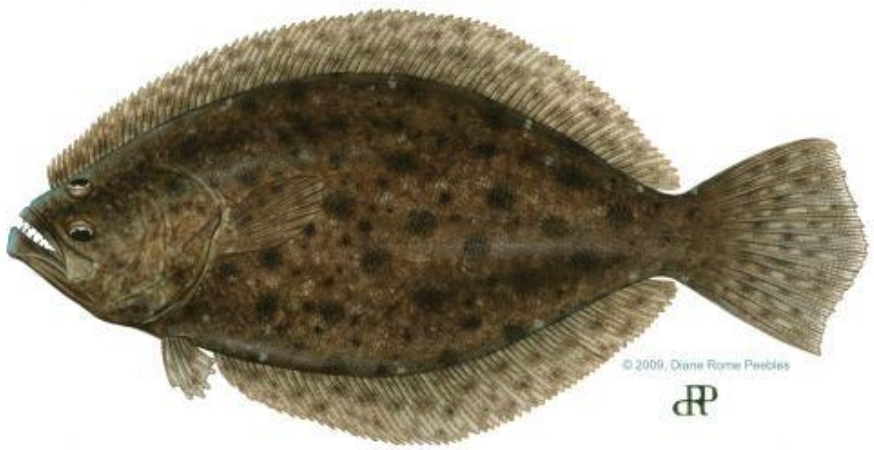
An Assessment of Southern Flounder in Alabama Coastal Waters



Sean P. Powers[1], Mark Albins[1], and John Mareska[2]

[1]Department of Marine Sciences, University of South Alabama and the Dauphin Island Sea Lab

[2]Alabama Department of Conservation and Natural Resources, Marine Resources Division

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Abstract

Southern Flounder (*Paralichthys lethostigma*) is a popular recreational and commercial finfish throughout the Gulf of Mexico. Recent landings by both commercial and recreational fishers indicate lower abundance of Southern Flounder in Alabama coastal waters – an observation also common in anecdotal reports from fishermen. To evaluate these patterns and assess the current status of the stock, we synthesized fisheries-dependent and independent data and applied those data in an age-structured modeling environment. Fisheries dependent sources of information included commercial and recreational landings, age data from commercial and recreational port sampling, and recreational effort data. Fisheries-independent data from a 17 year gillnet survey was also included. From these data sources two indices of abundances (fisheries-independent and recreational CPUE), two catch-at-age matrixes (commercial and recreational) and growth parameters were calculated and entered into the National Marine Fisheries Service's (NMFS) ASAP model (version 3.0 April 2018 release) for the period from 2001-2017, which were the maximum number of years that met the minimum data requirements of the model. The ASAP model is a statistical catch-at-age model that allows internal estimation of a Beverton-Holt stock-recruitment relationship. The assessment model indicates a stock that is experiencing a decline in overall population abundance most likely due to low recruitment. Currently (2017), the stock biomass is above B_{msy} (the stock biomass at maximum sustainable yield) indicating that the stock is not overfished. However, $F_{current}$ (the current Fishing mortality rate) is above the $F_{SPR30\%}$ (0.66 vs 0.50) indicating that the stock is currently experiencing overfishing (the rate of exploitation is too high and will lead to an overfished condition in the future). Although the stock has experienced similar lows in landings in the past (late 1980's), the results of this analysis indicate that management intervention is necessary to rebuild a sustainable stock.

1. Life history

Southern Flounder *Paralichthys lethostigma* is a common species encountered in the norther Gulf of Mexico from Alabama to Texas. Along with Gulf Flounder *Paralichthys albigutta*, they are the common flounder species captured by anglers in Alabama. Small southern flounder grow rapidly and may reach 12 inches in length by the end of their first year. Male Southern Flounder seldom exceed 12 inches, but females grow larger than males and often reach a length of 25 inches. Longevity differs between the sexes of Southern Flounder with males living to 3 years and females up to nine years. Adult Southern Flounder leave the bays during the fall for spawning in the Gulf of Mexico. Lengths where 50Z% of the population are sexually mature is 275 mm for males and females mature at 320 mm. The eggs are buoyant and fertilization is external. After hatching, the larval fish/early juveniles enter the bays during late winter and early spring. At this time, they are about one-half inch in length and seek shallow, structured areas (seagrasses, marshes) near the Gulf passes. As growth continues, some will move farther into bays. Some will enter coastal rivers and bayous. Juvenile flounder feed mainly on crustaceans, but as they grow fish become more important in their diet.

Gulf Flounders are distinguished by three large dark eye-like spots, arranged in a triangle with a pair of spots about midway on the length of the fish and a third closer to the tail. Southern Flounders may also have large spots but they are much more diffuse and gradually disappear as the fish grows older. Southern Flounders are larger and live longer than Gulf flounders. Female Gulf Flounders reach only about 18 inches and males reach only 10 to 14" in length.

The ranges of both species overlap. Southern Flounder and Gulf Flounder occur from North Carolina into Mexico, with the exception that Southern Flounder do not occur in southern Florida. Within this broad geographic range, flounders are found in a wide range of salinity and water temperature, from shallow, low-salinity estuaries to nearshore and shallow offshore waters to depths of 200 feet. Southern Flounder may enter fresh water and have been found in rivers. As late stage juveniles and adults, they prefer soft sediment bottoms and are found throughout the estuaries and in the mouths of bays, bayous, and channels, often around rock jetties, piers, and pilings. Female Southern Flounder reportedly remain in brackish waters most of the year, only moving offshore to spawn in fall and winter. Most adult males remain offshore year-round. Gulf Flounder-seem to prefer sandy bottoms, and typically stay further offshore as adults.

2. Management history

Until 2000 regulations for the flounder fishery solely addressed the type of gear used and seasons for the commercial sector. For recreational fisherman flounder are regulated with a 12-inch total length (TL) size limit (Regulation 2000-MR-16, effective Jan. 1, 2001) and a bag limit of 10 (Regulation 2008-MR-13, effective Sept. 23, 2008). Commercial fishermen are currently only regulated with the 12-inch TL size limit. Recreational fishing pressure varies throughout the

year and commercial fishing pressure tends to be the highest during the fall spawning migration from estuaries to the Gulf of Mexico.

3. Model Inputs

We use a statistical catch-at-age model designed by NMFS to assess Southern Flounder in Alabama coastal waters. ASAP is used to evaluate the current status of Southern Flounder in Alabama coastal waters from 2001-2017. The ASAP model is a statistical catch-at-age model that allows internal estimation of a Beverton-Holt stock recruitment relationship. The model environment included both fisheries-dependent and independent data and applied those data in an age-structured modeling environment. Fisheries-dependent sources of information included commercial and recreational landings, age data from commercial and recreational port sampling, recreational effort data, and fisheries-independent survey data. From these data sources two indices of abundances (fisheries-independent and recreational CPUE), two catch-at-age matrixes (commercial and recreational) and growth parameters were calculated and entered into the ASAP model for the period from 2001-2017, which was the maximum number of years that met the minimum data requirements of the model.

3.1 Landings

In Alabama, the vast majority of landed flounder are Southern Flounder. Commercial landings included both Southern and Gulf Flounder combined. Recreational landings were separated by species. Commercial landings data were obtained from the Alabama Department of Conservation and Natural Resources/Marine Resources Division (ADCNR/MRD) for the years from 2001-2017. Landings were provided by gear type (Figure 1). Commercial landings were summed across gear type and entered as one data stream (Figure 2) with one associated selectivity pattern. Although some landings were recorded as Gulf flounder, the majority of sampled flounder were of sizes that exceeded the maximum size of Gulf Flounder. Consequently, we assumed that 100% of the commercial landings were Southern Flounder. Recreational landings (A+B1) for Southern Flounder and Gulf Flounder were downloaded from the NMFS Marine Recreational Information Program (MRIP) website on August 28, 2018 (Figure 3). Live discards were not included in the landings data nor were discards specifically modeled in the assessment. Discards were relatively low in the data set and likely a function of the size limit and gear selectivity. Recreational data for Southern Flounder were entered as one data set into the ASAP model.

