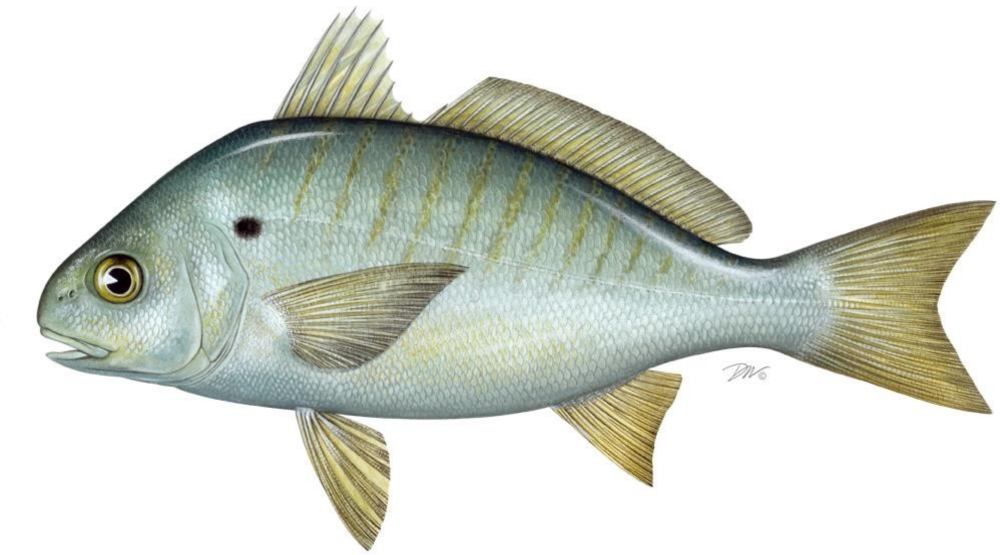
Atlantic States Marine Fisheries Commission

2020 Traffic Light Analysis of Spot (*Leiostomus xanthurus)*



Spot Technical Committee

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1 INTRODUCTION

Spot is managed under the Omnibus Amendment for Spot, Spotted Seatrout, and Spanish Mackerel (2011), Addendum II (2014), and Addendum III (2020). The Omnibus Amendment updates all three species plans with requirements of the Atlantic States Marines Fisheries Commission's (ASMFC) Interstate Fisheries Management Program (ISFMP) Charter. The benchmark stock assessment for spot in 2017 was not recommended for management use due to uncertainty in biomass estimates from conflicting signals among abundance indices and catch time series, as well as sensitivity of model results to assumptions and model inputs.

Previously, in the absence of a coastwide stock assessment, the South Atlantic Board (SAB) approved Addendum II to the Spot Fishery Management Plan (FMP) in 2014. The Addendum established the use of a Traffic Light Analysis (TLA), similar to that used for Atlantic croaker, to evaluate fisheries trends and develop state-specified management actions (e.g., bag limits, size restrictions, time and area closures, and gear restrictions) when harvest and abundance thresholds are exceeded for two consecutive years. The TLA is a statistically-robust way to incorporate multiple data sources (both fishery -independent and -dependent) into a single, easily understood metric for management advice. It is often used for data-poor species, or species which are not assessed on a frequent basis. The name comes from assigning a color (red, yellow, or green) to categorize relative levels of indicators on the condition of the fish population (abundance metric) or fishery (harvest metric). For example, as harvest or abundance increase relative to their long-term mean, the proportion of green in a given year will increase and as harvest or abundance decrease, the amount of red in that year becomes more predominant. The TLA improves the management approach as it illustrates long-term trends in the stock and includes specific management recommendations in response to declines in the stock or fishery. Under Addendum II, state-specific management action would be initiated when the proportion of red exceeds specified thresholds (30% or 60%), for both harvest and abundance, over two consecutive years.

Starting in the late 2000s, there were inconsistent signals in the data used to examine the resource. While strong declines in harvest and reports of poor fishing prompted concern, management action was not triggered through the TLA because similar declines were not observed in abundance indices. These conflicting signals suggested the abundance indices being used in the TLA may not adequately represent coastwide adult abundance and the TLA may not be sensitive enough to trigger management action if declines in the population and fishery occur. Additionally, management lacked specificity in what measures to implement if a trigger did occur and how the fishery should be evaluated following management action. In February 2020, the SAB approved Addendum III to the Spot FMP. Addendum III addressed these issues by modifying the TLA to better reflect stock characteristics and identify achievable management actions based on stock conditions.

Addendum III incorporated the use of a regional approach to better reflect localized fishery trends and changed the TLA to trigger management action if two of the three most recent years of characteristics exceed threshold levels. These changes to management allow the TLA to better detect population and fishery declines. Addendum III also defined management responses for the recreational and commercial fisheries and a method for evaluating the population's response to TLA-triggered management measures.

The following changes were incorporated into the TLA by Addendum III:

- Incorporation of indices from the Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP) and the North Carolina Division of Marine Fisheries (NCDMF) Pamlico Sound Survey (Program 195) into the adult composite characteristic index, in addition to the currently used indices from the Northeast Fisheries Science Center (NEFSC) Multispecies Bottom Trawl Survey and the South Atlantic component of the Southeast Area Monitoring and Assessment Program (SEAMAP).
- Use of revised adult abundance indices from the surveys mentioned above, in which age-length keys and length composition information are used to estimate the number of adult (age 1+) individuals caught by each survey.
- Use of regional metrics to characterize the fisheries north and south of the Virginia-North Carolina state border. The ChesMMAP and NEFSC surveys will be used to characterize abundance north of the border, and the NCDMF Program 195 and SEAMAP surveys will be used to characterize abundance south of the border.
- Change/establish the reference time period for all surveys to be 2002-2012.
- Change the triggering mechanism to the following: Management action will be triggered according to the current 30% and 60% red thresholds if both the abundance and harvest thresholds are exceeded in any two of the three terminal years.

Addendum III also established a Spot Technical Committee (TC) with the ability to alter the TLA as needed to best represent trends in spot harvest and abundance, including selection of surveys and methods to analyze and evaluate these data. Such changes may be made without an addendum, but Addendum III was necessary because of the change to the management-triggering mechanism. The TC will evaluate state implementation of management responses triggered through the TLA.

This report includes the harvest and abundance composite indices in Section 2 which are the TLAs that trigger management action. Individual TLAs for commercial and recreational harvest by region, which go into the harvest composite, as well as effort and discards of spot in the South Atlantic Shrimp Trawl Fishery, which are included as supplementary information to be reviewed by the TC and are not included in harvest composite indices, are described in Section 4. TLAs for each fishery-independent index that go into the abundance composite are described in Section 5. Supplemental information with NEAMAP incorporated into the TLAs is provided in Section 6.

2 TRAFFIC LIGHT ANALYSIS (COMPOSITE INDICES)

2.1 Harvest Composite Characteristic Index

- The harvest (recreational and commercial landings) composite characteristic TLA shows the general decline in landings since 2008 in both the Mid-Atlantic and South Atlantic (Figure 1 and Figure 2).
- The composite characteristic for the Mid-Atlantic has exceeded the 30% threshold for four of the last five years (Figure 1) with an average red proportion of 40.4%. The red proportion in 2019 was 34.7%.
- The composite characteristic for the South Atlantic has exceeded the 30% threshold for three of the last four years (Figure 2) with an average proportion of 35.6%. The red proportion in 2019 was 41.6%.
- The declining trend in spot fishery landings continues to occur coastwide.
- The TLA composite index triggered in 2019 at the 30% threshold for both regions.

Figure 1. Annual TLA color proportions for harvest composite (commercial and recreational landings) in the Mid-Atlantic coast (NJ-VA) for spot using a 2002-2012 reference period.

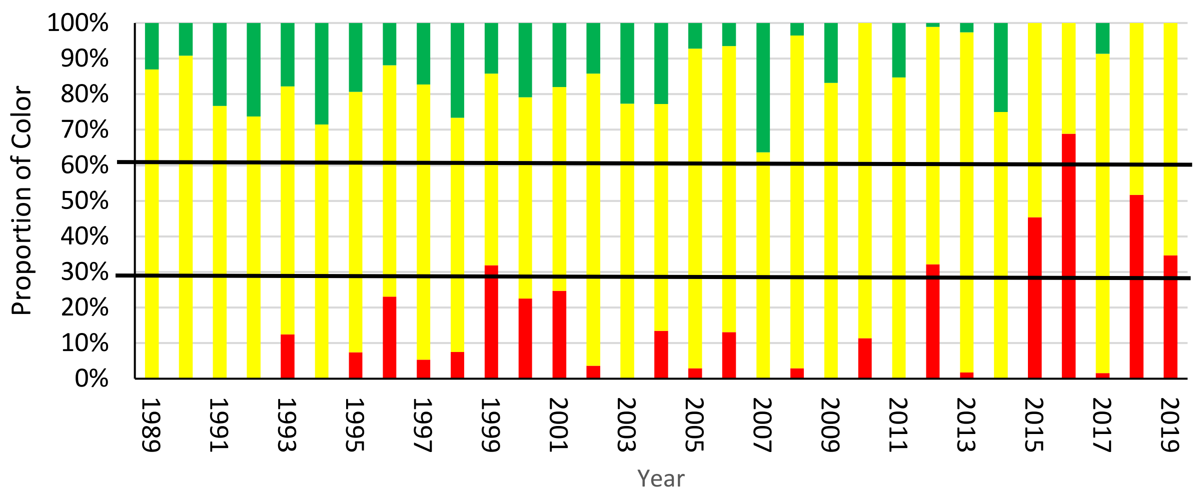
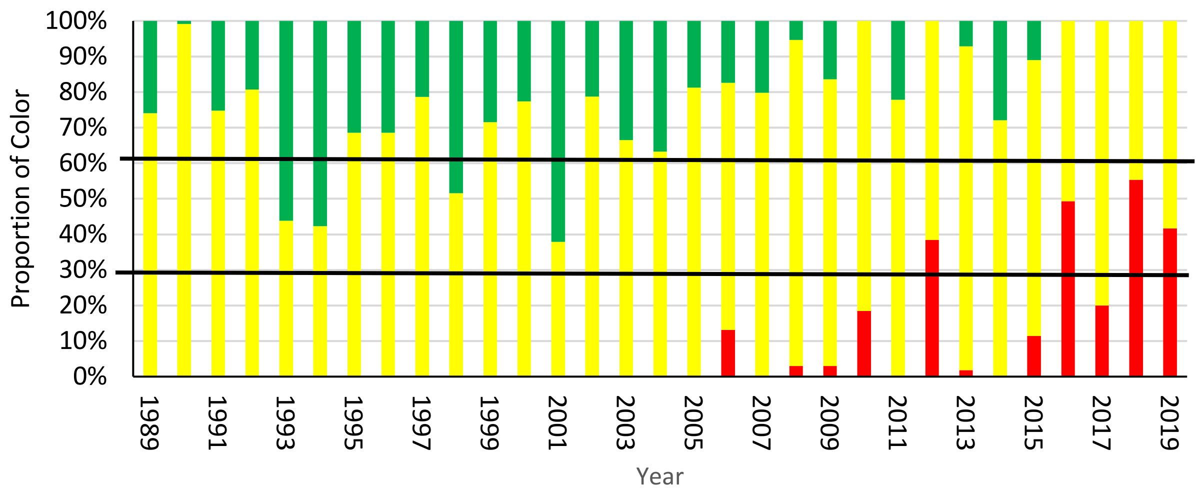


Figure 2. Annual TLA color proportions for harvest composite (commercial and recreational landings) for the South Atlantic coast (NC-FL) for spot using a 2002-2012 reference period.



