# An evaluation of sampling adequacy for Atlantic Menhaden fisheries

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**Submitted to:**
Eric Powell, Ph.D.
Director, Science Center for Marine Fisheries
703 East Beach Drive
Ocean Springs, MS 39564

**Prepared by:**
Geneviève M. Nesslage, Ph.D.
Assistant Research Professor
University of Maryland Center for Environmental Science
Chesapeake Biological Laboratory
PO Box 38
Solomons, MD 20688

Robert Leaf, Ph.D.
Assistant Professor
Division of Coastal Sciences
School of Ocean Science and Engineering
The University of Southern Mississippi
703 East Beach Drive
Ocean Springs, MS 39564

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
CHESAPEAKE BIOLOGICAL LABORATORY

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

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## Executive summary

### *Rationale and objectives*

The Atlantic Menhaden (*Brevoortia tyrannus*) stock supports the largest commercial fishery by volume on the East Coast (National Marine Fisheries Service 2017). In order to characterize the size and age composition of landings for use in stock assessment, data are collected through an extensive port sampling program. Biological samples allow for conversion of landings from weight to numbers caught by age class and provide critical information about the stock that allows the assessment model to track year class strength and estimate fishing mortality by age and fleet.

The goal of this study was to evaluate the adequacy of current and potential alternative port sampling targets in their ability to characterize the size and age composition of the Atlantic Menhaden reduction and bait fishery catch. Previous studies of the sampling program design were conducted in the 1950s and 1980s prior to the spatial contraction and decline in magnitude of reduction landings. In addition, the bait fishery sampling program has not been evaluated since 2012 when increased port sampling requirements were implemented with Amendment 2. Therefore, our objectives were to:

1. Assess the ability of the current reduction and bait fishery sampling programs to characterize the size and age composition of the catch.
2. Examine the relative performance of a suite of alternative reduction and bait fishery two-stage sampling targets.
3. Simulate the potential impact of ageing error on accuracy of sample age composition.

### *Methods*

We conducted a simulation study to evaluate the adequacy of the current reduction fishery sampling targets and to examine relative performance of a suite of alternative targets. We conducted a bootstrap analysis in which we extensively resampled the existing data, with replacement, across a range of current and alternative sampling schemes (i.e., combinations of number of trips and fish sampled). By comparing the coefficient of variation of the bootstrap distribution of size and proportions at age among different sampling schemes, we were able to examine tradeoffs between sampling intensity and uncertainty in the estimated size and age composition of the catch. We evaluated the potential impact of ageing error on accuracy of catch age composition estimates by multiplying the age composition of the resampled collections by an ageing error matrix.

### *Results*

Current sampling targets appear adequate for characterizing mean weight and fork length of fish caught. However, target sampling levels are not always achieved, particularly in northern regions and for most gears within the bait fishery. Current sampling intensity appears to be adequate for characterizing annual catch proportions at age for most age classes, particularly ages 2-3 y. Proportions of age 1 fish were better characterized in the southern region where they are more likely to reside prior to migrating northward as they age. However, proportions of age 4+ fish were poorly characterized in all regions and sectors likely due to the lack of spatial overlap between age 4+ fish habitat and current fishing activities. Thus, we urge caution when interpreting apparent fluctuations in the commercial age composition for ages 4+ Atlantic Menhaden.

Our results indicated that increased sampling of the reduction and purse seine bait fisheries above current target levels will not greatly improve the precision of estimates of catch age composition with the potential exception of proportions at age 4, assuming the fisheries overlap with their spatial distribution. In addition, our results indicate that reducing the number of fish sampled per trip to as few as 6 would have little impact on estimating the proportions at age in the catch. Therefore, it may be possible to increase efficiency of the sampling program by sampling fewer fish per trip. However, in both regions, the number of fish sampled per trip impacted estimation of catch size composition in the bait pound net fishery, indicating pound nets select for a wider range of fish sizes than the more active bait and reduction purse seines and cast net fisheries. Maintaining a target of 8-10+ fish per trip may be critical for properly sampling pound nets.

We observed a lack of trend in the impact of ageing error with increased sampling intensity, indicating that increased sampling will not alleviate issues with ageing fish 4+ and that including fish ages 4+ in the SCAA model used for stock assessment may result in the model chasing noise rather than tracking good year classes. In addition, consistency in the results of age composition analyses in this study between 2015 and 2016 suggest that changes in the primary scale reader at the NOAA Beaufort Laboratory during that time period did not result in directional (consistent over or under ageing) bias.

***Management impact***

This study has already impacted Atlantic Menhaden management by bringing to light problems with data delivery from the states that collect bait samples to the NOAA Beaufort Laboratory that analyzes and collates data for use in the stock assessment. While preparing data for this study we discovered that some states were not providing samples from the bait fishery in a timely fashion to NOAA Beaufort Laboratory (Appendix 1). This issue was rectified by the Atlantic States Marine Fisheries Commission (ASMFC) in time for inclusion of these missing data in the 2019 benchmark assessment.

In addition, concerns had been raised during the 2015 benchmark assessment regarding the ability of the port sampling program to characterize the size and age composition of the current reduction fishery catch given significant contraction of the fishery since the sampling program was last evaluated (Chester 1984). This resulted in the highest priority research recommendation for data collection in the most recent Atlantic Menhaden benchmark stock assessment being "to analyze sampling adequacy of the reduction fishery" (SEDAR 2015). Also, with expansion of the bait fishery and changes to sampling requirements with Amendment 2, an updated study was needed to demonstrate whether or not these new sampling targets were adequate for characterizing the size and age composition of the bait fishery catch.

Our results indicated that the reduction and bait fishery port sampling programs are likely more than adequate for characterizing the size composition of the catch which is required for converting weight to number of fish landed for the stock assessment. Also, we found that efficiency of the sampling program may be increased by sampling fewer fish per trip (minimum 6) without negatively impacting estimation of catch proportions at age. The ASMFC Atlantic Menhaden Technical Committee will be presented with the results of this study in early 2020 and will use our results to decide if the sampling program achieves an adequate level of precision when characterizing the age composition of the catch, a critical input in the statistical catch-at-age model used for management. Upon reviewing the results of this study, the TC may recommend future changes to the stock assessment model or to sampling target requirements in the Atlantic Menhaden Fishery Management Plan.

## Rationale

The Atlantic Menhaden (*Brevoortia tyrannus*) stock supports the largest commercial fishery by volume on the East Coast (National Marine Fisheries Service 2017). The fishery is composed of a purse seine reduction sector and a mixed-gear bait sector that account for approximately 76% and 24%, respectively, of coastwide landings in recent years (ASMFC 2017). In order to characterize the size and age composition of the landings for use in stock assessment, data are collected through an extensive port sampling program. Biological samples allow for conversion of landings from weight to numbers caught by age class and provide critical information about the stock that allows the assessment model to track year class strength and estimate fishing mortality by age and fleet.

The reduction fishery port sampling program for Atlantic Menhaden has been conducted since 1955 by the Beaufort Laboratory of the National Marine Fisheries Service (ASMFC 2017). A two-stage cluster sampling scheme is employed in which the primary sampling unit is the fishing trip sampled and the secondary sampling unit is the individual fish (June and Reintjes 1959; Chester 1984). Agents randomly select vessels dockside and retrieve a bucket of fish from the top of the vessel's hold, which is representative of fish collected during the last set of the day (SEDAR 2015). A subset of fish is then selected by the agent at random from the bucket. Each fish is measured (fork length in mm), weighed (grams), and a collection of scales (n=10) are removed, cleaned, and mounted on a glass microscope slide for ageing. Given the schooling nature of Atlantic Menhaden, each trip sampled is assumed to be an independent sampling event (ASMFC 2017). Sampling is typically conducted throughout the fishing season and across all ports of landing to account for seasonal growth (i.e. length-at-age) and migration patterns.

The reduction fishery port sampling program design was modified over time as scientific understanding of Atlantic Menhaden biology grew and the nature of the fishery changed. Soon after implementation of the reduction port sampling program, June and Reintjes (1959) conducted a study of the homogeneity of the reduction fishery catch and determined that a sample size of 20 fish per trip was adequate to estimate mean length of fish in a purse seine to within +-2% (Chester 1984). Variability among trips was also found to be much greater than within a trip. Therefore, sampling protocols were changed in 1971 from a target of 10-15 trips per port and week (hereafter, "port/week") with 20 fish sampled per trip to a new target of 20-25 trips per port/week and 10 fish per trip (Figures 1-2). As the number of active reduction plants and fleet size declined (Figure 3), the average number of trips sampled per port/week (Figure 1), total number of trips per year (Figure 4), and the number of fish collected from each trip decreased (Figure 2). Chester (1984) conducted an in-depth analysis of the port sampling program and suggested that the minimum number of trips sampled should be 10 per port/week to adequately characterize the size and age composition of the catch at the port/week level. Although even greater declines in the spatial extent and magnitude of the reduction fishery have occurred since Chester's 1984 study (SEDAR 2015), the reduction fishery port sampling program has not been recently re-evaluated to determine if the sampling program is meeting its goals. Thus, the highest priority research recommendation for data collection made in the most recent Atlantic Menhaden benchmark stock assessment was to "analyze sampling adequacy of the reduction fishery" (SEDAR 2015).

Port sampling of the bait fishery for Atlantic Menhaden began in 1985 using 10 fish per trip as a guideline but with no established sampling targets for the number of trips (Figure 5). As the magnitude of the bait fishery increased in the late 2000s, the Atlantic States Marine Fisheries Commission's Atlantic Menhaden Management Board expressed interest in establishing regional port sampling targets. A power analysis was conducted in 2012 to determine the number of trips that should be sampled across the species' range (McNamee 2012). The results of this analysis were used to set landings-based port sampling requirements for the bait fishery as outlined in Amendment 2 to the Fishery Management Plan for Atlantic Menhaden (ASMFC 2012). Although the number of samples collected since Amendment 2 was adopted has increased (Figures 6), adequacy of the new bait fishery port sampling requirements has not been recently evaluated.

The goal of this study was to evaluate the adequacy of current and potential alternative two-stage sampling targets in characterizing the size and age composition of the Atlantic Menhaden reduction and bait fishery landings. Previous studies of the sampling program design were limited to analytical approaches (June and Reintjes 1959; Chester 1984; Chester and Waters 1985). With the advent of high speed computing, a more complex and thorough simulation study can be conducted that examines the combined effects of sampling more or fewer trips and individual fish as well as the impact of ageing error on fishery catch composition estimates.

## Objectives

The objectives of our study were to:

1. Assess the ability of the current reduction and bait fishery sampling programs to characterize the size and age composition of the catch.
2. Examine the relative performance of a suite of alternative reduction and bait fishery two-stage sampling targets.
3. Simulate the potential impact of ageing error on accuracy of sample age composition.

## Methods

We conducted a simulation study to evaluate the adequacy of current reduction and bait fishery sampling targets and to examine relative performance of a suite of alternatives targets. We conducted a bootstrap analysis in which we extensively and systematically resampled the existing data with replacement across a range of current and alternative sampling schemes (i.e., combinations of number of trips and fish sampled). By comparing the coefficient of variation of the bootstrap distribution of size and proportions at age among different sampling schemes, we were able to examine tradeoffs between sampling intensity and uncertainty in the estimated size and age composition of the catch (Manly 2007).

### *Biological sampling data*

We focused our study on the two most recent years for which data were available at the start of the project (2016 and 2015) because extensive changes have occurred in the Atlantic Menhaden stock, fishery, and management plan from 1955 to 2012 (ASMFC 2017). Thus, 2015-2016 were assumed to most closely reflect current and near future stock and fishery conditions. Analysis of 2015-2016 data also allowed us to look for apparent large differences in age data given the transition in primary readers that occurred at NOAA Beaufort Laboratory in 2016. During 2015-2016, only one reduction plant in Reedville, VA was operational. In contrast, numerous ports from NC to MA and gear types were sampled to obtain data from the bait sector.

In the stock assessment model used in management of Atlantic Menhaden, both the reduction and bait fleets are divided into northern and southern regions to account for spatial changes in the fishery over time relative to the extent of the coastwide stock (ASMFC 2017). Therefore, we analyzed performance of various two-stage sampling schemes at the regional scale for each sector to provide results that would be most informative to future stock assessments. Note that fisheries operating in the South Atlantic region are very small; thus, available samples were insufficient for evaluation in this study. A complete list of simulations conducted in this study are summarized in Table 1.

***Simulation study***

We evaluated the performance of various sampling targets on metrics important to the statistical catch-at-age (SCAA) stock assessment model used in Atlantic Menhaden management, namely accuracy of the mean size and age composition of fish landed. The SCAA models the population in terms of abundance, and thus requires that landings be converted from weight to numbers caught. Mean weight of fish collected in port samples from the reduction fishery in a given port/week is used to convert landings (t) to number of fish landed (SEDAR 2015). Therefore, our simulation study evaluated the impact of sample size on mean weight of the reduction catch at the port/week level by year and region. For the bait fishery, mean weight of fish sampled is calculated after pooling the data by gear and year because of differences in gear selectivity and the small number of samples collected from the bait fishery in most years (SEDAR 2015). Thus, our simulation study evaluated the impact of sample size on mean weight of the bait catch by gear, region, and year. Fork length data were treated similarly to weight. When generating catch-at-age estimates for the SCAA, port sampling age composition data are pooled annually by region for both sectors. Thus, our evaluation of sample size on estimation of catch age composition was conducted at the sector, year, and region level.