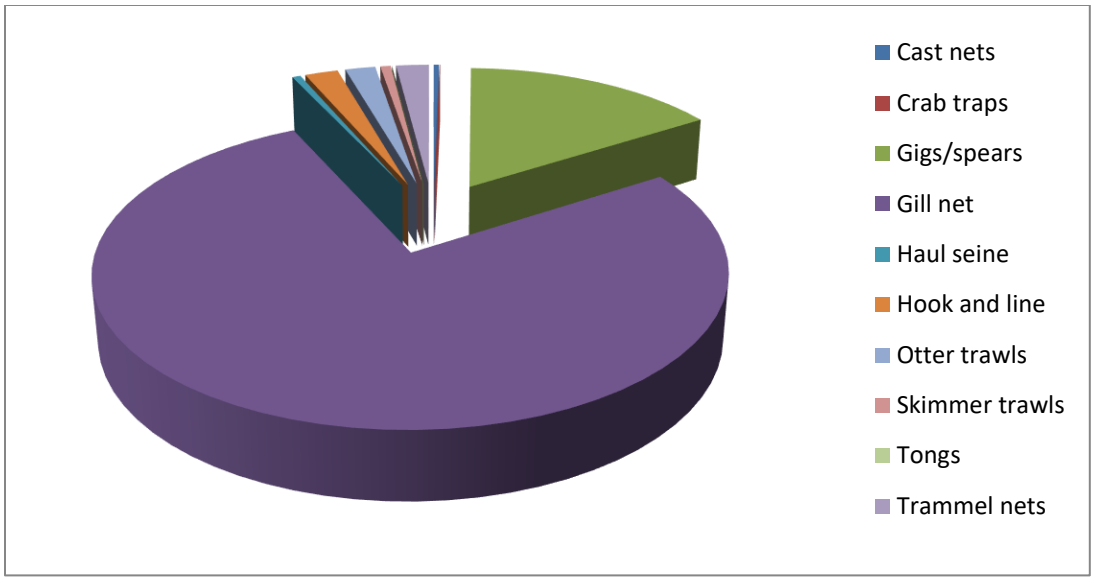


Figure 1. Commercial landings by gear type based on total landings from 2001-2017.

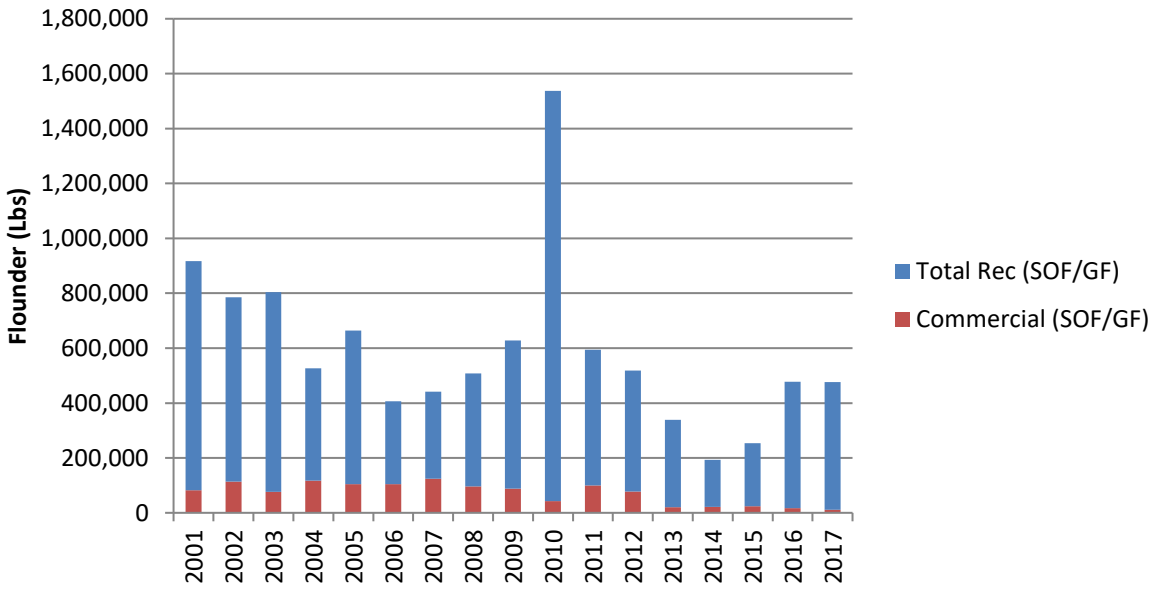


Figure 2. Commercial and recreational landings of flounder (Southern and Gulf combined) in Alabama waters from 2001 to 2017.

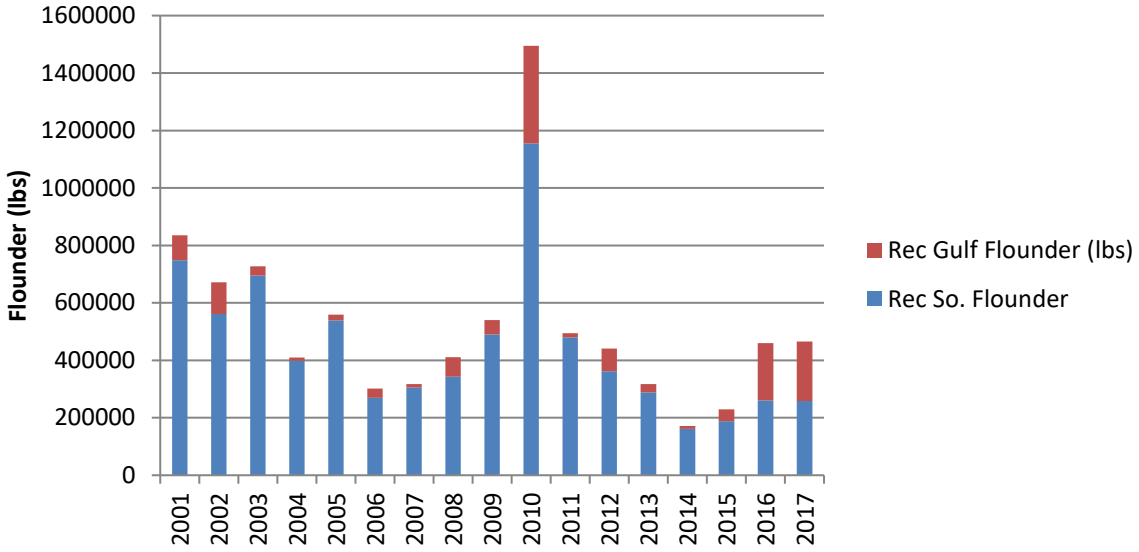


Figure 3. Recreational landings of flounder (Southern and Gulf) in Alabama waters from 2001 to 2017.

3.2 Age Composition Data

Samples from both the commercial and recreational fisheries were collected by ADCNR/MRD and aged according to the Gulf States Marine Fisheries Commission's protocols. Ages ranged from 0-5 years. The majority of Southern Flounder in both the commercial and recreational catch were 1 and 2 years fish (Figure 4). Sample size varied by year with a noticeable trend of last samples in the later year of the time series. Age and length data were used to generate a state specific von Bertalanffy growth curve (Figure 5) as well as average weight at age. Data were entered into the ASAP model to create a catch at age matrix.

