Catch Advice Methods for the Northeast Multispecies Fishery:

Report of Phase 3Work

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Executive Summary

Scientific uncertainty in the assessments and projections used to set catch advice for many groundfish stocks has resulted in achieved harvest rates far from the desired levels. For stocks with age-based assessments, overestimation of target catches was frequent, whereas for stocks with index-based assessments, target catches were often underestimated. The aim of this work is to identify methods for setting catch targets that will come closer to achieving the target harvest rates. We selected six groundfish stocks for this analysis, five of which had problems of overestimation of historical catch targets (Georges Bank cod, Gulf of Maine cod, Georges Bank yellowtail flounder, witch flounder, and Southern New England / Mid-Atlantic winter flounder), and one with underestimation of catch targets (pollock).

For stocks with age-based assessments that overestimated catch targets, we tested a number of alternative methods, and identified several approaches that were substantial improvements to the historical approach, often greatly reducing the overestimation in target catches. The most successful alternative approaches we identified were those that 1) used a fixed catch target in the years between assessments, and 2) adjusted the most recent estimate of population size downward to account for the pattern of frequent overestimation. Adjustments to the terminal abundance estimate have been made for some stocks in recent years using the mean retrospective bias estimated from the assessment, but our results suggests that if such modifications had been made in the past, they would have been insufficient in most cases. An improvement is to use a fixed adjustment factor across stocks (assuming terminal biomass is overestimated by 38%, 66% or 100%), as doing so outperformed using assessment-specific adjustment factors. The largest adjustment factor had the lowest frequency of overfishing across stocks, but it was overly conservative in a number of years for some stocks. Threshold-based control rules that decreased the harvest rate as the population biomass fell below the MSY level were effective to a lesser degree, but were overly conservative when paired with the abundance adjustment methods. Although catch-averaging (or smoothing) methods were not used in the setting of previous catch targets, they have been suggested as a viable alternative to reduce interannual variability in catches. Our work shows that although these smoothing methods do reduce variability in target catches, they perform worse in nearly all cases (greater overestimation of target catches). Avoiding projections is preferred to averaging methods, as it both reduces the variability in target catches and results in less overestimation of target catches overall. Because improved methods were identified here, in future work we will apply these methods to additional groundfish stocks not included in the current analysis to determine if the success of these approaches can be generalized across most New England groundfish stocks.

We also evaluated the performance of data-limited alternatives to the catch advice for all six stocks (including pollock, which had index-based catch advice from 2004 to 2010). Contrary to the other groundfish stocks in this analysis, historical catch advice for pollock was too conservative, resulting in annual harvest rates well below the desired levels. We evaluated a range of alternative methods that utilized information from both

the NEFSC bottom trawl survey, as well as the age structure in the catch. For pollock and witch flounder, performance of the data-limited methods was variable over time, and overly conservative. For the remaining stocks, again performance of the approaches was variable, with no single method being best for all stocks in all years. However, many of the data-limited approaches set alternative catch targets well below the historical catch targets following each assessment, although not enough to prevent overfishing. Because of the overall performance of some of these methods, they will be tested on additional groundfish stocks in future work.

Introduction

Frequent overfishing has occurred for many stocks in the New England groundfish complex, and many populations remain overfished despite efforts to constrain harvest rates and rebuild populations (NEFSC 2015). Previous work (Wiedenmann and Jensen 2015) showed that recent catch targets (since 2004) were overestimated for many groundfish stocks. Overestimation of catch targets was particularly problematic for Gulf of Maine (GOM) cod, Georges Bank (GB) cod, GB yellowtail flounder, witch flounder, Cape Cod / Gulf of Maine (CC/GOM) yellowtail flounder, American plaice, and Southern New England / Mid Atlantic (SNE/MA) winter flounder, all stocks with age-based stock assessment models. This overestimation was largely due to scientific uncertainty in the estimated abundance, as terminal abundance in the assessment models was frequently overestimated. Recruitment for many stocks has also been declining since 2004, compounding the error in catch targets based on projections. Underestimation of catch targets was less common, occurring for pollock, GOM haddock (both stocks relied on index-based assessment methods for much of the time series), and Acadian redfish.

Because of the magnitude of scientific uncertainty in previous catch advice for New England groundfish, it is important to 1) identify the sources of this scientific uncertainty (i.e., what caused the assessments to overestimate abundance), and 2) understand how alternative methods would have performed with respect to and preventing overfishing. Due to the many data inputs and model assumptions for each assessment for each stock, addressing 1) is well beyond the scope of this work. Here we focus on addressing 2), so that effective methods can be identified and used in the setting of future catch targets.

This work expands on the previous analysis (Wiedenmann and Jensen, 2015), focusing on the catch advice following the GARM 1, 2, and 3 age-based projections for GOM cod, GB cod, GB yellowtail flounder, witch flounder, SNE/MA winter flounder, and on the index-based catch advice for pollock from these same assessments (NESC 2002, 2005, and 2008). We explored a variety of alternative methods for setting catch advice for the age-based estimates. Because our earlier work identified overestimation of terminal abundance and declining recruitment as two major factors contributing to the uncertainty in catch advice, we explored methods for adjusting the terminal abundance estimate, as well as a way to adjust forecasted recruitments based on perceived changes in recruitments. Furthermore, because projection models often predicted increasing stock biomass under the target harvest rates (and therefore increasing target catches), overestimation of the starting abundance has the potential to amplify the error in target catches by using projections. We therefore explored the impact of using a fixed target catch over the interval between assessment models. We also evaluated alternative control rules that reduced the target harvest rate as the estimated biomass falls below some specified threshold, and the effect of gradual changes in the catch targets that prevent dramatic increases or decreases from year to year. Finally, we explored a variety of data-limited approaches for setting catch advice to compare with both the age-based projections and the index-based method used for pollock for much of the time series.

Performance of each alternative method was evaluated with respect to the ability to set target catches (C_{target}) each year close to the level that would have achieved F_{MSY} in each year (estimated using the most recent stock assessment). We also quantified the frequency of overfishing and the interannual variability in catch targets for each method to identify those that limited overfishing and prevented dramatic changes in catches from year to year.

Methods

To determine how alternative methods for setting catch targets would have performed in a given year with respect to preventing overfishing ($F \leq F_{MSY}$), we need to know what level of catch would have achieved F_{MSY}. The true catch at F_{MSY} is unknown because we do not know what the true population size, weight-at-age, and fishery selectivities were over time. However, we do have the most recent stock assessments that provide estimates of these quantities. The most recent assessment for a stock (that passed review) is considered the best available science, and we used the most recent assessment for each stock as the primary source of information for our analyses. In some cases the most recent assessment exhibited a retrospective pattern, where the model has a tendency to over- or under-estimate terminal biomass in recent years (calculated by sequentially removing one year of data and refitting the model) relative to the biomass estimates when the assessment is fit using the full time series of data. We did not adjust the biomass estimates over time from the most recent assessment to account for the retrospective pattern in recent years. Therefore, a caveat to our approach is that we are still using estimates from an assessment model, sometimes with a moderate to strong retrospective pattern, which may be revised up or down in future assessments. For four of the six stocks used in this analysis, the most recent age-based assessment that passed review was the 2015 groundfish update assessment (NEFSC 2015; herein we refer to it as the GARM 4 assessment for continuity). These stocks were GOM cod, witch flounder, SNE/MA winter flounder, and pollock. GB cod and GB yellowtail were also assessed in GARM 4, but the GB cod assessment did not pass review, and the GB yellowtail assessment relied on swept-area estimates of total biomass. For these stocks we used the most recent age-based assessment that passed review as the source of all necessary information (NEFSC 2013 for GB cod and Legault et al. 2013 for GB yellowtail flounder; Table 1).

We focused on the catch advice following the GARM 1, 2, and 3 assessments for each stock. For most stocks, GARM 1 was the basis for catch targets for 2004 and 2005, GARM 2 the basis for catch targets from 2006 through 2008, and GARM 3 was the basis for catch targets starting in 2009 to a variable end date. For some stocks GARM 3 informed catch targets through 2012, although a number of stocks were reassessed and the catch targets were updated prior to 2012. An exception to these patterns was GB yellowtail, which has had annual updates to catch targets following annual assessments. For consistency across stocks with age-based assessments in our analysis, we assumed that GARM 1 informed catch targets for 2004-2005, GARM 2 informed targets from 2006 – 2008, and GARM 3 informed catch targets for 2009-2012. For pollock, we assume the same dates for GARM 1 and 2, but only use GARM 3 to inform catch targets in 2010, as this period represents the catch targets from the index-based assessment model. In 2010 an age-based assessment for pollock was completed (NEFSC 2010), and subsequent catch targets were derived from the age-based model.

Our analyses used two distinct approaches. For stocks where catch targets were derived from age-based assessments (GOM and GB cod, GB yellowtail flounder, witch flounder, and SNE/MA winter flounder), we used an age structure projection model that we developed in R (R Core Team, 2015), and modified the inputs when testing alternative methods for setting catch targets. For all stocks including pollock, we used a variety of data-limited methods available in the R package DLMtool (Carruthers 2014). We first describe the age-structured projection model and all of the modifications we explored, and then describe the data-limited approaches.

Age-Structured Population Model and Projections

We developed an age-structured projection model for our analyses to mimic the AGEPRO model used for age-based projections for New England groundfish stocks (Brodziak et al. 1998). A benefit to developing our own model (in lieu of using the AGEPRO model) is that it can be easily modified as needed to test alternative catch advice methods. When using the same inputs and assumptions, our projection model resulted in estimates of biomass and catches that closely matched those from the AGEPRO model. The equations governing the projection dynamics of our model are presented in Table 2, and we provide a summary of the model here. The projection model requires inputs of the initial abundance-at-age, mean maturity-, fishery selectivity, and weight-at-age (in the population and catches if different). Additional inputs include the target *F*, the stock-recruit relationship (or empirical recruitment estimates in the absence of a relationship), the assumed catch and / or *F* during the interim years between the assessment estimates and when the catch targets are being calculated (termed the bridge years). In year 1 of the projection, the *F* is either based on the input value, or it is calculated using the input catch and the Baranov catch equation (equation 5 in Table 2). In the second year of the projection, recruitment is determined from the specified recruitment model with the appropriate lag in years when necessary. Witch flounder was the only stock with a lag greater than 1 year, but the projections relied on an empirical distribution of past recruitments and not a stock-recruit relationship, so we did not need to account for the 3-year recruitment lag for this stock. For all other age-classes, abundance at age in year 2 is determined by the abundance in the previous year discounted by fishing and natural mortality rates (equation 1 in Table 2). Spawning biomass is calculated each year using the estimated abundance at age and the specified mean maturity- and spawning weight-at-age, discounted by a specified fraction of the total mortality that occurs before spawning in a year. Total catch in a year is calculated using the Baranov catch equation for a given target *F*. The stock is projected forward a number of years under the specified *F*, and this process is repeated 1,000 times to account for the bootstrap- or MCMC-derived uncertainty in the initial abundance and future recruitments, producing a distribution of predicted spawning biomass, recruitment, and total catch for each year in the model.

We ran the projection model for each stock using the original projection inputs following GARM 1, 2, and 3 (obtained from the New England Fishery Management Council). The median target catch in each year from each projection period (e.g., 2004-2005 for GARM 1) was set as the baseline level for comparison with the target catches from alternative approaches.

We evaluated a range of alternative methods for setting catch targets (see Table 3 for a summary of each method). These methods can be broadly classified as 1) adjustments to the population inputs, and 2) alternative ways of determining the target catch given the inputs. Adjustments to the population inputs involved modifying the initial abundance-at-age, or using a different way of forecasting recruitments in the projections. For the alternative ways of setting the target catch, we evaluated different control rules, whether or not to do projections, and methods for "smoothing" the target catch time series.

Alternative Methods for Setting Catch Targets: *Adjusted Abundance-at-Age*

We evaluated eight methods (numbered 1-8) for setting the initial abundance-at-age in the projection model (Table 3). For run 1, we used the original (unmodified) distribution of abundance-at-age for each projection. For runs 2 – 5, we used an adjustment factor, ϕ, and calculated a modified abundance-at-age with:

$$N_{mod}(a) = \frac{N(a)}{1+\phi} \qquad (1)$$

For run 2, ϕ was based on the estimate of Mohn's ρ (Mohn 1999) following each assessment for each stock (Table 4). For runs 3, 4, and 5 we used a fixed ϕ for all stocks across assessments. The values for runs 3 and 4 were based on the median and mean relative errors (0.38 and 0.66, respectively) in terminal biomass across groundfish stock assessments identified by Wiedenmann and Jensen (2015). For run 5 we tested a larger value of ϕ (1.0).

For runs 6, 7, and 8, the initial abundance-at-age in each projection was based on the estimated abundance 3, 4, and 5 years prior to the terminal year in each assessment, respectively. For example, the terminal year in the GARM 1 assessment was 2001, so for run 5 the initial abundance used to calculate the target catch would be the estimated abundance-at-age in 1999. The rationale for using an older estimate of abundance is that many of the GARM 1-3 assessments predicted sharp increases in biomass in the final few years of the model that never materialized (Wiedenmann and Jensen 2015), and using older abundance estimates could alleviate some of the error resulting from these erroneous predicted increases in terminal abundance. Uncertainty in the initial abundance in each age class was generated using a lognormal distribution:

$$N_{mod}(a) \sim Lognormal(N_{old}(a), \sigma(a)^2) \qquad (2)$$

where $N_{old}(a)$ is the is the point estimate of numerical abundance-at-age 3, 4, or 5 years before the terminal year, and $\sigma(a)^2$ is the estimated uncertainty in the original (unmodified) abundance-at-age used in the projection because we did not have the estimated uncertainty in years prior to the terminal year. For these runs, all other age-based projection inputs (weight, maturity, selectivity) were not modified.

Alternative Methods for Setting Catch Targets: *Recruitment*

Forecasted recruitments in the projections were estimated using 1) the unmodified method (either a stock-recruit relationship or an empirical cumulative distribution function specified in the original projection input files), or 2) a truncated empirical distribution using recent recruitments if a decline has been identified. To determine if a decline in recruitment occurred in recent years, we used the algorithm developed by Rodionov (2004) to detect recent climatic regime shifts. This method was used by Vert Pre et al. (2013) to determine if temporal changes in stock productivity had occurred for a large number of global fish stocks. The algorithm works by calculating the mean recruitment over a specified initial time period, then calculates the mean for a subsequent period and assigns this period as a new regime if the mean is significantly different from the old mean according to the Student's t-test. The algorithm continues sequentially until each time period is assigned to an existing or new regime.

For each stock and each assessment, we used the regime-shift algorithm to determine if the estimated recruitment had declined in recent years (Figures 1-5). We assumed a minimum initial interval of 5 years, and omitted the terminal year estimate of recruitment due to the high uncertainty in the estimate. In some cases, no regime shift was detected for the entire time series, while in others, increases and decreases were predicted in a single time series. In cases where the mean recruitment from the terminal regime was lower than the mean from the previous regime, we used the empirical recruitment estimates from the terminal regime period only in the projection model. For example, using the GARM 3 estimates the algorithm detected a decline in GB cod mean recruitment starting in 1990 and continuing until the terminal year (2007; Figure 1). Projections for GB cod therefore used the recruitment estimates from 1990 onward to create an empirical cumulative distribution function (ECDF) to determine forecasted recruitments. If no decline in recent recruitment was detected, no modification was made to the forecasted recruitment method. When a lower recruitment regime was detected, we did not adjust the reference points because this would have altered the performance of the threshold control rules that reduce the harvest rate as the biomass falls below the biomass reference point S_{MSY} (see below).

Alternative Methods for Setting Catch Targets: *Control Rules*

The existing control rule for New England groundfish stocks has been to use the lesser value of 75% of F_{MSY} or $F_{Rebuild}$ (if the population is in need of rebuilding; Federal Register 2009). We evaluated a total of 6 control rules (runs 1-6), with the historical F_{target} used in run 1. For run 2 the F_{target} was set to 75% of F_{MSY} in each projection, regardless of whether or not it was lower than the estimated $F_{Rebuild.}$ Control rule runs 3-6 were variations of the threshold-based P^* control rule (Shertzer et al. 2008) used by the Mid-Atlantic Fishery Management Council (MAFMC) and tested in the simulation work of Wilberg et al. (2015). The general P^* approach uses the point estimate of the overfishing limit, or OFL (the catch at F_{MSY}), and assumes that the point estimate of the OFL is the median of a lognormal distribution with a specified coefficient of variation (C.V.). The catch target (also called the acceptable biological catch, or ABC) is determined by selecting a percentile of the OFL distribution below the median. Selecting the 40th percentile of the OFL as the ABC implies a 40% chance of overfishing, or $P^* = 0.4$. This approach results in the catch target being lower than the median (point estimate) of the OFL, and the size of the buffer increases with a lower percentile for a given C.V., or a higher assumed C.V. for a given percentile. The MAFMC uses a C.V. of 1.0 to generate the OFL distribution, and the target P^* varies with the estimated stock size:

$$P^* = \begin{cases} 0.4 & \frac{S}{S_{MSY}} \geq 1 \\ int + slope * \frac{S}{S_{MSY}} & S_{thresh} < \frac{S}{S_{MSY}} < 1 \\ 0 & \frac{S}{S_{MSY}} \leq S_{thresh} \end{cases} \qquad (3)$$

When biomass is at or above S_{MSY}, a fixed P^* of 0.4 is used. As the biomass falls below S_{MSY}, P^* declines linearly until the S / S_{MSY} reaches some threshold level (S_{thresh}), where P^* is set to 0 and the fishery is closed. The MAFMC uses an $S_{thresh} = 0.1$ for their control rule. For control rule runs 3 and 4 we used a C.V. = 1.0, and S_{thresh}= 0.1 and 0.2, respectively. For runs 5 and 6 we used a CV = 1.2, and S_{thresh}= 0.1 and 0.2, respectively (Figure 6).

Alternative Methods for Setting Catch Targets: *Projected or Fixed Catch Targets*

Catch targets following GARM 1, 2, and 3 for stocks with age-based estimates were derived from the projected biomass and catch in the future under F_{target}. For many stocks, biomass was projected to increase, but overestimation of the initial abundance in the projection model and below-forecasted recruitment resulted in catch targets being overestimated as well (Wiedenmann and Jensen 2015). In addition to using the standard projections (projection run 1), we explored two alternatives. One alternative (run 2) was to project only to the first year of the management period and fix the target catch for the remainder of the management period. For example, following the GARM 1 assessment, biomass would be projected from 2002 to 2004, and the catch at F_{target} in 2004 would also be used in 2005. Alternatively, no projections could be done (run 3) and the catch target for the management period is calculated using F_{target} and the initial abundance in the projection model. Using GARM 1 as an example again, the target catch in 2004 and 2005 would be based on the catch at F_{target} using the estimated initial abundance at age in 2002.

Alternative Methods for Setting Catch Targets: *Gradual Changes in Catch Targets*

All of the methods described thus far only use information from the most recent assessment when estimating catch targets. Using only the most recent assessment can result in a large change in the target catch between assessments if the current biomass estimate has deviated substantially from the projected biomass from the previous assessment. We evaluated three methods for smoothing the estimated catch targets: 1) use only the most recent information from the assessment when setting catch targets (i.e., no smoothing; the status quo approach), 2) constrain the catch targets based on the most recent assessment to only allow for annual changes of + / – 20%, and 3) use a weighted average of the catch target from the previous assessment and the current catch targets. For 2), if $C^*_{target}(t)$ is the new target catch in year t, then the actual catch target in year t will be

$$C_{target}(t) = \begin{cases} \max(0.8 * C_{target}(t-1), C^*_{target}(t)) & C^*_{target}(t) < C_{target}(t-1) \\ \min(1.2 * C_{target}(t-1),\ C^*_{target}(t)) & C^*_{target}(t) > \ C_{target}(t-1) \end{cases} \tag{4}$$

For 3), if C_{prev} is the target catch in the final year of the previous management period, then the target catch in year t is a weighted average of C_{prev} and $C^*_{target}(t)$

$$C_{target}(t) = (1 - \omega) \cdot C_{prev} + \omega \cdot C^*_{target}(t) \tag{5}$$

We set $\omega = 0.5$, providing even weight to the previous and updated information, but weights between zero and one are valid.

Data-Limited Methods

For GARM 1-3, pollock catch advice was derived from index-based assessments (NEFSC 2002a, 2005, 2008). A full description of the index-based projections methods is provided in the NEFSC (2002b). Although it is possible to explore catch predictions from the method used with different indices of abundance (e.g., the spring survey index compared to the fall survey index), a more appropriate analysis for this stock requires exploring alternative methods for setting catch targets in data-limited situations. Carruthers (2014) developed an R package that contains more than 50 methods for setting target catches for data-limited fisheries. The complexity and level of data requirements and model assumptions varies greatly across methods. We restricted our analysis of alternatives methods to those that used 1) age structured information from the landings to perform catch curve analyses, and 2) indices of relative abundance over time that adjust the target catch based on the recent trend in the survey index. A full list and description of the different methods used is provided in Table 5. For each method that relied on an index of abundance, we predicted the catch targets using both the spring and fall NEFSC bottom trawl survey index. The motivation for using data-limited methods was pollock, but we used them to predict catch targets for all stocks to compare their performance to the data-rich approach of using a full stock assessment. Inputs to the DLMtool package for each stock are presented in Appendix A.

Performance of the Alternative Methods

The alternative methods for the age-structured assessments described above were combined in a factorial manner, such that every combination of models was applied to each stock to determine the methods that set catch targets close to the estimated catch at F_{MSY} following each assessment. In total, we ran 864 combinations (8 abundance runs x 2 recruitment runs x 6 control rule runs x 3 projection / fixed runs x 3 gradual change in catch runs) for each stock following the GARM 1, 2, and 3 assessments. For all combinations we evaluated performance using three metrics. The first was the ratio of fishing mortality rate in each year, $F(t)$ to the most recent estimate of F_{MSY} (the F-ratio). F-ratios close to 1.0 indicate that the method would have set the target catch close to the catch that would have achieved F_{MSY}. The annual estimates of F were numerically estimated using the target catch and the abundance-at-age in a give year. We explored three methods for calculating $F(t)$, with each method differing by the manner in which abundance changes annually in response to the fishing intensity earlier in the time period. Each approach for calculating F assumed that the target catch from an alternative method was removed each year, such there was no implementation uncertainty. The first method for calculating F (which we call the static approach) used the fixed abundance-at-age estimates from the most recent assessment, and did not account for possible changes in abundance that may have occurred if a particular approach was more or less conservative than the catches that that occurred for a stock. The second and third approaches allowed for changes in abundance over time resulting from more or less conservative catches over time. The difference between these dynamic approaches was the way in which recruitments were handled. In the first dynamic method, recruitment in each year was fixed at the observed value from the most recent assessment (called the dynamic with fixed recruitment). This method assumes recruitment is independent of stock size, as fishing under a lower F would result in increased spawning biomass, yet the recruitments each year remain the same. The second dynamic approach we explored was to estimate a stock-recruit relationship for each stock, and calculate the relative deviations in each year around the predicted recruitments (called the dynamic approach with variable recruitment). Using the estimated spawning biomass and recruitment time series' from the most recent assessment for each stock, we assumed recruitment followed the Beverton-Holt relationship:

$$R(t) = \frac{\gamma S(t-a_R)}{\beta + S(t-a_R)} \qquad (6)$$

and estimated the parameters γ and β for each stock using a maximum likelihood approach assuming a lognormal distribution for the errors (Figure 7). With a model to predict recruitment from spawning biomass (lagged by the age at recruitment, a_R) and estimates of the relative deviations in recruitment each year, we were able to predict changes in recruitment following changes in spawning biomass under the different levels of F. A caveat to both of the dynamic approaches is that large changes in biomass (up or down) are not reflected in changes in the assessment estimates used to set catch targets.

The second metric we calculated was the frequency, or probability, of overfishing (P_{OF}), calculated as the proportion of years from 2004-2012 when $F > F_{MSY}$. This metric was sensitive to the resulting F from a method, and we calculated it using the static and dynamic abundance methods described above.

The final metric we calculated is a relative measure of the interannual variation in catch, or AAV. This metric was proposed by Punt (2003), and is calculated with

$$AAV = \frac{\sum_{t>1} \left| C_{target}(t) - C_{target}(t-1) \right|}{\sum_t C(t)} \qquad (7)$$

Large values of AAV indicate a method resulted in larger interannual changes in the C_{target}. We used these metrics to help identify alternative methods for setting catch advice that would have limited overfishing ($P_{OF} <= 0.5$) without being too conservative (avoid F-ratios <<1), while allowing for stable catches (small AAV).

For the data-limited approaches, performance was evaluated in a slightly different manner. For each approach we calculated the ratio of the target catch to the estimated OFL (calculated using the static approach), and refer to this metric as the *C*-ratio (*C*-ratio (t) =C_{target}(t)/OFL(t)). As with the *F*-ratio, we are looking for methods that result in a *C*-ratio close 1.0 across years for a stock.