In order to assess the two-stage cluster sampling design employed in the Atlantic Menhaden port sampling program, we examined the combined effects of both the number of trips sampled and the number of individual fish sampled from each trip by sector and region. For the reduction fishery, port/weeks with <8 trips and fish collections with <8 fish per trip were not used in the simulation study to ensure sampling data were representative and adequate for resampling. Using the remaining data, we first evaluated the effect of sampling targets on estimated size composition of the catch at the port/week level. The first stage of the two-stage cluster sampling design was simulated such that between 2 and 20 trips were randomly selected with replacement in each port/week. We then simulated the random selection with replacement of between 2 and 20 individual fish from each trip selected. Thus, our simulated sample target combinations spanned 20 trips per port/week with 2 fish sampled per trip to 2 trips per port/week and 20 fish per trip. This resampling procedure for each trip/fish sample size combination was then repeated 1,000 times, and the coefficient of variation for the distribution of mean weight and length of fish caught per port/week was calculated for the reduction fishery. The same procedure was used for the bait fishery with the exception that data were pooled across gears within a year instead of by port/week.

Next, we evaluated the effect of sampling targets on estimated age composition of the catch at the annual level by region for each sector. In the first stage, a subset of trips per year was selected with replacement; the range of trips selected for resampling was chosen based on reasonable fishery performance expectations for each sector and region, spanning approximately 50% fewer to approximately 25% more trips sampled in recent years. From each trip selected, we then simulated the random selection with replacement of 2 to 20 individual fish. This resampling procedure for each trip/fish sample size combination was then repeated 1,000 times, and the coefficient of variation for the distribution of proportions at age in the catch was calculated.

We evaluated the potential impact of ageing error on accuracy of catch age composition estimates by multiplying the age composition of the resampled collections by an ageing error matrix. This ageing error matrix was generated by NOAA Beaufort Laboratory based on a study in which the same technician re-reads of a subset of scales from across the time series of available port samples (SEDAR 2015); ageing was informed by the length and date of capture. Assuming the simulated samples approximated the true age composition of the catch, we calculated the percent relative error (RE) in age composition of the catch by age class (*a*), using the equation:

$$RE_a = \frac{ACerror_a - ACsim_a}{ACsim_a} \times 100$$

for each ageing error matrix, such that *ACsim* was the simulated age composition and *ACerror* was the age composition with estimated ageing error applied.

## Results

In general, low interannual variability in simulation results resulted in similar conclusions for both years. Therefore, for brevity, results using 2016 data are presented below. Results using 2015 data are available as supplemental materials[1].

### *Weight and fork length*

At current target sampling levels of 10 trips per port/week and 10 fish sampled per trip, the bootstrap distribution coefficient of variation (CV) for mean weight and fork length of the catch by port/week (reduction) or gear (bait) was generally <10% for the reduction and <5% for the bait fishery in both regions. As expected, increasing the number of simulated trips that were sampled resulted in a lower CV, and decreasing the number of simulated trips resulted in a higher CV. However, low to moderate reductions in CV were achieved with either increased or decreased number of fish sampled per trip. Across all simulations, the CV of the bootstrap distribution of mean weight of the catch was typically higher than that of fork length.

Reduction fishery operations in the northern region have been limited in recent years. Thus, reported landings were insufficient for resampling in 2015 and sufficient for resampling in only three port/weeks in 2016 (Figure 7). In those port/weeks in which the fishery was active in the northern region, the bootstrap distribution CV ranged from approximately 1-22% for mean weight and 0.5-9% for mean fork length of fish in the catch. In the southern region where the

[1] Additional materials available on line at http://bit.ly/2UTI0gh.

fishery primarily operates, bootstrap distribution CVs for mean weight and fork length of fish in the reduction catch by port/week ranged from approximately 3-22% and 0.5-9%, respectively (Figure 8).

For the northern region bait fishery, the bootstrap distribution CV for mean weight of fish in the catch by gear in 2016 ranged from approximately 0.5-3% for bait purse seines, 2-5% for pound nets, and 2.5-5% for cast nets (Figure 9A); the bootstrap distribution CV for mean fork length of fish in the catch ranged from approximately 0.2-0.75% for bait purse seines, 0.75-1.75% for pound nets, and 0.75-1.75% for cast nets (Figure 9B). For the southern region bait fishery, the bootstrap distribution CV for mean weight of fish in the catch by gear in 2016 ranged from approximately 1.5-5% for bait purse seines and 0.5-3% for pound nets (Figure 10A); the bootstrap distribution CV for mean fork length of fish in the catch ranged from approximately 0.75-1.75% for bait purse seines and 0.25-1% for pound nets (Figure 10B). In both regions, a larger effect of the number of fish sampled per trip was observed in the pound net fishery.

***Proportions at age***

The bootstrap distribution CV for proportions at age in the northern reduction fishery (Figure 11) was relatively high for age 1 (range ~20-70%) and 4 (range ~25-100%). A lower bootstrap distribution CV was observed for proportions at age 2 (range ~10-33%) and age 3 (range ~10-35%). The number of fish sampled per trip had a greater impact on bootstrap distribution CV with increasing age. In the southern region, the bootstrap distribution CV for proportions at age (Figure 12) was relatively high for age 4 (range ~35-100%). A lower bootstrap distribution CV was observed for proportion at age 1 (range ~8-14%), age 2 (range ~3-8%), and age 3 (range ~ 8-19%). Too few samples of ages 5+ were encountered to calculate the CV of the bootstrap age distributions.

Similar to the northern reduction fishery, the northern bait fishery exhibited higher bootstrap distribution CVs for proportions at ages 1 (range ~20-40%) and 4 (range ~20-50%; Figure 13). The bootstrap distribution CV for proportions at age 2 (range ~5-12%) and age 3 (range ~5-12%) were lower than ages 1 and 4. In the southern region, the bootstrap distribution CV for proportions at age (Figure 14) was relatively high for age 4 (range ~25-125%). A lower bootstrap distribution CV was observed for proportion at age 1 (range ~14-33%), age 2 (range ~5-20%), and age 3 (range ~10-25%). Too few samples of ages 5+ were encountered to calculate the CV of the bootstrap age distributions. In contrast to reduction fishery results, the impact of number of fish sampled per bait fishery trip on the bootstrap distribution CV did not increase linearly with age.

***Ageing error***

The impact of applying estimated ageing error to bootstrapped proportions at age across all regions and sectors (Figures 15-18) was relatively low (range ±1-12%) for ages 1-3, but large for age 4 (range ~90-500%). The number of fish sampled per trip did not impact relative error in proportions at age. In situations where increasing the number of trips reduced the impact of ageing error, such as the northern reduction fishery, the change in relative error in Atlantic Menhaden proportions at age was typically <2%.

## Discussion

This study evaluated the ability of current and alternative port sampling targets to characterize the size and age composition of the current Atlantic Menhaden commercial fishery catch. In general, current sampling targets appear to be adequate for characterizing mean weight and fork length of fish caught (Figures 7-10). Our results confirmed that of previous studies which found Atlantic Menhaden schools captured in the purse seine reduction fishery to be highly homogeneous with regards to size (June and Reintjes 1959; Chester 1984; Chester and Waters 1985). Fewer fish per trip could be sampled if we were only concerned with characterizing the mean size of fish in the catch. However, this study demonstrated that characterizing the age composition of the catch requires higher sampling intensity than characterizing size alone (Figures 11-14). Whether this is due to ageing error (Figures 15-18) or fish of similar sizes but different ages schooling together is unknown.

### *Weight and fork length*

Although current sampling targets of 10 trips per port/week and 10 fish per trip achieved low CVs for the bootstrap distribution of mean weight and fork length of the catch, it should be noted that the number of trips actually sampled on average in 2016 was 4 trips per port/week in the northern component of the reduction fishery and 6 trips per port/week in the southern reduction fishery (Figure 19). The shortfall in number of trips sampled may be due to a combination of fewer trips conducted per port/week relative to previous decades when the fishery was larger (Figure 1) or weather complications. By not achieving the target number of trips per port/week, the CV for mean weight and fork length of the catch actually achieved is larger than the target by 50-100% in some port/weeks (Figures 7-8). However, the CV for both measures of mean size of the catch was already quite small such that the actual CV achieved remained at or below 10% at achieved sampling levels. The average number of fish sampled per trip in both regions was 9 (Figure 20), which is likely less than the target of 10 due to damaged or otherwise unreadable scale collections. Reducing the number of fish sampled per trip had a very small impact on estimating the mean size of the catch, indicating fish caught in the same school are highly homogenous with regards to size.

Evaluating sampling achieved relative to target levels is more difficult for the bait fishery because sampling requirements are based on metric tons landed by state not gear and region (the units at which the data are pooled for use in the stock assessment). Given the small number of operators in the Atlantic Menhaden bait fishery, landings data at the region and gear level are confidential; therefore, we are unable to report the achieved sampling levels relative to target sampling levels. In general, the northern purse seine bait fishery is large enough such that the total number of trips sampled per year is likely adequate to characterize the size composition of the catch. However, sampling of the southern purse seine bait fishery and the pound net and cast fisheries may be too small to adequately characterize the size composition of the catch from these small fisheries which could impact accuracy of the weight to number conversion for landings in the stock assessment. This concern is likely outweighed at present by the fact that the bait fishery, particularly for these smaller gear subsectors, comprises a very small fraction of total landings. Should these fisheries expand in the future, this study will provide guidance for increasing target sampling levels.

***Proportions at age***

The total number of trips sampled in 2016 was 70 in the northern component of the reduction fishery and 180 in the southern reduction fishery (Figure 21). There are no established total annual target number of trips for characterizing the age composition of the Atlantic Menhaden reduction fishery. However, current sampling levels appear to have achieved reasonably low CVs for the bootstrap distribution of annual catch proportions at age for most age classes, particularly ages 2-3 (Figures 11-14). Proportions of age 4+ fish were poorly characterized in all regions and sectors likely due to their rarity in the commercial fisheries. Age 4+ fish are typically encountered farther offshore and in more northerly regions of their range where they are not often encountered by most of the current reduction or inshore bait fishery (SEDAR 2015). Proportions of age 1 fish were well characterized in the southern region where they are more likely to reside prior to migrating northward as they age (Liljestrand et al. 2019); catches of age 1 fish in the northern region are rarer and thus CVs were higher for both sectors.

As expected based on sampling theory (Manly 2007), increasing the number of trips sampled per port/week (reduction) or year (bait) resulted in a lower CV for the distribution of proportions at age. However, our results indicated that increased sampling of the reduction and purse seine bait fisheries above current target levels will not greatly improve characterization of catch age composition with the potential exception of proportions at age 4. In some situations, such as the northern reduction fishery, port samplers are likely already sampling nearly all of the available trips per port/week. Given how few trips are taken in the northern region, increasing sampling may not be feasible. Similarly, it may not be possible to improve sampling for age 4 fish given the lack of spatial overlap between their locations and current fishing activities.

Our results indicate that reducing the number fish sampled per trip to as few as 6 would have little impact on estimating the proportions at age in the catch (Figure 11-14). It may be possible to increase efficiency and effectiveness of the sampling program by sampling fewer fish per trip but more trips per port/week or gear, when possible. However, in both regions, the number of fish sampled per trip impacted estimation of catch composition in the bait pound net fishery, indicating pound nets select for a wider range of fish sizes and ages than the more active bait and reduction purse seines and cast net fisheries. Pound nets are static gear and may interact with multiple schools composed of fish of different sizes and ages within a given period of soak time than other gears. Thus, maintaining a target of 8-10+ fish sampled/trip may be critical for sampling pound nets.

***Ageing error***

When ageing error was applied to bootstrap distributions of Atlantic Menhaden proportions at age in the catch, we observed a lack of trend in relative error with increased sampling intensity (Figures 15-18). This lack of relationship indicates that increased sampling will not fix the problem. More accurate ageing techniques will be required to improve age composition estimation for the commercial catch. High relative error for proportions of age 4 in the catch also indicates that including fish ages 4+ in the SCAA model used for stock assessment may result in the model chasing noise rather than tracking good year classes. In addition, consistency in the results of age composition analyses in this study between 2015 and 2016 suggest that changes in the primary scale reader at the NOAA Beaufort Laboratory during that time period did not result in obvious patterning or bias.

***Study limitations***

This study assumed that the available port sampling data for reduction and bait fisheries represented the full range of sizes and ages in the commercial catch. Appearance of age 5+ fish was so rare in recent years that we were unable to assess the adequacy of the sampling program for these older age classes, possibly due to contraction of the reduction fishery out of the range of the larger, older Atlantic Menhaden. To address this concern, we preformed the same resampling procedures on data collected in 1969, prior to large reductions in the number of trips and fish per trip (Figures 22-23). Both size and age composition results were on par with that of 2016, indicating that our results are not unique to recent years and that the current sampling scheme is adequate to produce representative data for this resampling study. However, if significant shifts in the geographic distribution of the fish or fishery occur in the future, this analysis should be repeated to provide updated advice to menhaden scientists and managers.