3.3 Abundance indices

Two abundance indices could be derived for the stock assessment. The first was a fisheries-dependent index that was derived using MRIP recreational landings (in numbers of fish) divided by the number of trips targeting Southern Flounder. This latter estimate was derived using the number of reported angler trips that harvested a Southern Flounder or trips where the angler interviewed stated that Southern Flounder were the primary or secondary target of the trip. The proportional standard errors of targeted trips and landings were combined (multiplied) and used to scale the coefficient of variation that was entered into the ASAP model. The second index was derived from a fishery-independent gillnet survey conducted by ADCNR/MRD. A negative binomial General Linear Model (GLM) was fit to the ADCNR/MRD gill net catch data for Southern Flounder. The first model included year, ADCNR/MRD area designation, temp, salinity, dissolved oxygen, and depth as well as an interaction between year and ADCNR/MRD

area. The best fitting model included all predictors except for dissolved oxygen. The final model excluded data from Perdido Bay , which had a higher frequencies of zero catch, and only included data from Mobile Bay and Mississippi Sound.

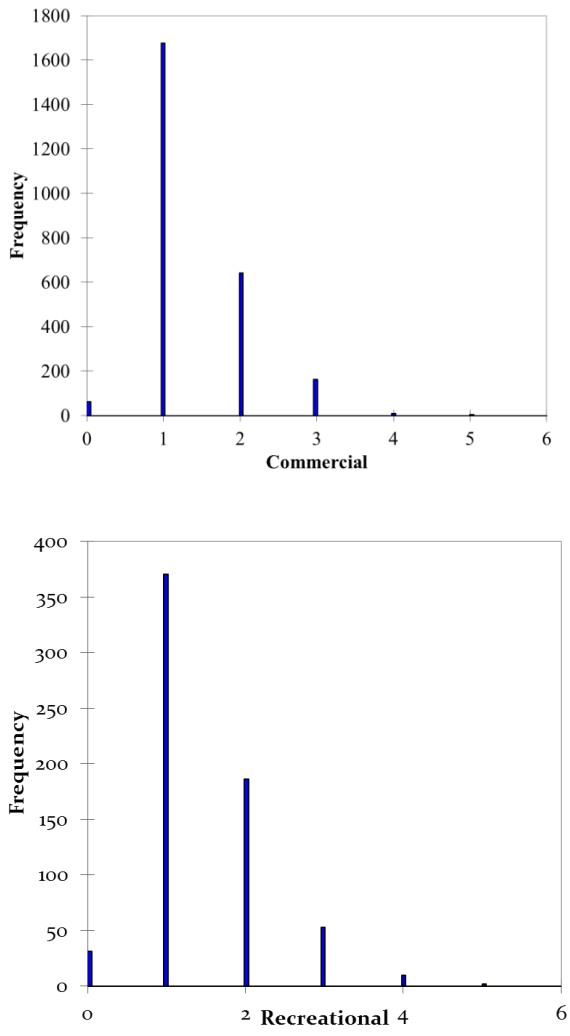


Figure 4. Age composition of Southern Flounder sampled from the commercial (upper panel) and recreational fisheries (lower panel) from 2001 to 2017.

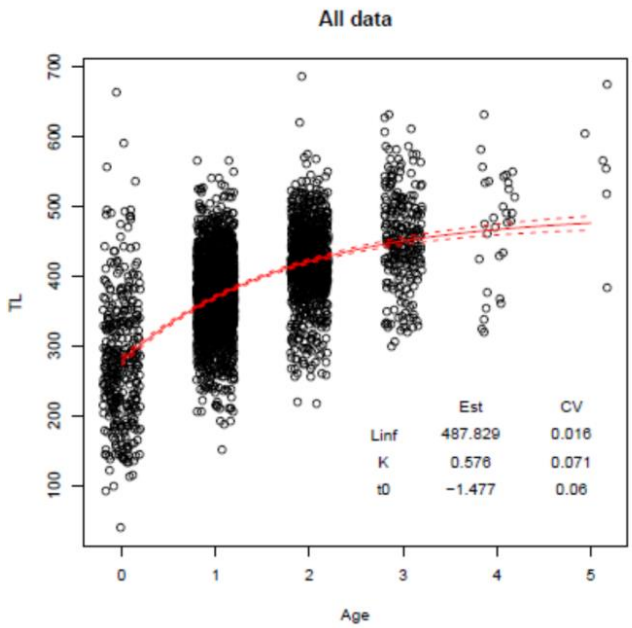


Figure 5. Von Bertalanffy growth curve for Southern Flounder derived samples collected from 2001-2017.

4. Model fit

4.1 Landings

With a few exceptions, the model reproduced the commercial and recreational landings time series well. The model fit to the commercial landings was high (Figure 6). This is not surprising given the relative small CV assumed around the commercial landings (0.1). For the recreational landings series, a consistent underestimate of recreational landings was seen in the final model run. For most years, this disagreement was minor with the exception of 2010. MRIP reported a high spike in landings for the year. The model did not include this spike. Given the abbreviated fishing season in 2010 due to the *Deepwater Horizon* oil spill the lower landings predicted by the model seems reasonable.

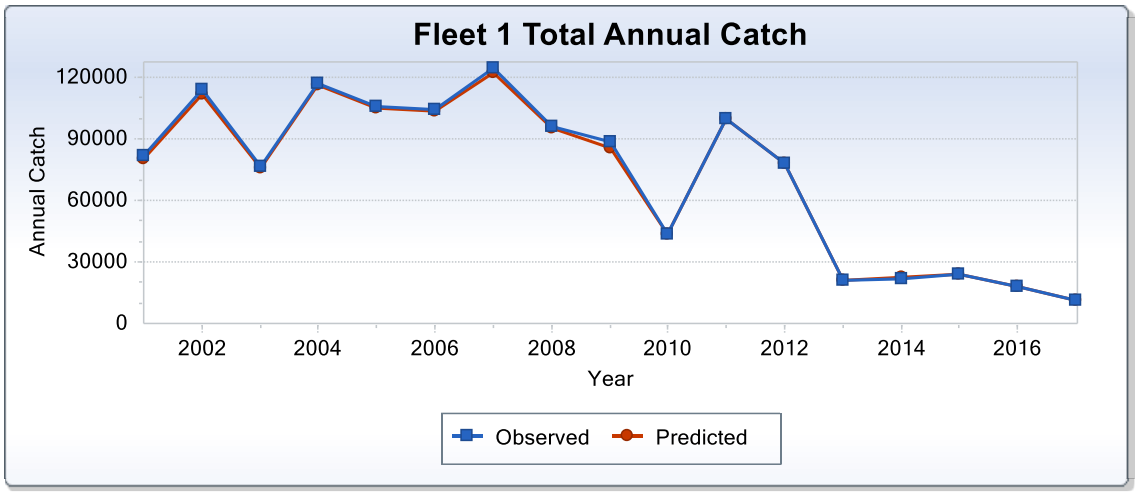


Figure 6. Observed Alabama commercial (Fleet 1) landings versus model predicted commercial landings from 2001 to 2017.

