SEFSC Computation of Uncertainty for Southeast Regional Headboat Survey and Total Recreational Landings Estimates, with Applications to SEDAR 68 Scamp and Yellowmouth Grouper

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SEDAR68-DW-31

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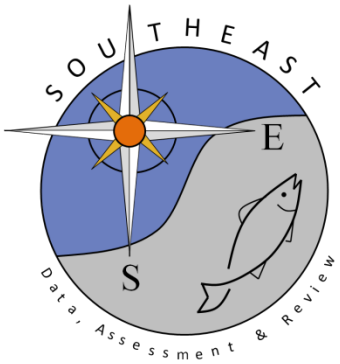

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SEDAR 68-DW-31

SEFSC Computation of Uncertainty for Southeast Region Headboat Survey and Total Recreational Landings Estimates, with Application to SEDAR 68 Scamp and Yellowmouth Grouper

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Introduction

The Southeast Fisheries Science Center (SEFSC) routinely provides stock assessment analysts with estimates of recreational catch and associated measures of uncertainty. The data used to inform these estimates are primarily collected by four surveys in the southeast region (i.e., Texas to North Carolina):

1) Marine Recreational Information Program (MRIP; Matter and Nuttall 2020c)
2) Southeast Region Headboat Survey (SRHS; Fitzpatrick et al. 2017)
3) Texas Marine Sport-Harvest Monitoring Program (TPWD; Nuttall and Matter 2020)
4) Louisiana Creel Survey (LACreel; LDWF 2017, 2020)

Regional estimates for private and rental boats (PR), shore-based anglers (SH), and for-hire guide and charter boat fishing (CH) are largely informed by MRIP survey data (1981+). However, estimates for PR and CH anglers in Texas and PR/SH and CH anglers in Louisiana are, respectively, informed by TPWD (1983+) and the LACreel survey (2014+). Catches of PR, SH, and CH fishing in all other southeastern states and time periods are provided by MRIP: Mississippi to North Carolina (1981+) and Louisiana (1981-2013). Regional estimates for headboats (HB) are primarily estimated from the SRHS, which has operated along the southeast Atlantic since 1972 and in the Gulf of Mexico since 1986. Headboat sampling was initially included in the MRIP survey design, but was discontinued in the southeast in 1986 to avoid overlap with SRHS HB estimates. HB catch is therefore estimated from SRHS data in the South Atlantic (1981+) but from both MRIP (1981-1985) and SRHS data (1986+) in the Gulf of Mexico.

The SEFSC also provides the associated coefficients of variation for MRIP catch estimates, which are commonly applied as measures of uncertainty in regional stock assessments. The

coefficients of variation for MRIP catch totals ($\widehat{CV}_{MRIP}$) are discussed in Dettloff et al. (2020) and summarized below. However, this working paper is the first to introduce the method by which the SEFSC estimates uncertainty for SRHS catch ($\widehat{CV}_{SRHS}$). Additionally, stock assessment scientists regularly aggregate fishing fleets to reduce model complexity, requiring aggregation of the catch and uncertainty estimates calculated from these two surveys. This working paper also introduces the method by which the SEFSC estimates uncertainty for total recreational catch ($\widehat{CV}_T$), which is a combination of $\widehat{CV}_{MRIP}$ and $\widehat{CV}_{SRHS}$. The SEFSC does not provide uncertainty measures for TPWD (1983+) and LACreel (2014+) catch estimates. Future efforts may be directed towards applying the $\widehat{CV}_{MRIP}$ approach (Dettloff et al. 2020) to estimate $\widehat{CV}_{TPWD}$ and $\widehat{CV}_{LACreel}$, but uncertainty in Texas catches and in recent Louisiana catches are currently assumed represented by the $\widehat{CV}_{MRIP}$ estimates from Gulf of Mexico states.

Methods

Uncertainty in MRIP Catch

The SEFSC provides annual estimates of catch uncertainty for each fishing mode covered by the MRIP survey (e.g., $\widehat{CV}_{CH}$, $\widehat{CV}_{PR}$, and $\widehat{CV}_{SH}$) and for the total annual catch across all MRIP modes (i.e., $\widehat{CV}_{MRIP}$) (Dettloff et al. 2020). These uncertainty measures are calculated using standard survey methodology (Woodruff 1971, Lohr 2010) directly from the raw data to ensure estimates are appropriate for custom (assessment-specific) data aggregations.

