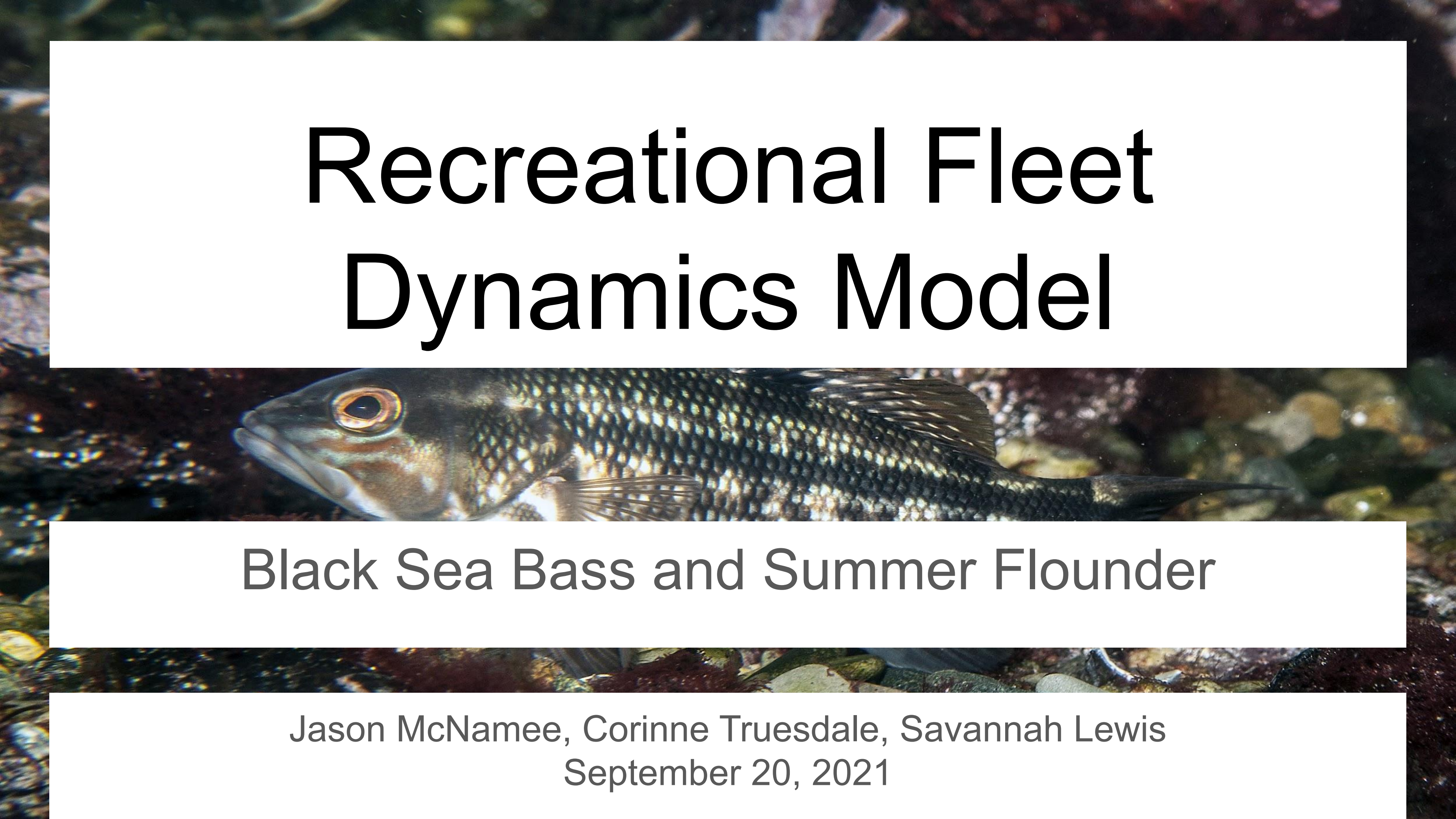

Recreational Fleet Dynamics Model

Black Sea Bass and Summer Flounder

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Overview

- Introduction
- Background on GAMs and why we chose this approach (TOR 1)
- Details on data used (TOR 1)
- Scales that the model can work on (TOR 2)
- Model diagnostics and output (TOR 3)
- Future considerations and uses (TOR 4)
- Summary

Introduction

- Currently states, or groups of states, use differing recreational management measures to meet pre-specified harvest targets
  - Effectiveness of this strategy has been questioned through the years

- Desire to explore new strategies for recreational management at MAFMC; important to investigate new techniques that may be more effective than this yearly and somewhat ad hoc approach

- Current process assumes similarity between years in fishing behavior and population dynamics
  - Process ignores many dynamic factors including implementation error, changes to discard rates, population growth, and changes in availability
  - Process rarely allows for a re-evaluation of performance

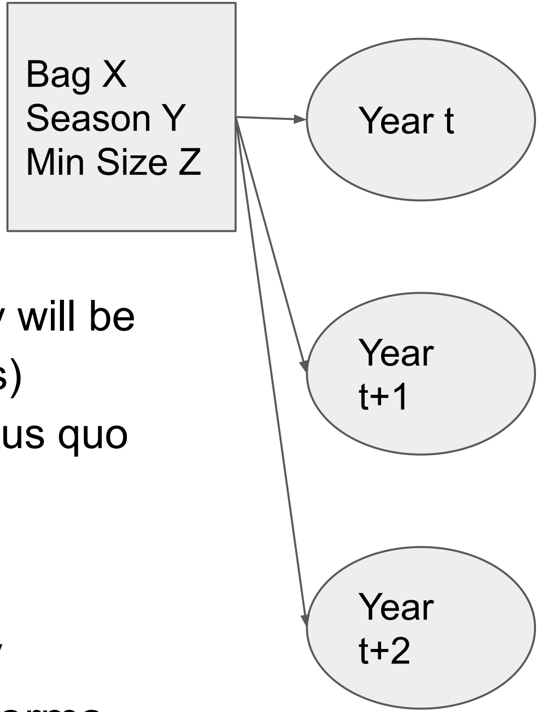
Introduction

- This project designed to develop a new methodology that can:
  - Perform better over time by accounting for more known pop dynamics
  - Allowing for transparency in the specification setting process
  - Assess uncertainty in management choices

