South Atlantic Red Snapper (*Lutjanus campechanus*) monitoring in Florida: Revised recreational private boat mode estimates for 2012 and 2013 mini-seasons, and new private boat mode estimates for the 2014 mini-season

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South Atlantic Red Snapper (*Lutjanus campechanus*) monitoring in Florida: Revised recreational private boat mode estimates for 2012 and 2013 mini-seasons, and new private boat mode estimates for the 2014 mini-season.

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Introduction

This report provides revised estimates of Red Snapper recreational harvest during mini-season openings in 2012 and 2013 for the private boat segment off the Atlantic Coast of Florida. Methods and results previously described in reference documents for SEDAR41 (SEDAR41-RD14, SEDAR41-RD15) were submitted in 2014 for publication to a peer-reviewed journal. As a result of comments received by three anonymous peer reviewers, methods and results described in this report are substantially improved over those previously reported. In addition, new results for the 2014 fishing season are presented here.

Methods

From 2012 to 2014, recreational harvest of Red Snapper in the South Atlantic region (NC through Atlantic coast of FL) was open a total of six weekends (Friday through Sunday). The length of the season varied each year and included two weekends (six days) during September 2012, one weekend (three days) in August 2013, and three weekends (eight days) during July 2014 (with the third weekend only open Friday and Saturday). The area included in this study was the east coast of Florida from the northern state line south to Saint Lucie Inlet, which is the southern limit for recreational access to fishing areas where Red Snapper are sufficiently abundant to target. Any trip to offshore fishing grounds that originates from within this area must pass through one of nine inlets that serve as navigable egress points to the Atlantic Ocean (Figure 1). Cumberland Sound defines the border between Florida and Georgia, and fishing effort from this egress point may originate from either state.

Boat Trip Survey.— During each year, boat traffic was monitored continuously between sunrise and sunset (from 0700 to1900 hours) every day of the season in two designated reference inlets (inlets 3 and 7 in 2012, and inlets 3 and 8 in 2013 and 2014). For the remaining seven inlets in Figure 1, boat traffic was monitored during one time period over three randomly selected days during the first season in 2012, and every day during subsequent seasons in 2013 and 2014. Time periods were randomly selected and were defined during the first two years as a.m. (0700 to 1359) and p.m. (1400 to 1900). During the longest season in 2014, days were divided into shorter periods defined as a.m. (0700 to 1100 hours), mid-day (1100 to 1500 hours), and p.m. (1500 to 1900 hours); and samples were distributed across weekends (periods sampled without replacement within each weekend).

Field observers were stationed at the outermost area of the inlet where vessels could be clearly viewed exiting into the Atlantic Ocean. Monitoring took place from land, with the exception of the largest inlet (inlet 2), where monitoring took place from a small boat during 2013 and 2014. For this inlet, an exception to random selection of the time period was permitted in 2013 to accommodate limited availability of the research vessel. Each power boat was identified either as a private recreational boat or another vessel type. If the viewer could not ascertain with the aid of binoculars whether a vessel was a private recreational power boat, then the vessel was classified as “undetermined”. If individual vessels were observed making multiple passes through an inlet, then field observers made notes on the data sheets so that they were not included more than once in boat trip counts.