This study provides guidance on the ability of the current Atlantic Menhaden port sampling program to characterize the size and age distribution of the commercial catch. This catch composition information is used to generate inputs to the stock assessment model such as the catch-at-age matrix. To determine the ultimate impact of these results on the SCAA assessment model outcomes, these resampled data sets would need to be passed through the data preparation and modeling processes in order to quantify the impact of the sampling program on model estimates. This is a natural next step and will be pursued in future studies.

## Management impact

This study has already impacted Atlantic Menhaden management by bringing to light problems with data delivery from the states that collect bait samples to the NOAA Beaufort Laboratory that analyzes and collates data for use in the stock assessment. While preparing data for this study we discovered that some states were not providing samples from the bait fishery in a timely fashion to NOAA Beaufort Laboratory (Appendix 1). This issue was rectified by the ASMFC in time for inclusion of these missing data in the 2019 benchmark assessment.

In addition, concerns had been raised during the 2015 benchmark assessment regarding the ability of the port sampling program to characterize the size and age composition of the current reduction fishery catch given significant contraction of the fishery since the sampling program was last evaluated (Chester 1984). This resulted in the highest priority research recommendation for data collection in the most recent Atlantic Menhaden benchmark stock assessment being “to analyze sampling adequacy of the reduction fishery” (SEDAR 2015). Also, with expansion of the bait fishery and changes to sampling requirements with Amendment 2, an updated study was needed to demonstrate whether or not these new sampling targets were adequate for characterizing the size and age composition of the bait fishery catch. Our results indicated that the reduction and bait fishery port sampling programs are likely more than adequate for characterizing the size composition of the catch, which is required for converting weight to number of fish landed the stock assessment. The ASMFC Atlantic Menhaden Technical Committee will be presented with the results of this study in early 2020 and will use our results to decide if the sampling program achieves an adequate level of precision when characterizing the age composition of the catch, a critical input in the statistical catch-at-age model used for management. Upon reviewing the results of this study, the TC may recommend changes in sampling requirements for future amendments to the Atlantic Menhaden Fishery Management Plan.


## Acknowledgments

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## Tables

Table 1. Summary of regions, sectors, and sampling areas with sufficient port sampling data to be evaluated in this simulation study. Area 1 includes samples collected from Maine to Connecticut. Area 2 includes New York to coastal Maryland. Area 3 includes Chesapeake Bay and coastal Virginia. Area 4 includes North Carolina to Florida.

| Year | Sector | Region | Areas |
|---|---|---|---|
| 2016 | Reduction | North | 1, 2 |
| 2016 | Reduction | South | 3, 4 |
| 2015 | Reduction | South | 3, 4 |
| 2016 | Bait | North | 1, 2 |
| 2015 | Bait | North | 1, 2 |
| 2016 | Bait | South | 3, 4 |
| 2015 | Bait | South | 3, 4 |
| 1969 | Reduction | South | 3, 4 |

## Figures

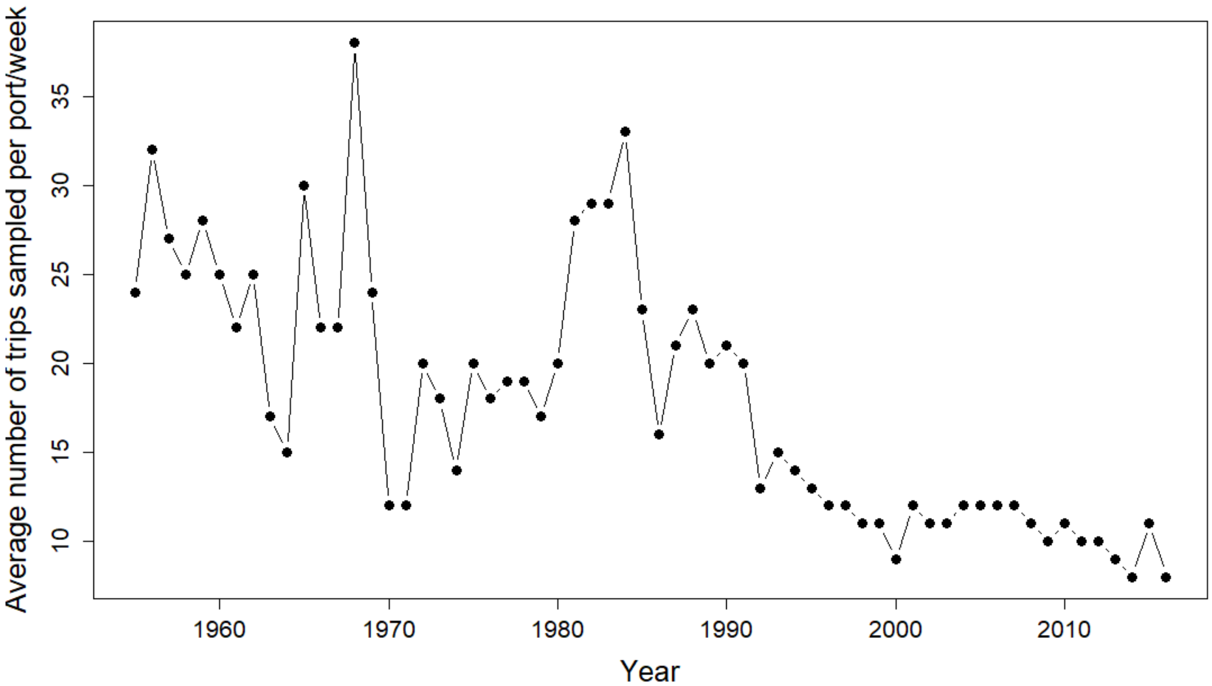


Figure 1. Average number of trips sampled per port/week in the Atlantic Menhaden reduction fishery port sampling program.

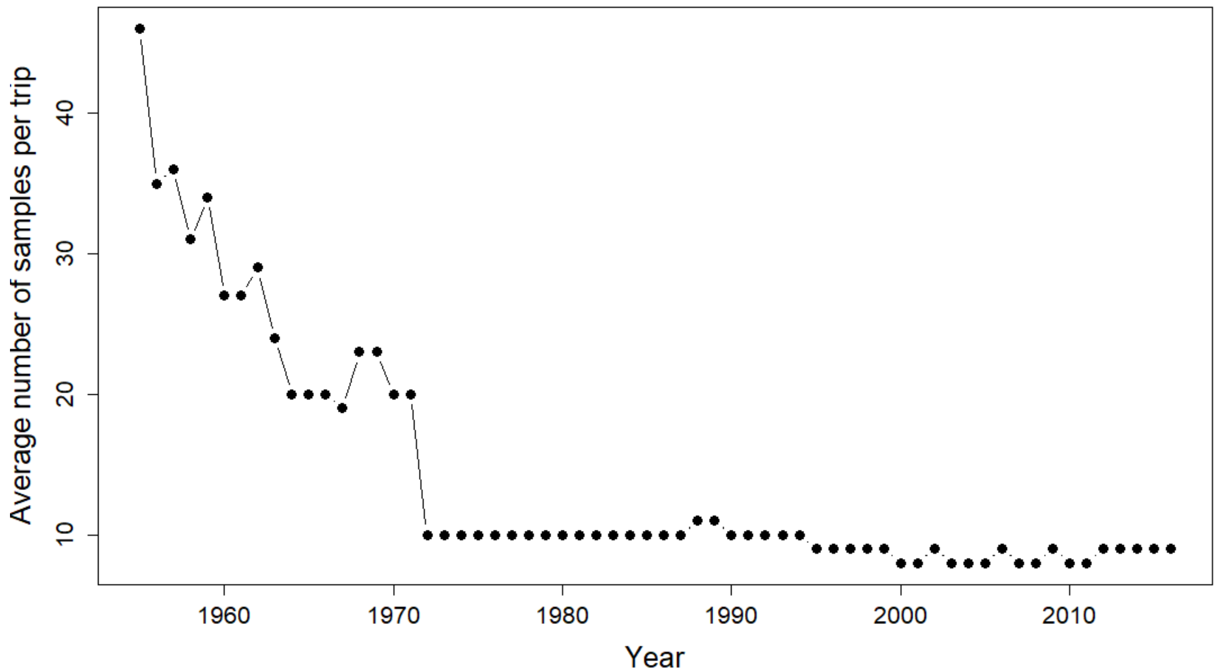


Figure 2. Average number of fish sampled per trip in the Atlantic Menhaden reduction fishery port sampling program.

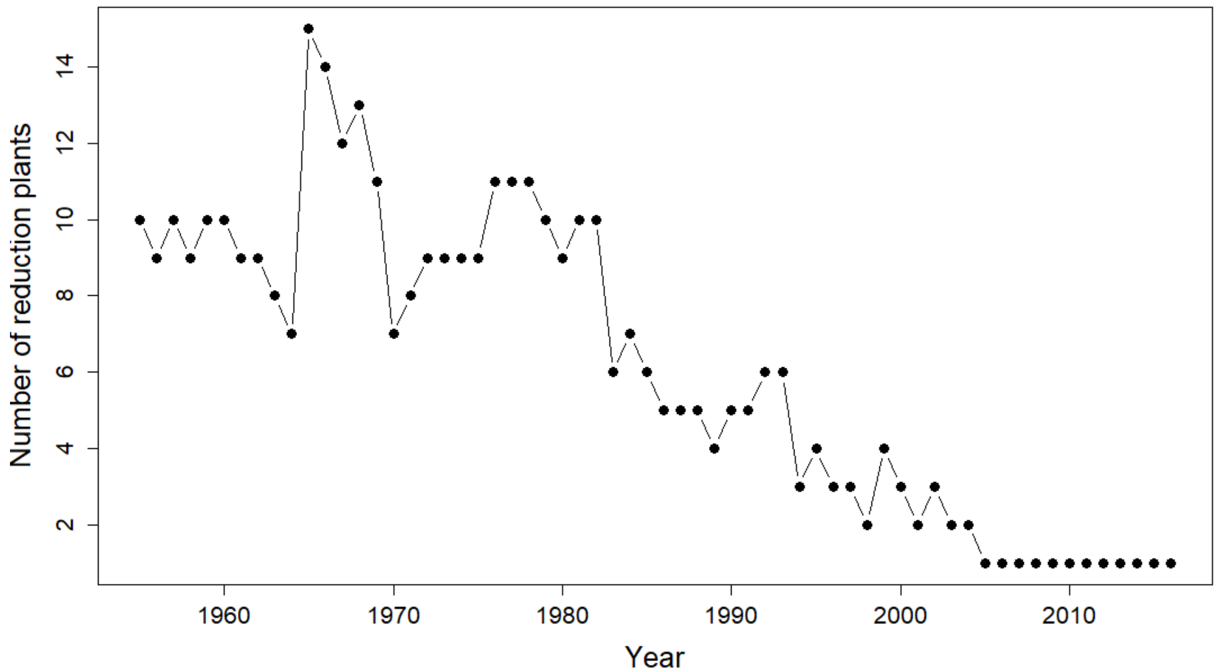


Figure 3. Number of Atlantic Menhaden reduction plants on the East Coast since inception of the NOAA Beaufort Laboratory port sampling program in 1955.

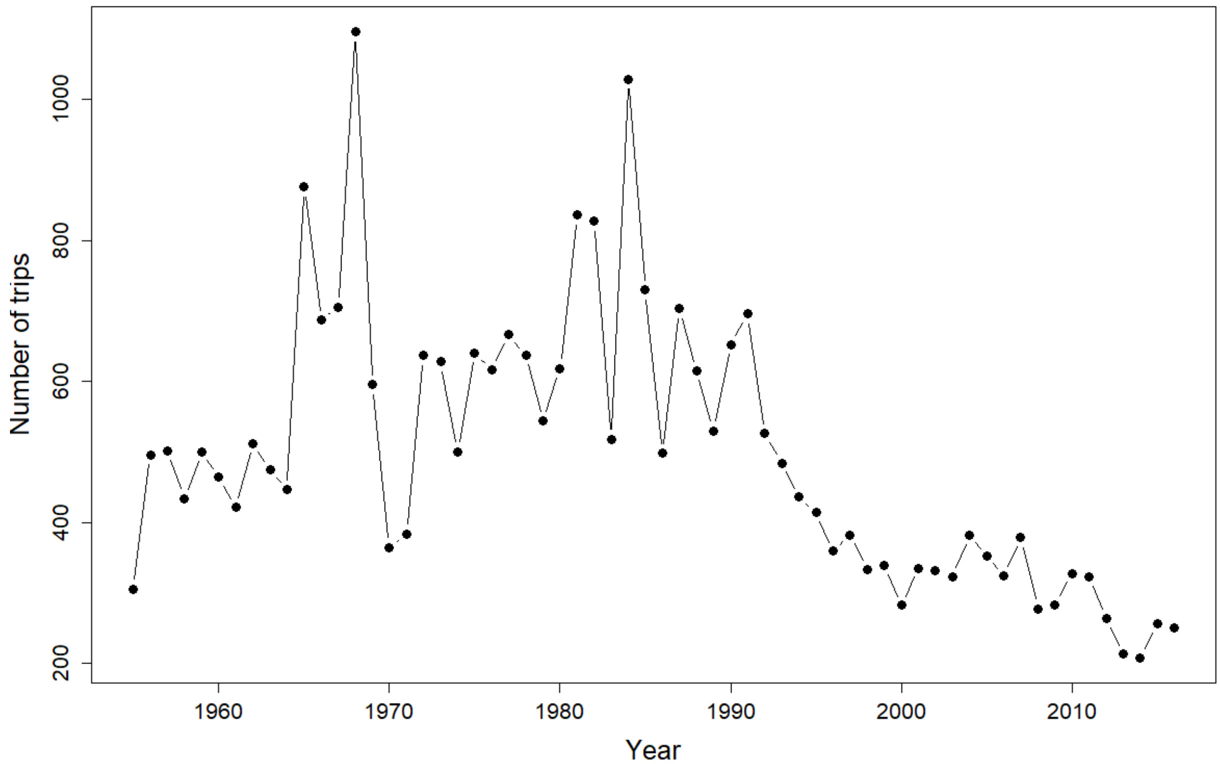


Figure 4. Total number of trips sampled per year in the Atlantic Menhaden reduction fishery port sampling program.