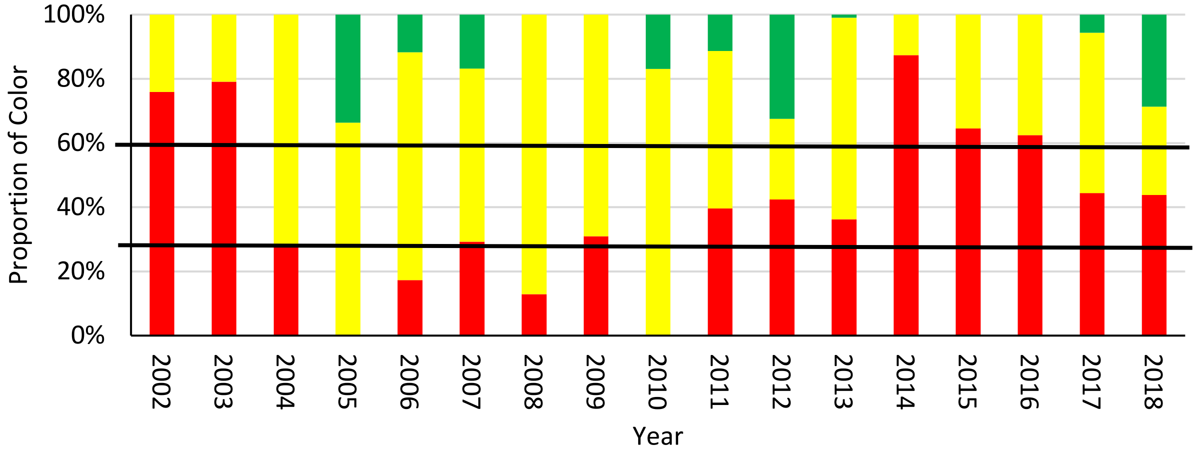
2.2 Abundance Composite Characteristic Index

The abundance composite TLA index was broken into two components based age composition in each region. The adult composite index was generated from the NEFSC and ChesMMAP surveys for the Mid-Atlantic and SEAMAP and NCDMF Program 195 in the South Atlantic since the majority of spot captured in these surveys were ages 1+. The Mid-Atlantic abundance composite TLAs in 2019 could only be estimated using the MD and NEFSC surveys for the juvenile (Section 5.7) and adult TLAs, respectively, owing to the lack of indices from ChesMMAP. ChesMMAP should return to use for the 2020 sampling year, including calibrated indices for 2019. One additional survey that is available in the Mid-Atlantic is the Northeast Area Monitoring and Assessment Program (NEAMAP) which samples from Block Island Sound south to Cape Hatteras. The NEAMAP survey has been considered for use in the TLA but is currently not utilized due to the shorter time frame (2007-2019) compared to all the other surveys. It is anticipated that this survey will come into use with the TLA once it reaches a 15 year sampling time span. There is a supplemental section at the end of this report that describes the trends in the NEAMAP survey and gives composite characteristics that include NEAMAP for the Mid-Atlantic. Only adult abundance will be used to determine if management action is triggered. Juvenile data is presented as supplementary information.

2.2.1 Mid-Atlantic

- The TLA composite characteristics for spot abundance (NEFSC and ChesMMAP surveys) in the Mid-Atlantic did not have 2019 data points owing to the fact that the ChesMMAP survey indices were not available (Figure 3).
- The adult index still triggered at the 30% threshold because the red proportions in the index have exceed the 30% threshold for the previous five years (Figure 3).

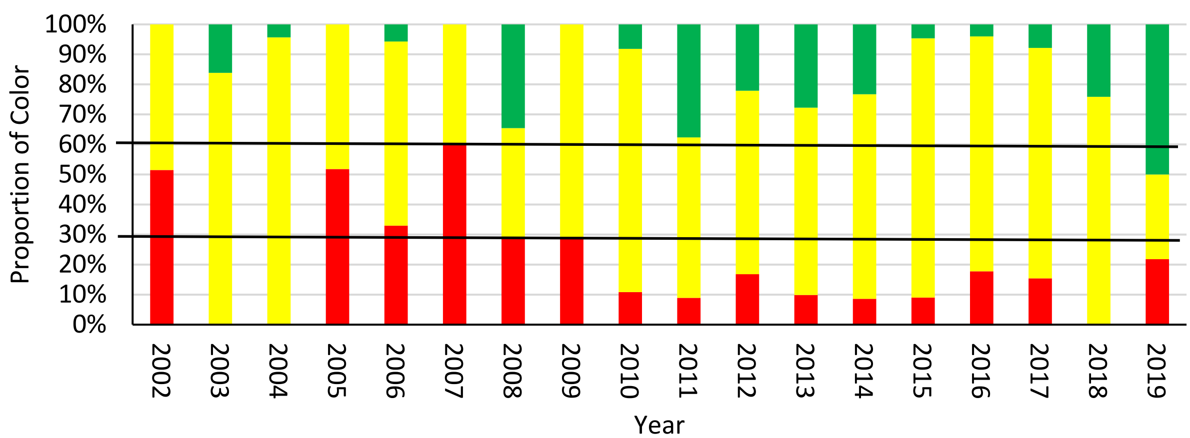
Figure 3. Annual TLA for adult (age 1+) spot for composite characteristic of adult fishery independent surveys in the Mid-Atlantic (NJ-VA) (NEFSC and ChesMMAP) using a 2002-2012 reference period.



2.2.2 South Atlantic

- The South Atlantic adult abundance composite characteristic did not trigger in 2019 since none of the red proportions in recent years have exceeded the 30% red threshold (Figure 4). There has been a bit of conflict in the index with both red and green proportions in the same years. This has been due to the NCDMF Program 195 index having higher red proportions and SEAMAP having relatively high green proportions in recent years.

Figure 4. Annual TLA composite characteristic for adult spot (age 1+) in the South Atlantic (SEAMAP and NCDMF Program 195) using a 2002-2012 reference period.



3 SUMMARY

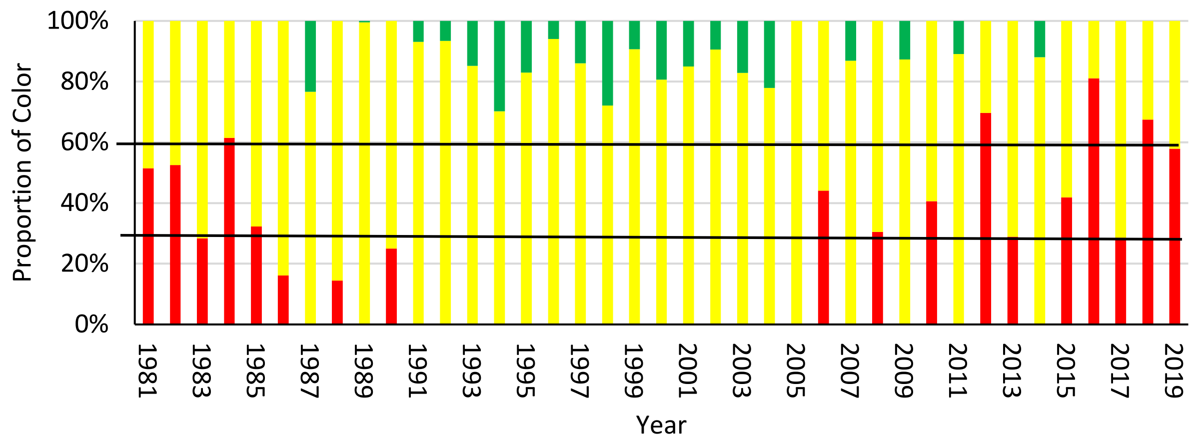
- The harvest composite TLA for spot exceeded the 30% threshold in both regions and triggered in 2019.
- The Mid-Atlantic abundance composite characteristic did not have a 2019 data point, but did trigger the two previous years thus triggering in two of the three terminal years.
- The South Atlantic abundance composite characteristic did not trigger in 2019 for adults with red proportions in the terminal three years either not present or below the 30% threshold of concern.
- With the harvest TLAs triggering at 30% for both regions and the abundance composite TLA triggering at the 30% threshold in the Mid-Atlantic region in 2019, management action outlined in Addendum III has been triggered coastwide for both the commercial and recreational fisheries in 2021.

4 TRAFFIC LIGHT ANALYSIS (FISHERY DEPENDENT)

4.1 Commercial

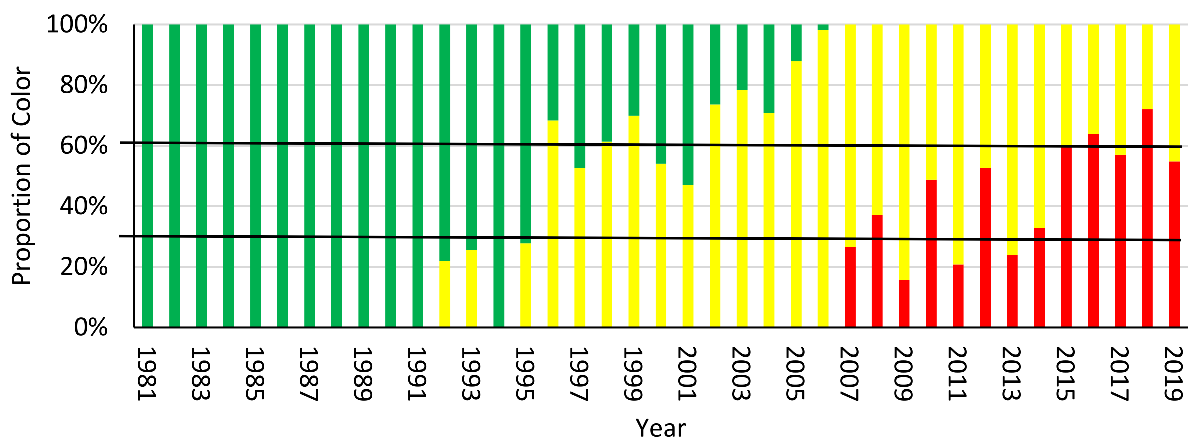
- Commercial landings of spot on the Atlantic coast decreased 59.5% in 2018 from 2017, but increased 44.7% in 2019 from 2018. Landings were still well below the long term mean although they were up from the time series low which occurred in 2016. Long term, there is still a declining trend in commercial landings that has been occurring since 2003. Total annual landings have declined 86.7% from 2004 to 2018 (Figure 5).
- The TLA for commercial landings in the Mid-Atlantic peaked in the 1990s and early 2000s (Figure 5). The general trend has been a decline since 2005, although there is some year-to-year variability between red and green proportions. In the last five years the red proportion has been above the 30% threshold in all but one year.
- The TLA commercial index was above the 30% threshold level in 2019 and represents the fourth year since 2012 where this has happened.

Figure 5. Annual TLA color proportions using 2002-2012 reference period for spot from commercial landings for the Mid-Atlantic (NJ-VA) coast of the US.



- In the South Atlantic, commercial spot landings were high from the 1980s through the mid-2000s (Figure 6). Commercial spot landings began to decline steadily from 2005 onward and red proportion levels have been above the 30% threshold for most years since 2010 and above the 60% threshold three of the last five years.
- The continued decline in commercial landings may be due to changes in effort in some other fisheries (most notably the shrimp trawl fishery) so it is difficult to determine the exact cause of the general decline in commercial landings in the South Atlantic.

