# Age-0 Mutton Snapper Abundance Index from Inshore Surveys of Indian River Lagoon on Florida’s Atlantic Coast

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# Mutton Snapper Abundance Indices from Inshore Surveys of Indian River Lagoon on Florida's Atlantic Coast

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## Abstract

An index of abundance for age-0 Mutton Snapper (*Lutjanus analis*) in Indian River Lagoon was generated using catch data from the Florida Fish and Wildlife Conservation Commission's Fisheries Independent Monitoring program. A negative binomial model incorporating year, month, geographic zone, bottom type, temperature, depth, and salinity was used to model the age-0 Mutton Snapper catch data. Estimates of age-0 Mutton Snapper were relatively low for most years in the data set with a notable exception in 2007 when observed and estimated catches were more than twice that of the next highest year.

## Introduction

Mutton Snapper (*Lutjanus analis*) are a subtropical member of the Lutjanidae family often targeted by recreational and commercial fishermen. In the United States, the species is managed as a single stock and occurs from Texas to Massachusetts although the fishery is predominantly located in South Florida. While the stock is not currently overfished or undergoing overfishing, there are concerns about the species as they are vulnerable to cold snaps as juveniles (SEDAR 15A update 2015) and their spawning aggregations can be heavily exploited (Graham et al. 2008).

The Florida Fish and Wildlife Conservation Commission's Fisheries Independent Monitoring (FIM) program began in 1989 with seasonal stratified random sampling in Tampa Bay. In 1996, sampling switched from seasonal to monthly and long-term data sets have been established for seven estuaries throughout Florida (Apalachicola Bay, Cedar Key, Tampa Bay, Charlotte Harbor, Northeast Florida, Northern Indian River Lagoon and Southern Indian River Lagoon). Sampling within each estuary is stratified by habitat and gear type proportional to the available sampling area. The primary gear type used to sample juvenile and adult sportfishes is a 183 x 2.5 m center bag haul seine that has a stretched mesh length of 38 mm. This seine is deployed by boat along a shoreline to cover an approximately 40 m x 103 m area before being retrieved by hand. Species captured in the gear are identified to the lowest taxonomic level and enumerated with up to 40 individuals measured for standard length to the nearest mm. Numerous habitat and water quality metrics are recorded for each sampling event.

## Data and Index Construction

Of the seven FIM labs that conduct long term sampling, Mutton Snapper have been caught by the 183-m seine in five of them. Mutton Snapper occur very rarely in Apalachicola (n=1), Northeast Florida (n=1) and Charlotte Harbor (n=55). Mutton Snapper have been caught in Tampa Bay but not in the 183-m seine. No Mutton Snapper have been caught in Cedar Key as of

2022. Mutton Snapper were most commonly caught by the two labs that sample Indian River Lagoon, Indian River (IR) and Tequesta (TQ). Between 1997 and 2022, IR has caught 418 individuals in Northern Indian River Lagoon and 2412 individuals have been caught by TQ in Southern Indian River Lagoon (Figure 1). However, catches of Mutton Snapper were almost exclusive to a single geographic zone in IR (IRH) and two zones in TQ (TQJ and TQI) (Figures 1 and S1). A simulation-based power analysis (Appendix A) indicated when IR and TQ were analyzed as separate estuaries there was low power to detect trends in population abundance over a 10-year (21-90% probability to detect a 50% increase or decrease in abundance) or 20-year period (35-90%). Whereas, when data from IR and TQ were combined into a single estuary the power to detect trends over a 10-year (70-79%) and 20-year period (74-87%) was increased. Therefore, the initial IOA was set to run on the combined estuary dataset using the three geographic zones of IRH, TQI and TQJ. The size range for Mutton Snapper caught by the 183-m seine in Indian River Lagoon during this time period ranged from 34 to 331 mm SL (Figure 2). In the previous SEDAR assessment for Mutton Snapper (SEDAR 15A 2008), both age-0 (0-80 mm SL) and age-1+ (80+ mm SL) IOAs were created for Mutton Snapper using FIM data, however an update to SEDAR 15A (2015) revealed that nearly 89% of age-1 fish were likely age-0 fish based on a stochastic age-length key. Thus, the previously used size cutoff of 80 mm SL to delineate between age-0 and age-1+ Mutton Snapper would need revision. Based on previously established von Bertalanffy growth functions (Burton 2002, SEDAR 15A 2008, SEDAR 15A update 2015) for the species a new size cutoff of 190 mm SL was selected for age-0 fish. Monthly length frequency data indicated that peak recruitment to the 183-m seine occurred from August to November (Figure 3). This led to us selecting the months of July-December as our recruitment window for age-0 Mutton Snapper in the IOA. Yearly length frequencies for age-0 Mutton Snapper in Indian River Lagoon indicated that catches are typically low and variable (Figure 4). The years of 1997 and 1998 were also excluded from the initial IOA as sampling effort was not yet standardized for these years.

Generalized linear models were used to construct the IOA for age-0 Mutton Snapper in Indian River Lagoon. Variables considered for IOA construction were year, month, geographic zone, shore type (emergent, mangrove, none, structure and terrestrial), bottom habitat (submerged aquatic vegetation [SAV], sediment and structure). Three covariates (depth [m], salinity [ppt], and temperature [C°]) were also included in the model with each being log transformed and normalized to 1. Fish per haul was used as the dependent variable. Due to the nonnormality and high numbers of zero catches in this data set, Poisson, negative binomial and their zero inflated counterparts were assessed for IOA construction. Neither zero inflated model converged, and the negative binomial proved to be a better fit than the Poisson. Prior to IOA construction all levels within variables were examined for excessive empty cells or low sample sizes. Variable levels with either were removed. Variable selection for the IOA was done via a stepwise selection process based on Akaike Information criteria (AIC). Least squares means (±SE) were calculated for each year along with annual coefficients of variation (CV). These annual CVs were determined by multiplying the standard error of the model by deviates derived from a standard normal distribution (n=10,000) and adding these values to the calculated least squares mean. This new sampling distribution was then used to calculate the standard deviations from which the annual CVs could be derived. The IOA was conducted in SAS statistical software using Proc GLIMMIX (SAS institute 2013).

## Results and Discussion

A total of 1864 hauls and 1723 Mutton Snapper were sampled based on our initial conditions set forth in the IOA (Table 1). Due to a high number of excessive empty cells, the emergent shore type (~2% of total samples) was removed prior to running the initial model. Based on stepwise AIC selection the variables of year, month, bottom type, zone and the covariates of depth, salinity, and temperature were included in the model and all were significant at $\alpha=0.05$ (Table 2). The IOA indicated that age-0 Mutton Snapper abundance was relatively low throughout the time series with one notable peak in 2007 (Figure 5). The exact cause of the peak is unknown, but we hypothesize that the path of Subtropical Storm Andrea (south along the Atlantic coast of Florida) in May of that year may have led to increased larval transport into the Indian River Lagoon. Noticeable declines in age-0 Mutton Snapper abundance occurred in 2016 and 2019. Since 2016, Indian River Lagoon has seen a reduction in seagrass habitat that has likely contributed to these particularly bad years. Additionally, both 2016 and 2019 had hurricanes run north along Florida's Atlantic coast which may have also impacted recruitment in these years. All calculated annual CVs were <0.5 (Table 3). The final negative binomial model had a dispersion value of 1.34 indicating that some level of overdispersion is present.

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SEDAR. 2015. Stock Assessment of Mutton Snapper (*Lutjanus analis*) of the U.S. South Atlantic and Gulf of Mexico through 2013. Florida Fish and Wildlife Conservation Commission. St. Petersburg, FL. 142 pages. http://sedarweb.org/docs/suar/SEDAR%20Update%20Stock%20Assessment%20of%20Mutton%20Snapper%202015_FINAL.pdf

Table 1. Frequency of occurrence and mean number of age-0 Mutton Snapper (0-190 mm SL) caught by year in the 183-m center bag seine in Indian River Lagoon. Only data from the recruitment window (July-December) included.