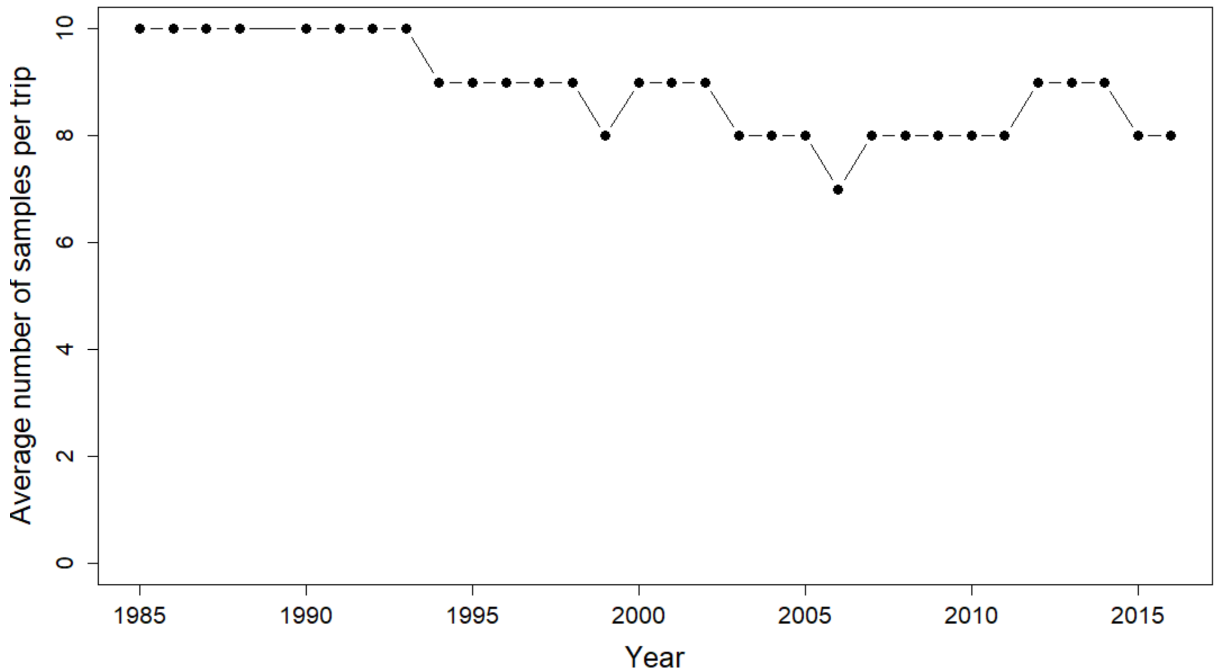


Figure 5. Average number of individual fish sampled per trip in the Atlantic Menhaden bait fishery port sampling program.

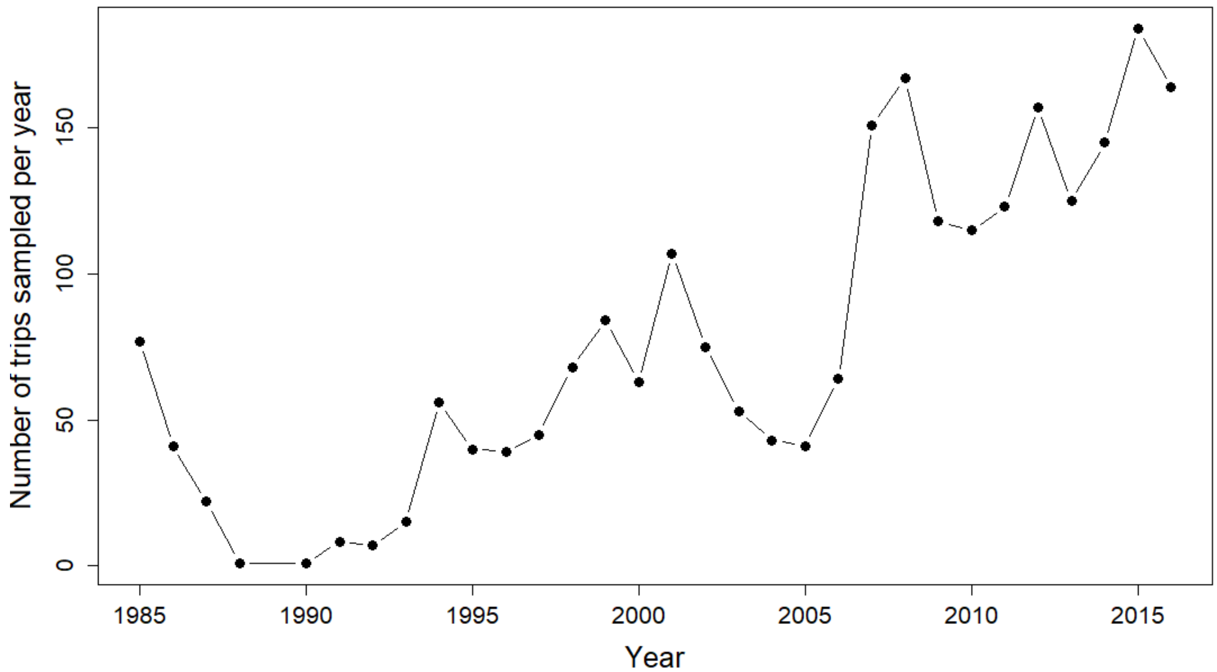


Figure 6. Number of trips sampled per year in the Atlantic Menhaden bait fishery port sampling program.

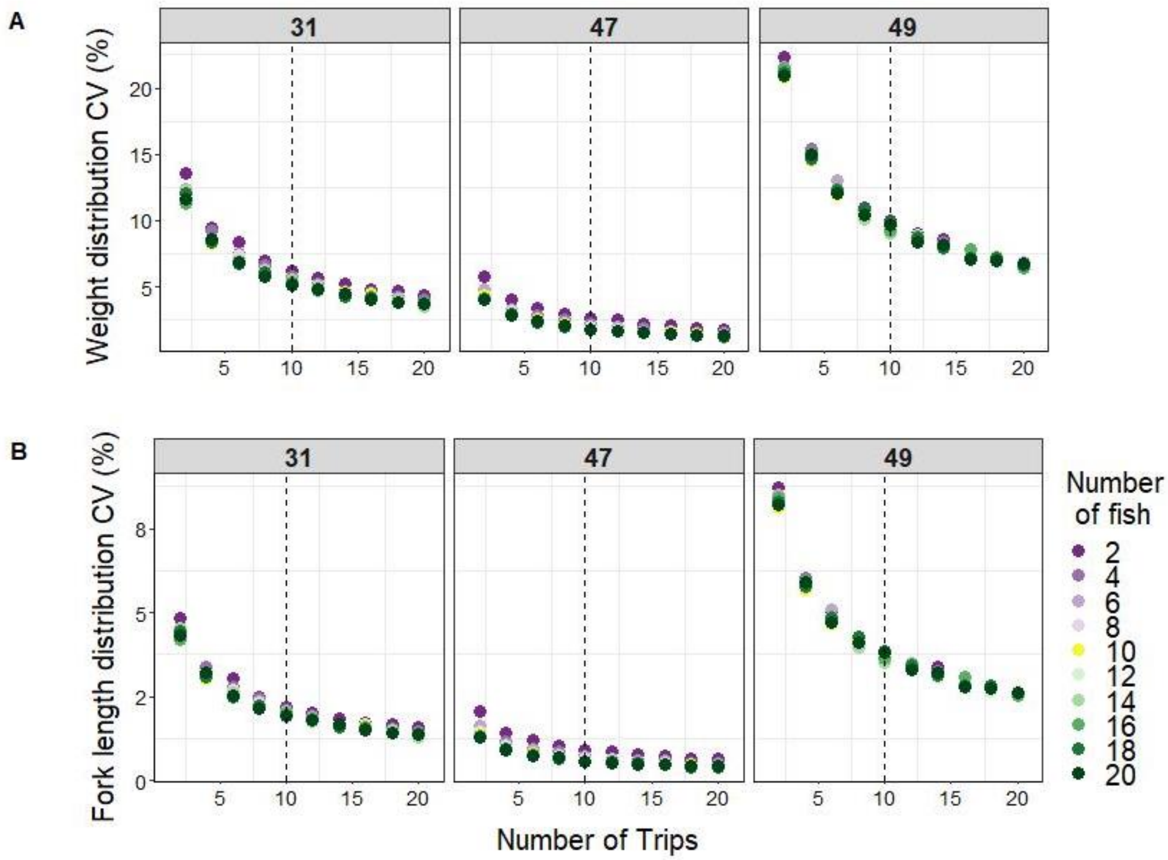


Figure 7. Bootstrap distribution coefficient of variation for Atlantic Menhaden mean catch A) weight and B) fork length by resample size (x-axis: number or trips sampled per portweek; point color: number of fish samples collected per trip) for the reduction fishery in the northern region, 2016. Panels represent portweeks for which adequate samples were available. A dashed bar indicates the current target of 10 trips per week and a yellow point represents the current target of 10 fish sampled per trip.

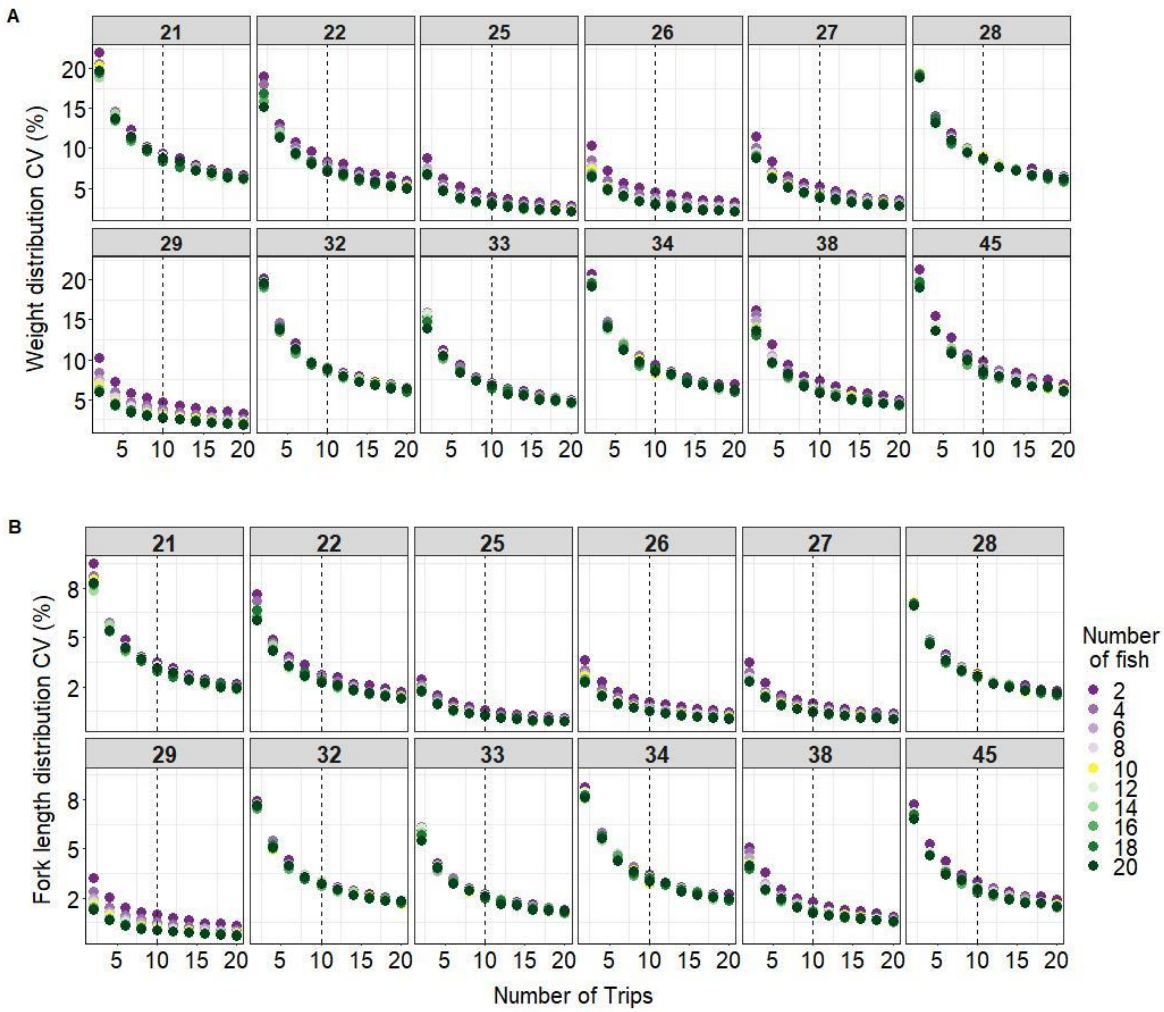


Figure 8. Bootstrap distribution coefficient of variation for Atlantic Menhaden mean catch A) weight and B) fork length by resample size (x-axis: number or trips sampled per portweek; point color: number of fish samples collected per trip) for the reduction fishery in the southern region, 2016. Panels represent portweeks for which adequate samples were available. A dashed bar indicates the current target of 10 trips per week and a yellow point represents the current target of 10 fish sampled per trip.