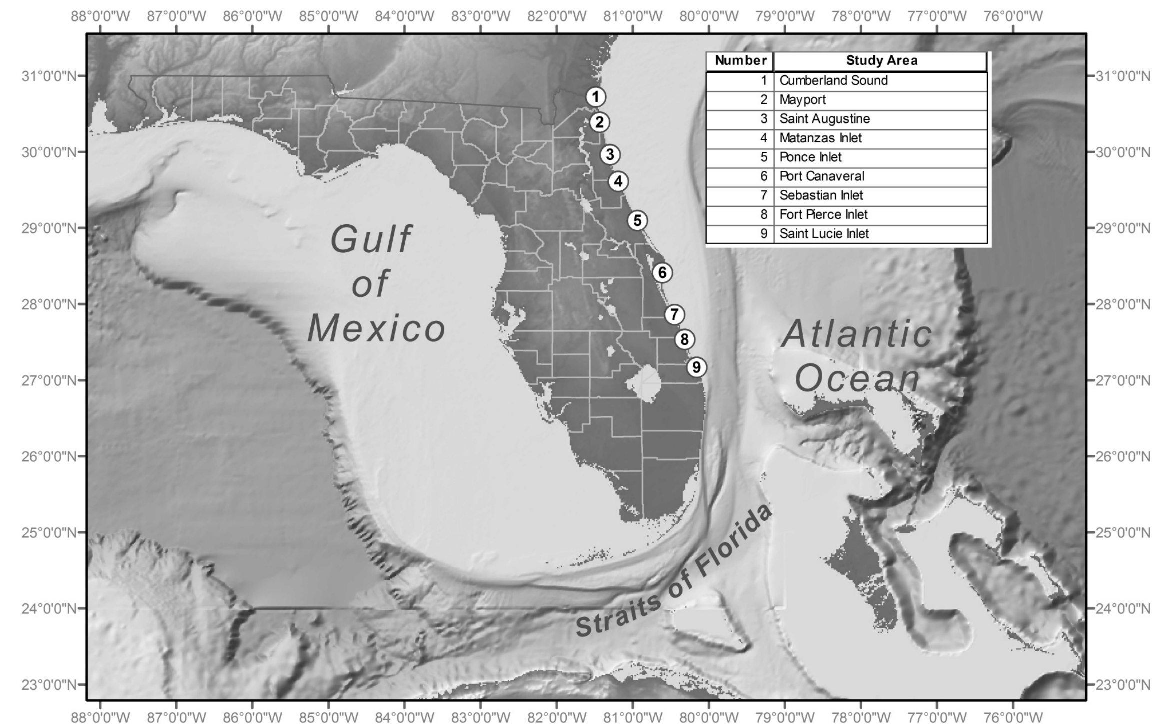

Figure 1. Inlets included in study area.

Access Point Trip Intercept Survey.—A list of boating access sites located in the vicinity of each inlet from which private recreational boats embark on offshore trips was generated for the study area. The list included 54 public and privately operated boat ramps, marinas and dry dock facilities. Each site was assigned a pressure of high or medium to low based on the number of offshore vessels expected to use the site on an average weekend. A list of all possible site and day combinations was generated and used to randomly select assignments. To ensure that assignments were distributed geographically, equal selection probabilities were given to sites associated with each inlet (i.e. an inlet with a low number of sites had the same probability for a site/day combination being selected as an inlet with a higher number of sites). Field staff were issued a fixed number of assignments at high and medium to low pressure sites (50% to each type) in the order they were randomly selected, and any remaining assignments were held in reserve and issued only when extra manpower was available. This method was chosen to insure that a minimum number of completely randomized combinations distributed across the study area were assigned, and then supplemented to maximize productivity for the amount of staff available over the short sampling periods. Assignments were moved only for circumstances that would otherwise result in cancellation. For example, one assignment was moved to an adjacent site due to construction at the assigned boat ramp, and a small number of assignments had to be moved to different days if staff was not available.

During a scheduled assignment, field staff arrived at their assigned site at 1000 hours and remained on site until sunset or the site closed (whichever occurred first). As vessels returned from recreational boating trips, the operator of the vessel was approached to confirm the nature of the trip. For all private recreational boat trips, the operator was interviewed to determine whether the vessel exited through the inlet into the Atlantic Ocean at any time during the trip. If not, the interview was complete. If so, the operator was also asked if the party fished for or caught Red Snapper (regardless of the intended target species). The exit time through the inlet was recorded for all ocean trips, and the following additional information was collected only for positive Red Snapper trips: 1) number of people in the party, 2) number of people who fished, 3) numbers of Red Snapper harvested and released for the party, 4) number of hours spent fishing, 5) the average depth fished (in feet), and 6) the minimum and maximum distance from shore (in miles) where fishing took place. If Red Snapper were harvested, the interviewer asked for permission to inspect the fish and recorded the length (mm at the midline) and weight (in kg) for each fish and extracted otoliths. Parties that released one or more Red Snapper were asked to recall how many of those fish were less than 16 inches, between 16 and 20 inches, and greater than 20 inches in length.

Effort Estimation.— Three main steps were used to estimate fishing effort for each year during the Red Snapper season: 1) the numbers of recreational boats observed exiting through each inlet during daylight hours was expanded to generate an unadjusted seasonal estimate of trips in the Atlantic Ocean across all inlets; 2) the seasonal estimate of boat trips was multiplied by an estimated proportion that were targeting Red Snapper; and 3) estimated Red Snapper trips were adjusted to account for additional boats that exited through inlets before sunrise. The seasonal estimate for boat trips (step 1) was calculated using two different methods. The first employs a ratio estimator (described in Cochran 1977) to expand observations from sampled inlets relative to observations in a corresponding reference inlet. The ratio estimator was calculated for the northern and southern reference inlets to yield two separate estimates. The second method uses observations within a sampled inlet to generate an expanded estimate for that inlet; therefore, this method does not require comparison with a reference inlet. To evaluate the accuracy of the second method, day and time period combinations were randomly sampled thirty times from each of the two reference inlets and used to generate repeated estimates, which were then compared to observed values.