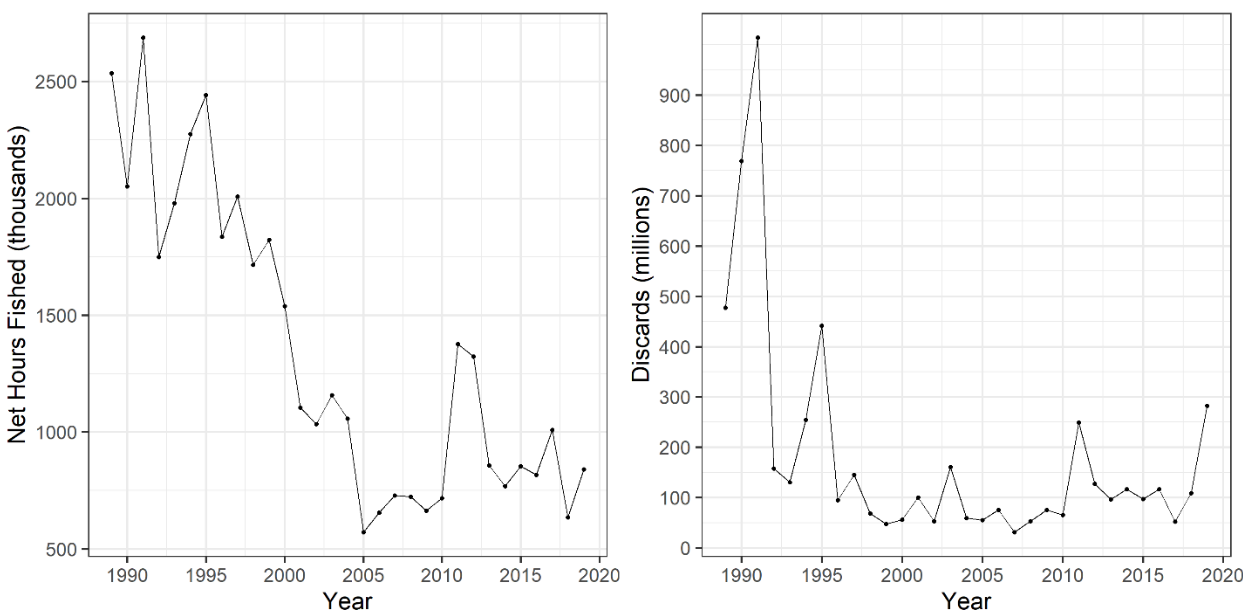
Figure 6. Annual TLA color proportions using a 2002-2012 reference period for spot from commercial landings for the South Atlantic (NC-FL) coast of the US.



- Total effort (net hours) in the South Atlantic Shrimp Trawl Fishery declined from a time series high in 1991 to a time series low in 2005 and varied around an increasing trend through the remainder of the time series (Figure 7; left).

- Total discards of spot in the South Atlantic Shrimp Trawl Fishery were highest during the late 1980s and early 1990s, declined to relatively low levels in the 2000s, and then increased to slightly higher levels in the 2010s (Figure 7; right). Discards increased in the terminal year of 2019 to the highest number since 1995.
- For additional information on the South Atlantic Shrimp Trawl Fishery, please see Appendix 1.

Figure 7. Total net hours fished (left) and discards of spot (right) in the South Atlantic Shrimp Trawl Fishery.

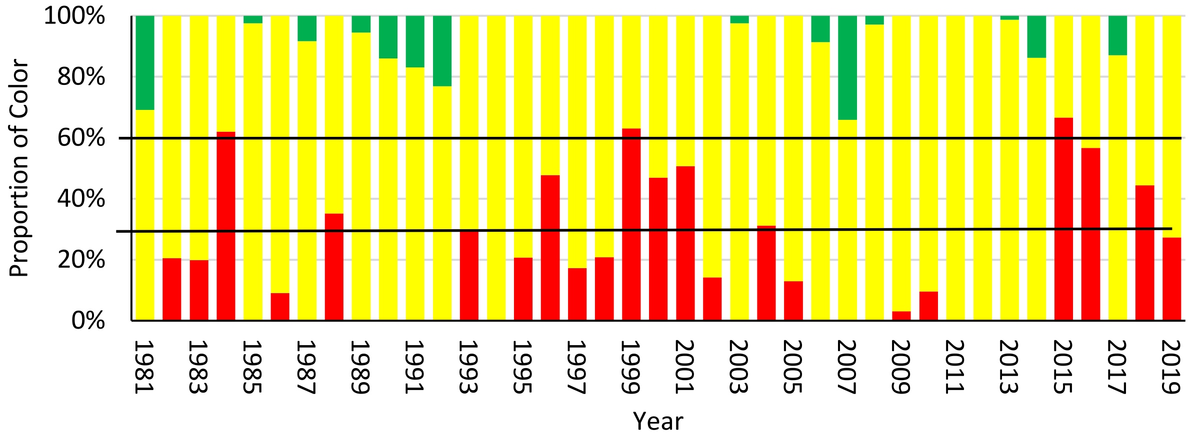


4.2 Recreational

In July 2018, the Marine Recreational Information Program transitioned from the catch estimates based on effort information from the Coastal Household Telephone Survey (CHTS) to effort information from the mail-based Fishing Effort Survey (FES). FES estimates are used in this and future reports, so recreational estimates and analyses may be different from previous years that used CHTS estimates.

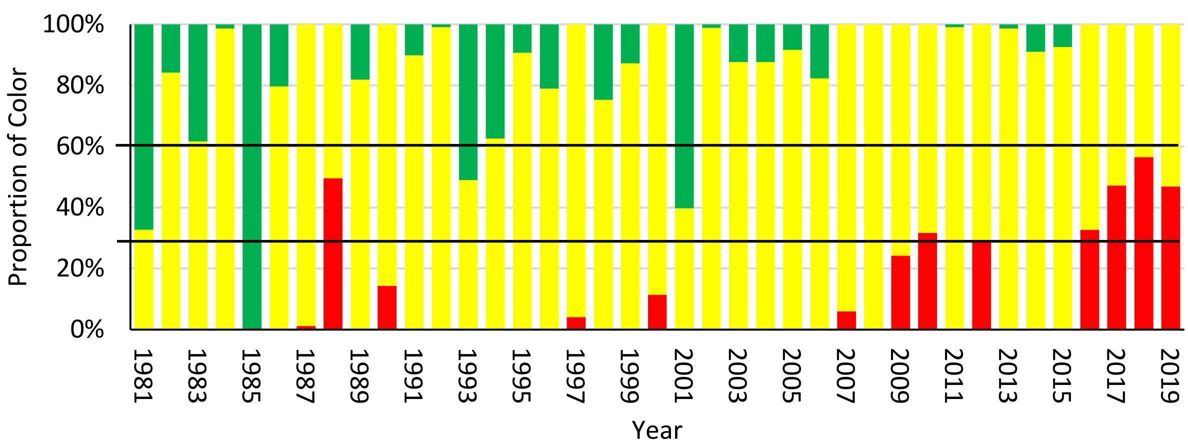
- The recreational harvest of spot on the Mid-Atlantic coast increased 42% in 2019 from 2018, with values of 2,991,200 pounds and 2,105,999 pounds, respectively.
- Annual harvest in the recreational fishery has been below the long term mean (LTM) for the last five years (with the exception of one year, 2017).
- The red proportion of the TLA declined to 27.3% in 2019 compared to 44.3% in 2018. The recreational TLA only exceed the 30% threshold in one of the last three years (2018; Figure 8).

Figure 8. Annual color proportions for the Mid-Atlantic (NJ-VA) coast of the US for recreationally harvested spot using a 2002-2012 reference period.



- In the South Atlantic, recreational harvest increased 35% in 2019 (1,531,869 lbs) from 2018 (1,132,145 lbs).
- Recreational harvest in 2019 was still below the long term mean with a red proportion of 46.9%. Red proportions have been above the 30% threshold since 2016 (Figure 9).

Figure 9. Annual color proportions for the South Atlantic (NC-FL) coast of the US for recreationally harvested spot using a 2002-2012 reference period.



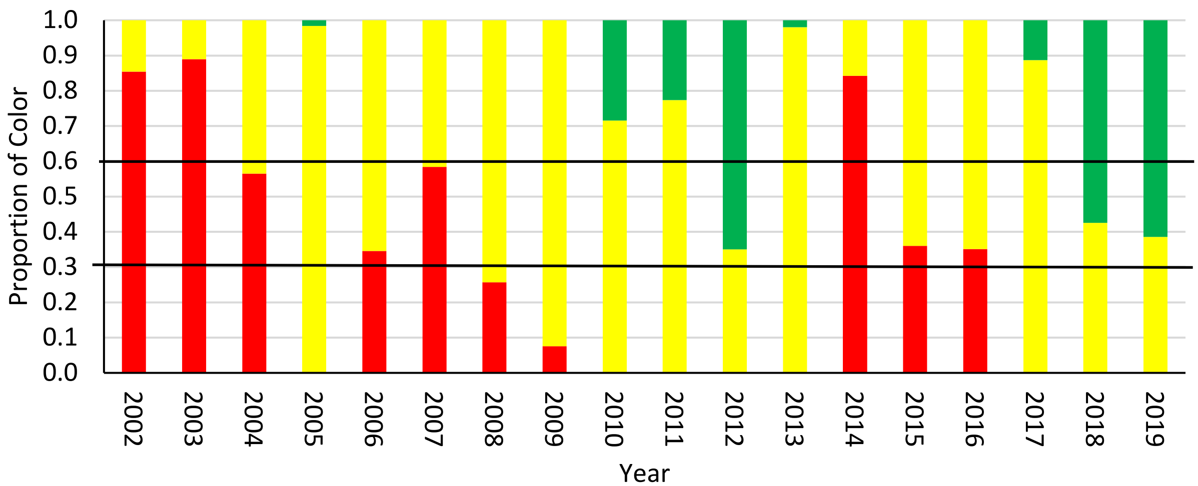
5 TRAFFIC LIGHT ANALYSIS (FISHERY INDEPENDENT)

5.1 NEFSC Fall Groundfish Trawl Survey

- The CPUE for spot in 2019 increased 4.4% from 2018 and was in a similar range to the series peak value seen in 2012.

- There was no red in the TLA index for 2019, so this index did not exceed the 30% threshold (Figure 10).
- The NEFSC was not carried out in 2017 due to mechanical problems with the RV Bigelow. An imputed index for 2017 was calculated as the mean of 2015-2016 and 2018.

Figure 10. Annual TLA color proportions for adult spot (age 1+) from Mid-Atlantic NEFSC fall groundfish trawl survey using a 2002-2012 reference period.



5.2 ChesMMAP Trawl Survey

- The ChesMMAP survey made major changes to the survey in 2019 (vessel change, gear change, altered protocols, etc.) but maintained the same sampling strata and design. Side-by-side comparison tows were made between the new and old vessels/gears and the survey is in the process of producing conversion factors by species so that historic survey index values can be compared to ongoing survey values in the future. Since the conversion factor determination won't likely be finished until the end of 2020, the ChesMMAP index is only available through 2018 for the adult and juvenile TLA composite characteristics.
- The juvenile spot index showed a declining trend from the late 2000s through the present (Figure 11) with high proportions of red. Red proportions exceeded the 30% threshold for all years since 2011 and exceeded the 60% threshold for six of the last eight years in the data series.
- The adult spot index also showed a similar declining trend during the same time period (2010-2018) with red proportions exceeding the 60% threshold in the terminal four years of the time series (Figure 12).
- Even with the currently missing values for 2019, the ChesMMAP index would have exceeded the 60% threshold in two of the previous three years for adults, and the 30%

threshold for juveniles given the high red proportions in 2017 and 2018 (Figure 11 and Figure 12).

Figure 11. Annual TLA color proportions for juvenile spot (age 0) from the Mid-Atlantic ChesMMAP survey using a 2002-2012 reference period.