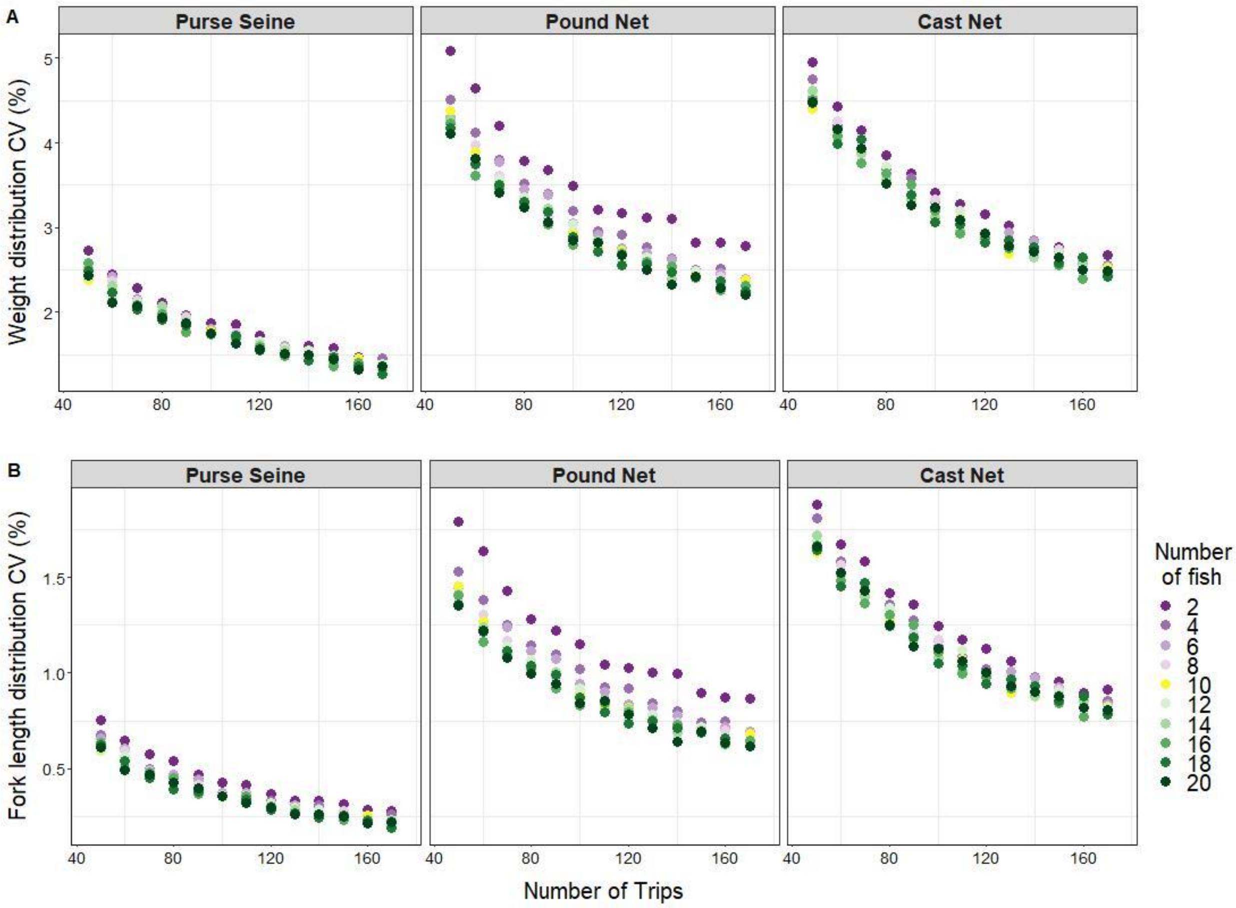


Figure 9. Bootstrap distribution coefficient of variation for Atlantic Menhaden mean catch A) weight and B) fork length by resample size (x-axis: number or trips sampled per year; point color: number of fish samples collected per trip) for the bait fishery in the northern region, 2016. Panels represent gears for which adequate samples were available. A dashed bar indicates the current target of 10 trips per week and a yellow point represents the current target of 10 fish sampled per trip.

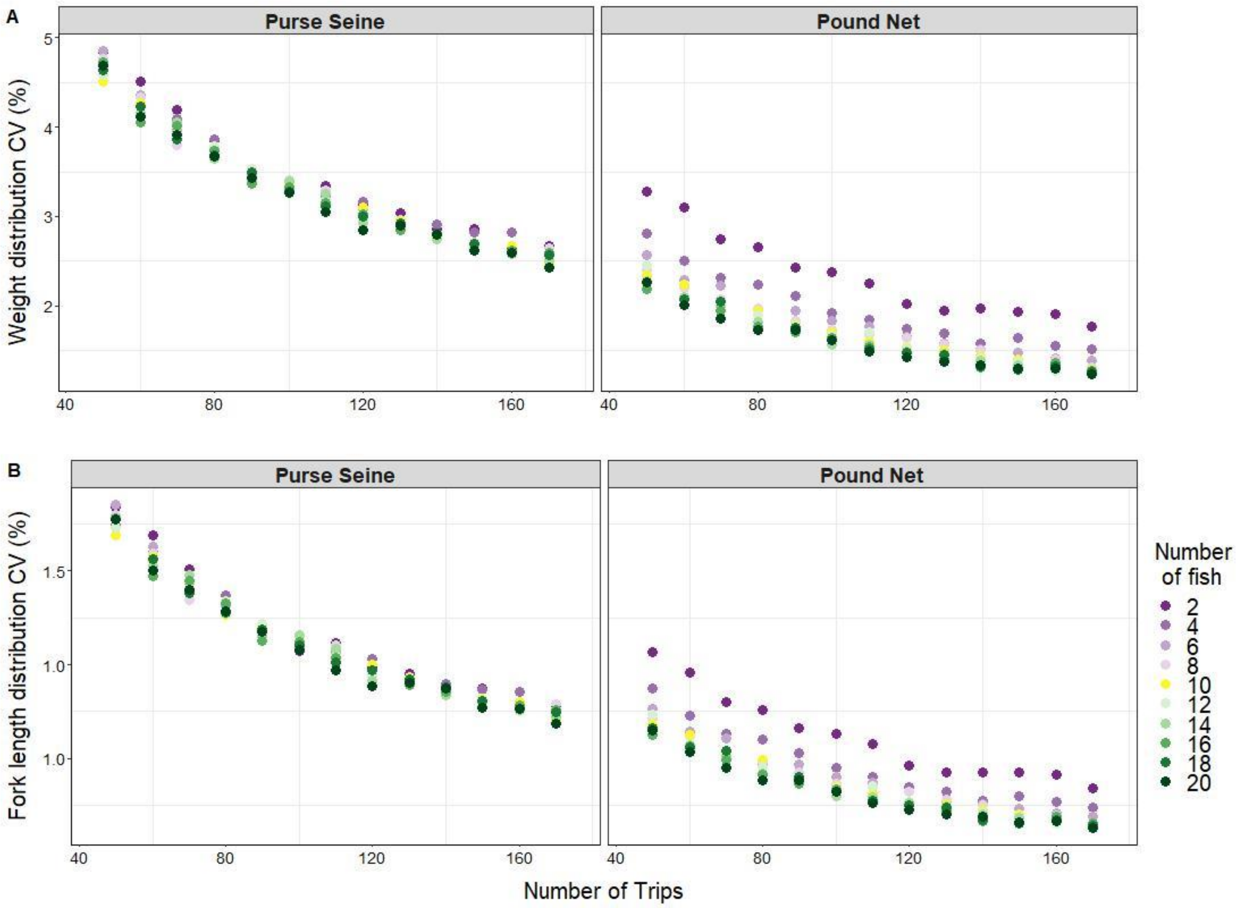


Figure 10. Bootstrap distribution coefficient of variation for Atlantic Menhaden mean catch A) weight and B) fork length by resample size (x-axis: number or trips sampled per year; point color: number of fish samples collected per trip) for the bait fishery in the southern region, 2016. Panels represent gears for which adequate samples were available. A dashed bar indicates the current target of 10 trips per week and a yellow point represents the current target of 10 fish sampled per trip.

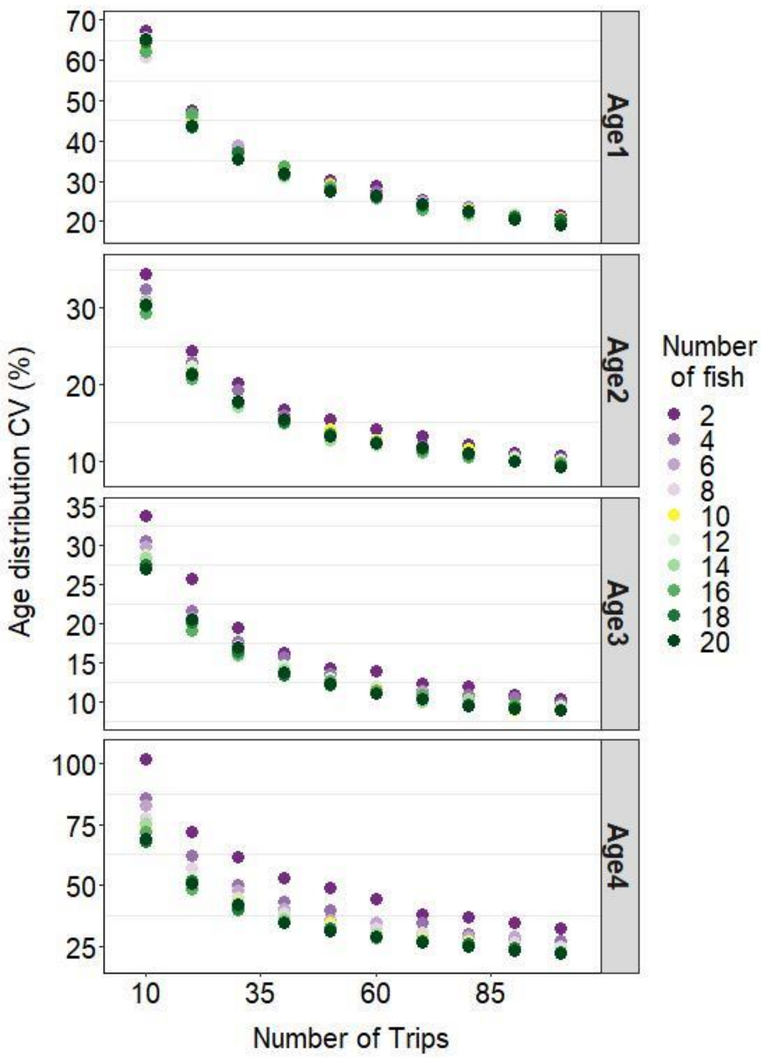


Figure 11. Bootstrap distribution coefficient of variation for Atlantic Menhaden proportions at age by resample size (x-axis: number or trips sampled per portweek; point color: number of fish samples collected per trip) for the northern region reduction fishery, 2016. Yellow points represent the current target of 10 fish sampled per trip.

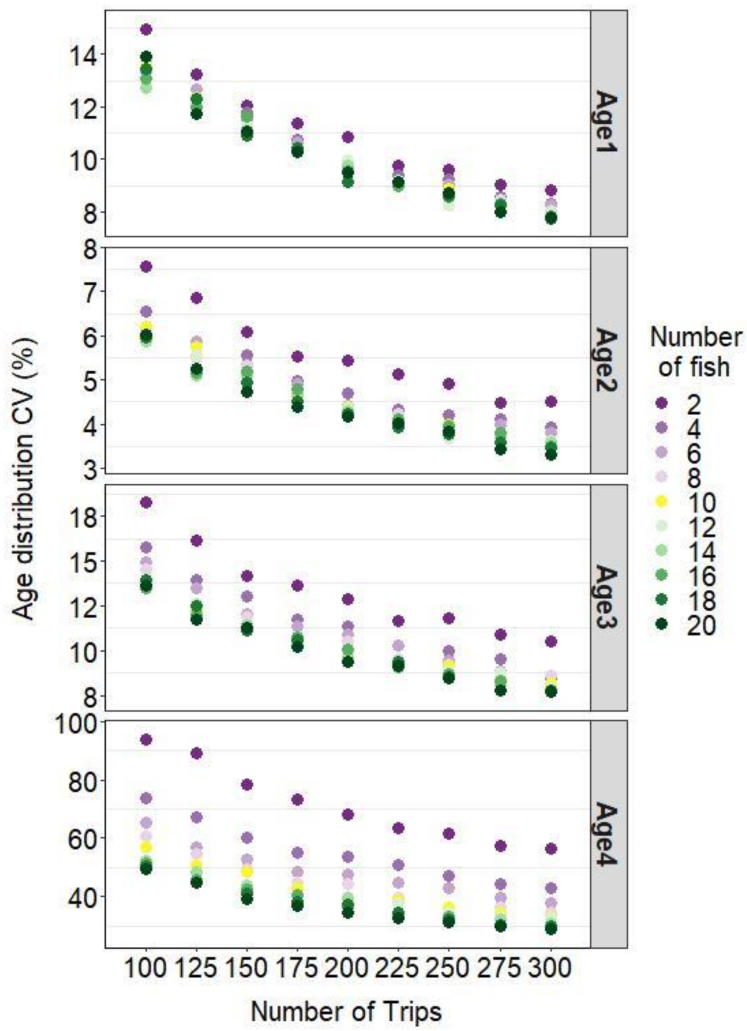


Figure 12. Bootstrap distribution coefficient of variation for Atlantic Menhaden proportions at age by resample size (x-axis: number or trips sampled per portweek; point color: number of fish samples collected per trip) for the southern region reduction fishery, 2016. Yellow points represent the current target of 10 fish sampled per trip.

