Report on the Project:
Evaluation of F-Based Management for the Recreational Summer Flounder Fishery

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Introduction

This project uses a Management Strategy Evaluation (MSE, c.f. Bunnefeld et al. 2009) framework to conduct a set of management model forecast simulations of alternative management options for the recreational summer flounder fishery and their associated plausible uncertainties to compare the expected performance of these alternatives. While the framework is developed in the context of management strategy evaluation through the use of an operating model coupled with a management model, stakeholder input on the goals and objectives are not a part of the project, and therefore we have used some general goals and objectives for the recreational summer flounder fishery for judging performance. Once the modeling tools are developed for this project, a more inclusive process for generating management goals and objectives can be undertaken if this project misses any important considerations.

The management alternatives are constructed in the context of their eventual application to the specification setting process for summer flounder. The project is informed by extending work by Dr. John Ward (Ward 2015) on quantifying the historical effects of changes in management measures on catch and harvest as well as the previous MSE done by Wiedenmann et al. (2013), both sponsored by the MAFMC. These management effects will be integrated into the MSE simulations as a way of emulating behavioral responses (and their uncertainty) to summer flounder management measures, to demonstrate the implications for achieving management objectives and to understand the relative value of management options.

Background

Given the current use of conservation equivalency (CE) and regional approaches in summer flounder management, which allow states or groups of states the ability to use differing recreational management measures, provided that state specific harvest falls within pre-specified harvest targets, it is important to investigate the efficacy of this yearly and somewhat ad hoc approach to management versus alternative recreational management strategies. Underlying the current process are the assumptions of similarity between years in the fishery for both fishing behavior and in the population dynamics of summer flounder. The process ignores many dynamic factors including implementation error in the new management procedure, changes to discard rates based on the new management regime, growth in the population, and inter-annual changes in availability of the resource to anglers. It was noted during the process for Addendum XXVIII that current methods for developing CE measures each year are subject to variability and uncertainty, and the performance of this strategy has not been good historically. Additionally, the process rarely allows for a re-evaluation of the performance of the chosen management in the following year to quantify how the program is working, beyond accounting for harvest limit adjustments that are needed in the following year to meet the new management objectives.

This project was designed to develop a new methodology that can perform better over time by accounting for more of the known population dynamics, allow for fairness, equity, and clarity in the specification setting process, and can allow for more stability through time in the management program.

One of the ways this project will progress from the current specification setting procedures used to try and meet management objectives is to demonstrate the relative value of the current procedures and alternatives using an F-based approach for recreational management of summer flounder. Moving from a harvest-based approach to an F-based approach may allow for more inter-annual stability in recreational management by not being directly subject to single year swings in MRIP harvest estimates. The F-based approach may also better account for important population dynamics that are currently being ignored, such as accounting for recreational discards, growth, and future changes in availability due to cohort strength. Proposed advantages of an F-based approach are that performance of projections will be enhanced as stability will be increased in specification-setting thus improving buy-in and knowledge of regulations by the fishing public, and because more factors are being accounted for in the population projections that have the potential to impact future performance.

In addition to the F-based strategies, tradeoffs that exist in the current management approach will also be investigated. These investigations will offer value to managers by providing context of existing versus new approaches to managing the recreational summer flounder fishery, thus allowing them to optimize the eventual management regime they select. All of the various options will be reviewed at different regional configurations to provide trade-off information with regard to the management unit chosen. Variants of these approaches will also be explored that better use the inherent uncertainty in the system by translating this in to risk-based setting of the management program. In other words, the management system will only change if the recreational harvest limit exceeds some threshold of uncertainty that exists in the output from the various models. These offer a potential for enhanced stability in management setting and these approaches better recognize the fact that the harvest estimates and population information are both derived from statistical methods.

We are using a forecasting simulation modeling framework, using MSE, to test the performance of the current and potential alternative F-based management approaches for the recreational summer flounder fishery. Simulation testing and MSE are powerful frameworks for testing the expected performance of decision-making tools with respect to management objectives and robustness to uncertainty scenarios (e.g. Smith et al. 1999, Bunnefeld et al. 2009, Punt et al. 2016). Critically, MSE can allow for error associated with the implementation of management actions, associated with uncertain or unforeseen responses by resource users to changes in management measures. Additionally, our proposed work will seek to match the current spatial (regional) management set up to the extent that data allows, thus facilitating easier transition from the simulation results to applied use by fisheries managers and technical working bodies.

Management alternatives to be tested:

1. Status quo
2. Risk-based status quo
3. F-based management
4. Risk-based F-based management
5. Spatial management scale, from coast-wide to state specific

Methods

Recreational fishery fleet dynamics model

Crucial to short-term fishery forecasts of the approaches outlined above is a consideration of how changes to recreational management measures such as minimum size, bag limits, season length, etc. affect recreational harvest and discarding rates. To allow for management effects to feed back in to the operating model, a recreational fishery fleet dynamics model was developed that predicts both harvest and discards using the historical MRIP dataset. The MRIP dataset uses the newly calibrated MRIP data timeseries (see: https://www.fisheries.noaa.gov/feature-story/fishing-effort-survey-calibrating-recreational-catch-estimates), and the data were queried to produced harvest and discards by length. The discard dataset was derived from “Type 9” records from

MRIP. These are discard estimates that are generated on observed party and charter trips. To supplement this discard information, American Littoral Society discard and tagging information was also used. The discard and harvest information was truncated to drop fish that were smaller than 10 inches and larger than 28 inches. This was a small percentage of the overall information and it was removed due to the belief that much of the information in this range were outliers that could influence the model negatively. This dataset was overlaid with state specific historical management measures dating back to 1993, the year coastwide recreational management measures were put in to place. From this empirical catch information, and the knowledge of the management structure in place in each state, a series of Generalized Additive Models (GAMs) were built to model the effects of management on harvest and catch. In cases where management plans do not line up well with the existing wave structure of MRIP, the management that was in place for the majority of the wave was used. In other words, if the bag limit changed within a wave, the bag limit that was in place for the most time in that wave was used. The "gam" function from the "mgcv" package was used in the statistical software R for the analysis (R core team 2018).

By using available information on recreational fishing to evaluate plausible alternatives for these relationships, we can account for uncertainty in the management responses of recreational fishery fleet dynamics. Since a statistical model will be used, estimates of uncertainty can also be produced. The estimated uncertainty from these analyses will be used to describe alternate states of nature in the recreational fleet dynamics model within our MSE simulations.

