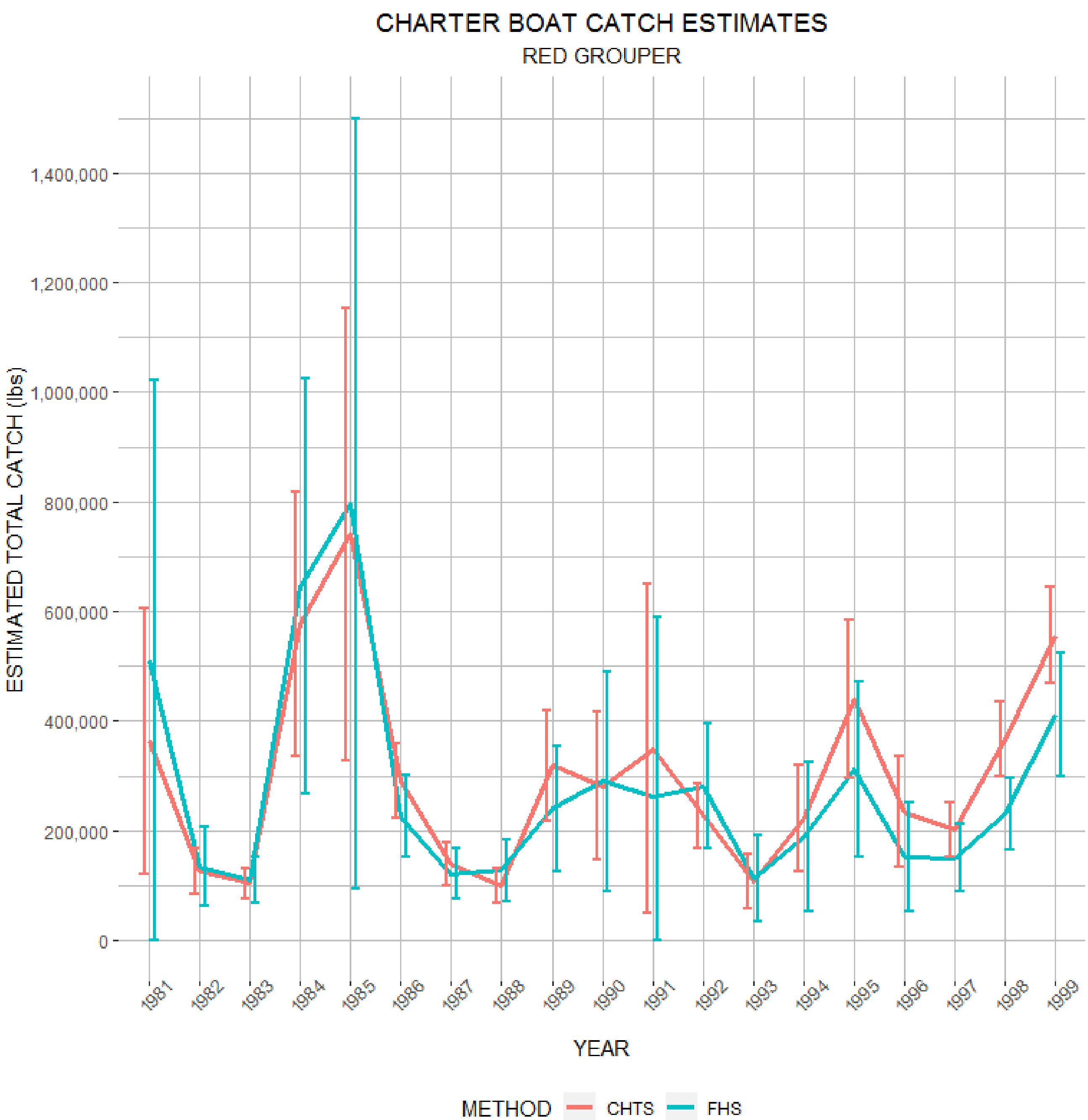
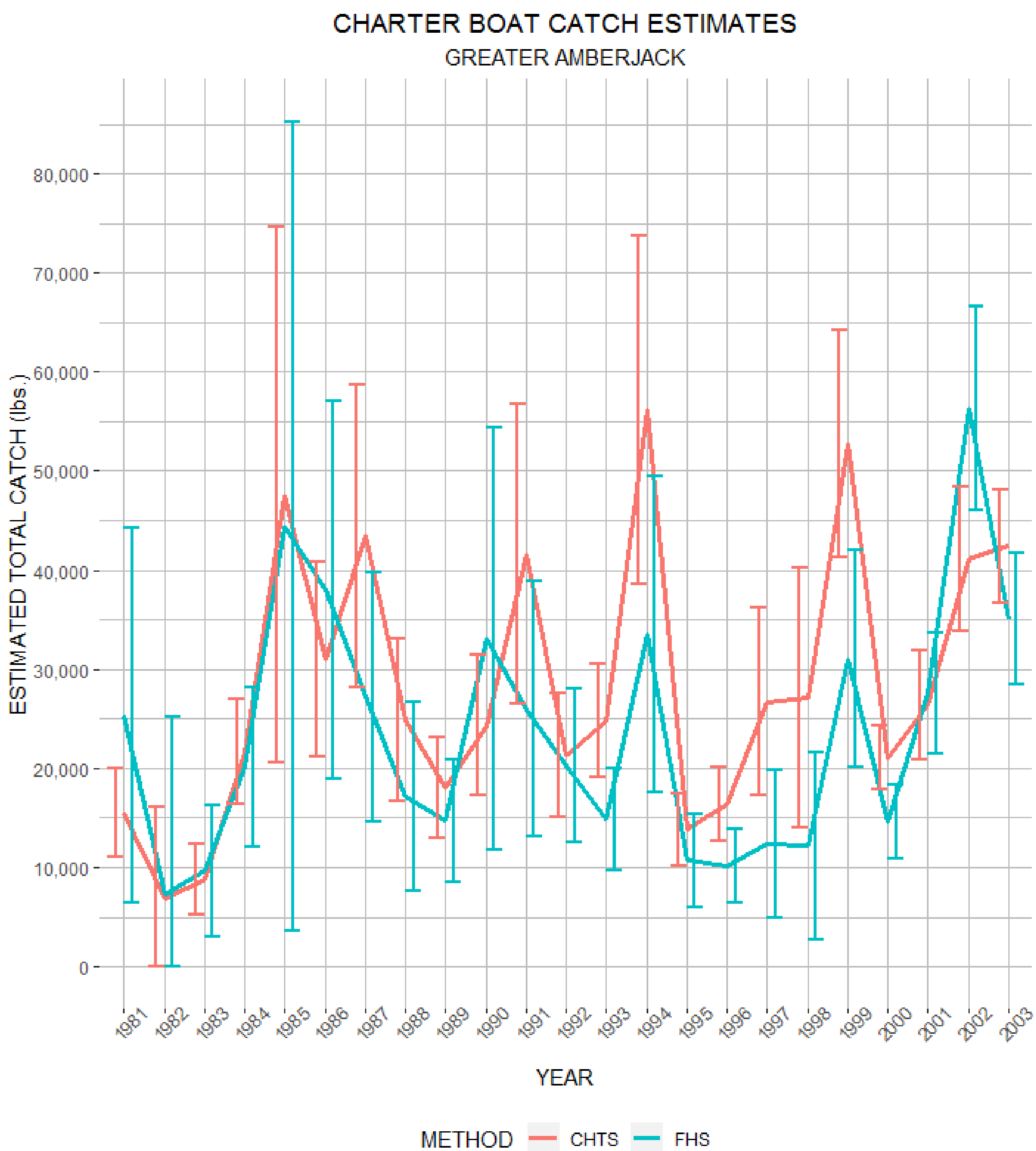


Table 4: FHS vs. CHTS total catch estimates and standard errors (lbs.) for South Atlantic greater amberjack by year and state.