Results

The effects that each alternative method had on the performance metrics for a stock depended on whether or not we assumed abundance in each year changed in response to changes in the estimated *F* (the dynamic or static approaches). We present results from both the dynamic approach with fixed recruitments and the static approach, omitting discussion of the dynamic approach with variable recruitment. Estimates of the *F*-ratio (F / F_{MSY}) grouped by each method are shown in Figures 8 -12 for each assessment period for each stock with age-based GARM 1 – 3 assessments (GB and GOM cod, GB yellowtail flounder, witch flounder, and SNE/MA winter flounder). Each of these Figures has a panel a) and b), corresponding to the results from the dynamic approach with fixed recruitment and the static approach, respectively. The run numbers correspond to those listed in Table 3, with the run numbered 1 for a given method representing the approach originally used for each stock. For example NAA 1 is the model run where abundance-at-age is not modified, and PR1 is the model run where projections were used in the calculation of target catches. The distribution of estimates of the *F*-ratio for a given run represents all other combinations of alternative methods (e.g., all combinations of the different control rules, gradual change methods, etc. for NAA 1). The key to interpreting these plots is to compare the distribution of alternative methods relative to the original method (e.g., are NAA runs 2-7 improvements over NAA run 1?), and whether or not patterns are consistent across assessments. Also, it is important to identify which runs for a given method are the most successful (distribution of *F*-ratio close to 1.0) for each assessment for all stocks.

Based on Figures 8 - 12 a number of generalizations can be made about the success or failure of alternative methods. First, modifying the method for forecasting the recruitments had little effect on estimates of the *F*-ratio. This result is not surprising for stocks where no decline in recent recruitment was predicted following an assessment (e.g., GOM cod, witch flounder, GB yellowtail flounder; Figures 2, 3, and 5), but is somewhat surprising for SNE/MA winter flounder (Figure 4). Using the modified recruitment for SNE/MA winter flounder did result in improved estimates of catch targets following GARM 2 and GARM 3, but the magnitude of the improvement was small relative to some of the other methods tested for this stock (Figure 12). The second generalization is that averaging or smoothing methods aimed at reducing the magnitude of interannual changes in C_{target} performed comparable or worse across assessments and stocks to the approach that did not use any smoothing.

Methods that resulted in large improvements to the catch advice across stocks were those that modified the initial abundance, and those that used fixed target catches (i.e., no projections). Using the Mohn's ρ estimated from each assessment (NAA run 2) to adjust the abundance typically resulted in small changes in the target catch, while fixed adjustments (NAA runs 3, 4, and 5) were more effective at getting *F* close F_{MSY}. Using estimates of abundance that were 3-5 years out of date (NAA runs 6, 7, and 8) sometimes improved the catch advice, but the pattern of the improvement was not consistent across stocks, nor across assessments for a given stock. In other words, in some cases data that were 3 years out of date (NAA run 6) provided the greatest improvement, while in other cases data that were 4 or 5 years out of date (NAA runs 7 and 8) outperformed the runs using information from 3 years ago (Figure 8 -12). Smaller improvements in catch advice generally occurred when using the threshold-based $P*$ control rule (Figure 8 -12). While these methods improved the catch advice relative to the original method, the improvements were not always enough (i.e., the distributions for the F-ratio did not overlap with 1.0).

The plots of the F-ratio are separated out by assessment, and the F-ratio estimates can vary considerably by assessment (Figures 8-12). For some stocks (e.g.) the F-ratio distribution was well above 1 for one assessment, and centered around or below 1.0 for another (e.g., SNE/MA winter flounder; Figures 12a and 12b). In addition to the F-ratio we calculated the proportion of years for the entire management period (2004-2012 for all except GB cod, where the period ended in 2011) in which $F > F_{MSY}$ (Figure 13-17). For GB yellowtail and witch flounder, most estimates of P_{OF} were 1.0, indicating overfishing in all years for most methods (Figures 15 and 16). For these stocks decreases in P_{OF} did occur for methods that do not use projections and do not use smoothing methods, although estimates were still largely above 0.5. For GB and GOM cod, abundance modifications, threshold-based control rules, not doing projections, and not suing smoothing methods resulted in the distribution of P_{OF} centered near or below the 0.5 level (Figures 13 and 14). For SNE/MA winter flounder, distribution for POF were generally centered between 0.5 and 1.0, although not doing projections and avoiding smoothing methods reduced the frequency of overfishing below 0.5 for more than half the runs explored for this stock (Figure 17).

For each method for each stock we calculated a relative measure of the interannual variability in C_{target} (AAV; equation 7) to identify methods that resulted in greater stability in catches. Not surprisingly, the methods that smoothed the catch series had less variability overall, as did methods that fixed C_{target} over the interval (Figures 18 - 22). Alternative control rules and recruitment modifications did not impact AAV, while adjustments to the abundance had a small, albeit variable, impacts on AAV.

The boxplots of F-ratios across methods show how each alternative method performed relative to the other methods, but it does not identify which combinations of approaches may be the most effective. To identify the most effective combinations of approaches we used regression trees. In regression trees the data are split along coordinate axes of the explanatory variables (in this case, the different runs) to identify areas of greatest distinction in the response variable (F-ratio; Crawley 2007). In other words, which combinations of model runs resulted in large differences in the F-ratios for a stock? We used regression trees for each stock with estimates combined across assessments (Figures 23 - 27). Across stocks, the trees indicate different pathways to getting F-ratios closer to 1.0. Detailing each potential pathway for each stock is impractical, but some generalizations can be made, and they are in agreement with the patterns shown in Figures 8-12. F-ratios were generally higher when smoothing methods were used (AVG runs 2 and 3), and often when projections were done (PR run 1). Improved F-ratios often occurred for fixed abundance modifications (NAA runs 3-5), but such an adjustment was often not enough, supporting the conclusions of Brooks and Legault (2015). Combining abundance modifications with no projections, or with a threshold-based control rule (CR runs 3-6) was often more effective at lowering the *F*-ratio. Combining all three approaches was too conservative for some stocks (*F*-ratio << 1.0), and was only effective for stocks with the highest overestimation of historical catch targets (GB yellowtail and witch flounder; Figures 25 and 26, respectively).

Based on the regression trees we selected combinations of approaches for further exploration. In Table 6 we compare the mean value of the *F*-ratio by stock without projections or smoothing methods for the abundance modification runs 3, 4, and 5 (fixed adjustments using $\phi = 0.38$, 0.66 and 1.0, respectively, in equation 1), and control rule runs 1 (the original approach), and 3 (a threshold-based P* approach; see Table 3 for more details). Combining fixed abundance modifications with a threshold-based control rule without using projections prevented frequent overfishing ($P_{OF} < 0.5$) for each stock (when POF was calculated using the dynamic approach with fixed recruitment). However, this approach was too conservative for some stocks, particularly GB cod and SNE/MA winter flounder, where the adjusted biomass triggered the closing of the fishery and target catches were set to 0. When using the abundance modification without projections and using the original control rule, frequent overfishing did not occur for witch flounder for an abundance adjustment $\phi = 1.0$, for GOM cod for abundance adjustments of 0.66 and 1.0 ($P_{OF} = 0.56$ when $\phi = 0.38$), and for GB cod and SNE/MA winter flounder for all adjustment factors (Table 6). For this combination of approaches though using largest adjustment factor ($\phi = 1.0$) was very conservative for GB cod and SNE/MA winter flounder, resulting in a mean *F*-ratio of 0.66 and 0.45, respectively.

Performance of the alternative data-limited approaches listed in Table 7 varied by stock and assessment. We tested the index-based data-limited methods using both the spring and fall NEFSC survey indices of abundance. Results were generally comparable for the different indices for a given stock and assessment, so we focused on the results using the fall index of abundance. For pollock and witch flounder, most approaches were overly conservative (catch well below the level that would have achieved F_{MSY}). For the remaining four stocks (GOM and GB cod, GB yellowtail flounder, and SNE/MA winter flounder), the performance varied widely within both the catch-curve and index-based method categories. Some methods were consistent improvements to the original target catches, but they still would have resulted in overfishing (*C*-ratio > 1) in nearly all cases. Two methods in particular consistently performed well (lower values of η) for these four stocks. One method (Fratio_CC), relies on catch curve analysis to approximate the OFL by estimating total mortality, which is then used to estimate recent biomass with assumed distributions for natural mortality rate (*M*) and the ratio of F_{MSY} / M (Carruthers 2014). The other relatively effective approach (Itarget4) was a conservative index-based method proposed by Geromont and Butterworth (2014) that makes incremental adjustments to the average of recent catches based on changes in the survey index relative to a specified target index level. Choosing a particular data-limited approach requires careful consideration of the different data sources and assumptions, as catch curve and index-based methods have a range of strengths and weaknesses that must be considered. Catch curve methods are sensitive to trends in recruitment and also the vulnerability of older fish to the fishery, but are insensitive to changes in a survey index. In contrast, index-based approaches adjust an average catch based on index trends, and are therefore sensitive to the choice of the average catch level, as well as to whether or not the changes in the index are reflective of changes in stock abundance. Because some of the index and catch curve methods we explored performed relatively well (Table 7), we will explore these methods further for additional groundfish stocks.

Conclusions

We evaluated a number of alternative methods for setting catch advice for a sample of New England groundfish stocks to identify possible methods, or combinations of methods, that would have reduced the frequency of or prevented overfishing since 2004. For stocks with age-based assessments (GB and GOM cod, GB yellowtail founder, witch flounder, and SNE/MA winter flounder), historical target catches were overestimated in many years. We identified a number of approaches that were substantial improvements, often greatly reducing the amount of overestimation in target catches. The alternative approaches we identified as the most successful were those that 1) used a fixed catch target in the years between assessments, 2) adjusted the most recent estimate of population size downward to account for the pattern of frequent overestimation, and 3) used a threshold-based control rule. Adjustments to the terminal abundance estimate have been made for some stocks in recent years using the Mohn's ρ estimated from the assessment, but our results suggests that if such modifications had been made in the past for all stocks, they would have been insufficient in many cases. A better alternative would be to use a fixed adjustment across stocks, as it outperformed the assessment-specific adjustments. We evaluated fixed adjustments (ϕ) of 0.37, 0.66, and 1.0, and found that all levels when used without projections were effective at reducing overfishing in many cases, although the largest adjustment factor was very conservative for some stocks in some years. We also found that threshold-based control rules provided improvements to the target catches in many instances, but when combined with abundance adjustments they were overly conservative, often triggering the closure of the fishery. Although averaging methods were not used in the setting of previous catch targets, they have been suggested as a viable alternative to reduce interannual variability in catches. Our work shows that while these smoothing methods reduce variability in catches, they preform worse in nearly all cases (greater overestimation of target catches). Avoiding projections is a much better alternative, as it both reduces the variability in target catches and results in less overestimation of target catches, overall. We will apply the successful methods identified here to additional groundfish stocks not included in the current analysis to determine if the success of these approaches can be generalized across most New England groundfish stocks.

We also evaluated performance of data-limited alternatives for setting catch advice, and found it varied widely across methods for each stock. For pollock and witch flounder, the data-limited methods were generally too conservative, setting catch targets well below the level that would have achieved F_{MSY}. For the remaining stocks, many of the methods were improvements over the original catch targets, although the reductions in catches were not sufficient to prevent overfishing. Because some methods we evaluated were relatively effective for many of the stocks in this analysis, further exploration of these approaches on additional groundfish stocks is warranted.

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Table 1. Stocks used in this analysis and the most recent assessments that passed review that were the sources of best available (updated) information for each stock.

Full Stock Name	Abbreviated Name	Most recent Assessment
Georges Bank Atlantic Cod	GB Cod	NEFSC 2013
Gulf of Maine Atlantic Cod	GOM Cod	NEFSC 2015
Gerges Bank Yellowtail Flounder	GB Yellowtail	Legault et al. 2013
Southern New England / Mid-Atlantic Winter Flounder	SNE / MA Winter	NEFSC 2015
Witch Flounder	Witch	NEFSC 2015
Pollock	Pollock	NEFSC 2015

Table 2. Equations governing the age-based projections. Recruitment is either based on a Beverton-Holt stock-recruit relationship, or drawn from an empirical cumulative distribution function (ECDF).

Eqn.		
1	$N(a,t) = \begin{cases} R(t) & a = a_R \\ N(a-1,t-1)e^{-Z(a-1,t-1)} & a_R < a < a_{max} \\ N(a-1,t-1)e^{-Z(a-1,t-1)} + & a = a_{max} \\ N(a,t-1)e^{-Z(a,t-1)} & \end{cases}$	Numerical abundance at age
2	$R(t) = \frac{\alpha S(t-a_R)}{\beta S(t-a_R)} e^{\theta_R - 0.5\sigma_R^2}$ $R(t) = ECDF_{all}$ $R(t) = \begin{cases} ECDF_{low} & S < S_{thresh} \\ ECDF_{high} & S \geq S_{thresh} \end{cases}$	Recruitment
3	$S(t) = \sum_a m(a) w_S(a) N(a,t)\, e^{-\phi\, Z(a,t)}$	Total spawning biomass
4	$Z(a,t) = M(a,t) + s(a,t)F(t)$	Total mortality
5	$C(a,t) = \frac{s(a,t)F(t)}{Z(a,t)} w_C(a) N(a,t)\left(1 - e^{-Z(a,t)}\right)$ $C(t) = \sum_a C(a,t)$	Catch (at age and total)

Table 3. Description of the alternative methods used to calculate target catches from age-based stock assessments. The abbreviations in parenthesis are used identify the different approaches in the Figures.

Modification	Run	Description
Initial Abundance-at-age (NAA)	1	Use the model-estimated terminal abundance estimates
	2	Adjust the terminal estimates with the ϕ = estimated Mohn's ρ
	3	Adjust the terminal estimate with a fixed $\phi = 0.37$
	4	Adjust the terminal estimate with a fixed $\phi = 0.66$
	5	Adjust the terminal estimate with a fixed $\phi = 1.00$
	6	Use the abundance estimates 3 years prior to the terminal year
	7	Use the abundance estimates 4 years prior to the terminal year
	8	Use the abundance estimates 5 years prior to the terminal year
Recruitment (R)	1	Use the original recruitment time series
	2	Use a shortened time series if a decline in recruitment is detected in recent years
Control Rules (CR)	1	Use the original target F in each year
	2	Use 75% FMSY in all years as the control rule
	3	Use the threshold P* control rules with a max P*=0.4; CV = 1.0; minimum $S / S_{MSY} = 0.1$
	4	Use the threshold P* control rules with a maximum P*=0.4; CV = 1.0; minimum $S / S_{MSY} = 0.2$
	5	Use the threshold P* control rules with a maximum P*=0.4; CV = 1.2; minimum $S / S_{MSY} = 0.1$
	6	Use the threshold P* control rules with a maximum P*=0.4; CV = 1.2; minimum $S / S_{MSY} = 0.2$
Projections (PR)	1	Use projections to estimate target catch each year
	2	Set a fixed target catch using the projection-estimated abundance in the first year of the management period (i.e., project from terminal year (TY) + 1 to the first year of the management period)
	3	Set a fixed target catch using the terminal year (TY) + 1 estimate of abundance (no projections)
Averaging or Smoothing (AVG)	1	Use the updated catch estimates
	2	Use the updated estimates, but only allow for annual changes of +/- 20%
	3	Use an evenly-weighted average of the old catch target and the updated one

Table 4. Estimated Mohn's ρ (a measure of the mean retrospective error in terminal assessment estimates) for biomass and the fishing mortality rate for each stock from each assessment.

			Mohn's *r*	
Stock	Variable	GARM 1	GARM 2	GARM 3
GB Cod	Biomass	0.42	0.28	0.13
	Fishing mortality	-0.51	0.25	-0.14
GOM Cod	Biomass	0.02	-0.04	0.19
	Fishing mortality	-0.11	-0.07	0.16
Witch Flounder	Biomass	0.58	0.81	0.43
	Fishing mortality	0.45	0.16	0.29
GB Yellowtail Flounder	Biomass	0.73	2.00	0.44
	Fishing mortality	0.16	1.10	0.08
SNE/MA Winter Flounder	Biomass	0.69	-0.10	-0.03
	Fishing mortality	-0.23	0.40	-0.02

Table 5. A list of the data-limited methods used in this analysis to predict catch targets for all stocks. Each method is available in the DLMtool R package developed by Carruthers (2014).

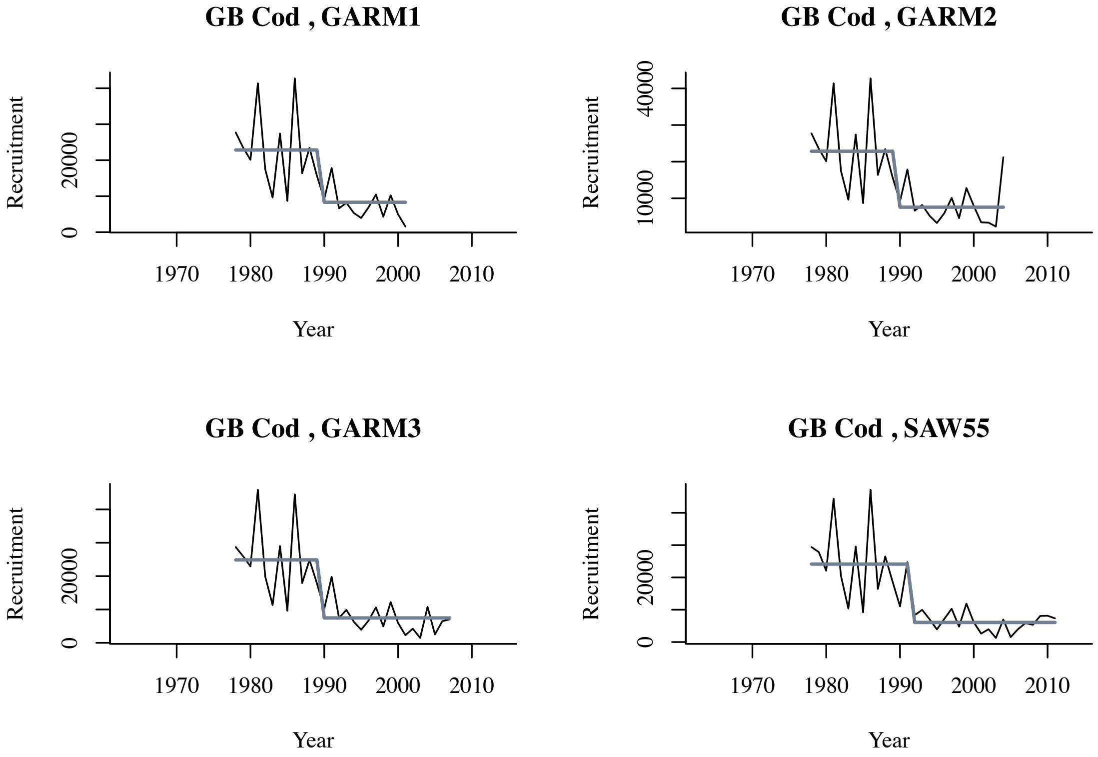
Control rule abbreviation	Description	Source
BK_CC	Beddington and Kirwood life history method combined with catch curve analysis. Calculates the OFL using a catch curve estimate of current F and an approximation of FMSY based on length at first capture.	Beddington and Kirkwood 2005
Fdem_CC	Demographic MSY method using catch-curve analysis to estimate recent Z	McCallister et al. 2001; Carruthers 2014
Fratio_CC	Calculates the OFL based on a fixed F_{MSY} / M ratio and a catch curve estimate of current stock size	Gulland 1971; Martell and Froese 2012; Carruthers 2014
GB_slope	A harvest control rule similar to SBT1 that modifies a time-series of catch recommendations aiming for stable catch rates, keeping annual changes within + / - 20%	Geromont and Butterworth (2014)
Islope1	The least biologically precautionary of two constant index / CPUE methods proposed by Geromont and Butterworth 2014	Geromont and Butterworth 2014
Islope4	The most biologically precautionary of two constant index / CPUE methods proposed by Geromont and Butterworth 2014	Geromont and Butterworth 2014
Itarget1	The least biologically precautionary of two index/CPUE target management procedures proposed by Geromont and Butterworth 2014.	Geromont and Butterworth 2014
Itarget4	The most biologically precautionary of two index/CPUE target management procedures proposed by Geromont and Butterworth 2014.	Geromont and Butterworth 2014
SBT1	A harvest control rule that makes incremental adjustments to quota recommendations based on the apparent trend in surplus production.	http://www.ccsbt.org/site/recent_assessment.php
DCAC_40	A method for adjusting average catches based on an assumed fixed change in biomass over the time period.	Carruthers 2014

Table 6. The mean *F*-ratio (F / F_{MSY}) across a subset of alternative methods. Results are shown for runs where no projections, smoothing, or recruitment modification methods were used (PR run 3, AVG run 1, R run 1, respectively) using different adjustment factors ($\phi = 0, 0.37, 0.68$, and 1.0), control rules (CR runs 1 and 3), and when *F* was calculated either using static abundance-at-age estimates from the most recent assessment, or dynamic abundance-at-age estimates (with fixed recruitment) that change in response to different catch targets. See Table 3 for details on the specific model runs. Values in bold represent the method where the frequency of overfishing (proportion of years when $F > F_{\mathrm{MSY}}$) was less than 0.5.

	Adj. Factor (ϕ)	0.00	0.38	0.38	0.66	0.66	1.00	1.00	0.38	0.38	0.66	0.66	1.00	1.00
	Abundance Static (S) or Dynamic (D)?	S	S	D	S	D	S	D	S	D	S	D	S	D
Stock	Control rule run	1	1	1	1	1	1	1	3	3	3	3	3	3
GOM Cod	GARM 1	4.22	2.36	2.08	1.89	1.64	1.53	1.28	0.39	0.31	0.28	0.22	0.19	0.17
	GARM 2	5.35	1.74	1.06	1.39	0.78	1.15	0.59	0.37	0.15	0.26	0.11	0.19	0.07
	GARM 3	21.86	4.69	0.99	3.53	0.72	2.74	0.56	1.56	0.29	1.08	0.21	0.76	0.14
	Mean	10.48	2.93	1.38	2.27	1.05	1.80	0.81	0.77	0.25	0.54	0.18	0.38	0.13
	P_{OF}	1.00	1.00	0.56	1.00	**0.33**	0.89	**0.22**	**0.33**	**0.00**	**0.11**	**0.00**	**0.11**	**0.00**
GB Cod	GARM 1	2.19	2.08	1.89	1.64	1.47	1.33	1.19	0.00	0.00	0.00	0.00	0.00	0.00
	GARM 2	4.44	1.30	0.85	1.06	0.63	0.87	0.48	0.00	0.00	0.00	0.00	0.00	0.00
	GARM 3	1.81	0.98	0.54	0.80	0.41	0.67	0.30	0.07	0.04	0.04	0.00	0.00	0.00
	Mean	2.82	1.45	1.09	1.16	0.84	0.96	0.66	0.02	0.01	0.01	0.00	0.00	0.00
	P_{OF}	1.00	0.75	**0.25**	0.75	**0.25**	**0.25**	**0.25**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Witch Flounder	GARM 1	20.87	2.65	2.46	2.06	1.85	1.67	1.44	1.46	1.26	1.00	0.83	0.70	0.57
	GARM 2	6.35	3.59	2.57	2.75	1.43	2.16	0.95	3.72	1.63	2.35	0.84	1.58	0.53
	GARM 3	3.10	0.99	0.81	0.81	0.44	0.66	0.29	0.32	0.17	0.24	0.10	0.18	0.06
	Mean	10.11	2.41	1.95	1.87	1.24	1.49	0.89	1.83	1.02	1.20	0.59	0.82	0.39
	P_{OF}	1.00	0.78	0.67	0.56	0.56	0.56	**0.33**	0.56	0.56	**0.44**	**0.11**	**0.33**	**0.00**
GB Yellowtail	GARM 1	34.48	21.83	21.83	20.14	20.14	11.12	5.59	2.90	1.84	1.83	1.17	1.22	0.79
	GARM 2	34.48	7.59	34.48	5.26	34.48	3.91	6.29	1.38	0.49	0.95	0.28	0.67	0.17
	GARM 3	25.53	2.49	31.77	1.93	29.46	1.53	1.99	0.91	0.36	0.63	0.24	0.44	0.16
	Mean	31.50	10.64	29.36	9.11	28.03	5.52	4.62	1.73	0.90	1.14	0.56	0.78	0.38
	P_{OF}	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.56	**0.22**	**0.44**	**0.22**	**0.11**	**0.00**
SNE/MA Winter	GARM 1	2.96	1.56	1.61	1.24	1.26	1.00	0.98	0.22	0.20	0.15	0.13	0.07	0.07
	GARM 2	2.11	0.64	0.62	0.52	0.46	0.43	0.36	0.00	0.00	0.00	0.00	0.00	0.00
	GARM 3	0.05	0.03	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mean	1.71	0.74	0.75	0.59	0.57	0.48	0.45	0.07	0.07	0.05	0.04	0.02	0.02
	P_{OF}	0.56	**0.22**	**0.22**	**0.22**	**0.22**	**0.11**	**0.11**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Table 7. The ratio of the target catches from each data-limited method (see Table 5 for descriptions of each method) to the catch at F_{MSY} (the OFL) for each stock, where the OFL was calculated using the fixed abundance-at-age estimates from the most recent assessment. For each assessment, the fall NEFSC index of abundance and the estimated catch at age in the fishery were used through the terminal year (2001, 2004, and 2007 for GARM 1, 2, and 3 respectively). Base is the original catch target ratio for each stock.

