Atlantic Menhaden Revised Natural Mortality Rate Estimate Public Comment Letter with Enclosures

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SEDAR102-RW-11

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July 29, 2025

Robert Beal, Executive Director
John Clark, Management Board Chair
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Re: Atlantic Menhaden Revised Natural Mortality Rate Estimate

Dear Messrs. Beal and Clark,

We are writing to follow up on our letters of October 31, 2024, and February 28, 2025, to Mr. Beal regarding the science underlying the Atlantic menhaden stock assessment.[1] In these letters, we brought to the ASMFC's attention new analysis in a draft manuscript undergoing peer review for publication by Drs. Jerry Ault and Jiangang Luo. This analysis shows that the menhaden stock assessment science is fundamentally flawed due to significant mistakes affecting the natural mortality rate (M) estimate used in the stock assessment model since 2019 (SEDAR 69). We explained that these mistakes resulted in a substantial overestimation of M, which in turn likely drove a substantial underestimation of fishing mortality rates and an overestimation of the coastwide stock size and allowable catch for the fishery. As a result, overfishing of Atlantic menhaden has likely been occurring. Our previous letters also summarized the ASMFC's legal obligations under the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) and the ASMFC's Rules and Charter that all Interstate Fishery Management Plans be based on the best available science (BAS) and prevent overfishing.

We thank you, Mr. Beal, for your responses, as well as to the SAS M Working Group for discussing Drs. Ault & Luo's analyses. While these discussions resulted in the admission of several significant mistakes and partial correction in the M estimate, the SAS declined to correct at least one critical mistake and further declined to reduce M to the level recommended by Drs. Ault & Luo. As a result, the overestimation of M persists, even with the Atlantic Menhaden Stock Assessment Subcommittee's (SAS) newly revised M estimate (from M=1.17 to M= 0.92). Further, it appears that staff leading the SAS analysis adjusted other critical model parameters, particularly the assumption for recruitment, which effectively offset the impact of the lower M estimate. Based on these adjustments, remarkably, the SAS concluded that even though M has been overestimated by at least 21 percent since 2019, the Atlantic menhaden stock is not overfished, overfishing is not occurring, and they project that continuing to fish at the current level presents little risk to the Atlantic menhaden resource. These conclusions are surprising, to say the least, and we are gravely concerned.

What is most concerning is that if Drs. Ault & Luo are correct that the M estimate should be even lower (M=0.52) because of a remaining uncorrected mistake in the analysis relied upon by the SAS (specifically, modeling time-area magnet efficiency as constants)—and the data and all

[1] Enclosed for reference.

other indicators suggest that Drs. Ault & Luo are correct—not only is it likely that overfishing has been occurring and that Atlantic menhaden are overfished, but the coastwide stock size could be only a fraction of the SAS estimate, perhaps as low as one quarter of the unfished biomass. The implications for Atlantic menhaden and the East Coast ecosystem are profound.[2] Because Atlantic menhaden is the key forage stock in the ASMFC's ecological reference point (ERP) model, menhaden stock assessment mistakes can ripple through other ASMFC assessments such as those for striped bass, the most valuable recreational gamefish in the country.

For these reasons, we request that you take steps to ensure a thorough and independent review of the SAS's work in view of the Ault & Luo analysis—in particular, the SAS's extraordinary findings regarding the appropriate M estimate and the status of the Atlantic menhaden resource. First, we understand that Drs. Ault & Luo's manuscript has been updated to reflect their significant engagement with the SAS and that publication is pending. To help ensure the August 12-15 Ecological Reference Point Peer Review fully examines these issues please include this letter and Drs. Ault & Luo's published paper or the most recent draft manuscript in the Peer Review materials. Second, please ensure that Drs. Ault & Luo's recommended M of 0.52 be included as a sensitivity run in the Beaufort Assessment Model (BAM)[3] and that the results – including impact on biomass and stock status - be available for consideration and adoption by the Menhaden Board. Note that the SAS stated it would introduce the Ault & Luo M analysis into the Peer Review through its inclusion as a sensitivity run, however this sensitivity run was not presented or discussed at the July SAS Technical Committee (SAS TC) meeting, nor were the full impacts of a lower M discussed. Third, please ensure that all of these materials are available to the Board and the ASMFC so that these management bodies can consider them and make their final decisions consistent with their legal duties to rely on the best available science and prevent overfishing.

Finally, as noted in our prior letters, Drs. Ault & Luo have raised concerns about the adoption of the extreme statistical outlier M recommended in the paper by Liljestrand, Wilberg & Schueller (2019)[4] since its inclusion in the 2019 SEDAR 69 benchmark stock assessment. Although the SAS M Working Group, SAS TC, and ERP Working Group discussed Drs. Ault & Luo's analyses and acknowledged some of the critical mistakes made by Liljestrand, Wilberg & Schueller, some of these authors also actively participated in the meetings, dominating much of the analysis and discussion and resisting Drs. Ault & Luo's findings. It is critical to prevent conflicts of interest and ensure impartiality in the Peer Review of the Atlantic menhaden M estimate and 2025 stock assessment. Thus, the authors of the Liljestrand, Wilberg & Schueller paper should be recused from participating in the Peer Review and additional related processes leading to the Board and ASMFC's final decisions. The ASMFC and NOAA Fisheries must

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[2] Especially given there is an East Coast "forage fish crisis" as all critical forage species (i.e., Atlantic herring, Atlantic mackerel, blueback herring, alewife, and shad) are also severely overfished (depleted).

[3] BAM is the model used for the menhaden single species stock assessment, and the outputs from BAM, including the rate of natural mortality, serve as the baseline for the ERP assessment.

[4] Liljestrand EM, Wilberg MJ and Schueller AM (2019). Estimation of movement and mortality of Atlantic menhaden from 1966 to 1969 using a Bayesian multi-state mark-recovery model. *Fisheries Research* 210: 204-2013. Based on the mistakes acknowledged to date, let alone the remaining impactful mistake in magnet tag recovery efficiency, in our opinion the authors should retract the paper.

ensure that the best available science is used for management of Atlantic menhaden. Additional details are provided below.

The SAS Corrections and Revised M

Drs. Ault & Luo analyzed the data, model and results contained in the Liljestrand, Wilberg and Schueller paper related to the NMFS 1966-71 mark-recapture study, including the paper's recommended M that was adopted for use in the benchmark Atlantic menhaden single species stock assessment in 2019 (SEDAR 69). The Ault & Luo analysis identified at least five significant mistakes made in the Liljestrand, Wilberg & Schueller paper affecting its recommended M including: (1) overstated tag releases; (2) underreported tag recoveries; (3) overstated primary magnet tag recovery efficiency; (4) underreported annual fishing effort[5]; and (5) modeled time-area magnet efficiency as constants. The SAS agreed with much of the Ault & Luo analysis and addressed the first four significant mistakes, concluding that the current M adopted by ASMFC from the Liljestrand, Wilberg & Schueller paper was too high and should be revised downward from M = 1.17 to 0.92.

However, Drs. Ault & Luo's analysis concludes that the SAS' revised M is still almost double what it should be: M = 0.52. Initially, the SAS attributed the difference between the M estimate recommended by Drs. Ault & Luo to their inability to access confidential fishing effort data.[6] However, despite the lack of access to the allegedly confidential 55 year old industry data, Drs. Ault & Luo's method for generating nominal fishing effort by month and area effectively characterized effort during the period of the mark-recapture study. The SAS M Working Group determined Drs. Ault & Luo's effort characterization to be 99 percent accurate compared to the confidential fishing effort data. Comparative analyses with SAS showed that weighting the average area efficiencies by catches in the "constant" method produced minute differences (~2.2%) in estimated M in comparison to the SAS estimate. Thus, the lack of access to the confidential fishing effort data had a minimal effect on their results. Despite this, at the July 2025 SAS TC meeting the SAS presentation continued to highlight the data access issue as though it compromised Ault & Luo's analysis, instead of objectively presenting the competing approaches to magnet tag recovery efficiency as the basis for the difference.

The Remaining Uncorrected Mistake -- Magnet Tag Recovery Efficiency

After agreeing on the first four highlighted mistakes in the Liljestrand, Wilberg & Schueller paper, the only significant remaining factor accounting for the difference between the SAS's new

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[5] Fishing effort was under-reported by Liljestrand, Willberg and Schueller by an annual average of -47.8 percent.
[6] This data was requested by Drs. Ault & Luo but was not provided by NMFS because the fishing industry (Ocean Harvesters) refused to authorize its release, despite the fact these data are over 55 years old and unlikely to include any information that reasonably can be considered confidential business information. The Atlantic ecosystem and menhaden fishery have changed significantly in the past 55 years. Further, Ocean Harvesters is (supposedly) not even the same fishing company that originally collected the data; that was Omega Protein. Failure to provide the fishery data in support of improving fisheries science for management is inconsistent with the intent of the Magnuson-Stevens Act's confidentiality provisions, which did not even exist at the time of the mark-recapture study. 16 U.S.C. § 1801 et seq. (1976), 16 U.S.C. § 1881a(b) (1996). Refusal to provide the data is also in conflict with the Magnuson-Stevens Act's and ASMFC's mandate to ensure conservation and managements measures be based on the best available scientific information available and that management be in the public interest. 16 U.S.C. § 1801(c)(3); 16 U.S.C. § 5104(a)(2). Drs. Ault & Luo are renewing their request for this data through a formal FOIA request.

recommended M=0.92 and Drs. Ault & Luo's recommended M=0.52 results from the SAS failure to apply the most scientifically sound method to correct the Liljestrand, Wilberg & Schueller approach to magnet tag recovery efficiency at the menhaden reduction plants. As explained by Drs. Ault & Luo, the Liljestrand, Wilberg & Schueller analysis incorrectly applied simple weighted arithmetic averages of magnet efficiency by area over time.[7]

A key decision in the analysis was how to best represent plant magnet efficiencies in the estimation process. Rather than relying on simple parametric averages of random non-parametric distributions of plant- and area-specific magnet efficiencies, Drs. Ault & Luo incorporated all the empirical data to ensure a comprehensive estimation framework for natural mortality. Integrating both recapture data and the variability of trial-based magnet efficiency distributions was critical for achieving reliable model fits and scientifically robust mortality estimates. Drs. Ault & Luo's analysis shows that using a "parameters" estimation approach, which allows the magnet efficiency parameters to be estimated directly from the observed recapture data, accounted for the random nonparametric distribution of magnet efficiencies and substantially improved model fits to data. The Liljestrand, Wilberg & Schueller approach of averaging data across all plants and areas over time was, and remains, an inappropriate, non-representative and inefficient use the data, resulting in unreliable estimates of natural mortality.

The failure to appropriately address the nonparametric distribution of magnet recapture efficiency data continues to significantly inflate the M adopted by the SAS. As stated in Dr. Ault's March 14 memorandum submitted to the SAS,

> "The ASMFC SAS has failed to apply standard objective statistical criteria in selecting the appropriate mark-recapture model estimates of natural mortality rate. Instead, they made a subjective, *ad hoc* choice for the value of M to be used in the upcoming stock assessment."

In contrast, Drs. Ault & Luo applied a more data-driven method for estimating magnet efficiencies, without prescribing any prior distribution or assumptions about full mixing.

Drs. Ault & Luo also applied a "Stepwise" approach to estimation of the natural mortality rate. In contrast to the characterization in the SAS TC presentation, Drs. Ault and Luo used the Stepwise method as a diagnostic tool, systematically estimating magnet efficiencies in stages to assess how sensitive model performance is to changes in M. As explained, the method was designed solely to explore the sensitivity of M estimates to increasing model complexity and spatio-temporal resolution of magnet efficiencies, not as a formal hypothesis-testing framework.