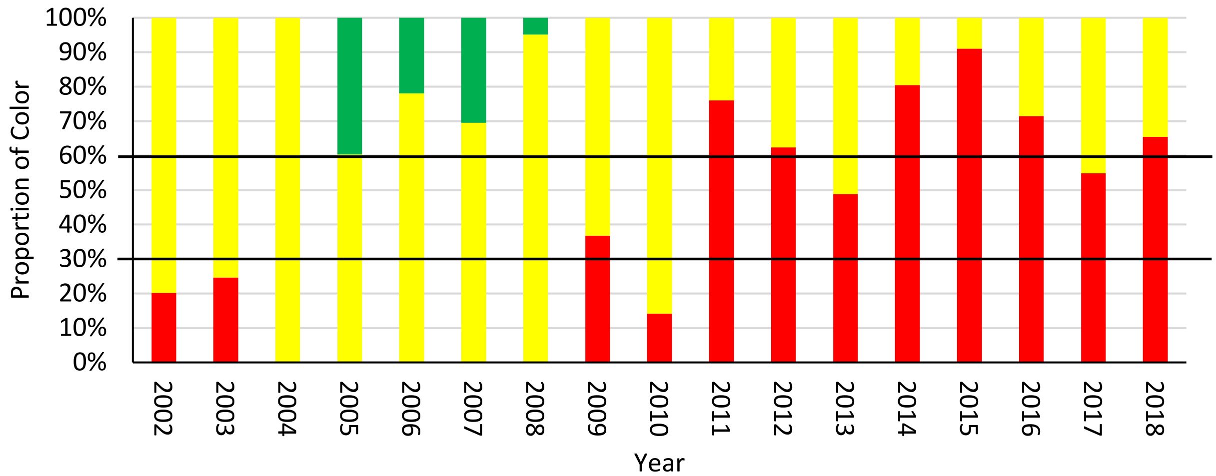
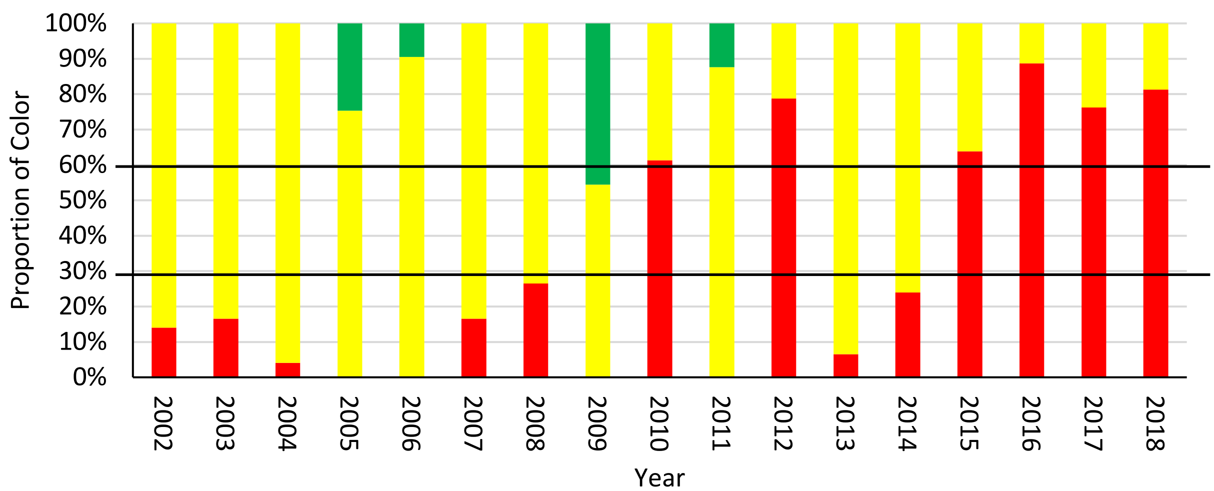


Figure 12. Annual TLA color proportions for adult spot (age 1+) from the Mid-Atlantic ChesMMAP survey using a 2002-2012 reference period.

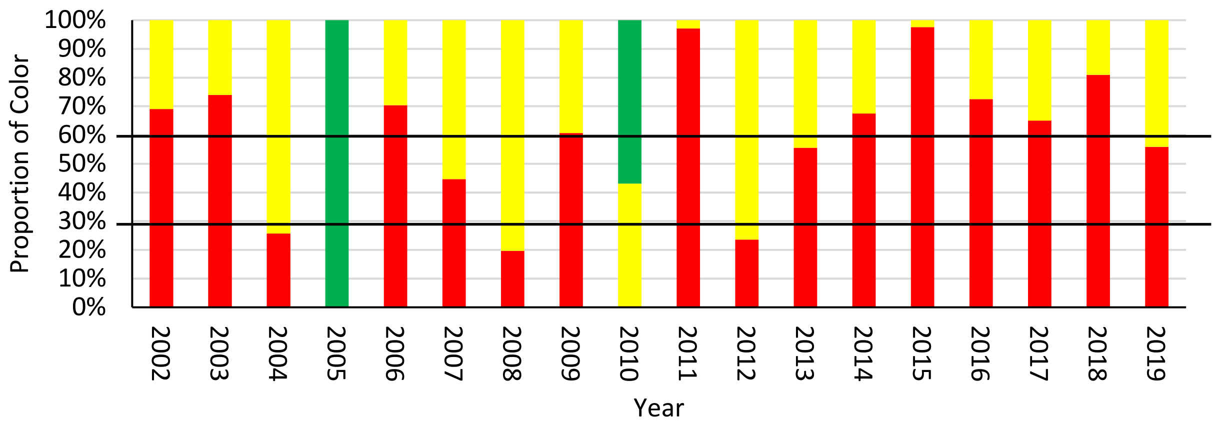


5.3 Maryland Juvenile Fish Seine Survey

- The Maryland CPUE increased 111% in 2019 from 2018 but was still well below the long-term mean.
- CPUE was below the long-term mean for the ninth year in a row, indicating annual recruitment and year-class strength remain poor in the Maryland portion of the Chesapeake Bay.

- The TLA exceeded the 30% threshold for the seventh year in a row with a red proportion of 55.9% in 2019 (Figure 13).
- The index exceeded the 60% threshold level for the 2017-2019 time-period indicating cause for concern as the general decline in this index indicates a decline in spot recruitment has been occurring in Maryland waters.

Figure 13. Annual TLA color proportions for the Mid-Atlantic Maryland seine survey juvenile spot (age 0) index using a 2002-2012 reference period.



5.4 NCDMF Program 195 (Pamlico Sound Survey)

- The NCDMF Program 195 survey saw declines in both juveniles and adults as indicated by declining green proportion (juvenile) (Figure 14) and increasing red proportions (adults) (Figure 15).
- In the juveniles, CPUE was greater than the long term mean with mostly yellow and only a little green proportion (0.30%) in the index (Figure 14). This index has not exceeded any red threshold since 2016. This could indicate increased spot recruitment in recent years in the Pamlico Sound area of North Carolina.
- The adult TLA continued to show a declining trend that has been occurring since 2008, with a red proportion in 2019 of 43.6% (Figure 15). The adult TLA red proportions have exceeded the 30% threshold for three of the last four years.

Figure 14. Annual TLA color proportions for juvenile spot (age 0) from the South Atlantic NCDMF Program 195 Survey using a 2002-2012 reference period.

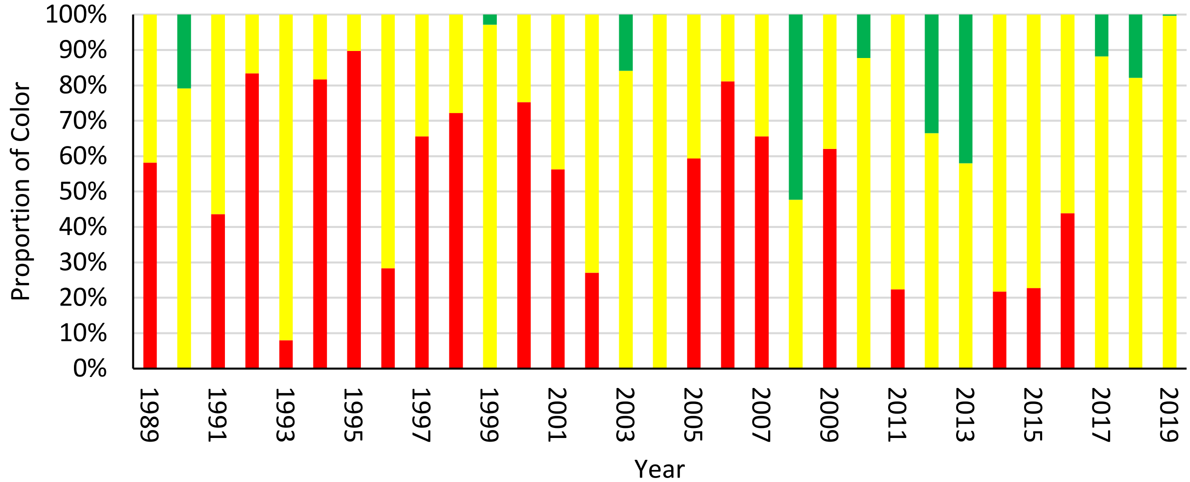
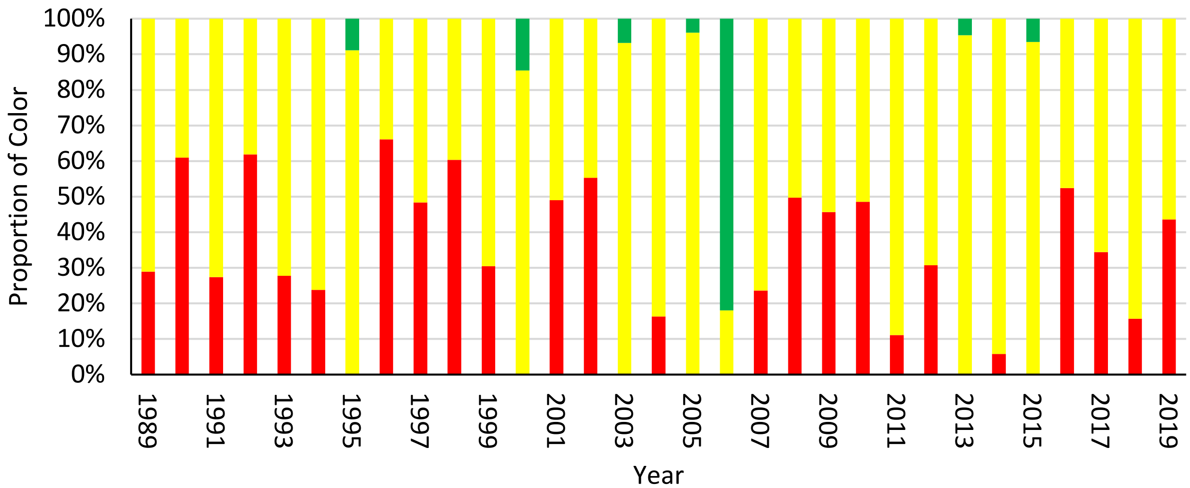


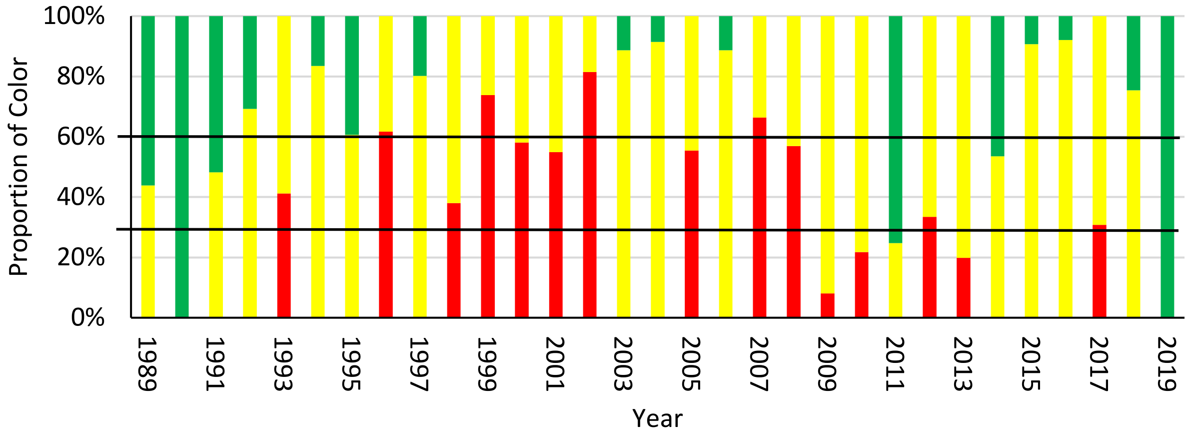
Figure 15. Annual TLA color proportions for adult spot (age 1+) from the South Atlantic NCDMF Program 195 Survey using a 2002-2012 reference period.