| YEAR | ST | CHTS | FHS | SE CHTS | SE FHS |
|---|---|---|---|---|---|
| 1981 | FLE | 14,592 | 16,724 | 4,361 | 8,876 |
| 1981 | NC | 772 | 7,727 | 934 | 16,608 |
| 1981 | SC | 171 | 857 | 190 | 1,692 |
| 1982 | FLE | 6,830 | 7,352 | 9,312 | 17,822 |
| 1983 | FLE | 8,035 | 8,703 | 3,527 | 6,539 |
| 1983 | NC | 659 | 471 | 662 | 842 |
| 1983 | SC | 71 | 460 | 63 | 703 |
| 1984 | FLE | 15,206 | 15,917 | 4,309 | 7,465 |
| 1984 | GA | 517 | 673 | 319 | 722 |
| 1984 | NC | 754 | 593 | 764 | 1,068 |
| 1984 | SC | 5,180 | 2,903 | 2,895 | 2,722 |
| 1985 | FLE | 20,429 | 21,225 | 10,445 | 18,631 |
| 1985 | GA | 2,215 | 2,037 | 2,085 | 3,287 |
| 1985 | SC | 24,962 | 21,129 | 24,876 | 36,191 |
| 1986 | FLE | 18,754 | 19,660 | 9,083 | 16,746 |
| 1986 | GA | 465 | 4,299 | 291 | 5,259 |
| 1986 | NC | 6,302 | 10,650 | 2,326 | 6,849 |
| 1986 | SC | 5,460 | 3,406 | 3,017 | 3,326 |
| 1987 | FLE | 37,531 | 19,109 | 15,095 | 12,079 |
| 1987 | GA | 1,024 | 2,663 | 900 | 2,767 |
| 1987 | NC | 2,619 | 2,861 | 1,689 | 1,629 |
| 1987 | SC | 2,291 | 2,608 | 785 | 1,624 |
| 1988 | FLE | 21,663 | 12,828 | 7,971 | 8,972 |
| 1988 | NC | 886 | 3,406 | 451 | 3,164 |
| 1988 | SC | 2,328 | 912 | 1,938 | 1,044 |
| 1989 | FLE | 14,641 | 11,440 | 4,959 | 6,018 |
| 1989 | NC | 1,336 | 2,629 | 439 | 1,523 |
| 1989 | SC | 2,026 | 639 | 1,037 | 475 |
| 1990 | FLE | 16,632 | 15,094 | 5,853 | 10,370 |
| 1990 | NC | 7,175 | 17,273 | 3,953 | 18,617 |
| 1990 | SC | 548 | 668 | 301 | 622 |
| 1991 | FLE | 38,419 | 21,958 | 15,048 | 12,732 |
| 1991 | GA | 392 | 640 | 370 | 1,076 |
| 1991 | NC | 1,710 | 2,650 | 512 | 1,282 |
| 1991 | SC | 1,133 | 725 | 820 | 902 |
| 1992 | FLE | 18,731 | 14,829 | 6,189 | 7,210 |
| 1992 | GA | 1,238 | 2,957 | 579 | 2,493 |
| 1992 | NC | 1,208 | 2,344 | 435 | 1,489 |
| 1992 | SC | 143 | 150 | 134 | 241 |
| 1993 | FLE | 18,565 | 8,921 | 5,269 | 4,404 |
| 1993 | NC | 2,656 | 4,361 | 688 | 2,111 |
| 1993 | SC | 3,575 | 1,582 | 2,171 | 1,667 |
| 1994 | FLE | 49,473 | 24,655 | 17,421 | 15,307 |
| 1994 | GA | 1,406 | 2,533 | 959 | 3,078 |
| 1994 | NC | 3,538 | 5,344 | 897 | 2,773 |
| 1994 | SC | 1,768 | 1,031 | 1,770 | 1,774 |
| 1995 | FLE | 11,417 | 7,571 | 3,603 | 4,577 |
| 1995 | GA | 52 | 159 | 18 | 99 |
| 1995 | NC | 2,195 | 2,798 | 520 | 1,225 |
| 1995 | SC | 181 | 146 | 184 | 257 |
| 1996 | FLE | 10,424 | 4,179 | 3,353 | 2,397 |
| 1996 | GA | 575 | 457 | 473 | 574 |
| 1996 | NC | 4,246 | 4,826 | 1,193 | 2,728 |
| 1996 | SC | 1,178 | 681 | 796 | 912 |
| 1997 | FLE | 24,304 | 10,312 | 9,442 | 7,388 |
| 1997 | GA | 176 | 386 | 126 | 538 |
| 1997 | NC | 1,323 | 1,031 | 427 | 761 |
| 1997 | SC | 942 | 616 | 375 | 439 |
| 1998 | FLE | 24,915 | 9,628 | 13,107 | 9,333 |