Both the "parameters" and "stepwise" methods better represent the empirical variability in magnet efficiencies observed in the plant trials, resulting in consistent and substantially lower natural mortality estimates. In the July 2025 SAS TC meeting, the SAS presentation selectively highlighted Drs. Ault & Luo's Stepwise approach, but failed to discuss the more statistically rigorous "parameters" estimation approach and its ability to improve model fits which effectively integrated both recapture data and the variability of trial-based magnet efficiency distributions, a

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[7] Magnet efficiency is a measure of the efficiency by which the magnets in the menhaden processing plants captured known ferro-magnetic tags seeded into catches in the underlying tagging study. Each plant had up to nine magnets, with the first two (primary) magnets were used in the Coston study, and all nine used in the NMFS data analysis.

modeling process that was critical for achieving reliable model fits and scientifically robust mortality estimates.

The ASMFC Must Fully Address All of the Identified Mistakes in the Analysis Leading to the Adoption of the Severely Inflated M Used in the SEDAR 69 Stock Assessment

The remaining mistake that accounts for the difference between the SAS recommended M=0.92 and Drs. Ault & Luo's recommended M=0.52 is the SAS's failure to apply the most scientifically sound method to magnet tag recovery efficiency at the menhaden reduction plants. Drs Ault & Luo's conclusions are fully supported by every other indicator of the actual M for Atlantic menhaden, including the life history estimate of M = 0.54, indirect mortality estimation methods which indicate that M should fall within a reasonable range of 0.30 and 0.50 based on empirical life history principles, and the more than a dozen peer reviewed estimates of M ranging from 0.37 to 0.53. Drs. Ault & Luo also detail that the M=1.17 estimate adopted in the SEDAR 69 stock assessment was anomalously high compared to more than 60 recent U.S. and international fish stock assessments. The estimate represented a 2.3-fold increase over the M=0.50 used in SEDAR 40 (2015) assessment -- 14 standard deviations above the mean of 0.46 for the peer-reviewed publications.

Another red flag signaling problems with adopting the M=1.17 in SEDAR 69 stock assessment was the manipulation of other parameters that occurred, including the steeply increased recruitment assumptions needed in the model to account for the extremely high M.[8] The parameter manipulation apparent in the Liljestrand, Wilberg & Schueller paper, ultimately adopted and approved in SEDAR 69, is inconsistent with sound science. Unfortunately, it may be occurring again. The July SAS TC presentation stated that they were "scaling" the recruitment assumption to decrease the effect of fishing and increase stock biomass. This scaling appears to be a results-driven change in recruitment by 1.5 orders of magnitude (15 times) to account for the decline in the estimated M. As a result, the SAS were able to conclude that fishing at current levels would have no impact on the status of the menhaden resource.

The SAS recommendation of M=0.92 remains a significant statistical outlier, still several standard deviations above all other credible estimates. The SAS agreed to introduce the Ault & Luo M analysis into the Peer Review through its inclusion as a sensitivity run, however this sensitivity run was not presented or discussed at the July SAS TC meeting, nor were the full impacts of a lower M discussed. It appears that the SAS may be reluctant to admit the full magnitude of their prior mistakes. It is understandable that there may be some professional embarrassment to the original authors, some of whom are active members or have colleagues on the SAS. Representatives from Omega Protein also apply pressure as the dominant special interest in the fishery. And states will also be affected by decreases in the allowable catch. However, Atlantic menhaden is the only major East Coast forage species that is supposedly at relatively healthy levels. It is critical to the health of striped bass, osprey, and countless other predators, and is the key forage stock in the ERP model. The ASMFC must meet its legal obligations under ACFCMA and the ASMFC's Rules and Charter to base its Interstate Fishery

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[8] SEDAR 69 continued a dramatic transition in how the health of the Atlantic menhaden population was viewed from less than 10 years prior when menhaden was considered likely overfished and overfishing occurring. SEDAR 69 not only concluded that menhaden was not overfished, but that the menhaden spawning stock was over 80 percent of the unfished population size.

Management Plans on the best available science and prevent overfishing and look to the long-term benefits of a healthy Atlantic menhaden population managed sustainably.

* * * * *

The work of the Atlantic Menhaden SAS and Drs. Ault & Luo is now consistent except for the SAS's mistaken application of the simple arithmetic average of plant- and area-specific magnet tag recovery efficiencies. The scientific evidence points to the method used by Drs. Ault & Luo as the best scientific approach for determining the M estimate. Given the magnitude of the difference between the M in use since 2019 (M=1.17) and Drs. Ault & Luo's estimate of M=0.52, there is a high risk that menhaden is overfished with overfishing occurring. Adopting their recommended M= 0.52 in the stock assessment will help prevent overfishing and rebuild the Atlantic menhaden resource.

For these reasons, we request that you do all that is possible to ensure that the August 12-15 Ecological Reference Point Peer Review fully examines the issues raised in this letter by first including Drs. Ault & Luo's paper[9] and our letter in the Peer Review materials. Second, please ensure that Drs. Ault & Luo's recommended (M=0.52) is included as a sensitivity run in the BAM and that the results – including impact on biomass and stock status - be available for consideration and adoption by the Menhaden Board. Third, please ensure that all of these materials are provided with the Peer Review results to the Board and ASMFC so that they can consider them and make their final decisions consistent with their legal duties to manage Atlantic menhaden based on the best available science and to prevent overfishing. And finally, to help ensure impartiality in the analysis and presentation of the issues raised here, please recuse the authors of the Liljestrand, Wilberg & Schueller paper from participating in the Peer Review and subsequent processes leading to the Board and ASMFC's final decisions.

Thank you for considering our concerns and recommendations.

Sincerely,

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[9] If Drs. Ault & Luo's paper is not published before the peer review begins, please provide the most recent manuscript and response to reviewer comments available.

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Encl:

1. Dr. Jerald S. Ault Memorandum to the ASMFC Stock Assessment Subcommittee, (March 14, 2025).
2. Dr. Jerald S. Ault & Dr. and Jiangang Luo, Magnet Efficiency Parameters, (February 27, 2025).
3. Dr. Jerald S. Ault & Dr. and Jiangang Luo, Report on Estimation of Area Magnet Efficiencies and Natural Mortality, (February 25, 2025).
4. Dr. Jerald S. Ault Letter to ASMFC Menhaden Management Board, (January 31, 2020).
5. Roger Fleming, Esq. and David Reed, Esq., Letter to Mr. Robert Beal, Executive Director, (February 28, 2025).
6. Roger Fleming, Esq. and David Reed, Esq., Letter to Mr. Robert Beal, Executive Director, (October 31, 2024).

Cc:
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Objective Criterion for Model Selection

The ASMFC SAS has failed to apply standard objective statistical criteria in selecting the appropriate mark-recapture model estimates of natural mortality rate. Instead, they have made a subjective, *ad hoc* choice for the value of M to be used in the upcoming stock assessment.

When using the Coston data, objective criteria for model selection should include three key metrics of model outputs for assessing the model efficacy:

(1) Aikake Information Criteria (AIC).
(2) Difference between observed and model-predicted recaptures.
(3) Visual inspection of the fit between observed and model-predicted recaptures.

Method	K	neg(LL)	R	Δ	AIC	$\widehat{M}$	$\widehat{M}_{MCMC}$
Constant:	106	10,579	102,992	92,611	21,370	0.8992	0.9039
Stepwise:	106	9,751	102,992	-6,570	19,714	0.5149	0.5102
Parameters:	206	9,484	102,992	10,123	19,380	0.5488	0.4965

Table 1.- Summary of findings from three analytical methods applied to the Coston mark-recapture data. Symbols are: K ≡ number of estimated model parameters; neg(LL) ≡ model's negative log-likelihood; R ≡ observed total recaptures; Δ ≡ difference estimated between predicted and observed recaptures; AIC ≡ Akaike Information Criterion; $\widehat{M}$ ≡ estimated single-run annual natural mortality rate; $\widehat{\widehat{M}}_{MCMC}$ ≡ MCMC mean estimated annual natural mortality rate.

For the Coston data, **Table 1** clearly indicates that: $AIC_{constant} \gg AIC_{stepwise} > AIC_{parameters}$.

Focusing on the "Constant" and "Stepwise" approaches, and using the objective model selection criteria outlined above:

(1) There was a 7.7% reduction in AIC for the "Stepwise" versus "Constant" approach.
(2) The "Constant" approach overestimated recaptures by +89.9%, whereas the "Stepwise" approach underestimated recaptures by only 6.4%—a significantly more accurate estimation.
(3) Visualizations (**Fig. 1**) of single-run results for Coston data further support the superiority of the "Stepwise" approach.

These findings clearly indicate that the "Stepwise" approach is far superior to the "Constant" approach and should be selected as the best model choice.

Thus, the objective choice of the “base” case for Atlantic menhaden stock assessment should be the Stepwise approach with an $\widehat{M} = 0.52$ $(\text{sd} = 0.0234)$; and on the other hand, the “sensitivity” case should be $\widehat{M} = 0.90$ $(\text{sd} = 0.0331)$.

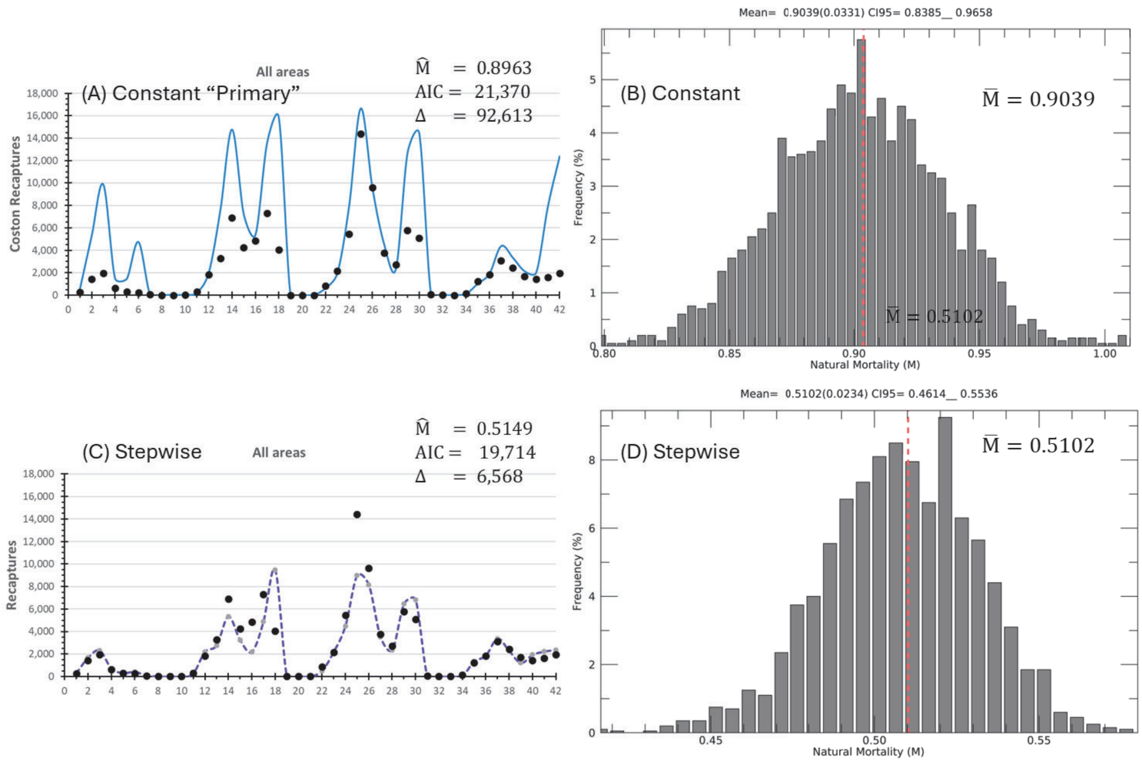


Figure 1.- Summary visualizations of single run results for Coston data: (A) “Constant” primary magnet efficiency coefficients; and (B) “Stepwise” (Step #4).