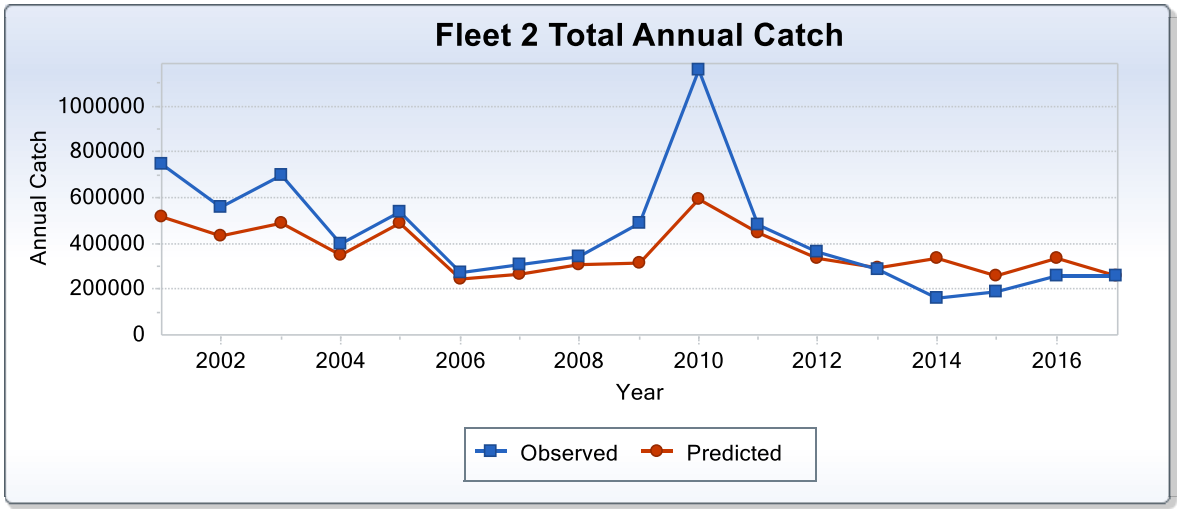
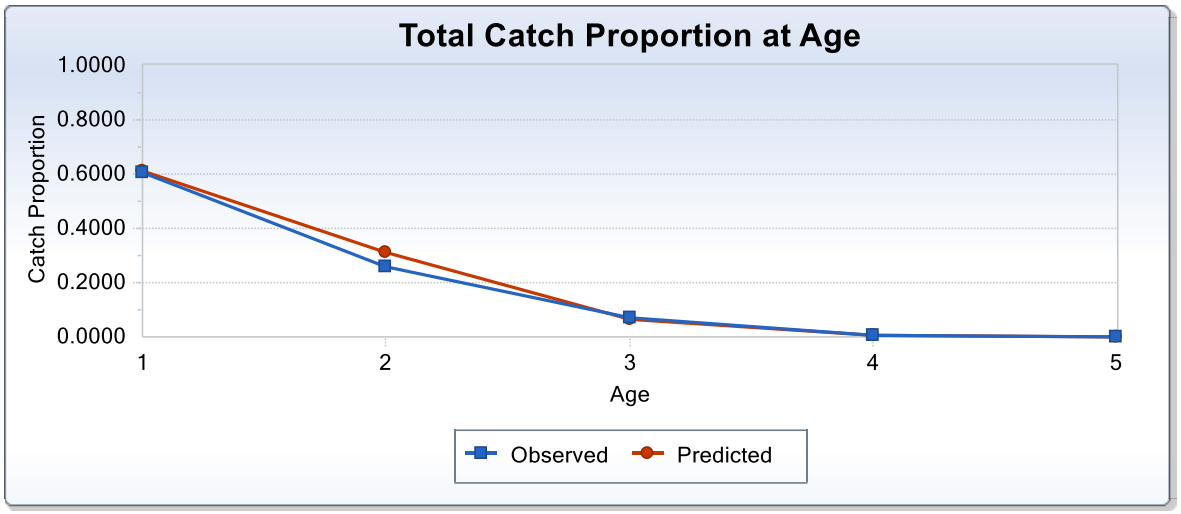


Figure 7. Observed Alabama MRIP recreational (Fleet 2) landings of Southern Flounder versus model predicted recreational landings from 2001 to 2017.

4.2 Age composition

Age composition of the landings was reproduced by the model with a high degree of fit between the sampled flounder and those predicted by the model. The majority of flounder landed were age 1 and 2 fish in both the sampled fish as well as the model (Figure 8).



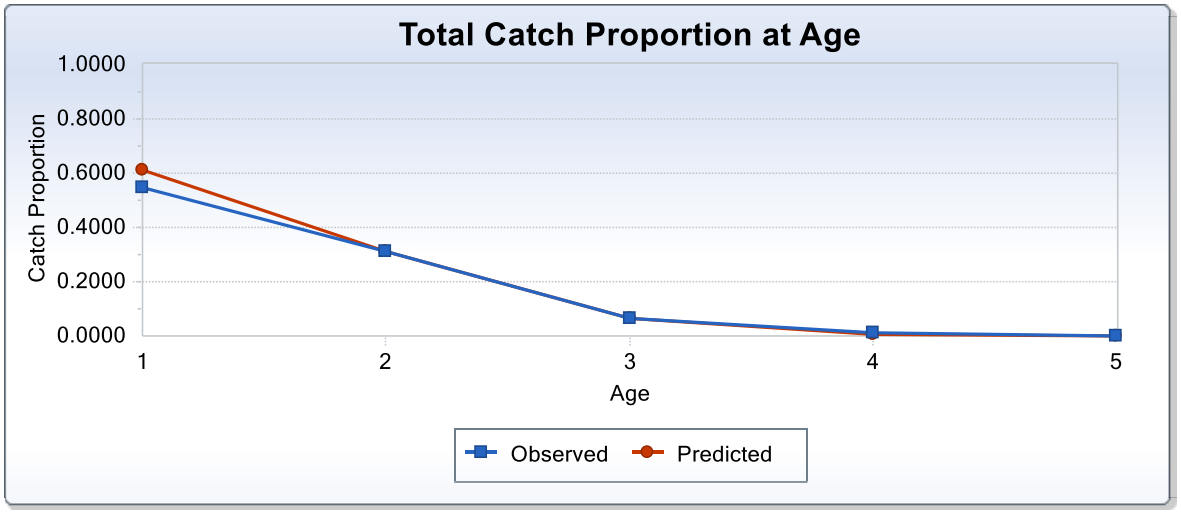


Figure 8. Observed age composition of flounder catch versus model predicted commercial (upper panel) and recreational (lower panel) landings of Southern Flounder from 2001 to 2017.

4.3 Fit to indices

Fits to abundance indices for both series were relatively poor. The recreational CPUE index (fisheries-dependent) predicted by the model reflected the overall declining trend in the observed index but tended to smooth the variability in the observed index (Figure 9). The index derived from the ADCNR/MRD gillnet data provided a fisheries-independent index for the model. The model overestimated the index values through the time series. In spite of the overestimation, the predicted index does reflect the overall trend in the observed values (Figure 10).

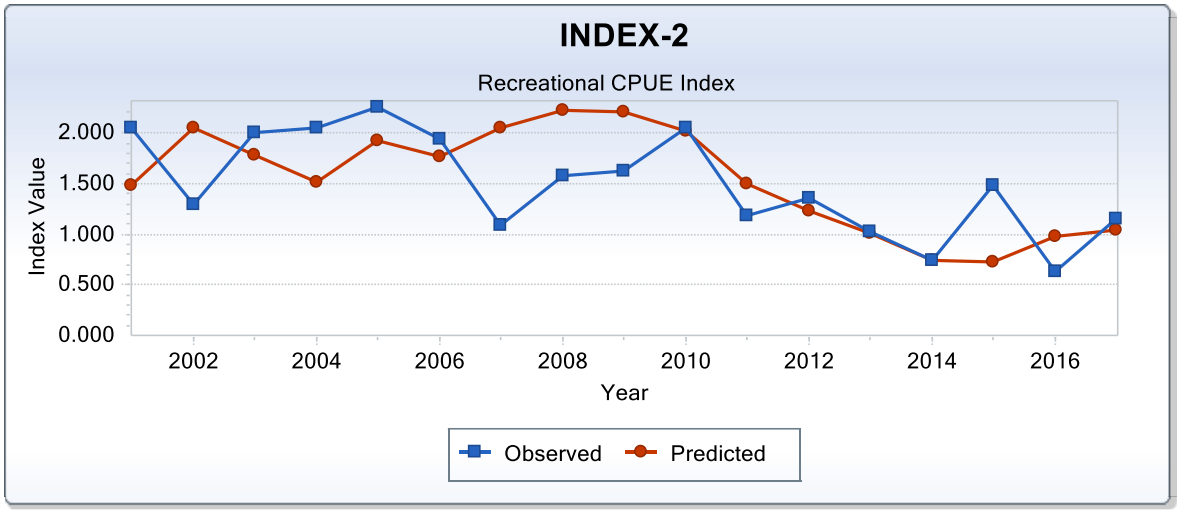


Figure 9. Observed (flounder/angler trip) versus the model predicted index for the recreational CPUE of Southern Flounder caught in Alabama from 2001 to 2017.