- Allow for application of risk tolerances and policies to management choices, potentially leading to more stability in the management program

- Moving from ad hoc harvest-based approach to a model-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

Introduction



- Proposed advantages of a model-based approach are:
  - Performance could be enhanced as management stability will be increased (improving buy-in and knowledge of regulations)
  - Include more factors in model-based projections than status quo process

- System could be designed where management will only change if the recreational harvest exceeds or underperforms relative to a threshold of uncertainty that exists in the output
  - Potential for enhanced stability in management and better recognizes that harvest estimates and population information are both derived from statistical methods

Background - Generalized Additive Models (TOR 1)

- Extensions of generalized linear models
- Incorporate smooth nonparametric functions of predictor variables
- Advantages over other regression techniques:
  - Additive structure
  - Ability to capture nonlinear patterns without *a priori* knowledge of distribution
  - Can control smoothness of predictor functions (variance vs. bias tradeoffs)
- Appropriate for prediction of harvest based on management measures and population dynamics

Background- Generalized Additive Models (TOR 1)

Model configuration:

- Gamma distribution, log link
- Smoothing basis: low-rank thin plate splines
- Interactive effects fitted using tensor product smooths
    - Interactions between RHL and management measures, year
- Model estimation via maximum likelihood with penalty term for smoothness of regression splines
- Number of knots optimized in the model fitting process

Background - Data Details (TOR 1)

- Datasets include landing and discard estimates from MRIP beginning with the initial year of federal coastwide management
    - Estimates were further broken down by Year, State, and then Wave
- State specific regulations were refined to the Wave level
    - Includes Season Length, Bag Limit, and Minimum Size
- RHLs, Recruitment (BSB only), and Spawning Stock Biomass were pulled from stock assessments
- Recruitment was lagged after age at minimum length was calculated using a Von Bertalanffy growth curve
    - The recruitment value assigned to a row was lagged by the age of the fish minus 1 year

Background - Data Details (TOR 1)

- Changes to some metrics for black sea bass
  - Bag_truncated for BSB
    - Used because of historically high bag limit
  - Recruitment_truncted for BSB
    - Most of the recruitment was in the order of magnitude of 50 billion or less, and the big year class in 2012 was an order of magnitude higher
- Metrics that we considered but didn’t use
  - Regionality groupings, groupings based on coastwide vs regional vs statewide measures, sea surface temperature (SF only)

Potential Scales (TOR 2)

- The current configuration treats the management as a coastwide unit
- Due to the way the data is organized, and because the model has a state effect in it, the management units can be configured from coastwide, to regional, to state by state
- The way this would be operationalized would be to run the model and organize the predicted information by the desired management unit post hoc

Diagnostics (TOR 3)

- Final Models: Black sea bass

$$Harvest = Year + s(Minimum\ Size) + s(Wave) + State + s(SeasonLength) + s(Bag) + Recruitment + s(Bag, RHL) + s(Year, RHL) + RHL$$

$$Discards = Year + s(Minimum\ Size) + s(Wave) + State + s(Bag) + s(Bag, RHL) + s(Year, RHL)$$

Diagnostics (TOR 3)

- Final Models: Summer flounder

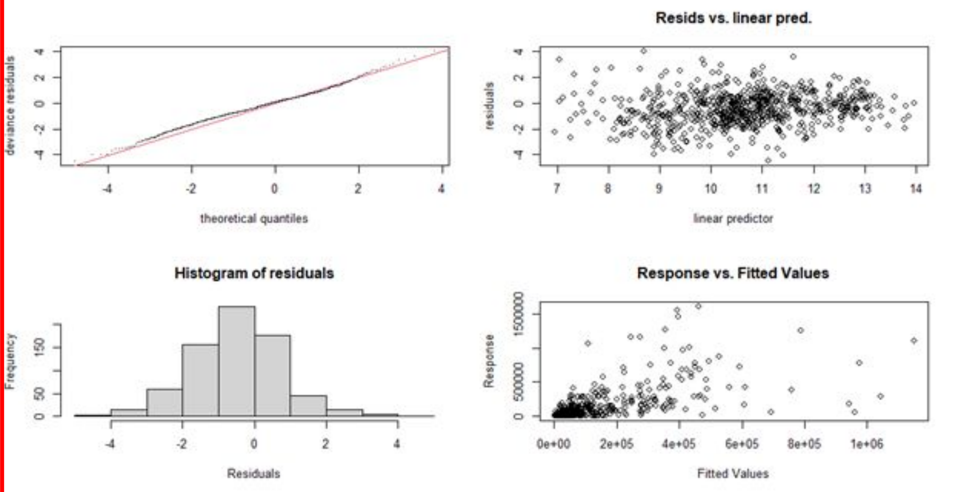
$$Harvest = Year + s(Minimum\ Size) + s(Wave) + State + s(SeasonLength) + s(Bag) + s(Minimum\ Size, RHL) + s(Year, RHL)$$

$$Discards = Year + s(Minimum\ Size) + s(Wave) + State + s(SeasonLength) + s(Bag) + SSB + s(Year, RHL)$$

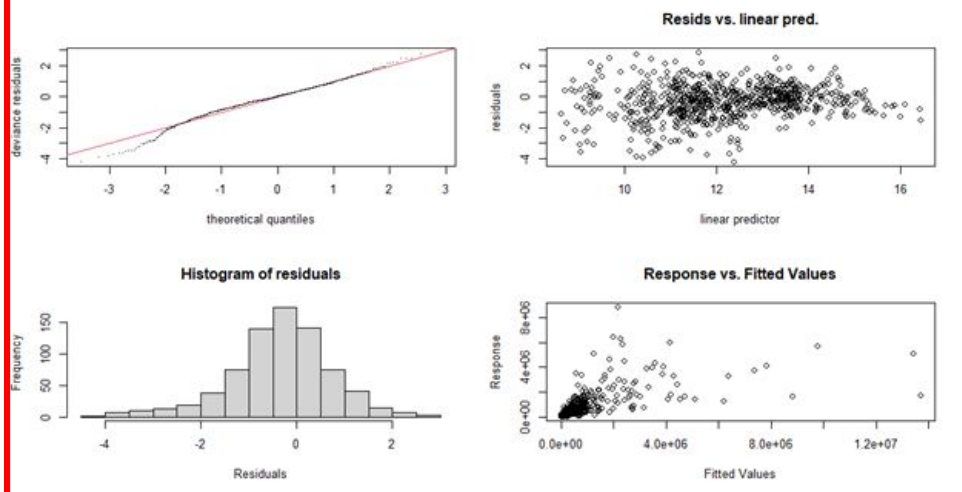
Diagnostics (TOR 3)