| Year | Number of samples | Number of fish | % Frequency of occurrence | Mean fish per haul | Standard error |
|---|---|---|---|---|---|
| 1999 | 78 | 29 | 16.67 | 0.372 | 0.107 |
| 2000 | 78 | 59 | 19.23 | 0.756 | 0.275 |
| 2001 | 78 | 31 | 16.67 | 0.397 | 0.116 |
| 2002 | 78 | 77 | 28.21 | 0.987 | 0.273 |
| 2003 | 78 | 48 | 20.51 | 0.615 | 0.170 |
| 2004 | 78 | 44 | 24.36 | 0.564 | 0.149 |
| 2005 | 76 | 43 | 21.05 | 0.566 | 0.159 |
| 2006 | 78 | 90 | 39.74 | 1.154 | 0.234 |
| 2007 | 78 | 237 | 48.72 | 3.038 | 0.688 |
| 2008 | 78 | 114 | 29.49 | 1.462 | 0.383 |
| 2009 | 78 | 48 | 21.79 | 0.615 | 0.218 |
| 2010 | 78 | 90 | 24.36 | 1.154 | 0.470 |
| 2011 | 78 | 57 | 17.95 | 0.731 | 0.285 |
| 2012 | 78 | 92 | 29.49 | 1.179 | 0.285 |
| 2013 | 78 | 101 | 29.49 | 1.295 | 0.341 |
| 2014 | 78 | 83 | 20.51 | 1.064 | 0.366 |
| 2015 | 78 | 83 | 29.49 | 1.064 | 0.242 |
| 2016 | 78 | 37 | 19.23 | 0.474 | 0.179 |
| 2017 | 78 | 42 | 16.67 | 0.538 | 0.199 |
| 2018 | 78 | 65 | 16.67 | 0.833 | 0.385 |
| 2019 | 78 | 26 | 15.38 | 0.333 | 0.112 |
| 2020 | 78 | 72 | 20.51 | 0.923 | 0.404 |
| 2021 | 78 | 67 | 25.64 | 0.859 | 0.286 |
| 2022 | 78 | 99 | 32.05 | 1.269 | 0.340 |

Table 2. Type III tests of fixed effects for final negative binomial model for age-0 Mutton Snapper relative abundance in Indian River Lagoon.

| Effect | Numerator DF | Denominator DF | F Value | Pr > F |
|---|---|---|---|---|
| Year | 23 | 1788 | 3.60 | <.0001 |
| Bottom habitat | 2 | 1788 | 24.95 | <.0001 |
| Month | 5 | 1788 | 13.24 | <.0001 |
| Zone | 2 | 1788 | 21.40 | <0.001 |
| Log depth+1 | 1 | 1788 | 35.24 | <.0001 |
| Log salinity+1 | 1 | 1788 | 42.25 | <.0001 |
| Log temperature+1 | 1 | 1788 | 4.59 | 0.0323 |

Table 3. Estimates of annual relative abundance of Mutton Snapper for Indian River Lagoon based on the final negative binomial model. Standard error (SE), coefficient of variation (CV) and lower (LCL) and upper (UCL) confidence limits (95%) also provided.

| Year | Mean | SE | CV | LCL | UCL |
|---|---|---|---|---|---|
| 1999 | 0.181 | 0.066 | 0.386 | 0.089 | 0.369 |
| 2000 | 0.250 | 0.078 | 0.326 | 0.136 | 0.460 |
| 2001 | 0.286 | 0.096 | 0.350 | 0.148 | 0.551 |
| 2002 | 0.455 | 0.139 | 0.313 | 0.250 | 0.827 |
| 2003 | 0.260 | 0.085 | 0.339 | 0.137 | 0.492 |
| 2004 | 0.360 | 0.115 | 0.334 | 0.192 | 0.673 |
| 2005 | 0.660 | 0.217 | 0.340 | 0.346 | 1.259 |
| 2006 | 0.445 | 0.134 | 0.308 | 0.247 | 0.803 |
| 2007 | 1.764 | 0.485 | 0.284 | 1.029 | 3.024 |
| 2008 | 0.784 | 0.229 | 0.305 | 0.442 | 1.391 |
| 2009 | 0.256 | 0.085 | 0.343 | 0.134 | 0.489 |
| 2010 | 0.298 | 0.096 | 0.337 | 0.159 | 0.559 |
| 2011 | 0.354 | 0.110 | 0.322 | 0.193 | 0.650 |
| 2012 | 0.599 | 0.176 | 0.303 | 0.336 | 1.065 |
| 2013 | 0.634 | 0.194 | 0.315 | 0.348 | 1.156 |
| 2014 | 0.568 | 0.183 | 0.336 | 0.302 | 1.068 |
| 2015 | 0.426 | 0.134 | 0.332 | 0.230 | 0.791 |
| 2016 | 0.148 | 0.053 | 0.377 | 0.073 | 0.300 |
| 2017 | 0.529 | 0.178 | 0.346 | 0.274 | 1.022 |
| 2018 | 0.667 | 0.212 | 0.331 | 0.357 | 1.244 |
| 2019 | 0.115 | 0.043 | 0.389 | 0.056 | 0.239 |
| 2020 | 0.744 | 0.226 | 0.316 | 0.410 | 1.350 |
| 2021 | 0.529 | 0.161 | 0.318 | 0.291 | 0.962 |
| 2022 | 0.665 | 0.197 | 0.312 | 0.372 | 1.190 |

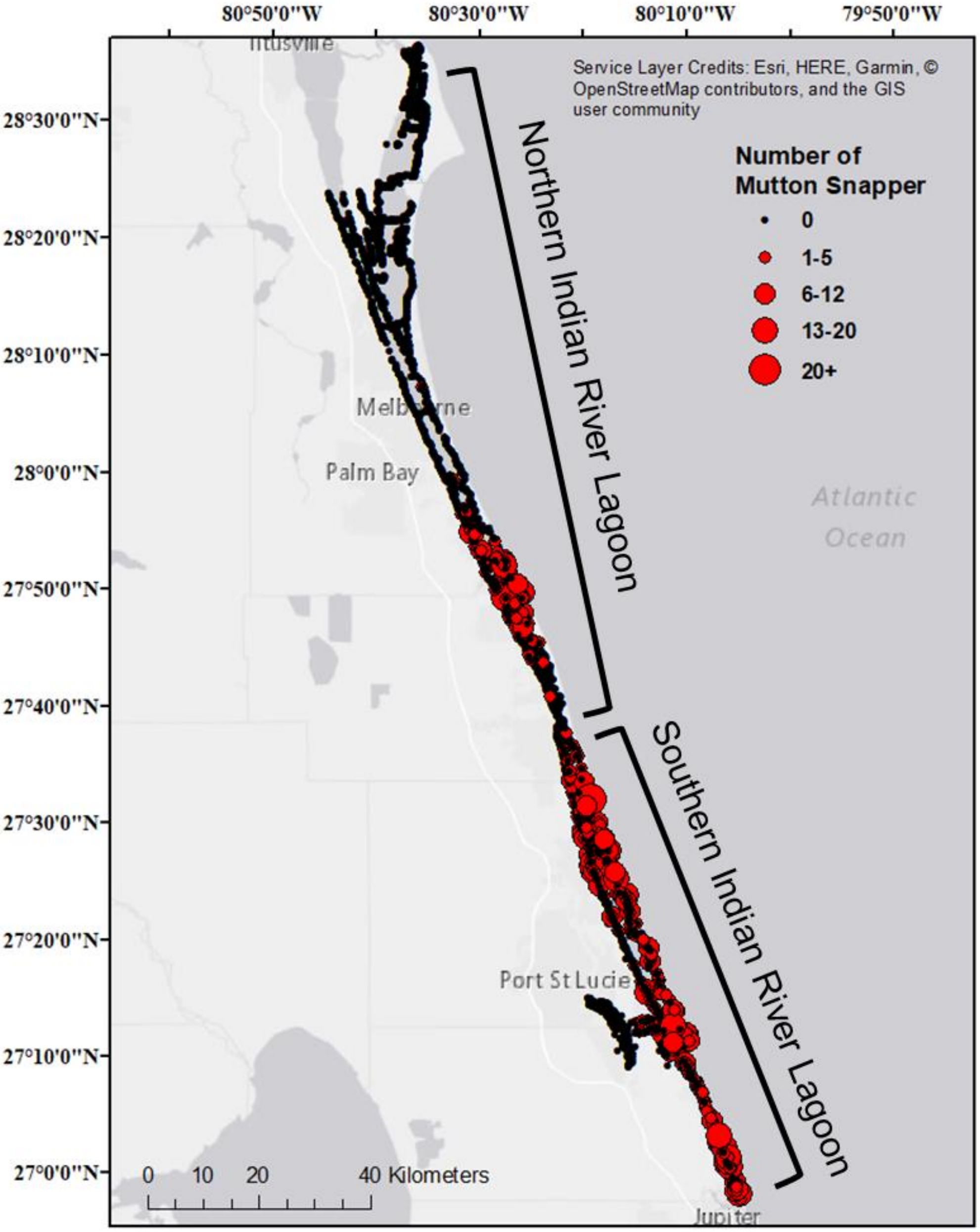

Figure 1. Sampling locations for Fisheries Independent Monitoring (FIM) with the 183 m center bag seine in Indian River Lagoon from 1997 to 2022. Black symbols indicate sets with no Mutton Snapper. Red symbols indicate sets with at least one Mutton Snapper with larger symbols corresponding to larger catches. Note that catches of Mutton Snapper are almost exclusive to the southern portion of Northern Indian River Lagoon.