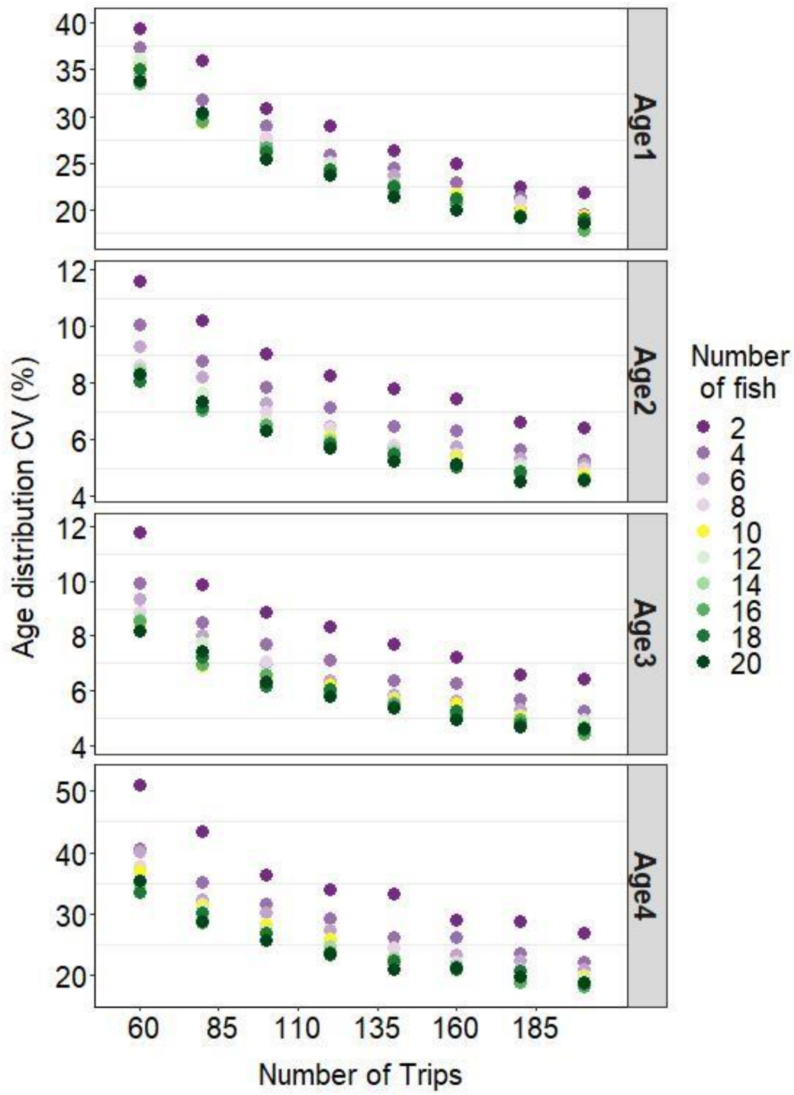


Figure 13. Bootstrap distribution coefficient of variation for Atlantic Menhaden proportions at age by resample size (x-axis: number or trips sampled per year; point color: number of fish samples collected per trip) for the northern region bait fishery, 2016. Yellow points represent the current target of 10 fish sampled per trip.

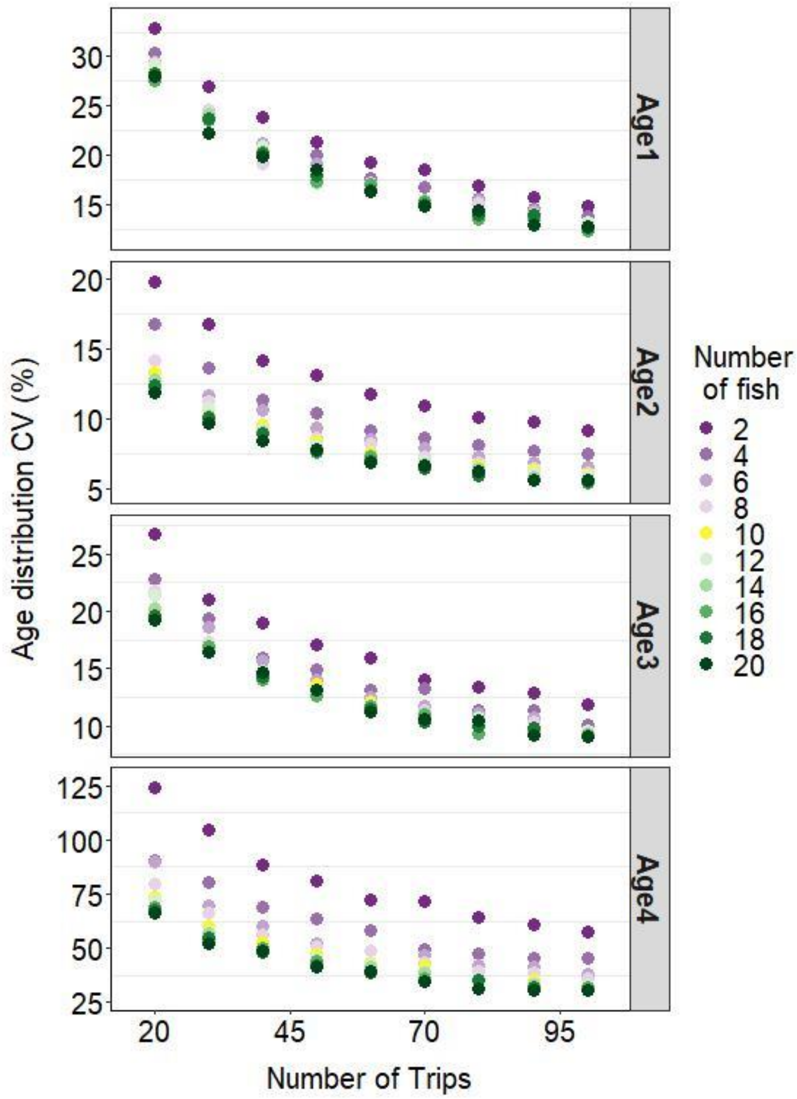


Figure 14. Bootstrap distribution coefficient of variation for Atlantic Menhaden proportions at age by resample size (x-axis: number or trips sampled per year; point color: number of fish samples collected per trip) for the southern region bait fishery, 2016. Yellow points represent the current target of 10 fish sampled per trip.

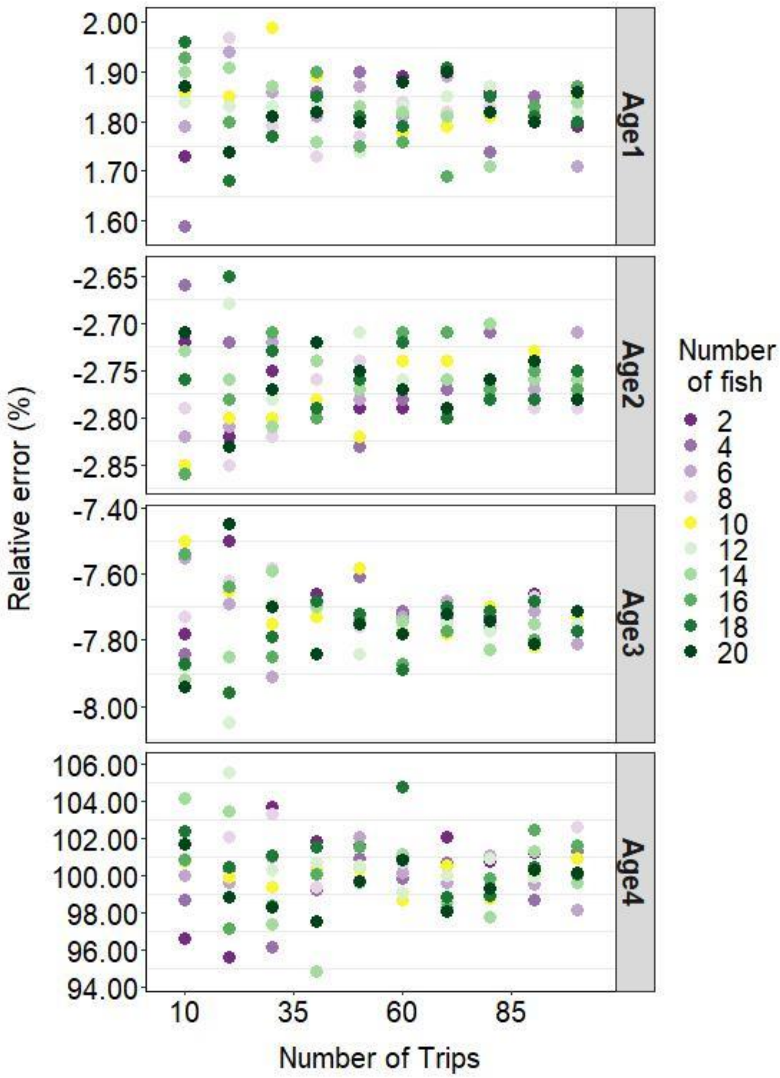


Figure 15. Estimated relative error in Atlantic Menhaden proportions at age by resample size (x-axis: number or trips sampled per portweek; point color: number of fish samples collected per trip) for the northern region reduction fishery, 2016. Yellow points represent the current target of 10 fish sampled per trip.

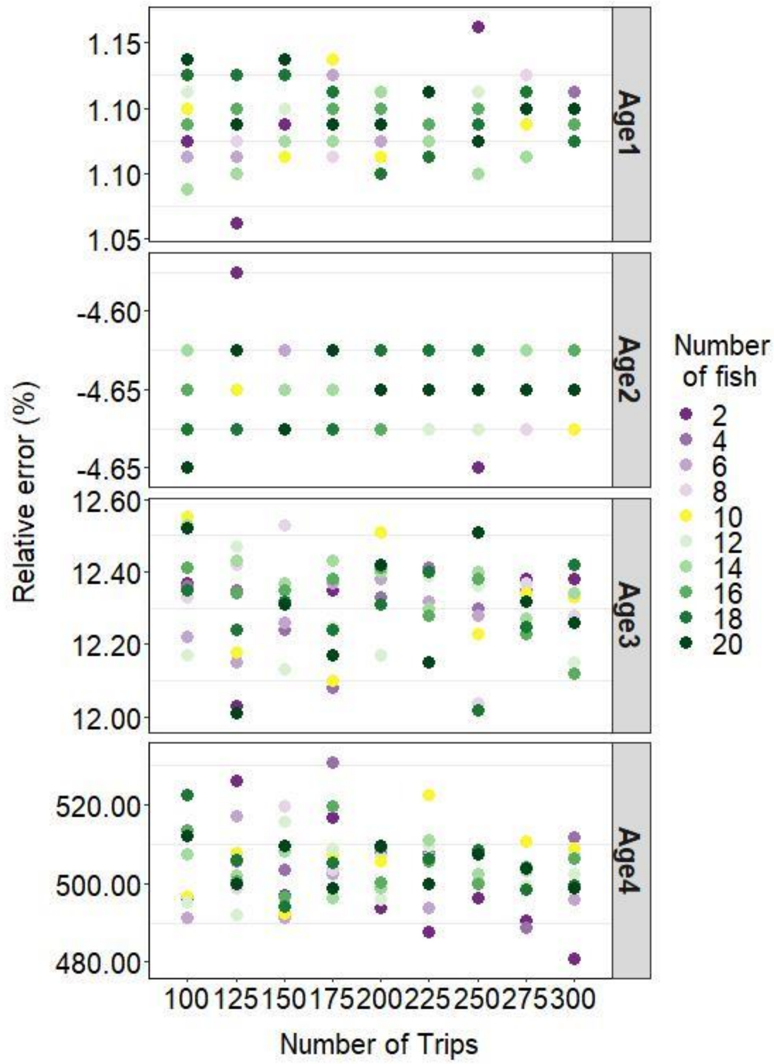


Figure 16. Estimated relative error in Atlantic Menhaden proportions at age by resample size (x-axis: number or trips sampled per portweek; point color: number of fish samples collected per trip) for the southern region reduction fishery, 2016. Yellow points represent the current target of 10 fish sampled per trip.