This analysis allows for a direct comparison of these estimates with other key mortality and survivorship parameters, including those generated by the single-species assessment model (BAM).

Magnet Efficiency Parameters

Some misunderstandings have been raised concerning the use and estimation of magnet efficiency parameters. Our objection to using the mean magnet efficiency from the Plant Test data is based on the fact that these frequency distribution(s) significantly deviate from a symmetrical normal distribution, instead appearing to resemble a uniform random distribution (**Figs. 1 & 2**). In fact, the true empirical distribution is neither normal nor uniform, but rather some type of a **random non-parametric distribution**.

In our model runs where magnet efficiencies were treated as parameters, we **did not** assume a uniform random distribution as a prior condition. Instead, the model estimated magnet efficiency parameters by fitting predicted recaptures to the observed recapture data using a **negative log-likelihood function** incorporated into an AIC to account for the additional estimated parameters. The resulting frequency distribution of magnet efficiency parameters emerged from the second half of a **4,000,000-step MCMC run**, saved every **1,000 steps** (**Fig. 1**).

The parameter frequency distributions by the four areas are shown in **Fig. 3**, demonstrating how the model-derived estimates reflect the underlying data structure(s) without imposing any predefined probability function. When magnet efficiency parameters are averaged by month and area, they exhibit slightly different patterns (**Fig. 4**). This pattern may not exactly match the Plant Test data *per se*, but there is no expectation that it would; however, It definitely covered the range of observed magnet efficiencies. This further highlights the limitations of using simple averages to represent these relatively complex data.

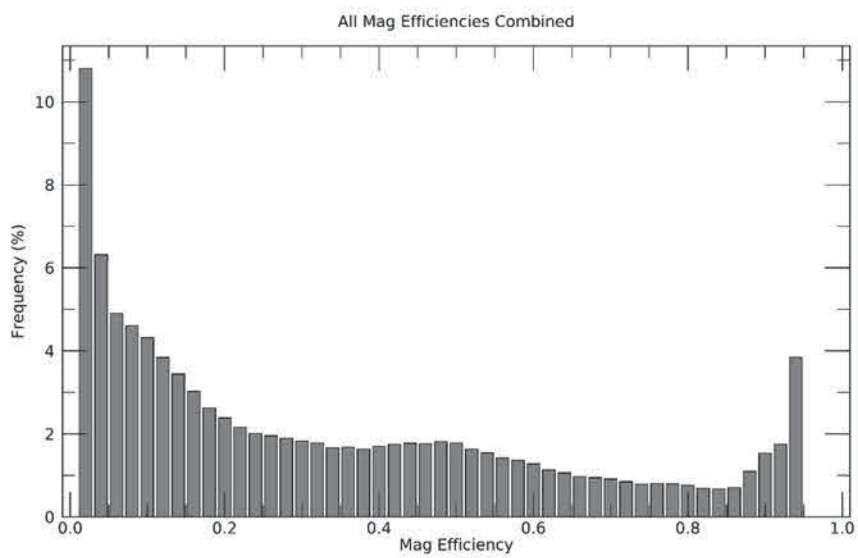


Figure 1.- Estimated primary magnet efficiency distribution corresponding to the Coston data for all months and areas combined. Data are from the second half of the 4 million step MCMC simulation, saved every 1000 steps and binned at 0.02 ($\mathrm{n} = 2{,}000$).

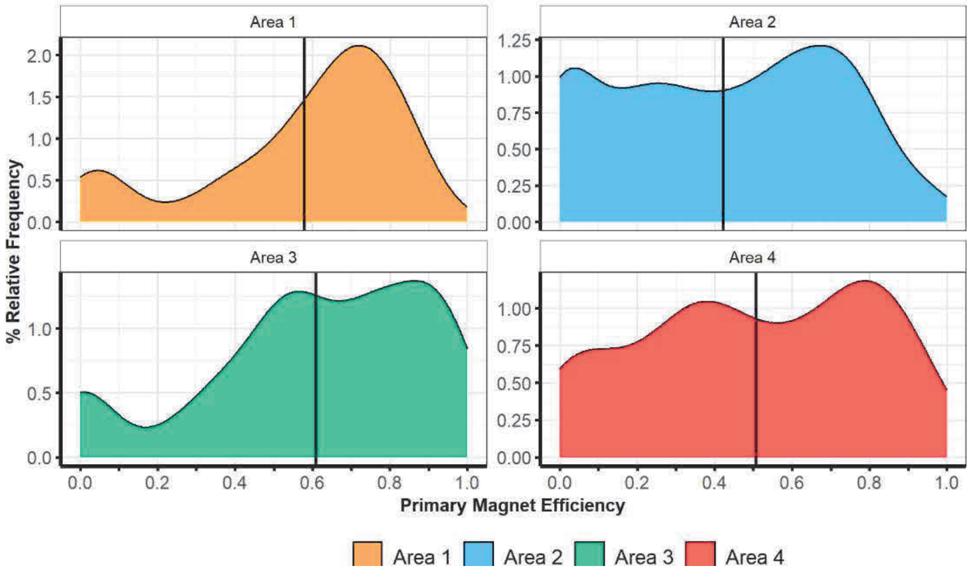


Figure 2.- Observed area-averaged primary magnet efficiency distributions from the 1966-1971 Plant Test data. Vertical black lines are the area-specific weighted means.

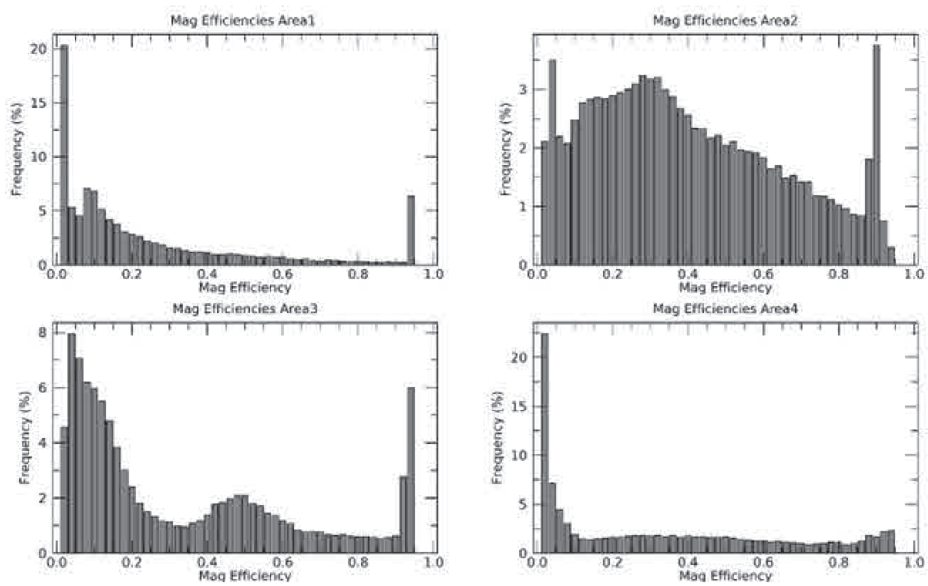


Figure 3.- Area-specific estimated primary magnet efficiency distribution for all 42 months from second half of the 4 million steps MCMC simulation saved every 1000 steps and binned at 0.02 $(n = 2{,}000)$.

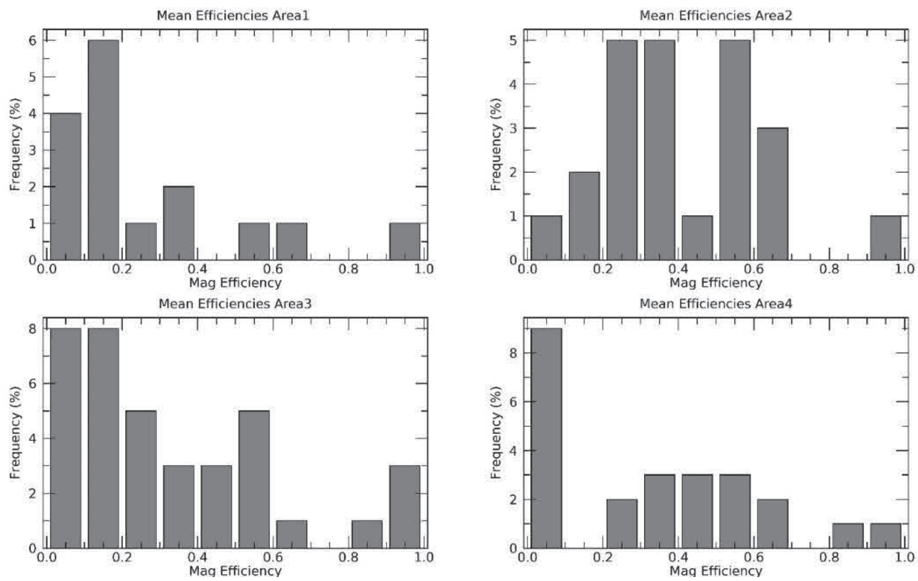


Figure 4.- Month and area averaged magnet efficiency distributions from second half of the 4 million step MCMC simulation saved every 1000 steps and binned at 0.05 $(\mathrm{n} = 2{,}000)$.

This report addresses the ASMFC's SAS M workgroup's request, dated February 12, 2025, for a detailed description of our Stepwise method used to estimate magnet efficiencies (MEs). This report also compares this method to the "Constant" and "MEs as parameters" approaches. The results from these analyses were then incorporated into a comprehensive evaluation of the two Atlantic menhaden mark-recapture databases to derive the best estimate of the natural mortality rate (M) for the species. We concluded that $M = 0.52$ is the best estimate of the annual natural mortality rate for Atlantic menhaden.

I. Constant Average Plant and Area Magnet Efficiencies $(\varepsilon_{t,a})$

Appropriate use of the Coston (1971) data required establishment of a quantitative definition of what constituted "primary" magnets. Because NMFS data for 1966 completely overlapped with the releases given in Coston, we were able to determine that recovery stations 1 and 2 should be defined as "primary magnets (p12)" in the "Plant Test" database, aligning perfectly with the reported recaptures in the Coston (1971) technical report. Determination of plant and area magnet efficiencies during 1966-1971 was accomplished through analysis of 964 batch trials conducted at 19 processing plants in 4 geographical areas (**Table S1**; note: no batch trials were conducted at plant #8), as was done by the ASMFC SAS M workgroup. Each batch trial consisted of release of approximately 100 known tagged menhaden into vessel catches received at the respective plants. The fraction of the known tags recovered was assessed for each batch according to two different magnet configurations relative to the database being analyzed: (1) Coston data required only "primary magnets (p12 -- recovery stations 1 and 2)"; while, (2) NMFS data used "all magnets" (all recovery stations). Comparisons of magnet efficiencies by plants and areas for the two databases are shown in **Fig. I.1**.