Step 1

For the ratio estimator, the number of boats observed (y) during each period (i) sampled for inlet (h) was summed and then divided by the number of boats observed in a corresponding reference inlet (x) during the same periods (equation 1).

$$\hat{R}_h = \sum_{i=1}^{n} y_i \;/\; \sum_{i=1}^{n} x_i \qquad (1)$$

The total unadjusted number of boats that entered the Atlantic Ocean during the Red Snapper harvest season was estimated by:

$$\hat{Y}_h = \hat{R}_h \, X \qquad (2)$$

where X is the total number of boats observed exiting through a corresponding reference inlet (between 7am and sunset) across all days of the season. Variance was estimated by:

$$v(\hat{Y}_h) = [N^2 \,(1 - n_i/N) \,/\, n_i(n_i-1)] * \sum_{i=1}^{n}(y_i - \hat{R}x_i)^2 \qquad (3)$$

where N is the total number of daytime periods in the season, and n_i is the number of periods sampled in inlet h. The overall seasonal estimate across all k sample inlets was simply:

$$\hat{Y} = \sum_{h=1}^{k} \hat{Y}_h, \qquad (4)$$

with variance calculated as:

$$v(\hat{Y}) = \sum_{h=1}^{k} v(\hat{Y}_h) \qquad (5)$$

For the expansion method, a weighted mean of y_i's within an inlet was used to calculate an expanded estimate for $\hat{Y}_h$. The primary sample weight (P) was calculated as the total number of days in the season divided by the number of days period p was sampled. If an inlet could not be observed for the entire time period sampled (for example, boat counts had to be suspended due to lightning), a secondary sample weight (S) was calculated as the total minutes in the sample period divided by the total minutes the period was observed. The mean weighted number of boats observed per sampled period in inlet h was calculated as:

$$\bar{y}_h = \sum_{p=1}^{t} \sum_{i=1}^{n} P_p S_i y_i \;/\; \sum_{p=1}^{t} \sum_{i=1}^{n} P_p S_i, \qquad (6)$$

for periods 1 to t, where i is an individual sample from period p. Variance was calculated as:

$$v\,(\bar{y}_h) = \sum_{p=1}^{t} \sum_{i=1}^{n} P_p S_i \,(y_i - \bar{y}_h)^2 \,/\, \sum_{p=1}^{t} \sum_{i=1}^{n} P_p S_i \qquad (7)$$

To estimate the total number of boats that exited through an inlet that was sampled during a given season, the weighted mean for the sample inlet was multiplied times the total periods (N) in the season (for example, in 2014, N = 8 days * 3 periods per day), calculated as:

$$\hat{Y}_h = \bar{y}_h N \tag{8}$$

Variance was calculated by:

$$v(\hat{Y}_h) = v(\bar{y}_h) N \tag{9}$$

Step 2

To estimate the proportion of trips targeting Red Snapper, the seasonal estimated number of boats that made a trip into the Atlantic Ocean was adjusted using additional information collected during the access point trip intercept survey. Following methods for estimating proportions and totals over subpopulations described by Cochran (1977), the proportion of intercepted trips that targeted Red Snapper was calculated for each inlet as:

$$p_h = t_h / n_h \tag{10}$$

where t_h is the number of boats intercepted at access points adjacent to a given inlet with at least one angler in the group who reportedly caught or tried to catch Red Snapper in the Atlantic Ocean, and n_h is the total boats intercepted that reportedly entered into the Atlantic Ocean. Since $\hat{Y}_h$ does not account for trips that entered the Atlantic Ocean before sunrise (this occurs in step 3, below), only boat intercepts that reported exiting an inlet at 0700 hours or later are included in the calculation for equation 10. The total number of targeted trips was then estimated by:

$$\hat{T}_h = \hat{Y}_h * p_h, \tag{11}$$

with error propagated by:

$$\sigma(\hat{T}_h) = \hat{T}_h \sqrt{\left(\frac{\sigma(\hat{Y}_h)}{\hat{Y}_h}\right)^2 + \left(\frac{\sigma(p_h)}{p_h}\right)^2} \tag{12}$$