- A series of model diagnostics were performed
    - Table of info is in the document, visualizations presented here

Black sea bass - Harvest



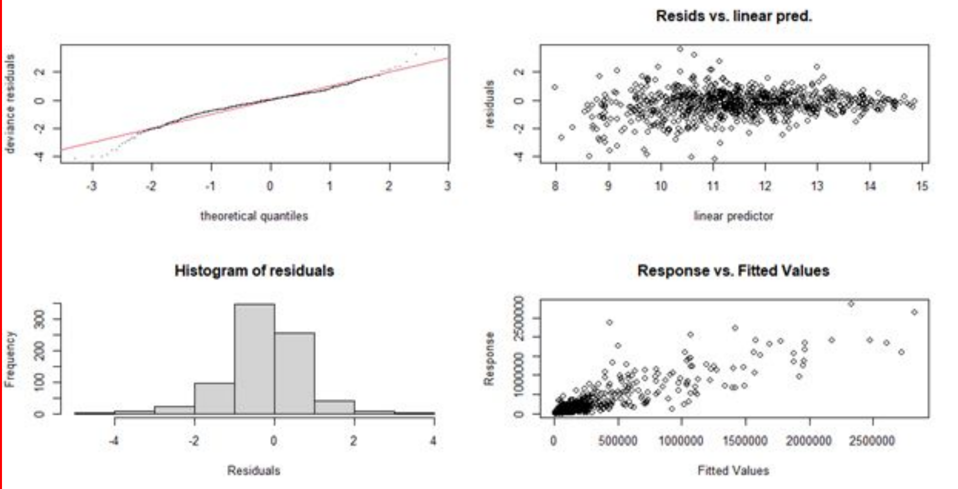
Black sea bass - Discards



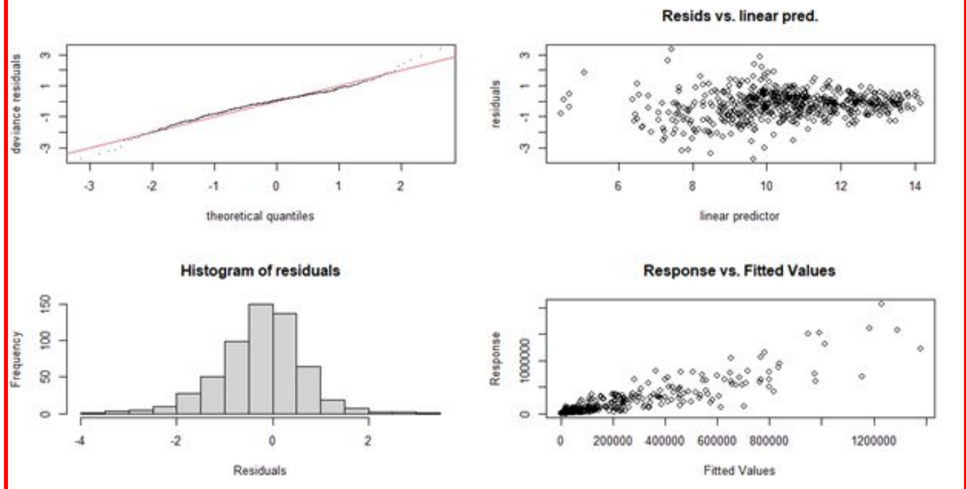
Diagnostics (TOR 3)

- A series of model diagnostics were performed
    - Table of info is in the document, visualizations presented here

Summer flounder - Harvest



Summer flounder - Discards



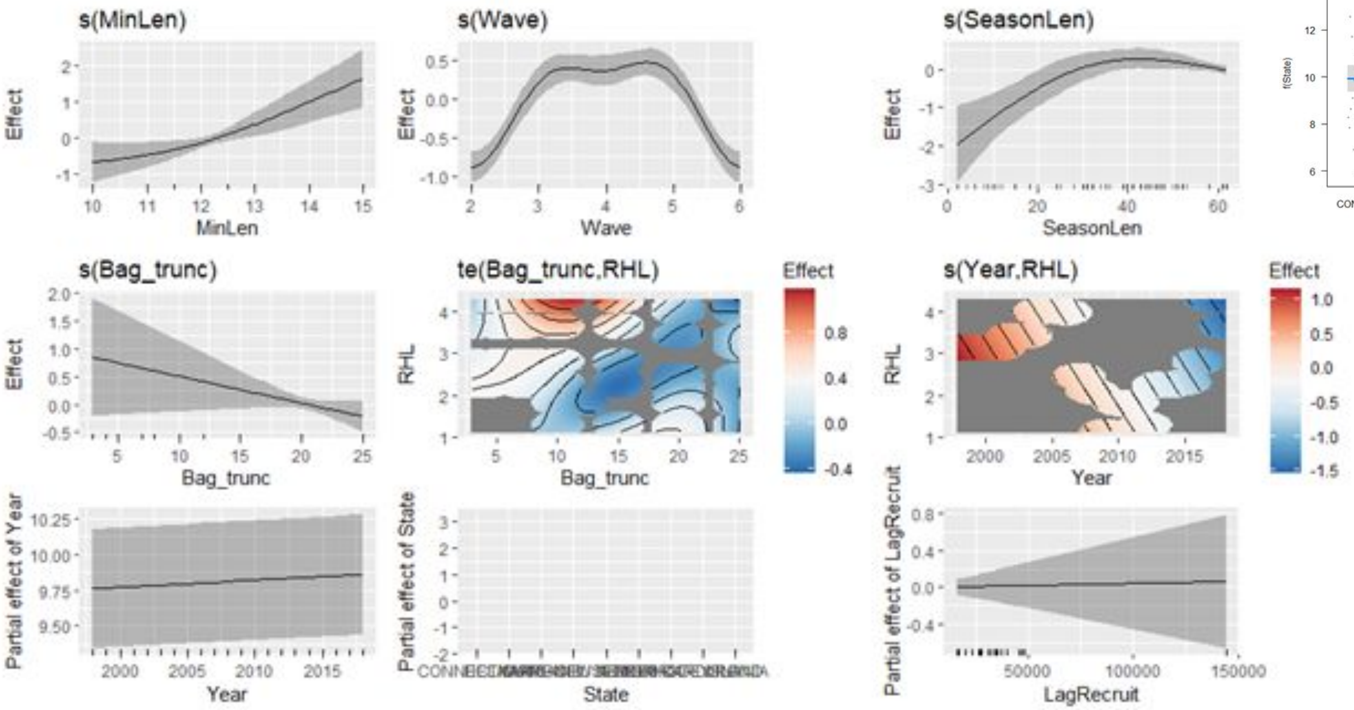
Output (TOR 3)