5.5 SEAMAP Trawl Survey

- The SEAMAP index used the spring season CPUE because it only catches adult spot (age 1+) during that season.
- The annual CPUE increased 265% in 2019 (48.6 kg/tow) from 2018 (13.3 kg/tow) and was the highest value in the time series.
- The TLA index has only exceeded the 30% threshold once in the past seven years (2017; Figure 16).

Figure 16. Annual color proportions for Adult spot (age 1+) TLA from the fall South Atlantic SEAMAP survey using a 2002-2012 reference period.

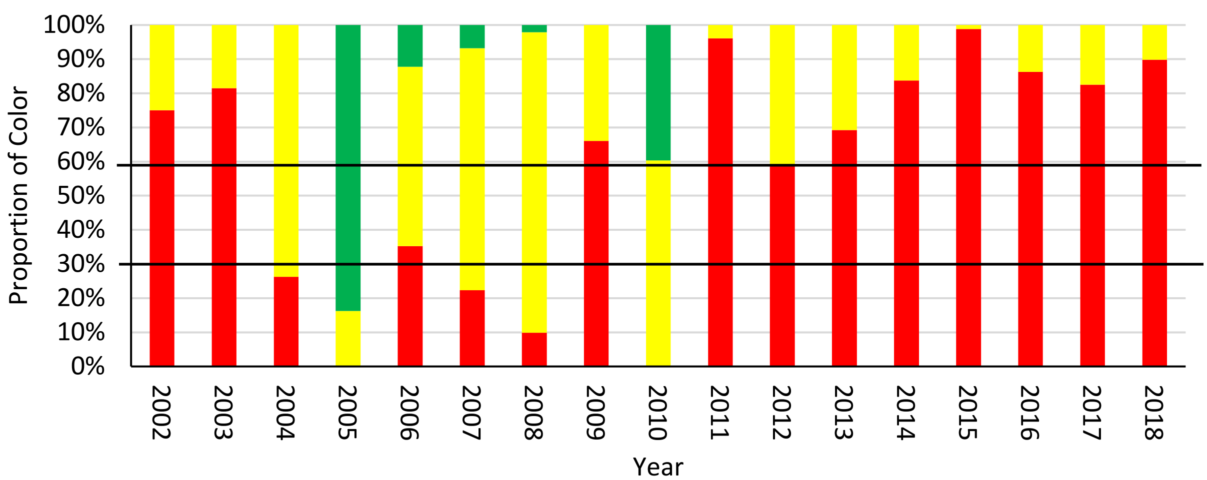


5.6 Juvenile Abundance Composite Indices

The juvenile composite index in the Mid-Atlantic was generated from the ChesMMAP and the Maryland juvenile fish seine survey. ChesMMAP has an age specific index for ages 0 which allowed its use as a juvenile index.

- The juvenile spot TLA for the Mid-Atlantic (MD survey and ChesMMAP) also showed a general decline in recruitment with very high red proportions for the last 8 years (Figure 17).
- The juvenile composite index was above the 30% threshold in two of the three terminal years (Figure 17).

Figure 17. Annual TLA for juvenile (age 0) spot for composite characteristic of fishery independent suveys in the Mid-Atlantic (NJ-VA) (MD seine survey and ChesMMAP) using a 2002-2012 reference period.



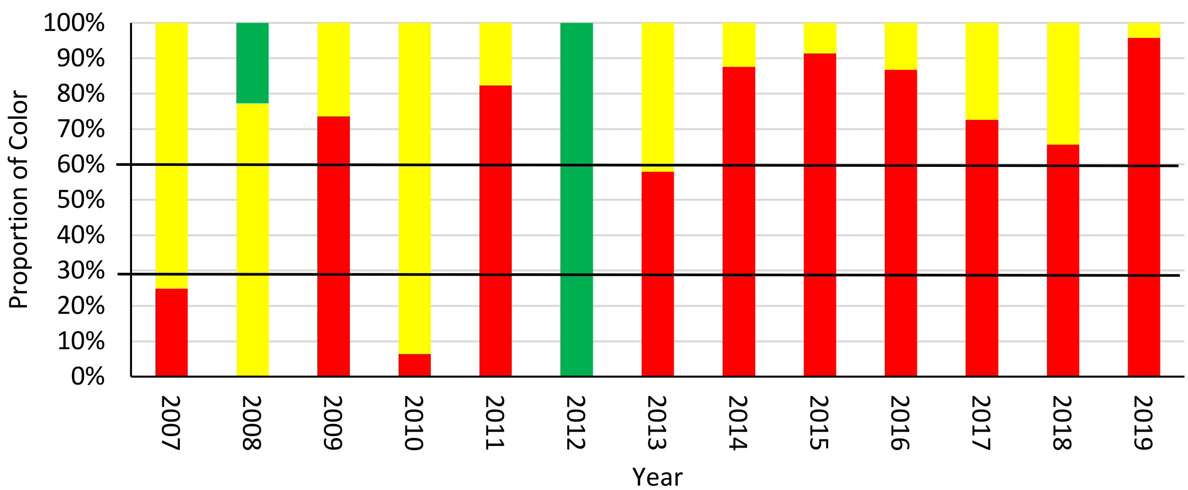
- The South Atlantic juvenile spot index (NCDMF Program 195) has not had any red proportion greater than 30% in the last three years (Figure 14) and has not had a red proportion exceeding the 30% threshold since 2016.

6 SUPPLEMENTAL MATERIALS

6.1 NEAMAP Survey

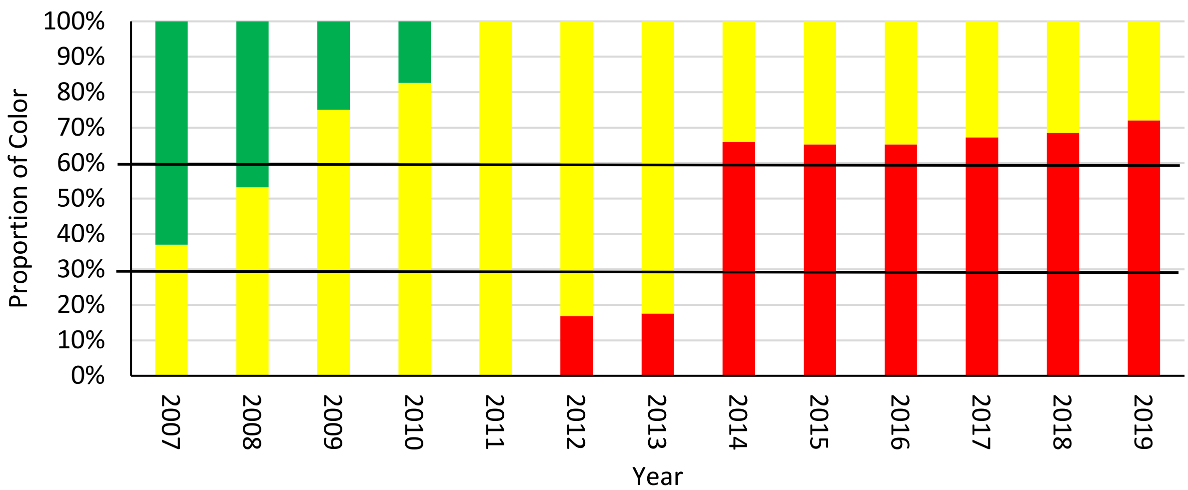
- The juvenile spot TLA index shows the evidence of low recruitment across all years except 2008 and 2012. This is similar to the declining trends seen in the MD seine survey and the ChesMMAP survey across the same years.
- Red proportions have exceeded the 60% threshold across all years since 2014 (Figure 18).

Figure 18. Annual color proportions from TLA for juvenile (age 0) spot from the Mid-Atlantic NEAMAP survey using a 2007-2019 reference period.



- The adult spot TLA index supports the general declining trend that has occurred since 2010 with red proportions exceeding the 60% threshold for the last six years of the survey (Figure 19).
- The trend in higher red proportions was very similar to the trends seen in the ChesMMAP survey across years where the surveys overlapped, but did not correlate with the NEFSC survey in terms of general trends.
- Both the juvenile and adult spot TLA indices exceeded the high level of concern threshold for the last several years.

Figure 19. Annual color proportion from TLA for adult (age 1+) spot from the Mid-Atlantic NEAMAP survey using a 2007-2019 reference period.



6.2 Composite TLA Characteristic for Mid-Atlantic including NEAMAP

In order to generate the composite TLA index that included NEAMAP in the Mid-Atlantic, the other Mid-Atlantic indices (NEFSC, ChesMMAP, and MD Seine Survey) had to be recalculated using the common time period of all three surveys (2007-2019) in order to have a common reference. The figures give the TLA composite characteristics through 2019 with no 2019 ChesMMAP data, but it was thought useful to still provide the composite index through 2019 with the indexes that were available.

- The juvenile spot composite characteristic (Figure 20) supported the general decline in recruitment in the Mid-Atlantic region with red proportions in excess of the 60% threshold in nine of the thirteen years common to all the separate indices.
- The adult spot composite characteristic (Figure 21) showed a similar declining trend, although the adult composite characteristic did not exceed the 60% threshold except in 2017. It did, however, exceed the 30% threshold every year since 2014. The one contrasting trend in the adult composite characteristic was between NEFSC and the other surveys, where the NEFSC survey contributed the green proportions seen in 2018 and 2019 due to the significant increase in catch levels seen in the NEFSC survey.

Figure 20. Juvenile spot (age 0) TLA composite characteristic index for the Mid-Atlantic (NJ-VA) using NEAMAP, ChesMMAP, and MD Seine surveys with a 2007-2019 reference period.

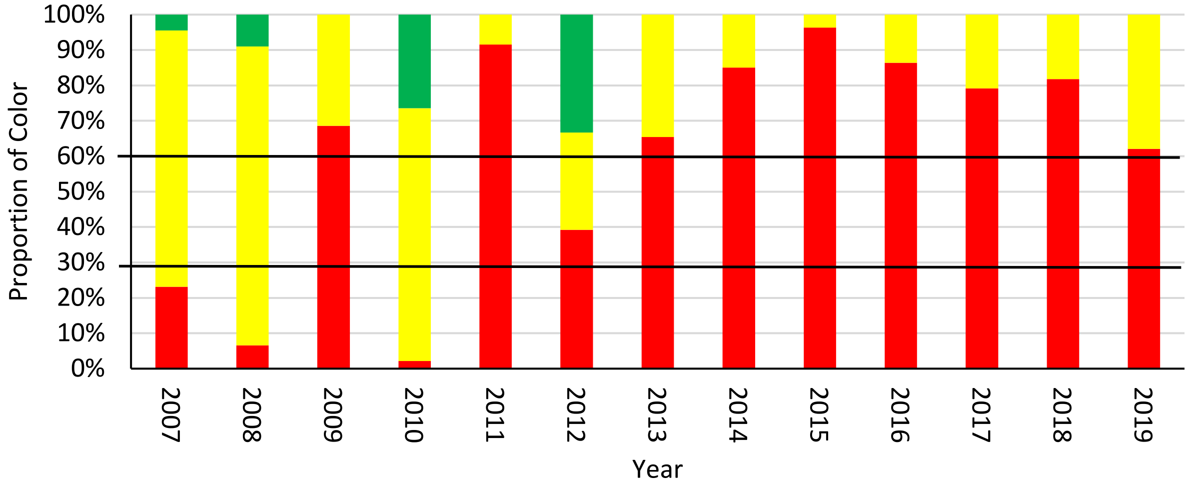
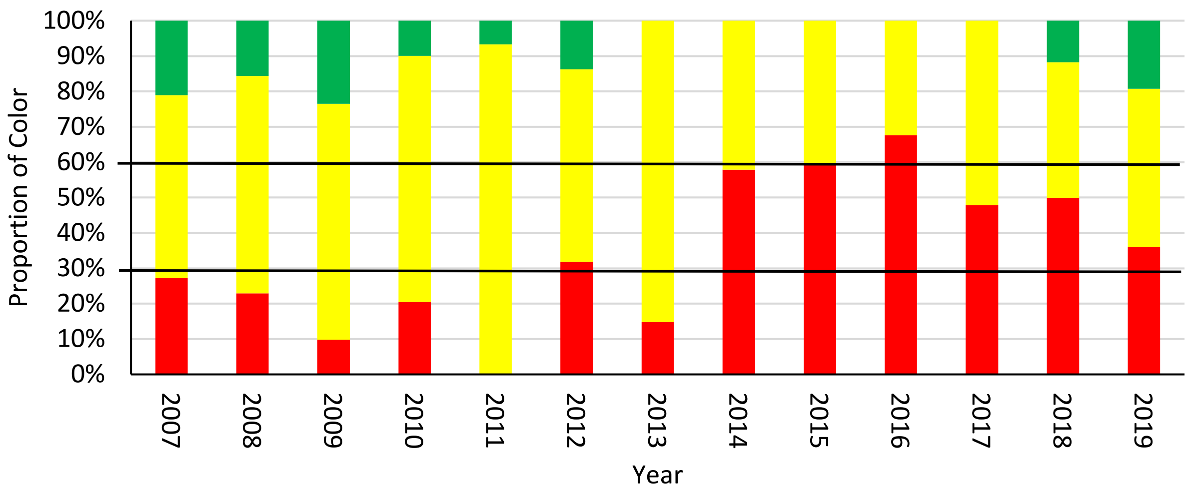