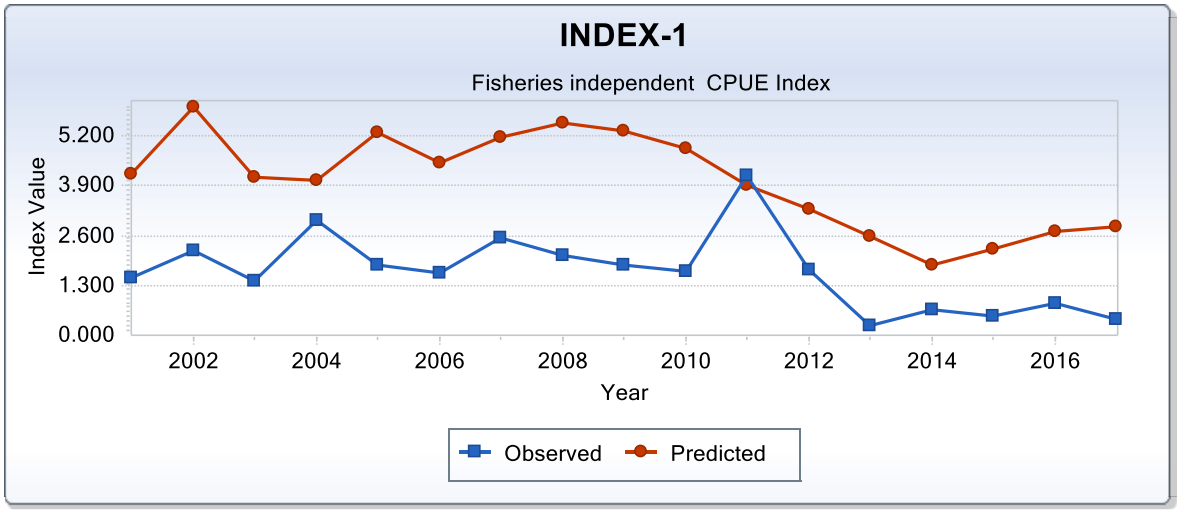


Figure 10. Observed versus model predicted index for CPUE of Southern Flounder collected in the ADCNR/MRD fisheries-independent gillnet survey from 2002 to 2017.

5. Reference points and model results

The assessment model indicates a stock that is experiencing a decline in overall population abundance due to low recruitment. Currently (2017), the stock biomass is above Bmsy (the stock biomass at maximum sustainable yield) indicating that the stock is not overfished. Caution should be used in interpreting any reference points based on MSY because the model does not estimate a stock recruitment relationship (steepness of the curve = 1.0). The flat relationship (Figure 11) predicts average recruitment (mean size of recruit = 6 inches) for most years and does not suggest a feedback loop of declining spawner abundance exists that would lead to declining recruitment. This lack of a clear spawner-recruit relationship may be a function of the limited extent (18 years) of our data series, i.e. a relationship may actually exist but we need more years of data or higher contrast in the data to detect it. Alternatively, a stock-recruit relationship may not exist on the spatial scale examined (Alabama) but may exist on a larger scale (e.g., Florida through Mississippi).

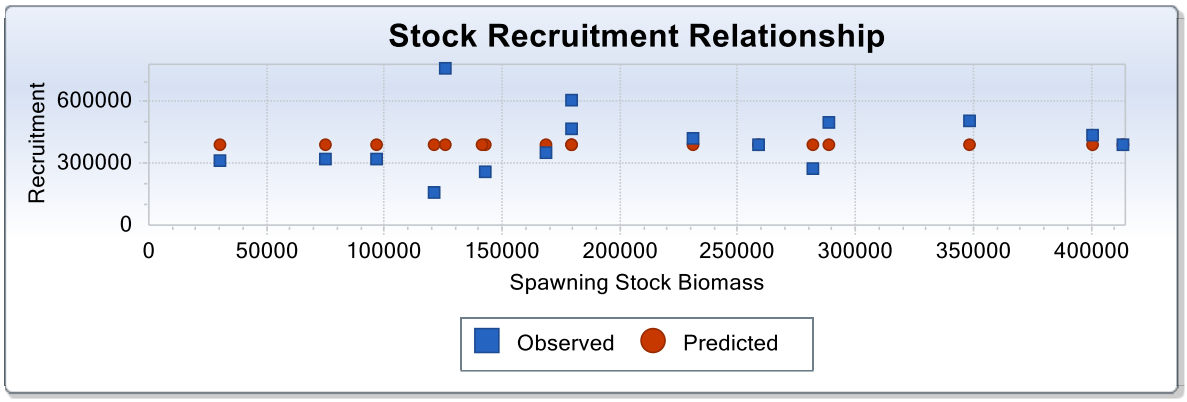


Figure 11. Predicted versus observed Southern Flounder recruitment.

Examination of the residuals (error) in the stock recruitment relationship over time indicates below average recruitment in the most recent years of the time series (Figure 12). The lower recruitment, without a change in management strategy, has resulted in recent years of high exploitation (Figure 13). $F_{current}$ (the current fishing mortality rate) is above the management target of $F_{SPR30\%}$ (0.66 vs 0.50) indicating that the stock is currently experiencing overfishing or, alternatively, the rate of exploitation is too high and will lead to an overfished condition in the future (see reference point in Table 1).

Table 1. Reference points and parameter values for Southern Flounder in Alabama coastal waters.

Parameter	Value
M	0.56
$F_{0.1}$	2.12
F_{MAX}	4.10
$F_{SPR30\%}$	0.50
F_{MSY}	1.63
$F_{Current}$	0.66
MSY	354,758 lbs
SSB MSY	52,037 lbs

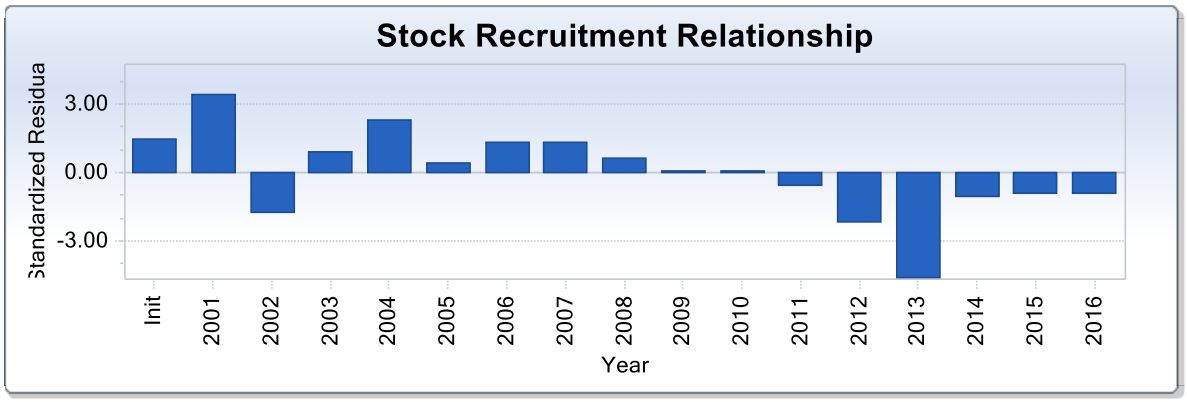


Figure 12. Standardized residuals of the stock recruitment relationship in Southern Flounder from 2001-2017. Note the low recruitment in the latter years of the time series.

