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SAM State-space Modeling

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TABLE OF CONTENTS

ABSTRACT

A state-space stock assessment model was applied to last year's Georges Bank yellowtail flounder data with three different values of natural mortality. The model results had small retrospective patterns and fit the indices well. There was a consistent, strong pattern in the residuals between observed and predicted total catch in weight, despite the residuals for catch at age not showing a strong pattern. This pattern was for the predicted total catch to be well below the observed catch early in the assessment period and well above the observed catch in recent years. The three models consistently estimated low recent adult biomass and recruitment and high fishing mortality rate over the entire assessment period. The adult biomass and recruitment results are consistent with the other state-space model application being presented at this meeting (WP08). The total mortality rate, fishing plus natural mortalities, is also consistently estimated by the two sets of state-space models.

RÉSUMÉ

INTRODUCTION

A state-space stock assessment model known as SAM is used in several ICES assessments (see for example ICES 2017). It is similar to the model in WP08 (Rossi et al. 2017) in that it uses a random effect to model population parameters such as fishing mortality and recruitment resulting in many fewer parameters than typical statistical catch-at-age models (Nielsen and Berg 2014). This model was used in standard configuration to assess the Georges Bank yellowtail flounder data from last year's assessment (Legault and Busawon 2016) to demonstrate some of its properties.

DATA AND METHODS

The Georges Bank yellowtail flounder data from the 2016 assessment was used (Legault and Busawon 2016). The catch and survey data were entered for years 1973 to 2015 and ages 1 to 6+, as was previously done when this stock was assessed using VPA. Three values of natural mortality were used to examine the sensitivity of model results to M: 0.2, 0.3, and 0.4. These M values were held constant over all years and ages in each run.

The Template Model Builder (TMB, Kristensen et al. 2016) version of SAM was downloaded from https://github.com/fishfollower/SAM. The standard settings were used for all initial values of parameters, for example, starting random effect values at zero and setting selectivity of the 6+ age group equal to the selectivity for age 5. The model is similar to that described in Rossi et al. (2017), with the exception that natural mortality is assumed constant over all years and ages in the results presented here while Rossi et al. (2017) allow M to change over time.

RESULTS

The model converged for all three values of M. There were slight retrospective patterns (Table 1), but these generally fell within the uncertainty estimates of the terminal year model, so would not require retrospective adjustments (Figure 1a-c). All three models indicate low recent SSB, high F throughout the assessment period, and low recent recruitment. The fits to the catch and surveys at age did not indicate any strong patterns (Figure 2a-c). However, the total catch had a strong trend in residuals with predicted catch well below observed catch in the early years and well above the observed catch in recent years (Figures 3-4).

DISCUSSION

The SAM results indicate a large variance associated with the catch and a troubling residual pattern in total catch over time. This residual pattern does not appear in the one-step-ahead residuals shown in Figure 2a-c because these residuals are conditioned on the previous state of the population. It is hard to understand how the observed catch would be so much larger than the model predictions early in the time series. The model could be modified to force the residual for total catch to be zero in the first year, similar to forcing the value of M in a random walk to begin at a specific value. This would limit the difference between observed and predicted catch early in the time series, and would likely require larger differences between observed and predicted total catch in the recent years to compensate. This sensitivity analysis was not explored due to time limitations.

The SAM analysis indicates a systematic change in catch reporting occurred over time. This has been shown in previous TRAC assessments as one way to eliminate the retrospective pattern (see for example Figure 37 of Legault et al. 2012). The SAM analysis did not require identifying a specific time when the reporting changed or estimating a fixed magnitude of change. Rather, the SAM estimation produced a model with low retrospective pattern but allowed the catch residuals to vary over time to produce the best fitting model. The SAM approach relies on signals in the data to determine the relative strength of fits to the observations, both catch and survey, as opposed to subjective choices such as breakpoints or constant multipliers applied to many years.

There are a number of similarities between the results shown here and those presented in Rossi et al. (2017) for Georges Bank yellowtail flounder. Specifically, both sets of results indicate that both adult biomass and recruitment are low in recent years and that total mortality (the sum of fishing and natural mortalities) has been high throughout the assessment period. The latter observation is easily seen in these results because the constant M value can be added to the fishing mortality time series. In the Rossi et al. (2017) paper, both the fishing and natural mortality rates are changing over time, but the time series can still be added “by eye” to produce a relatively flat time series at a high value (>1 for many years). Thus, both sets of models indicate poor condition of the stock with few adults, low expectation of incoming cohorts, and high total mortality. The modeling approaches differ in how the total mortality is split between fishing and natural mortalities. However, given the commonalities, how the total mortality is split may not be important when setting catch advice.

LITERATURE CITED

ICES. 2017. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 26 April-5 May 2016, Hamburg, Germany. ICES CM 2016/ ACOM:14. 19 pp.

Kristensen, K., Nielsen, A., Berg, C.W., Skaug, H.J., and Bell, B. 2016. TMB: Automatic Differentiation and Laplace Approximation Journal of Statistical Software 70(5): 1-21.