Step 3

To adjust the targeted trip estimate for boats that departed before sunrise, the proportion given by equation 10 was recalculated using the number of intercepted trips that targeted Red Snapper and reported exiting through an inlet at 0700 hours or later for the numerator (t_h), and the total number of intercepted trips that targeted Red Snapper for the denominator (n_h). The estimated number of targeted Red Snapper trips was then adjusted by:

$$\hat{T}_{h,adj} = \hat{T}_h / p_h , \tag{13}$$

with error propagated by:

$$\sigma(\hat{T}_{h,adj}) = \hat{T}_{h,adj}\sqrt{\left(\frac{\sigma(\hat{T}_h)}{\hat{T}_h}\right)^2 + \left(\frac{\sigma(p_h)}{p_h}\right)^2} \quad (14)$$

Catch Estimation.—Red Snapper reported during targeted trips interviews in the access point trip intercept survey were used to estimate total harvest and discards. For each inlet, the mean number of Red Snapper caught per angler in targeted trip interviews was calculated as:

$$\bar{c}_h = \frac{\sum_{i=1}^{n} c_i}{\sum_{i=1}^{n} a_i} \quad (15)$$

Where c_i is the number of Red Snapper either retained (for harvest estimates) or released (for discard estimates) by all anglers on the boat during trip interview *i,* and a_i is the number of anglers in each interviewed party. Catch per unit effort was calculated at the angler level to account for variance in catch (partially due to the one fish per person bag limit) among boats with varied numbers of anglers. Variance was estimated by:

$$v(\bar{C}_h) = \left(\frac{1}{\sqrt{t_h a_h}}\sqrt{\frac{\sum_{i=1}^{n} c_{h,i}^2 - 2\hat{R}_h(\sum_{i=1}^{n} c_{h,i}a_{h,i}) + \hat{R}_h^2(\sum_{i=1}^{n} a_{h,i}^2)}{t_h - 1}}\right)^2 \quad (16)$$

where t_h is the total number of boat party intercepts that were targeting Red Snapper. The mean number of anglers in each boat party intercepted was calculated as:

$$\bar{e}_h = \frac{\sum_{i=1}^{n} a_{h,i}}{t_h} \quad (17)$$

Variance is given by:

$$v(\bar{e}_h) = \frac{\sum_{i=1}^{n} a_{h,i}^2 - ((\sum_{i=1}^{n} a_{h,i})^2/t_h)}{t_h(t_h - 1)} \quad (18)$$

To estimate total catch, the estimated number of boat parties that targeted Red Snapper was converted to angler trips by:

$$\hat{E}_h = \hat{T}_h \hat{e}_h \quad (19)$$

and variance is estimated following methods described by Goodman (1960) as:

$$v(\hat{E}_h) = \hat{T}_h^2 v(\bar{e}_h) + \bar{e}_h^2 v(\hat{T}_h) - v(\bar{e}_h)v(\hat{T}_h) \quad (20)$$

Lastly, total catch was estimated by:

$$\hat{C} = \sum_{h=1}^{9} \hat{E}_h \bar{c}_h \quad (21)$$

with variance:

$$v(\hat{C}) = \sum_{h=1}^{9}[\hat{E}_h^2 v(\bar{c}_h) + \bar{c}_h^2 v(\hat{E}_h) - v(\hat{E}_h)v(\bar{c}_h)] \quad (22)$$

Results

Effort Estimation.— The overall percentage of boat parties intercepted in the access point survey that targeted Red Snapper ranged from 53% to as high as 89% over the three seasons (Table 1). Among boat parties interviewed that were targeting Red Snapper, between 49% and 67% reported exiting through an inlet during daylight hours (Table 1) and effort was adjusted accordingly to account for trips departing through inlets before sunrise.

When the ratio estimator method was used to calculate the total number of boat trips in the study area, point estimates did not vary significantly with the choice of reference inlet, and this result was consistent across all years (Table 1 and Figure 2). Therefore, the relationship between time of day and boat activity across inlets appears to be a reliable predictor of effort. A paired t-test was used to compare estimates among the two reference inlets within each year, and the mean difference was not significant (mean -77.7 trips, d.f. 2, t -0.32, p 0.777).