Stock	Assessment	Base	BK_CC	Fratio_CC	Fdem_CC	SBT1	GB_slope	Itarget1	Itarget4	Islope1	Islope4	DCAC_40
GB Cod	GARM 1	1.99	4.16	2.18	10.45	7.37	6.41	3.14	2.19	4.77	3.69	11.76
	GARM 2	3.69	1.42	0.77	3.61	2.62	3.24	3.94	2.19	5.53	3.67	10.69
	GARM 3	1.55	1.04	0.57	2.58	1.83	1.49	0.92	0.65	1.23	1.02	6.35
	Mean	2.41	2.21	**1.17**	5.55	3.94	3.71	2.67	1.68	3.84	2.79	9.60
GOM Cod	GARM 1	3.04	1.52	1.61	1.44	4.40	5.44	2.45	1.33	3.83	2.37	4.18
	GARM 2	4.22	1.22	1.22	1.15	3.21	3.49	3.84	1.88	3.76	2.23	4.12
	GARM 3	6.95	1.67	1.80	1.62	4.38	3.56	1.51	1.06	2.51	2.23	5.74
	Mean	4.74	1.47	1.54	**1.40**	3.99	4.16	2.60	1.43	3.37	2.28	4.68
Witch	GARM 1	5.85	0.22	0.10	0.44	0.27	0.33	0.11	0.06	0.11	0.08	0.31
	GARM 2	3.79	0.45	0.20	0.88	0.47	0.41	0.36	0.20	0.35	0.26	0.57
	GARM 3	2.67	0.08	0.03	0.15	0.10	0.09	0.18	0.13	0.31	0.24	0.74
	Mean	4.10	0.25	0.11	0.49	0.28	0.28	0.22	0.13	0.26	0.19	**0.54**
SNEMA Winter	GARM 1	2.06	3.39	1.79	4.37	3.26	3.85	2.56	1.32	2.46	1.72	3.87
	GARM 2	1.83	2.17	1.14	2.71	1.15	1.41	1.44	0.87	2.12	1.43	3.41
	GARM 3	0.05	1.64	0.81	2.06	1.08	0.88	0.69	0.44	0.41	0.38	3.13
	Mean	1.31	2.40	1.25	3.05	1.83	2.05	1.56	**0.88**	1.66	1.18	3.47
GB Yellowtail	GARM 1	10.00	5.33	1.43	6.68	6.21	7.59	5.39	2.47	5.93	3.57	2.88
	GARM 2	8.66	16.40	4.58	20.82	13.31	10.72	10.97	5.91	7.15	6.44	7.11
	GARM 3	7.38	3.05	0.87	3.98	3.43	4.19	4.64	3.13	9.32	6.04	7.42
	Mean	8.68	8.26	**2.29**	10.49	7.65	7.50	7.00	3.84	7.47	5.35	5.80
Pollock	GARM 1	0.25	0.08	0.06	0.06	0.13	0.14	0.12	0.06	0.10	0.07	0.24
	GARM 2	0.32	0.22	0.15	0.17	0.16	0.20	0.13	0.07	0.14	0.10	0.26
	GARM 3	0.16	0.70	0.53	0.57	0.37	0.30	0.22	0.12	0.08	0.12	0.39
	Mean	0.24	**0.33**	0.25	0.27	0.22	0.21	0.16	0.08	0.11	0.10	0.30



GB Cod , GARM1

GB Cod , GARM2

GB Cod , GARM3

GB Cod , SAW55

Figure 1. Estimated time series of recruitment from each stock assessment (black line) for Georges Bank (GB) cod (black line), along with the predicted mean recruitment (gray line) using the regime-shift detection algorithm of Rodionov (2004).

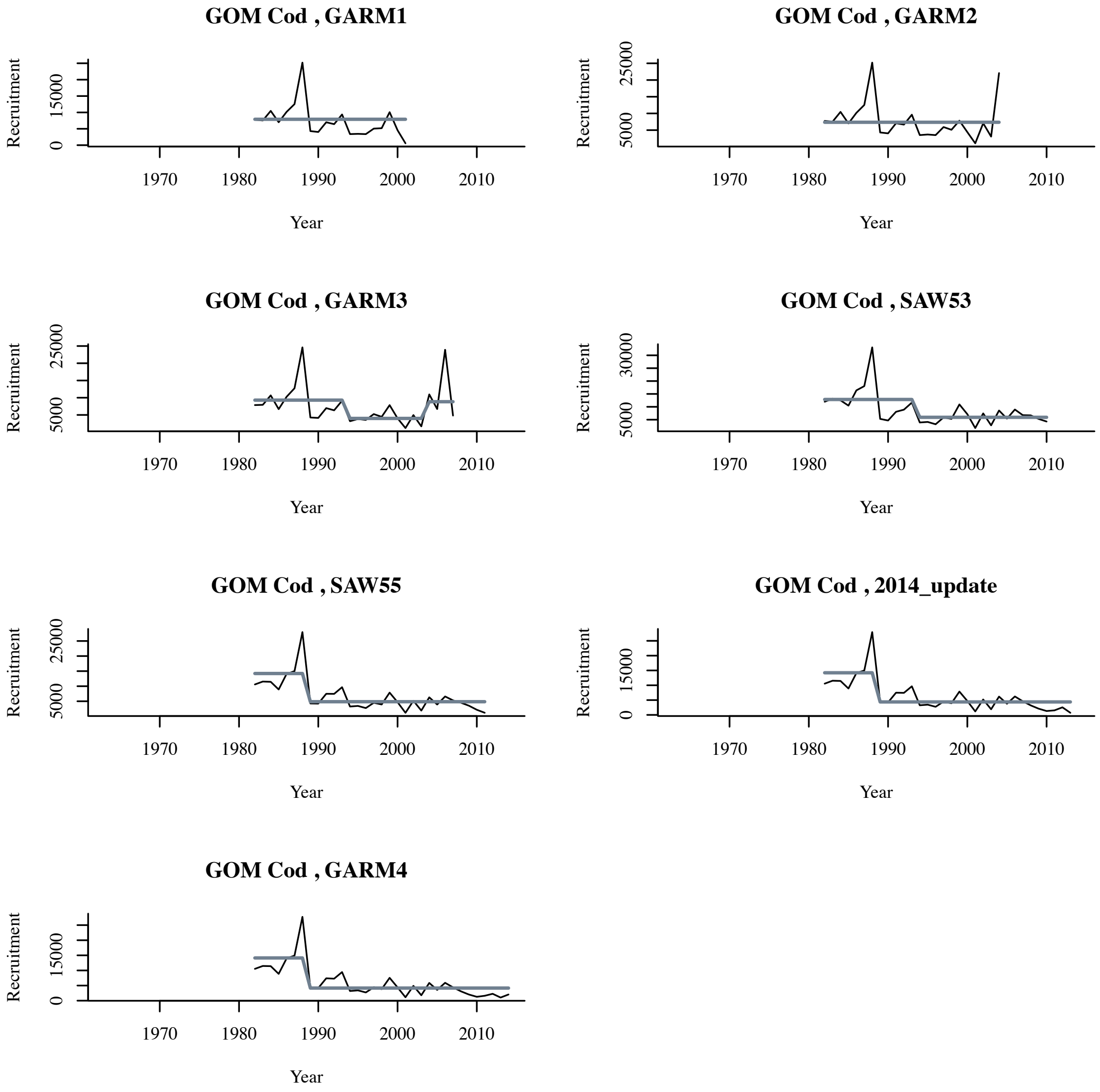


Figure 2. Estimated time series of recruitment from each stock assessment (black line) for Gulf of Maine (GOM) Cod cod (black line), along with the predicted mean recruitment (gray line) using the regime-shift detection algorithm of Rodionov (2004).

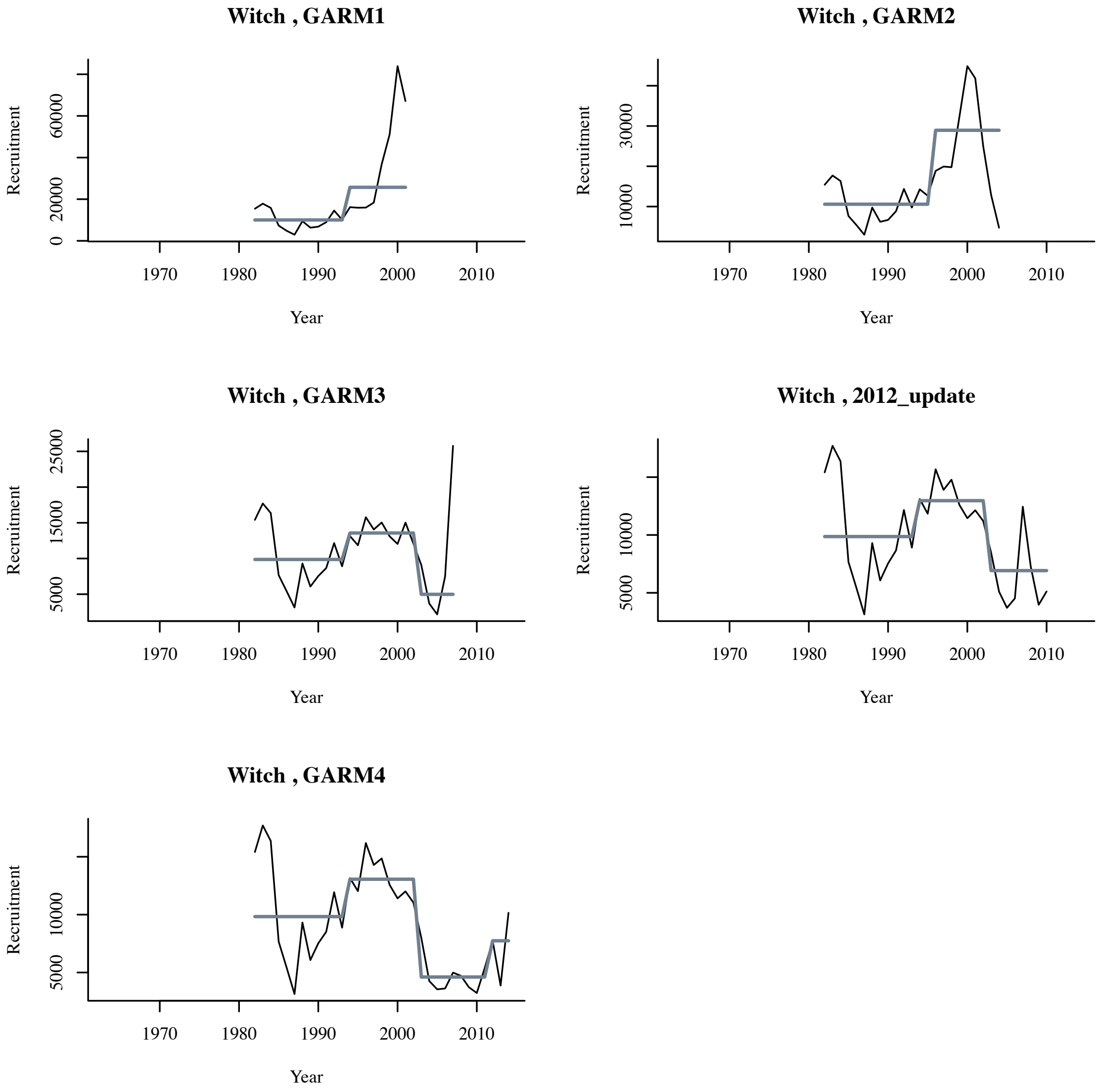


Figure 3. Estimated time series of recruitment from each stock assessment (black line) for witch flounder (black line), along with the predicted mean recruitment (gray line) using the regime-shift detection algorithm of Rodionov (2004).

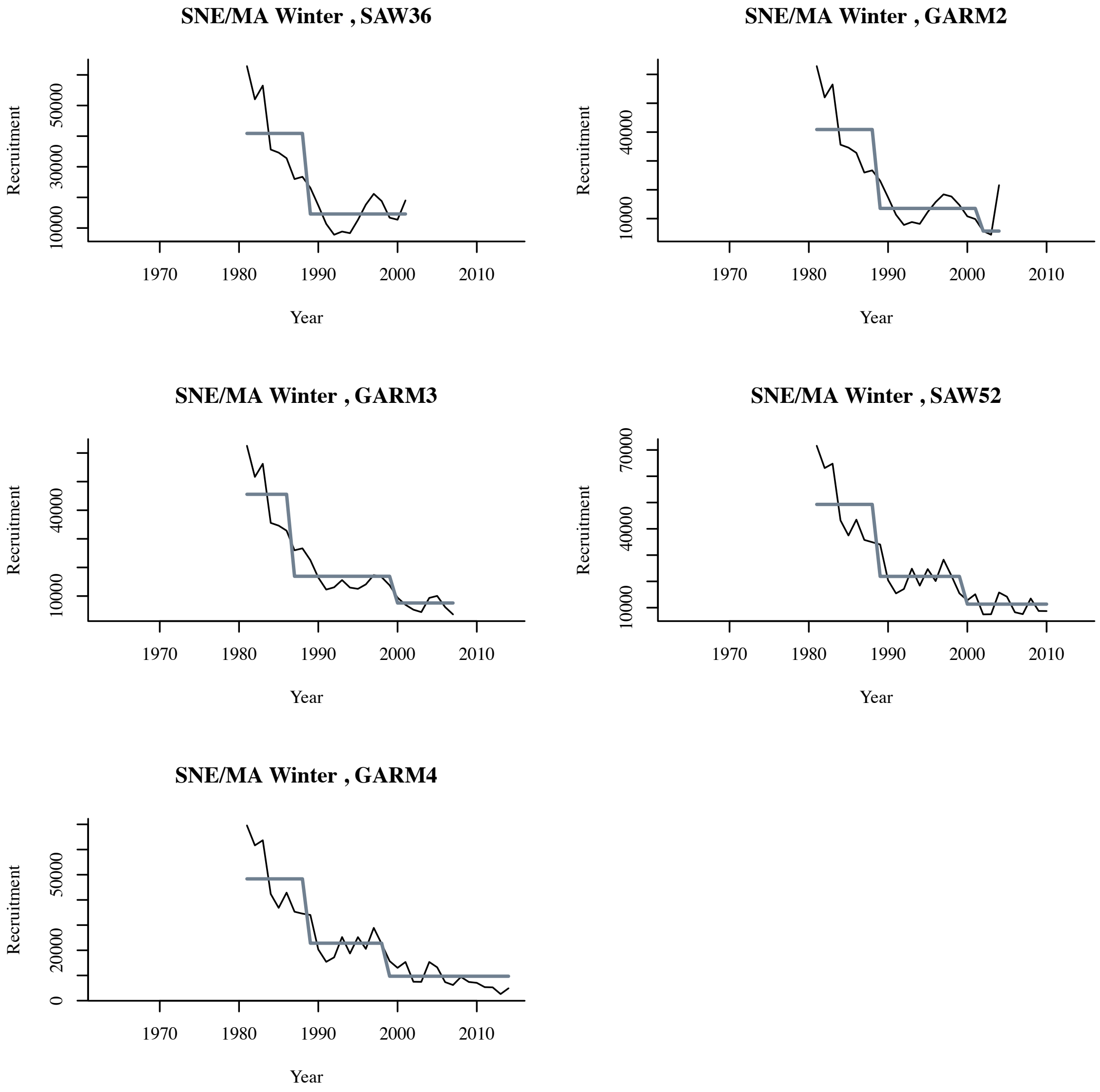


Figure 4. Estimated time series of recruitment from each stock assessment (black line) for Southern New England / Mid-Atlantic (SNE/MA) winter flounder (black line), along with the predicted mean recruitment (gray line) using the regime-shift detection algorithm of Rodionov (2004).

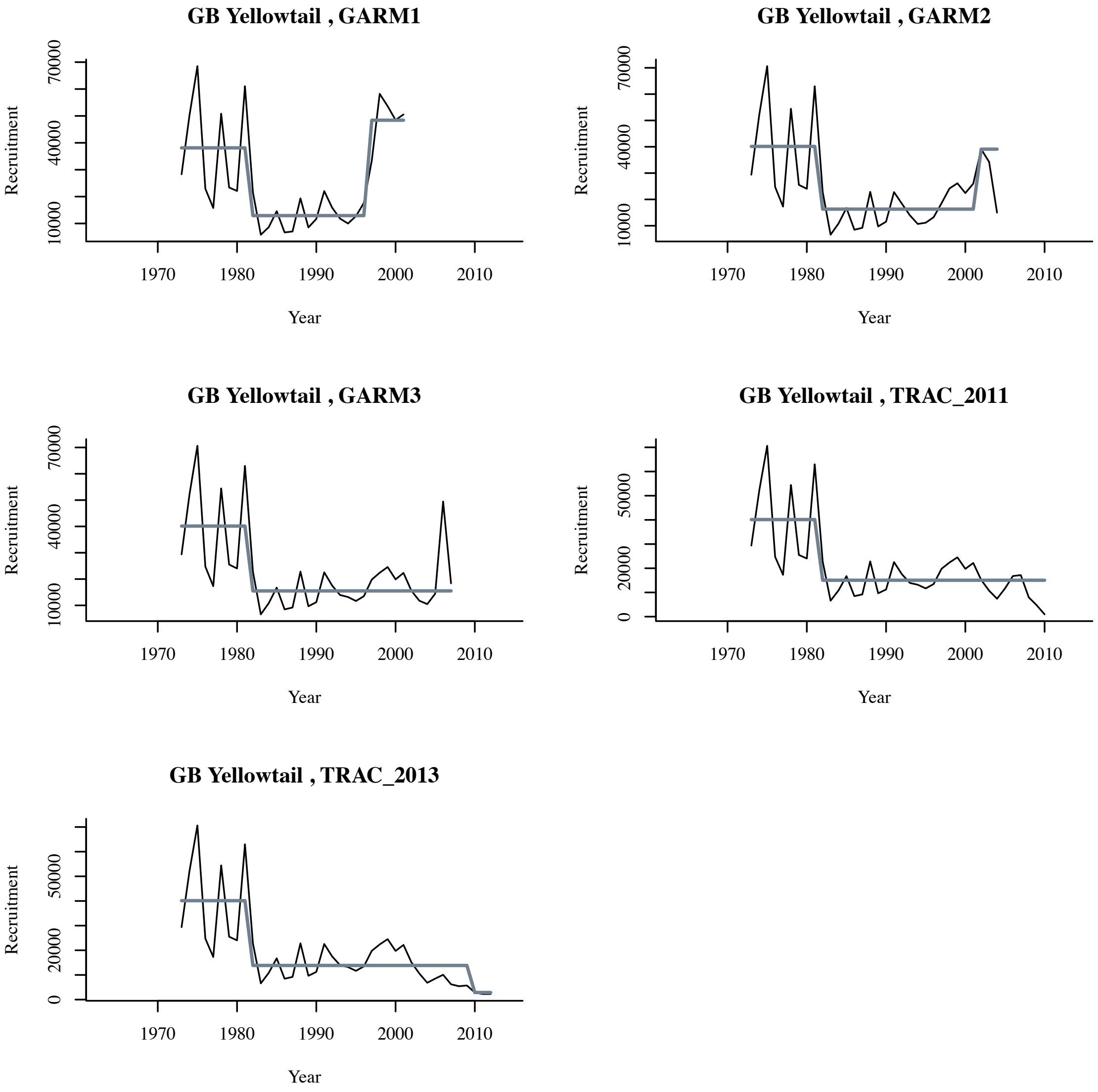


Figure 5. Estimated time series of recruitment from each stock assessment (black line) for Georges Bank (GB) yellowtail flounder (black line), along with the predicted mean recruitment (gray line) using the regime-shift detection algorithm of Rodionov (2004).

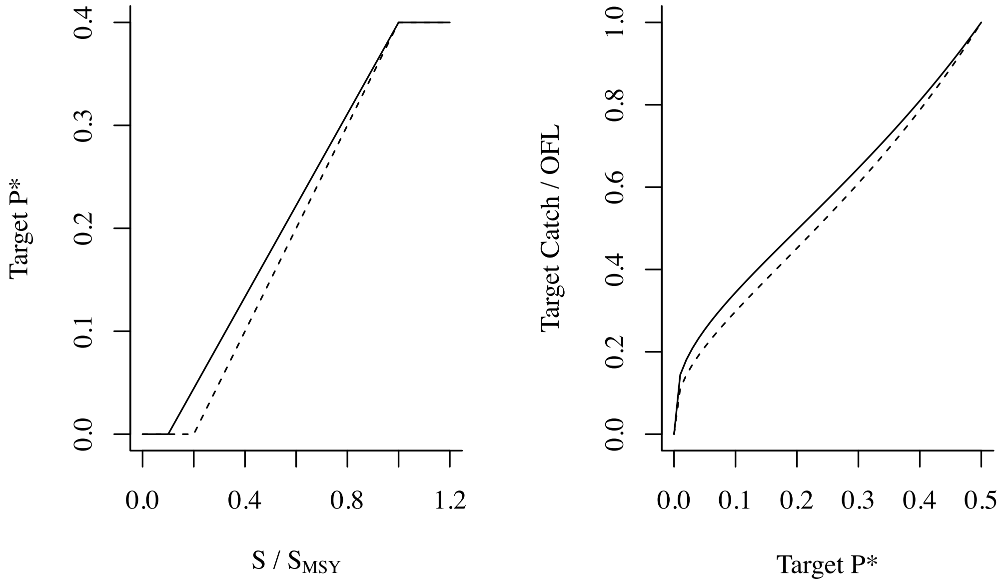


Figure 6. Left : Threshold-based *P** control rule, where the target P* declines linearly as the estimated spawning biomass falls below the S_{MSY} level, with P* = 0 for $S / S_{MSY} = 0.1$ (solid line) and 0.2 (dashed line) Right: Buffer size (target catch / OFL) as a function of the target *P** and the assumed C.V. of the distribution for the OFL (for the solid line the C.V.= 1.0, and for the dashed line the C.V. = 1.2).