Legault, C.M., Alade, L., Stone, H.H., and Gross, W.E. 2012. Stock Assessment of Georges Bank Yellowtail Flounder for 2012. TRAC Ref. Doc. 2012/02. 133 p.

Legault, C.M. and Busawon, D. 2016. Stock assessment of Georges Bank yellowtail flounder for 2016. TRAC Reference Document 2016/01. 63 p.

Nielsen, A.N. and Berg, C.W. 2014. Estimation of time-varying selectivity in stock assessments using state-space models. Fisheries Research 158: 96-101.

Rossi, S.P., Cox, S.P., Swain, D.P., and Benoît, H.P. 2017. A mixed-effects approach to estimating time-varying natural mortality in a statistical catch-at-age model: Application to stock assessments for eastern Georges Bank Atlantic cod and Georges Bank yellowtail flounder. TRAC Working Paper 2017-08.

TABLES

Table 1. Mhon's rho values for spawning stock biomass (SSB), average fishing mortality rate for ages 4-5 (F4-5), recruitment (Rec), and predicted catch (Catch) for three values of natural mortality (M) assumed constant over all years and ages.

M	SSB	F4-5	Rec	Catch
0.2	0.230	-0.038	0.504	0.156
0.3	0.232	-0.053	0.489	0.142
0.4	0.235	-0.072	0.473	0.125

FIGURES

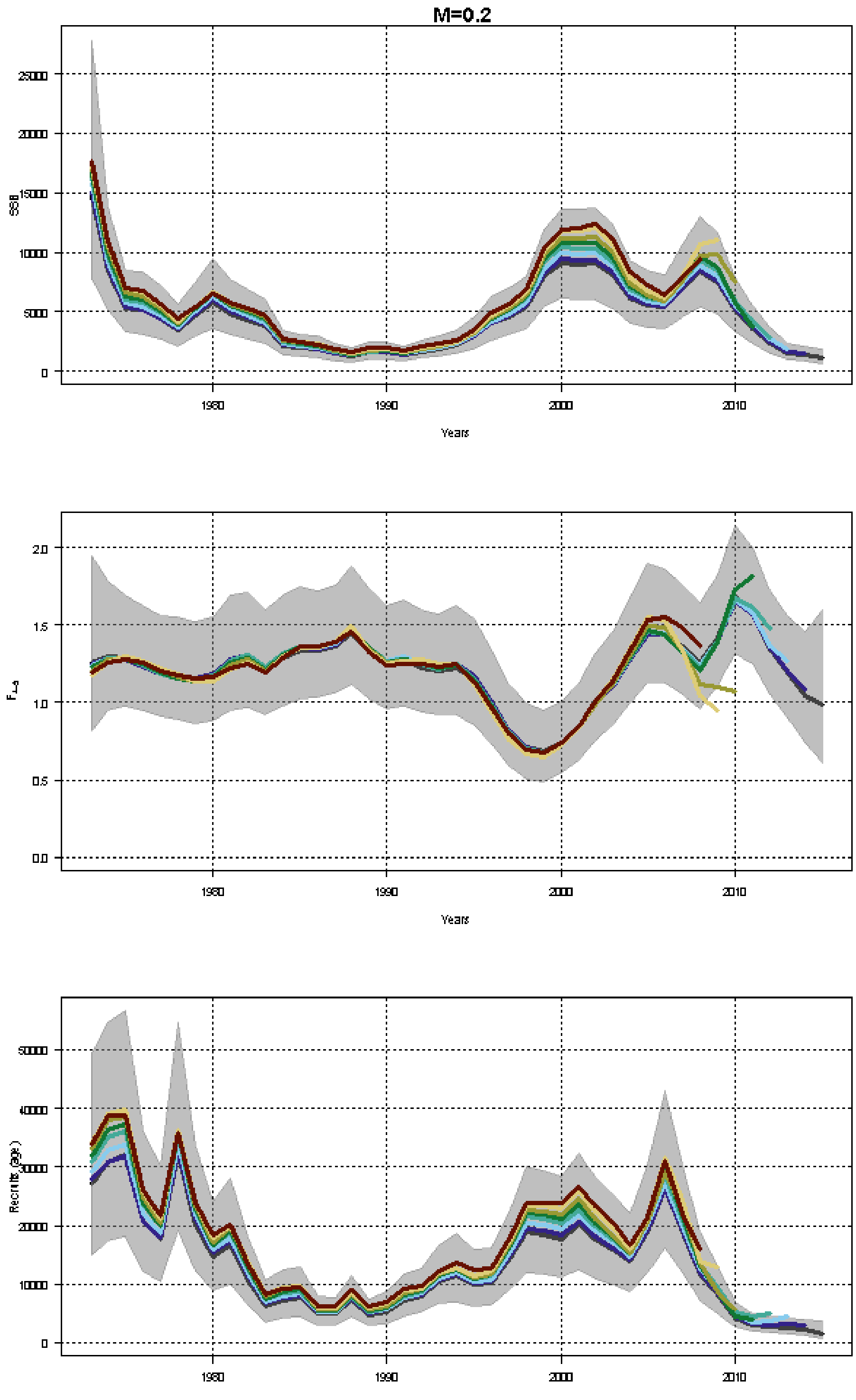

Figure 1a. Spawning stock biomass (top panel), mean fishing mortality rate on ages 4-5 (middle panel), and recruitment (bottom panel) for M=0.2. Colored lines show 7 retrospective peels in addition to terminal estimate. Grey shading indicates 95% confidence interval for terminal estimate.