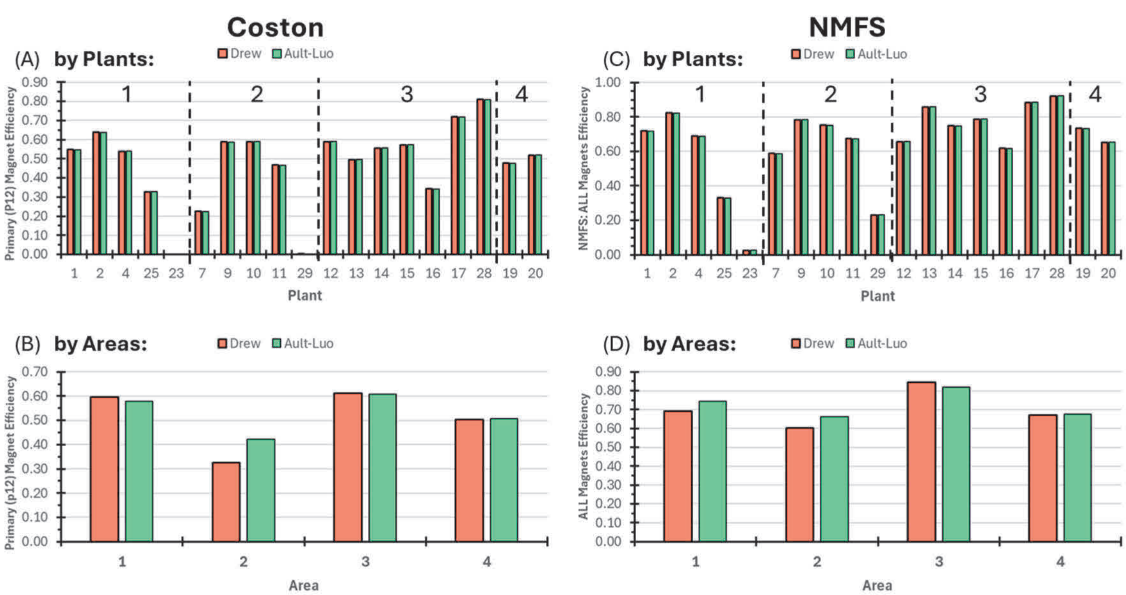


Figure I.1.- Average tag recovery magnet efficiencies over 1966-1971 at 19 reduction plants and four geographic areas for the two principal data sources: (A-B) "primary" magnets for Coston; and (C-D) "all" magnets for NMFS.

For the two data sources, average ME estimates were equivalent by plants (**Figs. I.1 A & C)**; and, area averages were only marginally different due to the catch weighting of coefficients by ASMFC. However, inspection of the statistical distributions of magnet efficiencies for all plants and areas combined shows these data are not normally distributed and are not well represented by the arithmetic mean as the central value of these data; nor are they either by individual plants or areas (**Figs. I.2-I.4**).

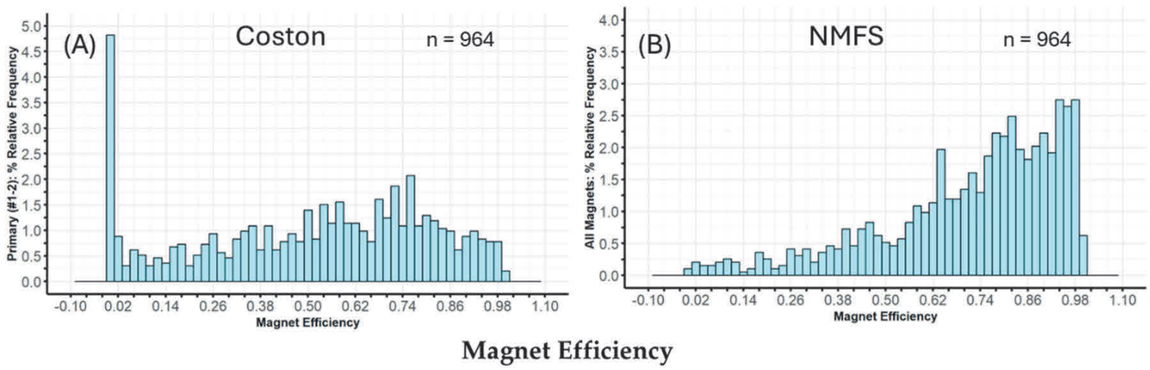


Figure I.2.- Distributions of combined magnet efficiencies for all plants and areas from 964 batch trials: (A) "primary" magnets (recovery stations 1 and 2) relevant to the Coston data; and (B) "all" magnets (all plant recovery stations) relevant to the NMFS data.

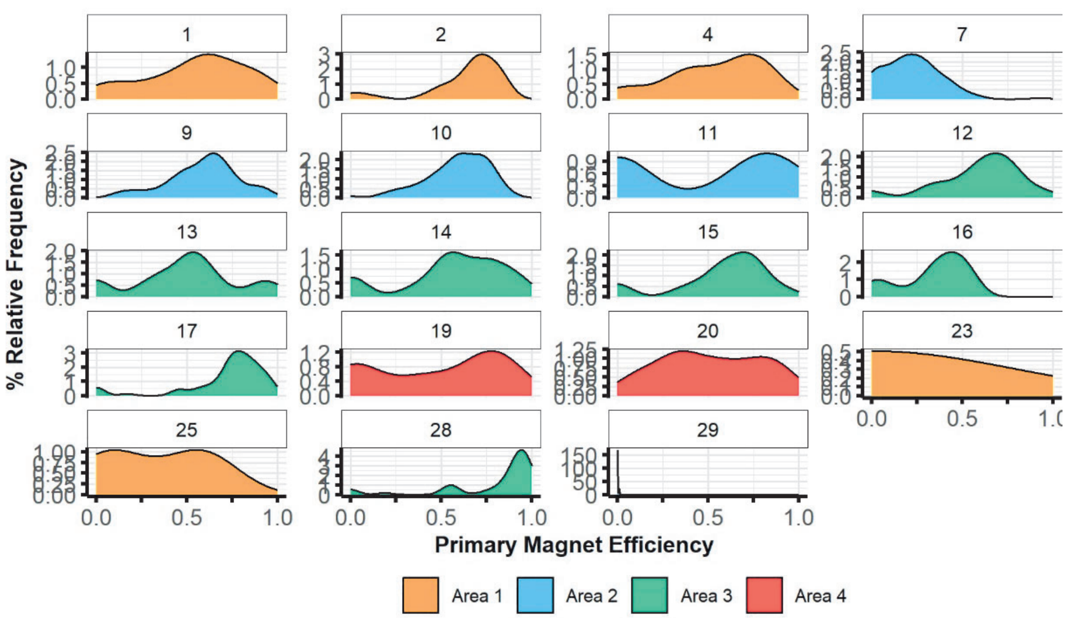


Figure I.3.- Plant-specific distributions of individual batch trial magnet efficiencies for "primary" (p12) magnets at 19 Atlantic menhaden reduction plants contained within four geographical areas (see **Table S1**) during 1966-1971.

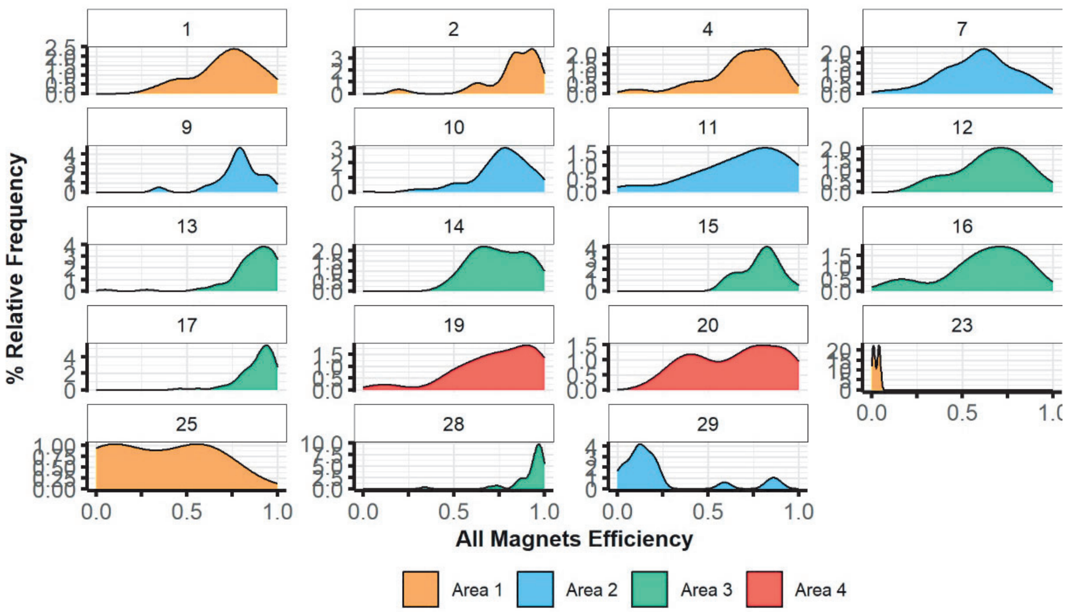


Figure I.4.- Plant-specific distributions of individual batch trials of magnet efficiencies for "ALL" magnets at 19 Atlantic menhaden reduction processing plants contained within four geographical areas (see **Table S1**) during 1966-1971.

Figs. I.2-I.4 each clearly show that the combined and individual magnet efficiency data were apparently distributed as uniform random variables ranging between 0 and 1, i.e., U(0,1). A "uniform distribution" means all possible outcomes in the range have an equal probability of occurring.

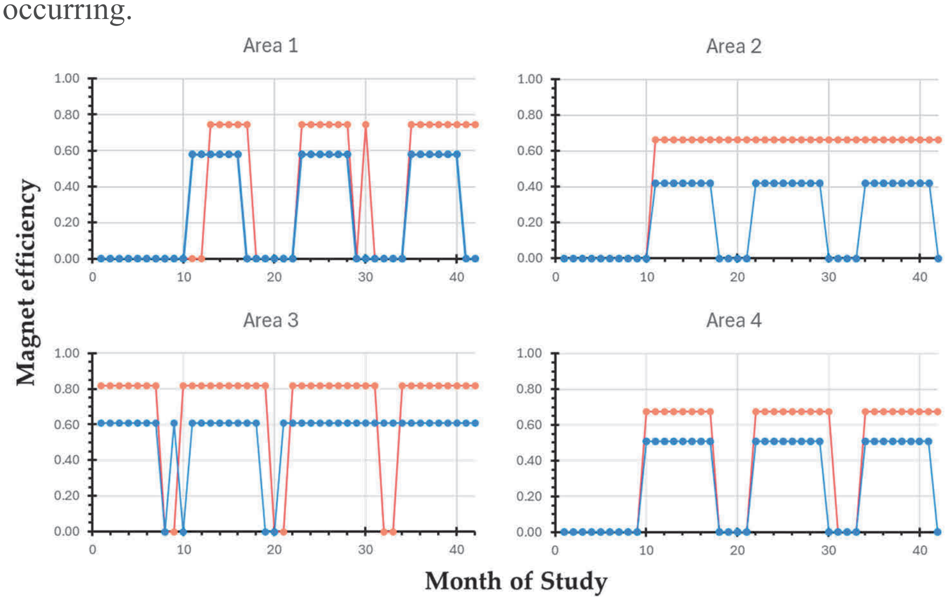


Figure I.5.- Temporal distribution of area averaged estimates of magnet efficiency within 4 geographical Areas over the 42 month (July 1966-December 1969) study. MEs are applied during months when recaptures were observed. Coston (p12) averages (blue closed dots) are from **Fig. I.1B**; while NMFS (all recovery stations) averages (red closed dots) are from **Fig. I.1D**.

In the null "Constant" modeling approach, Area averages were used by the SAS as monthly inputs by area for the estimated magnet efficiency matrix if recoveries were observed in that Area. However, given the uniform distributions of magnet efficiencies by plants, areas and all plants and areas combined, the Area mean is a poor descriptor of the underlying data.

As such, single run mean assessments were run. If the model converged, then and MCMC run of 4,000,000 trials was conducted to establish the mean and standard error of the estimated natural mortality parameter.