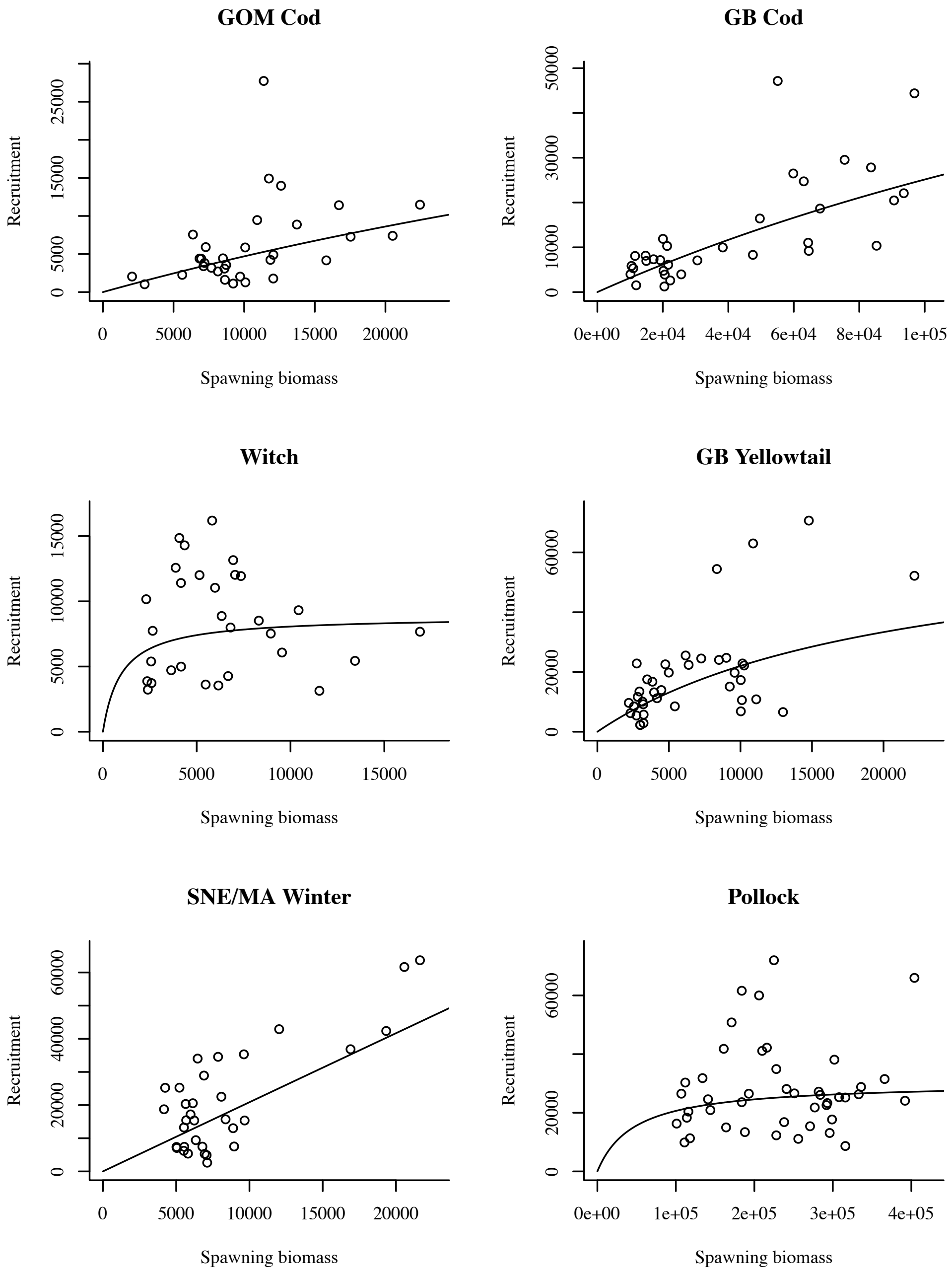


Figure 7. Estimated recruitment (in numbers x 10^3) as a function of spawning biomass (mt), and the best-fitting Beverton-Holt stock recruit relationship (solid black line). Recruitment estimates were lagged the appropriate number of years to account for the age at recruitment to the population (age 1 for all stocks except witch flounder, which recruits at age 3).

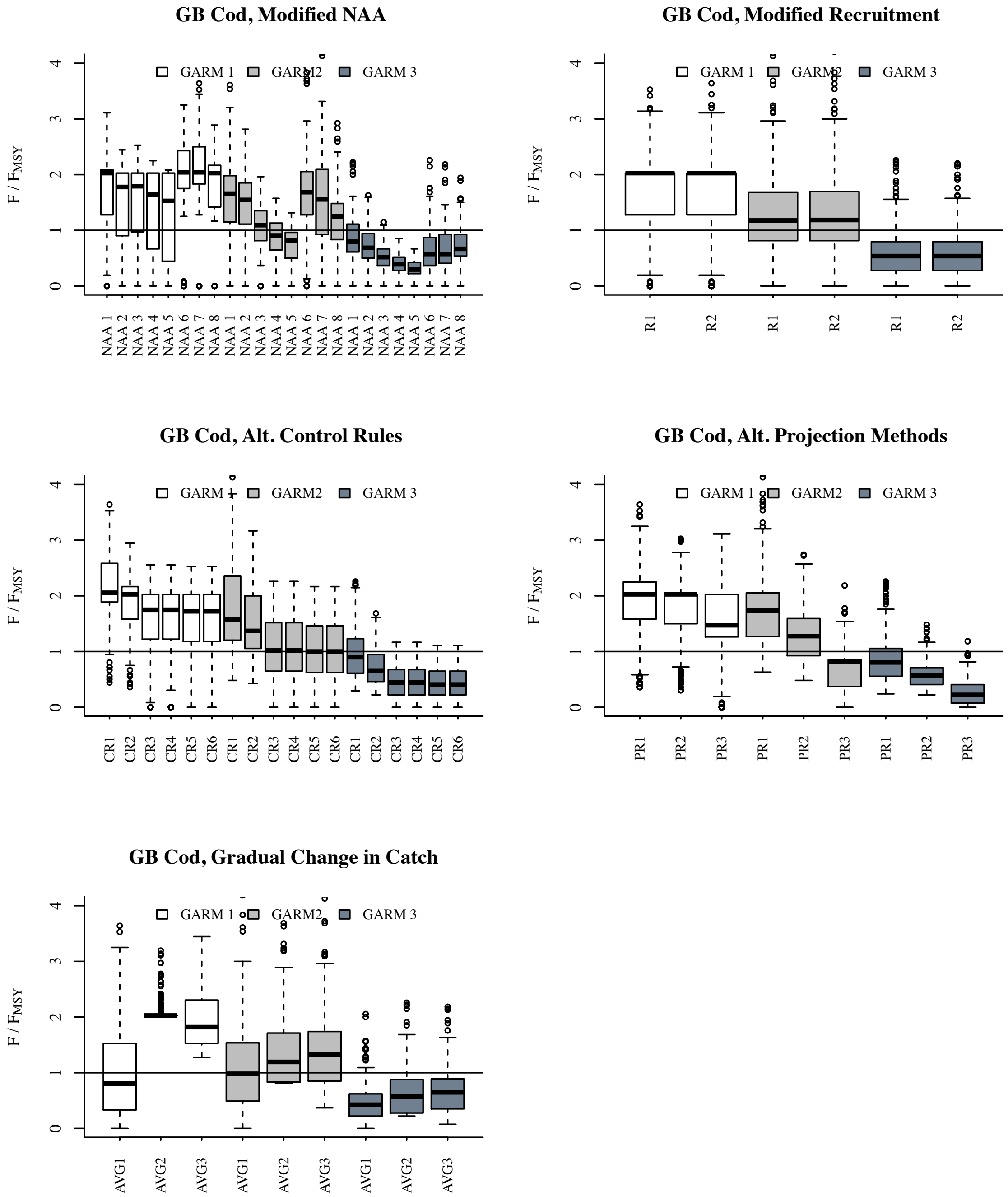


Figure 8a. Boxplot of the distribution of the *F*-ratio for a given modification in the way the target catch is calculated using information from the GARM 1 – 3 assessments for Georges Bank cod (NEFSC 2002; 2005; 2008). The *F*-ratio is the estimated F / F_{MSY} where *F* is calculated allowing for changes in biomass due to the altered catch targets (the dynamic approach with fixed recruitment). The solid line at 1 indicates catch targets that would have achieved F_{MSY}. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined.

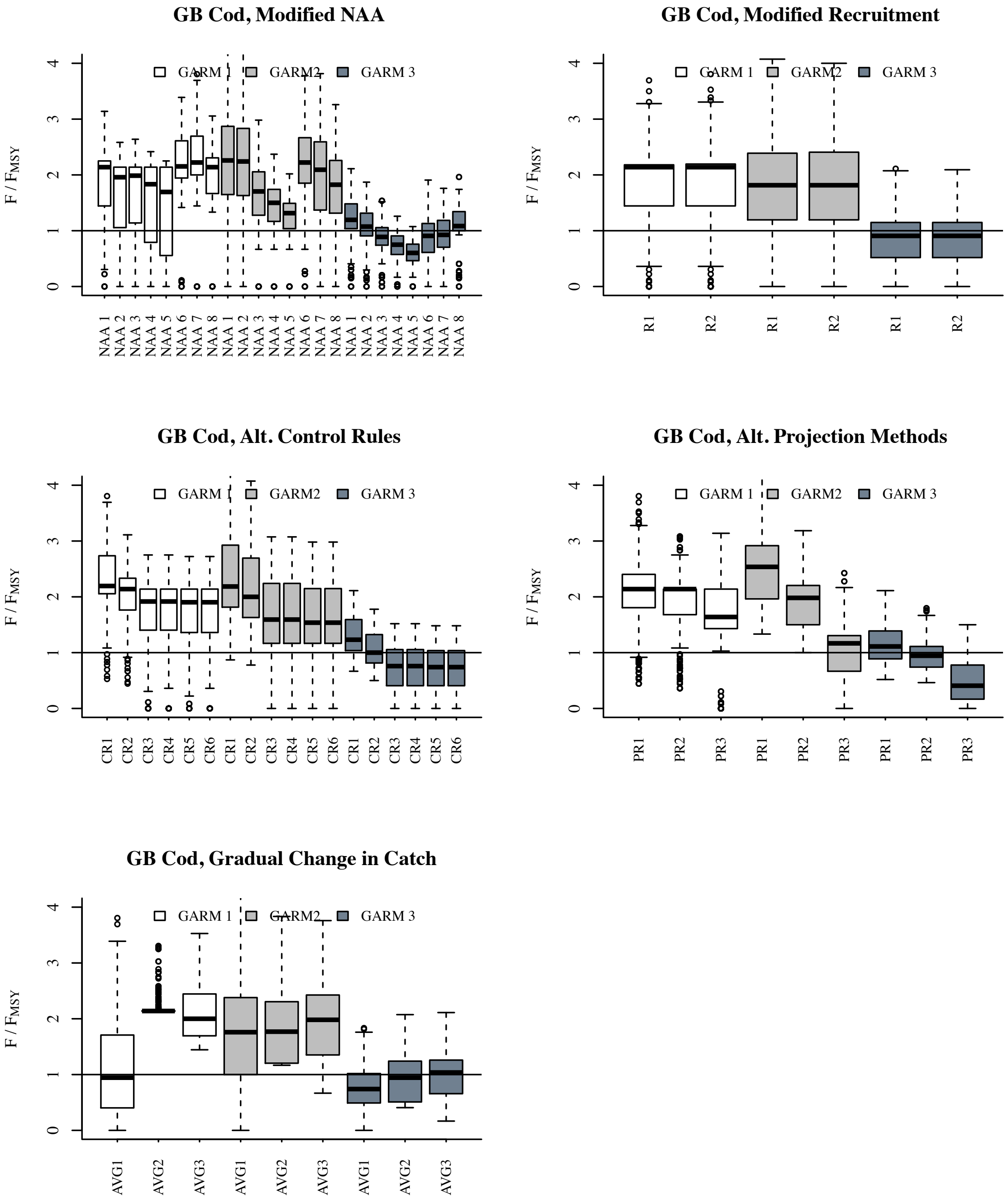


Figure 8b. Boxplot of the distribution of the *F*-ratio for a given modification in the way the target catch is calculated using information from the GARM 1 – 3 assessments for Georges Bank cod (NEFSC 2002; 2005; 2008). The *F*-ratio is the estimated F / F_{MSY} where *F* is calculated using the fixed abundance-at-age estimates from the most recent assessment (the static approach). The solid line at 1 indicates catch targets that would have achieved F_{MSY}. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined.

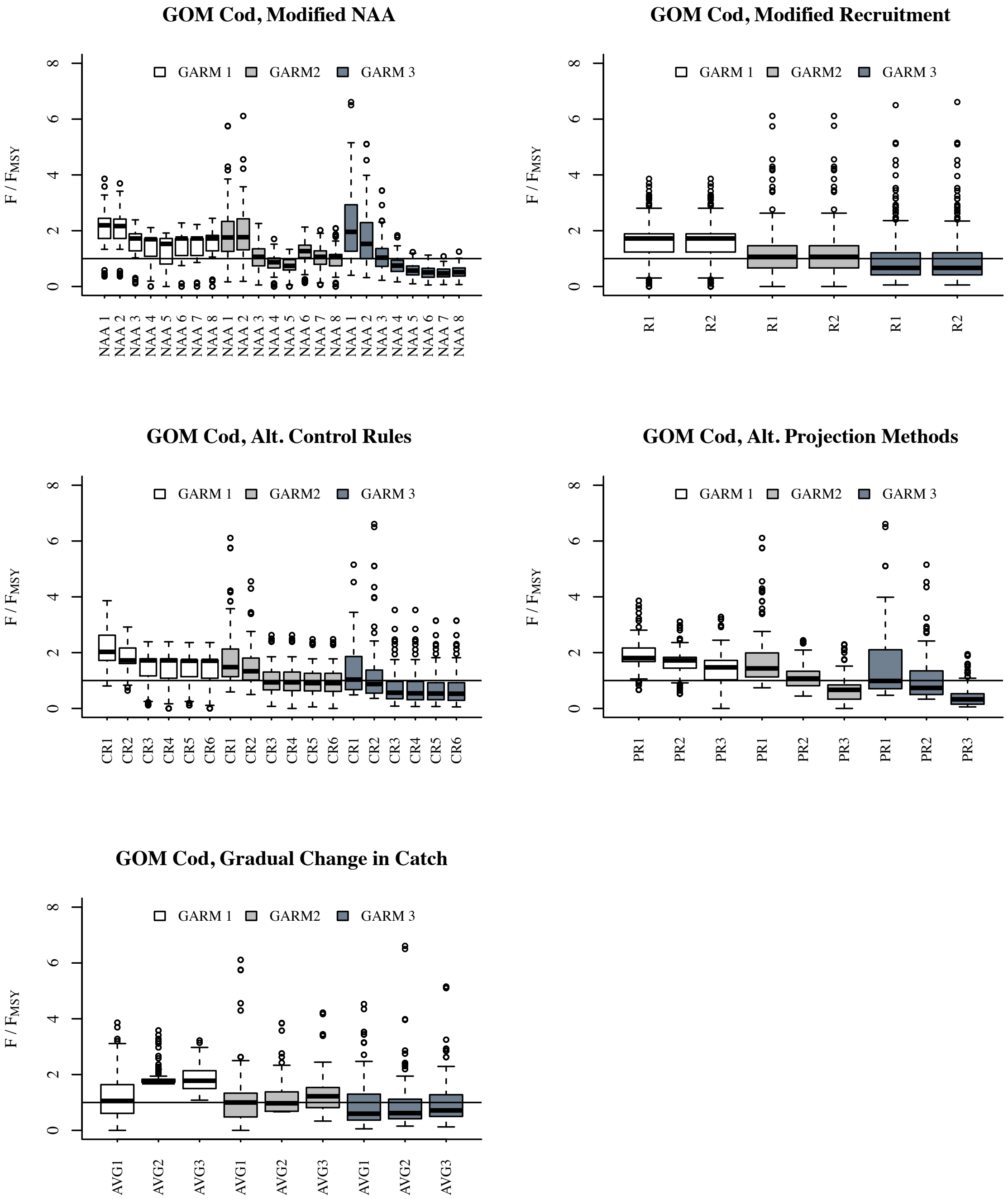


Figure 9a. Boxplot of the distribution of the F-ratio for a given modification in the way the target catch is calculated using information from the GARM 1 – 3 assessments for Gulf of Maine cod (NEFSC 2002; 2005; 2008). The F-ratio is the estimated F / F_{MSY} where F is calculated allowing for changes in biomass due to the altered catch targets (the dynamic approach with fixed recruitment). The solid line at 1 indicates catch targets that would have achieved F_{MSY}. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined.

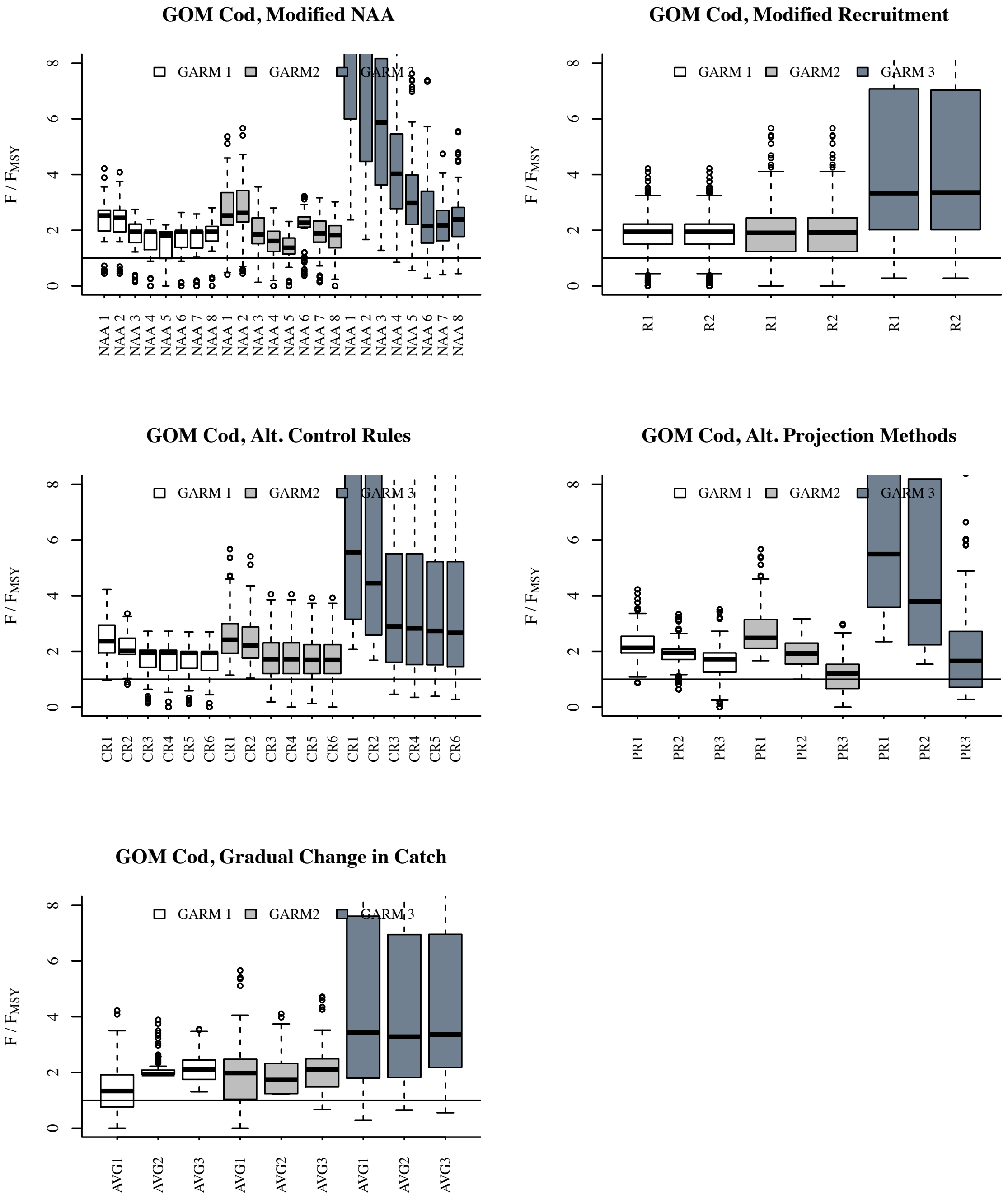


Figure 9b. Boxplot of the distribution of the *F*-ratio for a given modification in the way the target catch is calculated using information from the GARM 1 – 3 assessments for Gulf of Maine cod (NEFSC 2002; 2005; 2008). The *F*-ratio is the estimated F / F_{MSY} where *F* is calculated using the fixed abundance-at-age estimates from the most recent assessment (the static approach). The solid line at 1 indicates catch targets that would have achieved F_{MSY}. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined. The y-axis limits are fixed at 8 for comparison with Figure 9a.

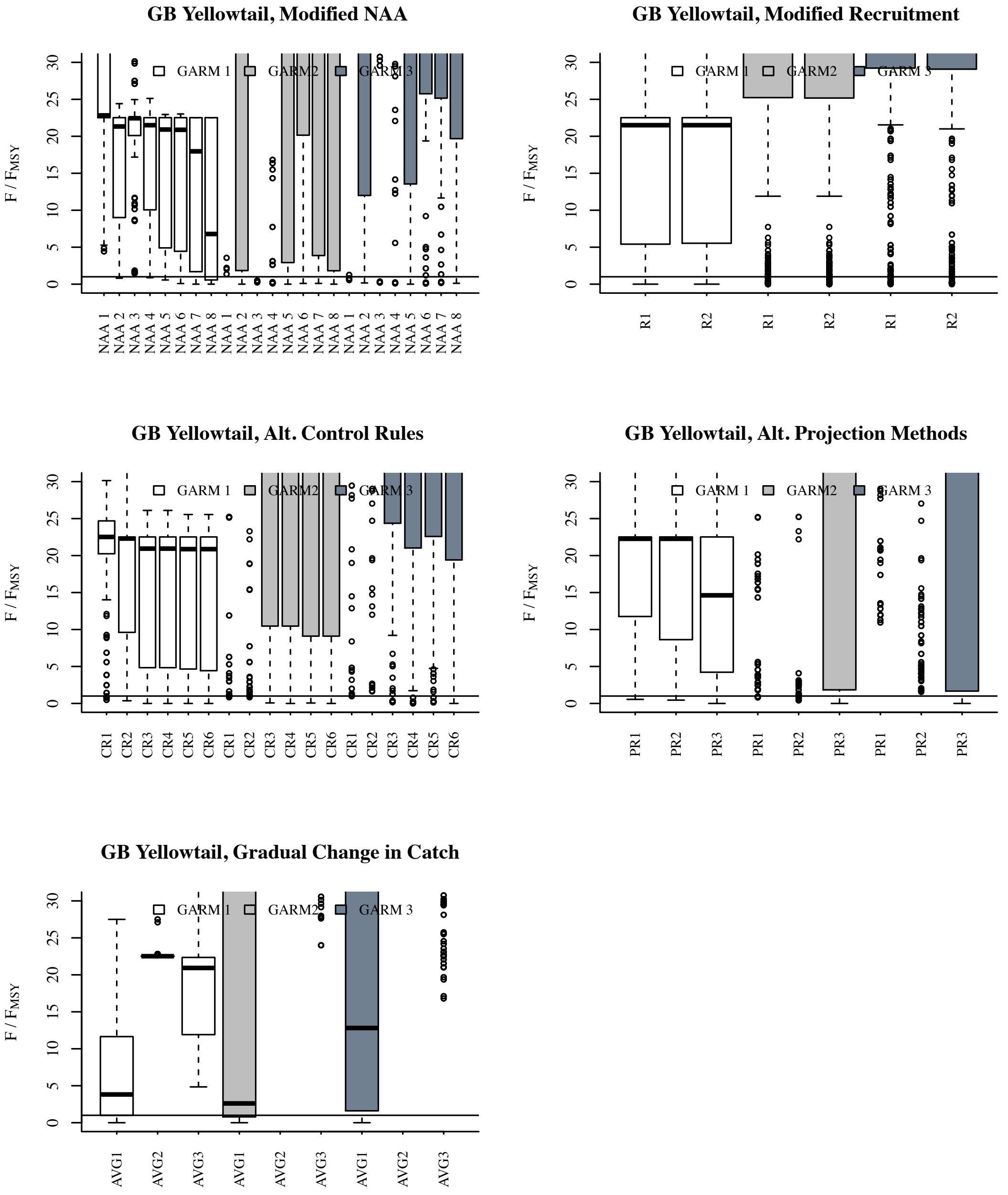


Figure 10a. Boxplot of the distribution of the *F*-ratio for a given modification in the way the target catch is calculated using information from the GARM 1 – 3 assessments for Georges Bank yellowtail (NEFSC 2002; 2005; 2008). The *F*-ratio is the estimated F / F_{MSY} where F is calculated allowing for changes in biomass due to the altered catch targets (the dynamic approach with fixed recruitment). The solid line at 1 indicates catch targets that would have achieved F_{MSY}. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined. The upper limit of the y-axis was fixed at 30 for ease of comparison with Figure 10b.