For each g aggregation of MRIP catch data, the variance in MRIP catch is calculated as:

Equation (1)

$$\hat{V}(\hat{C}_g) = \sum_{h=1}^{n_g} \frac{n_h}{n_h - 1} \sum_{i=1}^{n_h} (y_{hi} - \bar{y}_h)^2$$

where MRIP catch observations for a given species at the PSU-level (primary sampling unit) (y_{hi}) are used to calculate stratum level variance estimates, with strata defined by unique combinations of year, mode, wave, and state. The number of observations within each h stratum is represented by n_h and the number of strata within each aggregation is represented by n_g. These estimates are then summed within unique combinations of year and mode to produce annual estimates of uncertainty for each fishing mode (e.g., $\widehat{CV}_{CH}$, $\widehat{CV}_{PR}$, or $\widehat{CV}_{SH}$). Estimates of variance and total catch for each mode are further summed across modes when calculating $\widehat{CV}_{MRIP}$. To avoid low-biased or zero-variance estimates, the SEFSC also substitutes the grand mean of the custom aggregation for $\bar{y}_h$ in strata with only a single primary sampling unit (i.e., "lonely" PSUs).

The SEFSC converts these variances into CVs using:

Equation (2)

$$\widehat{CV}_g = {\hat{\sigma}_g}\Big/{\hat{C}_g}$$

where $\hat{C}_g$ is the total estimated catch of a given species in each g aggregation of MRIP data. These mode-specific (e.g., $\widehat{CV}_{CH}$, $\widehat{CV}_{PR}$, and $\widehat{CV}_{SH}$) and total catch CVs (i.e., $\widehat{CV}_{MRIP}$) are provided to regional stock assessment scientists as a measure of uncertainty for MRIP catch.

Uncertainty in SRHS Landings

Industry-reported trip data (i.e., logbooks) are used by the SRHS to estimate the total landings of HB anglers operating throughout the southeast region (Fitzpatrick et al. 2017). This estimation includes a correction factor to account for non-reporting and misreporting of HB fishing activity in the SRHS logbooks, which were originally designed to census all HB fishing activity in the region. Vessel compliance is calculated as the fraction of the total number of fishing trips taken by an individual HB vessel (estimated from the SRHS headboat activity report) for which a corresponding landings record is available from the SRHS logbooks. Correction factors (K_{amv}) are calculated as the inverse of vessel compliance and used to scale vessel-level logbook landings (y_{amv}) into estimates for each v vessel in each SRHS strata, defined by year, area (a), and month (m). Note that total estimated landings ($\tilde{y}_{amv}$) include both reported logbook data (i.e., y_{amv}, with $K_{amv} \geq 1$) and imputed records for vessels missing catch reports entirely, in which case records are substituted from observations in similar strata (with $K_{amv} = 1$). As an example where g identifies landings for a given species at the year level (i.e., $\widehat{CV}_{SRHS}$), total headboat landings are estimated as:

Equation (3)

$$\hat{C}_g = \sum_{a=1}^{n} \sum_{m=1}^{n_a} \sum_{v=1}^{n_{am}} \tilde{y}_{amv} * K_{amv}$$

where logbook landings estimates are aggregated across vessels, areas, and months. The total number of headboat fishing vessels within a particular a-m strata is represented by n_{am}, the number of months within a given area by n_a, and total number of headboat areas by n.

As an associated measure of uncertainty for SRHS landings estimates (i.e., $\widehat{CV}_{SRHS}$), the SEFSC calculates the variance in reported landings from SRHS logbooks (y_{amv}) across all v vessels within each SRHS strata. These variances are additive and therefore summed across areas and months to estimate the total variance in landings for a given species and year:

Equation (4)

$$\hat{V}(\hat{C}_g) = \sum_{a=1}^{n} \sum_{m=1}^{n_a} \left(\frac{{N_{am}}^2}{n_{am}} \right) \frac{\left(1 - {n_{am}}/{N_{am}}\right)}{n_{am} - 1} \sum_{v=1}^{n_{am}} \left((y_{amv} * K_{amv}) - \frac{\sum_{v=1}^{n_{am}} (y_{amv} * K_{amv})}{n_{am}} \right)^2$$

where N_{am} is the actual number of active fishing vessels within a given a-m strata and n_{am} the number of active vessels for which the SRHS logbooks contain reported landings data. The $\left(1 - {n_{am}}/{N_{am}}\right)$ term in Equation (4) is a finite population correction factor to account for the

relative coverage of regional headboat fishing effort by the SRHS logbook program and goes to zero when SRHS logbooks are a census of the entire HB fishery. The $\left({N_{am}}^2/n_{am}\right)$ term is a scalar to account for vessels for which catch data is completely missing.