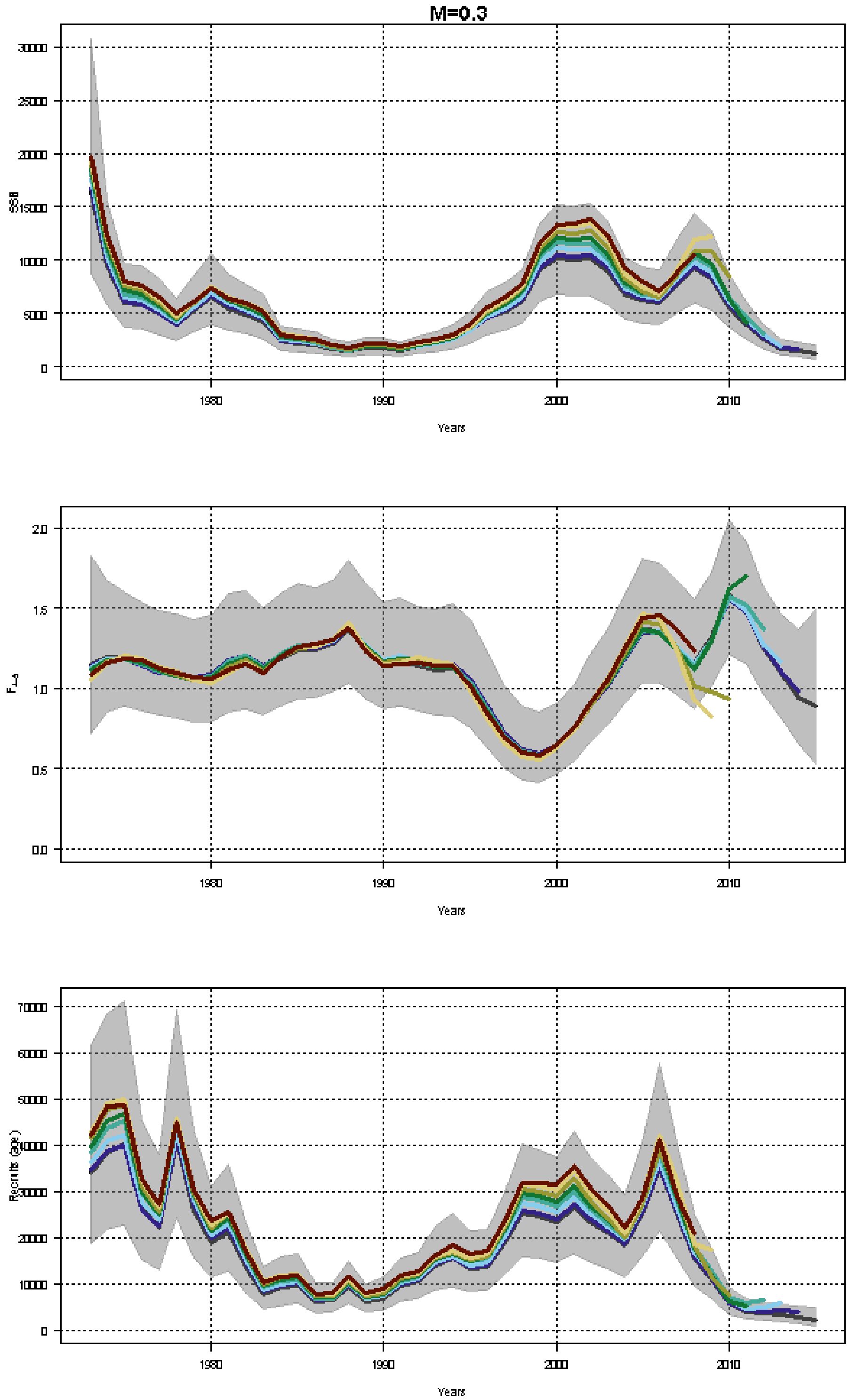

Figure 1b. Spawning stock biomass (top panel), mean fishing mortality rate on ages 4-5 (middle panel), and recruitment (bottom panel) for M=0.3. Colored lines show 7 retrospective peels in addition to terminal estimate. Grey shading indicates 95% confidence interval for terminal estimate.