To explore an alternative method that did not rely on comparisons across inlets, time periods were randomly sub-sampled from the reference inlets and expanded estimates were compared with observed values. Due to the survey design employed during the first year of the study, the expansion method could not be used to estimate effort for the 2012 season. During this year, inlets were only sampled three out of six days and, because the season was not open until later in the year (September), daily fishing activity was highly dependent upon weather conditions offshore. If offshore conditions were unfavorable and almost no boats were observed on the one or two days that a period was sampled in an inlet, then the expansion resulted in an underestimate. On the other hand, effort was overestimated if a period was only sampled during days with favorable offshore conditions. During 2013 and 2014, the sample design was improved to measure fluctuations in effort daily (one period sampled each day in each inlet). Under this sample design, the expansion method yielded estimates that were reasonably precise and unbiased. Resulting estimates fluctuated within close range of observed values and were unbiased, with approximately equal numbers of points falling above and below observed values (Figure 3). When the expansion method was used to calculate total effort across all inlets in 2013 and 2014, estimates did not vary significantly from those generated using the ratio estimator (paired t-test mean difference -194.5, d.f. 3, t -1.67, p 0.194).

Catch Estimation.— Both effort and harvest were centered about Ponce Inlet (Figure 2). Total effort and harvest peaked in 2014, the longest of the three seasons (Table 2 and Figure 4). After effort was recalculated for the 2012 and 2013 seasons, the standard error around estimated harvest was lower and point estimates were higher than previously reported, although they remained within 95% confidence limits of original estimates (previously 7,479 with 95% CI ±4,597 in 2012, and 3,993 with 95% CI ±2,733 in 2013). Compared to harvest estimates generated from the MRIP survey (for the two-month sample period that the annual season occurred), estimates generated from this directed survey were more precise and reflected the season length (i.e. point estimate was lowest during shortest season, higher during six day season, and peaked during eight day season; Figure 5).

Table 1. Total number of boat trips targeting Red Snapper estimated by comparison to a reference inlet or by expansion (no reference inlet).

Season	Reference Inlet	Boat trips intercepted	Proportion targeting Red Snapper	Proportion departed before sunrise	Targeted trips ($\hat{T} \pm s.e.$)
September 2012	St. Augustine	508	0.882±0.031	0.660±0.053	6,492±517
	Sebastian Inlet		0.892±0.027	0.665±0.046	6,157±422
August 2013	St. Augustine	803	0.648±0.017	0.571±0.133	3,854±690
	Fort Pierce		0.684±0.017	0.597±0.044	3,926±223
	None		0.698±0.017	0.598±0.053	4,181±289
July 2014	St. Augustine	2,303	0.541±0.011	0.504±0.054	10,455±844
	Fort Pierce		0.535±0.011	0.500±0.048	10,951±750
	None		0.534±0.011	0.494±0.052	10,801±902

Table 2. Total catch estimates for private boat mode expressed in numbers of Red Snapper.

Season	Reference inlet	Estimated harvest $\hat{C}_{harv}(\pm s.e.)$	c.v. harvest	Estimated discards $\hat{C}_{disc}(\pm s.e.)$	c.v. discards
September 2012	Saint Augustine	11,136 (±1,734)	0.156	17,587 (±9,031)	0.513
	Sebastian Inlet	10,729 (±1,629)	0.152	17,033 (±8,219)	0.483
August 2013	Saint Augustine	6,320 (±1,426)	0.226	4,567 (±1,476)	0.323
	Fort Pierce	6,428 (±1,011)	0.157	4,802 (±1,453)	0.303
	None	6,999 (±1,321)	0.189	5,033 (±1,512)	0.300
July 2014	Saint Augustine	21,234 (±2,517)	0.119	9,658 (±1,657)	0.172
	Fort Pierce	22,282 (±2,407)	0.108	9,996 (±1,724)	0.173
	None	22,013 (±2,782)	0.126	9,755 (±1,741)	0.178