The general form of the management model is:

$$Harvest\ or\ Discards = s(Length, MinLength) + State + s(Wave) + s(Season) + s(Bag)$$

Where a s indicates variables in the GAM that are smoothed, $Length, MinLength$ is an interaction term between the length of the fish caught and the regulatory minimum size, $State$ is the state in which the harvest occurred (states of MA – NC were used in the analysis), $Wave$ is the two month period in which the catch occurred as defined by MRIP (waves go from 1 to 6 for the year), $Season$ is the length of the season in the specific wave, and Bag is the regulatory bag limit in the given state, year, and wave. Other covariates were tested in the model, including year as a factor, Allowed Biological Catch (ABC), and Spawning Stock Biomass (SSB), but the model as defined above was selected as the final model for use in the MSE process. In particular, ABC and SSB were tested as elements that could provide information on availability of the stock to anglers, but these covariates did little by way of explaining variability in the model. This may be due to the fact that regulations were set based on uncalibrated MRIP data in years past, so the link between these variables and eventual harvest and discards by anglers may be confounded.

A gamma distribution was selected for the model (with a log link) after some model testing, with the gamma distribution performing the best relative to the existing data. For the "gam" function, the "REML" method was used for the smoothness selection of the model. Separate models were developed for harvest and discards, but the model structure and covariates remained the same for either harvest or discard estimation.

This general model can be applied to the coast, can be run as a stand-alone state specific model, and can be run as different regional configurations.

In addition to the estimated mean prediction, a function was developed that samples from the uncertainty within the model to produce an observation, or a single estimate within the envelop of uncertainty in the model. This function simulates data from a multivariate normal distribution conditioned on the covariance matrix from the GAM model. This function is used to produce a single observation for use in the operating model and helps to understand the uncertainty that is possible within a single management choice.

Forecasting model

We conditioned an age-structured operating model to reflect the life history and dynamics of summer flounder. Parameter values and initial conditions are taken from estimates from recent stock assessments for summer flounder (NEFSC 2013, Terceiro 2015, NEFSC 2019). The operating model will project numbers at age, subject to recruitment variability, forward in time given removals (or F rates) from commercial and recreational fishing. An observation model generates data from the operating model to represent a simplified result from a summer flounder stock assessment (biomass estimates and fishing mortality relative to targets), and an estimate of recreational catch/harvest. These observations are subject to autocorrelated bias and imprecision. The observations are then used by one of the alternative management procedures described above to provide a new F or catch level to update the dynamics of the operating model.

The modeling is conducted using the 'sinatra' software (Fay et al. 2009), which is implemented in R and FORTRAN, and is a general age-structured modeling platform for MSE and stock assessment performance testing. Aside from providing parameter values appropriate for summer flounder, modifications to the software have been made to include the recreational fishery fleet dynamics model that links changes in recreational management measures to changes in fishing mortality and harvest. The commercial fleet is parameterized by using the removal data provided in the most recent stock assessment document (NEFSC 2019). Further details for the operating model can be found in Appendix A of Fay et al. (2011).

Evaluating performance

The performance of the options will be evaluated by comparing the projections of recreational harvest to prescribed limits (for options that retain RHLs), as well as projected stock biomass and fishing mortality rates relative to reference points and risk tolerances. The forecast simulations will also allow tradeoffs in the ability to meet objectives while maintaining recreational opportunities.

Results

Recreational fishery fleet dynamics model

Output from the recreational fishery fleet dynamics model shows logical outcomes from the historical dataset and the model diagnostics are largely good for both the harvest and discard models (Figures 2 and 4).

Bag limit is statistically significant, but only has minor effects on harvest and discards (Tables 1 and 2, Figures 1, 3, 5 - 7). The effect is to increase harvest as bag limit increases (Figure 1) and conversely to decrease discards as bag limit increases (Figure 3).

Season length is also significant (Tables 1 and 2) and has a positive effect on harvest and discards, meaning as season length increases, so does harvest and discards (Figures 1 and 3). In the case of discards, the increase occurs and then plateaus at about 20 days, so there is a threshold season length where it doesn't impact discards anymore.

Wave is a significant effect in the model (Tables 1 and 2) and has a parabolic effect on both harvest and discards, matching with the fact that the majority of the harvest is occurring during the spring, summer, and fall times of year across states (Figures 1 and 3).

The interaction between minimum size and length at harvest and discards is significant (Tables 1 and 2). For harvest it shows an increase in harvest as length increases, peaking at around 14 – 18 inches, and then declines as size gets larger (Figure 1). This is also true for discards, though the peak occurs at a smaller size, just under 14 inches (Figure 3). The effect on harvest from this factor is shown in Figures 5 – 7. This shows that minimum size has a strong effect on harvest with an increase up to 15 inches and then a steep decline as the minimum size gets larger. Conversely, as minimum size gets larger, discards increase. When accounting for both harvest and discards, the interaction between the two model effects largely cancel each other out, minimizing the effect of minimum size as a management tool. There is still a decrease in catch (harvest + discards) but it is much less than when viewed by harvest alone.

State has a logical effect, with the states of NY and NJ having the strongest positive effect on harvest and discards, and the states of MD and DE having the strongest negative effect on both harvest and discards (Tables 1 and 2, Figures 1 and 3). Having a positive or negative effect is made in reference to the reference state in the model, in this case the state of CT.

A retrospective analysis was done to look at the performance of the model relative to years past. A six-year retrospective was performed. Figures 8 – 13 show the results of the retrospective analysis. What can be seen is that the model largely is able to predict, within the range of uncertainty, the observed MRIP estimate for that state in that year. The states of NJ and NY have the largest differences in some of the earlier years, but this appears to improve in the later years.