Figure 21. Adult spot (age 1+) TLA composite characteristic index for Mid-Atlantic (NJ-VA) using NEFSC, ChesMMAP, and NEAMAP surveys with a 2007-2019 reference period.



6.3 Summary

The addition of the NEAMAP survey generally supported the declining trends in recent years seen in the harvest composite characteristic as well as the fishery-independent surveys (with the exception of the NEFSC survey). The TC might consider adding the NEAMAP survey to the Traffic Light Analysis for the 2020 sampling year and re-evaluate the use of the NEFSC survey for use in the TLA. This could be done for next year's report or after the next benchmark assessment (currently scheduled for completion in 2024).

Appendix 1. Shrimp Trawl Discard Estimates

Estimates of spot discards in South Atlantic shrimp trawl fisheries were developed following the methods of Walter and Isley (2014) and Zhang and Walter (2020). Discard rate data from the Southeast Shrimp Trawl Observer Program were used to estimate the magnitude and trend of discard rates and discard rate data from the Southeast Area Monitoring and Assessment Program (SEAMAP) Trawl Survey were used to supplement the observer program data for estimating the trend of discard rates. Total effort data from the South Atlantic Shrimp System (SASS) and state trip ticket programs were used to extrapolate estimated discard rates to the scale of the fishery to estimate total discards.

Discard Rate Data Sets

Southeast Shrimp Trawl Observer Program

A voluntary shrimp trawl bycatch observer program was implemented in the South Atlantic (NC-FL) through a cooperative agreement between NOAA Fisheries, the Gulf and South Atlantic Fishery Management Councils, and the Gulf and South Atlantic Fisheries Foundation, Inc. to characterize catch and bycatch, as well as evaluate bycatch reduction devices (BRDs). Total catch, total shrimp catch, and a subsample (one basket per net, or approximately 32 kg) for species composition is taken from each observed net. Beginning in 2008, the program became mandatory in the South Atlantic and NOAA Fisheries-approved observers were placed on randomly selected shrimp vessels. The voluntary component of the observer program also continued. Penaeid shrimp (primarily inshore) and rock shrimp (primarily offshore) fisheries in the South Atlantic are covered by the observer program. Observed coverage is allocated by previous effort, or shrimp landings when effort data are not available. Based on nominal industry sea days, observer coverage of South Atlantic shrimp trawl fisheries ranged from 0.2-1.4% and totaled 0.9% from 2007-2010 (see Scott-Denton (2012) Table 1). Number of observed tows are in Table 1. See Scott-Denton (2007) for more details on the voluntary component of the Shrimp Trawl Observer Program and Scott-Denton et al. (2012) for more details on the mandatory Shrimp Trawl Observer Program.

Biological information, such as length and weight of bycatch species, was collected from the subsample of total catch in observed nets. Very limited biological sampling has been conducted for spot. Only 698 spot have been measured for length, caught from just twenty three tows on three trips occurring from October to November in 2003. Lengths ranged from 13 to 23 cm FL (Figure 1). No spot age samples have been collected.

Spot is typically one of the most prevalent bycatch species, often outweighing and/or outnumbering individual species of shrimp (see Scott-Denton (2007) Figure 9, Figure 11, Table A2 and Scott-Denton (2012) Table 9, Table 11, Table 12, Figure 6).

SEAMAP Trawl Survey

The SEAMAP- South Atlantic (SEAMAP-SA) Coastal Survey (previously known as the Shallow Water Trawl Survey) began in 1986 and is conducted by the South Carolina Department of Natural Resources (SCDNR) Marine Resources Division (MRD). This survey has provided long-term, fisheries-independent data characterizing the seasonal abundance and biomass of all finfish, elasmobranchs, decapod and stomatopod crustaceans, sea turtles, horseshoe crabs, and cephalopods that are accessible by high-rise trawls. The sampling area extends from the coastal zone of the South Atlantic Bight (SAB) between Cape Hatteras, North Carolina, and Cape Canaveral, Florida (SEAMAP-South Atlantic Committee 2005). The survey uses a stratified random design, where strata are delineated by the 4-m depth contour inshore and the 10-m depth contour off shore. A total of 102 stations are sampled each season within 24 shallow water strata. The R/V Lady Lisa, a 23-m wooden-hulled, double-rigged, St. Augustine shrimp trawler owned and operated by the SCDNR, is used to tow paired 22.9-m mongoose-type Falcon trawl nets, without turtle excluder devices (TEDs). The body of the trawl is constructed of #15 twine with 47.6-mm stretch mesh. The cod end of the net is constructed of #30 twine with 41.3-mm stretch mesh and is protected by chafing gear of #84 twine with 10-cm stretch "scallop" mesh. A 91.4-m three-lead bridle is attached to each of a pair of wooden chain doors, which measure 3.0 m × 1.0 m and to a tongue centered on the headrope. The 26.3-m headrope, excluding the tongue, has one large (60 cm) Norwegian "polyball" float attached top center of the net between the end of the tongue and the tongue bridle cable and two 22.3-cm PVC foam floats located one-quarter of the distance from each end of the net webbing. A 1-ft chain drop-back is used to attach the 89-ft footrope to the trawl door. A 0.6-cm tickler chain, which is 0.9 m shorter than the combined length of the footrope and drop-back, is connected to the door alongside the footrope. Trawls are towed for twenty minutes, excluding wire-out and haul-back time, exclusively during daylight hours (1 hour after sunrise to 1 hour before sunset). Each net is processed separately and assigned a unique collection number. Multi-legged cruises are conducted in the spring (April–May), summer (July), and fall (October).

After each tow, the contents of each net are sorted to species or genus, and the total biomass and number of individuals are recorded for all species of finfish, elasmobranchs, decapod and stomatopod crustaceans, cephalopods, sea turtles, xiphosurans, and cannonball jellies. Where a large number of individuals of a species occur in a tow, the entire catch is sorted and all individuals of that species are weighed; a random subsample is processed and the total number is estimated. For large trawl catches, the contents of each net are weighed prior to sorting and a randomly chosen subsample of the total catch is then sorted and processed. In every collection, each of the majority of priority species is weighed collectively and individuals were measured to the nearest centimeter. When a large number of individuals of any of the priority species are collected in a tow, a random subsample consisting of 30 to 50 individuals is weighed and measured

Modeled Discard Rates

Only discarded spot are recorded by shrimp trawl observers, so no adjustments were needed to account for fish landed. Observer data were subset to exclude operation codes X, M, H, and J (Appendix 1a). Observations with all other operation codes were included under the assumption that these observations are representative of effort in the shrimp trawl fisheries.

Trends in catch rates (number of fish/hour fished) of the SEAMAP Trawl Survey and the Shrimp Trawl Observer Program are in Figure 2 and generally track well during overlapping years. Spatial coverage of both surveys overlap throughout most of the sampled ranges.

Discard rates in numbers of spot were modeled with a negative binomial generalized linear model (GLM). The negative binomial GLM predicts the number of fish caught per observation with effort as an offset variable. Factors considered in the model were year, data set, depth zone, state, and season. Data sets included observer data from the rock shrimp (observer project types W, X, Y) and penaeid shrimp (observer project types A, C) commercial fisheries and fishery-independent data from SEAMAP tows. Depth zones were less than or equal to 10 meters (=<10m), greater than 10 meters to 30 meters (10-30m), and greater than 30 meters (>30m). All SEAMAP tows were conducted in the shallowest depth zone. State borders were defined by the latitudes used by Scott-Denton et al. (2012). Seasons were December through March (offseason) and April through November (peak season). The seasons were defined to align with shrimp fishing relative to operation in nearshore waters throughout the time series. Shrimp fishing in nearshore waters where catch rates are expected to increase has generally started as early as April and lasted through November. Discard rate data by factor are summarized in Table 2.

Model structure was evaluated with stepwise deletion of factors and the model with the lowest AIC was selected as the final model. The final model summary is in Table 3. All factors were retained in the final model (Table 4).

Shrimp Trawl Effort Data
Detailed catch and effort statistics from individual commercial shrimp fishing trips were collected and processed by a cooperative effort between the South Atlantic states and, beginning in 1982, the NOAA Fisheries Southeast Fisheries Science Center (SEFSC). Early trip data starting in 1978 were collected through the South Atlantic Shrimp System (SASS), while more recent data were collected through individual state trip ticket programs. Trip ticket data are available from FL since 1986, GA since 2001, SC since 2004, and NC since 1994. Trip counts and total hours fished were provided by the SEFSC by state, year, month, and gear following the methods described in Gloeckner (2014). There was a gap in 1993 in NC when data were not available from either a trip ticket program or the SASS. The number of monthly trips in NC in 1993 were estimated as the average of the two adjacent years (1992, 1994). Discard rates are estimated on an hourly basis by individual net, so there is the need for hours and number of nets fished per trip to extrapolate the discard rates to total effort. Average hours fished per trip by state and year were used from Walter and Isley (2014) and updated for years 2011-2019 from shrimp effort data provided by the SEFSC. Average number of nets fished per tow by state and year were used from Zhang and Walter (2020) for 2011 and later. Averages from 2016-2017 were used for 2018-2019. Total effort was calculated as the product of total number of trips, average hours fished per trip, and average number of nets fished per tow. Effort is summarized by month in Figure 3. As effort was only available by state, year, and month, some assumptions were made to partition the effort among depth zones and fisheries. The proportions of observations from the observer data by depth zone were applied to overall

effort, assuming that the observer data are representative of fishing effort at depth and that fishing effort at depth is static over time. The proportions of observations in each depth zone allocated to penaeid and rock shrimp fisheries were applied to the effort data in the respective depth zone. Proportions used to partition effort are in Table 5.