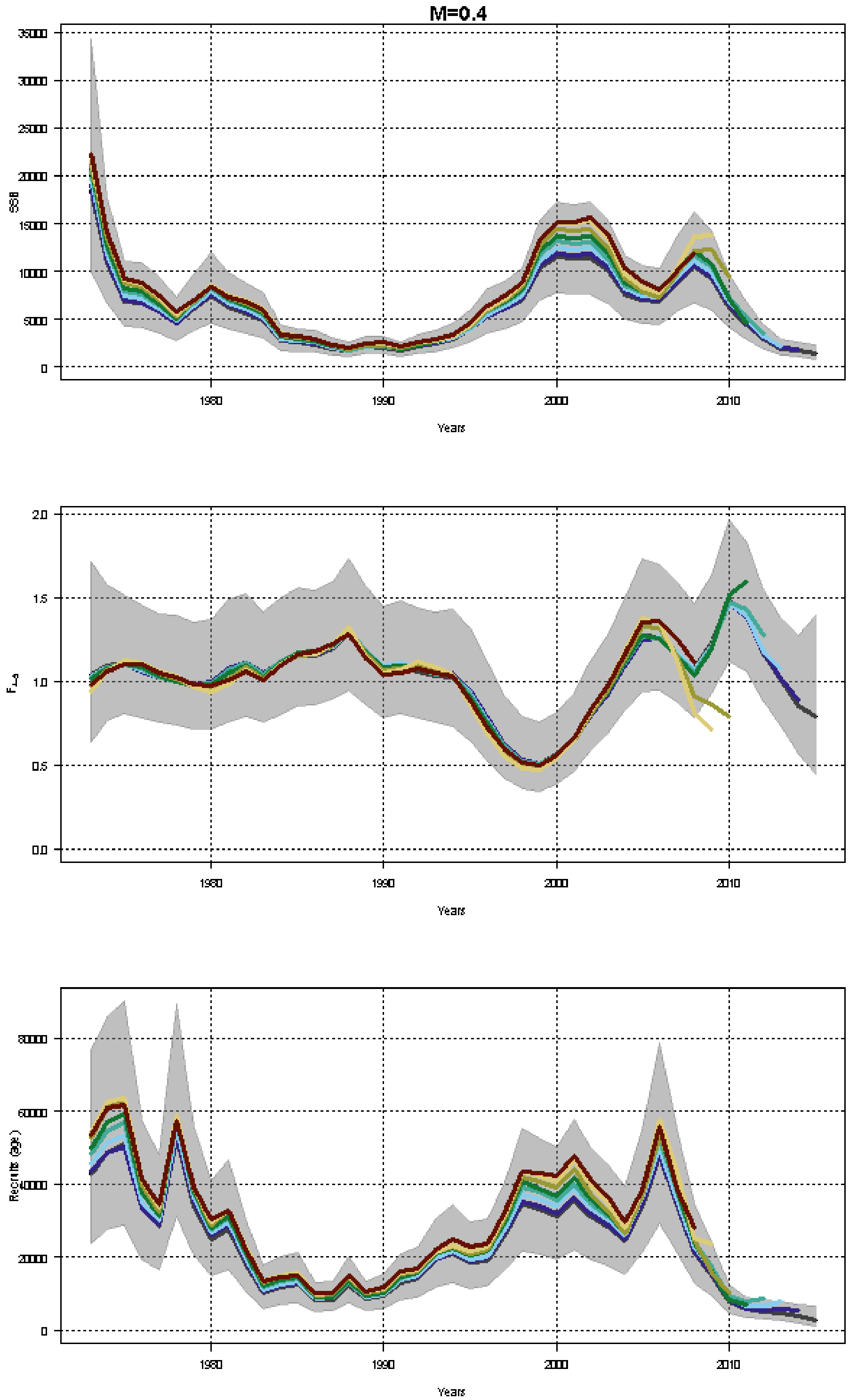

Figure 1c. Spawning stock biomass (top panel), mean fishing mortality rate on ages 4-5 (middle panel), and recruitment (bottom panel) for M=0.4. Colored lines show 7 retrospective peels in addition to terminal estimate. Grey shading indicates 95% confidence interval for terminal estimate.