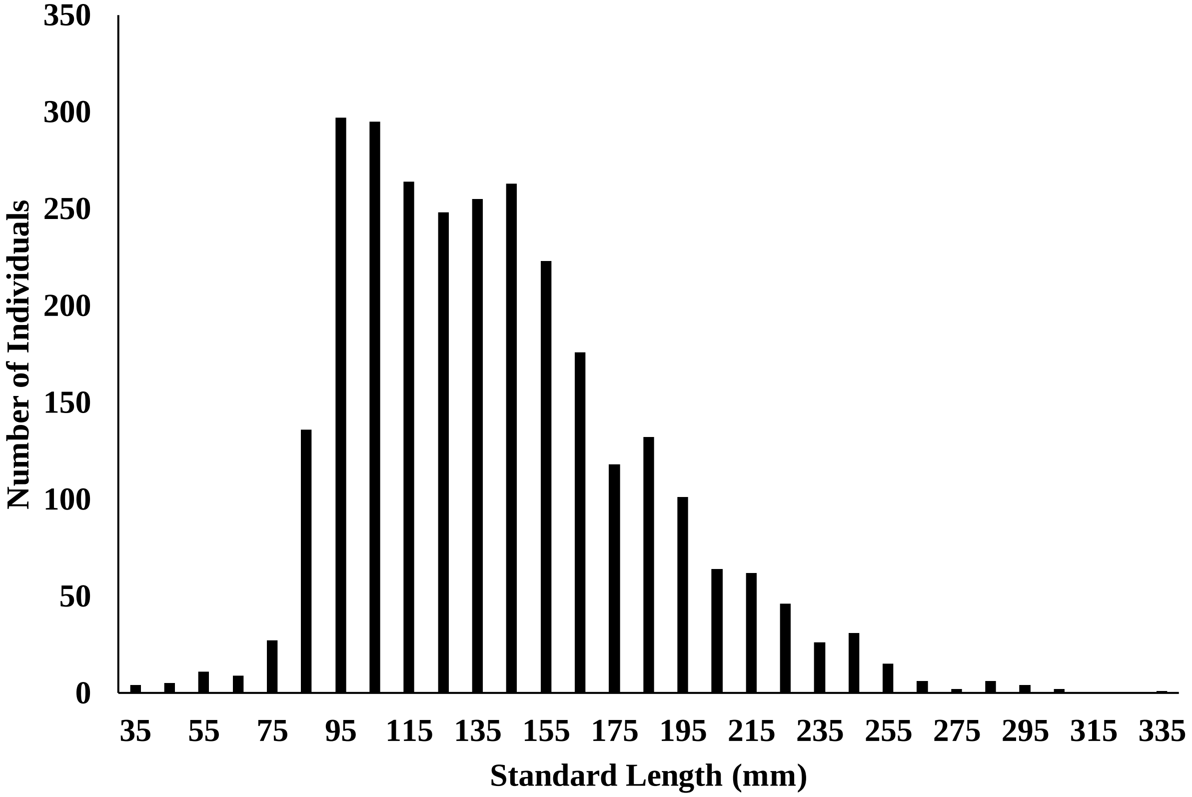

Figure 2. Length frequency of Mutton Snapper captured by the 183 m seine in Indian River Lagoon from 1997 to 2022.

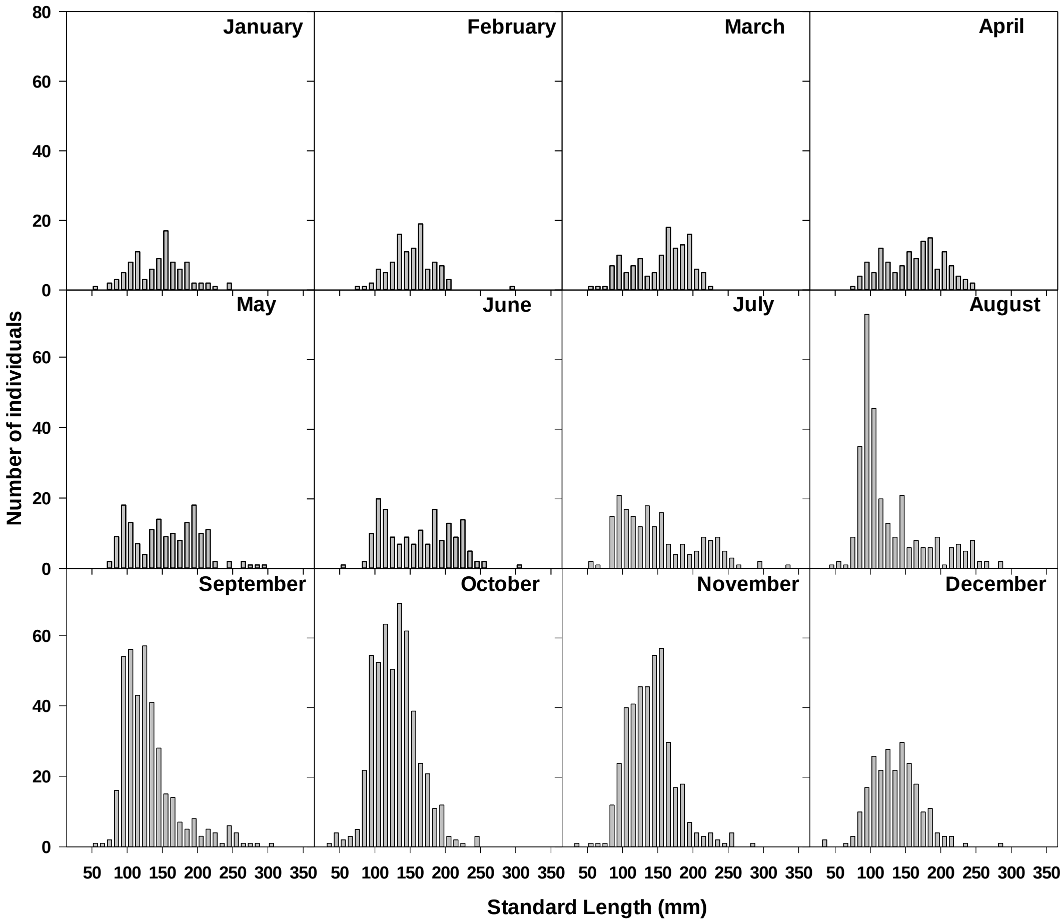

Figure 3. Monthly Length frequencies for Mutton Snapper caught during Fisheries Independent Monitoring (FIM) in Indian River Lagoon for the 183-m center bag seine from 1997 to 2022. Size bins are in 10mm increments.