The variance estimation approach described in Equation (4) assumes HB vessels with no reported landings are missing completely at random (MCAR). Note that such an assumption is not made for SRHS landings estimates (Equation 3), within which missing observations of HB landings are imputed from estimated catch records from similar strata, assuming vessels are missing at random (MAR). When converting SRHS variances into CVs (Equation 2), total landings ($\hat{C}_g$) is estimated from reported landings estimates (y_{amv}) under the MCAR assumption for consistency with the variance calculation, rather than using the imputed $\tilde{y}_{amv}$ totals from Equation (3). However, the imputed estimates of total landings (Equation 3) are provided to analysts for use in stock assessments, not the reported y_{amv} estimates. Future efforts may be directed towards incorporating a more formal imputation approach (e.g., hot deck) for missing records of SRHS landings to relax the MCAR assumption in Equation (4) and increase consistency between SRHS landings and uncertainty estimates.

Uncertainty in Total Landings

In assessments where all four recreational fishing modes are combined, total recreational catch ($\hat{C}_T$) is simply the sum of the individual catch estimates:

Equation (5)

$$\hat{C}_T = \hat{C}_{MRIP} + \hat{C}_{SRHS}$$

$$\hat{C}_{MRIP} = \hat{C}_{CH} + \hat{C}_{PR} + \hat{C}_{SH} \qquad \hat{C}_{SRHS} = \hat{C}_{HB}$$

where $\hat{C}_{MRIP}$ may also contain a $\hat{C}_{HB}$ component if the SRHS does not cover the entire time period (e.g., 1981-1985 for Gulf of Mexico assessments). Similarly, the variances of $\hat{C}_{MRIP}$ and $\hat{C}_{SRHS}$ are also additive given the estimates are generated from independent surveys for distinct fishing fleets. The variance sum law is then applied to calculate the variance of total recreational catch ($\hat{V}(\hat{C}_T)$):

Equation (6)

$$\hat{V}(\hat{C}_T) = \hat{V}(\hat{C}_{MRIP}) + \hat{V}(\hat{C}_{SRHS})$$

where $\hat{V}(\hat{C}_{MRIP})$ is calculated from Equation (1) and $\hat{V}(\hat{C}_{SRHS})$ from Equation (4). This approach was taken in SEDAR 49 (2016) to calculate catch uncertainties for various data-limited species caught by a combined commercial and recreational fleet. Substituting CVs for each $\hat{V}(\hat{C}_g)$ term (see Equation 2) and solving for $\widehat{CV}_T$, we have:

Equation (7)

$$\widehat{CV}_T = \frac{\sqrt{\left(\widehat{CV}_{MRIP} * \hat{C}_{MRIP}\right)^2 + \left(\widehat{CV}_{SRHS} * \hat{C}_{SRHS}\right)^2}}{\hat{C}_T}$$

which the SEFSC provides as a measure of uncertainty for total recreational catch estimates. Although CVs are only calculated from MRIP and SRHS data, total recreational catch in the Gulf of Mexico (i.e., AB1 in Table 3) includes catch estimates from TPWD and LACreel.

Note that while this section was written with the objective of estimating uncertainty for total recreational catch (i.e., CV_T), it can easily be adapted for custom (assessment-specific) aggregations of fishing modes. For example, considering only charter boat estimates within the MRIP components of Equations (1) and (5) would provide uncertainty estimates for a total for-hire fleet, composed of MRIP charterboat and SRHS headboat anglers.