Forecasting model

PENDING

Evaluating performance

PENDING

Discussion

PENDING

References

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Table 1 – Model output from the recreational fishery fleet dynamics GAM for the harvest model

```
Family: Gamma
Link function: log

Formula:
x ~ s(Length, MinLen) + State + s(Wave, bs = "tp", k = 3) +
    s(SeasonLen, bs = "tp", k = 4) + s(Bag, bs = "tp",
    k = 4)

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept)  9.01332    0.05868 153.590  < 2e-16 ***
StateDE     -0.83045    0.07673 -10.823  < 2e-16 ***
StateMA      0.06125    0.08616   0.711   0.4772    
StateMD     -0.58701    0.08554  -6.863 7.38e-12 ***
StateNC     -0.26488    0.08111  -3.266   0.0011 ** 
StateNJ      1.64197    0.07497  21.903  < 2e-16 ***
StateNY      1.33785    0.07761  17.239  < 2e-16 ***
StateRI     -0.17420    0.07796  -2.235   0.0255 *  
StateVA      0.70970    0.07467   9.504  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:
                    edf Ref.df       F  p-value    
s(Length,MinLen) 27.116 28.722 105.475  < 2e-16 ***
s(Wave)           1.999  2.000 352.128  < 2e-16 ***
s(SeasonLen)      2.275  2.618   3.731   0.0184 *  
s(Bag)            2.794  2.968  13.869 1.05e-08 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =   0.55   Deviance explained = 51.4%
-REML =  68160  Scale est. = 1.8505    n = 6632
```

Table 2 – Model output from the recreational fishery fleet dynamics GAM for the discard model

```
Family: Gamma
Link function: log

Formula:
x ~ s(Length, MinLen) + State + s(Wave, bs = "tp", k = 3) +
    s(SeasonLen, bs = "tp", k = 4) + s(Bag, bs = "tp",
    k = 4)

Parametric coefficients:
             Estimate Std. Error t value Pr(>|t|)    
(Intercept)  7.507849   0.058144 129.126  < 2e-16 ***
StateDE     -0.543369   0.083248  -6.527 7.30e-11 ***
StateMA     -0.516609   0.106706  -4.841 1.32e-06 ***
StateMD      0.007574   0.082473   0.092    0.927    
StateNC     -2.459664   0.117969 -20.850  < 2e-16 ***
StateNJ      1.733797   0.071222  24.344  < 2e-16 ***
StateNY      1.237742   0.071511  17.308  < 2e-16 ***
StateRI     -1.070918   0.085204 -12.569  < 2e-16 ***
StateVA      1.276285   0.086022  14.837  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
                    edf Ref.df       F  p-value    
s(Length,MinLen) 27.394 28.805  215.73  < 2e-16 ***
s(Wave)           2.000  2.000 1325.22  < 2e-16 ***
s(SeasonLen)      2.917  2.994   51.36  < 2e-16 ***
s(Bag)            2.959  2.998   14.26 2.06e-09 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.627   Deviance explained = 69.1%
-REML =  50369  Scale est. = 1.6325    n = 5593
```

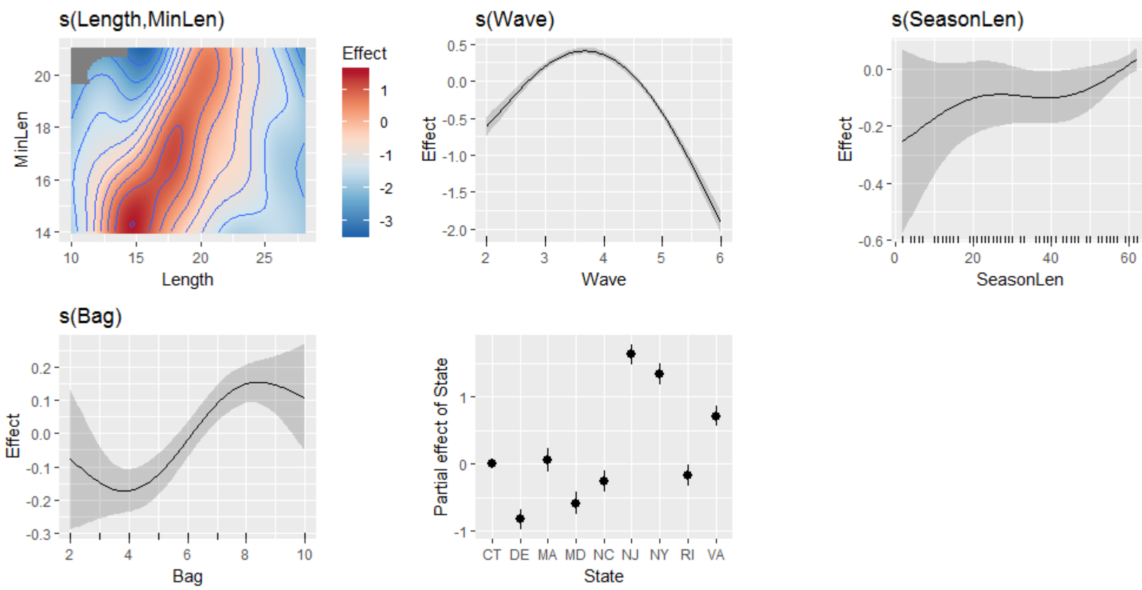

Figure 1 – Output on the covariate effects from the recreational fishery fleet dynamics GAM for the harvest model.

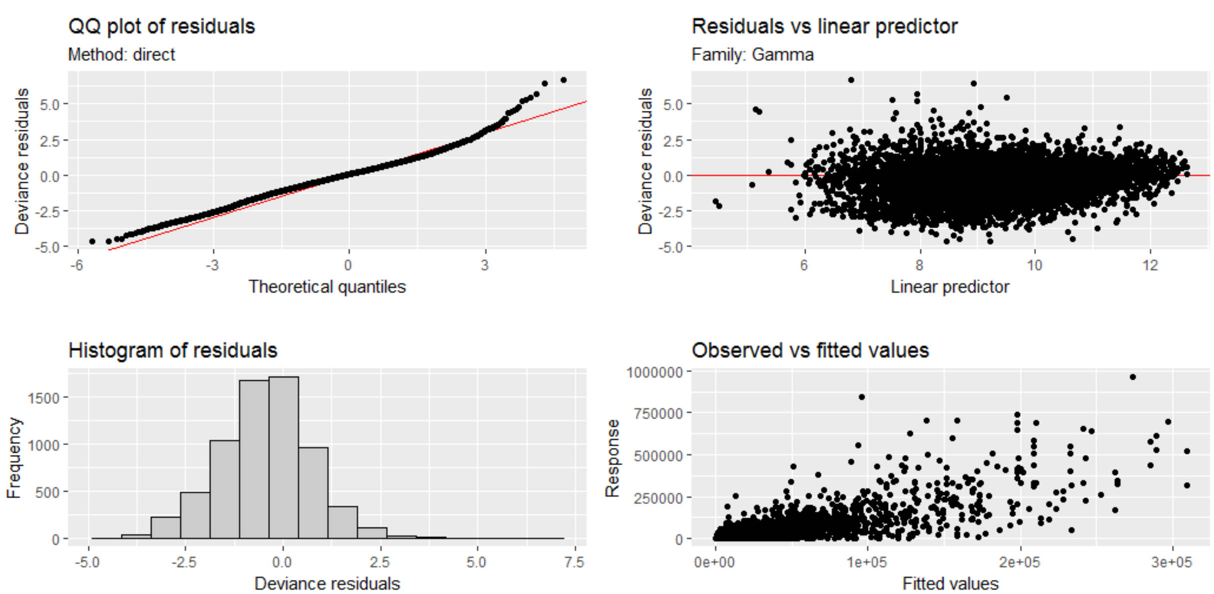

Figure 2 – Model diagnostics for the recreational fishery fleet dynamics GAM for the harvest model.