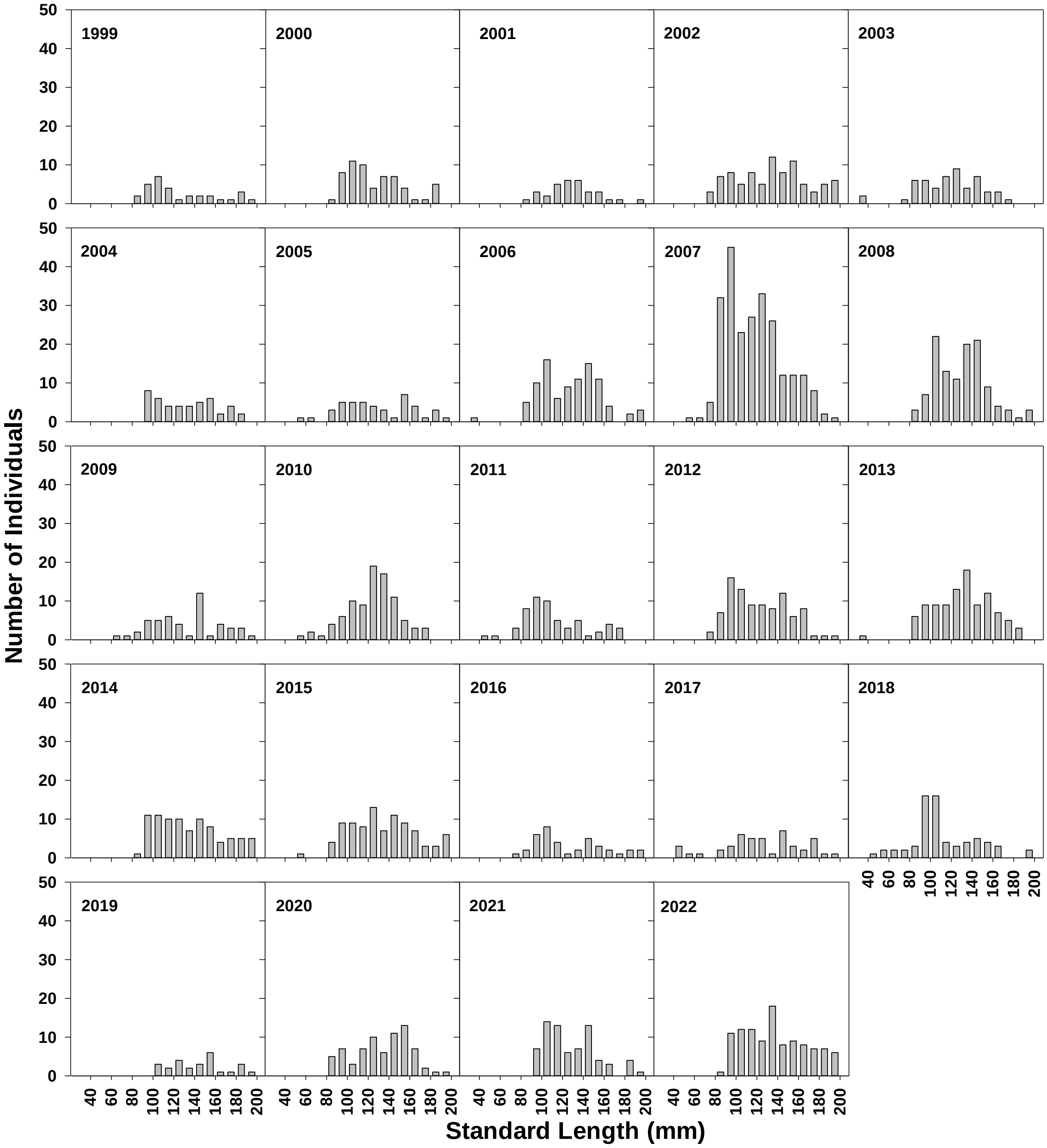

Figure 4. Yearly length frequencies for age-0 Mutton Snapper caught during Fisheries Independent Monitoring (FIM) in Indian River Lagoon for the 183-m center bag seine from 1999 to 2022. Size bins are in 10mm increments. Only recruitment months of July-December included.

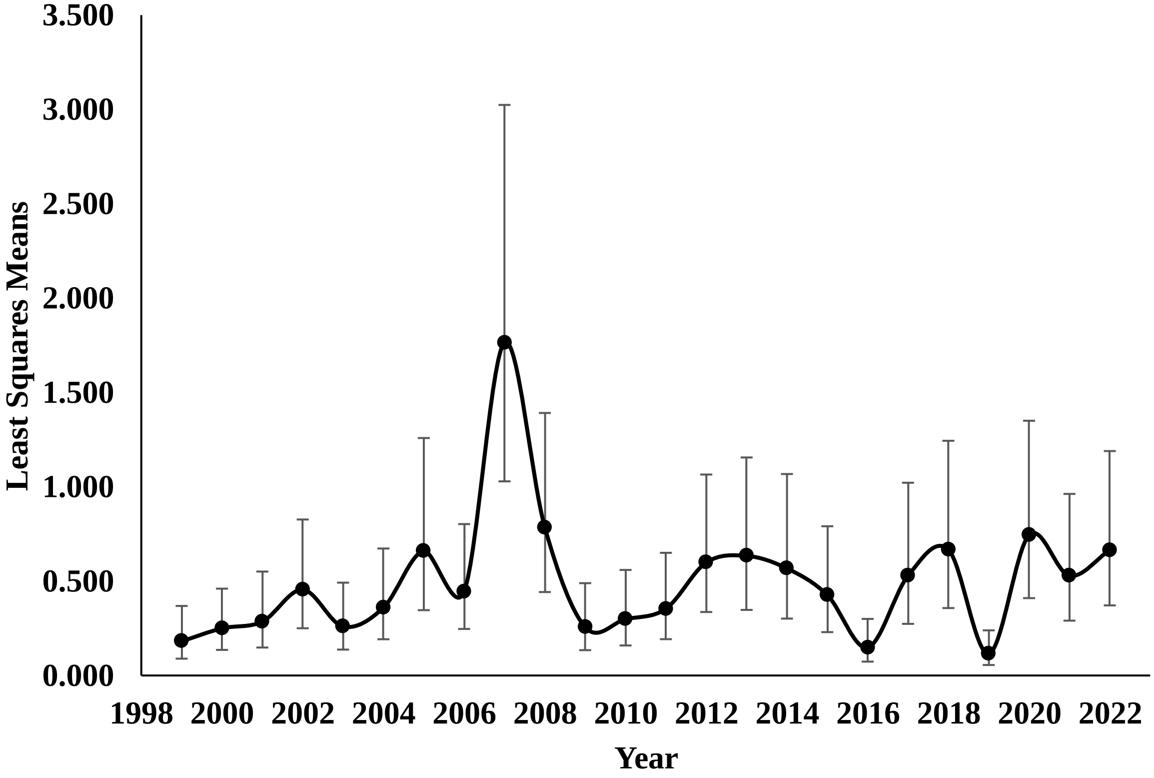

Figure 5. Annual estimates of age-0 Mutton Snapper relative abundance for Indian River Lagoon. Least squares means with upper and lower confidence limits estimated using the final negative binomial model.

Supplemental Material

Table S1. Number of 183-m seines by year and factor included in the final negative binomial model for age-0 Mutton Snapper in Indian River Lagoon 1999-2022. Seines with missing data or emergent shore type removed during model fitting process.

| Year | Bottom Type | | | Month | | | | | | Geographic Zone | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sav | Sediment | Structure | 7 | 8 | 9 | 10 | 11 | 12 | IRH | TQI | TQJ |
| 1999 | 48 | 21 | 8 | 12 | 13 | 13 | 13 | 13 | 13 | 29 | 24 | 24 |
| 2000 | 56 | 22 | 0 | 13 | 13 | 13 | 13 | 13 | 13 | 30 | 24 | 24 |
| 2001 | 47 | 23 | 6 | 12 | 13 | 13 | 13 | 13 | 12 | 28 | 24 | 24 |
| 2002 | 51 | 22 | 3 | 13 | 13 | 11 | 13 | 13 | 13 | 29 | 23 | 24 |
| 2003 | 58 | 14 | 6 | 13 | 13 | 13 | 13 | 13 | 13 | 30 | 24 | 24 |
| 2004 | 54 | 19 | 4 | 13 | 13 | 13 | 13 | 12 | 13 | 29 | 24 | 24 |
| 2005 | 45 | 25 | 5 | 13 | 13 | 13 | 10 | 13 | 13 | 29 | 24 | 22 |
| 2006 | 65 | 7 | 5 | 13 | 12 | 13 | 13 | 13 | 13 | 30 | 24 | 23 |
| 2007 | 53 | 18 | 2 | 13 | 10 | 13 | 13 | 11 | 13 | 25 | 24 | 24 |
| 2008 | 46 | 21 | 10 | 13 | 13 | 13 | 12 | 13 | 13 | 29 | 24 | 24 |
| 2009 | 39 | 32 | 5 | 13 | 13 | 13 | 12 | 12 | 13 | 29 | 23 | 24 |
| 2010 | 68 | 2 | 5 | 12 | 13 | 13 | 13 | 12 | 12 | 28 | 24 | 23 |
| 2011 | 35 | 6 | 33 | 13 | 13 | 12 | 12 | 13 | 11 | 26 | 24 | 24 |
| 2012 | 40 | 3 | 33 | 12 | 13 | 13 | 13 | 12 | 13 | 28 | 24 | 24 |
| 2013 | 55 | 0 | 20 | 13 | 13 | 13 | 11 | 12 | 13 | 29 | 23 | 23 |
| 2014 | 46 | 0 | 30 | 13 | 13 | 13 | 13 | 11 | 13 | 29 | 24 | 23 |
| 2015 | 49 | 0 | 26 | 13 | 13 | 13 | 13 | 11 | 12 | 28 | 23 | 24 |
| 2016 | 41 | 1 | 35 | 13 | 13 | 12 | 13 | 13 | 13 | 29 | 24 | 24 |
| 2017 | 33 | 5 | 39 | 13 | 13 | 13 | 13 | 13 | 12 | 29 | 24 | 24 |
| 2018 | 33 | 1 | 44 | 13 | 13 | 13 | 13 | 13 | 13 | 30 | 24 | 24 |
| 2019 | 28 | 3 | 44 | 13 | 12 | 12 | 13 | 13 | 12 | 27 | 24 | 24 |
| 2020 | 20 | 3 | 55 | 13 | 13 | 13 | 13 | 13 | 13 | 30 | 24 | 24 |
| 2021 | 24 | 2 | 51 | 13 | 13 | 13 | 13 | 13 | 12 | 29 | 24 | 24 |
| 2022 | 24 | 5 | 48 | 13 | 13 | 12 | 13 | 13 | 13 | 29 | 24 | 24 |
| All | 1058 | 255 | 517 | 308 | 307 | 306 | 304 | 301 | 304 | 688 | 572 | 570 |