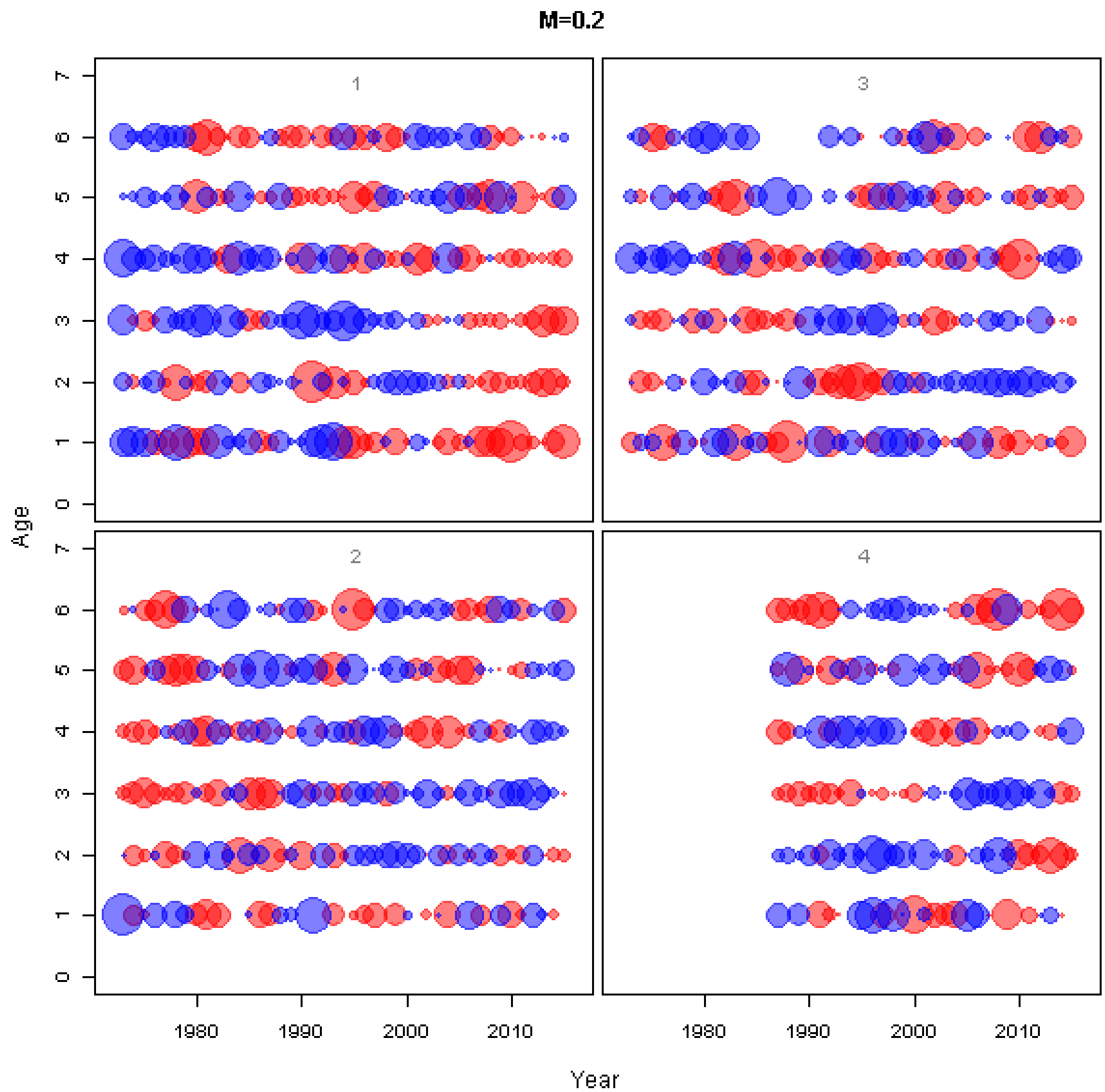

Figure 2a. Residuals for catch (labeled 1), NEFSC spring survey (labeled 2), NEFSC fall survey (labeled 3), and DFO survey (labeled 4) by year and age for M=0.2. The size of the bubble is proportional to the magnitude of the residual. Blue symbols indicate the predicted value is less than the observed value while red symbols indicate the predicted value is greater than the observed value.