Results – South Atlantic and Gulf of Mexico Scamp and Yellowmouth Grouper

SRHS Landings and Uncertainty

Regional estimates of SRHS landings and associated uncertainties are presented for SEDAR 68 scamp and yellowmouth grouper in Figure 1 and Tables 1 and 2. SRHS uncertainty was low overall (grand mean $\widehat{CV}_{SRHS} = 0.022$), but slightly higher in the Gulf of Mexico (max $= 0.102$, mean $= 0.026$) than in the South Atlantic (max $= 0.059$, mean $= 0.019$). This result is largely a function of the census correction factor in Equation (4), which goes to zero in years when the SRHS covers the entire headboat fleet and reported landings can be treated as realized landings. Coverage has generally been high over the entire time series (mean ≈ 80%; Tables 1 and 2) and has been close to 100% since 2010, as represented by the tight error bars over the last decade (Figure 1). This corresponds with an increase in compliance which resulted from enforcement of mandatory reported regulations, which began in 2008 (Fitzpatrick et al. 2017).

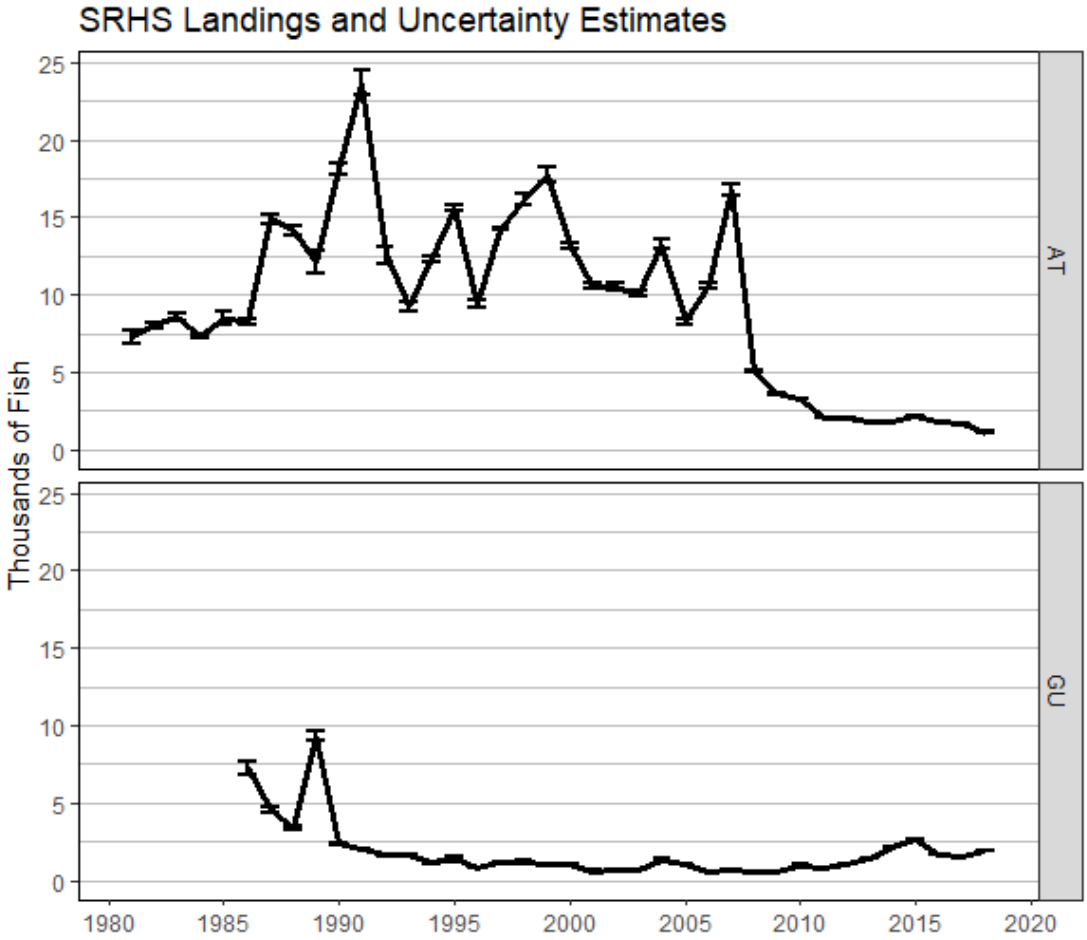

Figure 1. *Regional estimates of SRHS landings for scamp and yellowmouth grouper with associated uncertainties. Estimates are provided for the South Atlantic (AT) and Gulf of Mexico (GU) with landings calculated from Equation (3) and uncertainties from Equation (4). Error bars represent standard errors of SRHS catch.*