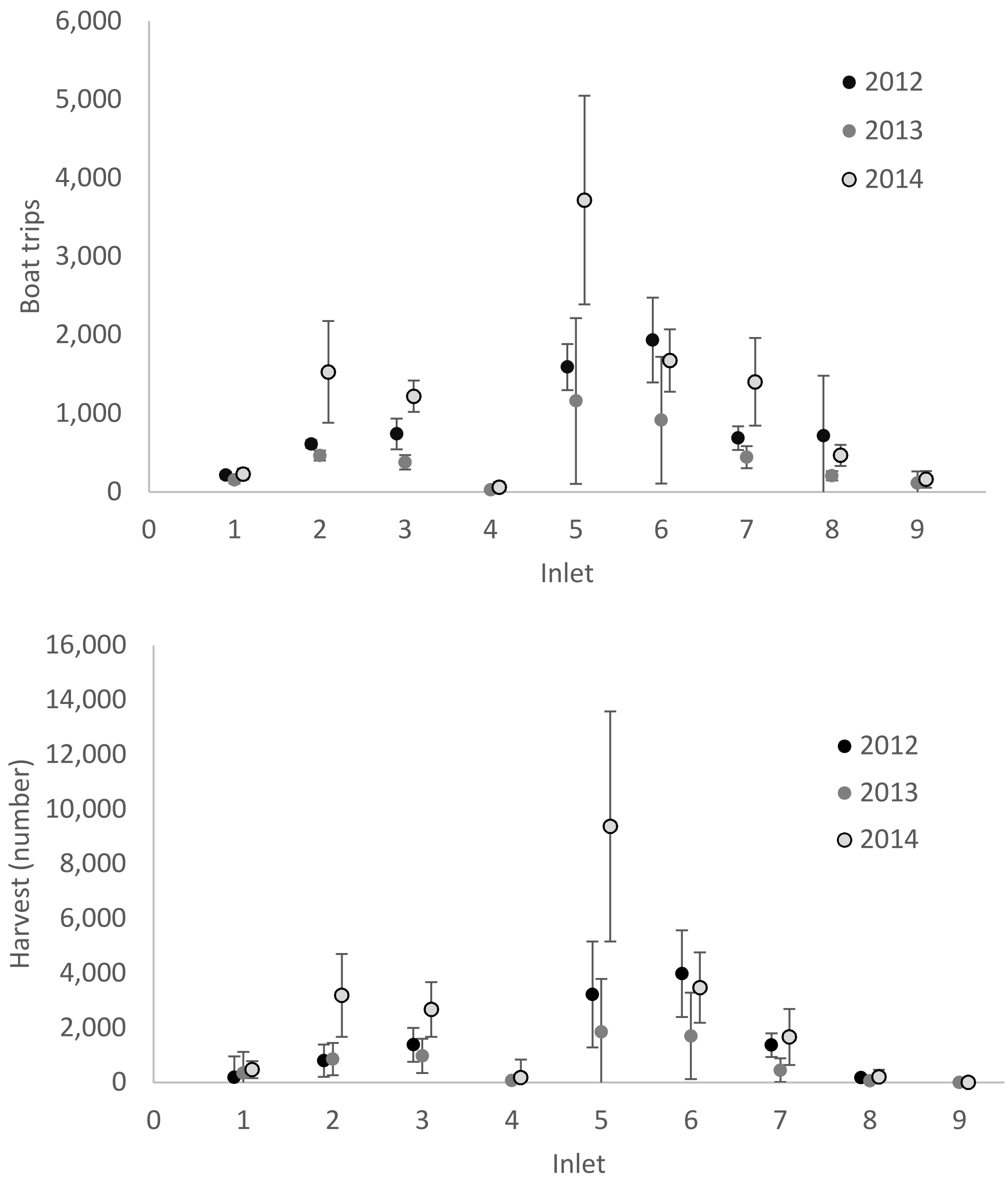

Figure 2. Total estimated targeted effort (top panel) and harvest (bottom panel) by inlet with 95% confidence intervals (using the ratio estimator method and northern reference inlet).