Table S2. Counts of age-0 Mutton Snapper by year and factor that were included in the final negative binomial model for Indian River Lagoon from 1999-2022. Seines with missing data or emergent shore type removed during model fitting process.

| Year | Bottom Type | | | Month | | | | | | Geographic Zone | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sav | Sediment | Structure | 7 | 8 | 9 | 10 | 11 | 12 | IRH | TQI | TQJ |
| 1999 | 28 | 1 | 0 | 8 | 0 | 7 | 10 | 4 | 0 | 4 | 13 | 12 |
| 2000 | 51 | 8 | 0 | 0 | 2 | 11 | 18 | 13 | 15 | 15 | 6 | 38 |
| 2001 | 22 | 9 | 0 | 2 | 6 | 9 | 5 | 7 | 2 | 13 | 9 | 9 |
| 2002 | 56 | 20 | 0 | 8 | 15 | 21 | 8 | 23 | 1 | 2 | 48 | 26 |
| 2003 | 37 | 10 | 1 | 1 | 3 | 15 | 2 | 13 | 14 | 5 | 10 | 33 |
| 2004 | 37 | 6 | 1 | 18 | 14 | 3 | 5 | 4 | 0 | 4 | 26 | 14 |
| 2005 | 29 | 8 | 6 | 4 | 6 | 7 | 2 | 15 | 9 | 20 | 11 | 12 |
| 2006 | 87 | 3 | 0 | 18 | 2 | 20 | 9 | 22 | 19 | 13 | 48 | 29 |
| 2007 | 172 | 62 | 3 | 23 | 69 | 22 | 83 | 29 | 11 | 32 | 84 | 121 |
| 2008 | 70 | 37 | 7 | 11 | 19 | 16 | 51 | 5 | 12 | 31 | 49 | 34 |
| 2009 | 29 | 15 | 1 | 1 | 3 | 6 | 3 | 17 | 15 | 8 | 23 | 14 |
| 2010 | 88 | 0 | 2 | 0 | 6 | 38 | 22 | 24 | 0 | 0 | 31 | 59 |
| 2011 | 41 | 1 | 15 | 4 | 17 | 4 | 24 | 0 | 8 | 1 | 32 | 24 |
| 2012 | 74 | 2 | 16 | 10 | 20 | 14 | 27 | 3 | 18 | 8 | 60 | 24 |
| 2013 | 51 | 0 | 44 | 3 | 6 | 13 | 12 | 45 | 16 | 30 | 38 | 27 |
| 2014 | 77 | 0 | 6 | 6 | 3 | 29 | 18 | 25 | 2 | 3 | 30 | 50 |
| 2015 | 71 | 0 | 5 | 7 | 5 | 5 | 30 | 20 | 9 | 16 | 19 | 41 |
| 2016 | 30 | 0 | 6 | 1 | 5 | 18 | 1 | 11 | 0 | 2 | 10 | 24 |
| 2017 | 16 | 0 | 26 | 3 | 1 | 10 | 15 | 13 | 0 | 8 | 27 | 7 |
| 2018 | 58 | 0 | 7 | 1 | 20 | 0 | 27 | 1 | 16 | 53 | 8 | 4 |
| 2019 | 14 | 1 | 11 | 0 | 0 | 8 | 13 | 1 | 4 | 6 | 16 | 4 |
| 2020 | 14 | 1 | 57 | 3 | 4 | 7 | 11 | 45 | 2 | 18 | 39 | 15 |
| 2021 | 26 | 1 | 40 | 7 | 10 | 4 | 13 | 8 | 25 | 10 | 22 | 35 |
| 2022 | 16 | 4 | 79 | 5 | 3 | 7 | 41 | 28 | 15 | 9 | 42 | 48 |
| All | 1194 | 189 | 333 | 144 | 239 | 294 | 450 | 376 | 213 | 311 | 701 | 704 |

Table S3. Number of samples, number of fish and frequency of occurrence of age-0 Mutton Snapper (0-190 mm SL) for the sequences retained in the final negative binomial model.

| Year | Number of samples | Number of fish | % Frequency of occurrence |
|---|---|---|---|
| 1999 | 77 | 29 | 16.88 |
| 2000 | 78 | 59 | 19.23 |
| 2001 | 76 | 31 | 17.11 |
| 2002 | 76 | 76 | 27.63 |
| 2003 | 78 | 48 | 20.51 |
| 2004 | 77 | 44 | 24.68 |
| 2005 | 75 | 43 | 21.33 |
| 2006 | 77 | 90 | 40.26 |
| 2007 | 73 | 237 | 52.05 |
| 2008 | 75 | 103 | 29.33 |
| 2009 | 73 | 45 | 21.92 |
| 2010 | 75 | 90 | 25.33 |
| 2011 | 74 | 57 | 18.92 |
| 2012 | 76 | 92 | 30.26 |
| 2013 | 75 | 95 | 29.33 |
| 2014 | 76 | 83 | 21.05 |
| 2015 | 75 | 76 | 28.00 |
| 2016 | 76 | 36 | 18.42 |
| 2017 | 77 | 42 | 16.88 |
| 2018 | 78 | 65 | 16.67 |
| 2019 | 75 | 26 | 16.00 |
| 2020 | 78 | 72 | 20.51 |
| 2021 | 77 | 67 | 25.97 |
| 2022 | 77 | 99 | 32.47 |

Table S4. Fit Statistics for the final negative binomial model for Mutton Snapper from Indian River lagoon.

| -2 Log Likelihood | AIC | Pearson Chi-Square | Pearson Chi-Square / DF |
|---|---|---|---|
| 3657.08 | 3731.08 | 2396.23 | 1.34 |

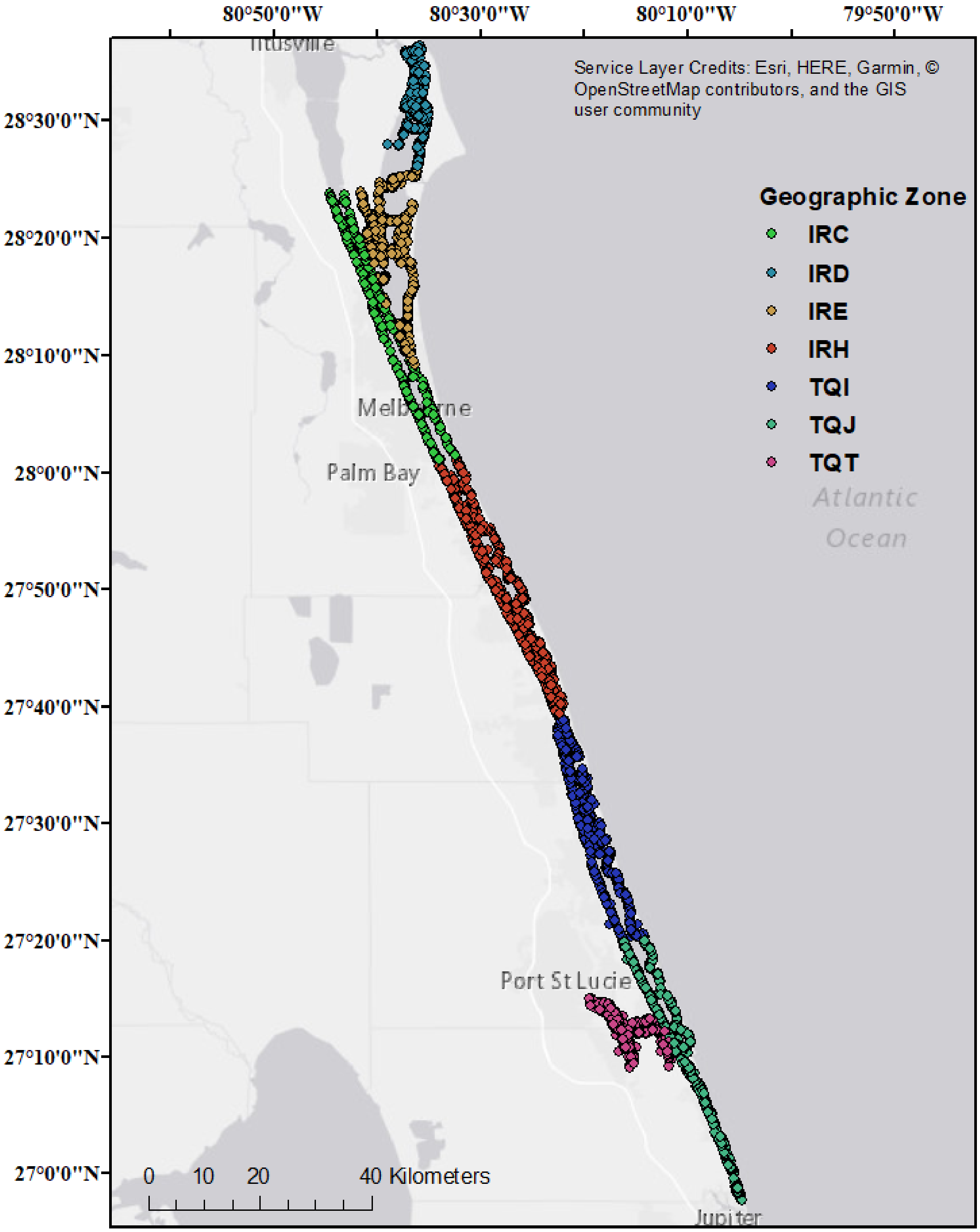

Figure S1. Map distinguishing the geographic zones sampled with the 183-m seine during annual monitoring by FWC's Fisheries Independent Monitoring program. Different colors represent the different zones. Individual dots represent individuals sets with the 183-m seine.