| 1998 | GA | 101 | 109 | 95 | 184 |
| 1998 | NC | 1,984 | 2,400 | 728 | 1,642 |
| 1998 | SC | 75 | 39 | 74 | 66 |
| 1999 | FLE | 50,784 | 27,811 | 11,357 | 10,646 |
| 1999 | GA | 332 | 1,530 | 166 | 1,470 |
| 1999 | NC | 1,631 | 1,699 | 1,279 | 2,073 |
| 1999 | SC | 25 | 20 | 24 | 34 |
| 2000 | FLE | 19,119 | 11,055 | 3,137 | 2,751 |
| 2000 | GA | 349 | 1,524 | 269 | 2,127 |
| 2000 | NC | 715 | 1,007 | 289 | 696 |
| 2000 | SC | 903 | 1,088 | 408 | 1,115 |
| 2001 | FLE | 23,224 | 23,136 | 5,406 | 5,475 |
| 2001 | GA | 1 | 3 | 1 | 6 |
| 2001 | NC | 3,009 | 4,302 | 1,005 | 2,642 |
| 2001 | SC | 123 | 140 | 85 | 170 |
| 2002 | FLE | 34,090 | 43,978 | 7,067 | 8,638 |
| 2002 | GA | 542 | 1,834 | 367 | 2,212 |
| 2002 | NC | 6,470 | 10,501 | 1,819 | 5,204 |
| 2002 | SC | 36 | 43 | 40 | 86 |
| 2003 | FLE | 38,615 | 26,701 | 5,578 | 5,094 |
| 2003 | GA | 1,208 | 3,176 | 683 | 2,732 |
| 2003 | NC | 1,755 | 2,838 | 895 | 2,577 |
| 2003 | SC | 864 | 2,366 | 551 | 1,987 |
| **Total** | | **653,912** | **541,686** | **50,054** | **67,619** |

Figure 5: South Atlantic greater amberjack annual estimates for FHS calibrated years (error bars represent ±1 SE).



# APPENDIX 2: Model Output

Gamma GLM (log-link)

| | FHS TRIPS | | | | | |
|---|---|---|---|---|---|---|
| | North Atlantic | Mid Atlantic | South Atlantic | South Atlantic (81-85) | Gulf of Mexico | Gulf of Mexico (81-85) |
| ESTRIPS | 5.25e-5** (2.56e-5) | 9.54e-6*** (3.23e-6) | 1.82e-6 (3.88e-6) | 5.07e-6*** (8.38e-7) | 6.88e-6** (3.07e-6) | 3.57e-6* (1.85e-6) |
| ESTRIPS:AREA_X2 | -7.71e-5***(2.66e-5) | | | | | |
| ESTRIPS:AREA_X5 | -1.21e-5 (2.93e-5) | | | | | |
| ESTRIPS:AREA_X6 | | | | | | |
| AREA_X1 | 6.357*** (0.315) | | 9.999*** (0.191) | | 5.554*** (0.218) | |
| AREA_X2 | 6.851*** (0.280) | 0.950*** (0.318) | 9.149*** (0.192) | | 6.609*** (0.219) | |
| AREA_X3 | | | | | 4.700*** (0.422) | |
| AREA_X4 | | | | | 5.380*** (0.429) | |
| AREA_X5 | 5.928*** (0.315) | 1.048*** (0.318) | 8.312*** (0.178) | | 4.756*** (0.228) | |
| AREA_X6 | 3.169*** (0.467) | -2.695*** (0.829) | | | | |
| ST9 | -1.920*** (0.350) | | | | | |
| ST12 | | | | | 4.707*** (0.349) | |
| ST13 | | | -3.689*** (0.271) | | | |
| ST22 | | | | | 0.939*** (0.268) | 8.267*** (0.142) |
| ST24 | | 0.526 (0.402) | | | | |
| ST25 | 1.142*** (0.332) | | | | | |
| ST28 | | | | | -0.960*** (0.342) | |
| ST33 | -0.124 (0.369) | | | | | |
| ST34 | | 2.850*** (0.321) | | | | |
| ST36 | | 2.544*** (0.330) | | | | |
| ST37 | | | -3.087*** (0.255) | 8.999*** (0.109) | | |
| ST44 | 0.837** (0.330) | | | | | |
| ST45 | | | -4.322*** (0.240) | 8.035*** (0.104) | | |
| ST51 | | -0.442 (0.323) | | | | |