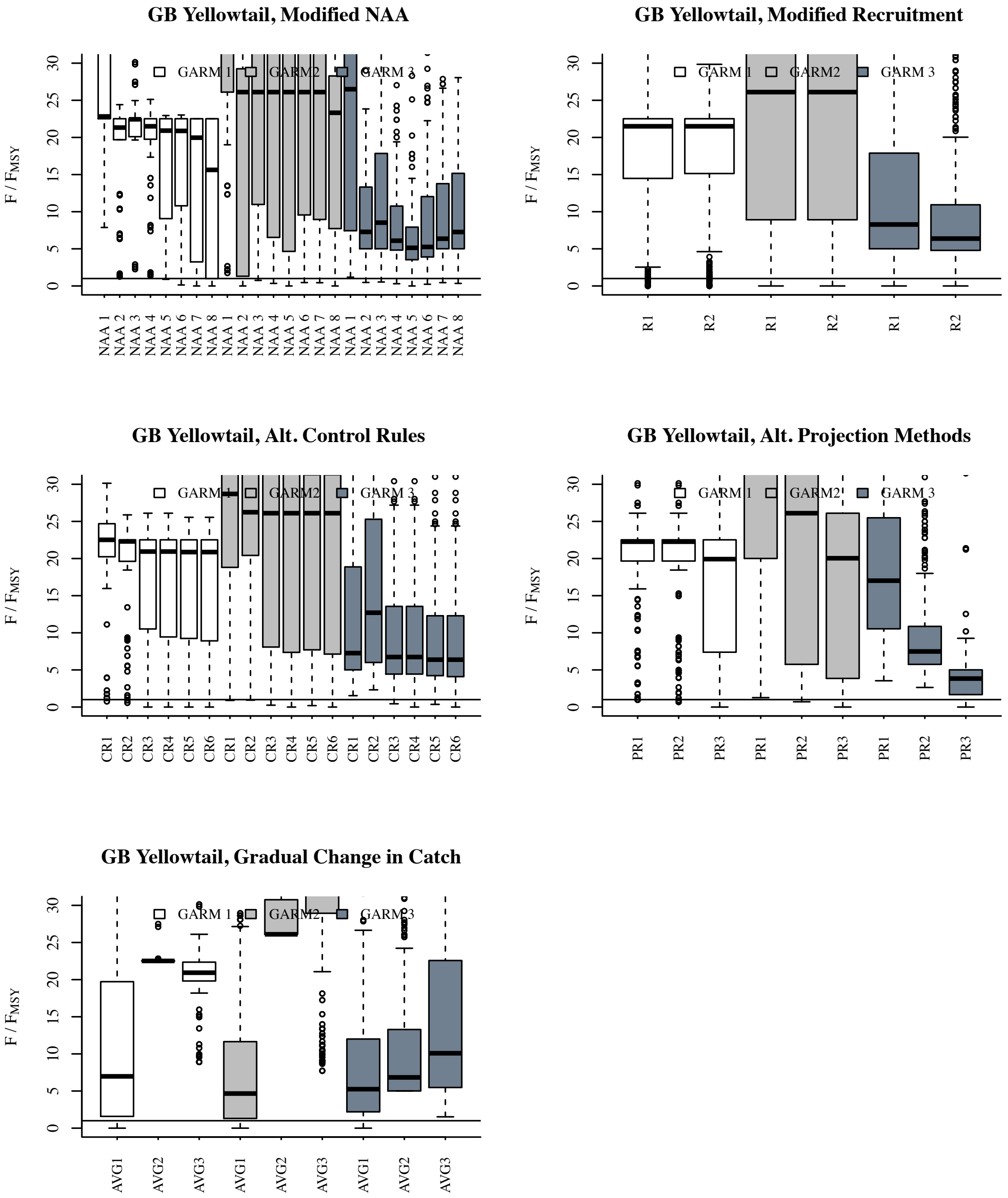


Figure 10b. Boxplot of the distribution of the *F*-ratio for a given modification in the way the target catch is calculated using information from the GARM 1 – 3 assessments for Georges Bank yellowtail (NEFSC 2002; 2005; 2008). The *F*-ratio is the estimated F / F_{MSY} where *F* is calculated using the fixed abundance-at-age estimates from the most recent assessment (the static approach). The solid line at 1 indicates catch targets that would have achieved F_{MSY}. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined.

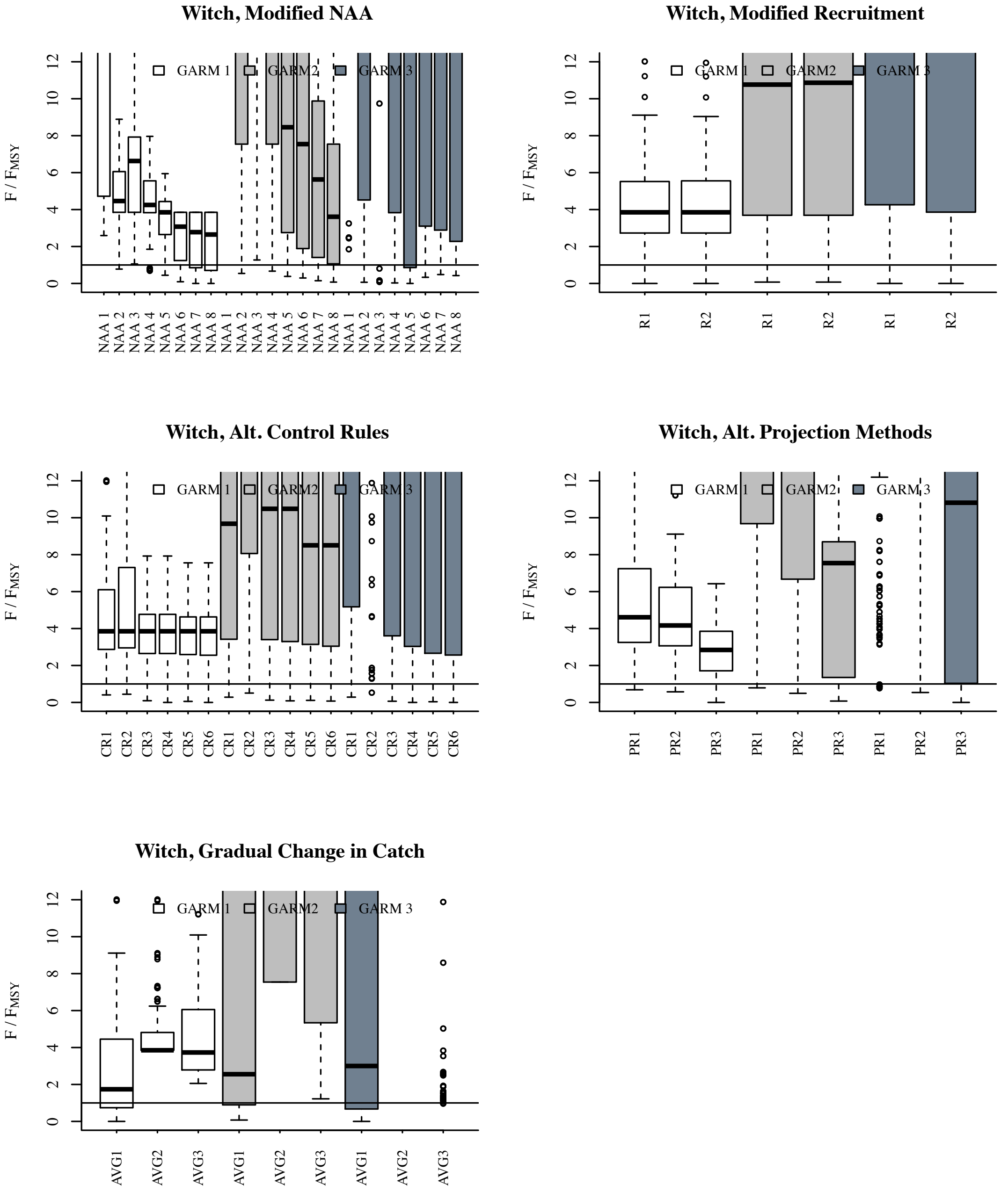


Figure 11a. . Boxplot of the distribution of the *F*-ratio for a given modification in the way the target catch is calculated using information from the GARM 1 – 3 assessments for witch flounder (NEFSC 2002; 2005; 2008). The *F*-ratio is the estimated F / F_{MSY} where *F* is calculated allowing for changes in biomass due to the altered catch targets (the dynamic approach with fixed recruitment). The solid line at 1 indicates catch targets that would have achieved F_{MSY}. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined. The upper limit of the y-axis was fixed at 12 for ease of comparison with Figure 11b.

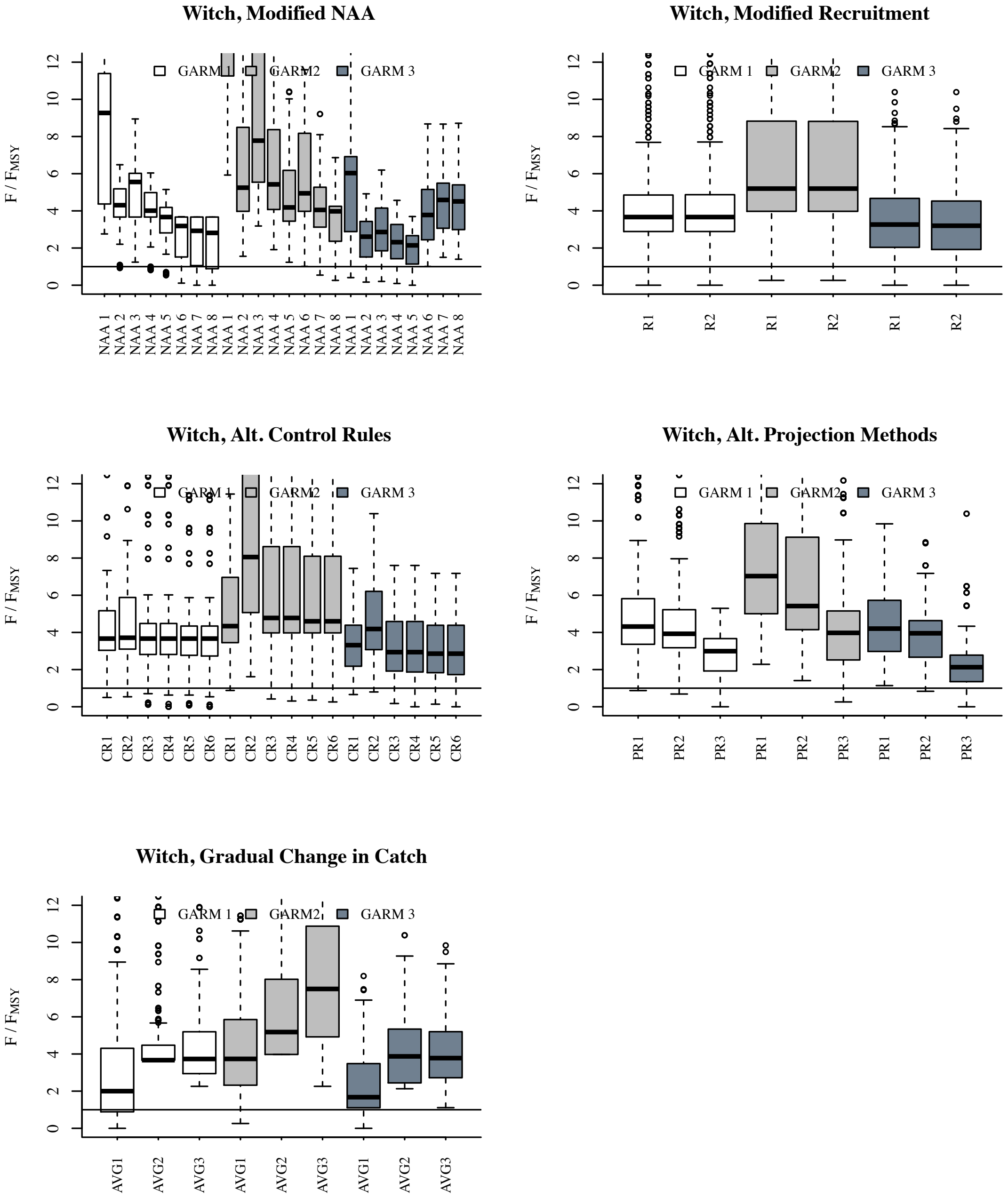


Figure 11b. Boxplot of the distribution of the *F*-ratio for a given modification in the way the target catch is calculated using information from the GARM 1 – 3 assessments for witch flounder (NEFSC 2002; 2005; 2008). The *F*-ratio is the estimated F / F_{MSY} where *F* is calculated using the fixed abundance-at-age estimates from the most recent assessment (the static approach). The solid line at 1 indicates catch targets that would have achieved F_{MSY}. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined.

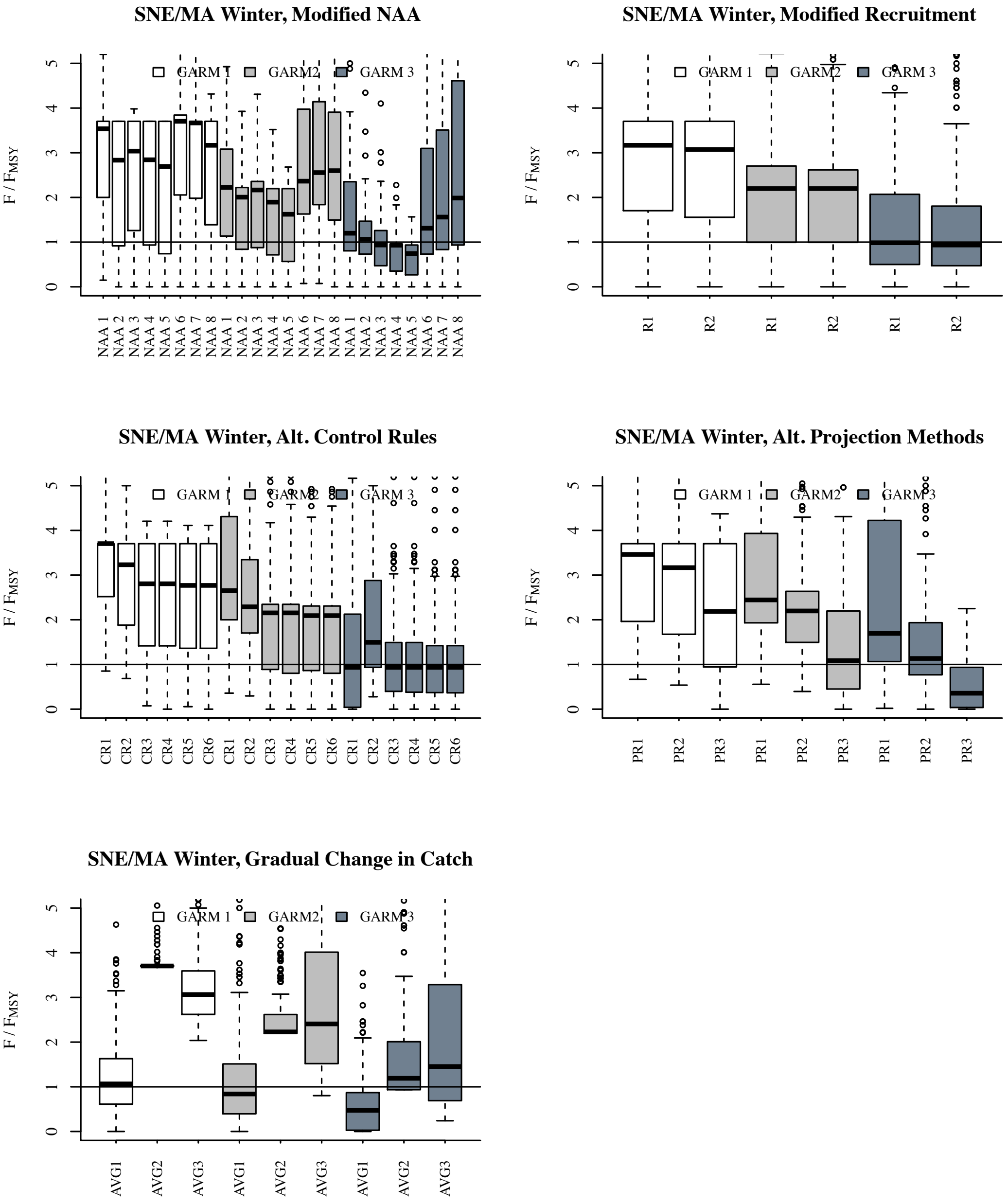


Figure 12a. Boxplot of the distribution of the *F*-ratio for a given modification in the way the target catch is calculated using information from the GARM 1 – 3 assessments for SNE/MA winter flounder (NEFSC 2002; 2005; 2008). The *F*-ratio is the estimated F / F_{MSY} where *F* is calculated allowing for changes in biomass due to the altered catch targets (the dynamic approach with fixed recruitment). The solid line at 1 indicates catch targets that would have achieved F_{MSY}. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined.

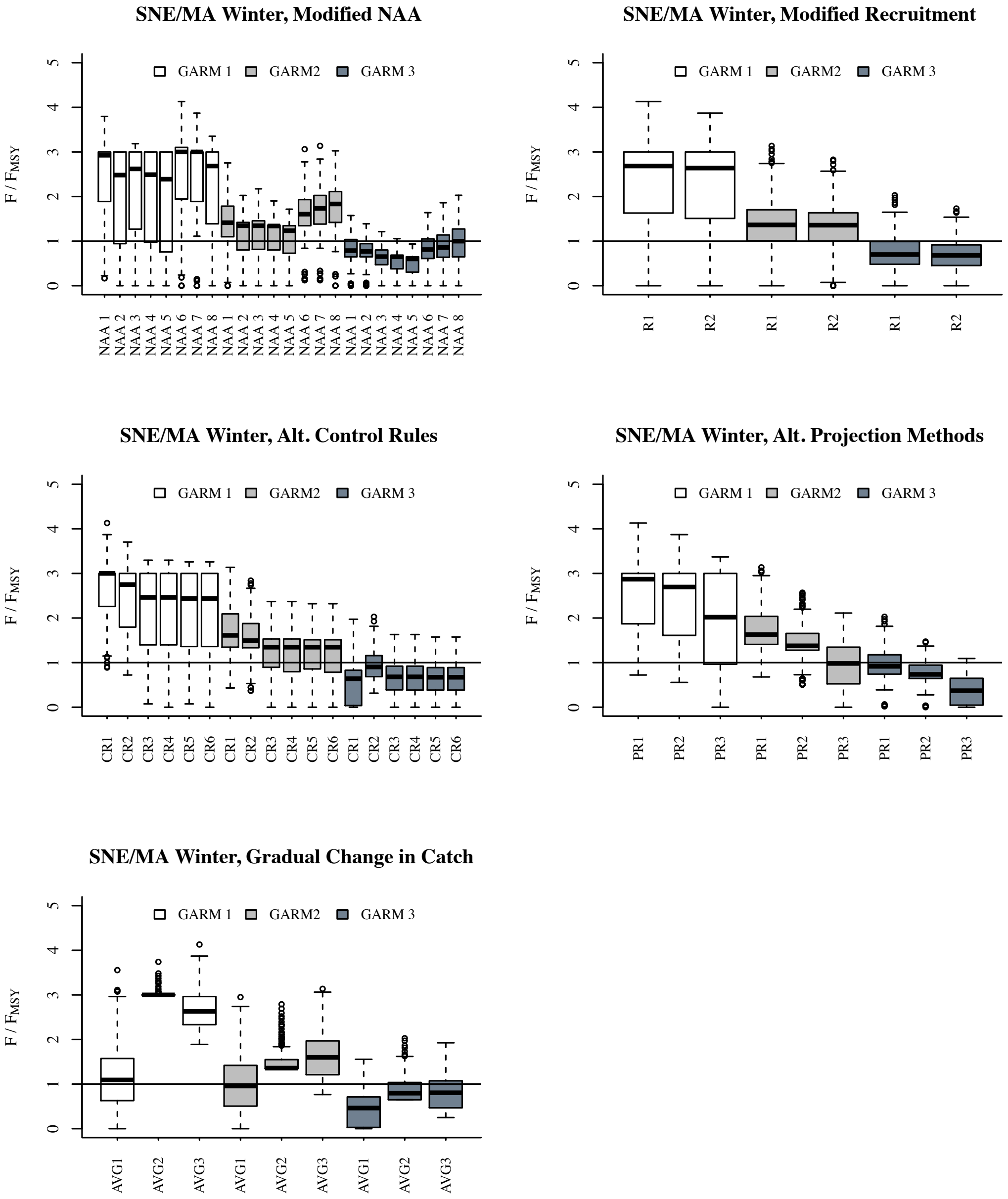


Figure 12b. Boxplot of the distribution of the *F*-ratio for a given modification in the way the target catch is calculated using information from the GARM 1 – 3 assessments for SNE/MA winter flounder (NEFSC 2002; 2005; 2008). The *F*-ratio is the estimated F / F_{MSY} where F is calculated using the fixed abundance-at-age estimates from the most recent assessment (the static approach). The solid line at 1 indicates catch targets that would have achieved F_{MSY}. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined.

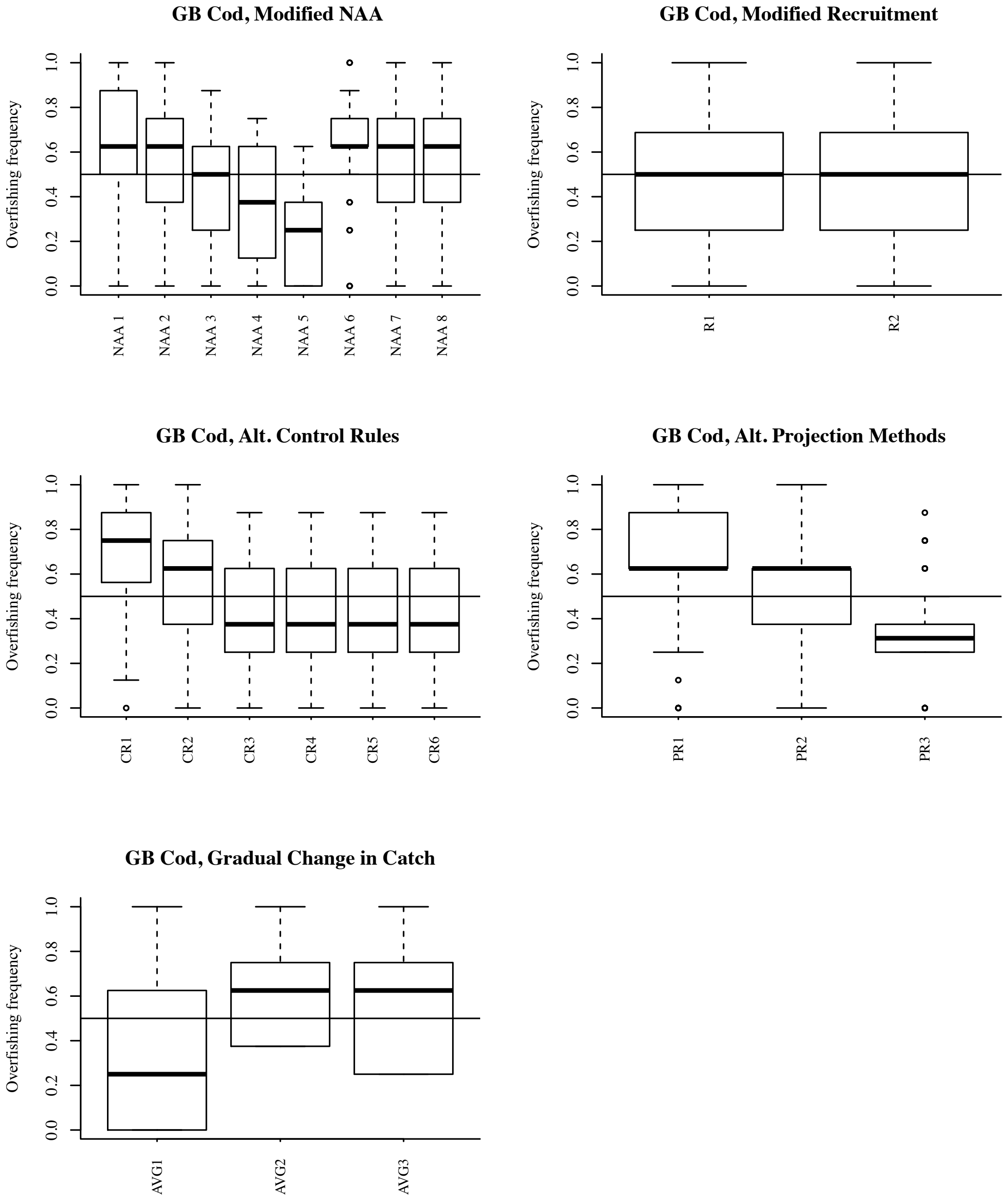


Figure 13. The frequency of overfishing for Georges Bank cod, defined as the proportion of years (from 2004-2011) when $F > F_{\text{MSY}}$, calculated allowing for changes in biomass due to the altered catch targets (the dynamic approach with fixed recruitment).

