# A Bayesian State-Space Approach to Improve Projections of Stock Biomass for Managing New England Groundfish

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## Motivation

Specification of Allowable Biological Catch (ABC) requires projecting biomass one to three or more years beyond the terminal year of fish stock assessments. However, these projections are often highly uncertain and may perform poorly under retrospective review. For many stocks, consistent biases in assessments, known as retrospective errors, have led to overestimation of biomass resulting in unintentional overfishing, sharp reductions in catch quotas, and decreased stakeholder confidence in the management process[1,2]. This work seeks to develop a Bayesian state-space approach aimed at better quantifying uncertainty and improving prediction performance.

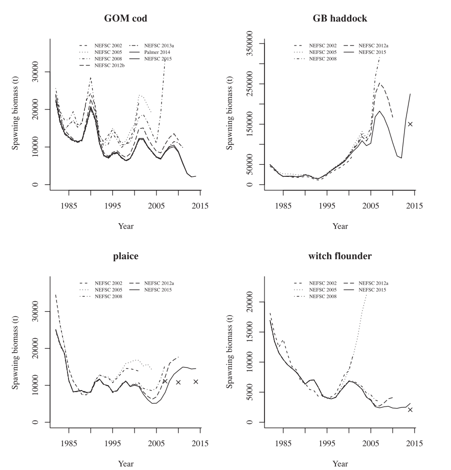


**Figure 1.** Adapted from Wiedenmann & Jensen (2017). The historic retrospective errors in recent stock assessments of four New England groundfish species. "X" symbols represent retrospective adjustments of biomass estimates to account for errors. In all cases, the projections from each stock assessment were over-optimistic. GOM: Gulf of Maine, GB: Georges Bank.

## Objectives

- Develop a simulation analysis for index-based and age-structured stock assessments for six groundfish species with a range of life history characteristics
- Optimize state-space models for prediction skill up to 3 years ahead
- Evaluate performance against existing projection methods
- Write and make available R code to implement the approach

## Approach

**Index-Based Assessment Species**

1. Log-transform survey data and covariate(s)
2. Develop diffuse priors based on data for the measurement and evolution errors
3. Regress landings on survey abundance and use landings anomalies as a covariate
4. Fit a dynamic trend-only model to the survey indices using a Gibbs sampler
5. Determine the lag of the relationship with the covariate(s) using trend model residuals
6. Fit a dynamic trend model with covariates using a Gibbs sampler

Observation Equation

$$S_t = \theta_{1,t} + \theta_{3,t}LA_t + \nu_t$$

State Equation

$$\begin{bmatrix}\theta_{1,t}\\ \theta_{2,t}\\ \theta_{3,t}\end{bmatrix} = \begin{bmatrix}\theta_{1,t-1}+\theta_{2,t-1}\\ \theta_{2,t-1}\\ \theta_{3,t-1}\end{bmatrix} + \omega_t$$

$S_t$: log survey abundance at time t
$LA_t$: landings anomalies at time t
$\theta_{1,t}$: dynamic trend of survey at time t
$\theta_{2,t}$: unobserved slope in trend of survey at time t
$\theta_{3,t}$: coefficient on LA at time t
$\nu_t$: measurement error at time t, $\nu_t \sim N(0, V)$
$\omega_t$: evolution error at time t, $\omega_t \sim MVN(\mathbf{0}, \mathbf{W})$
V: variance of $\nu_t$
$\mathbf{W}$: variance-covariance matrix of $\omega_t$

**Extended to a joint model of three surveys**

## Advantages

- Highly flexible model structure that can handle time-varying coefficients/errors, autocorrelation, and non-normality[3]
- Missing data are estimated from the predictive distribution
- Dynamic coefficients can capture effects of latent variables or processes
- Fit and forecasts easily updated when new/additional data becomes available
- Adaptability well-suited to confront challenges often associated with fisheries data

## Preliminary Results

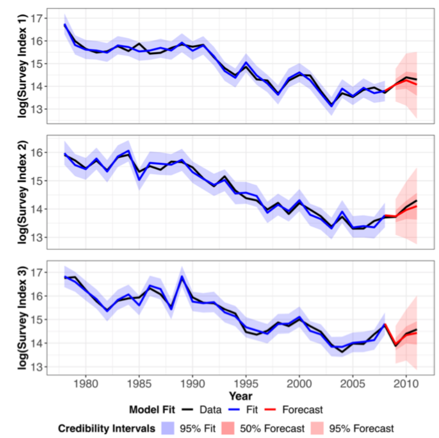


**Figure 2a.** A dynamic trend model fit to three simulated survey indices of Georges Bank cod using landings anomalies as a covariate. The model was fit to the first thirty-one years of the time series and the remaining three years were used to evaluate prediction accuracy.

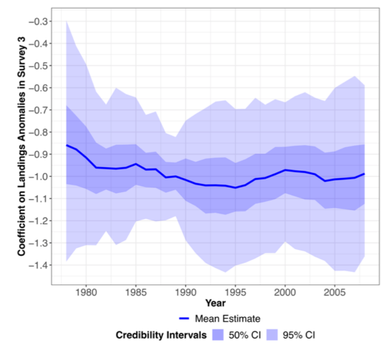


**Figure 2b.** The estimated dynamic coefficient on landings anomalies for survey 3 in the model fit described in Figure 2a. The coefficient is negative and appears to decrease slightly with abundance.

- Provides a formalized forecasting method for data-poor, index-based stocks with realistic accounting of uncertainty
- Coefficients on landings anomalies can follow changing abundance
- Forecast intervals are wide, but mean forecasts are generally close to the data
- Joint estimation of multiple survey indices greatly improves model fit

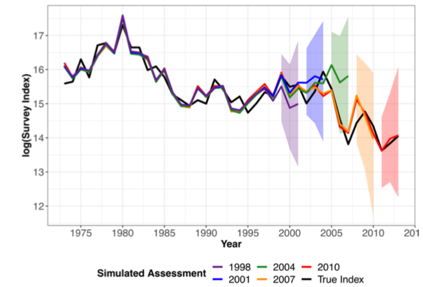


**Figure 3.** Retrospective model fits of simulated Georges Bank yellowtail flounder abundance spaced at three year intervals as if each was a stock assessment. Shaded polygons matching the color of each model fit and forecast represent the 95% forecast intervals.

- Retrospective peels suggest a consistent view of abundance is achieved
- Sharp abundance changes impact forecast success, but have little affect on in-sample model fit

## Next Steps

- Finalize approach for index-based stocks
- Compare against existing methods with simulated and real data
- Develop method to provide ABC guidance for stocks with multiple surveys
- Transition the index-based model to an age-structured approach incorporating available information for these stocks
- Compare age-structured model projections to existing methods
- Create a user interface in R to allow for future use of the projection method

## References

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2. Wiedenmann J & Jensen OP. 2017. Uncertainty in stock assessment estimates for New England groundfish and its impact on achieving target harvest rates. Can. J. Fish. Aquat. Sci. 75(3): 342-356.
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