Total Discard Estimates

Discard rates were applied to effort data summarized by “strata” (i.e., combination of factors included in the discard rate model). BRDs were required in federal penaeid shrimp fisheries in 1996 under Amendment 2 to the Shrimp FMP for the South Atlantic Region (1995) and federal rock shrimp fisheries in 2005 under Amendment 6 to the Shrimp FMP (2004). State BRD regulations generally fit these time frames. There were no observer data before BRDs were required in the penaeid shrimp fishery, so discard estimates for penaeid shrimp trawl effort prior to 1997 were adjusted for the reduction in catch due to the required use of certified BRDs on observed tows. Adjustments were based on a weighted average of Atlantic croaker catch reductions in the Gulf of Mexico shrimp trawl fishery estimated depending on the distance of fisheye BRDs from tie-off rings (Helies et al. 2009). The adjustments of spot discard estimates were based on the Atlantic croaker adjustments, as there are no known BRD reduction estimates for spot. 99.6% of observer trips used fisheye BRDs. BRDs in the observed trips ranged from 6 to 21 feet from tie-off rings. Catch reduction estimates were available for BRDs <9 feet (69.7% reduction), 9-10 feet (0% reduction), and 10-11 feet (17.2% reduction) from the tie off rings. There was no estimated reduction for fisheye BRDs greater than 11 feet from the tie-off rings, so the estimate for the 10-11 foot category was used for the proportion of nets greater than 11 feet from the tie-off rings. The proportion of observed trips that fell into the categories of <9 feet, 9-10 feet, 10-11 feet, and >11 feet were 0.26, 0.26, 0.29, and 0.19, respectively. The weighted average adjustment was 0.26 (i.e., adjusted discard = discard*1/(1-adjustment)). Observed trips were assumed representative of BRDs used in the fisheries.

Final discard estimates with 95% confidence intervals are in Table 6 and Figure 4. Total discards of spot were highest during the late 1980s and early 1990s, declined to relatively low levels in the 2000s, and then increased to slightly higher levels in the 2010s. Discards increased in the terminal year of 2019 to the highest number since 1995 and appear to be driven primarily by increasing catch rates (Figure 5).

References

Gloeckner, D. 2014. Methods Used to Compile South Atlantic Shrimp Effort Used in the Estimation of King Mackerel Bycatch in the South Atlantic Shrimp Fishery. SEDAR38-RW-02. SEDAR, North Charleston, SC. 22 pp.

Helies, F. C. and Jamison, J. L. 2009. Reduction rates, species composition, and effort: Assessing bycatch within the Gulf of Mexico shrimp trawl fishery. Report for Award No. NA07NMF4330125. Tampa, FL.

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Scott-Denton, E., P. F. Cryer, M. R. Duffy, J. P. Gocke, M. R. Harrelson, D. L. Kinsella, J. M. Nance, J. R. Pulver, R. C. Smith, and J. A. Williams. 2012. Characterization of the U.S. Gulf of Mexico and South Atlantic penaeid and rock shrimp fisheries based on observer data. Marine Fisheries Review 74(4): 1-26.

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Tables

Table 1. Number of tows observed by the Southeast Shrimp Trawl Observer Program by South Atlantic fishery and year.

Year	Fishery	
	Penaeid Shrimp	Rock Shrimp
2001	30	23
2002	34	146
2003	0	177
2005	158	0
2006	0	22
2007	135	0
2008	239	111
2009	458	19
2010	187	60
2011	320	0
2012	377	0
2013	308	96
2014	174	39
2015	279	51
2016	417	73
2017	389	46
2018	401	11
2019	195	32

Table 2. Number of observations, number of positive observations, proportion positive observations, and mean CPUE (number) of spot by factor level considered in the model.

season	N	N_pos	prop_pos	mean_CPUE
off	496	421	0.849	71.770
peak	21,581	14,859	0.689	367.642
depth_zone	**N**	**N_pos**	**prop_pos**	**mean_CPUE**
=<10m	19,806	13,851	0.699	395.347
>30m	837	256	0.306	15.431
10-30m	1,434	1,173	0.818	88.233
data_set	**N**	**N_pos**	**prop_pos**	**mean_CPUE**
penaeid_shrimp	4,050	3,494	0.863	130.445
rock_shrimp	903	299	0.331	15.116
SEAMAP	17,124	11,487	0.671	433.761
state	**N**	**N_pos**	**prop_pos**	**mean_CPUE**
FL	5,398	3,820	0.708	304.439
GA	4,694	2,713	0.578	180.249
NC	4,689	4,106	0.876	770.309
SC	7,296	4,641	0.636	256.065
year	**N**	**N_pos**	**prop_pos**	**mean_CPUE**
1989	318	201	0.632	487.604
1990	462	310	0.671	807.786
1991	466	343	0.736	899.163
1992	468	290	0.620	365.083
1993	468	300	0.641	194.532
1994	468	269	0.575	327.673
1995	468	309	0.660	555.301
1996	468	281	0.600	212.442
1997	468	227	0.485	305.231
1998	468	329	0.703	157.712
1999	468	259	0.553	119.660
2000	468	235	0.502	186.795
2001	664	476	0.717	250.279
2002	789	392	0.497	94.127
2003	789	532	0.674	405.438
2004	612	380	0.621	339.377
2005	770	556	0.722	559.115
2006	634	402	0.634	396.413
2007	742	472	0.636	97.518
2008	961	609	0.634	229.564
2009	1,147	895	0.780	242.337
2010	919	596	0.649	382.498
2011	992	828	0.835	539.305
2012	1,047	890	0.850	313.924
2013	986	729	0.739	320.467
2014	823	629	0.764	569.776
2015	985	734	0.745	389.451
2016	1,146	877	0.765	336.180
2017	1,009	589	0.584	192.449
2018	866	735	0.849	388.499
2019	738	606	0.821	768.807

Table 3. Negative binomial GLM summary for spot discard rate in numbers from shrimp trawl fisheries.

```
Call:
glm.nb(formula = catch ~ year + season + data_set + state + depth_zone +
    offset(log_eff), data = CPUE_data, init.theta = 0.1986636884,
    link = log)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-1.8557  -1.4410  -0.6999  -0.1288   5.6150

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)          4.83254    0.25360  19.056  < 2e-16 ***
year1990             0.77984    0.23029   3.386 0.000710 ***
year1991             0.82139    0.22989   3.573 0.000354 ***
year1992            -0.31455    0.22978  -1.369 0.171034
year1993            -0.73416    0.22984  -3.194 0.001404 **
year1994            -0.25942    0.22977  -1.129 0.258894
year1995             0.26520    0.22972   1.154 0.248320
year1996            -0.92060    0.22988  -4.005 6.23e-05 ***
year1997            -0.26199    0.22977  -1.140 0.254200
year1998            -0.77719    0.22986  -3.381 0.000723 ***
year1999            -1.36306    0.23002  -5.926 3.15e-09 ***
year2000            -1.06073    0.22992  -4.613 3.98e-06 ***
year2001            -0.18368    0.21593  -0.851 0.394990
year2002            -0.94105    0.21151  -4.449 8.66e-06 ***
year2003             0.25851    0.21217   1.218 0.223072
year2004            -0.73864    0.21882  -3.376 0.000738 ***
year2005             0.14880    0.21117   0.705 0.481060
year2006            -0.04615    0.21750  -0.212 0.831972
year2007            -1.20258    0.21242  -5.661 1.52e-08 ***
year2008            -0.67801    0.20600  -3.291 0.000999 ***
year2009            -0.18722    0.20227  -0.926 0.354674
year2010            -0.31949    0.20658  -1.547 0.121984
year2011             0.75809    0.20490   3.700 0.000216 ***
year2012            -0.05893    0.20406  -0.289 0.772764
year2013             0.01296    0.20541   0.063 0.949708
year2014             0.37936    0.20954   1.810 0.070241 .
year2015             0.02622    0.20515   0.128 0.898318
year2016             0.13232    0.20259   0.653 0.513663
year2017            -0.83861    0.20523  -4.086 4.40e-05 ***
year2018             0.39439    0.20966   1.881 0.059972 .
year2019             1.13065    0.21305   5.307 1.13e-07 ***
seasonpeak          -0.15749    0.16267  -0.968 0.332979
data_setrock_shrimp -1.35460    0.35572  -3.808 0.000140 ***
data_setSEAMAP       1.39153    0.07102  19.593  < 2e-16 ***
stateGA             -0.98741    0.06942 -14.224  < 2e-16 ***
stateNC              0.95216    0.07042  13.522  < 2e-16 ***
stateSC             -0.37672    0.06493  -5.802 6.63e-09 ***
depth_zone>30m      -0.43039    0.37101  -1.160 0.246046
depth_zone10-30m    -0.17458    0.11861  -1.472 0.141053
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Negative Binomial(0.1987) family taken to be 1.9811
74)

    Null deviance: 29315  on 22076  degrees of freedom
Residual deviance: 24952  on 22038  degrees of freedom
AIC: 209010

Number of Fisher Scoring iterations: 1
```

Table 4. Model selection summary for spot negative binomial GLM of discard rate in numbers from shrimp trawl fisheries.

Drop	Df	Deviance	AIC	Pr(>Chi)
none	NA	24,952	209,010	NA
year	30	25,019	210,335	9.34E-273
season	1	24,953	209,009	1.94E-01
data_set	2	24,979	209,614	8.24E-133
state	3	25,033	210,685	0
depth_zone	2	24,953	209,012	5.48E-02

Table 5. Proportions used to partition effort data. Effort data are partitioned across depth zones first and then within each depth zone across fisheries.

	Depth Zone		
	=<10m	10-30m	>30m
proportion all effort	0.542	0.289	0.170
proportion penaeid shrimp effort	0.998	0.950	0.013
proportion rock shrimp effort	0.002	0.050	0.987

Table 6. Spot discard estimates in numbers (1,000s of fish) with 95% confidence intervals. Unadjusted estimates are estimates before making adjustments due to catch reductions by BRDs.

Year	Lower CI	Discards	Upper CI	Unadjusted Discards
1989	367,918	477,486	657,926	366,762
1990	613,194	768,864	1,023,870	590,573
1991	810,437	1,013,709	1,346,511	778,642
1992	125,693	157,735	210,251	121,158
1993	104,014	130,392	173,611	100,156
1994	203,152	254,402	338,344	195,409
1995	352,285	441,731	588,303	339,299
1996	76,030	95,179	126,539	73,108
1997	112,643	145,394	187,896	NA
1998	53,212	68,790	89,042	NA
1999	36,400	47,139	61,131	NA
2000	43,503	56,113	72,461	NA
2001	80,118	100,376	125,928	NA
2002	42,887	53,176	66,013	NA
2003	129,298	160,682	199,946	NA
2004	46,889	59,142	74,694	NA
2005	44,089	54,900	68,503	NA
2006	59,569	75,134	94,907	NA
2007	25,092	31,161	38,763	NA
2008	43,747	53,227	64,881	NA
2009	63,053	75,735	91,141	NA
2010	53,723	65,533	80,068	NA
2011	203,358	249,413	306,573	NA
2012	104,555	127,608	156,085	NA
2013	79,245	96,721	118,302	NA
2014	94,373	116,567	144,249	NA
2015	79,142	96,798	118,657	NA
2016	96,046	116,810	142,352	NA
2017	42,224	51,848	63,824	NA
2018	88,232	108,483	133,622	NA
2019	224,842	282,435	355,638	NA

Figures

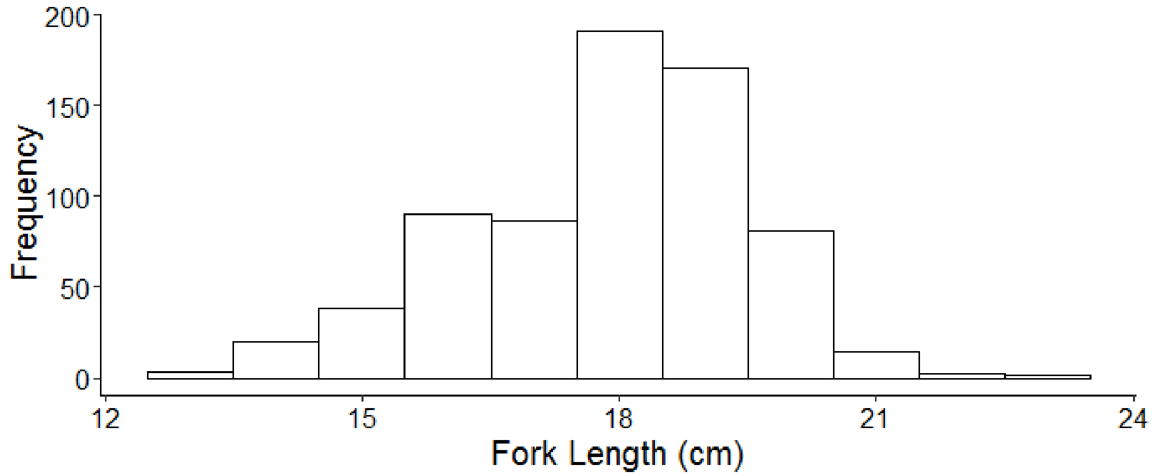

Figure 1. Length distribution of spot measured by shrimp trawl observers. All length samples were collected in 2003.