| STAFW | | | | | | 11.145*** (0.229) |
| STGFE | | | | 10.825*** (0.103) | | |
| WAVE2 | | 5.608*** (0.271) | -0.394* (0.234) | 0.317** (0.130) | 1.546*** (0.290) | 0.644*** (0.202) |
| WAVE3 | 1.187*** (0.212) | 7.208*** (0.262) | -0.335 (0.232) | 1.989*** (0.136) | 2.127*** (0.287) | 2.156*** (0.202) |
| WAVE4 | 2.078*** (0.238) | 7.784*** (0.258) | -0.238 (0.235) | 2.157*** (0.138) | 2.268*** (0.287) | 1.947*** (0.201) |
| WAVE5 | 0.908*** (0.217) | 6.697*** (0.262) | -1.392*** (0.234) | 1.357*** (0.129) | 0.720** (0.287) | 1.469*** (0.202) |
| WAVE6 | -0.317 (0.243) | 6.067*** (0.259) | -0.836*** (0.235) | 0.146 (0.091) | -0.818*** (0.305) | 0.455** (0.201) |
| AREA_X2:ST9 | 0.707 (0.475) | | | | | |
| AREA_X2:ST12 | | | | | | |

| | | | | |
|---|---|---|---|---|
| AREA_X2:ST13 | | | 1.303*** (0.222) | |
| AREA_X2:ST22 | | | | -0.618*** (0.220) |
| AREA_X2:ST24 | | -0.109 (0.499) | | |
| AREA_X2:ST25 | 1.450*** (0.444) | | | |
| AREA_X2:ST28 | | | | -1.897*** (0.242) |
| AREA_X2:ST33 | 1.551*** (0.474) | | | |
| AREA_X2:ST34 | | -0.354 (0.439) | | |
| AREA_X2:ST36 | | -0.718 (0.436) | | |
| AREA_X2:ST37 | | | 1.343*** (0.194) | |
| AREA_X2:ST44 | -0.477 (0.438) | | | |
| AREA_X2:ST45 | | | 1.514*** (0.229) | |
| AREA_X2:ST51 | | -0.129 (0.436) | | |
| AREA_X2:WAVE2 | | | 1.423*** (0.299) | 0.824** (0.349) |
| AREA_X2:WAVE3 | | | 1.088*** (0.303) | 0.859** (0.351) |
| AREA_X2:WAVE4 | | | 0.788*** (0.299) | 0.583* (0.350) |
| AREA_X2:WAVE5 | | | 1.296*** (0.296) | 1.323*** (0.349) |
| AREA_X2:WAVE6 | | | 0.820*** (0.300) | 0.296 (0.370) |
| AREA_X3:ST12 | | | | |
| AREA_X3:ST22 | | | | |
| AREA_X3:ST28 | | | | |
| AREA_X3:WAVE2 | | | | 0.870 (0.606) |
| AREA_X3:WAVE3 | | | | 1.162* (0.606) |
| AREA_X3:WAVE4 | | | | 1.118* (0.606) |
| AREA_X3:WAVE5 | | | | 1.705*** (0.605) |
| AREA_X3:WAVE6 | | | | 1.763*** (0.615) |
| AREA_X4:ST12 | | | | |
| AREA_X4:ST22 | | | | |
| AREA_X4:ST28 | | | | |
| AREA_X4:WAVE2 | | | | 0.234 (0.607) |
| AREA_X4:WAVE3 | | | | 0.425 (0.621) |
| AREA_X4:WAVE4 | | | | 0.536 (0.619) |
| AREA_X4:WAVE5 | | | | 1.662*** (0.604) |
| AREA_X4:WAVE6 | | | | 1.552** (0.616) |
| AREA_X5:ST9 | 3.169*** (0.516) | | | |
| AREA_X5:ST12 | | | | |
| AREA_X5:ST13 | | | 2.405*** (0.222) | |
| AREA_X5:ST22 | | | | 2.465*** (0.221) |
| AREA_X5:ST24 | | 1.677*** (0.502) | | |
| AREA_X5:ST25 | 0.644 (0.486) | | | |
| AREA_X5:ST28 | | | | 0.493** (0.223) |
| AREA_X5:ST33 | -0.105 (0.574) | | | |

| | | | | |
|---|---|---|---|---|
| AREA_X5:ST34 | | -1.390*** (0.431) | | |
| AREA_X5:ST36 | | -0.690 (0.428) | | |
| AREA_X5:ST37 | | | 1.019*** (0.196) | |
| AREA_X5:ST44 | -0.308 (0.456) | | | |
| AREA_X5:ST45 | | | 2.422*** (0.223) | |