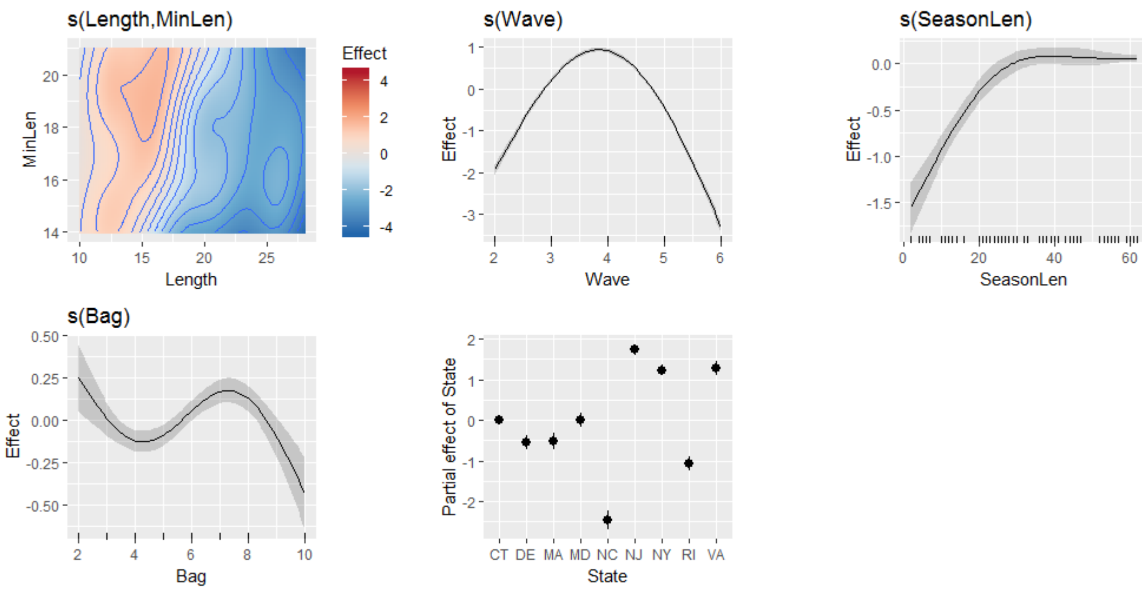

Figure 3 – Output on the covariate effects from the recreational fishery fleet dynamics GAM for the discard model.

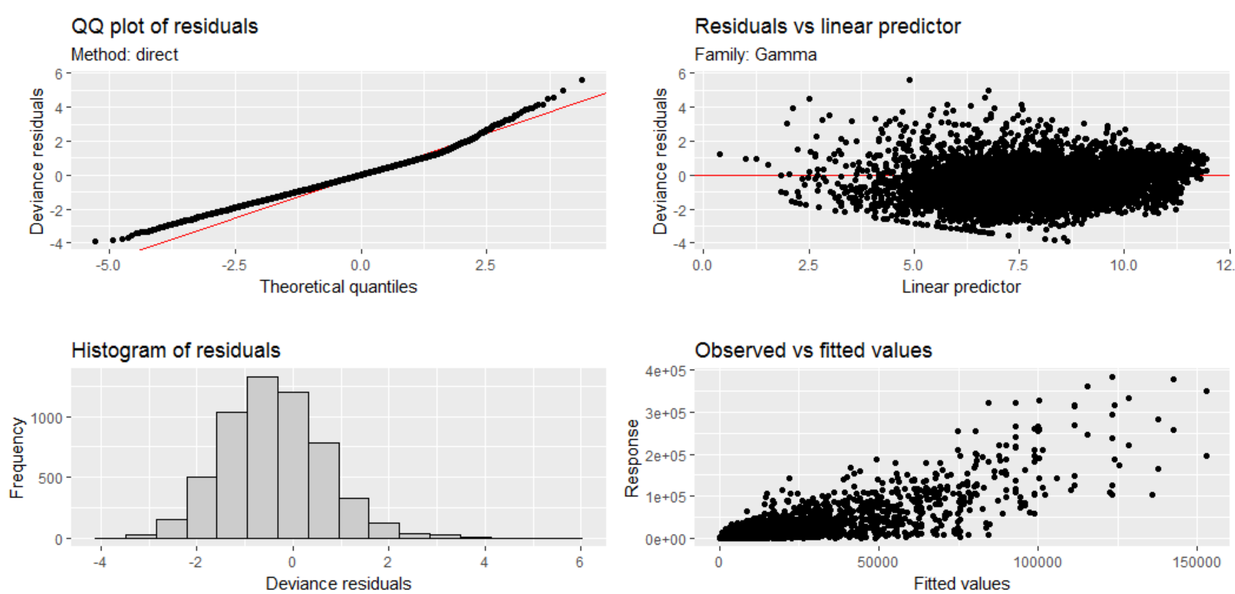

Figure 4 – Model diagnostics for the recreational fishery fleet dynamics GAM for the discard model.