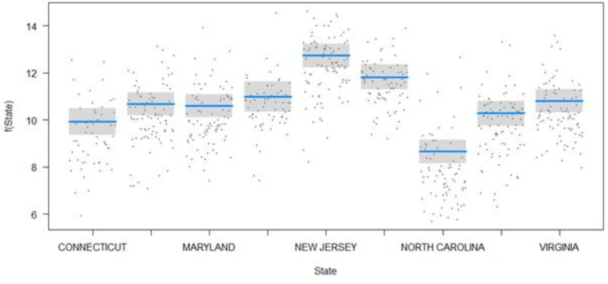
- Final models: Black sea bass - Harvest

```
Family: Gamma
Link function: log

Formula:
x ~ Year + s(MinLen, k = 4) + s(Wave, k = 5, bs = "cc") +
    State + s(SeasonLen, k = 4) + s(Bag_trunc, k = 5) + LagRecruit +
    te(Bag_trunc, RHL, bs = "fs", k = 6) + s(Year, RHL,
    bs = "fs", k = 5)

Parametric coefficients:
                       Estimate Std. Error t value Pr(>|t|)
(Intercept)           0.000e+00  0.000e+00      NA       NA
Year                  4.886e-03  1.053e-04  46.402  < 2e-16 ***
StateDELAWARE         7.432e-01  2.459e-01   3.022 0.002603 **
StateMARYLAND         6.643e-01  2.466e-01   2.693 0.007245 **
StateMASSACHUSETTS    1.040e+00  2.682e-01   3.877 0.000116 ***
StateNEW JERSEY       2.796e+00  2.431e-01  11.503  < 2e-16 ***
StateNEW YORK         1.882e+00  2.408e-01   7.815 2.06e-14 ***
StateNORTH CAROLINA  -1.284e+00  2.521e-01  -5.092 4.58e-07 ***
StateRHODE ISLAND     3.489e-01  2.337e-01   1.493 0.135973
StateVIRGINIA         8.650e-01  2.452e-01   3.528 0.000446 ***
LagRecruit            4.655e-07  2.557e-06   0.182 0.855602
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
                      edf Ref.df      F  p-value
s(MinLen)           2.000  2.255  6.396 0.000905 ***
s(Wave)             2.907  3.000 33.443  < 2e-16 ***
s(SeasonLen)        2.480  2.784  6.716 0.000252 ***
s(Bag_trunc)        1.002  1.003  2.515 0.113466
te(Bag_trunc,RHL)   8.588 30.000  0.771 0.000943 ***
s(Year,RHL)         2.002  2.003  5.561 0.004012 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Rank: 57/58
R-sq.(adj) =  0.407   Deviance explained =   49%
-REML = 8400.7  Scale est. = 1.7766    n = 718
```

Output (TOR 3)

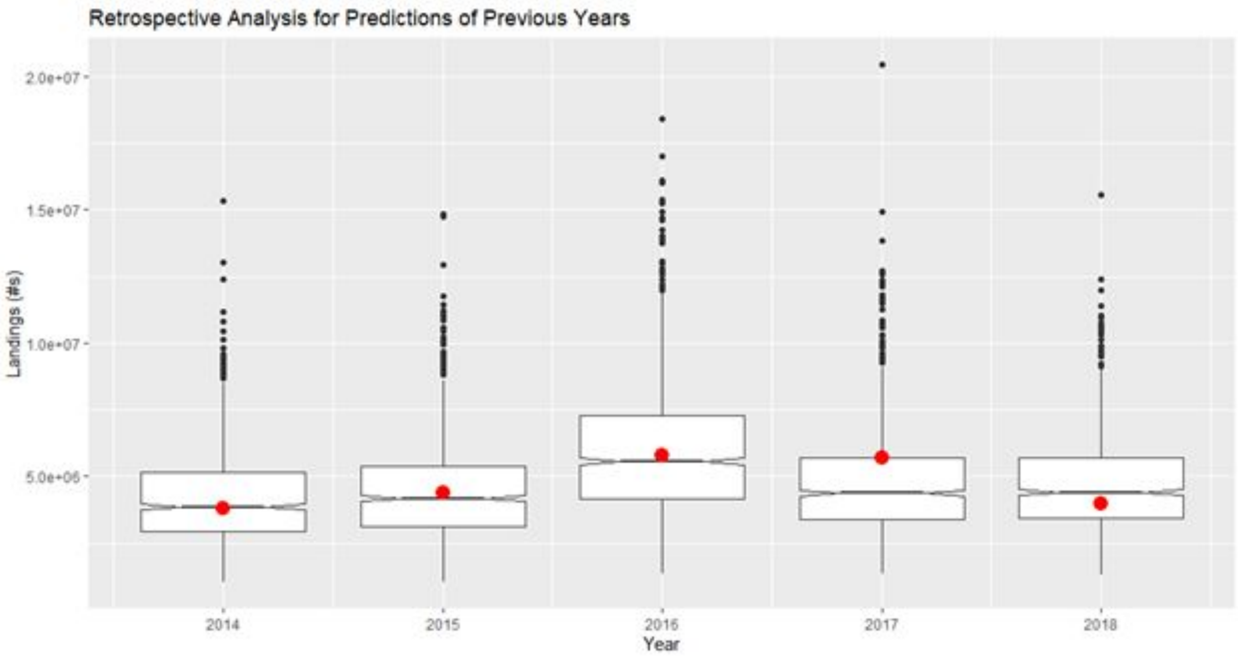
- Final models: Black sea bass - Harvest





Output (TOR 3)