| AREA_X5:ST51 | | 1.272*** (0.436) | | |
| AREA_X5:WAVE2 | | | 1.003*** (0.304) | 0.577* (0.340) |
| AREA_X5:WAVE3 | | | 0.416 (0.298) | 0.529 (0.337) |
| AREA_X5:WAVE4 | | | 0.308 (0.299) | 0.254 (0.336) |
| AREA_X5:WAVE5 | | | 1.100*** (0.301) | 1.371*** (0.338) |
| AREA_X5:WAVE6 | | | 1.065*** (0.304) | 1.619*** (0.357) |
| AREA_X6:ST9 | 0.832 (0.696) | | | |
| AREA_X6:ST24 | | -1.988** (0.998) | | |
| AREA_X6:ST25 | -0.647 (0.681) | | | |
| AREA_X6:ST33 | 0.180 (0.762) | | | |
| AREA_X6:ST34 | | -1.771* (0.925) | | |
| AREA_X6:ST36 | | -1.578* (0.944) | | |
| AREA_X6:ST44 | -1.469** (0.648) | | | |
| AREA_X6:ST51 | | -1.579 (1.020) | | |
| ST12:WAVE2 | | | | -1.384*** (0.459) |
| ST12:WAVE3 | | | | -2.000*** (0.462) |
| ST12:WAVE4 | | | | -2.509*** (0.461) |
| ST12:WAVE5 | | | | -2.339*** (0.461) |
| ST12:WAVE6 | | | | -0.898* (0.461) |
| ST13:WAVE2 | | | -0.410 (0.290) | |
| ST13:WAVE3 | | | 0.871*** (0.287) | |
| ST13:WAVE4 | | | 1.087*** (0.287) | |
| ST13:WAVE5 | | | 0.850*** (0.287) | |
| ST13:WAVE6 | | | | |
| ST22:WAVE2 | | | | -1.278*** (0.312) |
| ST22:WAVE3 | | | | -0.830*** (0.307) |
| ST22:WAVE4 | | | | -0.795** (0.309) |
| ST22:WAVE5 | | | | -0.632** (0.306) |
| ST22:WAVE6 | | | | 0.047 (0.314) |
| ST28:WAVE2 | | | | 0.402 (0.401) |
| ST28:WAVE3 | | | | 0.816** (0.400) |
| ST28:WAVE4 | | | | 0.938** (0.399) |
| ST28:WAVE5 | | | | 1.270*** (0.401) |
| ST28:WAVE6 | | | | 1.120*** (0.425) |
| ST37:WAVE2 | | | 0.566* (0.291) | |
| ST37:WAVE3 | | | 2.583*** (0.299) | |

| | | | | | | |
|---|---|---|---|---|---|---|
| ST37:WAVE4 | | | 2.867*** (0.304) | | | |
| ST37:WAVE5 | | | 2.593*** (0.296) | | | |
| ST37:WAVE6 | | | 1.481*** (0.292) | | | |
| ST45:WAVE2 | | | 0.622** (0.290) | 1.148*** (0.119) | | |
| ST45:WAVE3 | | | 1.842*** (0.273) | 0.406*** (0.115) | | |
| ST45:WAVE4 | | | 2.348*** (0.273) | 0.487*** (0.119) | | |
| ST45:WAVE5 | | | 1.860*** (0.281) | 0.447*** (0.115) | | |
| ST45:WAVE6 | | | | | | |
| STAFW:WAVE2 | | | | | | -0.173 (0.292) |
| STAFW:WAVE3 | | | | | | -1.670*** (0.326) |
| STAFW:WAVE4 | | | | | | -1.500*** (0.298) |
| STAFW:WAVE5 | | | | | | -1.553*** (0.303) |
| STAFW:WAVE6 | | | | | | -0.637** (0.285) |
| STGFE:WAVE2 | | | | -0.075 (0.122) | | |
| STGFE:WAVE3 | | | | -1.790*** (0.120) | | |
| STGFE:WAVE4 | | | | -1.806*** (0.115) | | |
| STGFE:WAVE5 | | | | -1.533*** (0.146) | | |
| STGFE:WAVE6 | | | | | | |
| Observations | 178 | 222 | 322 | 78 | 332 | 60 |
| Log Likelihood | -1,539.0 | -2,076.1 | -2,939.3 | -775.0 | -2,959.7 | -656.3 |
| Bayesian Inf. Crit. | 3,221.2 | 4,290.6 | 6,119.0 | 1,626.4 | 6,230.9 | 1,367.9 |

Note: Standard errors in parenthesis *p<0.1; **p<0.05; ***p<0.01