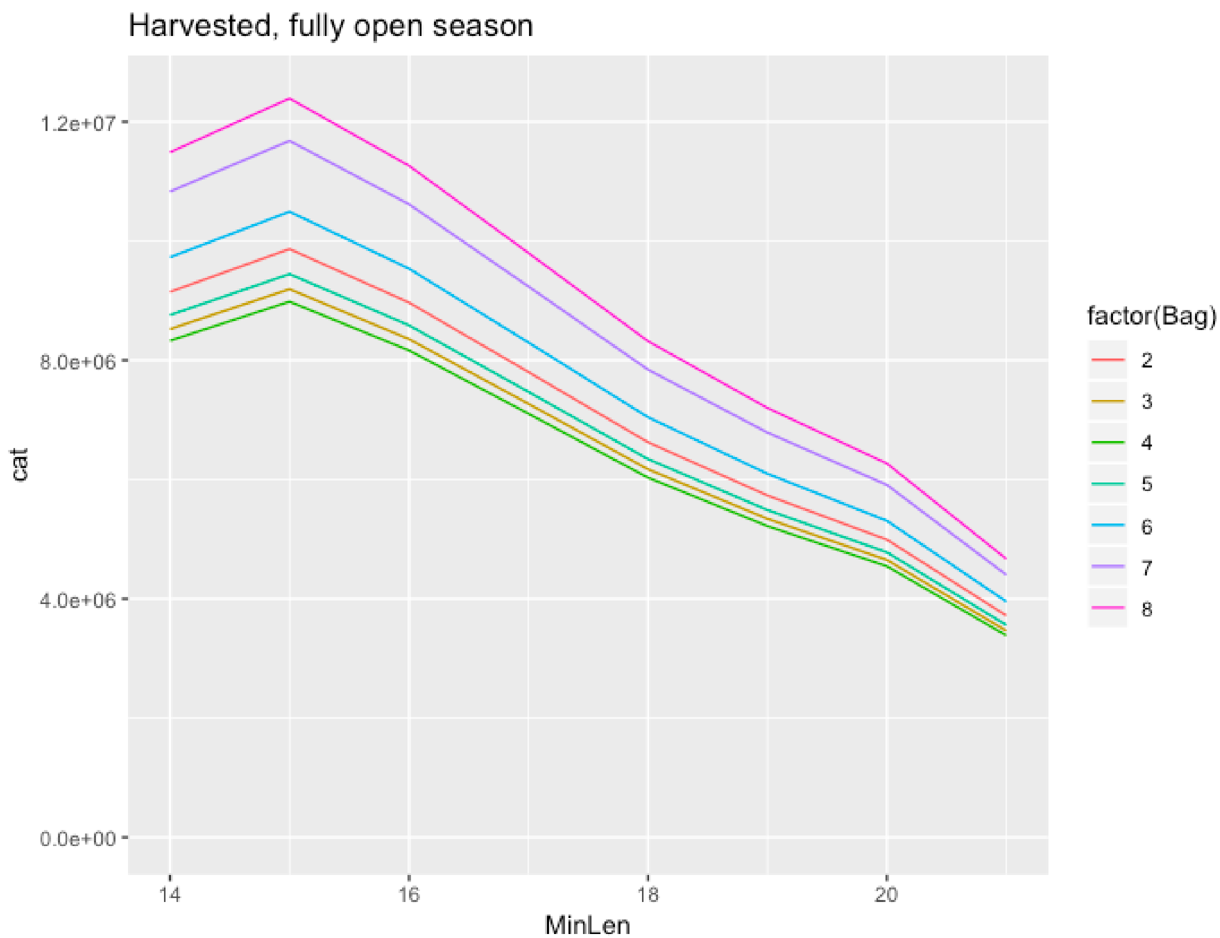

Figure 5 – The effect of increasing minimum size on harvest from the GAM by different bag limits.

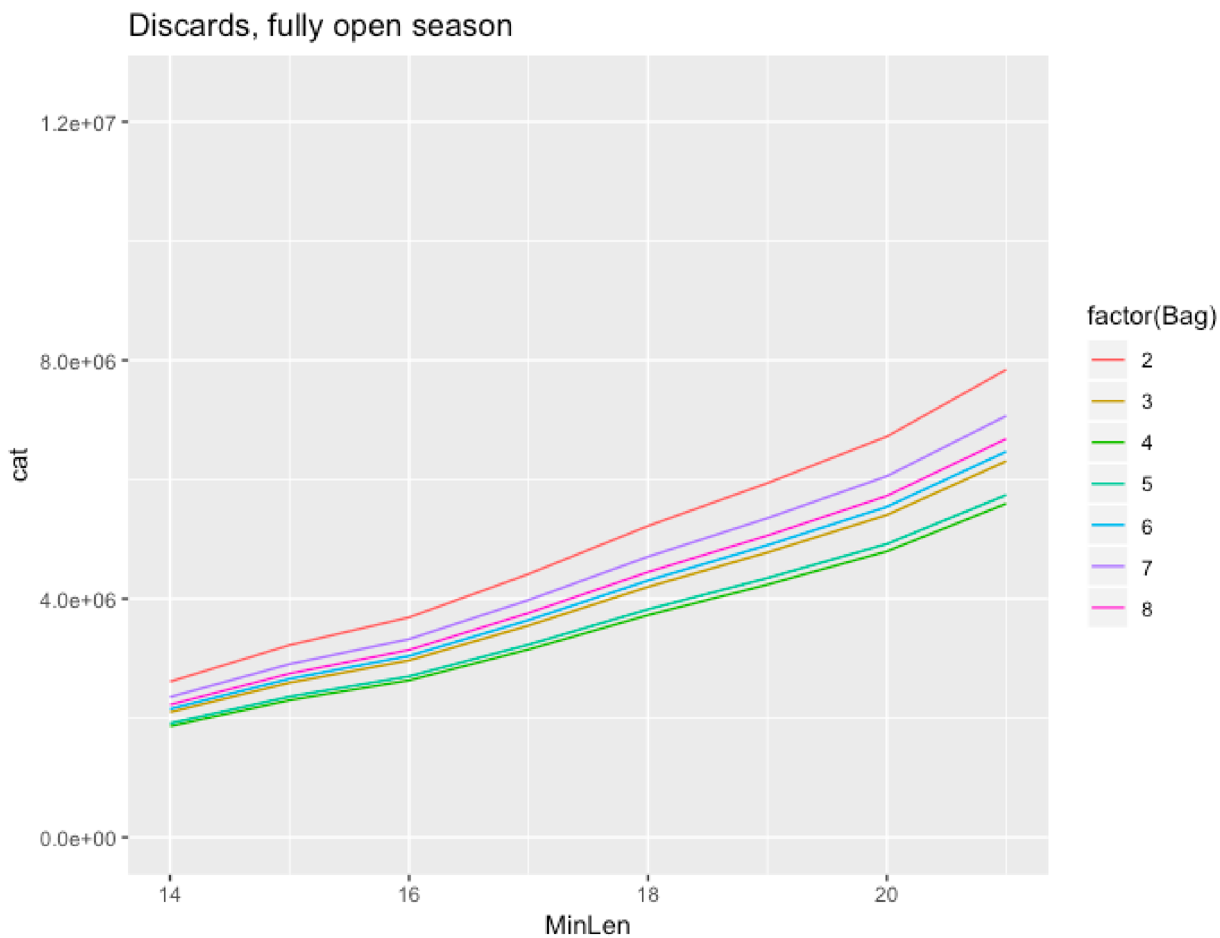

Figure 6 – The effect of increasing minimum size on discards from the GAM by different bag limits.