II. Stepwise Analysis of Magnet Efficiencies $\left(\boldsymbol{\varepsilon}_{\mathbf{t,a}}\right)$

Recoveries (theoretical catch of tagged cohorts of menhaden) for each month t and area a of tagged cohorts $\left(C_{T,A,t,a}\right)$ is the product of the unknown time and area-specific tagged fish abundance, $N_{T,A,t,a}$, the proportion of mortality due to fishing $F_{t,a}$ and natural M causes, and the time and area specific plant magnet efficiency rate $\varepsilon_{t,a}$.

$$C_{T,A,t,a} = \left[N_{T,A,t,a}\frac{F_{t,a}}{(F_{t,a}+M)}\left(1-e^{(F_{t,a}+M)}\right)\right]\varepsilon_{t,a} \tag{1}$$

The Stepwise procedure is conducted as follows:

Step 0: Input the matrix of "Constant" average "primary" magnet efficiencies $\left[\hat{\varepsilon}_{0_{t,a}}\right]$ determined in the Section I analyses for each area a $(\mathrm{a}=1,\cdots,4)$ and month t $(\mathrm{t}=1,\cdots,42)$. Input these values and conduct a single run, letting the model estimate recaptures $C_0(t,a)$ according to Eq. (1).

Simple rearrangement of Eq. (1) produces a mean area-time estimate of magnet efficiency $\hat{\varepsilon}_{t,a}$.

$$\hat{\varepsilon}_{1_{t,a}} = \frac{\text{Observed } C_{t,a}}{N_{t,a}\frac{F_{t,a}}{(F_{t,a}+M)}\left(1-e^{(F_{t,a}+M)}\right)} = \frac{\text{Observed } C_{t,a}}{\hat{C}_0(t,a)} \tag{2}$$

where,

$$\hat{C}_0(t,a) = N_{t,a}\frac{F_{t,a}}{(F_{t,a}+M)}\left(1-e^{(F_{t,a}+M)}\right) \tag{3}$$

The denominator of Eq. (2) is calculated internally in the model through sequencing tagged cohorts released over time in the 4 areas, resulting in an updated estimate of magnet efficiency.

Step 1: Use the theoretical numbers of tagged fish (Eq. 1) from Step 0, or "actual unknown" recaptures $\left(\hat{C}_0(t,a)\right)$, without application of $\hat{\varepsilon}_{1_{t,a}}$, to re-estimate magnet efficiencies as: $\hat{\varepsilon}_{1_{t,a}} = \text{Observed } C_{t,a}/\hat{C}_0(t,a)$. Use these adjusted $\hat{\varepsilon}_{1_{t,a}}$ values as magnet efficiency parameters.

Additionally, minimum and maximum limits on the area-specific estimates of magnet efficiencies ($\hat{\varepsilon}_{t,a}$) were set to range between 0.10 – 0.98 for "primary" magnet when using the Coston data. This constraint was reduced to 0.20 – 0.98 for "all" (all recovery stations) when using NMFS data. Upon model convergence, the new matrix of magnet efficiencies $\left[\hat{\varepsilon}_{S_{t,a}}\right]$ was used in the Stepwise analysis process.

Step 2: Use Step 1's theoretical catch of tagged fish $\left(\hat{C}_1(t,a)\right)$ to re-estimate magnet efficiencies $\left[\hat{\varepsilon}_{1_{t,a}}\right]$ and use as Step 2 model inputs.

The Akaike Information Criterion (AIC) was the estimator of prediction error and thereby relative quality of the statistical models for the given sets of data. Given a collection of models for a given set of data, AIC estimates the quality of each model, relative to each of the other models. Thus, AIC provides an objective means for model selection.

$$\mathrm{AIC} = -2\ln(\mathrm{L}) + 2\mathrm{K} \tag{4}$$

Where, K ≡ number of estimated parameters in the model; and, L ≡ maximum value of the likelihood function for the model. A lower AIC indicates a better fit and thus better model.

Step 3+: Continue stepwise procedure outlined above until an objective stopping criterion is met.

Step	$\widehat{\mathbf{M}}$	**neg(LL)**	$\widehat{\mathbf{R}}$	**R**	**Δ**	**AIC**
0	0.8963	10,579	195,603	102,992	92,611	21,370
1	0.7289	9,795	143,697	102,992	40,705	19,802
2	0.6891	9,777	100,340	102,992	-2,652	19,766
3	0.5956	9,744	97,346	102,992	-5,646	19,700
4	0.5149	9,751	96,422	102,992	-6,570	19,714
5	0.4406	9,763	96,044	102,992	-6,948	19,738
6	0.3790	9,773	95,753	102,992	-7,239	19,758
7	0.3243	9,784	95,569	102,992	-7,423	19,780

Table II.1.- Stepwise analysis of the Coston data. Symbols are: $\widehat{\mathrm{M}}$ ≡ estimated annual natural mortality rate: neg(LL) ≡ model's negative log-likelihood; $\widehat{\mathrm{R}}$ ≡ total estimated recaptures by the model; ; R ≡ observed total recaptures; Δ ≡ difference between predicted and observed recaptures; AIC ≡ Akaike Information Criterion.

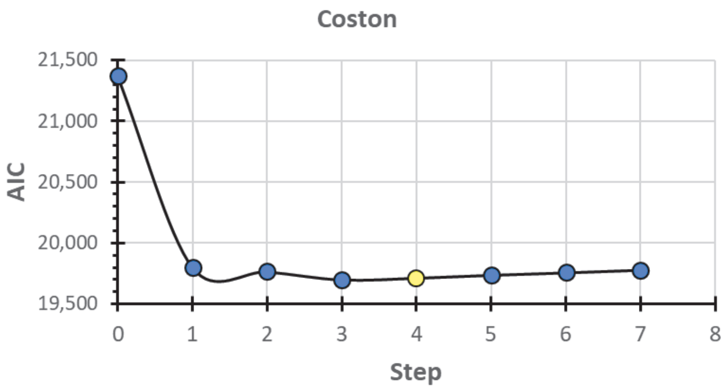


Figure II.1.- AIC reduction using the Stepwise iterative procedure for the Coston data. Minimum AIC was identified as Step 4.

Stepwise analysis for the NMFS data showed a minimum AIC in Step 7 (**Table II.2** & **Fig. II.2**).

Step	$\widehat{M}$	neg(LL)	$\widehat{R}$	R	Δ	AIC
0	0.8909	8,044	133,279	93,335	39,944	16,300
1	0.8174	7,532	94,784	93,335	1,449	15,276
2	0.7737	7,500	88,188	93,335	-5,147	15,212
3	0.6938	7,505	95,008	93,335	1,673	15,222
4	0.6564	7,515	95,649	93,335	2,314	15,242
5	0.6294	7,519	95,962	93,336	2,626	15,250
6	0.5609	7,405	113,129	93,337	19,792	15,022
7	0.5279	7,372	107,830	93,338	14,492	14,956
8	0.4863	7,373	108,519	93,339	15,180	14,958
9	0.4498	7,377	108,746	93,340	15,406	14,966

Table II.2.- Stepwise analysis of the NMFS data. Symbols are: $\widehat{M}$ ≡ estimated annual natural mortality rate: neg(LL) ≡ model's negative log-likelihood; $\widehat{R}$ ≡ total estimated recaptures by the model; ; R ≡ observed total recaptures; Δ ≡ difference between predicted and observed recaptures; AIC ≡ Akaike Information Criterion.

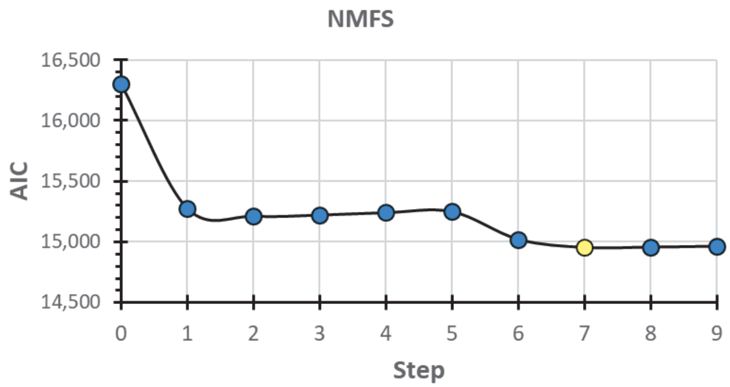


Figure II.2.- AIC reduction using the Stepwise iterative procedure for the NMFS data. Minimum AIC was identified as Step 7.

III. Magnet Efficiencies $(\varepsilon_{t,a})$ as Model Parameters

The probability distribution of estimated plant time-area magnet efficiencies closely resembled a uniform random distribution $U(0, 1)$ (**Fig. III.1**), and was not well represented by the average across all plants and areas over years. Thus, another reasonable method was to estimate magnet efficiencies $\hat{\varepsilon}_{t,a}$ by area and time $\hat{\varepsilon}_{t,a}$ by treating them as model parameters, done in the same way that the theta parameters (catchability $\Theta_{t,a}$) are already estimated in the model. To this end, we modified the model code to allow magnet efficiencies $\hat{\varepsilon}_{t,a}$ to be estimated as model parameters. The number (n) of non-zero recapture elements by area and time was used to determine the number of $\hat{\varepsilon}_{1-n}$ parameters, which map to the $\left[\hat{\varepsilon}_{0_{t,a}}\right]$ matrix. We employed a way similar to how the theta parameters were estimated as the natural log of theta, $\ln(\Theta)$, in the model, the log of magnet efficiencies, $\ln(\hat{\varepsilon}_{1-n})$, that were estimated in the model. We also constrained the log-parameter boundary to range from -3.5 to -0.05 for the Coston data, and from -2.0 to -0.05 for the NMFS data. The number of non-zero recaptures elements in Coston data is 100; thus, when estimating magnet efficiencies we have additional 106 parameters that needed to be estimated by the model, that is, a total of 206 parameters for the model. The model input data of releases and recaptures creates a matrix of:

$$\text{Months tagged } \times \text{Areas} \times \text{Months recaptured} \times \text{Areas} = 42 \times 4 \times 42 \times 4 = 28{,}224 \text{ d.f.}$$

For a total of 28,224 data points. Thus, the degrees of freedom are not significantly affected by the increase of 106 parameters to estimate time-area magnet efficiencies

$$28{,}224 - 106 = 28{,}118 \text{ d.f.}$$

IV. Summary

Results of these analyses are summarized graphically for the three model types and two data sources as comparative single model fits of observed data for the "Constant" (**Figs. IV.1A-C**), "Stepwise" (**Figs. IV.1B-E**) and "Parameters estimated" (**Figs. IV.1C-F**) methods for the Coston (left panels) and NMFS (right panels) data. The observed model fits to data are superior for both Stepwise and Parameter methods as compared to the Constant method.