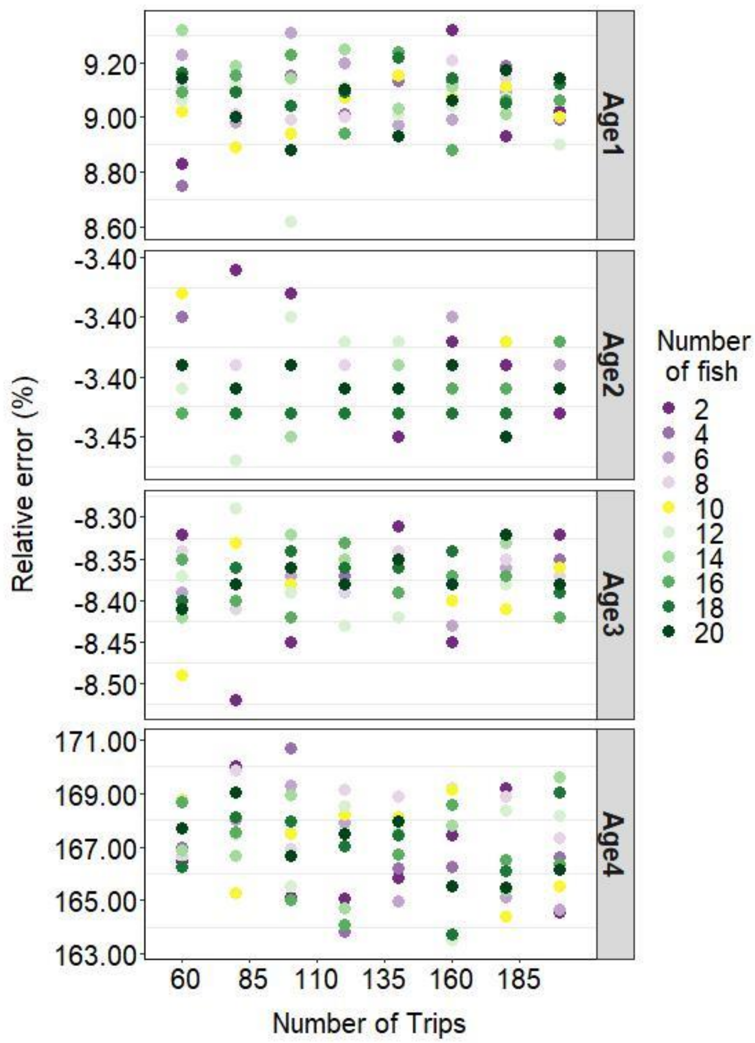


Figure 17. Estimated relative error in Atlantic Menhaden proportions at age by resample size (x-axis: number or trips sampled per year; point color: number of fish samples collected per trip) for the northern region bait fishery, 2016. Yellow points represent the current target of 10 fish sampled per trip.

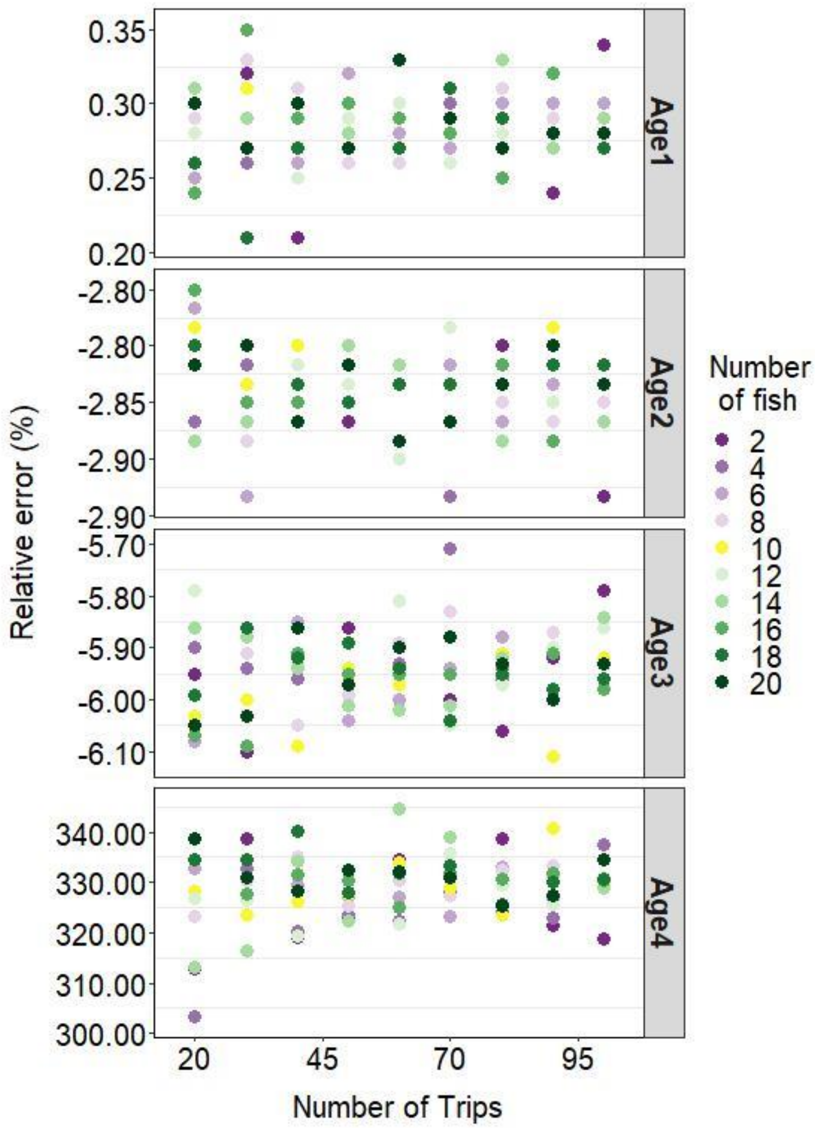


Figure 18. Estimated relative error in Atlantic Menhaden proportions at age by resample size (x-axis: number or trips sampled per year; point color: number of fish samples collected per trip) for the southern region bait fishery, 2016. Yellow points represent the current target of 10 fish sampled per trip.

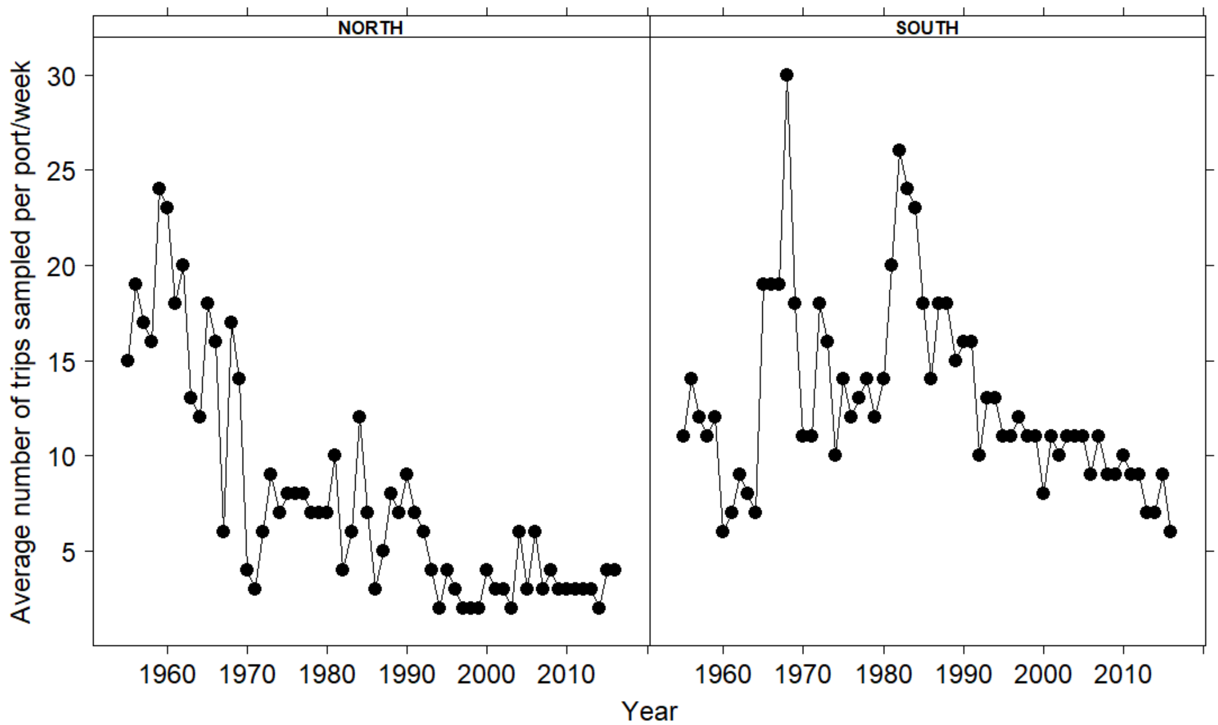


Figure 19. Average number of trips sampled per port/week in the Atlantic Menhaden reduction fishery port sampling program by region (North vs. South).

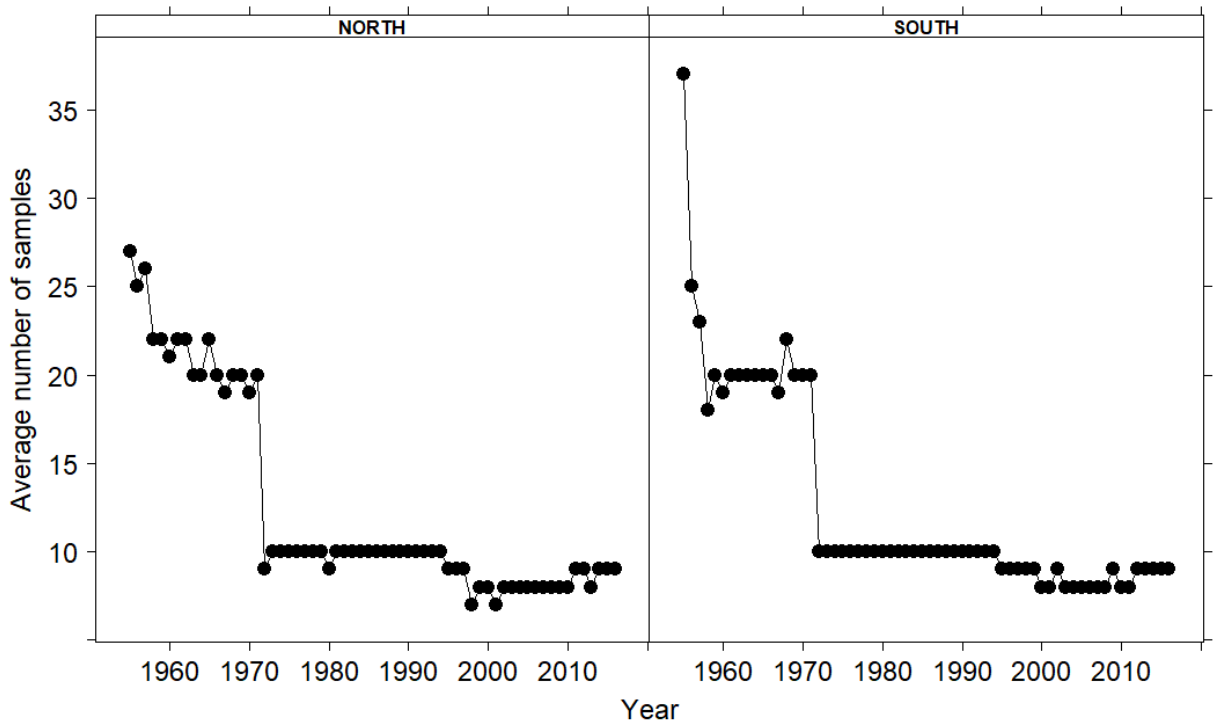

Figure 20. Average number of fish sampled per trip in the Atlantic Menhaden reduction fishery port sampling program by region (North vs. South).