- Retrospective analysis: Black sea bass - Harvest



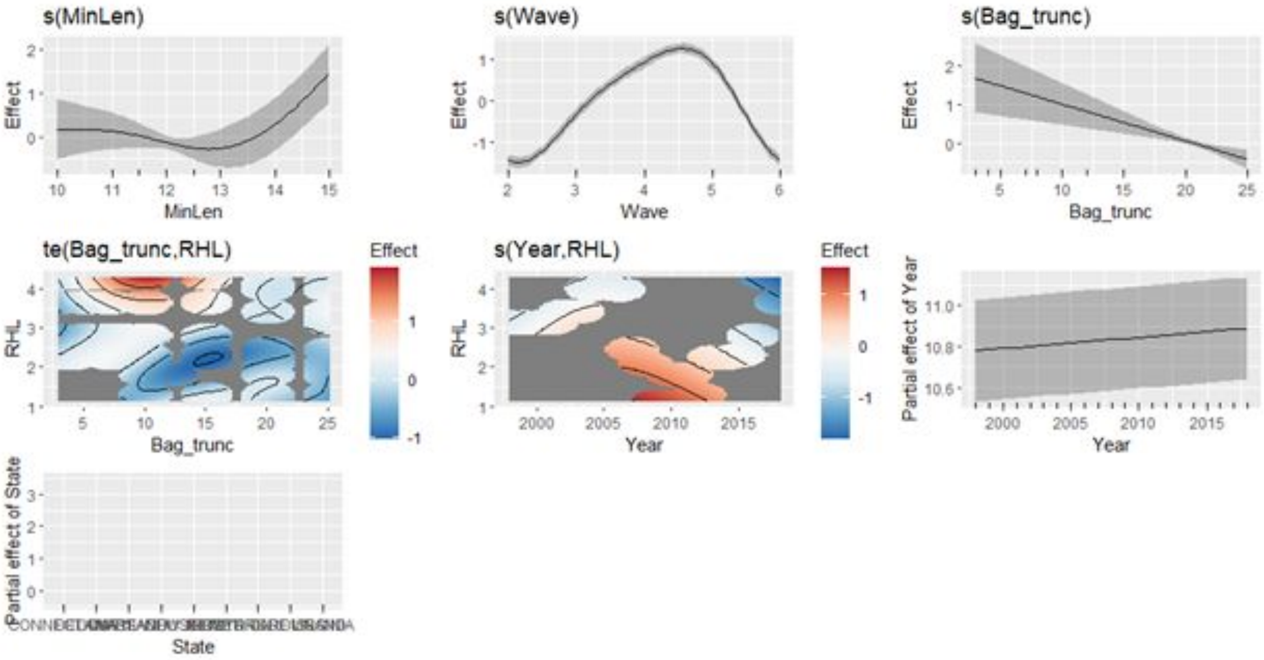
Output (TOR 3)

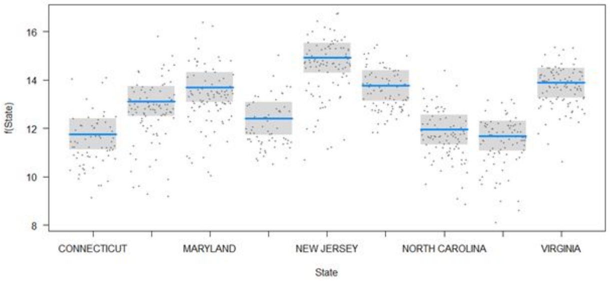
- Final models: Black sea bass - Discards

```
Family: Gamma
Link function: log

Formula:
x ~ Year + s(MinLen, k = 4) + s(Wave, k = 5, bs = "cc") +
    State + s(Bag_trunc, k = 5) + te(Bag_trunc, RHL, bs = "fs",
    k = 6) + s(Year, RHL, bs = "fs", k = 5)

Parametric coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)          0.000e+00  0.000e+00      NA       NA
Year                 5.395e-03  6.324e-05  85.309  < 2e-16 ***
StateDELAWARE        1.348e+00  1.694e-01   7.954 7.03e-15 ***
StateMARYLAND        1.928e+00  1.689e-01  11.417  < 2e-16 ***
StateMASSACHUSETTS   6.439e-01  1.993e-01   3.231  0.00129 **
StateNEW JERSEY      3.146e+00  1.678e-01  18.745  < 2e-16 ***
StateNEW YORK        1.996e+00  1.670e-01  11.952  < 2e-16 ***
StateNORTH CAROLINA  1.838e-01  1.704e-01   1.079  0.28108
StateRHODE ISLAND   -7.656e-02  1.623e-01  -0.472  0.63720
StateVIRGINIA        2.122e+00  1.681e-01  12.620  < 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(MinLen)          2.685  2.881  11.721 8.05e-05 ***
s(Wave)            2.971  3.000 254.206  < 2e-16 ***
s(Bag_trunc)       1.005  1.006  13.629 0.000243 ***
te(Bag_trunc,RHL) 14.953 30.000   2.819  < 2e-16 ***
s(Year,RHL)        3.451  3.758   7.652 1.01e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Rank: 53/54
R-sq.(adj) =  -0.0377   Deviance explained = 61.7%
-REML = 9988.8  Scale est. = 0.94714   n = 753
```

Output (TOR 3)