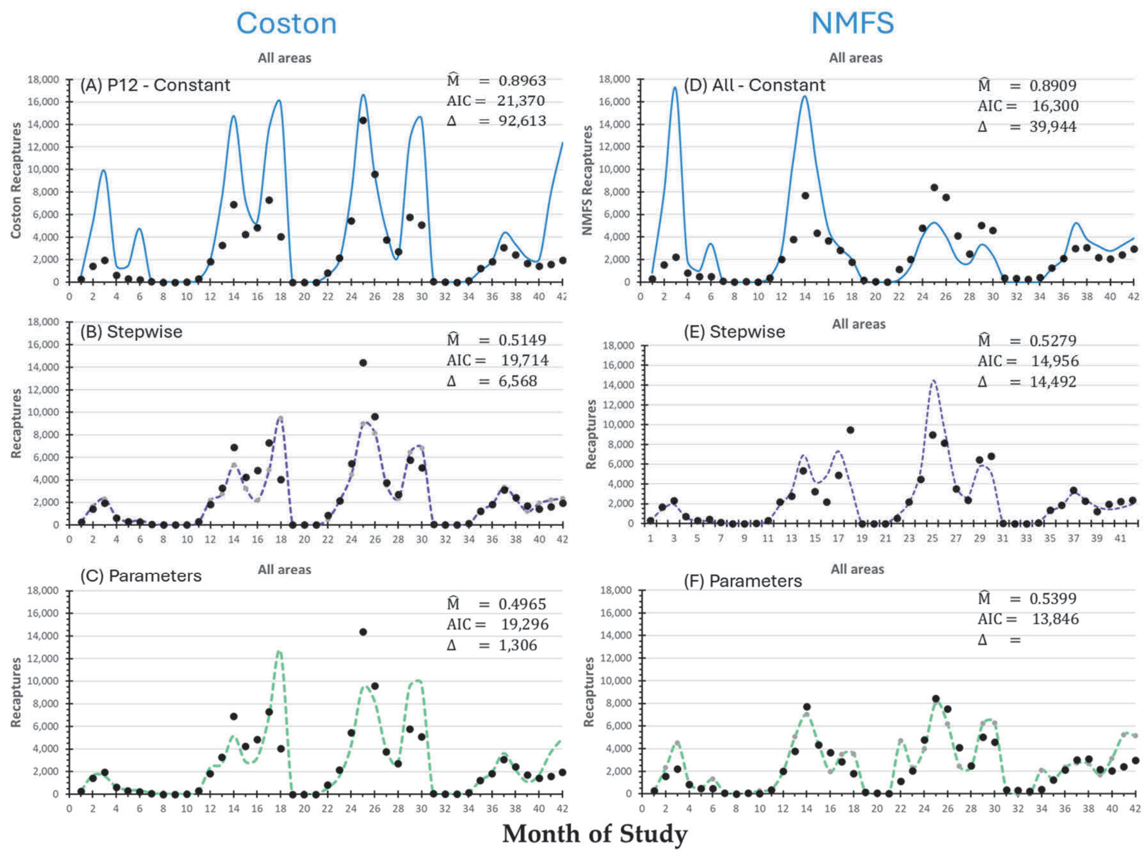


Figure IV.1.- Summary visualizations of single run results for the two data sources: **Coston**: (A) primary magnets with constant ME coefficients; (B) stepwise analysis (Step #4); (C) ME parameters estimated by model. **NMFS**: (D) all magnets with constant ME coefficients; (E) stepwise analysis (Step #7); (F) ME parameters estimated by model.

Given that all three models converged, MCMC analyses, each consisting of 4,000,000 trials, were completed (**Fig. IV.2**). While the unconstrained case for the ME parameter estimation was exploratory, it did produce an estimate of natural mortality lower than what we expected, and further, what we would probably consider to be unrealistic. In contrast, placing realistic constraints on the ME estimates marginally increased the AIC (Coston about +0.43%; NMFS about +1.8%), but significantly increased the value of M (Coston about +68.2%; NMFS about +83.6%) (**Tables IV.1 & IV.2**).

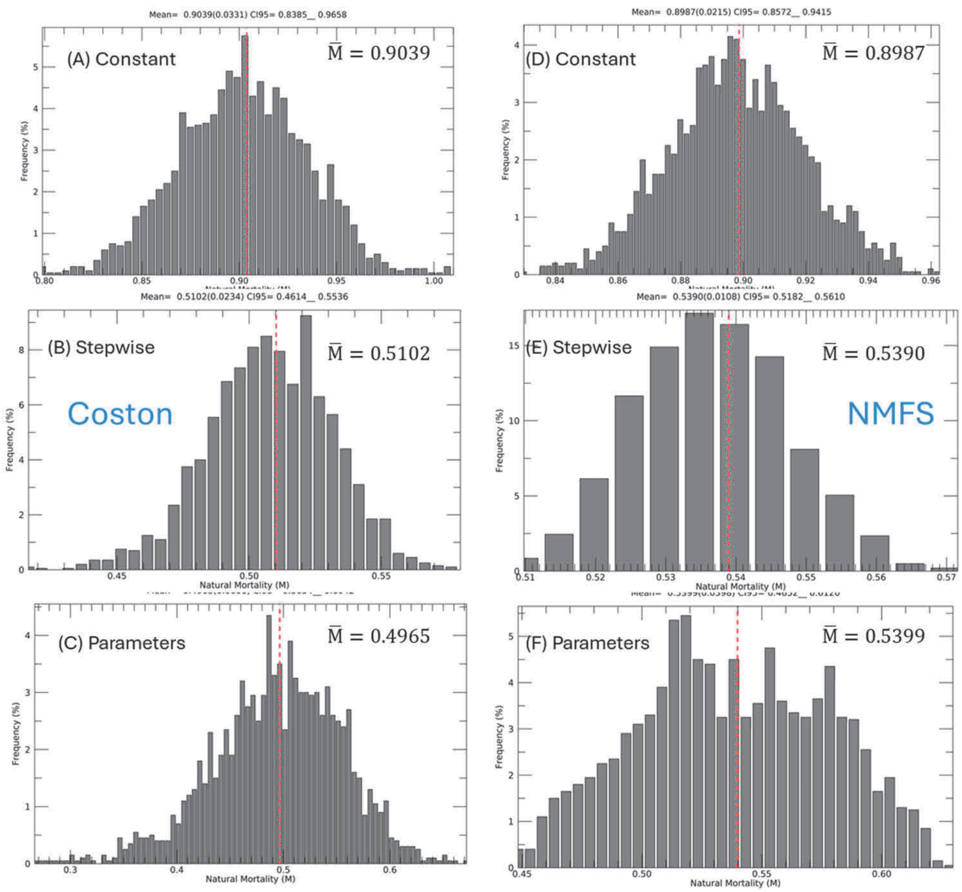


Figure IV.2.- Summary of MCMC trial results corresponding directly to the single-run results of **Fig IV.1**. **Coston**: (A) primary magnets with Constant MEs; (B) Stepwise analysis (Step #4); (C) ME Parameters estimated. **NMFS**: (D) ALL magnets with Constant MEs; (E) Stepwise analysis (Step #7); (F) ME Parameters estimated.

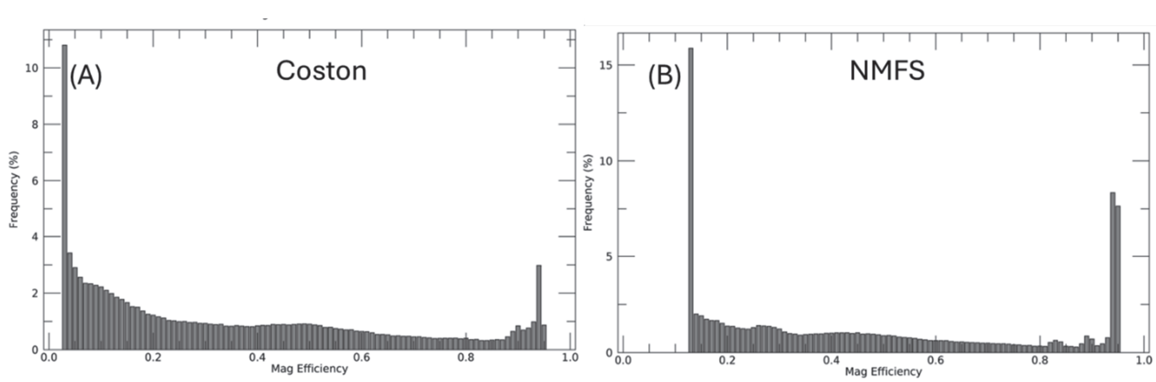
Method	**K**	**neg(LL)**	Δ	**AIC**	$\hat{M}$	$\hat{M}_{MCMC}$
Constant:	106	10,579	92,611	21,370	0.8992	0.9039
Step 4:	106	9,751	-6,570	19,714	0.5149	0.5102
As parameters:						
Unconstrained	206	9,442	8,296	19,296	0.3406	0.2939
Constrained	206	9,484	10,123	19,380	0.5488	0.4965

Table IV.1.- Summary of results from three analytical methods applied to the Coston data. Symbols are: K ≡ number of estimated model parameters; neg(LL) ≡ model's negative log-likelihood; Δ ≡ difference between predicted and observed recaptures; AIC ≡ Akaike Information Criterion; $\hat{M}$ ≡ estimated annual natural mortality rate; $\hat{\hat{M}}_{MCMC}$ ≡ MCMC mean estimated annual natural mortality rate.

Method	K	neg(LL)	Δ	AIC	$\widehat{M}$	$\widehat{M}_{MCMC}$
Constant:	106	8,044	39,944	16,300	0.8909	0.8987
Step 7:	106	7,372	14,492	14,956	0.5279	0.5390
As parameters:						
Unconstrained	206	6,717	1,306	13,846	0.2935	0.2940
Constrained	206	6,839	12,669	14,090	0.5689	0.5399

Table IV.2.- Summary of results from three analytical methods applied to the NMFS data. Symbols are: K ≡ number of estimated model parameters; : neg(LL) ≡ is the model's negative log-likelihood; Δ ≡ difference between predicted and observed recaptures; AIC ≡ Akaike Information Criterion. $\widehat{M}$ ≡ estimated annual natural mortality rate; $\widehat{\widehat{M}}_{MCMC}$ ≡ MCMC mean estimated annual natural mortality rate.

Using the all the data, the three central and most important metrics for assessing the efficacy of the model analyses are: (1) the AIC; (2) differences (Δ) between observed and predicted recaptures; and (3) visual inspection of the plot of the observed versus model-predicted recaptures. In general, for both data sets: $AIC_{constant} \gg AIC_{stepwise} > AIC_{parameters}$, which suggests that MEs estimated as parameters should be the best model choice. For the Coston data, the reduction in AIC ranged between -7.7% to -9.3% for the stepwise versus parameters, respectively. For the NMFS data, the reduction in AIC ranged between -8.2% to -13.6% for the "stepwise" versus "$\varepsilon_{t,a}$ as estimated parameters" approaches, respectively. It is obvious that both stepwise and ME parameter estimation methods are better fits to the data than constant MEs (**Fig. IV.1**).



Magnet Efficiency

Figure IV.2.- Modeled magnet efficiency parameter estimates for: (A) Coston; and (B) NMFS data sources. Note the similarity to the observed empirical plant test magnet efficiency data shown in **Fig. I.2**.

V. Conclusions

As discussed by the SAS M workgroup, our analyses estimated a natural mortality rate (M) of approximately 0.54 or lower using multiple methods and two data sources. In contrast, Schueller et al. estimated an M of about 0.92 based solely on the averaged plant-area magnet efficiencies. As it turns out, the largest driver of this difference was not the confidential effort data withheld by industry, nor was it the underlying magnet efficiency data *per se*. It was simply methodological differences associated with how the tag recovery-magnet efficiency data were applied.

In our opinion, it is inappropriate to use arithmetic averages of plant- and area-specific magnet efficiencies. The Plant Test trial data show that magnet efficiencies are uniformly distributed, meaning any level of magnet recovery efficiency is equally possible (**Figs. I.2-I.4**). Consequently, averaging magnet efficiencies by area results in a poor and inefficient use of the Plant Tests data. Therefore, we employed two alternative methods: a "Stepwise" approach which was initiated with arithmetic mean efficiencies, and then in an iterative stepwise process used observed and theoretical recoveries to improve the $\left[\hat{\varepsilon}_{S_{t,a}}\right]$; and a "Parameter Estimation" approach which directly estimated the MEs as model parameters. Both of these alternative methods substantially improved model fits, and also substantially lowered the natural mortality rate (M) estimates.

The preferred method(s) should be one(s) that utilize the entire data set. For both datasets, model(s) that estimated magnet efficiency parameters as a distribution produced recapture estimates closest to those observed. Similar results were obtained between the Stepwise and Parameter Estimation methods, and between the two data sources (**Tables IV.1** & **IV.2**). Given the uniform random distribution of magnet efficiencies, the use of the simple weighted arithmetic averages of magnet efficiency by areas will naturally produce the highest estimates of natural mortality, and also the most unreliable.