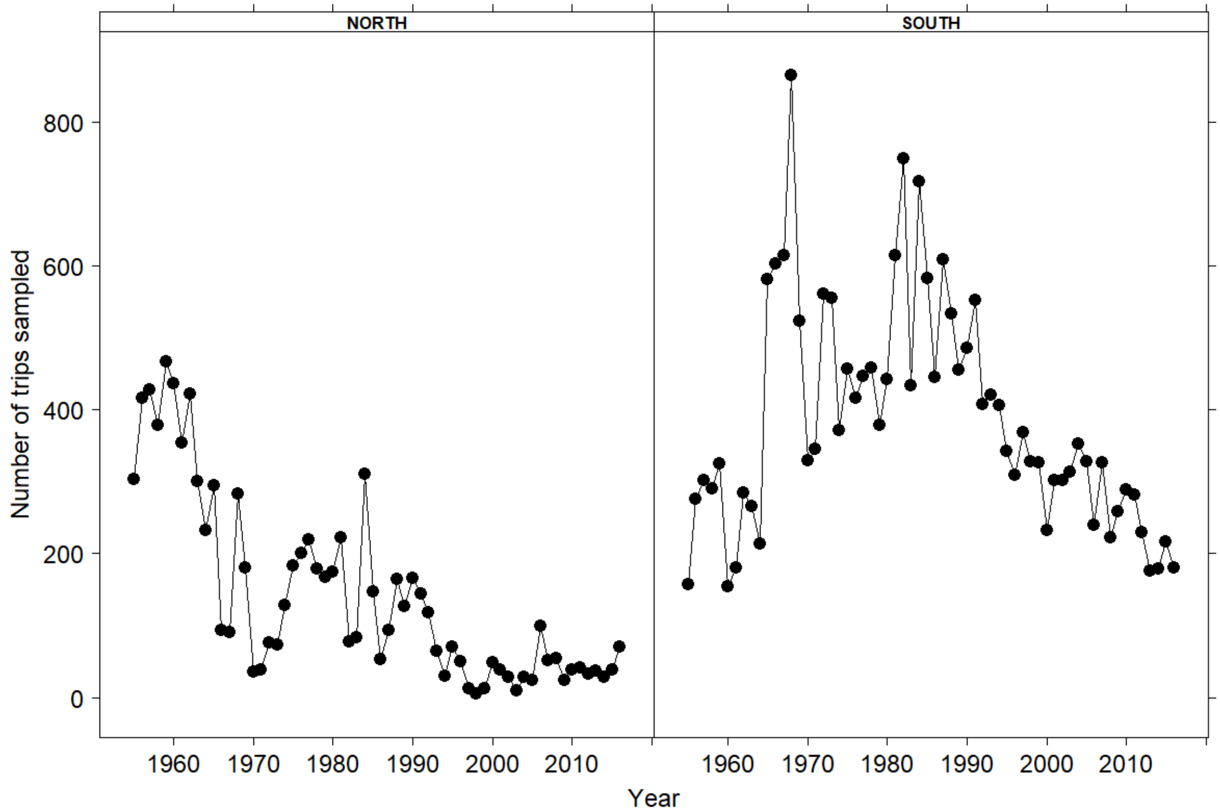


Figure 21. Total number of fish sampled per trip in the Atlantic Menhaden reduction fishery port sampling program by region (North vs. South).

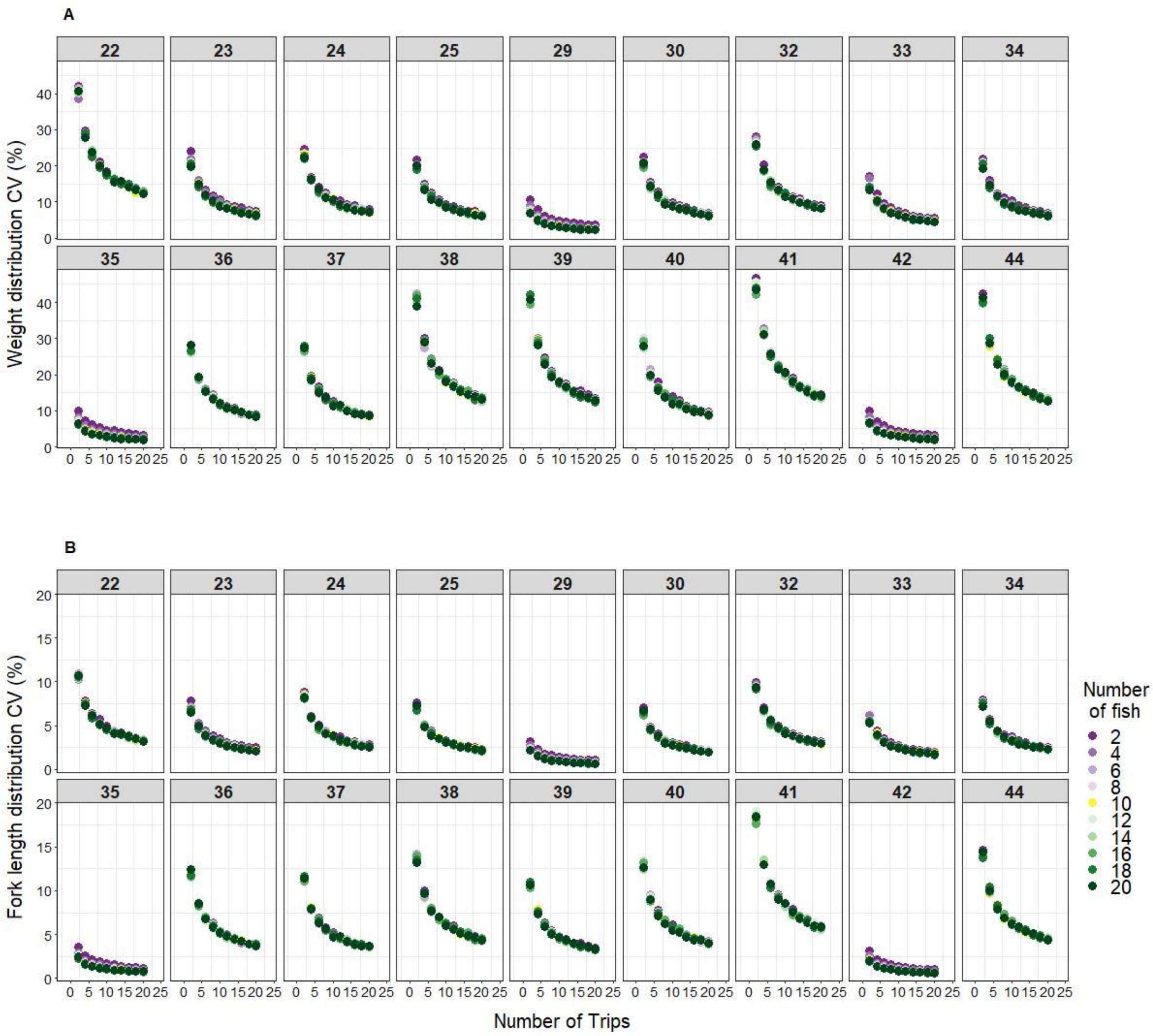


Figure 22. Bootstrap distribution coefficient of variation for Atlantic Menhaden mean catch A) weight and B) fork length by resample size (x-axis: number or trips sampled per portweek; point color: number of fish samples collected per trip) for the reduction fishery in the southern region, 1969. Panels represent portweeks for which adequate samples were available. Yellow points represent the current target of 10 fish sampled per trip; the actual target in 1969 was 20.

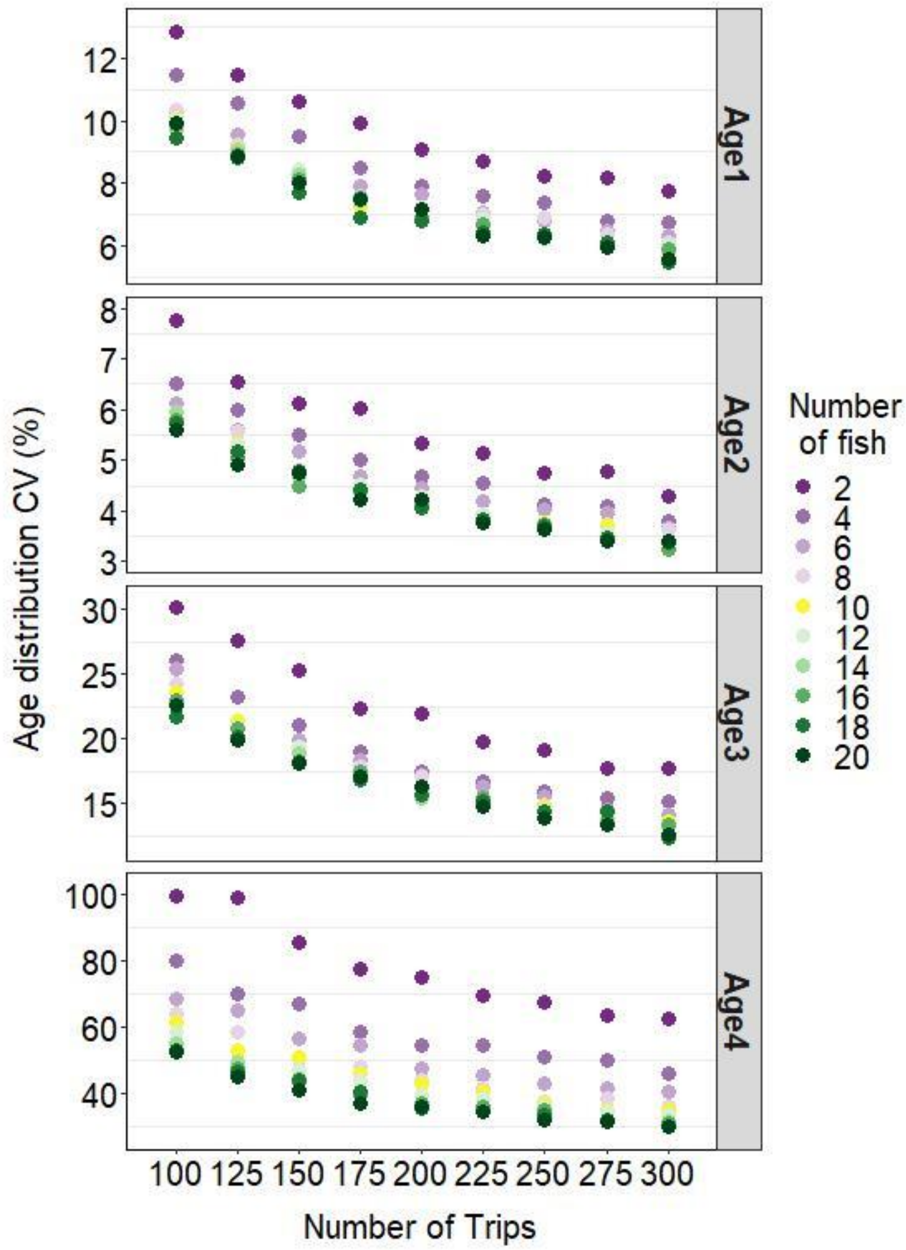


Figure 23. Bootstrap distribution coefficient of variation for Atlantic Menhaden proportions at age by resample size (x-axis: number or trips sampled per portweek; point color: number of fish samples collected per trip) for the southern region reduction fishery, 1969. Yellow points represent the current target of 10 fish sampled per trip; the actual target in 1969 was 20.

# Appendix 1

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
CHESAPEAKE BIOLOGICAL LABORATORY

**Chesapeake Biological Laboratory**
P.O. Box 38
146 Williams Street
Solomons, MD 20688-0038
Tel: 410-326-7223
http://www.umces.edu/genevieve-nesslage

Chesapeake Biological Laboratory
University of Maryland Center for Environmental Science
P.O. Box 38
146 Williams Street
Solomons, MD 20688-0038

October 30, 2017

Jason McNamee
ASMFC Atlantic Menhaden Technical Committee Chair
Chief of Marine Resource Management
Rhode Island DEM
235 Promenade Street
Providence, RI 02908

Dear Mr. McNamee:

I would like to bring to your attention a potential problem with the ASMFC bait sampling program for Atlantic menhaden. While conducting research on the statistical adequacy of the Atlantic menhaden fishery sampling program, I summarized the number of bait samples in the database maintained by NOAA Beaufort Laboratory by region in recent years. I then compared the number of samples in the database with both the number of samples reported in recent Fishery Management Plan (FMP) Reports and the number of samples included as model input in the 2017 update assessment. ***Large discrepancies appear to exist between the number of samples reported as having been collected in annual FMP reports and the number of samples in the database used for stock assessment.*** The number of bait samples used in the 2017 update assessment is approximately half the number of samples collected by the states as indicated by FMP review reports.

| | 10-fish samples | 10-fish samples collected | | Age samples | | |
|---|---|---|---|---|---|---|
| | required | FMP Review | Database | FMP Review | Database | BAM update |
| 2013 | 153 | 181 | 126 | 2,090 | 1,080 | 610 |
| 2014 | 177 | 278 | 162 | 2,836 | 1,477 | 1,250 |
| 2015 | 190 | 293 | 160 | 3,003 | 1,369 | 1,380 |
| 2016 | 179 | 265 | 154 | 2,568 | 1,217 | 1,160 |

The northern region (New England/Mid-Atlantic) agencies have submitted to Beaufort the target number of samples required in Amendment 2. However, several southern region agencies have not submitted their sample data for inclusion in the database. It appears that no samples have been submitted since the implementation of Amendment 2 from Maryland, North Carolina, and Virginia (with the exception of samples collected by Beaufort Lab staff from snapper rigs in the Reedville, VA port). Beaufort Lab staff have confirmed that they have not received bait sample data from these states since implementation of Amendment 2.

| | Bait landings (mt) | | Target #10-fish samples | | Collected #10-fish samples | | #10-fish samples in 2017 update assessment | |
|---|---|---|---|---|---|---|---|---|
| Year | North | South | North | South | North | South | BAM North | BAM South |
| 2013 | 20,100 | 17,200 | 67 | 86 | 68 | 60 | 67 | 34 |
| 2014 | 21,400 | 21,100 | 71 | 106 | 102 | 60 | 96 | 60 |
| 2015 | 25,300 | 21,100 | 84 | 106 | 130 | 30 | 126 | 30 |
| 2016 | 26,600 | 18,000 | 89 | 90 | 139 | 15 | 137 | 17 |

I hope the ASMFC Atlantic Menhaden Technical Committee will take this memo into consideration when preparing bait biological samples for the 2019 benchmark assessment. Please let me know if you have questions regarding my summary of the available data.

Sincerely,

Geneviève Nesslage
Assistant Research Professor

Cc: Ray Mroch Amy Schueller, Megan Ware, Toni Kerns, Robert Leaf