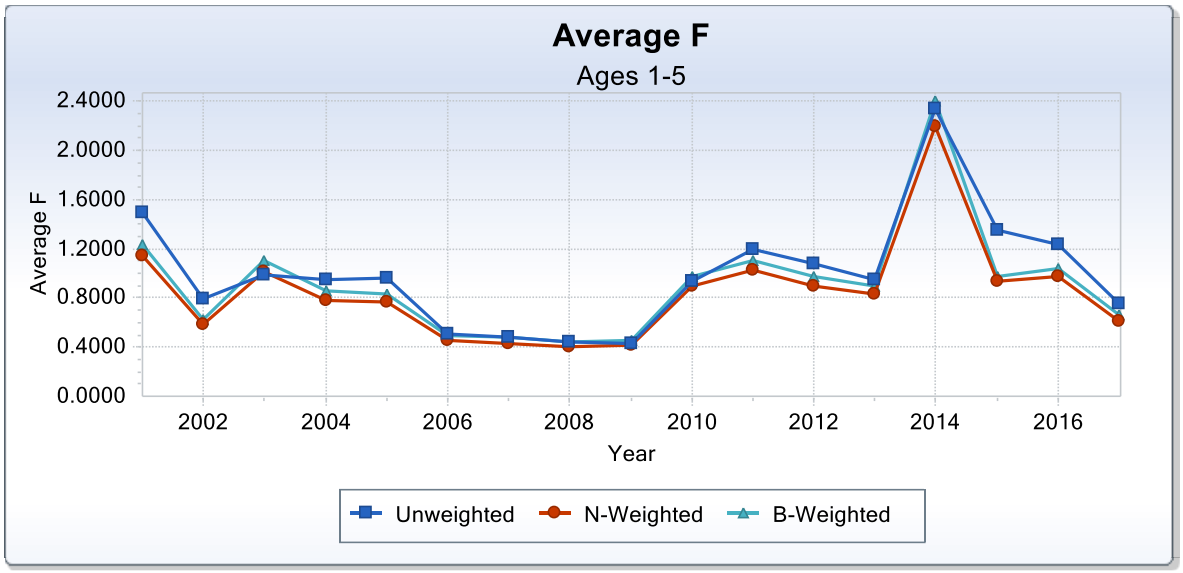


Figure 13. Average F (fishing mortality) of Southern Flounder in Alabama over time.

6. Management Recommendations

The results of this analysis indicate that management intervention is necessary to rebuild a sustainable stock. It is also important to note that the pattern of low landings of Southern Flounder is not restricted solely to Alabama. Gulf-wide landings (Figure 14) also show decreases beyond those that would be projected from the drop in Alabama landings alone suggesting region-wide decreases in recruitment. Management actions that are designed to increase recruitment should be adopted. Traditional fisheries conservation approaches would include increasing spawning stock biomass and hence the supply of flounder larvae to the population. These additional larvae would be expected to increase recruitment into the fishery. Increases in spawner stock could be realized through decreases in catch levels. Decreases in catch levels could be achieved by adopting a total allowable catch and closing the fishery once that catch is achieved, decreasing the bag limit for flounder, or increasing the minimum size of flounder that can be legally retained among other approaches. Of these methods increasing the minimum size of flounder may be the most effective (simplest to adopt and enforce). Based on 2016-2017 MRIP data, 35% of the recreational harvest was comprised of fish less than 14 inches (Figure 15). Assuming a low catch and release mortality (as is the case for Summer Flounder) this reduction should proportionally reduce fishing mortality. Increasing the minimum size by 1 or 2 inches also has the added benefit that a greater proportion of the female Southern Flounder population would be allowed to become sexually mature before harvest. This would increase the probability of greater larval production. For female Southern Flounder only 30% are sexually mature at 12 inches (the current size limit). This maturity values would increase to 60% at a 13-inch size limit and 80% at a 14-inch size limit (see Figure 16).

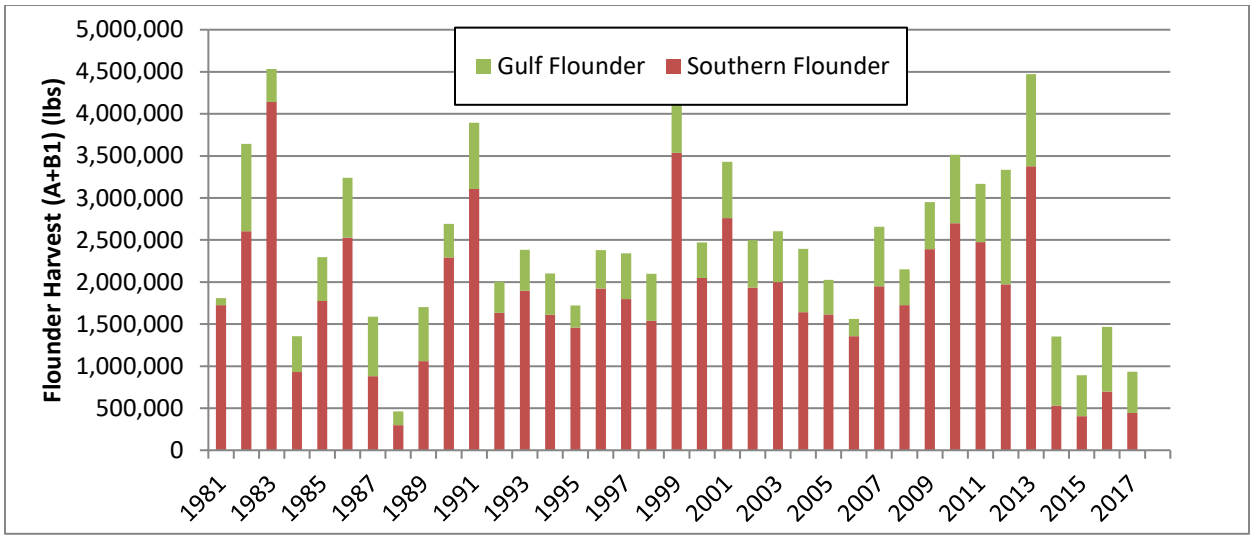


Figure 14. Recreational landings of Southern and Gulf Flounder in portions of U.S. Gulf of Mexico (FL, AL, MS, and LA). Note: LA landings are not included in NMFS data from 2014 – 2017.

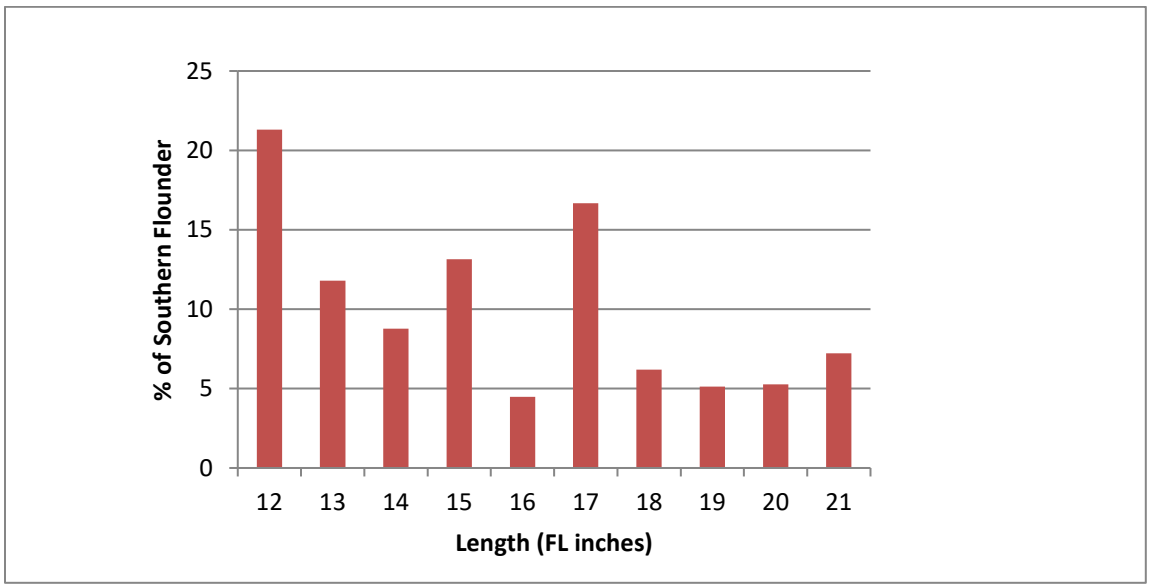


Figure 15. Length composition of Southern Flounder landed by recreational anglers from 2016-2017.