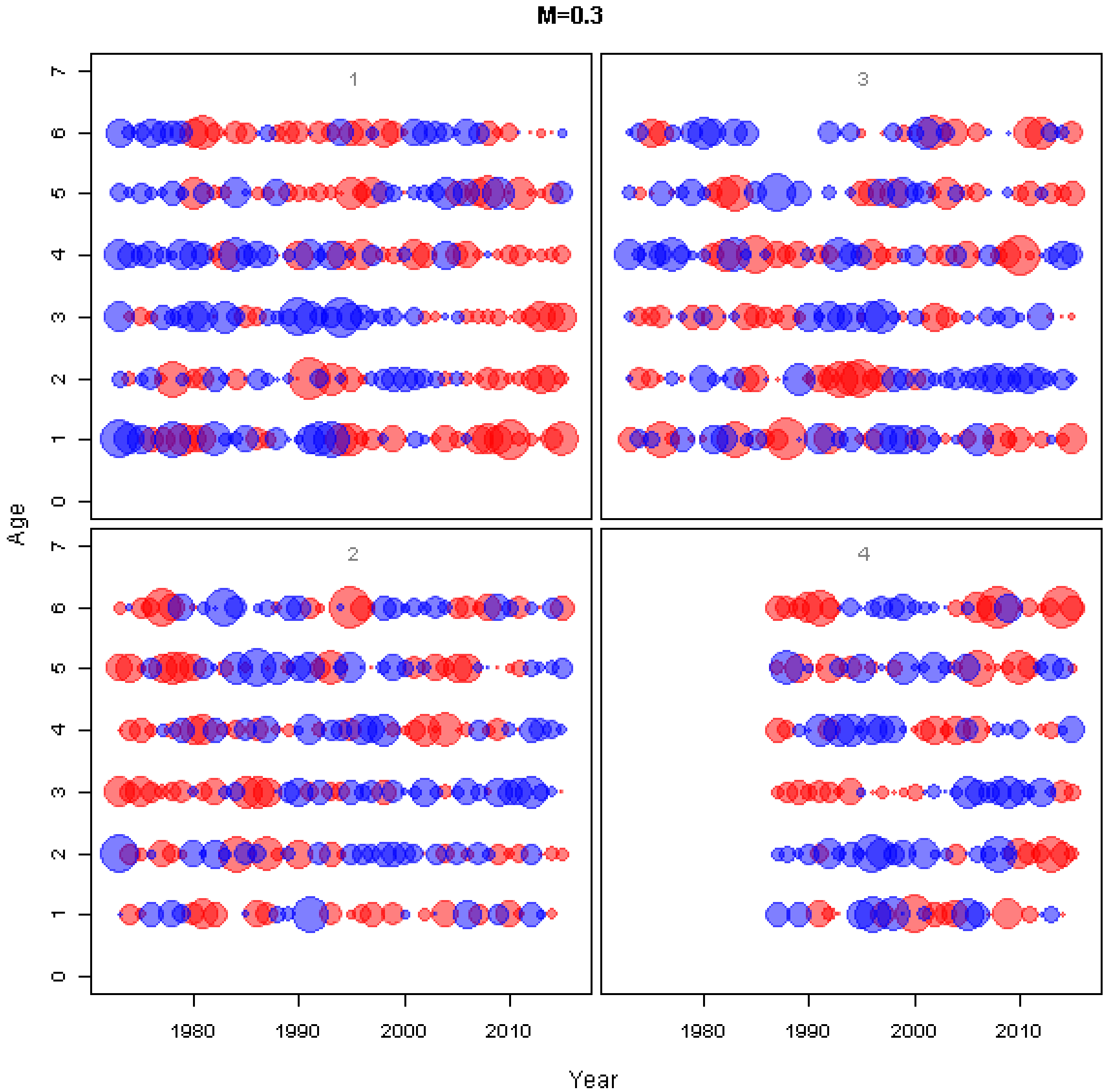

Figure 2b. Residuals for catch (labeled 1), NEFSC spring survey (labeled 2), NEFSC fall survey (labeled 3), and DFO survey (labeled 4) by year and age for M=0.3. The size of the bubble is proportional to the magnitude of the residual. Blue symbols indicate the predicted value is less than the observed value while red symbols indicate the predicted value is greater than the observed value.