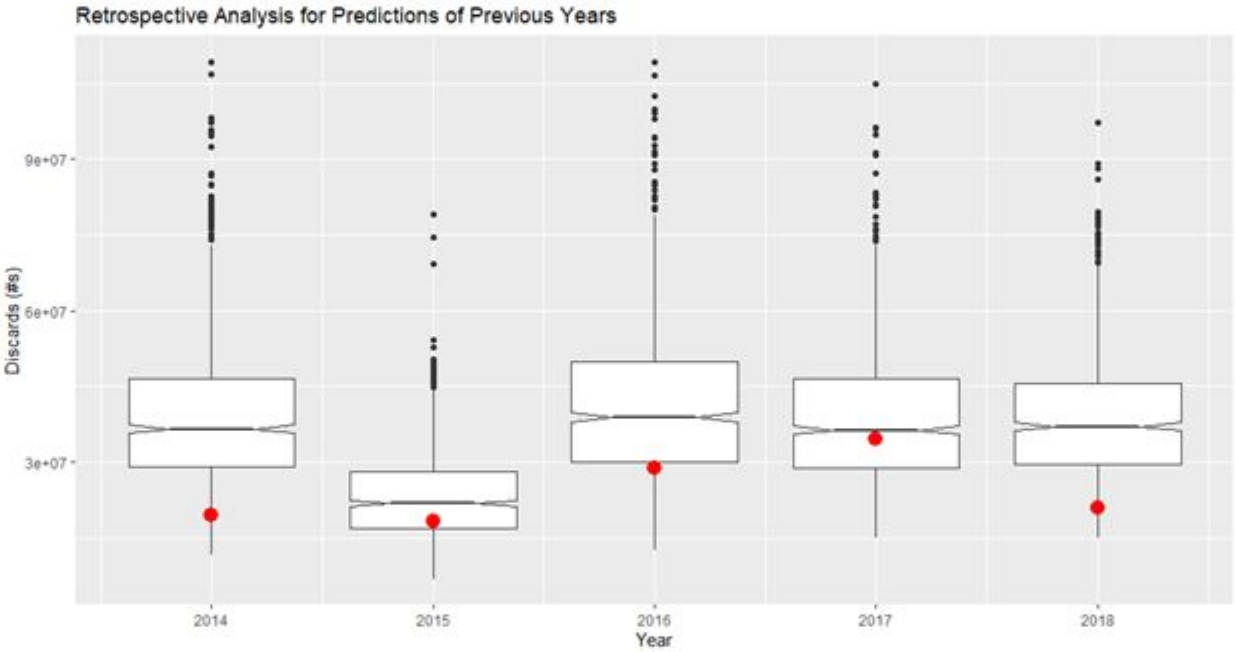
- Final models: Black sea bass - Discards





Output (TOR 3)

- Retrospective analysis: Black sea bass - Discards



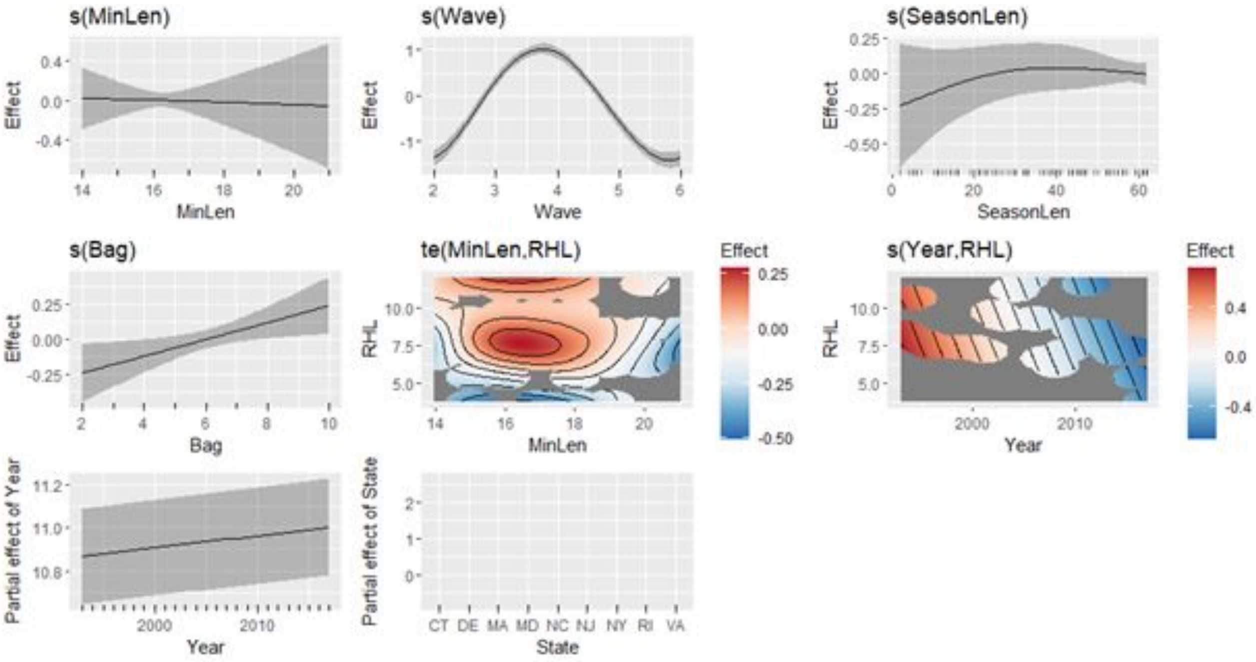
Output (TOR 3)

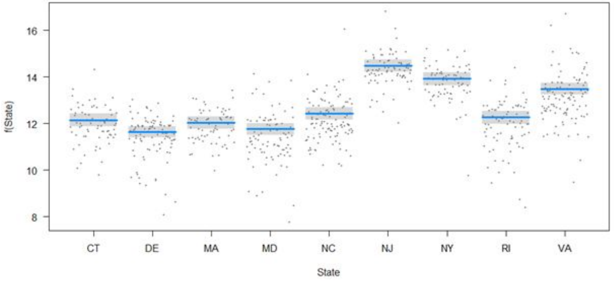
- Final models: Summer flounder - Harvest

```
Family: Gamma
Link function: log

Formula:
x ~ Year + s(MinLen, k = 4) + s(Wave, k = 5, bs = "cc") +
    State + s(SeasonLen, k = 4) + s(Bag, k = 5) + te(MinLen,
    RHL, bs = "fs", k = 5) + s(Year, RHL, bs = "fs",
    k = 5)

Parametric coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.000e+00  0.000e+00      NA       NA
Year         5.454e-03  5.637e-05  96.759  < 2e-16 ***
StateDE     -5.077e-01  1.495e-01  -3.395 0.000722 ***
StateMA     -1.095e-01  1.611e-01  -0.680 0.497003
StateMD     -3.843e-01  1.531e-01  -2.510 0.012297 *
StateNC      2.721e-01  1.618e-01   1.681 0.093150 .
StateNJ      2.333e+00  1.562e-01  14.934  < 2e-16 ***
StateNY      1.777e+00  1.573e-01  11.296  < 2e-16 ***
StateRI      1.155e-01  1.571e-01   0.735 0.462435
StateVA      1.349e+00  1.472e-01   9.162  < 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(MinLen)       1.034  1.046   0.029    0.938
s(Wave)         2.952  3.000 160.919  < 2e-16 ***
s(SeasonLen)    1.687  2.032   0.512    0.570
s(Bag)          1.001  1.002   5.932    0.015 *
te(MinLen,RHL)  7.402 21.000   1.359 1.84e-05 ***
s(Year,RHL)     2.003  2.005  22.144  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Rank: 47/48
R-sq.(adj) =  0.728   Deviance explained = 65.2%
-REML = 9720.8  Scale est. = 0.86553   n = 777
```