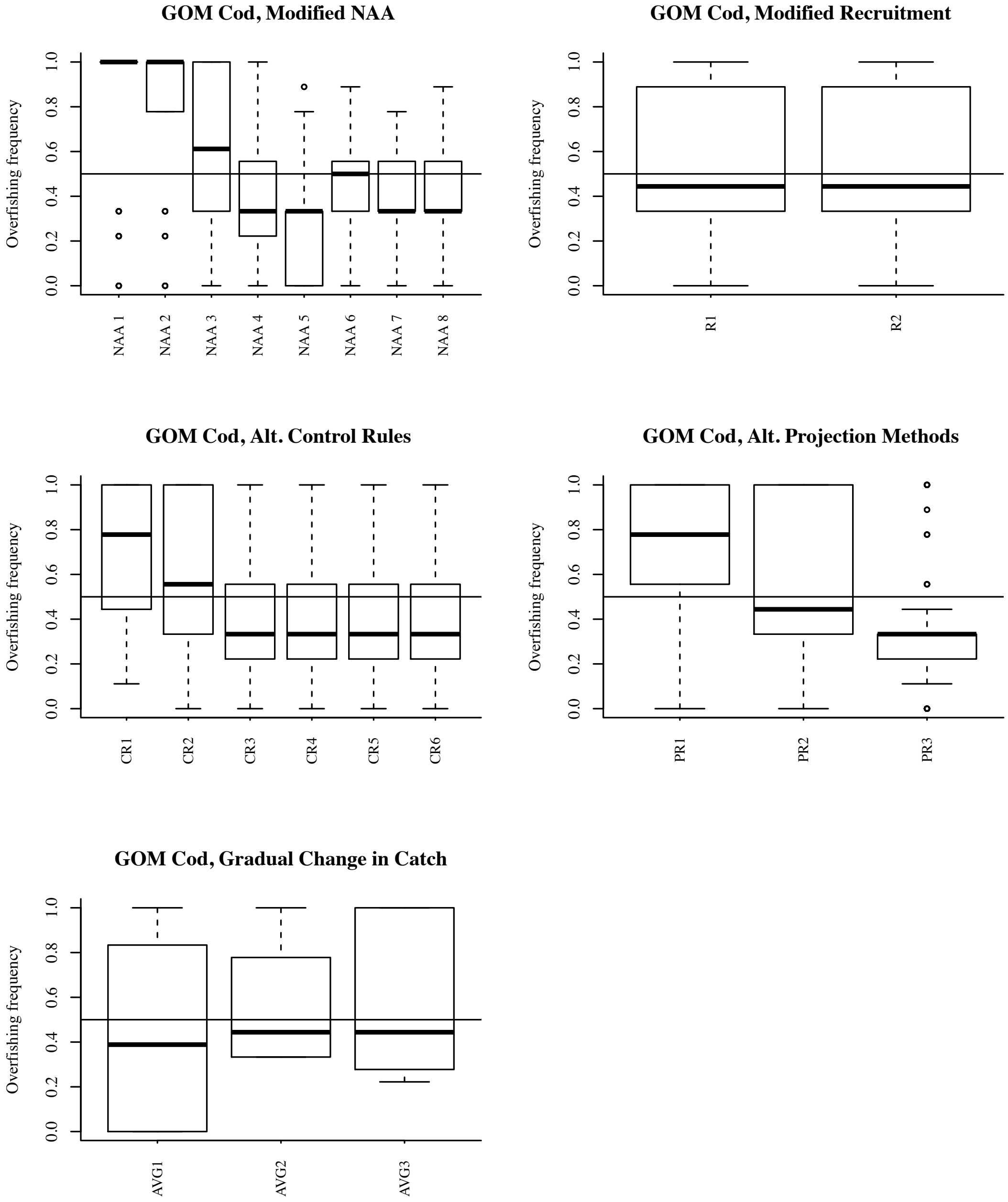


Figure 14. The frequency of overfishing for Gulf of Maine cod, defined as the proportion of years (from 2004-2012) when $F > F_{\mathrm{MSY},}$ calculated allowing for changes in biomass due to the altered catch targets (the dynamic approach with fixed recruitment).

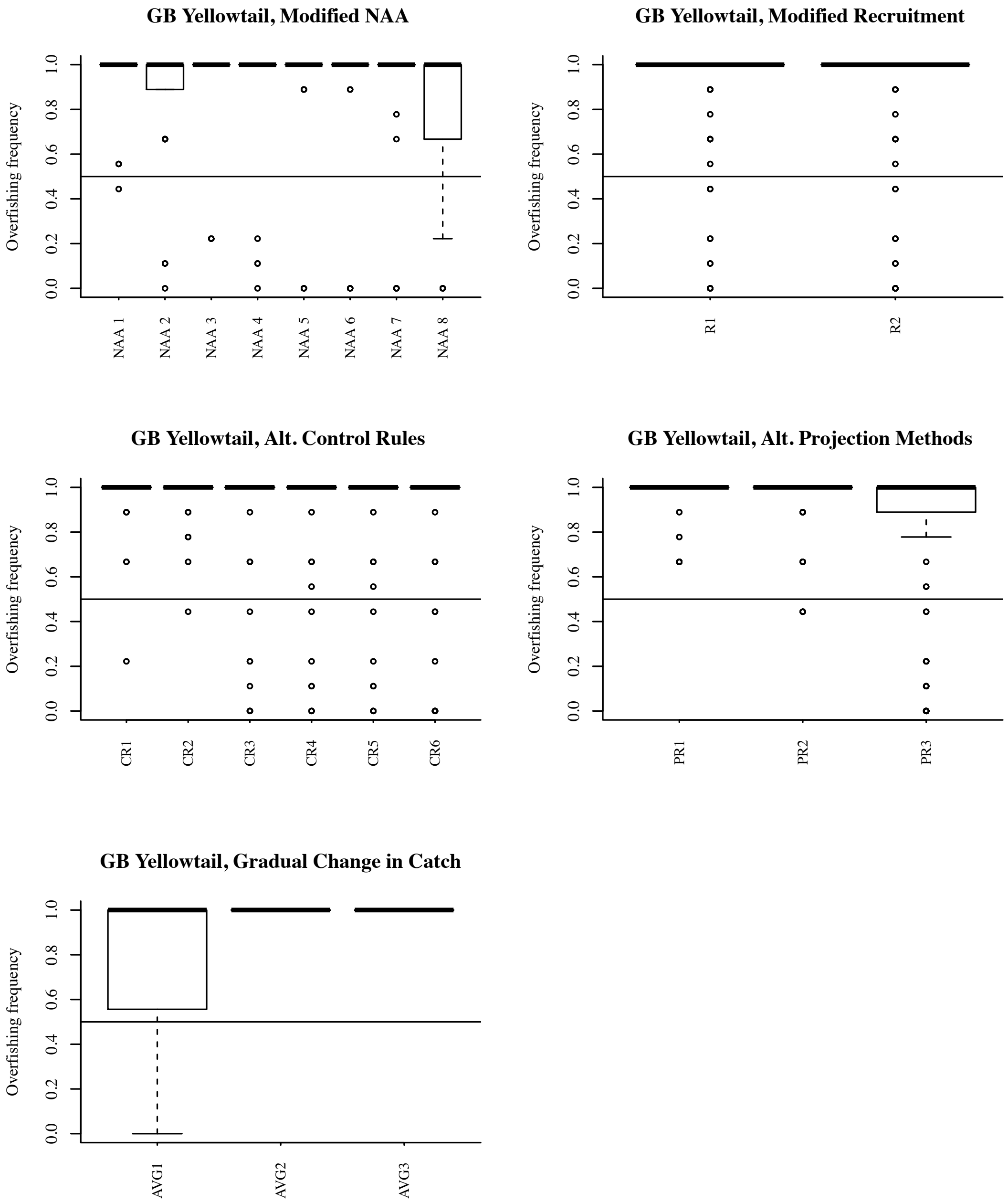


Figure 15. The frequency of overfishing for Georges Bank yellowtail, defined as the proportion of years (from 2004-2012) when $F > F_{\mathrm{MSY}}$, calculated allowing for changes in biomass due to the altered catch targets (the dynamic approach with fixed recruitment).

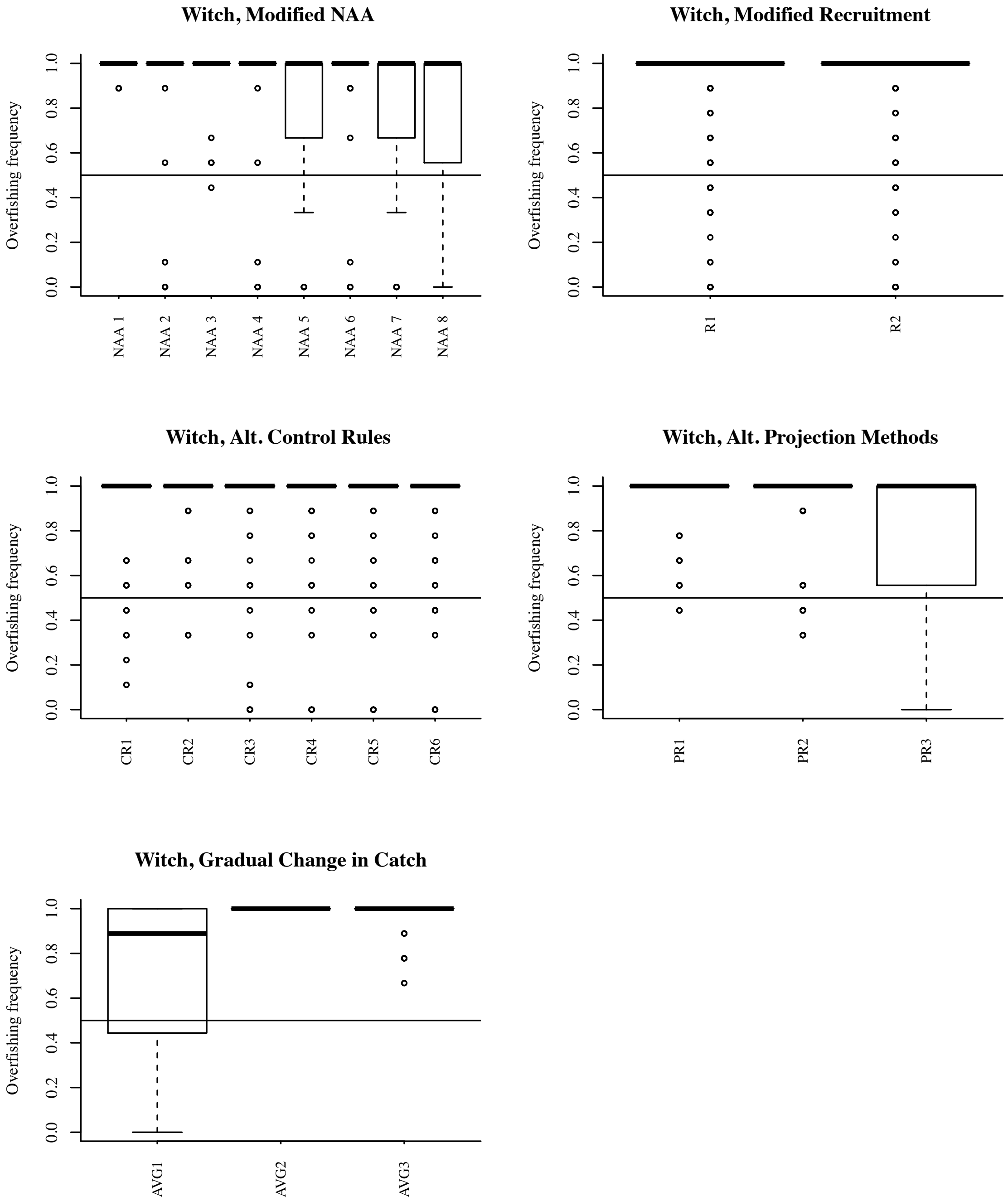
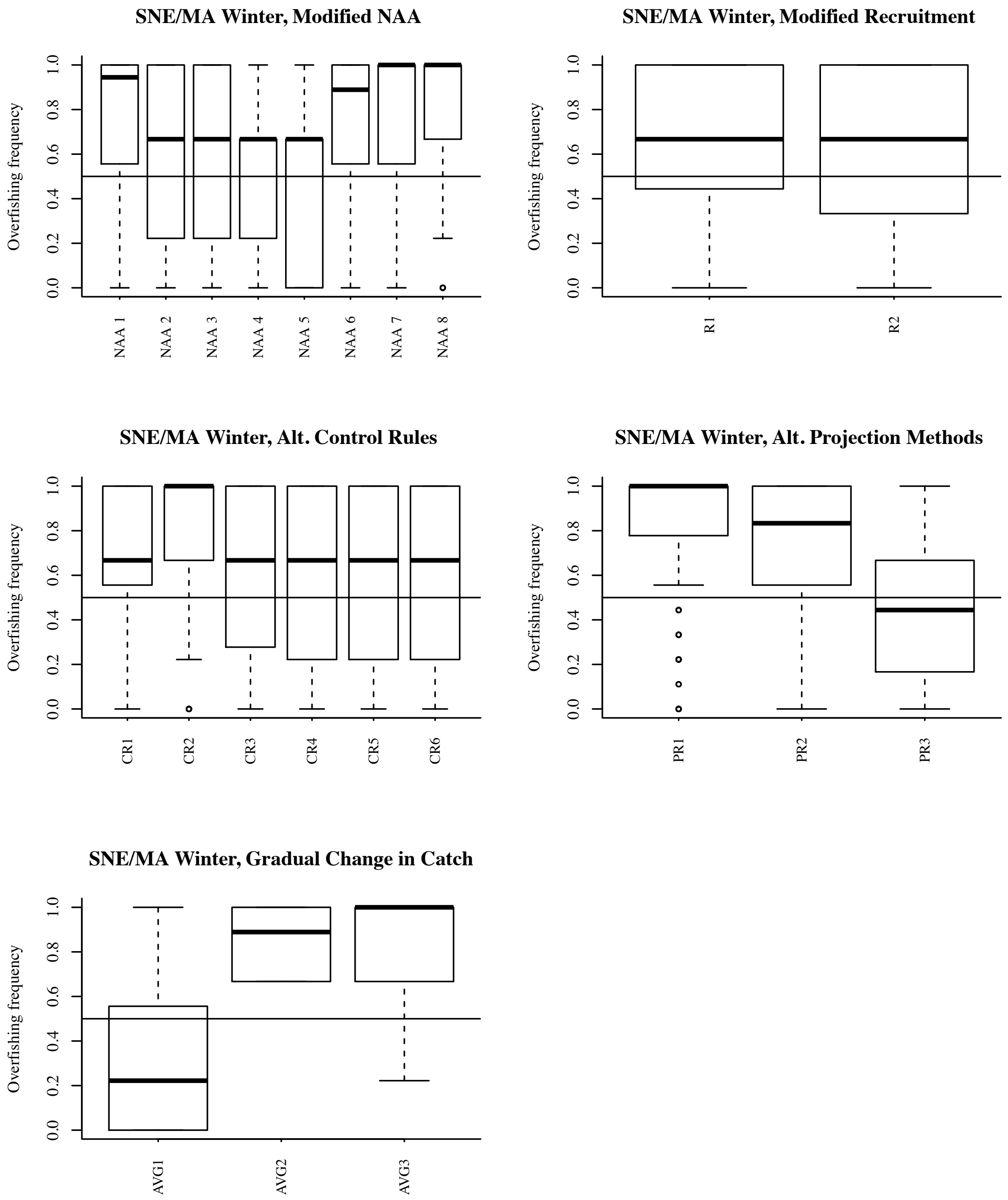


Figure 16. The frequency of overfishing for witch flounder, defined as the proportion of years (from 2004-2012) when $F > F_{\mathrm{MSY}}$, calculated allowing for changes in biomass due to the altered catch targets (the dynamic approach with fixed recruitment).


SNE/MA Winter, Modified NAA

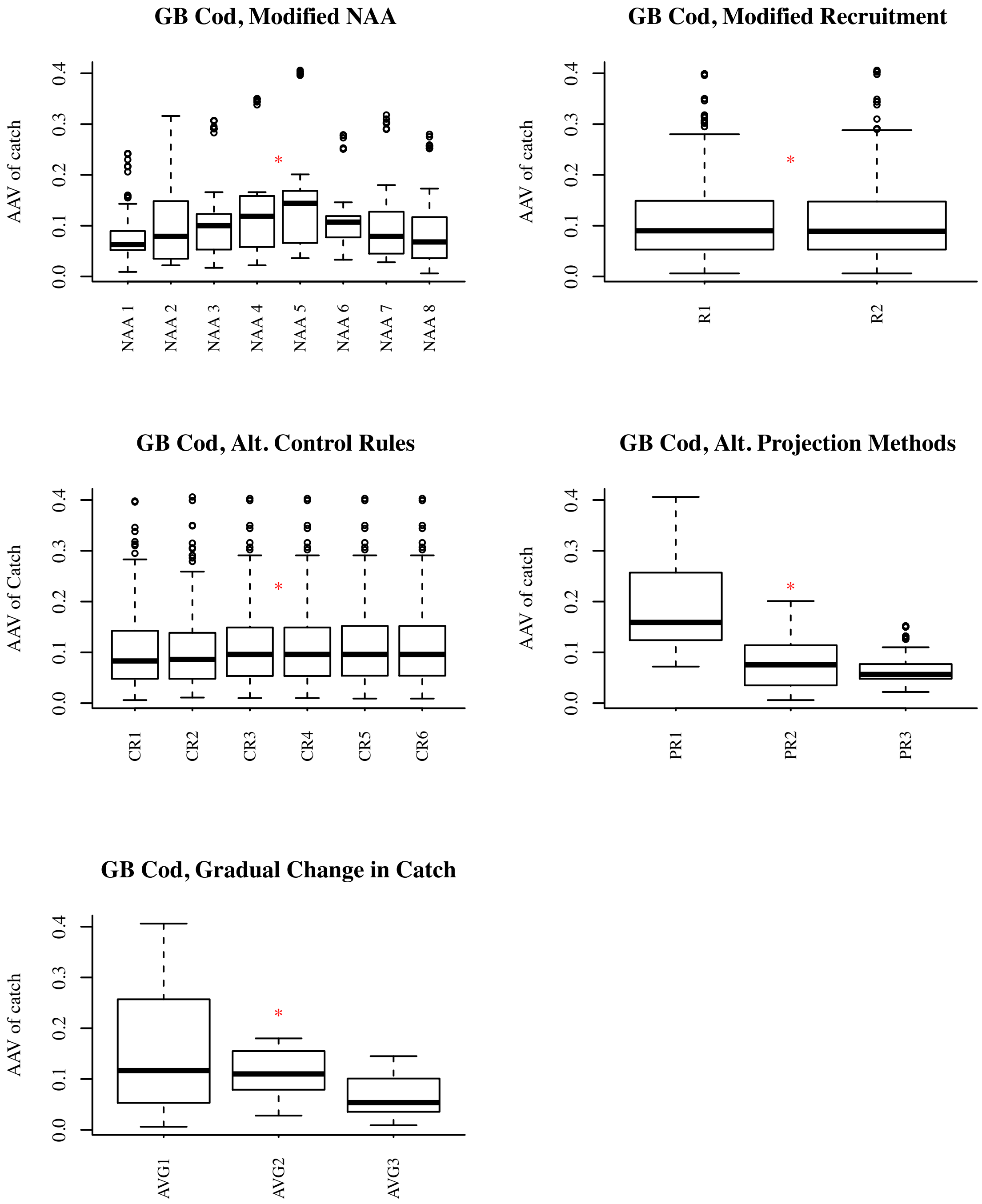
SNE/MA Winter, Modified Recruitment

SNE/MA Winter, Alt. Control Rules

SNE/MA Winter, Alt. Projection Methods

SNE/MA Winter, Gradual Change in Catch

Figure 17. The frequency of overfishing for southern New England / Mid-Atlantic (SNE/MA) winter flounder, defined as the proportion of years (from 2004-2012) when $F > F_{\mathrm{MSY}}$, calculated allowing for changes in biomass due to the altered catch targets (the dynamic approach with fixed recruitment).



GB Cod, Modified NAA

GB Cod, Modified Recruitment

GB Cod, Alt. Control Rules

GB Cod, Alt. Projection Methods

GB Cod, Gradual Change in Catch

Figure 18. Boxplot of the distribution of the interannual variability (AAV) in the target catch for a given modification in the way the target catch is calculated for GB cod. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined. The red * is the unmodified (i.e., original) AAV.

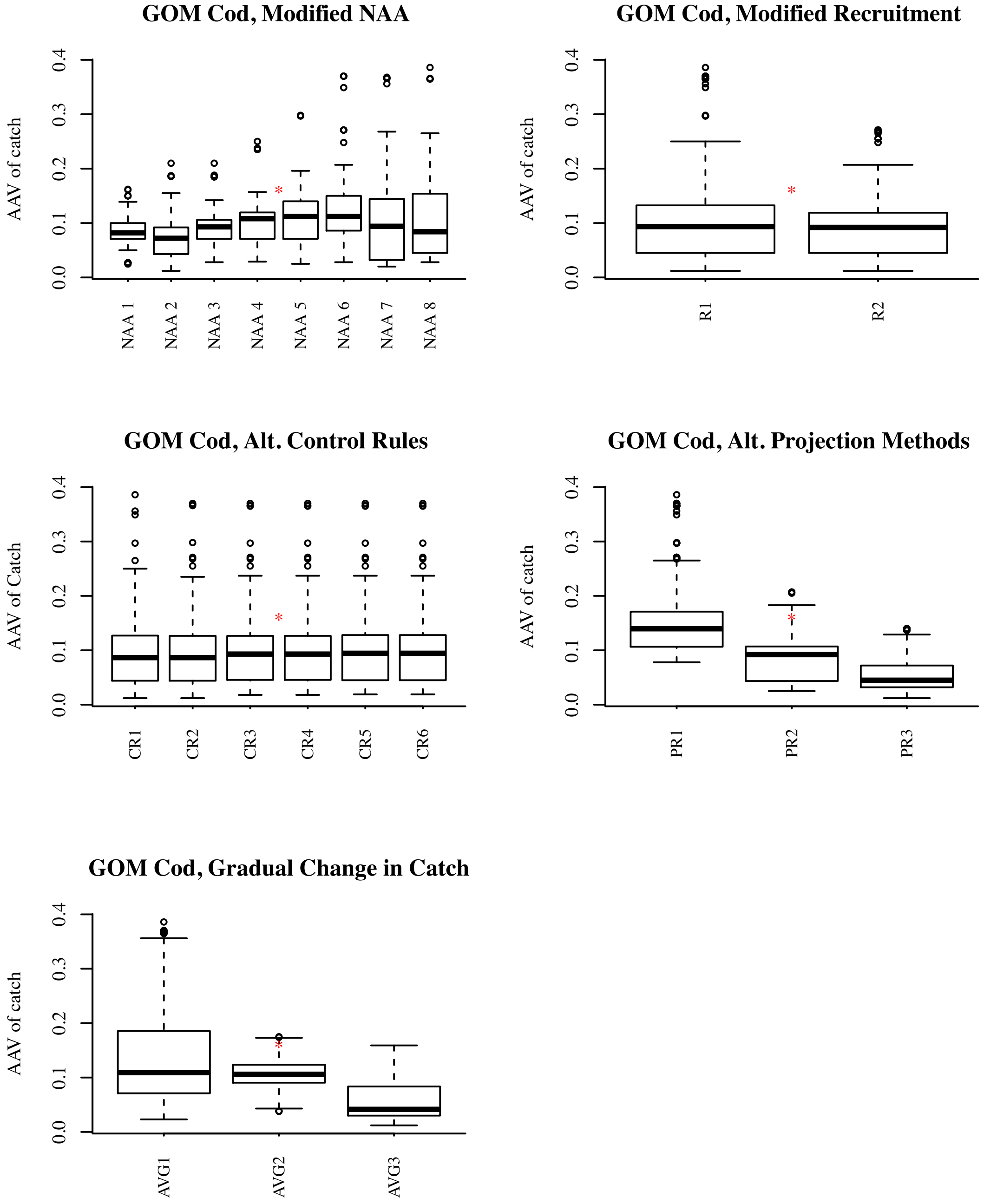


Figure 19. Boxplot of the distribution of the interannual variability (AAV) in the target catch for a given modification in the way the target catch is calculated for GOM cod. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined. The red * is the unmodified (i.e., original) AAV.