Simulations using the software Fishery Analysis and Management Simulations (FAMS, ver 1.64.4) were performed to evaluate the effect of changing size limits on spawning potential Ratio (SPR) of the population, mean size of the fish harvested, and the number of fish harvested. The simulations suggest that increasing minimum size increases the chance of maintain the population at a SPR above 30%, a common management benchmark for sustainable populations. At current level of fishing mortality (0.66), the current minimum size (12 inches) would not

maintain the population at a SPR of 30%. The simulations illustrate that some reduction in F will be necessary regardless of change to the size limit of 1- 2 inches; however, the reduction in F necessary decreases with the increasing size limits (Figure 17). The number of harvested Southern Flounder is predicted to decrease with increasing minimum size limits (Figure 18) and this decrease would decrease the F. Assuming an average annual recruitment of 400,000 Southern Flounder (the value predicted by the spawner-recruit relationship over the time series), increasing the minimum size to 13 inches would be expected to decrease the number of Southern Flounder harvested by 20% compared to the number harvested with a 12 inch minimum. An increase to 14 inches would decrease harvest in numbers by 38%. Finally, the average length of Southern Flounder would also be expected to increase with increases in the minimum size limit (Figure 19).

An additional Management Strategy Evaluation (MSE) analysis was carried out using the Data Limited Methods Toolkit (DLMtool, ver 5.2.3) in the R software environment (ver 3.5.0) to evaluate the effects of changing size limits on the F:FMSY and SB:SBMSY ratios as well as on the projected long term yield (LTY) of the fishery. This analysis used basic life history parameters and associated uncertainties to simulate 200 stochastic populations over a 50-year time horizon for each management scenario. Scenarios examined included the reference scenarios of no fishing and fishing at F = FMSY, as well as fishing at the current effort with no changes in management (size limit = 12 inches) and four different increased size limit scenarios corresponding to increasing the size limit to 13, 14, 15 and 16 inches. Increasing the size limit caused slight increases in LTY (measured as the probability that yield in the final 10 years exceeded 50% of the reference yield) for the 13, 14, and 15-inch limit scenarios, with a small decline in LTY between 15 and 16-inch limits (Figure 20). Increasing the size limit had a more pronounced effect on both F/FMSY and SB/SBMSY (Figure 20). The probability of not overfishing the stock (measured as the probability that F < FMSY) was 0.65 under the current management scenario and increased to 0.70, 0.79, 0.87, and 0.93 for the respective size limit scenarios (13, 14, 15, and 16-inch limits). The probability of maintaining a healthy spawning stock biomass (measured as the probability that SB > SBMSY) was 0.51 for the current management scenario and increased to 0.55, 0.63, 0.70, and 0.75 for the respective size limit scenarios (13, 14, 15, and 16-inch limits).

Increases in recruitment may also be possible through the introduction of hatchery raised flounder larvae. Depending on the size of release, this strategy could combat low larval supply and high post-settlement mortality. Given mean recruitment levels of 400,000 Southern Flounder, hatchery production of juvenile flounder could have a measurable effect on recruitment. The contribution of hatchery production to recruitment levels would depend on the number released and post-release mortality of those flounder, which would be expected to vary as a function of the length at the time of release.

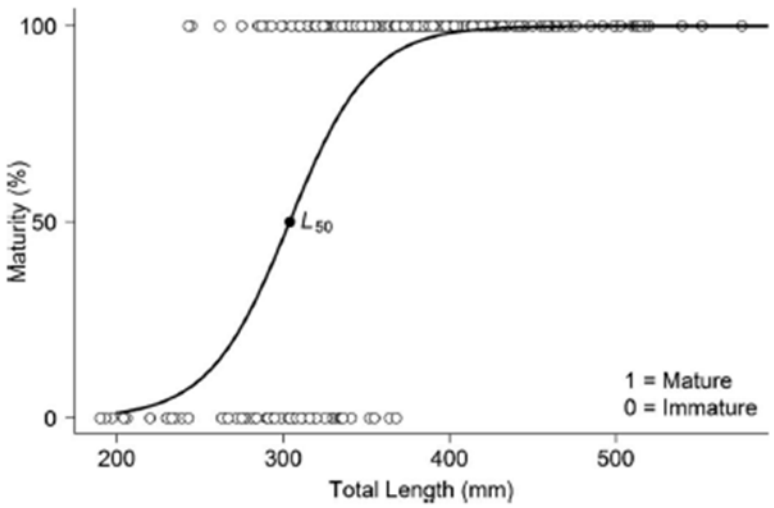


FIGURE 6. Logistic model describing length at maturity for female Southern Flounder (n = 332) collected in Mississippi waters of the Gulf of Mexico, where L_{50} (black circle) represents the mean parameter estimate for TL at 50% maturity. Individuals were assigned a binomial maturity code indicating immature (0) or mature (1) status.

Figure 16. Maturity of Southern Flounder females in Mississippi waters. Reproduced from Corey et al. 2017.

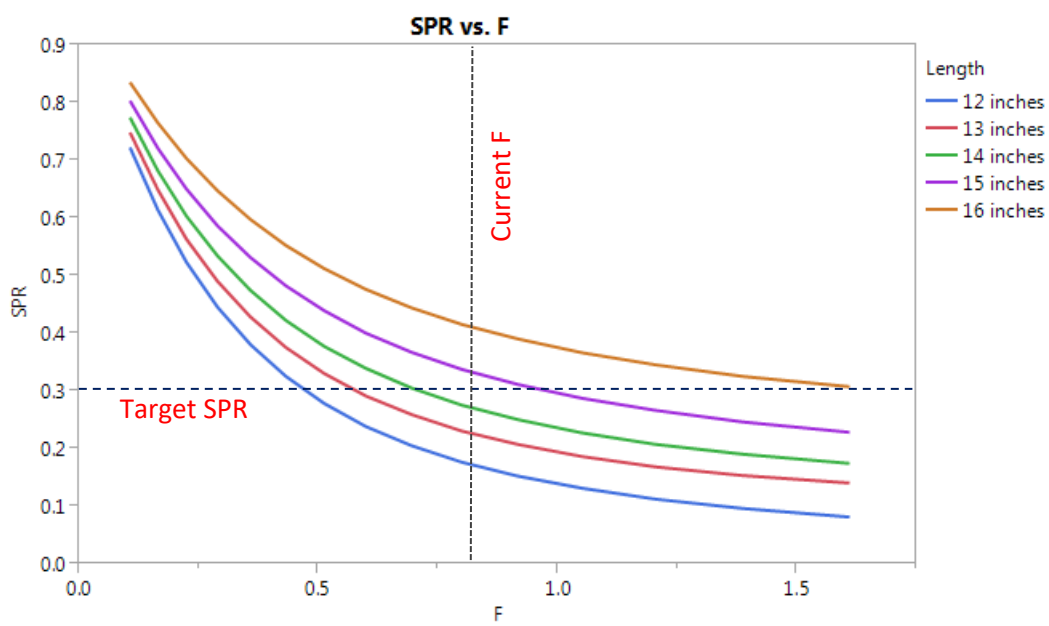


Figure 17. Results of simulations examining the response of spawning potential ratio to changes in the minimum size regulation of Southern Flounder.