Figure S2. Interaction plots for mean catch (fish/haul) of age-0 Mutton Snapper caught during Fisheries Independent Monitoring (FIM) in Indian River Lagoon for the 183-m seine from 1999 to 2022.

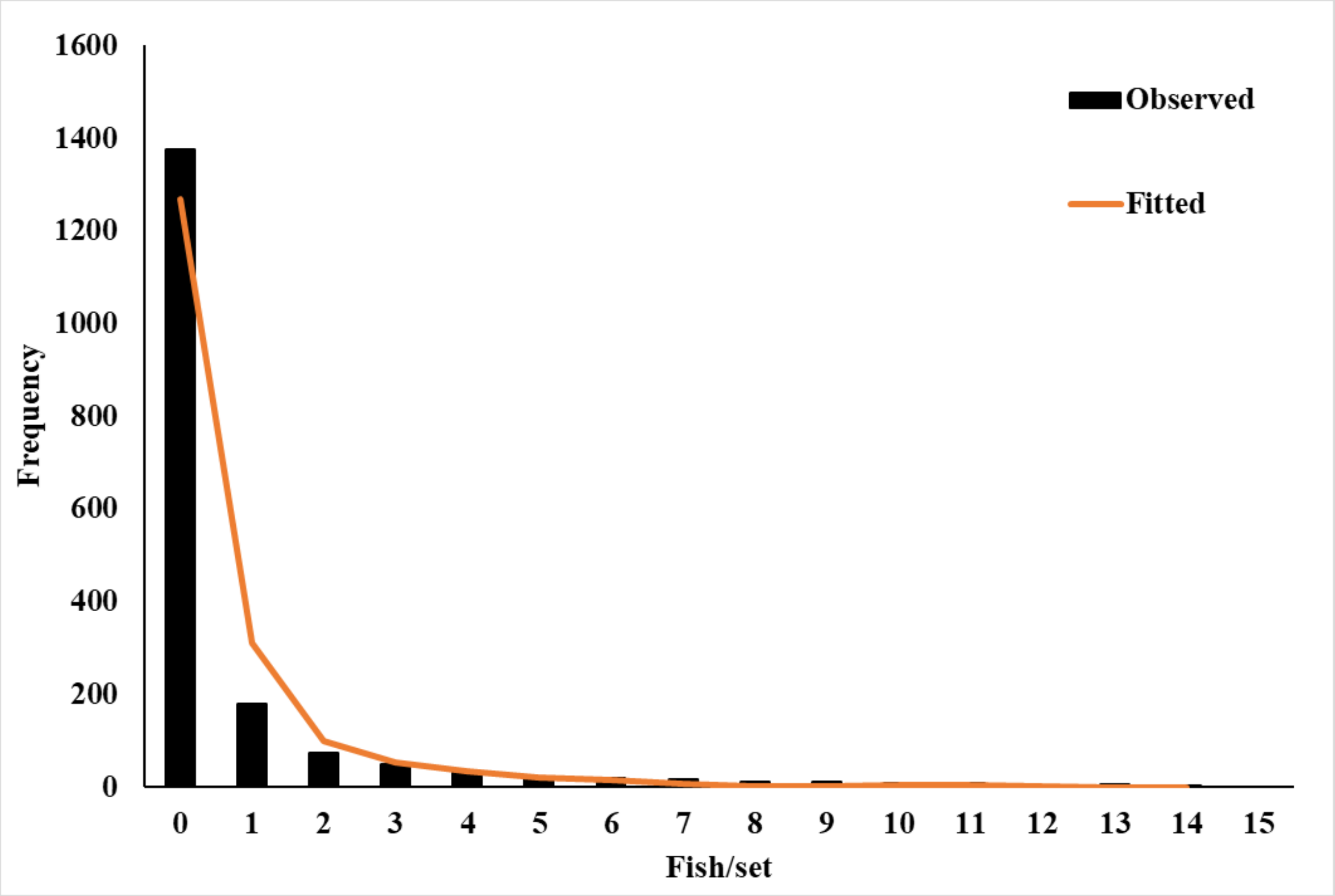

Figure S3. Frequency distribution of Mutton Snapper catches in the 183-m seine in Indian River Lagoon. The black bars represent observed data for sets deployed July-December from 1999 to 2021. The orange line represents the frequency for the fitted values produced by the final negative binomial model.

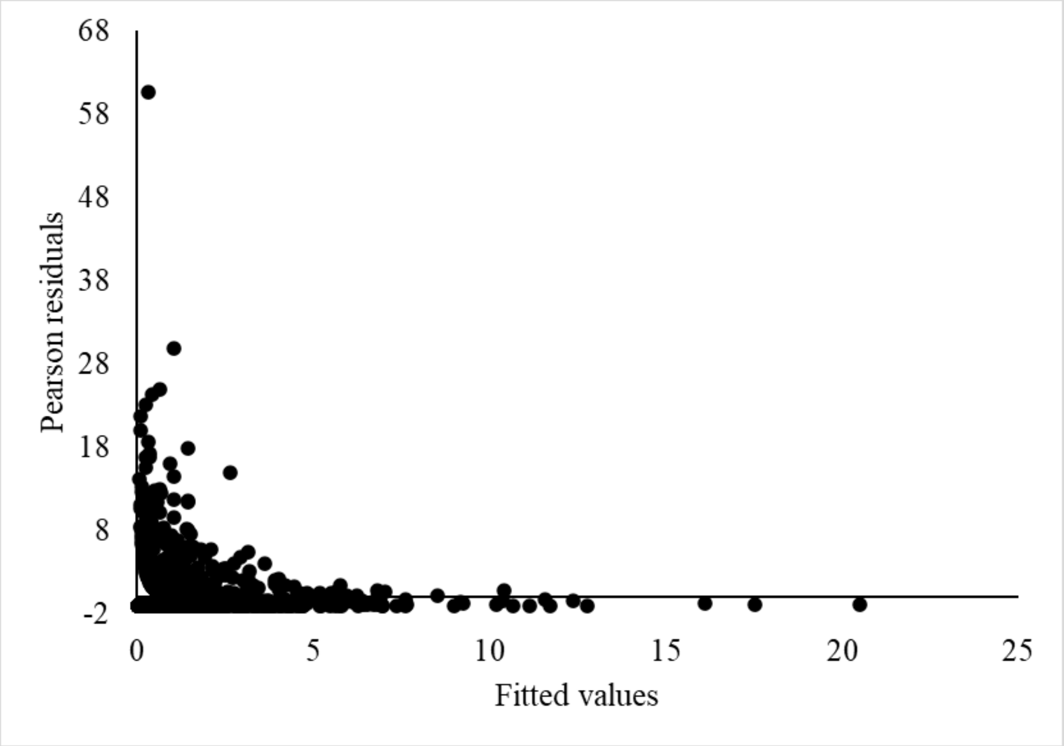

Figure S4. Pearson residuals versus the fitted values from the final negative binomial model.