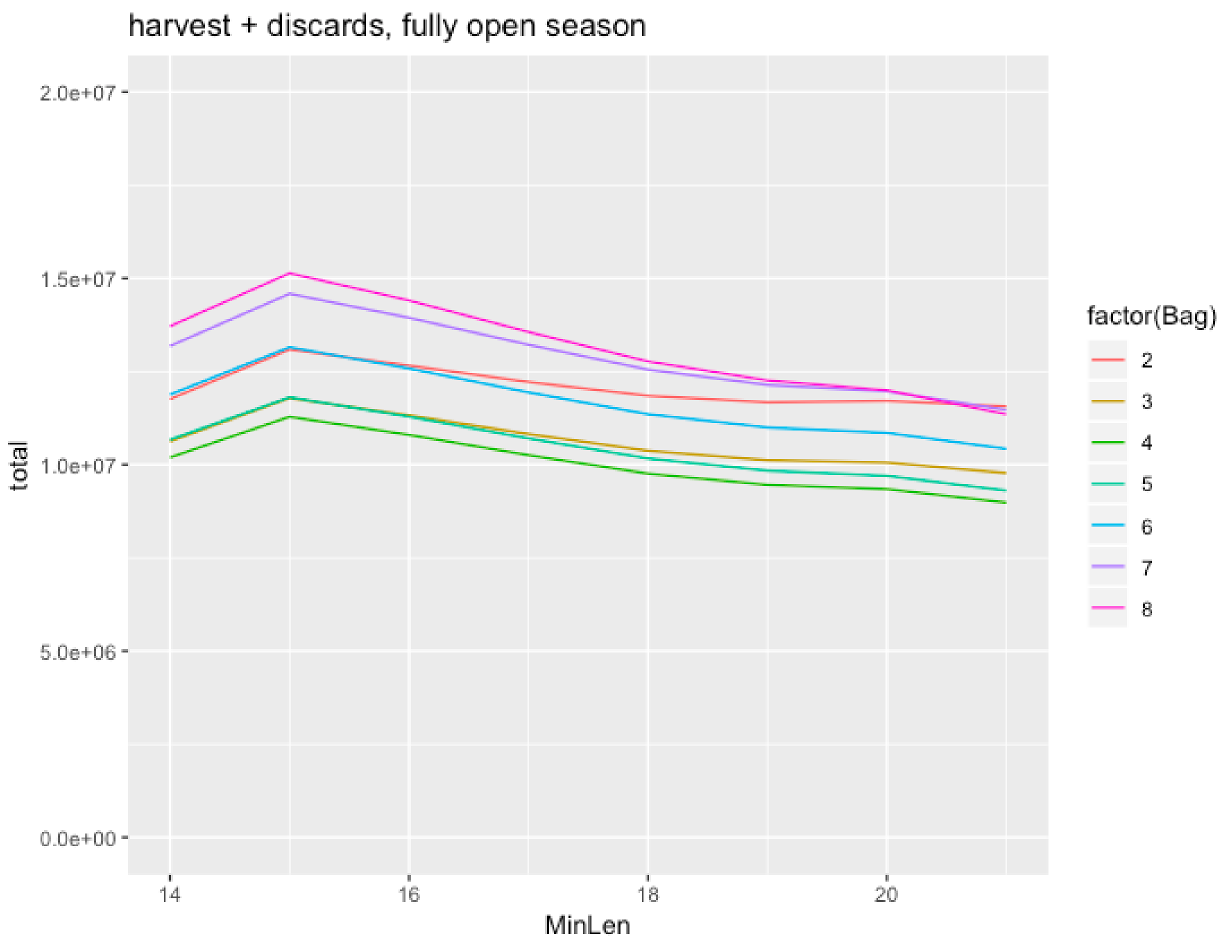

Figure 7 – The effect of increasing minimum size on both harvest and discards by different bag limits from the GAM.

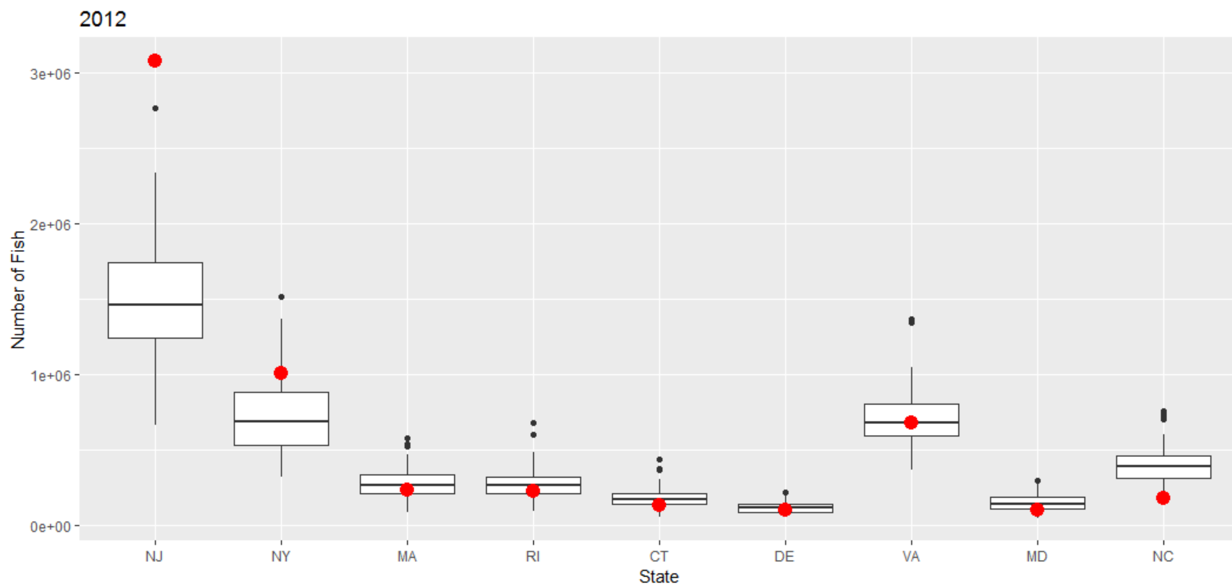

Figure 8 – Retrospective analysis using simulated data from the GAM and comparing it to MRIP harvest estimate for each state in 2012. The box and whisker plot is the model estimate with uncertainty and the red dot is the “observed” MRIP estimate.