Table 1. *SRHS landings (numbers of fish) of Gulf of Mexico scamp and yellowmouth grouper with associated uncertainties (CV). Sample size (SS) is provided as the number of active headboat vessels fishing in a given year (N_{am}; outside parentheses) and those active vessels for which SRHS logbooks contain reported landings data (n_{am}; inside parentheses). The relative coverage of the headboat fleet by the SRHS ($^{n_{am}}/_{N_{am}}$) is also provided.*

Year	Landings	CV	SS	Coverage
1986	7,263	0.058	666 (425)	0.638
1987	4,577	0.046	660 (463)	0.702
1988	3,399	0.049	722 (568)	0.787
1989	9,310	0.030	756 (584)	0.772
1990	2,388	0.033	773 (714)	0.924
1991	2,056	0.019	814 (669)	0.822
1992	1,611	0.011	709 (703)	0.992
1993	1,685	0.006	792 (773)	0.976
1994	1,137	0.040	833 (765)	0.918
1995	1,370	0.102	793 (646)	0.815
1996	813	0.069	732 (621)	0.848
1997	1,165	0.041	707 (609)	0.861
1998	1,241	0.026	746 (590)	0.791
1999	1,064	0.021	702 (392)	0.558
2000	1,028	0.030	657 (455)	0.693
2001	616	0.032	662 (437)	0.660
2002	705	0.046	564 (445)	0.789
2003	675	0.026	611 (444)	0.727
2004	1,315	0.063	619 (498)	0.805
2005	1,075	0.018	616 (542)	0.880
2006	589	0.040	598 (511)	0.855
2007	668	0.042	638 (500)	0.784
2008	608	0.016	623 (564)	0.905
2009	598	0.005	659 (644)	0.977
2010	992	0.005	614 (590)	0.961
2011	815	0.000	631 (630)	0.998
2012	1,096	0.000	644 (644)	1.000
2013	1,388	0.001	629 (627)	0.997
2014	2,100	0.000	606 (606)	1.000
2015	2,613	0.000	657 (657)	1.000
2016	1,730	0.000	658 (658)	1.000
2017	1,537	0.000	703 (701)	0.997
2018	1,866	0.000	684 (684)	1.000

Table 2. *SRHS landings (numbers of fish) of South Atlantic scamp and yellowmouth grouper with associated uncertainties (CV). Sample size (SS) is provided as the number of active headboat vessels fishing in a given year (N_{am}; outside parentheses) and those active vessels for which SRHS logbooks contain reported landings data (n_{am}; inside parentheses). The relative coverage of the headboat fleet by the SRHS ($^{n_{am}}/_{N_{am}}$) is also provided.*

Year	Landings	CV	SS	Coverage
1981	7,286	0.059	779 (513)	0.659
1982	8,021	0.025	810 (502)	0.620
1983	8,510	0.027	787 (523)	0.665
1984	7,317	0.020	783 (499)	0.637
1985	8,472	0.050	772 (506)	0.655
1986	8,241	0.026	839 (608)	0.725
1987	14,868	0.018	901 (641)	0.711
1988	14,128	0.020	863 (546)	0.633
1989	12,098	0.058	810 (452)	0.558
1990	18,095	0.022	789 (414)	0.525
1991	23,650	0.034	1022 (432)	0.423
1992	12,551	0.046	806 (779)	0.967
1993	9,253	0.030	855 (775)	0.906
1994	12,296	0.016	850 (745)	0.876
1995	15,585	0.008	798 (709)	0.888
1996	9,397	0.024	823 (631)	0.767
1997	14,206	0.004	839 (694)	0.827
1998	16,095	0.023	819 (637)	0.778
1999	17,697	0.027	823 (551)	0.670
2000	13,162	0.012	844 (569)	0.674
2001	10,549	0.021	790 (530)	0.671
2002	10,514	0.022	721 (442)	0.613
2003	10,065	0.013	672 (436)	0.649
2004	13,254	0.025	738 (528)	0.715
2005	8,244	0.018	712 (480)	0.674
2006	10,571	0.021	684 (451)	0.659
2007	16,741	0.025	778 (502)	0.645
2008	5,061	0.017	777 (691)	0.889
2009	3,622	0.016	796 (753)	0.946
2010	3,285	0.005	772 (750)	0.972
2011	2,020	0.010	748 (727)	0.972
2012	2,075	0.000	731 (726)	0.993
2013	1,790	0.002	734 (717)	0.977
2014	1,837	0.000	749 (747)	0.997
2015	2,223	0.000	742 (723)	0.974
2016	1,782	0.003	747 (703)	0.941
2017	1,669	0.000	656 (656)	1.000
2018	1,123	0.008	639 (636)	0.995