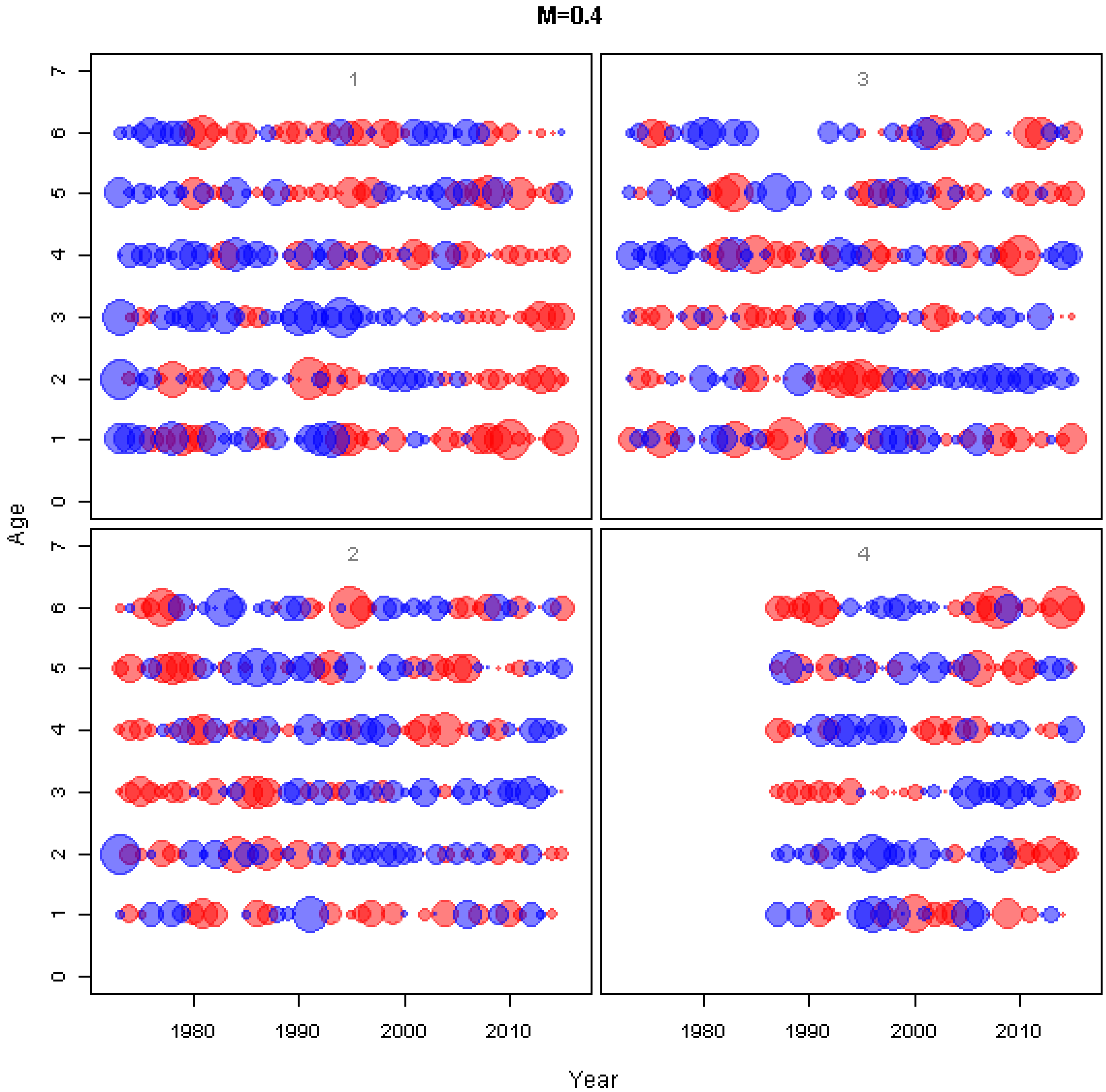

Figure 2c. Residuals for catch (labeled 1), NEFSC spring survey (labeled 2), NEFSC fall survey (labeled 3), and DFO survey (labeled 4) by year and age for M=0.4. The size of the bubble is proportional to the magnitude of the residual. Blue symbols indicate the predicted value is less than the observed value while red symbols indicate the predicted value is greater than the observed value.