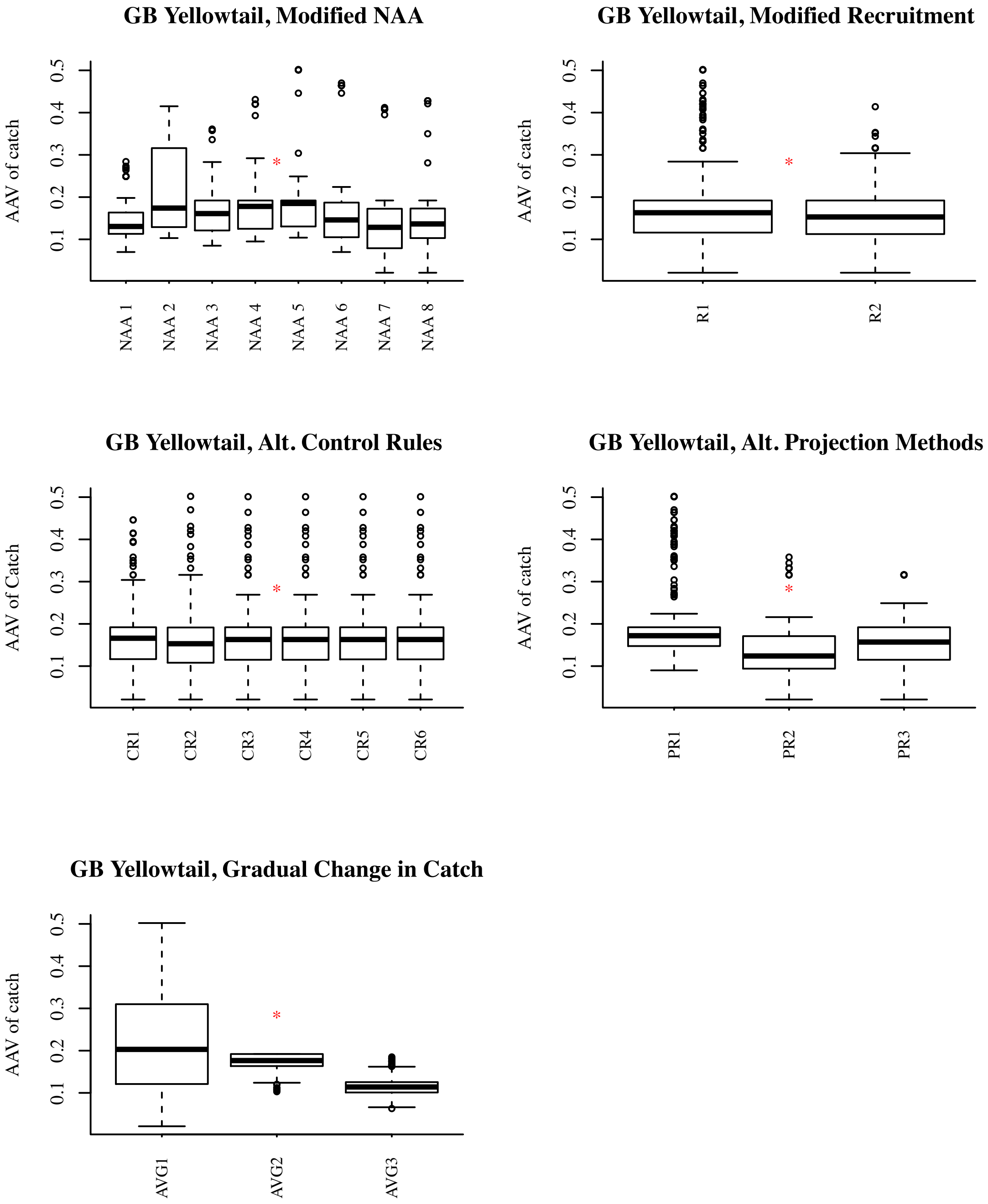


Figure 20. Boxplot of the distribution of the interannual variability (AAV) in the target catch for a given modification in the way the target catch is calculated for GB yellowtail flounder. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined. The red * is the unmodified (i.e., original) AAV.

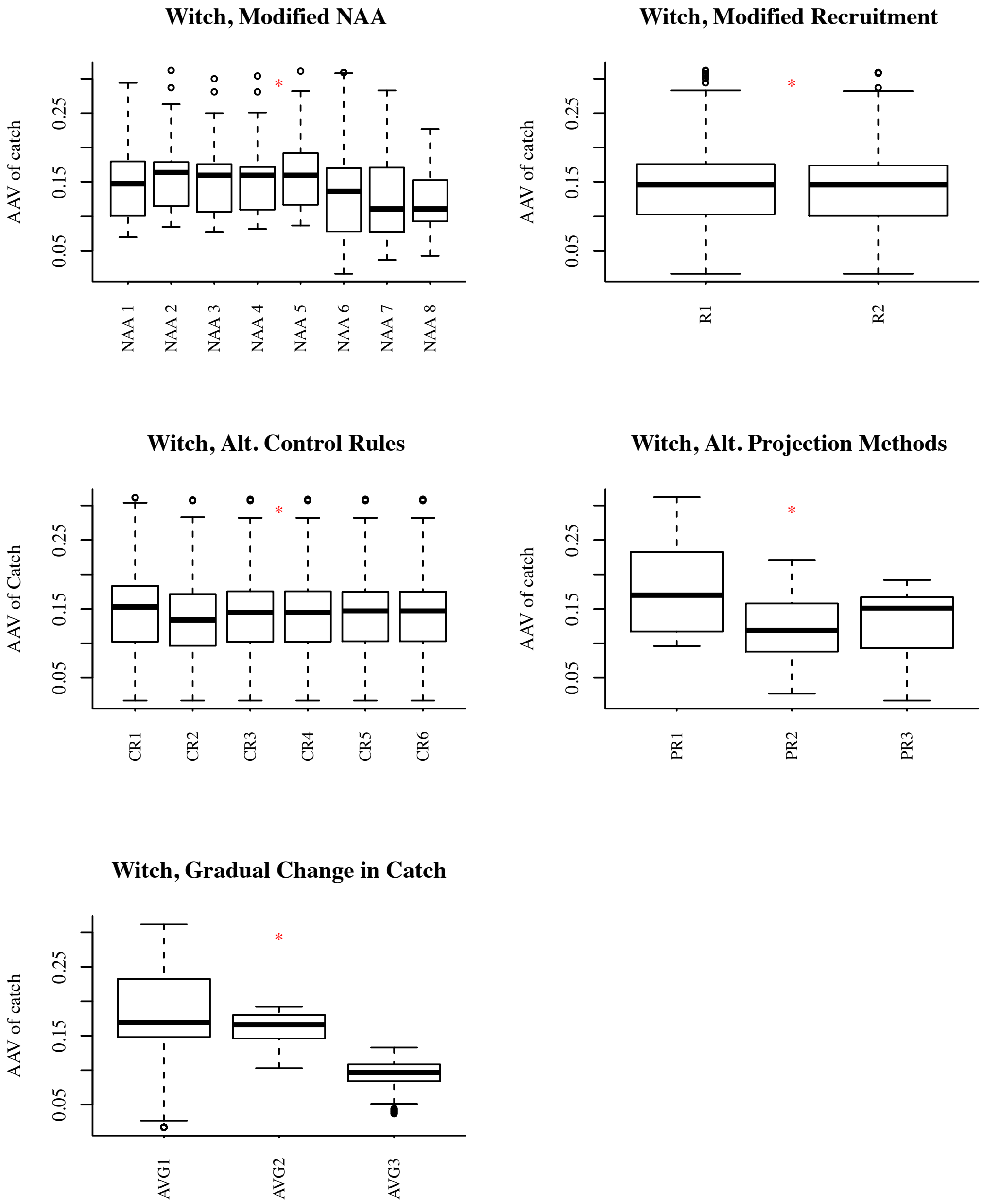
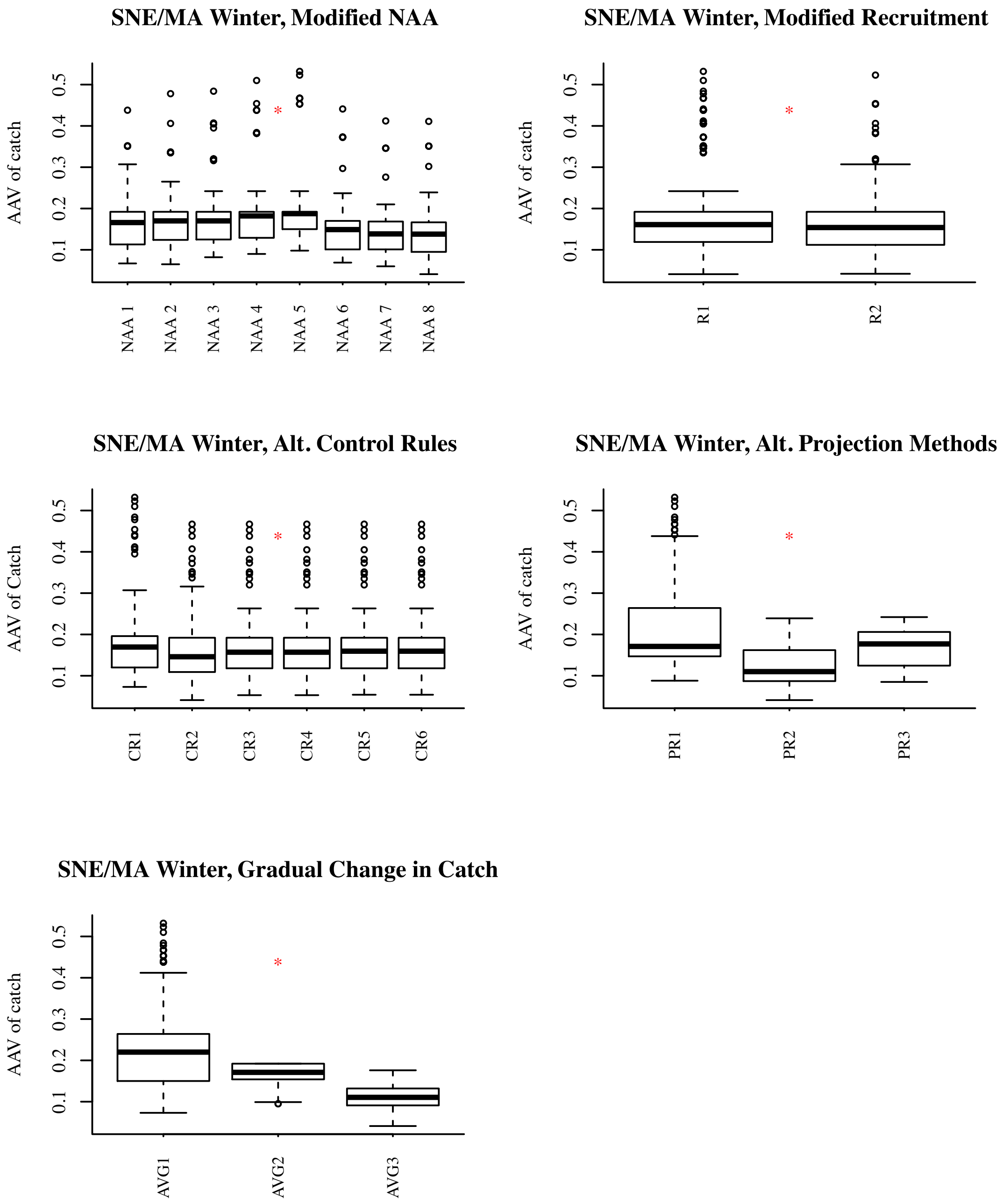


Figure 21. Boxplot of the distribution of the interannual variability (AAV) in the target catch for a given modification in the way the target catch is calculated for witch flounder. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined. The red * is the unmodified (i.e., original) AAV.



SNE/MA Winter, Modified NAA

SNE/MA Winter, Modified Recruitment

SNE/MA Winter, Alt. Control Rules

SNE/MA Winter, Alt. Projection Methods

SNE/MA Winter, Gradual Change in Catch

Figure 22. Boxplot of the distribution of the interannual variability (AAV) in the target catch for a given modification in the way the target catch is calculated for SNE/MA winter flounder. For a given modification (see Table 3 for details of each modification), the distribution is based on estimates across all modifications combined. The red * is the unmodified (i.e., original) AAV.

GB Cod, All Assessments Combined

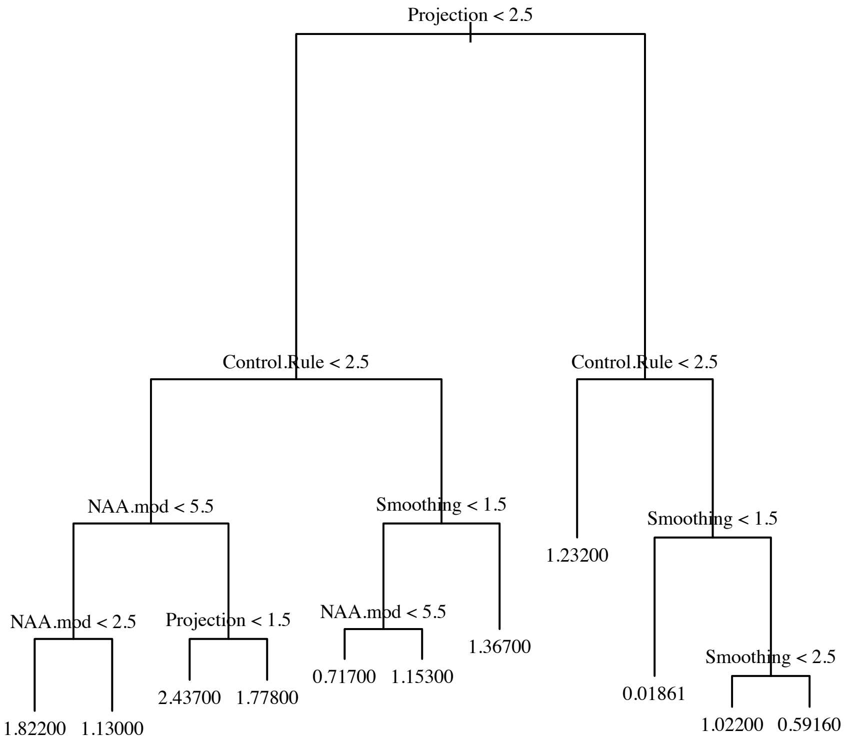


Figure 23. Regression tree predicting the *F*-ratio (F / F_{MSY} ; calculated using the dynamic approach with fixed recruitment) across alternative methods for setting catch advice for GB cod for the GARM 1, 2, and 3 assessments combined. Predictor values are integers corresponding to the run numbers in Table 3, such that splits occur at 0.5 threshold values for a given predictor. Numbers at the end of each branch are the mean *F*-ratios for each combination of methods (determined by the splits). This tree, for example shows that a mean *F*-ratio of 1.23 would have occurred if projections were not done (Projection > 2.5 splits the runs between PR runs 1 and 2 of the left branch, and PR run 3 on the right) without a threshold-based control-rule (CR runs 1 and 2; left branch of second split on right side of figure). The same predictors can occur on consecutive splits albeit for different levels. Here, on the left side of the tree, a split first occurs at an NAA.mod of 5.5. This indicates a difference between those runs that used older abundance data (NAA runs 6,7, and 8) and those that did not. For those that did not, there was a subsequent split at NAA.mod 2.5, splitting runs that used a fixed adjustment factor (NAA runs 3,4, and 5 which resulted in a mean F / F_{MSY} of 1.13), and those that did not (resulting in a mean F / F_{MSY} of 1.82).

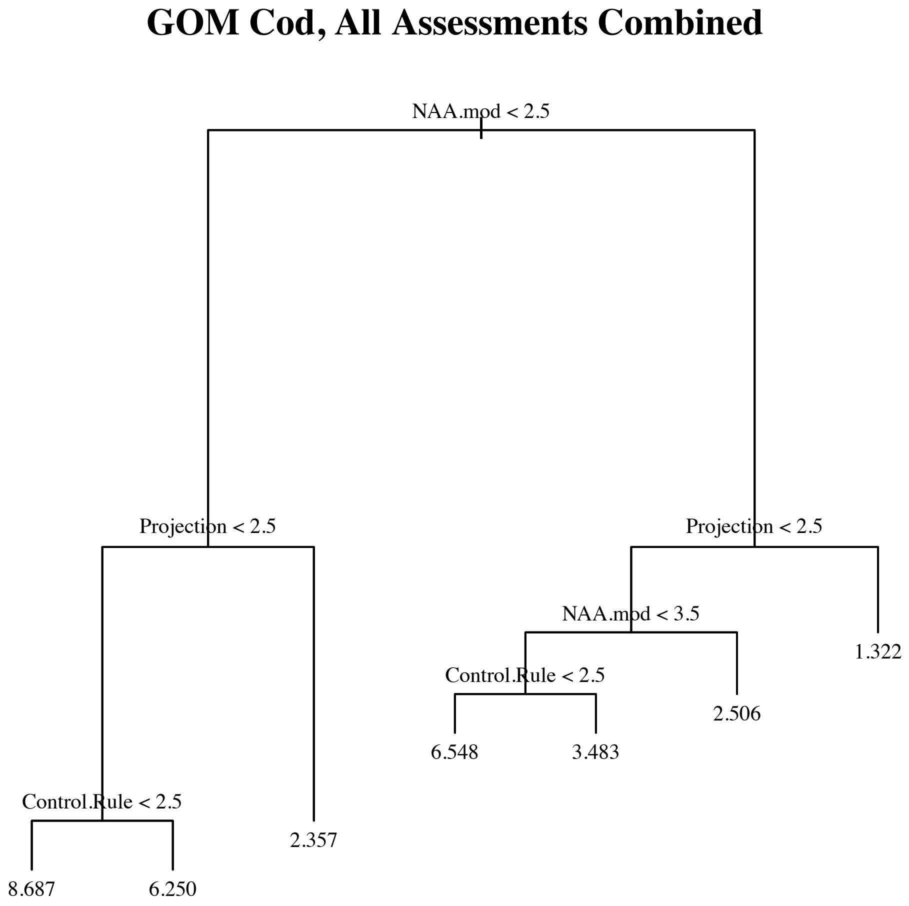


Figure 24. Regression tree predicting F / F_{MSY} (calculated using the dynamic abundance approach with fixed recruitment) across alternative methods for setting catch advice for GOM cod for the GARM 1, 2, and 3 assessments combined.

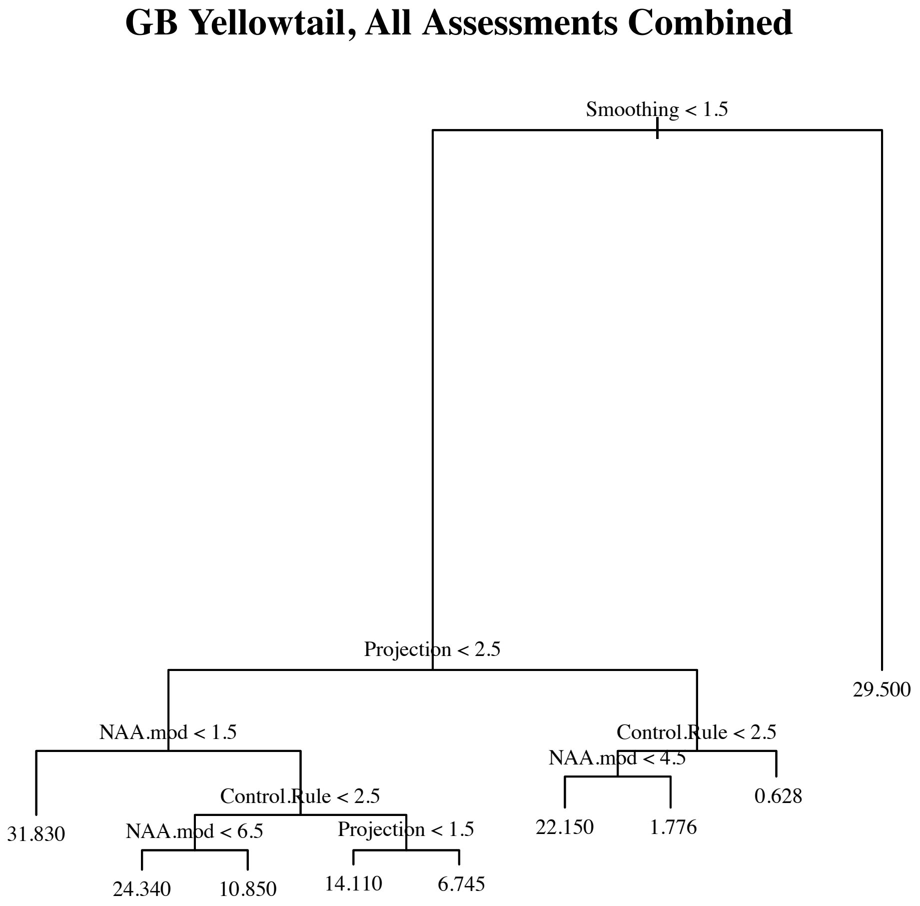


Figure 25. Regression tree predicting *F* / (calculated using the dynamic abundance approach with fixed recruitment) across alternative methods for setting catch advice for GB yellowtail flounder for the GARM 1, 2, and 3 assessments combined.

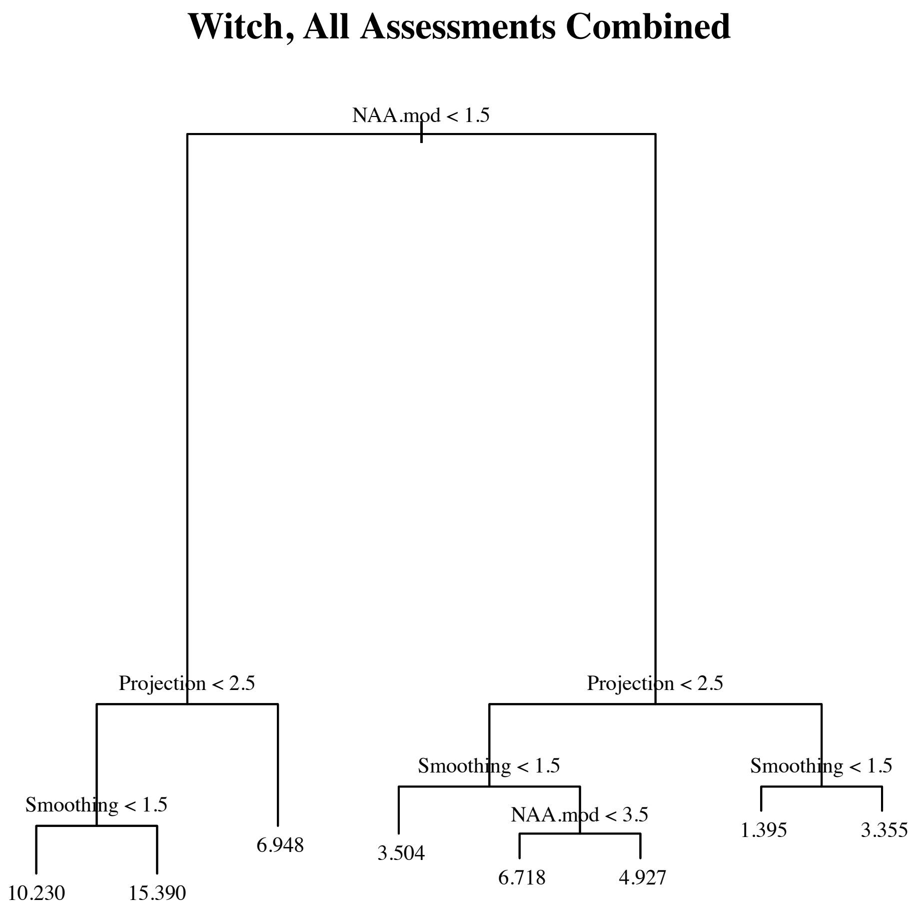


Figure 26. Regression tree predicting F / F_{MSY} (calculated using the dynamic abundance approach with fixed recruitment) across alternative methods for setting catch advice for witch flounder for the GARM 1, 2, and 3 assessments combined.

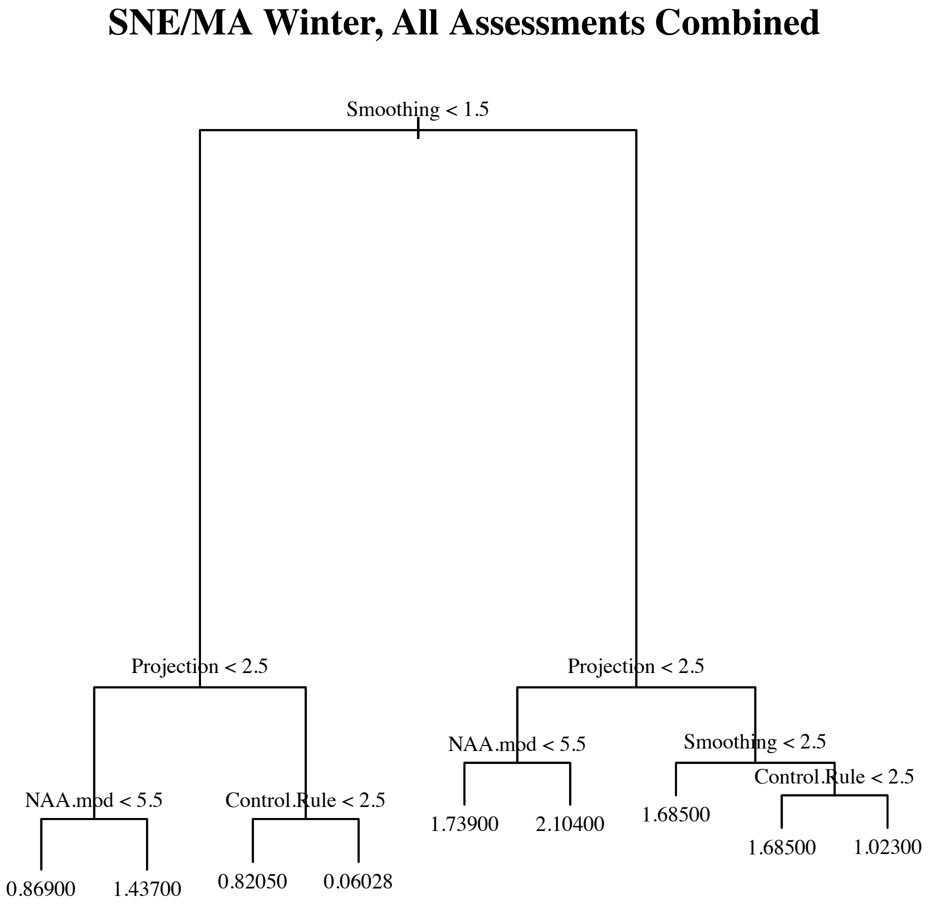


Figure 27. Regression tree predicting F / F_{MSY} (calculated using the dynamic abundance approach with fixed recruitment) across alternative methods for setting catch advice for SNE/MA winter flounder for the GARM 1, 2, and 3 assessments combined.