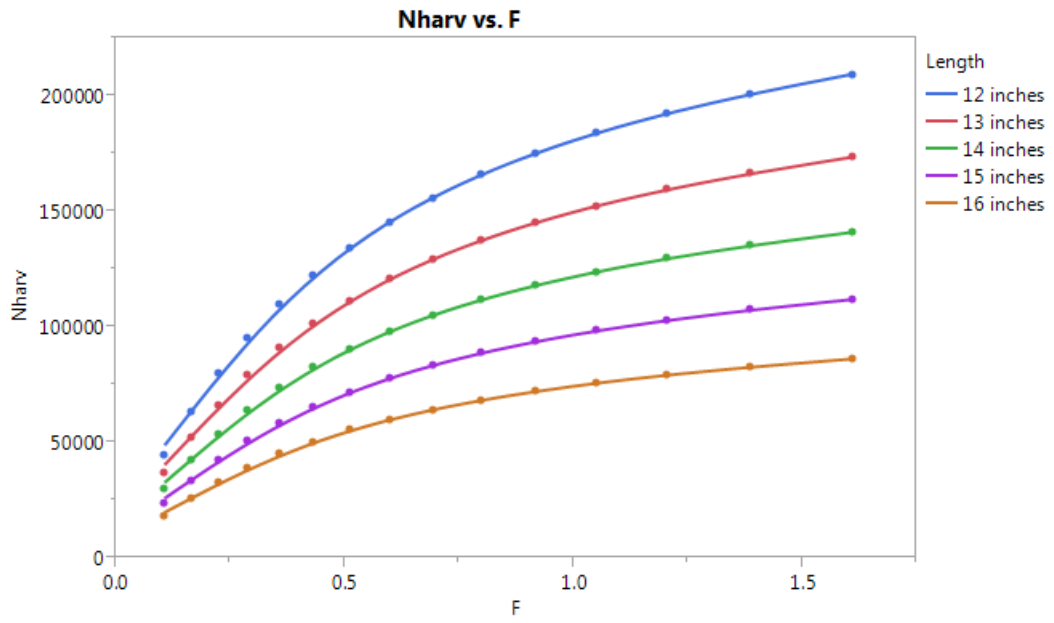


Figure 18. Results of simulations examining the response of the predicted number of Southern Flounder harvested with changes in the minimum size regulation of Southern Flounder.

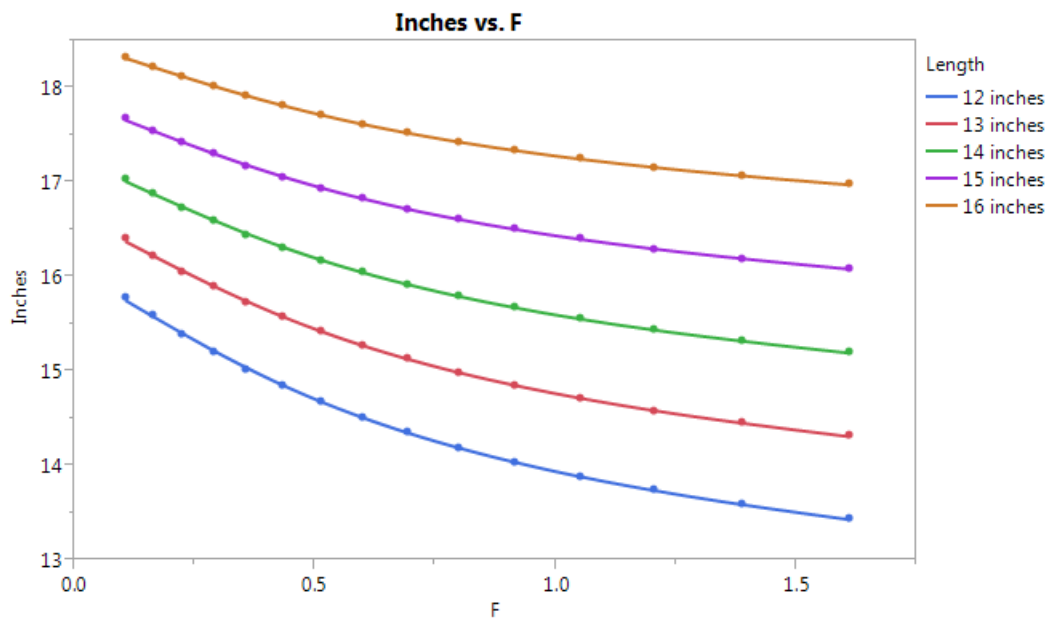


Figure 19. Results of simulations examining the response of the predicted average length of Southern Flounder with changes in the minimum size regulation.

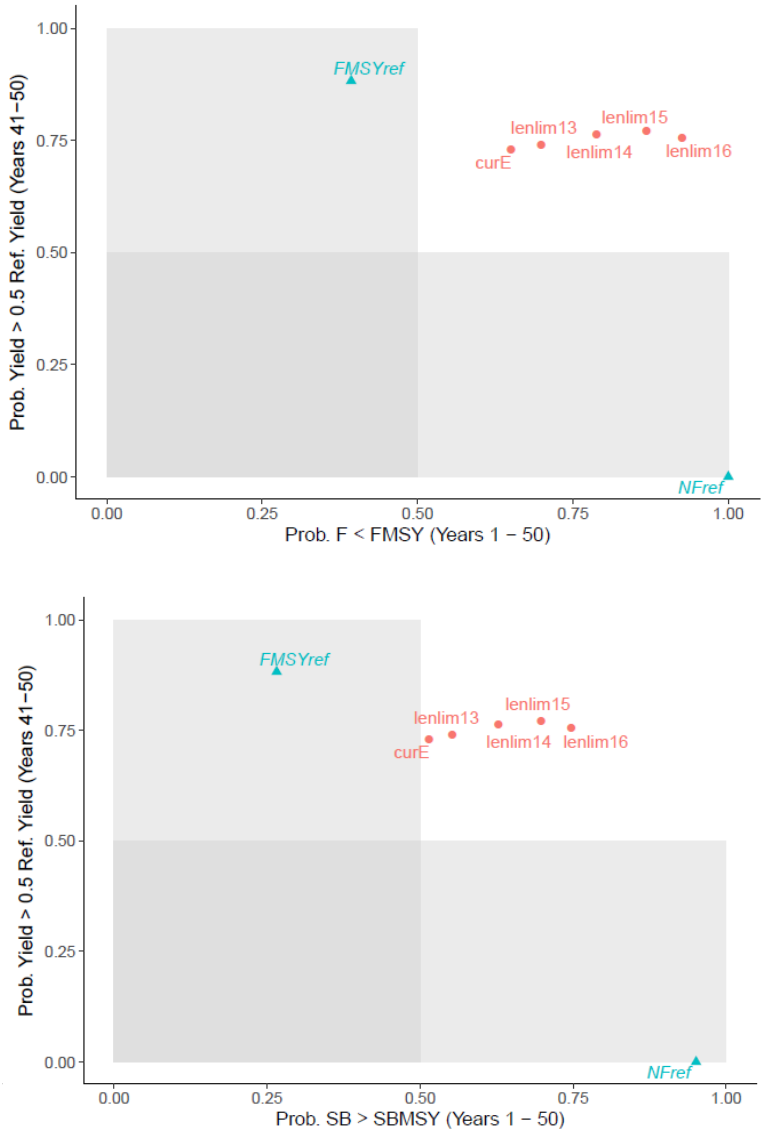


Figure 20. Results of Management Strategy Evaluation Analysis depicting the probabilities of simulated populations meeting three primary benchmark metrics for stock status. The y-axes of both plots represent the probability of long-term yield (in the final 10 years of the 50-year time horizon) exceeding 50% of the reference yield. The x-axis in the upper plot represents the probability of not overfishing (F < FMSY) and in the lower plot represents the probability of a healthy spawning stock biomass (SB > SBMSY). Reference points include setting a TAC based on F = FMSY (FMSYref) and no fishing (NFref). Other scenarios include current management (curE), and four different size-limit increase scenarios with size limits of 13 (lenlim13), 14 (lenlim14), 15 (lenlim15), and 16 inches (lenlim16).

References

Corey, M.M., R. T. Leaf, N. J. Brown-Peterson, M.S. Peterson, S.D. Clardy, D. A. Dippold. 2017. Growth and Spawning Dynamics of Southern Flounder in the North-Central Gulf of Mexico. Marine and Coastal Fisheries 9(1). https://doi.org/10.1080/19425120.2017.1290722