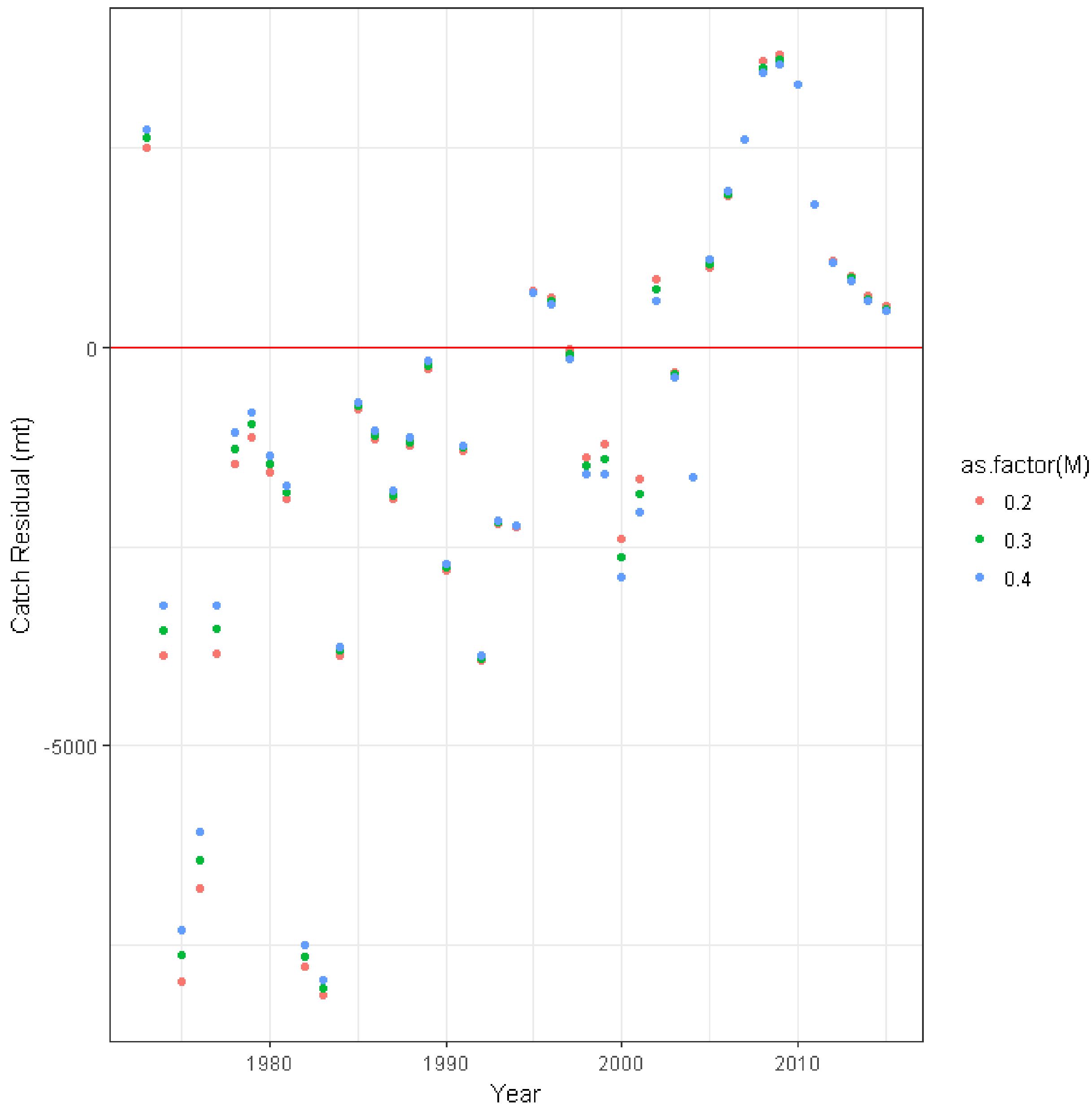

Figure 3. Catch residual (predicted – observed) in metric tons by year for the three natural mortality (M) values.

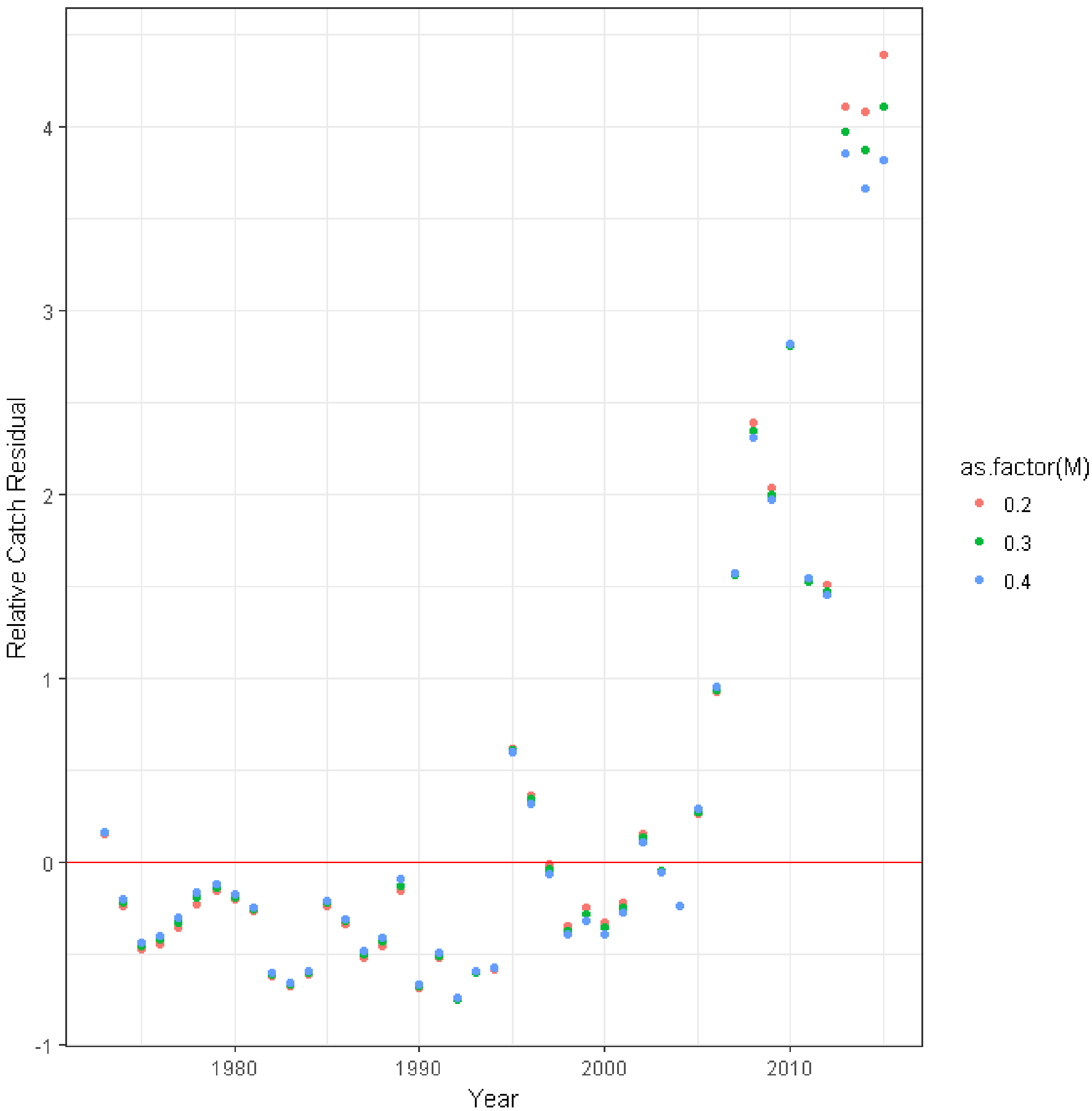

Figure 4. Relative catch residuals ((predicted – observed) / observed) by year for the three natural mortality (M) values.