In summary, our analyses that used appropriate statistical metrics strongly indicate that the most likely annual natural mortality rate estimate for Atlantic menhaden ranges between 0.50 to 0.54. These estimates represent a 43.3% and 40.0% reduction compared to the constant ME estimates derived from simple averaging of either the Coston and NMFS data, respectively. Therefore, we concluded that $\widehat{\mathrm{M}} = 0.52$ is the best estimate of annual natural mortality rate for Atlantic menhaden.

Supplemental

Area	Region	Code	Plant #	trials	Name	City	State
			1	29	Atlantic Processing Company	Amagansett	NY
	1	**NY**	23	4	Lipman Marine Products Co. (Gloucester Marine Protein)	Gloucester	ME
			25	2	Point Judith Byproducts Co.	Point Judith	RI
1							
	2	**NJ**	2	69	J. Howard Smith, Inc.	Port Monmouth	NJ
			4	25	New Jersey Menhaden Products Co.	Wildwood	NJ
			7	120	Standard Products Co.	Reedville	VA
			8	0	McNeal-Edwards (Standard Products Co.)	Reedville	VA
2	**3**	**CB**	9	21	Menhaden Co. (Standard Products Co.)	Reedville	VA
			10	151	Virginia Menhaden Products (Reedville Oil & Guano Co.)	Reedville	VA
			11	52	Standard Products Co.	White Stone	VA
			29	18	Cape Charles Processing Co.	Cape Charles	VA
			12	31	Fish Meal Co.	Beaufort	NC
			13	75	Beaufort Fisheries Inc.	Beaufort	NC
			14	31	Standard Products Co.	Beaufort	NC
3	**4**	**NC**	15	16	Standard Products Co.	Morehead City	NC
			16	22	North Carolina Menhaden Produxts	Morehead City	NC
			17	64	Standard Products Co.	Southport	NC
			28	49	Seashore Packing Co.	Beaufort	NC
4	**5**	**FL**	19	52	Quinn Menhaden Fisheries Inc.	Fernandina Beach	FL
			20	133	Nassau Oil & Fertilizer Inc.	Fernandina Beach	FL
			20	**964**			

Table S1.- Regional reduction processing plants distributed across four areas along the Atlantic coast that were involved in the 1966-1971 plant-area magnet efficiency trials as part of the Atlantic menhaden mark-recapture study conducted by the National Marine Fisheries Service.

UNIVERSITY OF MIAMI
ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

January 31, 2020

Nichola Meserve, Chair
ASMFC Menhaden Management Board

Dear Ms. Meserve & Board Members,

I greatly appreciate the immense amount of effort dedicated to the production of the SEDAR 69 Atlantic menhaden Stock Assessment (SA) and Ecological Reference Point (ERP) Working Group (WG) reports. I would further like to acknowledge both the scientists and the Menhaden Management Board (MMB) for their continued efforts to pursue ecological management of Atlantic menhaden. This is ground-breaking work made successful by the outstanding leadership, professional dedication and exceptional insights of the MMB and Drs. Matt Cieri, Dave Chagaris, Jason McNamee, Amy Schuller and, Katie Drew.

I also certainly appreciate the enormous challenges associated with this unprecedented paradigm shift by the ASMFC MMB to ecological management, and I commend the ERP WG for their diligent pursuit and evaluation of multiple relatively complex ERP models. It is clear that the SA and ERP reports provide the initial roadmap for the necessary move to ecological management, thereby allowing ASMFC to begin to manage from multispecies and ecological perspectives. I encourage the Board to move forward to adopt ERPs as soon as possible and achieve this objective.

However, I have substantial concerns about the underlying data and model parameter assumptions, which if validated, mean that the SEDAR 69 benchmark stock assessment paints an overly rosy picture of Atlantic menhaden stock status.

In particular, my greatest concern relates to extremely high rates of natural mortality (M) used in the SEDAR 69 benchmark stock assessment. The new M estimate used was based on Liljestrand et al.'s (2019) re-evaluation of a 1960s tagging data set. They acknowledged that their estimated M was substantially greater than previously reported, particularly since several other published studies using the same data produced estimates that were ¼ of those of Liljestrand et al.'s (2019). Setting aside questions of whether it was appropriate to use data more than 55 years old, or whether in fact the Bayesian analysis was appropriate given the assumptions about parameter priors required, in the SEDAR 69 SA the HIGHEST rates of M-at-age were seemingly cherry-picked from the Liljestrand et al. (2019) paper, NOT the average rates. With the new rates and no fishing, only 0.6 of 1% of menhaden survive to reach their 4^{th} birthday. In **Figure 1** below you can clearly see that those rates chosen were far greater (i.e., >2.9 times greater) than those found in any other national or international fishery stock assessments, including stocks which had similar short-lived forage fish life histories. It should also be noted that the Ms used in ASMFC menhaden assessments over the past decade have been steadily increasing, and this trend has had substantial impacts on reported estimates of stock size (both abundance & biomass), recruitment, exploitation rates, and sustainability metrics.

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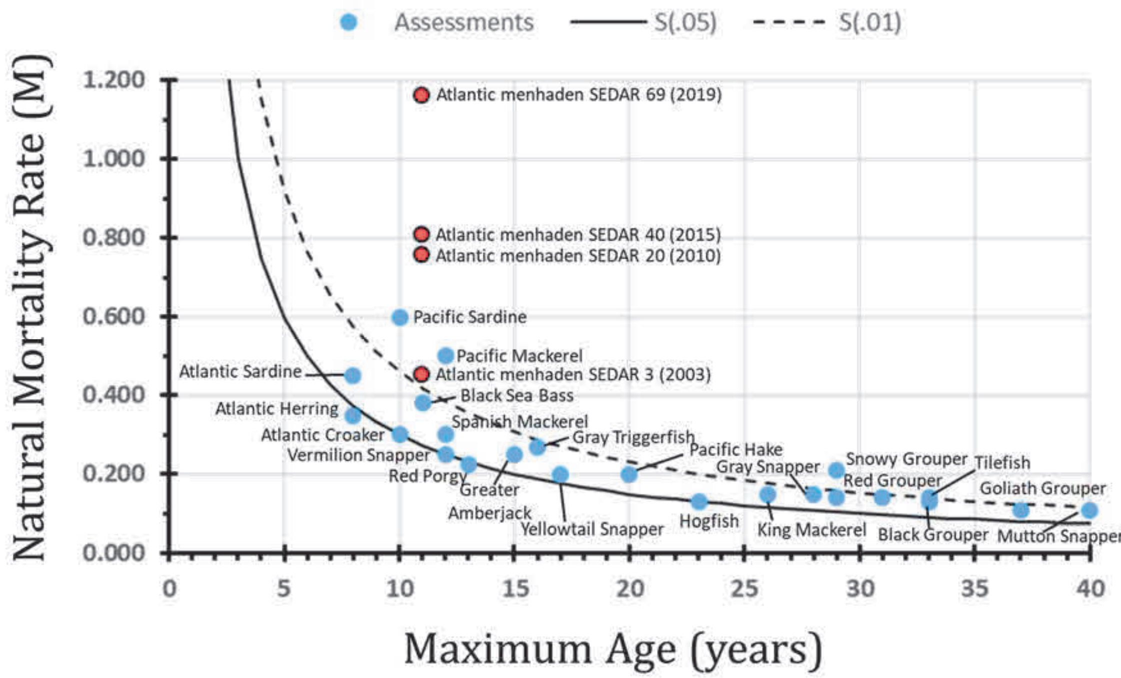


Figure 1.- Natural mortality rates $\widehat{M}$ as a function of maximum age used in various national and international Commission/Council's (i.e., NOAA Southeast Data & Assessment Review, SEDAR); Pacific Fishery Management Council, PFMC; and the International Council for Exploration of the Seas (ICES) species stock assessments during 2003-2019. Labeled red dots show the temporal progression of estimated $\widehat{M}$ used in four sequential SEDAR Atlantic menhaden stock assessment reviews conducted by the Atlantic States Marine Fisheries Commission (ASMFC). Lifespan $\widehat{M}$ model for 5% (solid line) and 1% (dotted line) survivorship to maximum age are also shown.

The upshot of employing such high M rates is the suggestion that mortality from fishing has had little to no impact on the Atlantic menhaden stock, leading to the most recent assertion that the Atlantic menhaden stock biomass is currently at 85% of the virgin (unfished) stock size (B_0). This is a highly unlikely conclusion. With the uncertain estimates being used for M, in a single species context, fishing effort could be cranked up to levels never seen before in the fishery. At a minimum, the stock assessment should have at least adjusted M downward to no higher than the average rates in the Liljestrand et al. (2019) paper.

In fact, the ERP WG report highlighted the issue of "unaccounted mortality" shown in **Figure 2** below. The ERP result suggests that the M is too high and cannot be reconciled, even when predators are considered in the Ecopath model.

For the single species modeling, in order to make the Beaufort Assessment Model (BAM) model work with these new extremely high rates of M, model estimates of recruitment had to be raised to levels more than ten times reported in the SEDAR 40 (2015) assessment, levels never before recorded. However, contra to this conclusion, observations from the young-of-the-year (YOY) surveys suggest that menhaden recruitment in 2017 was dangerously low. To this point, during their deliberations the SAS acknowledged there is a substantial risk that three bad years of recruitment in a row--which would not be picked up in the modeling until it is too late -- set the stock up for disaster. That is because the reduction fishery only fully selects menhaden after all fish reach three years of age. This kind of deleterious outcome is exactly what happened in the Atlantic herring fishery and we cannot afford to do the same with Atlantic menhaden.

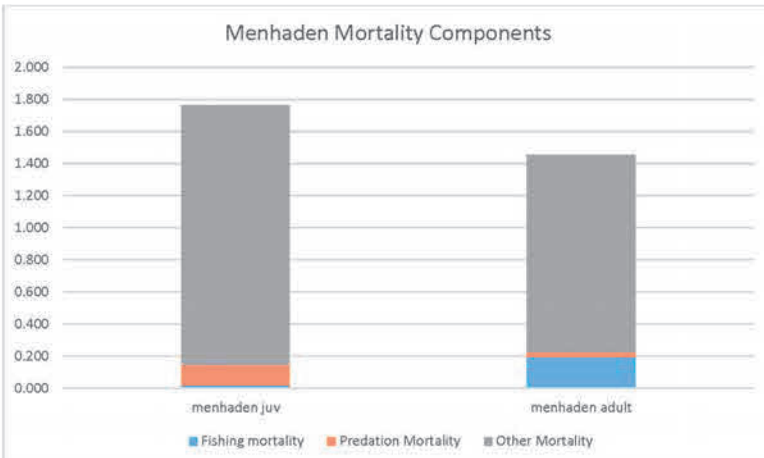
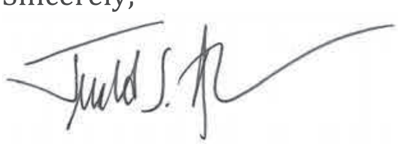


Figure 2.- Ecopath Atlantic menhaden mortality components from the NWACS-MICE model (Figure 129 from the ERP Stock Assessment Report, 2019).

Over the past year, I have shared these concerns with the SEDAR Peer Review Panel, Stock Assessment Subcommittee (SAS) and ERP Technical Committee. In addition, I have been in touch with key members of both the SAS and ERP WG to share my concerns. Now it is up the MMB to adopt a precautionary approach moving forward. The Board has a momentous opportunity and should immediately move forward with approval and implementation of ERPs; however, given the significant uncertainty and resource risks, menhaden catch should not be increased, and in fact, in my view it should be substantially reduced.

I look forward to working with the MMB and the SAS in the near future to closely evaluate the data and model parameter assumptions. I am particularly interested in assisting the ongoing analysis around M and strategies for improvement.

Sincerely,



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University of Miami

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Liljestrand, E.M., Wilberg, M.J., Schueller, A.M. 2019. Estimation of movement and mortality of Atlantic menhaden during 1966–1969 using a Bayesian multi-state mark-recovery model. Fisheries Research 210: 204-213.