Output (TOR 3)

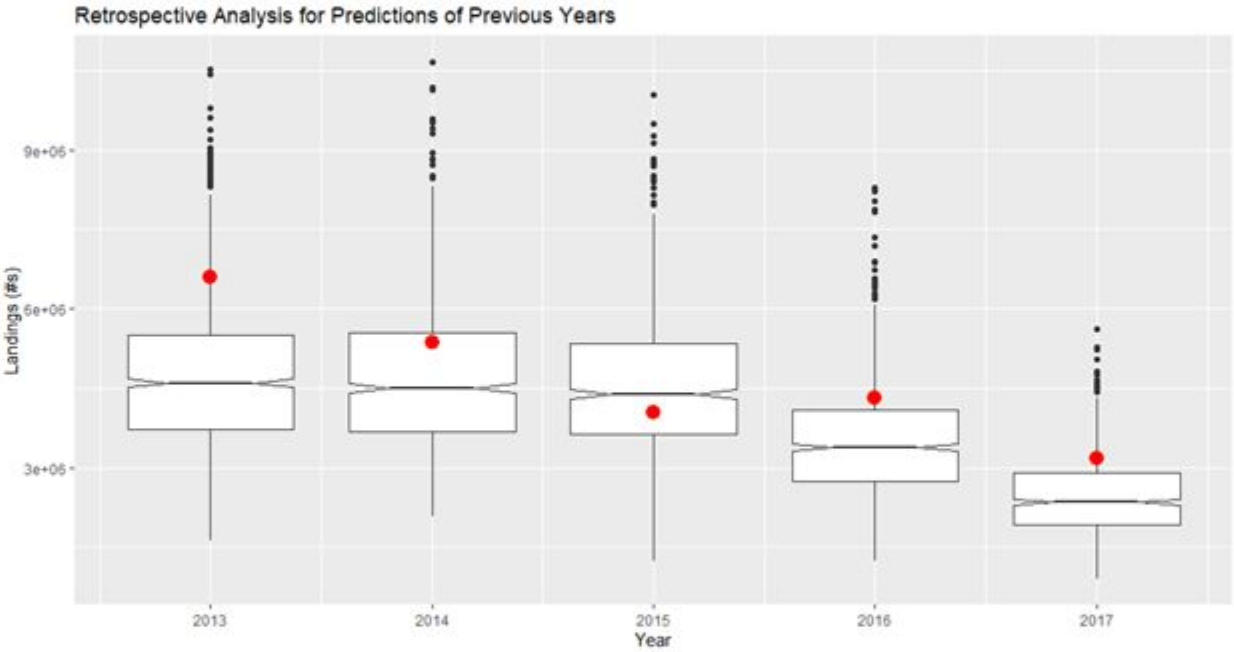
- Final models: Summer flounder - Harvest





Output (TOR 3)

- Retrospective analysis: Summer flounder - Harvest



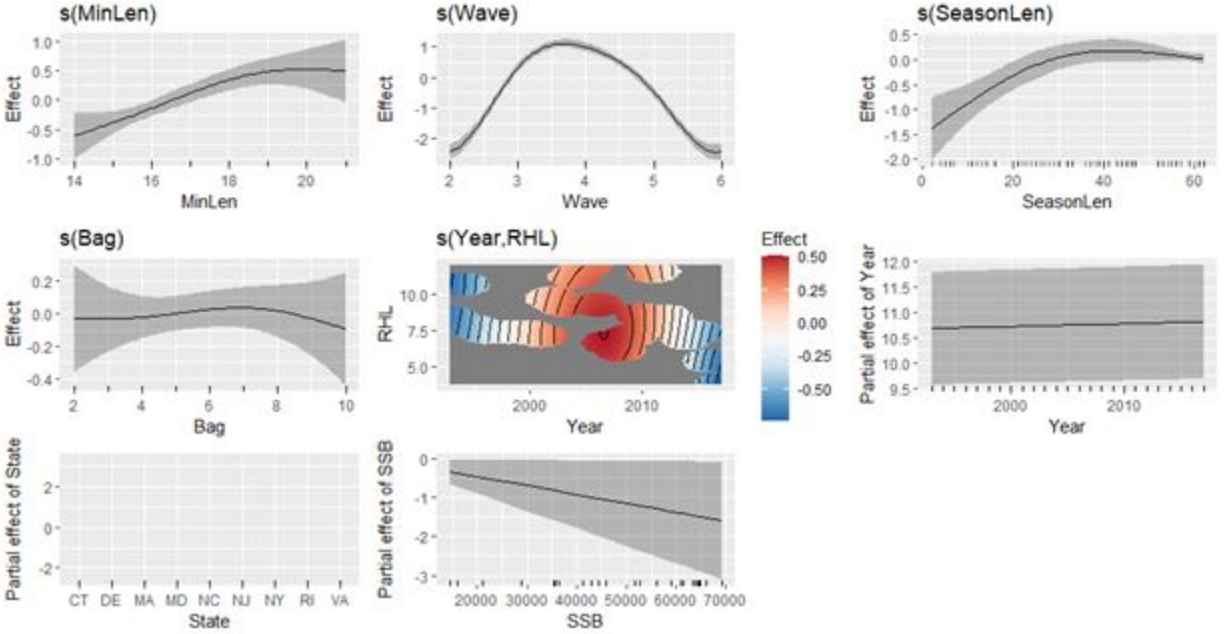
Output (TOR 3)