Total Recreational Landings and Uncertainty

Estimates of total recreational landings and associated uncertainties ($\widehat{CV}_T$) are presented for SEDAR 68 scamp and yellowmouth grouper in Figure 2 and Tables 3 and 4. Estimates of $\widehat{CV}_T$ are large compared to $\widehat{CV}_{SRHS}$, a function of the relatively large estimates of $\widehat{CV}_{MRIP}$ (Table 3 in Matter and Nuttall 2020a, 2020b). The relative contribution of each survey to $\widehat{CV}_T$ is a function of their associated catch estimates (Equation 7). Because MRIP-sampled gears landed twenty times more scamp and yellowmouth grouper than SRHS headboats in the Gulf of Mexico (1.9 vs. 42.0 thousand fish annually), $\widehat{CV}_{SRHS}$ contributes little to $\widehat{CV}_T$ in this region, which is approximately equal to $\widehat{CV}_{MRIP}$. The relative landings of scamp and yellowmouth grouper are more balanced in the South Atlantic (9.4 vs. 16.1 thousand fish), which gives more weight to the annual $\widehat{CV}_{SRHS}$ estimates and results in tighter error bars in the total recreational catch estimates.

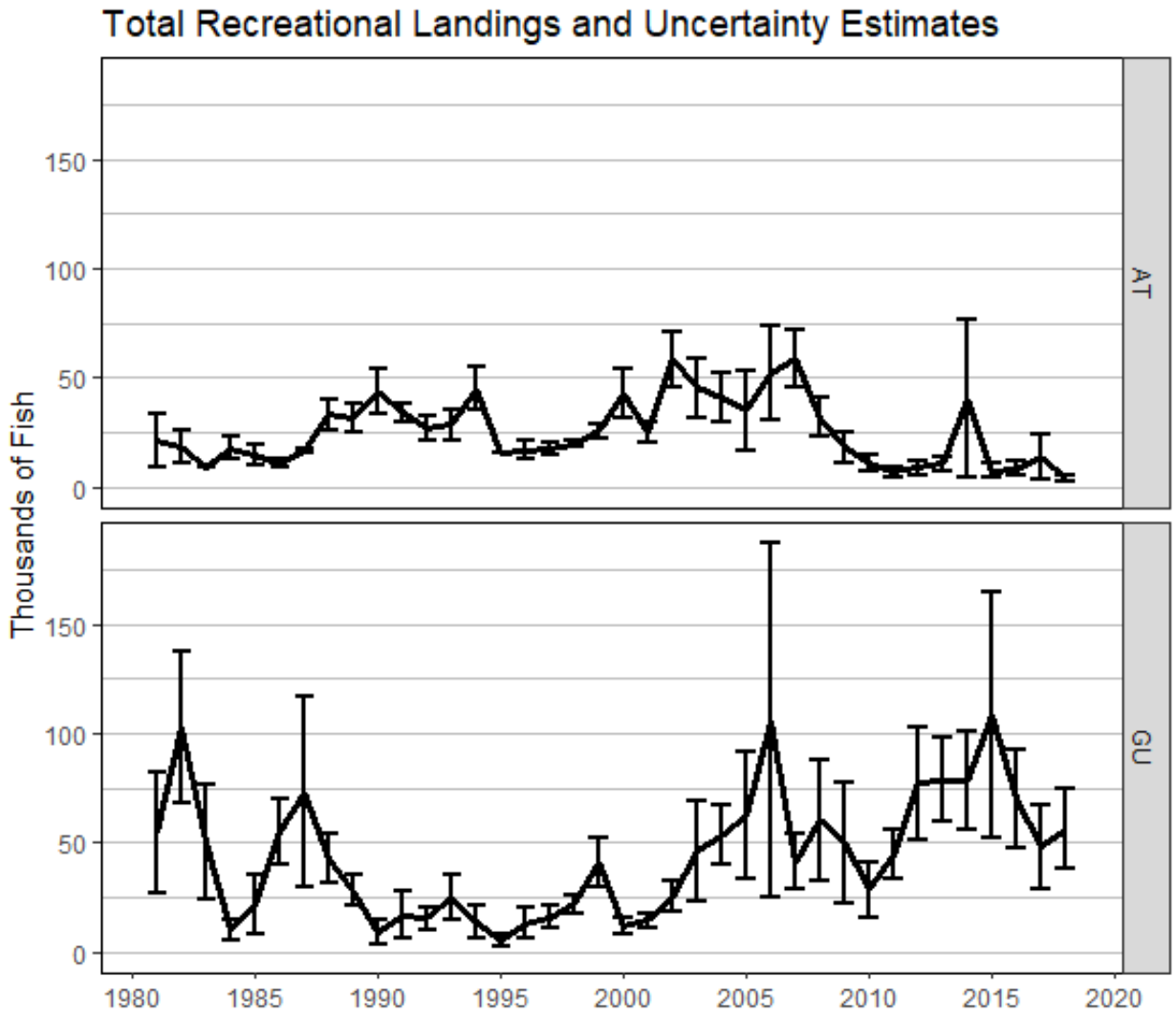

Figure 2. *Regional estimates of total recreational landings for scamp and yellowmouth grouper with associated uncertainties. Estimates are provided for the South Atlantic (AT) and Gulf of Mexico (GU) with landings calculated from Equation (5) and uncertainties from Equation (6). Error bars represent standard errors of total recreational catch.*

Table 3. *Total recreational landings (numbers of fish) of Gulf of Mexico scamp and yellowmouth grouper with associated uncertainties (CV).*