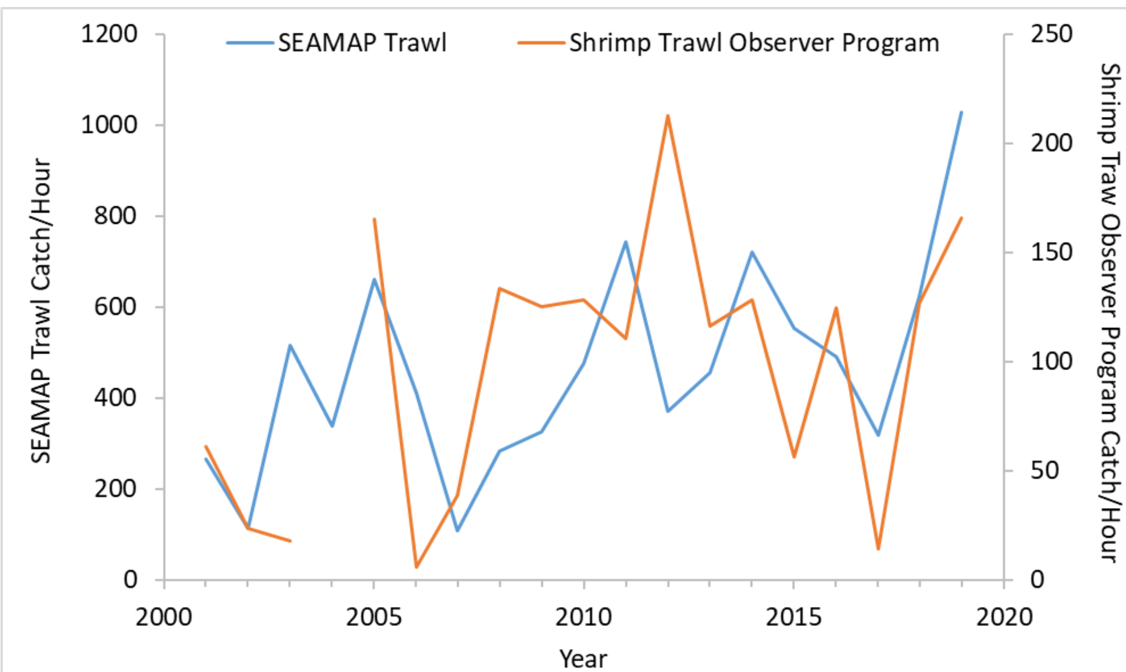

Figure 2. Annual mean CPUE of spot (number of fish/hour fished) during SEAMAP tows and observer program tows.

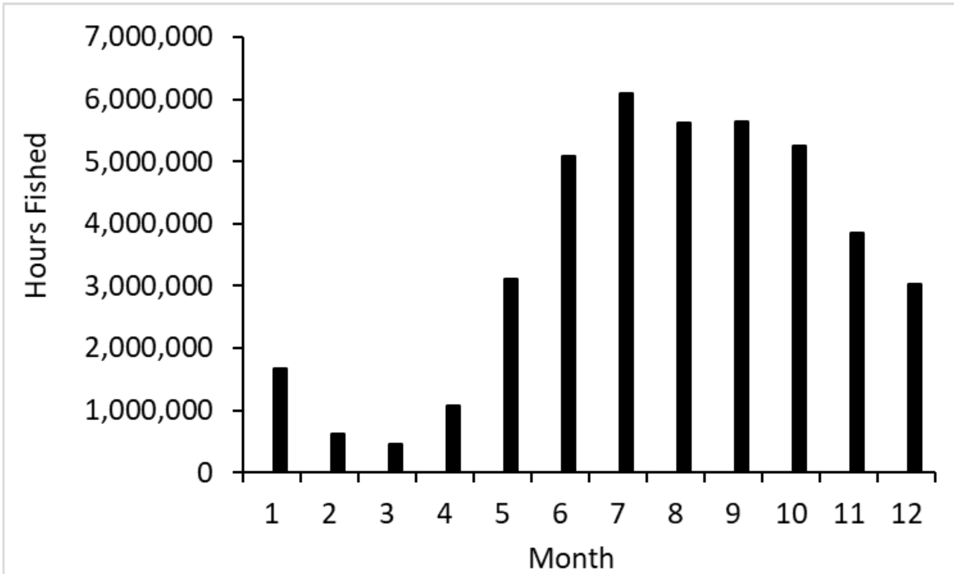

Figure 3. Shrimp trawl fishery effort (hours fished) by month.

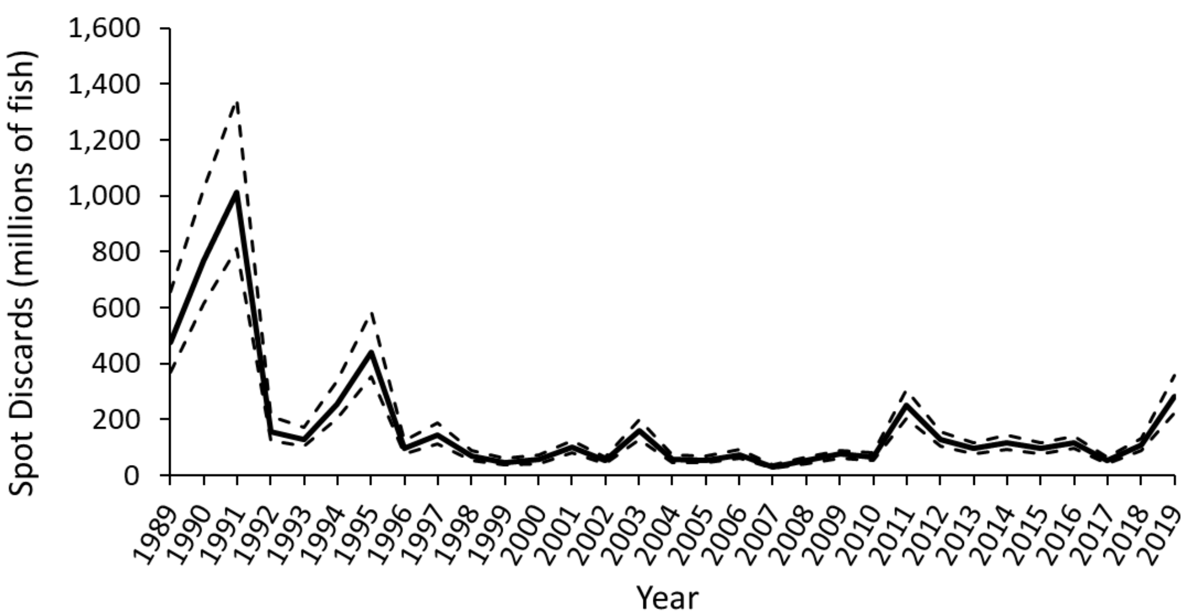

Figure 4. Spot discard estimates (millions of fish, solid line) from South Atlantic shrimp trawl fisheries with 95% confidence intervals (dashed lines).

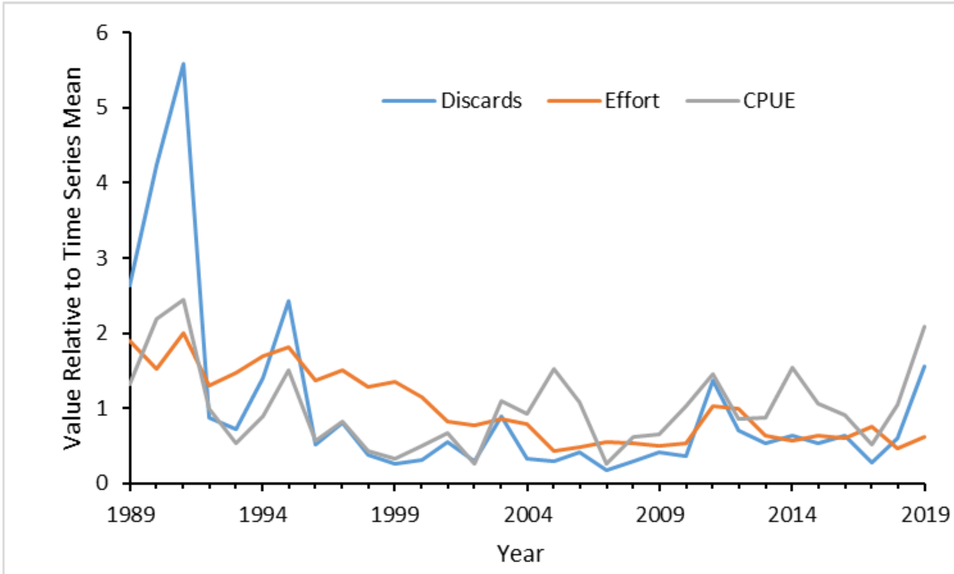

Figure 5. Shrimp trawl effort, spot discard estimates (numbers), and mean spot CPUE (number of fish/hour fished) scaled to time series means.

Appendix 1a. Shrimp trawl observer database net performance operation codes.

A - Nets not spread; typically doors are flipped or doors hung together so net could not spread.

B - Gear bogged; the net has picked up a large quantity of sand, clay, mud, or debris in the tail bag possibly affecting trawl performance.

C - Bag obstructed; the catch in the net is prevented from getting into the bag by something (i.e. grass, sticks, turtle, tires, metal/plastic containers etc.) or constriction of net (i.e. twisting of the lazy-line around net).

D - Gear not digging; the net is fishing off the bottom due to insufficient weight or not enough cable let out (etc.).

E - Twisted warp or line; the cables composing the bridle get twisted (from passing over blocks which occasionally must be removed before continuing to fish). Use this code if catch was affected.

F - Gear fouled; the gear has become entangled in itself or with another net. Typically this involves the webbing and some object like a float or chains or lazy line (etc.).

G -Bag untied; bag of net not tied when dragging net.

H - Rough weather. Bags mixed due to rough seas (too dangerous to separate); if the weather is so bad fishing is stopped, then the previous tow should receive this code if the rough conditions affected the catch.

I - Torn, damaged, or lost net; usually results from hanging the net and tearing it loose. The net comes back with large tears etc. if at all. Do not use this code if there are only a few broken meshes. Continue using this code until net is repaired or replaced

J - Dumped catch; tow was made but catch was discarded, perhaps because of too mud. Give reason in comments.

K - Catch not emptied on deck; nets brought to surface, boat changes location, nets redeployed. (explain in comments)

L - Hung up; untimely termination of a tow by a hang. Specify trawl(s) which were hung and caused lost time in Comments.

M - Bags dumped together, catches could not be kept separate.

N - Net did not fish; no apparent cause. Describe reasoning in comments.

O - Gear fouled on submerged object but tow was not terminated. Performance of tow could be affected. Give specifics in Comments.

P - No measurement taken of shrimp and/or total catch.

Q - Main cable breaks and entire rigging lost. Describe in Comments.

R - Net caught in wheel.

S - Tickler chain heavily fouled, tangled, or broken.

T - Other problems. Describe in comments.

U - Turtle excluder gear intentionally disabled.

V – Unknown operation code.

W - Damaged (i.e., bent or broken) excluder gear.

X - BRD intentionally disabled or non-functional. (Damaged) Describe in comments.

Y - Net trailing behind try net.

Z - Successful tow.