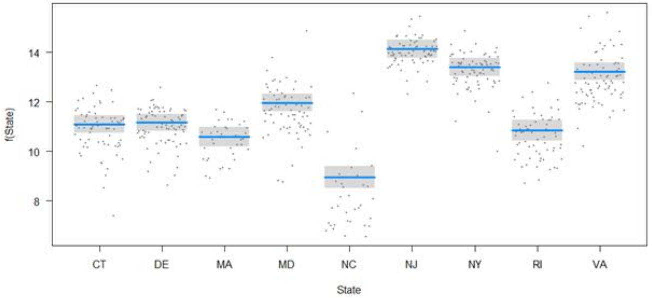
- Final models: Summer flounder - Discards

```
Family: Gamma
Link function: log

Formula:
x ~ Year + s(MinLen, k = 4) + s(Wave, k = 5, bs = "cc") +
    State + s(SeasonLen, k = 4) + s(Bag, k = 5) + SSB + s(Year,
    RHL, bs = "fs", k = 5)

Parametric coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.000e+00  0.000e+00      NA       NA
Year         5.361e-03  2.842e-04  18.865  < 2e-16 ***
StateDE      6.621e-02  1.648e-01   0.402  0.68807
StateMA     -5.112e-01  1.905e-01  -2.683  0.00751 **
StateMD      8.699e-01  1.713e-01   5.078 5.22e-07 ***
StateNC     -2.134e+00  2.123e-01 -10.054  < 2e-16 ***
StateNJ      3.034e+00  1.570e-01  19.323  < 2e-16 ***
StateNY      2.301e+00  1.581e-01  14.560  < 2e-16 ***
StateRI     -2.461e-01  1.707e-01  -1.441  0.15004
StateVA      2.124e+00  1.647e-01  12.893  < 2e-16 ***
SSB         -2.303e-05  1.112e-05  -2.071  0.03880 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
                edf Ref.df       F  p-value
s(MinLen)     2.225  2.632   8.468 0.000469 ***
s(Wave)       2.976  3.000 192.076  < 2e-16 ***
s(SeasonLen) 2.490  2.804   7.018 0.000133 ***
s(Bag)        1.791  2.235   0.133 0.804725
s(Year,RHL)   3.722  3.936   5.558 0.000232 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Rank: 27/28
R-sq.(adj) =  0.809   Deviance explained = 75.3%
-REML = 6686.2  Scale est. = 0.82874    n = 577
```

Output (TOR 3)

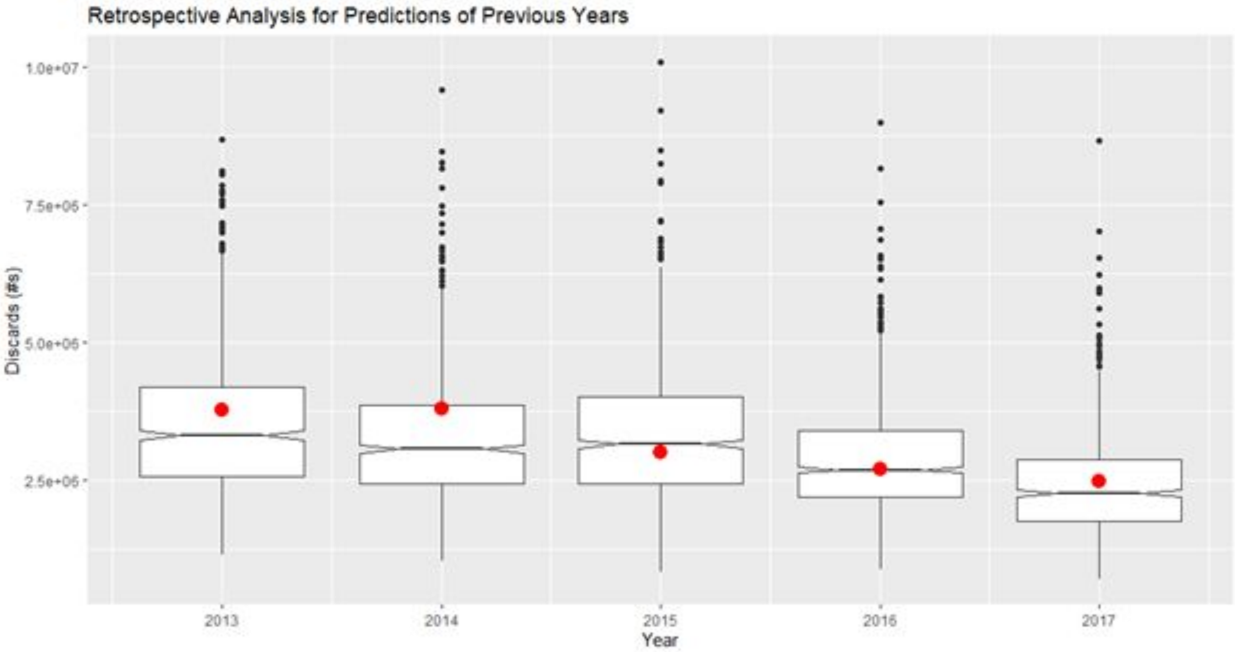
- Final models: Summer flounder - Discards





Output (TOR 3)

- Retrospective analysis: Summer flounder - Discards



Future Uses (TOR 4)

- This work can be used in two main ways in the management system
  - It can be used under the existing management system but provides a more formal and standardized process
  - It can be used to set the management measures for a new management system such as the one under discussion called the “Harvest Control Rule”

- The use of a modeling approach lends itself to creation of tools to simplify the process
  - Not everyone has skills in R or knows about GAMs, so Shiny apps can be developed to facilitate accessibility to everyone
  - Also extends the accessibility to managers

Future Uses (TOR 4)

- The development of Shiny app tools and the fact that the original development of the approach is in R and uses existing packages in R allows this work to be easily handed off to future analysts
  - Also allows for future development and integration with other tools, such as economic models...

- Switch to apps

Summary

- The project presents a technique that can be used to add transparency and standardization in to the existing spec setting process

- We've done a fair amount of work on this, but lots of room for improvement
  - Continue exploring model configurations
  - Incorporate new covariates to help with some of the elements not yet covered in the existing work (i.e. economic or behavioral covariates, environmental covariates, effort metrics, etc)

- The model can continue to be improved over time with updated data

Summary

- Models seem to perform well and seem to be able to reproduce past estimates with some degree of precision

- Would benefit from some simulation work
  - An additional thought was to run the models sampling from the dependent variables uncertainty to see if a more optimal set of coefficients can be produced

- All in all, we believe this is a valuable path to pursue for the two species examined here, and subsequently extended to other species of interest (i.e. bluefish, scup)