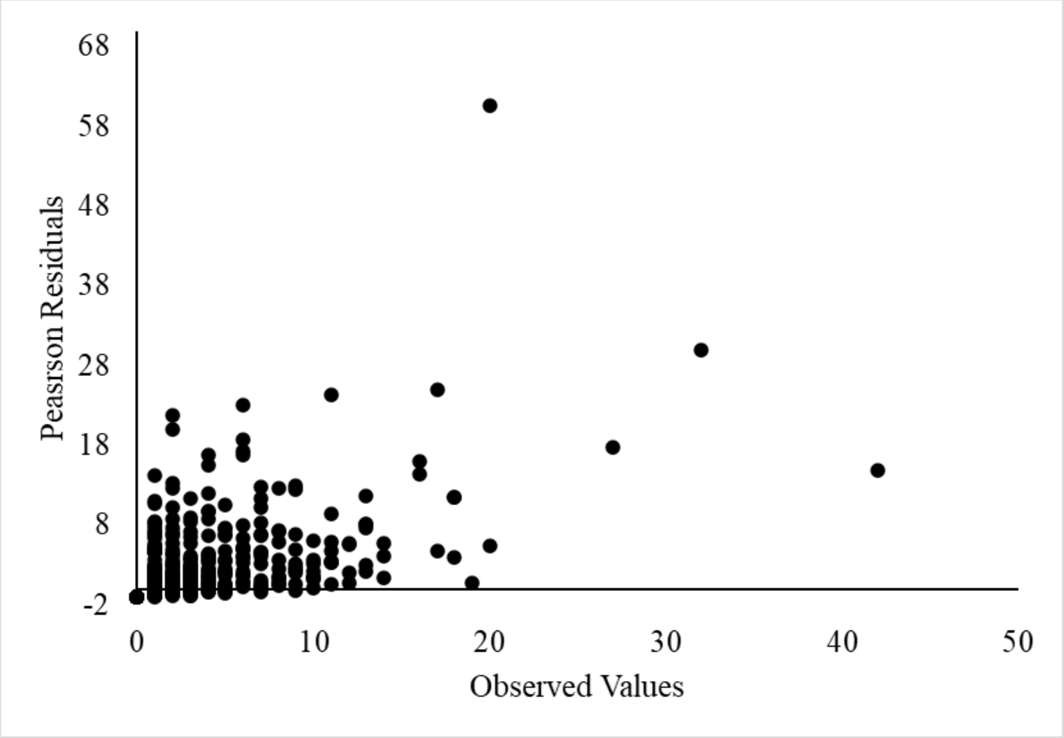

Figure S5. Pearson Residuals from the final negative binomial model versus observed values.

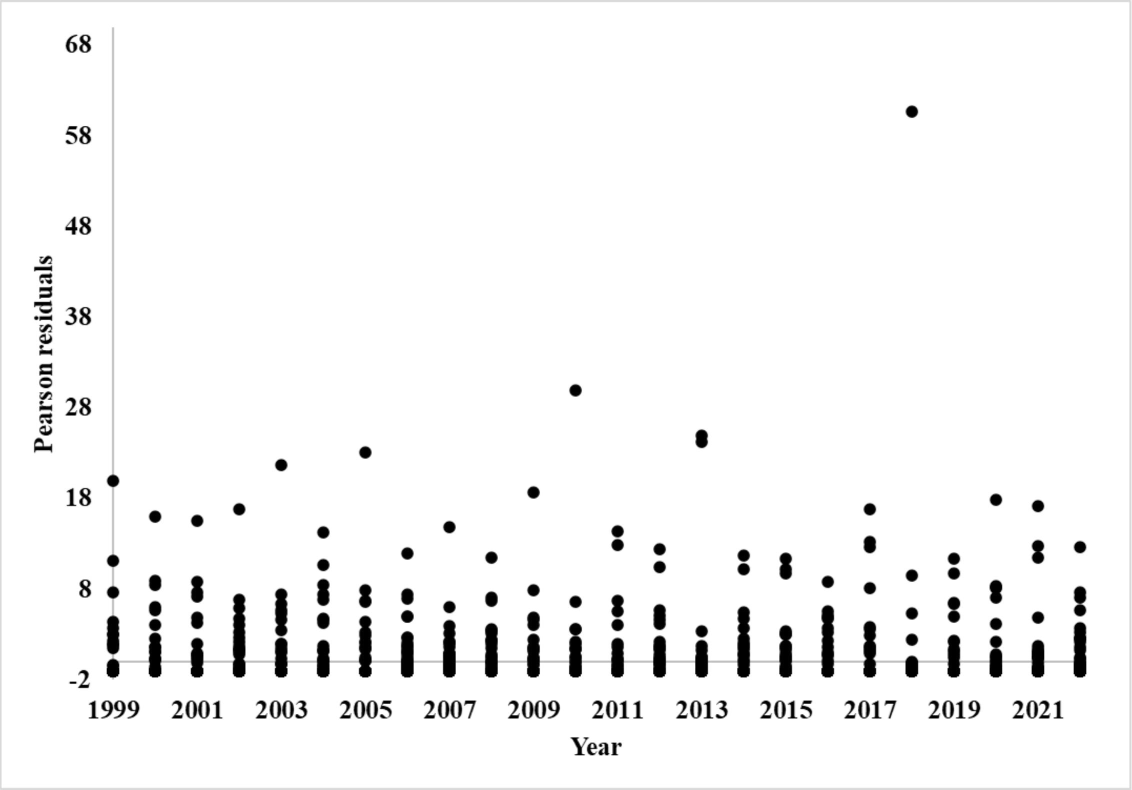

Figure S6. Pearson residuals from the final negative binomial model by year

## Appendix A

### Methods:

We conducted a simulation-based power analysis to assess our ability to detect negative or positive population trends for Mutton Snapper captured in 183-m haul seines over a 10- or 20-year sampling period in each sampling estuary. The power analysis was conducted following Schrandt et al. 2021, using the model developed above for the fisheries independent index of abundance.

Briefly, a generalized linear mixed model (GLMM) was fit to the catch data that assumed a negative binomial distribution with the number of Mutton Snapper caught per seine as the response variable. Predictor variables included year (as an integer ranging from 1 to 10 or 1 to 20), month, sampling estuary, and bottom habitat type. Depth, salinity, temperature, and dissolved oxygen were included as continuous predictors. Year and month were also included as random effects. With the exception of year, all continuous predictors were standardized to a mean 0 and standard deviation of 1. We extracted the maximum predicted count among years, as well as the overdispersion parameters; the predicted counts provided the starting values for the simulations.

Next, given the starting abundances for each estuary estimated above we calculated changes in the population trends resulting in year-10 (or year 20) populations ranging from 0.10 to 0.90 of the initial population for negative trends and 10 to 1.10 times the initial population for positive trends. We simulated sampling (number of nets in each estuary for 6 months over 10 or 20 years), adding error to the sampling process by drawing simulated samples from a negative binomial distribution with means (expected counts that decrease or increase, year after year) and overdispersion parameters from the initial negative binomial model fit to observed data.

For each simulated data set, we fit a negative binomial model with year as a continuous predictor variable (expressed as an integer ranging from 1 to 10 or 1 to 20) and extracted the estimated slope associated with year along with its 95 % confidence limits. This process was repeated 5,000 times for each level of percent annual change. The simulations excluded bottom type, salinity, temperature, depth, and dissolved oxygen; hence, the simulated populations were representative of those under average salinity, temperature, depth, and dissolved oxygen in each estuary.

Coverage and significance were determined from the 5,000 estimated slopes associated with each level of percent annual change, as defined by Schrandt et al. (2021): “Coverage was assigned a 1 for the simulation replicates for which the true slope (the known, simulated annual percent increase or decrease) was contained within the 95 % confidence interval (CI) of the estimated slope, and a 0 if it was not. Significance was assigned a 1 for the simulation replicates for which the upper 95 % CI of the slope estimate was <0 (indicating a negative trend) or the lower 95 % CI of the slope estimate was >0 (indicating a positive trend), which provided a measure of how often we detected a statistically significant temporal trend. Power for each replicate was calculated by multiplying the binary variables coverage and significance. Average power of the 5000 replicates indicated how well we were able to correctly detect a temporal trend (in terms of its direction and magnitude)."

All data analyses were conducted in R version 4.0.3 (R Core Team, 2020).

## Results and Discussion

Classic power curves were obtained for power simulations over a 10-year and 20-year period (Fig. A1). When estuaries were analyzed individually average power (calculated by averaging the estimated power for each of the estuaries) to detect a 50% change in abundance over a 10-year period ranged from 0.21 for Indian River to 0.64 for Tequesta (decreasing trend) and 0.24 for Indian River and 0.90 for Tequesta (increasing trend). When the time series was extended to 20 years there was slight improvements in power: 0.36 for Indian River and 0.86 for Tequesta for declining populations and 0.39 for Indian River and 0.90 for Tequesta for increasing populations.

The analysis was repeated for both estuaries combined and both the 10- and 20-year simulation (Fig. A2). An estuary/year x month random effect was also included to account for individual estuary. With estuaries combined the power to detect a doubling (0.79) or halving (0.70) of the population over a 10-year period increased. Over a 20-year period the power to detect a doubling (0.87) or halving (0.74) of the population was also increased. Due to sample size, the proximity of these two estuaries, and consistency in sampling protocols, it is our recommendation to combine the data from these two estuaries for one index of abundance that will provide more statistically powerful data.

## References:

R Core Team, 2020. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Schrandt, M. N., Shea, C. P., Kurth, B. N., & Switzer, T. S. 2021. Amending survey design to improve statistical inferences: Monitoring recruitment of juvenile reef fish in the eastern Gulf of Mexico. Fisheries Research 241: 106015.