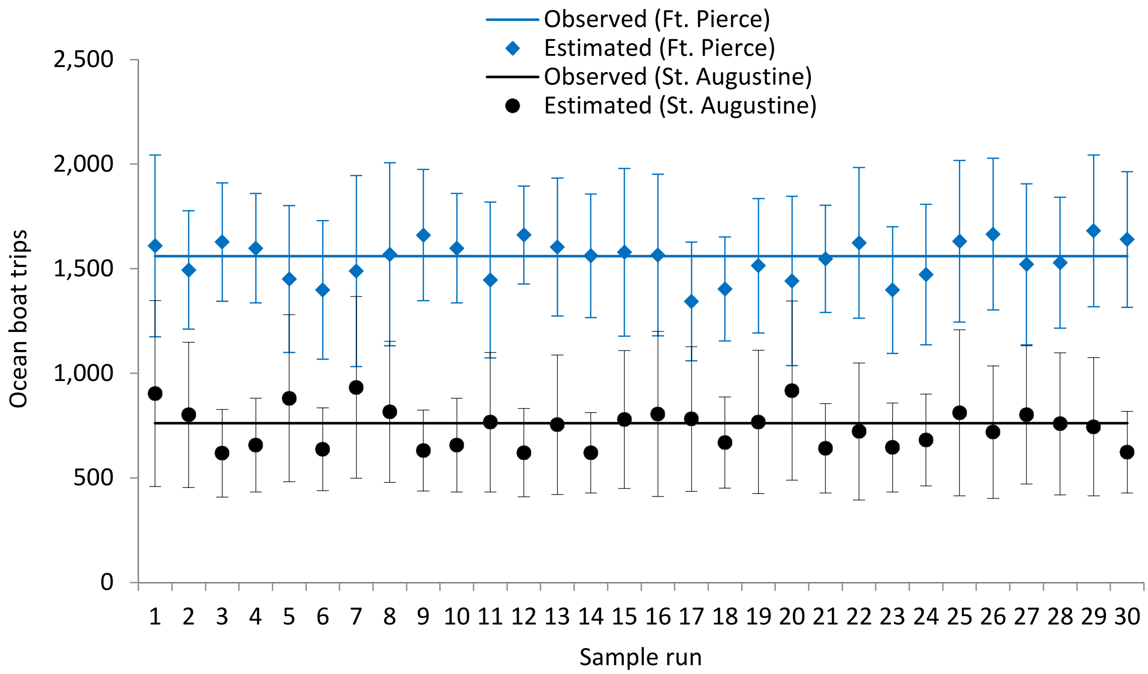

Figure 3. Observed (solid lines) and predicted (points with 95% confidence intervals) numbers of boats exiting into the Atlantic Ocean calculated using the expansion method for random sub-samples within reference inlets during 2014.

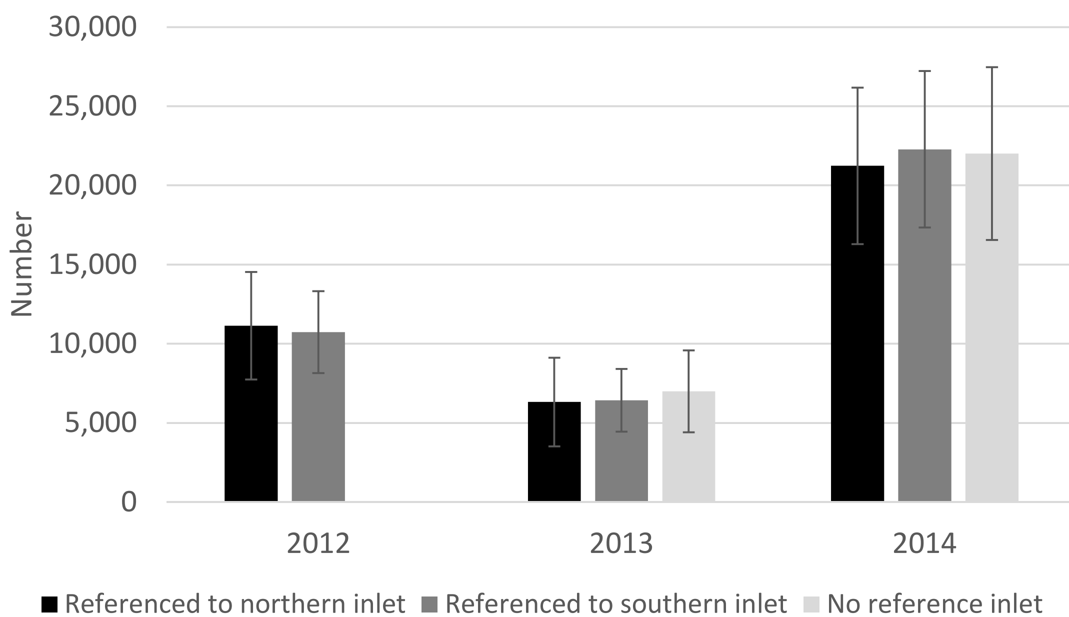

Figure 4. Estimated numbers of Red Snapper harvested by season.