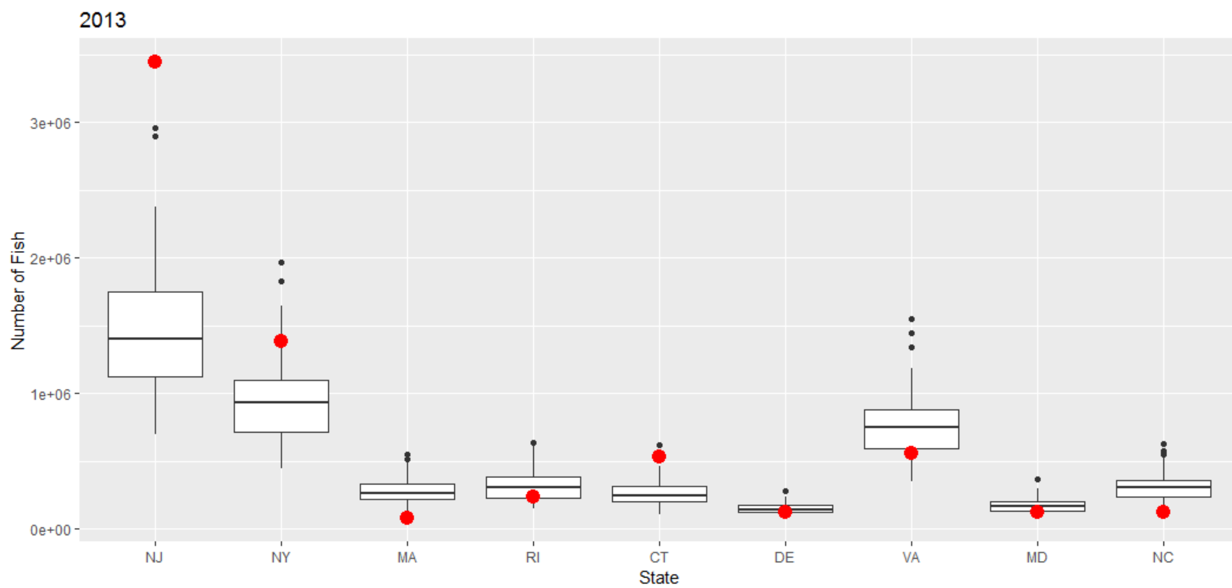

Figure 9 – Retrospective analysis using simulated data from the GAM and comparing it to MRIP harvest estimate for each state in 2013. The box and whisker plot is the model estimate with uncertainty and the red dot is the “observed” MRIP estimate.

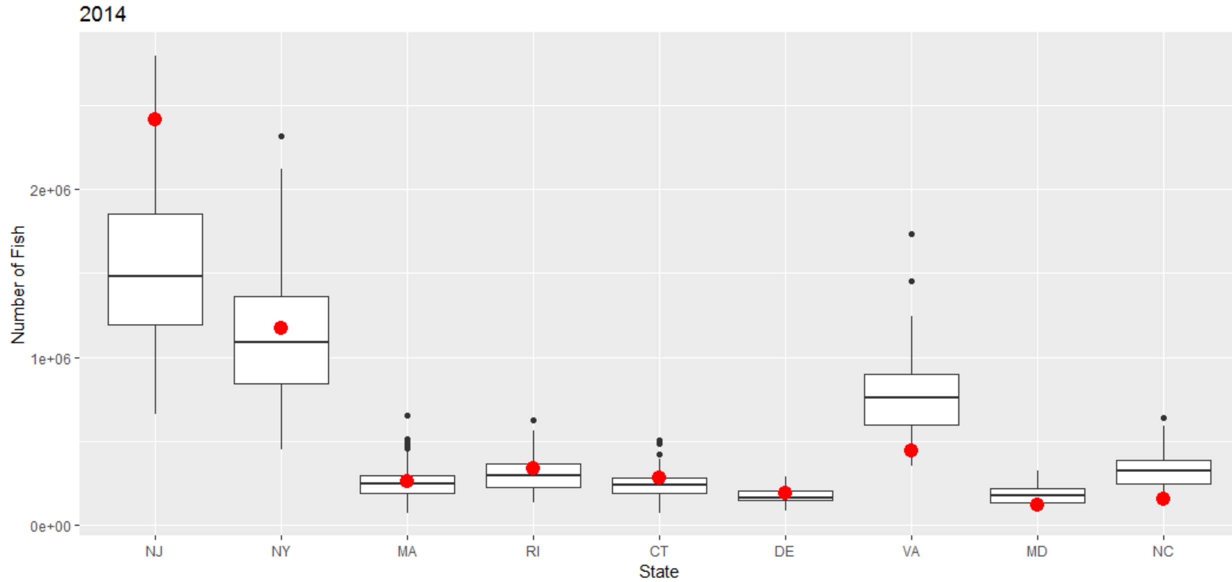

Figure 10 – Retrospective analysis using simulated data from the GAM and comparing it to MRIP harvest estimate for each state in 2014. The box and whisker plot is the model estimate with uncertainty and the red dot is the “observed” MRIP estimate.