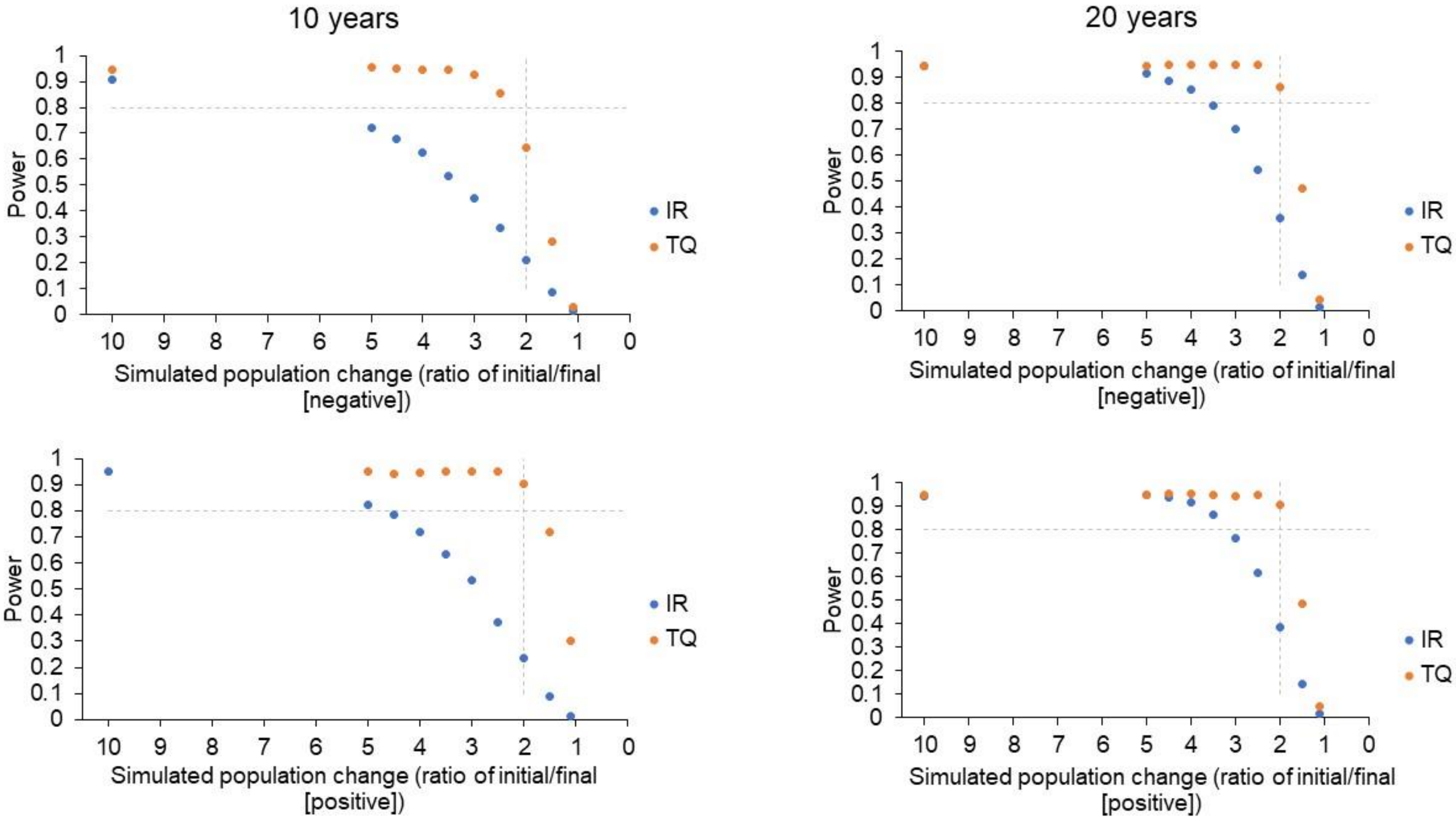

Figure A1. Power curves for 183-m seine sampling simulations for Mutton Snapper in Indian River Lagoon (IR) and Tequesta (TQ). The panels on the left display a simulated trend in the population size over 10 years and the panels on the right display a simulated trend in the population size over 20 years. The panels on the top display a simulated negative trend, while the panels on the bottom display a simulated positive trend. Dashed vertical gray lines are reference lines for a halving (negative trend) or a doubling (positive trend) of the population. Horizonal dashed gray reference lines denote power = 0.8, which is the desired power for the FIM inshore surveys.

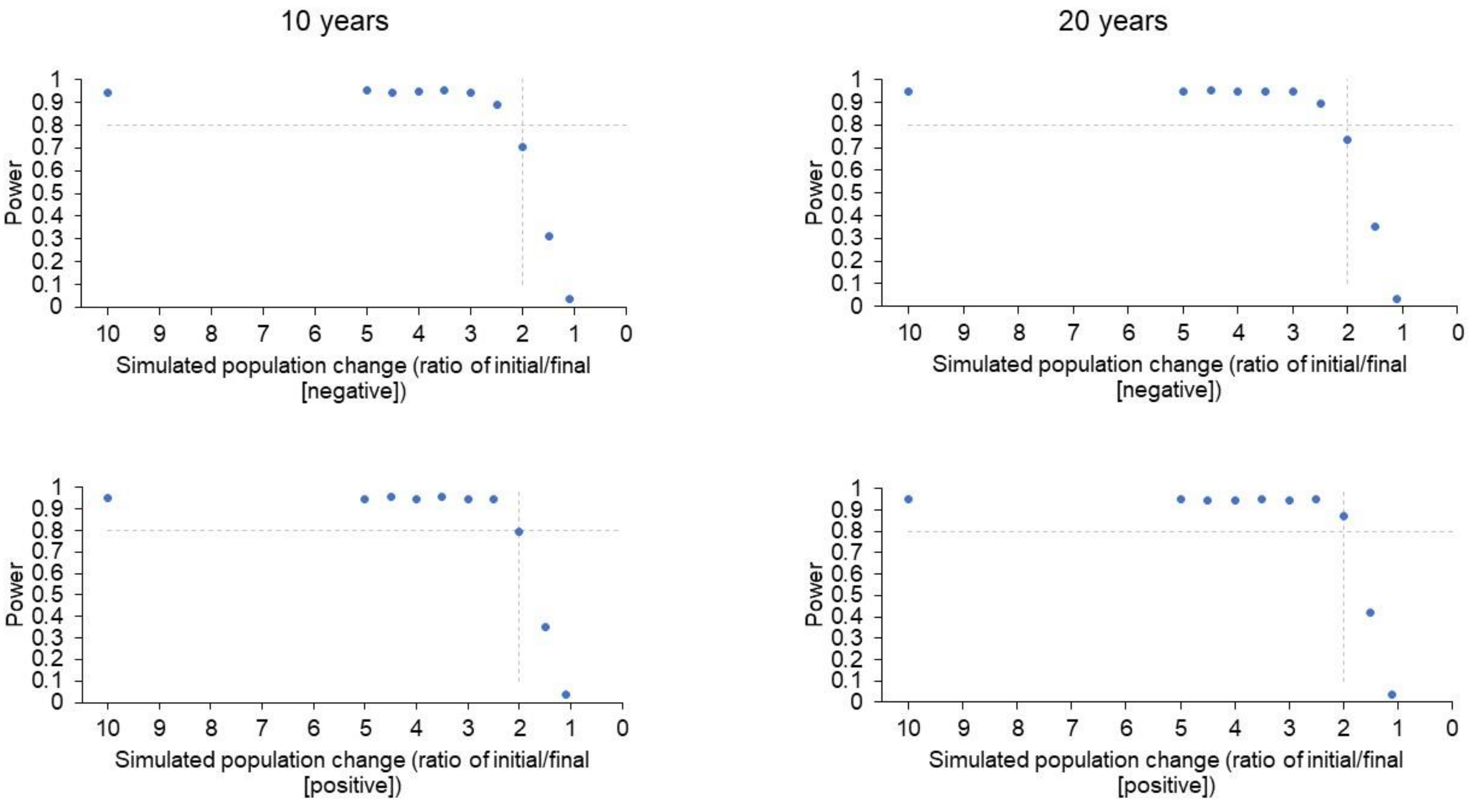

Figure A2. Power curves for 183-m seine sampling simulations for Mutton Snapper in Indian River Lagoon and Tequesta combined. The panels on the left display a simulated trend in the population size over 10 years and the panels on the right display a simulated trend in the population size over 20 years. The panels on the top display a simulated negative trend, while the panels on the bottom display a simulated positive trend. Dashed vertical gray lines are reference lines for a halving (negative trend) or a doubling (positive trend) of the population. Horizonal dashed gray reference lines denote power = 0.8, which is the desired power for the FIM inshore surveys.