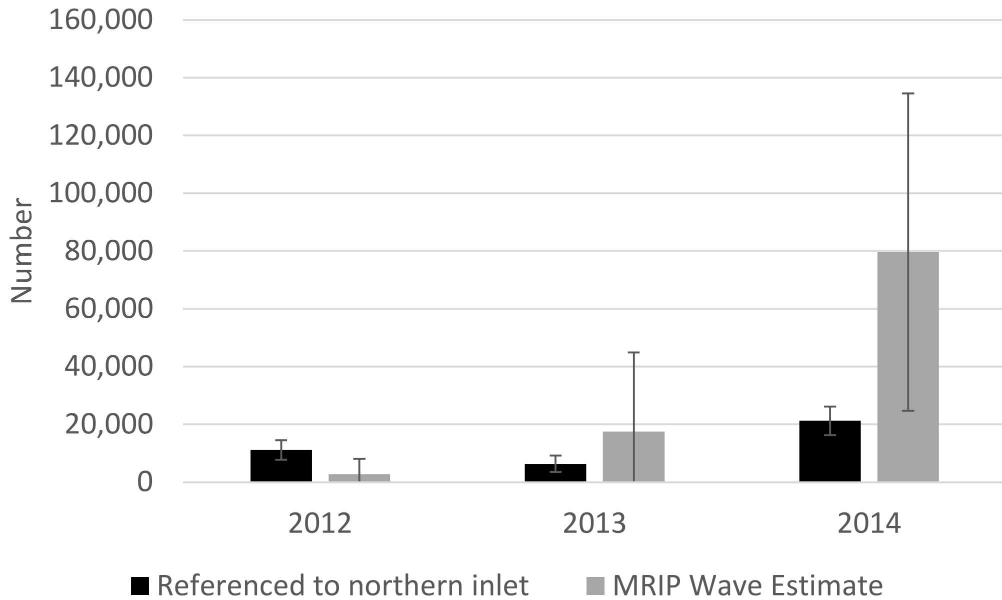

Figure 5. Estimates for numbers of Red Snapper harvested in-season from this study (referenced to northern inlet) and estimated by MRIP during the two-month wave that the season occurred in.

Discussion and Conclusions

Methods described in this report include significant improvements over previous years as a result of an anonymous, independent peer review of methods described in Sauls et al. (2013, 2014). Peer reviewers recommended improved methods for calculating effort to avoid pseudo-replication (summing observations across all hours within a sampled period) and reduce variance (calculate a ratio of means as opposed to the mean of ratios). Reviewers also questioned whether the relationship between observation time and boat volume in a reference inlet was a reliable predictor of effort across all inlets, and whether the choice of reference inlet could potentially bias estimates. Results presented here confirm the validity of the initial assumption that the choice of inlet did not influence estimates; however, point estimates were higher than previously reported. New methods described in this report are also improved with respect to variance, which reviewers said was both overestimated and underestimated in different steps of the estimation. The ratio of means has been shown to produces estimates that are more variable than a single ratio of means (Cochran 1977). In addition, when estimates for boat trips were adjusted using sample means from the intercept survey, corrections were treated as constant values instead of sample means with variance, and this error was not propagated through to estimates of targeted trips. The new methods described in this report correct for both over and under-estimation of variance, and the net result was improved precision around targeted trip estimates (c.v.'s around previous landings estimates were 0.31 for 2012 and 0.24 for 2013).

Two improvements for calculating catch were also incorporated into new estimates presented here. First, in previous estimates, sample variance around the catch rate was not propagated through the calculation of total catch. Second, catch rates in previous years were calculated at the boat level, which averaged the numbers of fish harvested or released from each boat party intercepted. However, catch per boat varies with party size, particularly given that harvest was limited to one fish per person per day. Creel surveys in the Great Lakes also rely on boat counts for calculating effort, and investigators improved precision around total catch estimates by averaging catch rates at the boat angler level (Lockwood 1997, Lockwood et al. 1999). This method was incorporated into new Red Snapper catch estimates and resulted in overall c.v.'s that were <0.25.

Sample coverage is an important consideration when estimating activity in a fishery over short time periods. During the short sampling window for the fishery monitored in this study, effort was influenced daily by offshore boating conditions. The ratio estimator and expansion methods produced similar results that were reasonably precise, provided variability in effort was measured across each day of the season. With the ratio estimator method, this measure was provided by reference inlets, but the expansion method was only effective when each inlet was sampled daily. However, the expansion method may be preferred if variability in effort is inconsistent across the spatial scale of the fishery (for example, in this study, if offshore conditions in the vicinity of the reference inlet differed from more northern or southern inlets).

With this specialized survey, we demonstrate that precise estimates can be obtained for the recreational mini-season for South Atlantic Red Snapper in Florida. The recently released NOAA Fisheries National Saltwater Recreational Fisheries Implementation Plan lists the execution of directed projects that improve recreational statistics for pulse and rare event fisheries as one of its focused actions for supporting stock assessments and informing fisheries management (NMFS 2015). This survey is an important complement to the larger-scale MRIP survey, which provides annual estimates for Red Snapper discards that occur off the Atlantic coast throughout the year, but produce very imprecise estimates for harvest during the pulse fishery that has developed during mini-seasons. The year-round MRIP survey also provides a measure of illegal harvest that occurs outside the recreational mini-season; however, occurrences are rare and estimates are imprecise (PSE's in Florida >90%).

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SEDAR41-RD15. South Atlantic Red Snapper ((*Lutjanus campechanus*) monitoring in Florida for the 2013 season. Sauls, B., R. Cody, B. Cermak, O. Ayala and K. Kowal.