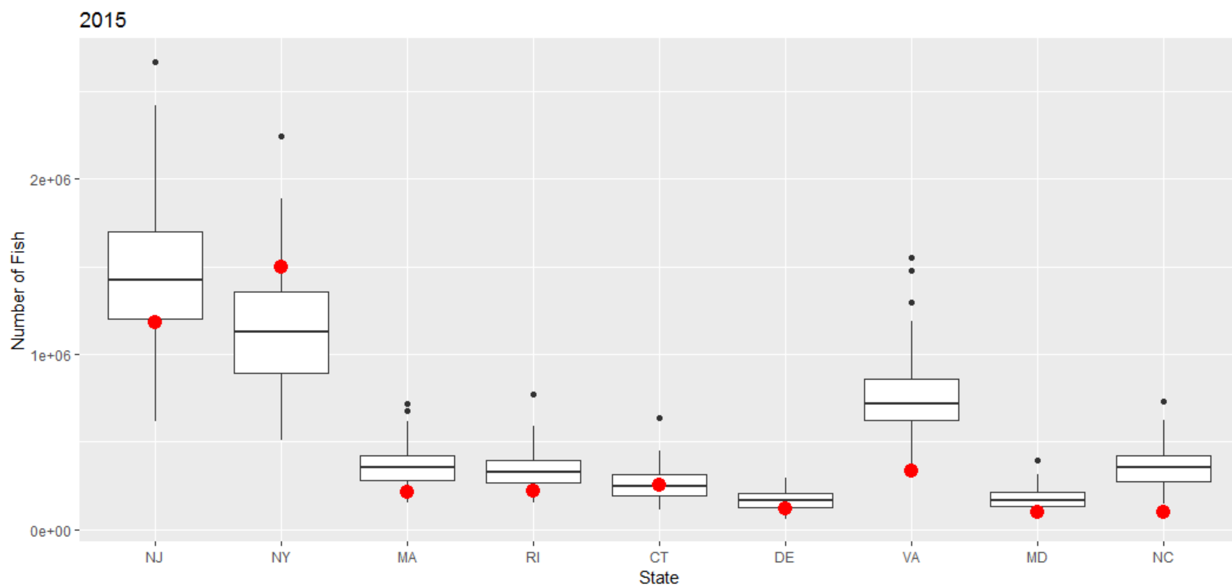

Figure 11 – Retrospective analysis using simulated data from the GAM and comparing it to MRIP harvest estimate for each state in 2015. The box and whisker plot is the model estimate with uncertainty and the red dot is the “observed” MRIP estimate.

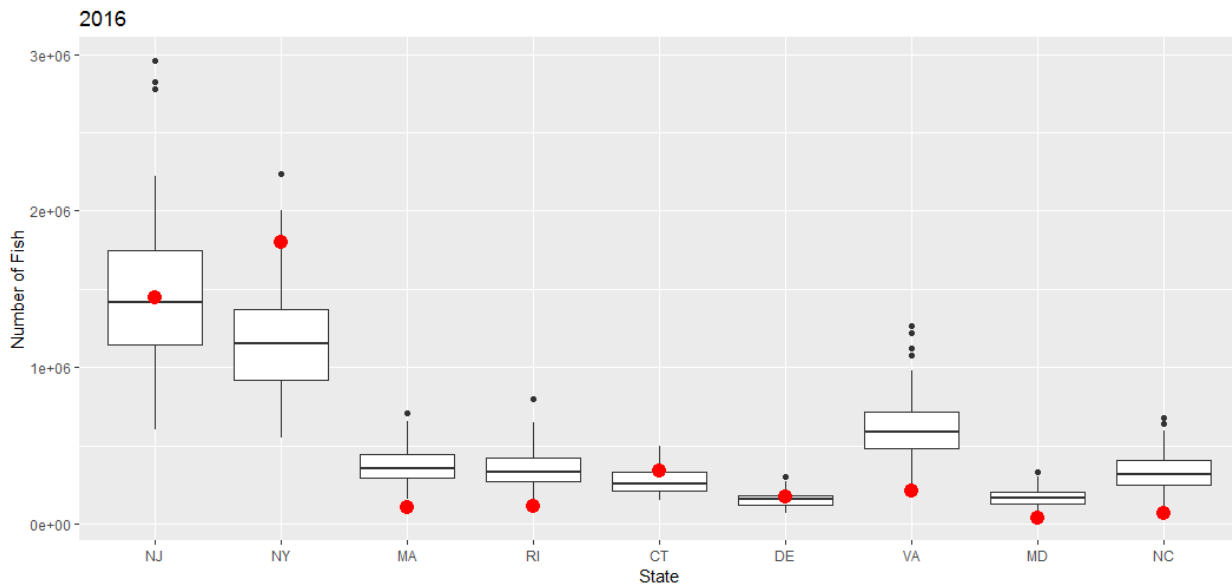

Figure 12 – Retrospective analysis using simulated data from the GAM and comparing it to MRIP harvest estimate for each state in 2016. The box and whisker plot is the model estimate with uncertainty and the red dot is the “observed” MRIP estimate.

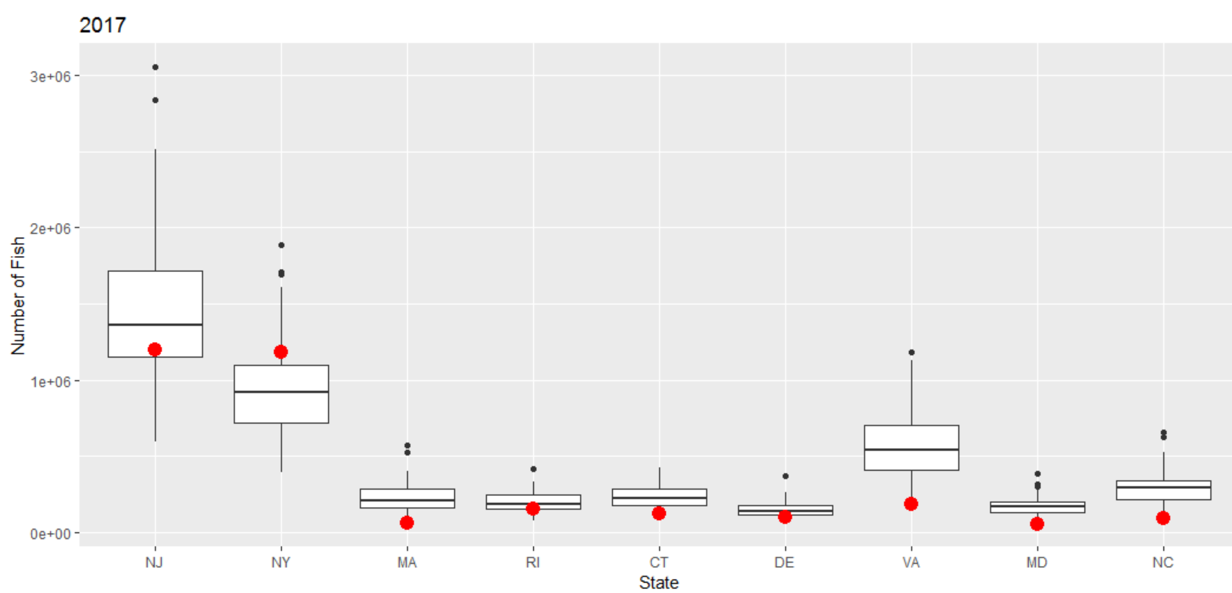

Figure 13 – Retrospective analysis using simulated data from the GAM and comparing it to MRIP harvest estimate for each state in 2017. The box and whisker plot is the model estimate with uncertainty and the red dot is the “observed” MRIP estimate.