February 28, 2025

Robert Beal, Executive Director
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Re: Atlantic Menhaden Revised Natural Mortality Rate Estimate

Dear Mr. Beal,

We are writing to follow up on our letter of October 31, 2024 regarding the science underlying the Atlantic menhaden stock assessment. In that letter, we explained that based on a recent paper currently in peer review by Drs. Jerry Ault and Jiangang Luo we are concerned that the menhaden stock assessment science may be flawed due to significant data errors affecting the natural mortality rate estimate (M) used in the stock assessment model. We explained that the scientific flaws have likely resulted in a substantial overestimation of the natural mortality rate, and in turn substantial overestimation of the coastwide stock size and allowable catch for the fishery, which could result in overfishing of the Atlantic menhaden resource. We also highlighted the ASMFC's obligation to base its conservation programs and management measures on the best scientific information available and to prevent overfishing. Our October 31 letter is enclosed for reference.

We extend our thanks to you for responding to our letter and related emails, as well as to the ASMFC Atlantic Menhaden Stock Assessment Subcommittee (SAS) and its Natural Mortality Work Group for considering the issues raised related to the M estimate used in the menhaden single species stock assessment since 2020. The SAS review confirmed that important mistakes were made in the paper that was relied on to establish the current estimated M (Liljestrand *et al.,* 2019). As a result, the SAS concluded that the current M is at least 20 percent too high -- 1.17 compared to 0.92. However, the enclosed additional analysis by Drs. Ault and Luo shows that the best available science requires an even more substantial revision.

This is largely because after uncovering critical errors made in the Liljestrand *et al.* paper, the SAS did not carefully apply the most scientifically sound methodological approach to correcting those errors. As explained in detail in the enclosed analyses, the use of simple weighted arithmetic averages of magnet efficiency by area[1] is inappropriate in this case. Instead, "Stepwise" or "Parameter Estimation" approaches account for the random distribution of magnet efficiencies and substantially improve model fits. Both methods also substantially lower the M estimates. This can be easily corrected based on the attached analysis. After applying the appropriate statistical metrics, the analysis strongly indicates that the most likely annual natural mortality rate estimate for Atlantic menhaden ranges between 0.50 to 0.54. This M estimate range is not only supported in the analysis because it results from the best model fit, an estimated

[1] Magnet efficiency is a measure of the efficiency by which the magnets in the menhaden processing plants captured tags in the underlying tagging study. Each plant had up to nine magnets, with the first two used in the Costen study, and all nine used in the NMFS data analysis.

M in this range would also be consistent with the prior 12 peer reviewed M estimates, adding credibility to its scientific soundness. In contrast, the SAS recommendation of 0.92 remains a significant statistical outlier, still several standard deviations above all prior estimates.

As you review the enclosed scientific analysis you will see that it is consistent with the work of the SAS and M Work Group leading up to the final step where the SAS inappropriately applied the simple arithmetic average of plant- and area-specific magnet efficiencies. We request that the ASMFC through its Ecological Reference Point Workgroup, which is meeting from March 3 to March 6, 2025, consider the enclosed analysis, apply one of the more statistically sound methods described, and adopt the resulting M estimate (expected to be in the range of 0.50 to 0.54) in the base run Beaufort Assessment Model (BAM)[2].

The importance of the ASMFC meeting its requirement to rely on the best scientific information available is amplified in this case because the magnitude of the substantial differences between the natural mortality rate currently being used (1.17), or alternatively currently recommended by the SAS (0.92), and that indicated by the Ault and Luo analysis (0.50 to 0.54). This suggests that there is high risk that overfishing may occur if not changed immediately, and that Atlantic menhaden could already be overfished with overfishing occurring because the incorrect natural mortality rate assumption has been used since the 2020 assessment. It is critical that the ASMFC make the scientifically and legally sound decisions at this juncture necessary to ensure the Atlantic menhaden resource and the East coast ecosystem it supports are protected.

Thank you for considering our concerns and recommendations.

Sincerely,

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Encl:

[2] BAM is the model used for the menhaden single species stock assessment, and the outputs from BAM, including the rate of natural mortality, serve as the baseline for the ERP assessment.

1. Dr. Jerald S. Ault Dr. and Jiangang Luo, Report on Estimation of Area Magnet Efficiencies and Natural Mortality, (February 25, 2025).
2. Dr. Jerald S. Ault Dr. and Jiangang Luo, Magnet Efficiency Parameters, (February 27, 2025).
3. Roger Fleming, Esq. and David Reed, Esq., Letter to Mr. Robert Beal, Executive Director, (October 31, 2024).

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October 31, 2024

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Re: Atlantic Menhaden Natural Mortality Rate Estimates

Dear Mr. Beal,

We are writing because it has come to our attention that the science that undergirds the Atlantic menhaden stock assessment may be flawed due to significant data errors affecting the natural mortality rate assumption used in the Atlantic menhaden stock assessment model. This has likely resulted in a substantial overestimation of the natural mortality rate (M), and in turn of the estimated coastwide stock size and catch limits for the fishery. Among other problems, this could result in overfishing of the Atlantic menhaden resource. We are encouraged to hear that the Atlantic Menhaden Single Species and ERP Methods Workshop from November 4th to 8th will begin a process for evaluating and potentially updating M as part of the ERP Benchmark Assessment. As this discussion and work aimed at resolving this matter are completed, we ask that the ASMFC, Atlantic Menhaden Management Board, and related committees remain cognizant of the ASMFC's legal obligations to base its decisions on the best scientific information available and to prevent overfishing. We also request that you address this matter immediately to protect the Atlantic menhaden resource and all the species that depend on it.

On September 25, 2024, Dr. Jerry Ault presented a paper he coauthored with Dr. Jiangang Luo, both from the University of Miami Rosenstiel School of Marine, Atmospheric and Earth Sciences, to the Atlantic Menhaden Stock Assessment Subcommittee (SAS) titled "Investigation of Atlantic menhaden mortality rates." This paper concludes that the extremely high M used in the menhaden assessment is based on flawed data inputs contained in the paper by Emily Liljestrand *et al.*, titled "Estimation of movement and mortality of Atlantic menhaden from 1966 to 1969 using a Bayesian multi-state mark-recovery model." In 2020, Dr. Ault submitted a letter to the Atlantic Menhaden Management Board highlighting what an extreme outlier the current M is, and his paper is a follow up investigation. See attached. Dr. Ault contacted Dr. Liljestrand and her coauthors several times when writing his paper, and again before the September 25th meeting, inviting them to review his draft and provide him with any mistakes, other concerns, or areas for improving his analysis. The SAS reviewed and discussed the paper at length. Neither Dr. Liljestrand nor members of the SAS articulated any significant flaws with the new analysis.

The authors have since submitted the paper for peer review and publication at the same respected journal, *Fisheries Research*, as the original paper.

Natural mortality is a key factor in determining stock status, so it is vital to use the most accurate M estimate during assessments. The authors noted that Dr. Liljestrand's M estimate is 2.3 times higher than the previous M estimate and more than 14 standard deviations above the average of 12 previously peer-reviewed estimates—an extraordinary outlier. This single parameter could be the deciding factor between a stock being considered as overfished or healthy. It is important to recognize that Ault and Luo attribute this result to underlying data errors, not to problems with the modeling methodologies used by Liljestrand *et al.* or the stock assessment team. Addressing these errors is critical and can be accomplished relatively quickly within the current assessment processes.

The Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) and the ASMFC's Rules and Charter all require that all Interstate Fishery Management Plans be based on the best available science (BAS) and prevent overfishing. ACFCMA requires that the Commission establish standards and procedures ensuring that IFMPs "promote the conservation of fish stocks throughout their ranges and are based on the best scientific information available[.]" 16 U.S.C. §5104(a)(2). Consistent with ACFCMA, Article VI Section 3 of the ASMFC's Rules and Regulations require that "fishery management plans, and any actions taken according thereto, promote conservation [and] use the best scientific information available." The ASMFC Charter, Section 1(c) establishes that it "is the policy of the Commission that its ISFMPs promote the conservation of Atlantic coastal fishery resources, be based on the best scientific information available, and provide adequate opportunity for public participation."

This policy is directly reflected in Charter Section 6, which provides 6 Standards and Procedures for IFMPs (similar to the Magnuson-Stevens Act's 10 National Standards for Fishery Conservation and Management), including that "(2) Conservation programs and management measures shall be based on the best scientific information available." These Standards also require that overfishing be prevented and that where necessary rebuilding plans be established providing for their long-term sustainability: "(1) Conservation programs and management measures shall be designed to prevent overfishing and maintain over time, abundant, self-sustaining stocks of coastal fishery resources. In cases where stocks have become depleted as a result of overfishing and/or other causes, such programs shall be designed to rebuild, restore, and subsequently maintain such stocks so as to assure their sustained availability in fishable abundance on a long-term basis."

These provisions make clear that the ASMFC's conservation programs and the management measures implemented through its IFMPs be based on the best available science and prevent overfishing. The Atlantic menhaden stock assessment is integral to the ASMFC's conservation programs and management, so it must be based on the BAS. The importance of meeting this requirement is amplified in this case because the magnitude of the difference between the natural mortality rate currently being used and that indicated by the Ault and Luo analysis suggests that there is significant risk that overfishing may occur if not changed immediately, and that Atlantic menhaden could already be overfished with overfishing occurring since the mortality rate has been used since the 2020 assessment.

As representatives of the conservation community, we want to emphasize that this is a pivotal time for the marine ecosystem on the East Coast. Most of the keystone forage species including Atlantic herring, Atlantic mackerel, river herring, shad, and American eel are at or near historic low levels of abundance. Over one-half of the coastal species managed by the ASMFC are classified as overfished, overfishing, depleted, or status unknown. It is important that the status of the most important ASMFC managed species remains healthy. The difference between an overfished menhaden stock and an abundant one may well determine how resilient marine life on the East coast are to a rapidly changing climate. The identified error in the stock assessment is coincident with dire new findings regarding the striped bass and osprey regional population health, making any corrections to the catch limit(s) all the more urgent for these menhaden-dependent species. From a management perspective, the application of the BAS and measures to prevent overfishing are cornerstones of effective fisheries management and healthy fisheries. Failure to address any data errors found in the science used to develop the Atlantic menhaden assessment's natural mortality rate risks a cascading ecosystem crisis.

Thus, in our view, it is critical that the ASMFC resolve this matter now. A corrected M estimate using a "realistic" M such as the one suggested by Ault and Luo will likely show a need to substantially reduce catches. As such, it is too risky to wait until the Assessment Update in 2028 or the next Benchmark Assessment in 2031 to address this issue. Options we have identified that are in line with the ASMFC's BAS and overfishing requirements that can be taken now, include the following: (1) adopt the recommended M from the Ault and Luo manuscript (pending confirmation of peer review) via the current "update" assessment process, as the M parameter methodologies would not change and only data errors would be corrected; (2) upgrade this cycle's assessment to a "benchmark" as was originally planned. These data concerns have been known to scientists since at least 2023, before the decision to downgrade the assessment to an "update" in February of 2024; (3) delay the single species assessment for approximately 3 months to accommodate the peer review and publication process; or (4) take emergency action to substantially increase the uncertainty buffer when setting specifications until this matter is resolved.

Thank you for considering our concerns and recommendations. We share the concern that addressing this matter now could result in a delay in the schedule for the 2025 ERP Benchmark Assessment, however we think this discussion demonstrates that it is critical that the ASMFC make the scientifically and legally sound decisions at this juncture necessary to ensure the Atlantic menhaden resource and the East coast ecosystem it supports are protected. For these reasons, we suggest that, if necessary, you consider moving forward with both assessments using more than one M as alternates until the peer review of the Ault and Luo paper, or other work necessary to make a final decision on the appropriate M, is complete.

Sincerely,

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