Year	AB1	CV_AB1
1981	54,543	0.500
1982	102,620	0.340
1983	50,387	0.520
1984	10,247	0.460
1985	21,534	0.630
1986	55,038	0.276
1987	73,093	0.600
1988	42,926	0.258
1989	27,921	0.247
1990	8,912	0.650
1991	16,929	0.633
1992	15,262	0.331
1993	25,119	0.401
1994	14,005	0.533
1995	5,700	0.486
1996	13,126	0.553
1997	15,885	0.334
1998	21,974	0.198
1999	40,794	0.273
2000	11,591	0.336
2001	14,190	0.201
2002	25,168	0.272
2003	46,067	0.503
2004	53,423	0.254
2005	62,358	0.472
2006	105,979	0.766
2007	41,129	0.305
2008	60,457	0.455
2009	49,845	0.553
2010	28,399	0.454
2011	44,764	0.255
2012	77,288	0.335
2013	78,538	0.246
2014	78,436	0.282
2015	108,607	0.517
2016	70,282	0.322
2017	47,987	0.406
2018	56,105	0.328

Table 4. *Total recreational landings (numbers of fish) of South Atlantic scamp and yellowmouth grouper with associated uncertainties (CV).*

Year	AB1	CV_AB1
1981	21,332	0.586
1982	18,472	0.407
1983	9,558	0.071
1984	17,971	0.285
1985	14,767	0.346
1986	11,145	0.152
1987	16,395	0.048
1988	33,179	0.207
1989	31,389	0.210
1990	44,079	0.230
1991	34,041	0.115
1992	27,071	0.200
1993	28,647	0.244
1994	45,068	0.218
1995	15,680	0.010
1996	16,991	0.255
1997	17,370	0.149
1998	19,820	0.065
1999	25,625	0.116
2000	42,917	0.257
2001	25,255	0.181
2002	58,482	0.213
2003	45,269	0.296
2004	40,968	0.264
2005	34,926	0.512
2006	52,551	0.407
2007	59,190	0.222
2008	31,888	0.286
2009	18,105	0.400
2010	11,148	0.317
2011	6,867	0.353
2012	9,073	0.363
2013	10,584	0.341
2014	40,226	0.897
2015	7,453	0.421
2016	8,590	0.396
2017	13,976	0.740
2018	4,068	0.347

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