Appendix A.

Table A1. Input values used in the DLMtool R package for GB cod. This file shows the model run using the fall index of abundance with all available years. For runs calculating the catch following GARM 1, 2, and 3, the dataset was truncated using data through 2001, 2004, and 2007, respectively.

Name	GB_cod_fall														
Year	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Catch	40929	44442	53949	48667	62509	54291	40430	43361	27548	32665	42712	34938	44541	39342	29827
Abundance index	23.3	16.5	6.7	20.3	6.1	7.4	10	3.1	3.7	4.4	5.6	4.7	11.5	1.4	3
Year (cont.)	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Catch (cont.)	26006	16042	9983	9840	12422	10372	10987	10294	13709	11372	8945	5182	5074	4441	5664
Abundance index (cont.)	2.2	3.3	5.6	2.7	1.9	2.8	3	1.4	2.1	11.3	2.1	5.9	1.6	2.6	1.1
Year (cont.)	2008	2009	2010	2011	2012	2013	2014								
Catch (cont.)	5163	4645	3960	4449	2653	1824	2082								
Abundance index (cont.)	2.9	4.2	2.5	3	1.6	2	1.4								
Duration t	37														
Average catch over time t	22304.3243														
Depletion over time t	NA														
M	0.2														
FMSY/M	0.85														
BMSY/B0	0.35														
MSY	NA														
BMSY	NA														
Age at 50% maturity	4.9														
Length at first capture	25														
Length at full selection	80														
Current stock depletion	NA														
Current stock abundance	NA														
Von Bertalanffy K parameter	0.21														
Von Bertalanffy Linf parameter	114														
Von Bertalanffy t0 parameter	0.17														
Length-weight parameter a	7.29E-06														
Length-weight parameter b	3.07555														
Steepness	0.8														
Maximum age	25														
CV Catch	0.2														
CV Depletion over time t	0.5														
CV Average catch over time t	0.221														
CV Abundance index	0.3														
CV M	0.4														
CV FMSY/M	0.3														
CV BMSY/B0	0.045														
CV current stock depletion	0.5														
CV current stock abundance	1														
CV von B. K parameter	0.1														
CV von B. Linf parameter	0.1														
CV von B. t0 parameter	0.1														
CV Age at 50% maturity	0.25														
CV Length at first capture	0.25														
CV Length at full selection	0.25														
CV Length-weight parameter a	0.1														
CV Length-weight parameter b	0.1														
CV Steepness	0.3														
Sigma length composition	0.2														
Units	metric tons														
Reference OFL	NA														
Reference OFL type	NA														
CAA_bins	1	2	3	4	5	6	7	8	9						
CAA1978	379.63	851.94	9025.46	2804.5	933.36	347.19	287.17	45.76	40.87						
CAA1979	513.82	2862.39	1691.46	4934.49	1194.56	621.18	200.64	330.81	10.96						
CAA1980	566.78	4600.67	6454.54	838.27	2568.92	1162.58	461.26	97	151.07						
CAA1981	863.49	4091.85	5220.85	2965.26	374.01	1349.91	432.6	156.43	162.22						
CAA1982	730.7	10888.35	4697.48	2983.96	2152.1	293.75	752.11	212.85	83.12						
CAA1983	471.69	4748.7	7825.15	2389.91	1296.03	953.12	181.62	319.44	125.72						
CAA1984	190.25	1519.86	3531.33	3390.72	870.53	619.72	484.24	57.64	198.43						
CAA1985	218.99	7511.86	2825.71	1715.69	2231.86	531.66	277.93	242.29	36.67						
CAA1986	665.63	1584.87	4711.16	901.49	565.28	670.1	98.38	79.31	62.16						
CAA1987	63.93	8395.26	1533.13	2265.05	312.87	269.13	289.73	61.28	39.4						
CAA1988	139.36	2256.39	9037.62	1139.54	1618.6	223.38	168.45	235.46	60.84						
CAA1989	360.2	2462.17	3217.42	4406.91	415.41	586.44	89.57	58.2	69.4						
CAA1990	42.5	5481.4	5740.71	2067.61	2335.14	227.94	229.13	23.97	19.8						
CAA1991	161.16	2161.58	3681.37	3260.34	1469.03	1078.03	137.77	95.58	27.9						
CAA1992	96.79	4669.01	2337.09	1080.36	1520.84	477.36	408.59	59.08	45.14						
CAA1993	31.68	1320.55	4854.99	1303.23	517.07	581.27	190.35	156.08	49.38						
CAA1994	45.54	559.87	1634.76	2101.46	450.18	101.07	166.32	54.18	39.58						
CAA1995	17.7	565.9	1407.64	740.46	473.53	58.16	61.4	26.57	11.31						
CAA1996	56.96	326.36	1012.91	1314.06	259.9	188.07	20.17	12.7	11.77						
CAA1997	86.05	666.32	778.23	1122.28	955.97	156.69	119.2	25.55	9.17						
CAA1998	70	923.21	1367.25	534.23	424.28	316.18	47.99	19.75	4.88						
CAA1999	45.91	401.92	2060.65	866.42	289.72	127.38	145.83	24.32	3.88						
CAA2000	61.88	968.33	791.14	1234.82	344.43	91.51	46.84	39.36	4.35						
CAA2001	12.63	710.11	2704.51	748.51	702.87	185.89	55.05	25.81	14.99						
CAA2002	11.73	66.06	1153.86	1529.7	372.44	378.3	84.85	17.92	10.69						
CAA2003	3.44	158.11	418.85	825.13	915.9	152.12	142	27.73	6.43						
CAA2004	53.08	60.06	421.8	253.18	314.73	253.75	56.42	48.62	10.99						
CAA2005	7.12	268.38	202.77	692.57	197.12	143.73	109.38	22.6	8.76						
CAA2006	10.37	47.6	742.19	207.8	371.65	71.88	31.43	28.75	3.98						
CAA2007	2.76	351.78	281.09	1226.38	74.88	138.39	16.94	10.48	8.84						
CAA2008	9.78	309.24	715.19	182.28	539.51	21.58	48.28	4.57	2.81						
CAA2009	18.75	117.55	612.45	462.79	127.09	210.05	12.88	14.09	1.79						
CAA2010	10.77	140.23	424.08	593.41	164.23	26.22	76.07	3.47	3.99						
CAA2011	14.87	119.46	490.56	433.76	328.6	89.35	20.83	23.53	2.98						
CAA2012	3.63	134.31	306.36	365.84	121.57	60.34	21.33	1.58	1.28						
CAA2013	3.66	140.1	415.85	183.6	34.19	11.67	4.09	2.71	0.11						
CAA2014	8.85	99.93	278.15	402.46	77.86	10.93	2.27	0.91	0.5						

Table A2. Input values used in the DLMtool R package for GOM cod. This file shows the model run using the fall index of abundance with all available years. For runs calculating the catch following GARM 1, 2, and 3, the dataset was truncated using data through 2001, 2004, and 2007, respectively.

Name	GOM_cod_fall												
Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Catch	17092.1	16478.1	12859.3	14382.5	12567.4	11981.4	10326.4	13332.8	19280.4	20944.1	12329.3	9909.4	9009.8
Abundance index	15.919	8.416	8.735	8.264	4.715	3.394	6.616	4.535	4.912	2.782	2.448	1.002	2.737
Year (cont.)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Catch (cont.)	7517.5	7716.2	5784.9	4541.9	3042.3	5753.9	7941.2	6365.7	6355.5	5768.8	5257.6	4207.3	5485
Abundance index (cont.)	3.665	2.351	1.872	1.5	3.505	4.652	7.324	24.659	5.988	4.906	2.897	4.229	2.714
Year (cont.)	2008	2009	2010	2011	2012	2013	2014						
Catch (cont.)	7186.5	8246.7	7517.4	6673.2	3471.7	1776.9	1470.6						
Abundance index (cont.)	5.307	5.776	1.985	2.667	1.024	1.068	2.662						
Duration t	33												
Average catch over time t	8865.87273												
Depletion over time t	NA												
M	0.2												
FMSY/M	0.925												
BMSY/B0	0.35												
MSY	NA												
BMSY	NA												
Age at 50% maturity	2.7												
Length at first capture	37												
Length at full selection	80												
Current stock depletion	NA												
Current stock abundance	NA												
Von Bertalanffy K parameter	0.1145												
Von Bertalanffy Linf parameter	152.5												
Von Bertalanffy t0 parameter	-0.47												
Length-weight parameter a	5.13E-06												
Length-weight parameter b	3.1625												
Steepness	0.8												
Maximum age	25												
CV Catch	0.2												
CV Depletion over time t	0.5												
CV Average catch over time t	0.221												
CV Abundance index	0.3												
CV M	0.4												
CV FMSY/M	0.3												
CV BMSY/B0	0.045												
CV current stock depletion	0.5												
CV current stock abundance	1												
CV von B. K parameter	0.1												
CV von B. Linf parameter	0.1												
CV von B. t0 parameter	0.1												
CV Age at 50% maturity	0.25												
CV Length at first capture	0.25												
CV Length at full selection	0.25												
CV Length-weight parameter a	0.1												
CV Length-weight parameter b	0.1												
CV Steepness	0.3												
Sigma length composition	0.2												
Units	metric tons												
Reference OFL	NA												
Reference OFL type	NA												
CAA_bins	1	2	3	4	5	6	7	8					
CAA 1982	446	2919.3	2286.7	1430.5	748.8	65.9	94.1	72.6					
CAA 1983	587.5	2446.4	2912.8	1201.6	704	452.7	50	62.5					
CAA 1984	366.3	2112.7	1674.5	1643.6	437.5	219.6	105.6	9.5					
CAA 1985	500.3	1931.7	2400.6	1151.8	738.1	161.4	107.2	48.4					
CAA 1986	756.7	1737.8	2747.6	991.6	279.3	202.7	48	38.2					
CAA 1987	275.7	1968.4	1560.1	1574.5	345.4	89.4	81	14.5					
CAA 1988	411.7	1528.8	2084	1156.9	447.7	67.4	25.6	26.2					
CAA 1989	163.7	1209.7	2361.7	1650.5	521.1	87.1	70.3	9.4					
CAA 1990	64.9	801.4	5510.2	2713.3	541.4	189.1	29.7	36.4					
CAA 1991	120.5	489.3	930.9	5539.9	1036.1	150.7	55.5	26					
CAA 1992	368.6	817.8	858.5	500.9	2187.3	226.1	80.2	6					
CAA 1993	104	463.4	2124.3	935	103.3	497.1	41.6	11.3					
CAA 1994	121.8	169	1482.1	1291.2	266.3	66.2	74.2	28.7					
CAA 1995	77	298.1	1276.2	1252.2	221.4	29.9	6.5	18.2					
CAA 1996	34.6	100.9	612.1	1983.8	404.1	36.7	4	0.5					
CAA 1997	67.7	126.9	506.9	464.7	863.3	72.1	5.5	2.3					
CAA 1998	4.3	152.2	479	620.2	152.7	205.2	28.7	5.2					
CAA 1999	66.6	67.2	329.3	333.6	171.2	53.5	59.4	12.4					
CAA 2000	17.9	416.4	533.8	808.1	176.1	85.1	12.5	10.5					
CAA 2001	0.6	323.2	1101.7	671.3	383	106.4	57.2	8.3					
CAA 2002	13.6	35	319.7	865.6	312.8	163.4	66.4	27.9					
CAA 2003	37.6	99.3	150.5	530.8	685.4	183.1	75.7	29.2					
CAA 2004	132.8	92.5	550.9	250.4	388.2	248	70.3	35.7					
CAA 2005	23.9	139.3	137.6	859.7	87.3	241.8	109.2	28.7					
CAA 2006	16.5	46.6	366.7	275.1	442.3	29.5	80.6	40.2					
CAA 2007	11.7	86	248	907.7	130.9	222.9	8.3	20.9					
CAA 2008	10.6	102.2	533	679.9	787.6	67.3	100.8	3.3					
CAA 2009	9.2	81.8	593.1	1055.4	468	277.5	22	30					
CAA 2010	6.7	53.5	338.8	842.5	634.5	160.2	82.5	13.2					
CAA 2011	7	37.1	234.1	551.5	585.4	354.5	36.3	39.9					
CAA 2012	13.1	83.1	288.7	431.2	243.4	125	58.8	7.6					
CAA 2013	6.3	165.3	296.1	188.8	122.9	22.9	12.6	6.9					
CAA 2014	15.3	49.3	241.4	254.9	71.9	28.3	8.8	1.9					

Table A3. Input values used in the DLMtool R package for GB yellowtail flounder. This file shows the model run using the fall index of abundance with all available years. For runs calculating the catch following GARM 1, 2, and 3, the dataset was truncated using data through 2001, 2004, and 2007, respectively.

Name	GB_yellow_fall												
Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Catch	6935	7539	6979	12520	11989	6280	3267	3474	3580	2759	1783	4089	2564
Abundance index	1.494	6.607	2.576	2.27	2.131	0.593	0.709	0.82	0.509	0.171	0.977	0.725	0.73
Year (cont.)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Catch (cont.)	5299	4300	4158	1135	1700	2464	3985	4963	7341	7419	5663	6562	6815
Abundance index (cont.)	0.576	0.546	0.897	0.354	1.303	3.781	4.347	7.973	5.838	11.553	3.754	4.038	5.117
Year (cont.)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014			
Catch (cont.)	3852	2057	1664	1499	1806	1170	1171	725	218	159			
Abundance index (cont.)	2.463	4.521	8.151	7.109	6.744	2.247	2.452	2.52	0.875	1.024			
Duration t	36												
Average catch over time t	4163.41667												
Depletion over time t	NA												
M	0.2												
FMSY/M	0.85												
BMSY/B0	0.35												
MSY	NA												
BMSY	NA												
Age at 50% maturity	2.1												
Length at first capture	15												
Length at full selection	37												
Current stock depletion	NA												
Current stock abundance	NA												
Von Bertalanffy K parameter	0.335												
Von Bertalanffy Linf parameter	50												
Von Bertalanffy t0 parameter	0												
Length-weight parameter a	5.76E-06												
Length-weight parameter b	3.1329												
Steepness	0.8												
Maximum age	25												
CV Catch	0.2												
CV Depletion over time t	0.5												
CV Average catch over time t	0.221												
CV Abundance index	0.3												
CV M	0.4												
CV FMSY/M	0.3												
CV BMSY/B0	0.045												
CV current stock depletion	0.5												
CV current stock abundance	1												
CV von B. K parameter	0.1												
CV von B. Linf parameter	0.1												
CV von B. t0 parameter	0.1												
CV Age at 50% maturity	0.25												
CV Length at first capture	0.25												
CV Length at full selection	0.25												
CV Length-weight parameter a	0.1												
CV Length-weight parameter b	0.1												
CV Steepness	0.3												
Sigma length composition	0.2												
Units	metric tons												
Reference OFL	NA												
Reference OFL type	NA												
CAA_bins	1	2	3	4	5	6	7	8	9				
CAA1979	321	10517	3789	1432	623	167	95	31	27				
CAA1980	318	3994	9685	1538	352	96	5	11	1				
CAA1981	107	1097	5963	4920	854	135	5	2	3				
CAA1982	2164	18091	7480	3401	1095	68	20	7	0				
CAA1983	703	7998	16661	2476	680	122	13	16	4				
CAA1984	514	2018	4535	5043	1796	294	47	39	0				
CAA1985	970	4374	1058	818	517	73	8	0	0				
CAA1986	179	6402	1127	389	204	80	17	15	0				
CAA1987	156	3284	3137	983	192	48	38	26	25				
CAA1988	499	3003	1544	846	227	24	26	3	0				
CAA1989	190	2175	1121	428	110	18	12	0	0				
CAA1990	231	2114	6996	978	140	21	6	0	0				
CAA1991	663	147	1491	3011	383	67	4	0	0				
CAA1992	2414	9167	2971	1473	603	33	7	1	1				
CAA1993	5233	1386	3327	2326	411	84	5	1	0				
CAA1994	71	1336	6302	1819	477	120	20	3	0				
CAA1995	47	313	1435	879	170	25	10	1	0				
CAA1996	101	681	2064	885	201	13	10	5	0				
CAA1997	82	1132	1832	1857	378	39	43	7	1				
CAA1998	169	1991	3388	1885	1121	122	18	3	0				
CAA1999	60	2753	4195	1548	794	264	32	4	1				
CAA2000	132	3864	5714	3173	826	420	66	38	4				
CAA2001	176	2884	6956	2893	1004	291	216	13	4				
CAA2002	212	4169	3446	1916	683	269	144	57	10				
CAA2003	160	3919	4710	2320	782	282	243	96	47				
CAA2004	61	1152	3184	3824	1970	889	409	78	74				
CAA2005	60	1580	4032	1707	392	132	37	16	0				
CAA2006	150	1251	1577	923	358	123	65	14	7				
CAA2007	51	1493	1708	664	137	44	9	2	0				
CAA2008	28	490	1897	853	125	17	8	0	0				
CAA2009	17	283	1266	1360	516	59	10	4	0				
CAA2010	2	141	651	899	449	88	10	2	0				
CAA2011	11	166	775	904	310	67	8	1	0				
CAA2012	12	108	370	579	240	38	4	4	0				
CAA2013	15	61	99	148	91	19	2	0	0				
CAA2014	6	43	90	98	50	19	3	0	0				

Table A4. Input values used in the DLMtool R package for witch flounder. This file shows the model run using the fall index of abundance with all available years. For runs calculating the catch following GARM 1, 2, and 3, the dataset was truncated using data through 2001, 2004, and 2007, respectively.

Name	Witch_fall														
Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Catch	1578.257	1675.899	1718.579	1358.998	758.047	489.436	597.397	348.327	178.91	258.14	377.086	390.553	332.805	157.504	115.674
Abundance index	0.83	2.12	2.33	1.59	1.09	0.37	0.57	0.38	0.4	0.54	0.24	0.54	0.42	0.62	1.02
Year (cont.)	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Catch (cont.)	71.13	72.318	57.421	238.914	314.427	202.932	354.081	295.21	134.255	75.316	44.743	67.414	77.624	47.179	35.077
Abundance index (cont.)	0.77	0.47	0.88	1.11	1.71	1.06	0.79	1.03	0.38	0.46	0.57	0.64	0.48	0.36	0.67
Year (cont.)	2012	2013	2014												
Catch (cont.)	39.581	37.63	26.348												
Abundance index (cont.)	0.44	0.35	0.51												
Duration t	33														
Average catch over time t	379.612485														
Depletion over time t	NA														
M	0.15														
FMSY/M	1.2														
BMSY/B0	0.35														
MSY	NA														
BMSY	NA														
Age at 50% maturity	4.9														
Length at first capture	25														
Length at full selection	44														
Current stock depletion	NA														
Current stock abundance	NA														
Von Bertalanffy K parameter	0.15														
Von Bertalanffy Linf parameter	60														
Von Bertalanffy t0 parameter	0.02														
Length-weight parameter a	2.39E-06														
Length-weight parameter b	3.2643														
Steepness	0.8														
Maximum age	25														
CV Catch	0.2														
CV Depletion over time t	0.5														
CV Average catch over time t	0.221														
CV Abundance index	0.3														
CV M	0.4														
CV FMSY/M	0.3														
CV BMSY/B0	0.045														
CV current stock depletion	0.5														
CV current stock abundance	1														
CV von B. K parameter	0.1														
CV von B. Linf parameter	0.1														
CV von B. t0 parameter	0.1														
CV Age at 50% maturity	0.25														
CV Length at first capture	0.25														
CV Length at full selection	0.25														
CV Length-weight parameter a	0.1														
CV Length-weight parameter b	0.1														
CV Steepness	0.3														
Sigma length composition	0.2														
Units	metric tons														
Reference OFL	NA														
Reference OFL type	NA														
CAA_bins	3	4	5	6	7	8	9	10							
CAA 1982	190.469	1064.356	1207.553	1475.266	665.14	655.94	399.464	239.378							
CAA 1983	337.191	1346.493	1521.128	1575.497	1590.578	978.033	737.875	510.521							
CAA 1984	146.594	1466.111	2002.444	1739.363	1486.309	1497.308	696.611	375.052							
CAA 1985	123.564	1175.948	2117.899	1935.95	1524.674	1247.715	605.91	400.341							
CAA 1986	22.944	376.985	1516.477	2774.784	1566.583	834.731	412.617	222.755							
CAA 1987	22.253	181.272	467.107	1280.154	1574.817	870.964	480.636	252.419							
CAA 1988	599.755	139.707	264.057	658.151	1382.461	1153.9	401.431	266.654							
CAA 1989	90.53	318.852	155.938	314.625	760.063	883.352	349.978	123.506							
CAA 1990	307.823	388.856	786.862	257.654	276.05	474.838	336.601	82.001							
CAA 1991	497.772	632.757	1084.661	650.616	236.109	244.901	292.529	314.01							
CAA 1992	161.463	965.867	1110.902	1064.458	729.018	201.681	177.916	120.064							
CAA 1993	75.366	873.822	1327.671	922.445	598.995	585.67	218.811	278.582							
CAA 1994	64.617	616.863	2029.23	1346.714	942.262	199.511	543.591	113.87							
CAA 1995	642.141	376.604	1043.203	1711.728	854.692	269.57	97.914	270.63							
CAA 1996	146.176	390.985	919.229	1351.766	1456.335	267.988	219.375	58.081							
CAA 1997	125.334	701.905	901.689	1217.59	1030.997	599.41	84.875	50.354							
CAA 1998	364.477	700.643	1114.072	1429.82	1654.558	381.962	146.02	15.986							
CAA 1999	144.302	443.269	920.998	1516.039	1258.313	807.795	266.12	33.348							
CAA 2000	124.839	375.114	571.665	1169.282	1720.094	1025.462	568.351	94.842							
CAA 2001	66.446	337.775	1048.933	1127.294	1754.205	1478.41	642.525	434.164							
CAA 2002	32.521	576.047	1121.432	1362.544	2149.737	1280.406	645.074	95.56							
CAA 2003	32.641	288.524	1123.742	1629.541	1912.285	1584.638	759.604	441.984							
CAA 2004	33.131	359.936	1181.08	1616.124	1531.616	1162.809	806.112	329.336							
CAA 2005	15.304	184.766	838.943	1874.78	1814.068	834.725	416.624	237.837							
CAA 2006	45.698	72.412	240.026	713.289	1566.505	885.292	362.137	135.654							
CAA 2007	73.424	88	105.387	266.751	900.385	617.566	175.247	100.3							
CAA 2008	29.975	190.118	173.944	313.571	594.316	454.44	312.898	111.714							
CAA 2009	26.715	165.937	439.874	301.099	499.459	455.882	324.419	74.697							
CAA 2010	29.666	64.017	231.926	448.434	295.162	402.506	179.774	234.712							
CAA 2011	62.186	62.263	126.689	506.384	573.612	440.562	155.65	83.056							
CAA 2012	70.109	102.807	232.883	352.203	752.391	562.132	211.056	84.969							
CAA 2013	17.379	97.32	149.948	254.405	437.66	323.2	181.1	82.511							
CAA 2014	49.095	45.292	135.516	145.268	261.32	325.278	133.923	47.675							

Table A5. Input values used in the DLMtool R package for SNE/MA winter flounder. This file shows the model run using the fall index of abundance with all available years. For runs calculating the catch following GARM 1, 2, and 3, the dataset was truncated using data through 2001, 2004, and 2007, respectively.

Name	SNEMA_winter_fall														
Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Catch	15764	14143	13582	15526	13891	9217	9352	8795	6915	5999	6842	4729	4311	3092	3434
Abundance index	18137	19706	8839	17879	4899	4523	2847	2434	2090	2875	4041	3830	5917	2354	8489
Year (cont.)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Catch (cont.)	3702	4483	3614	3745	4754	5147	3412	2827	1942	1563	2023	1866	1298	532	363
Abundance index (cont.)	3800	6219	16268	13002	7372	11633	6037	18571	6287	6794	7803	5818	7384	5915	3577
Year (cont.)	2011	2012	2013	2014											
Catch (cont.)	530	650	1074	753											
Abundance index (cont.)	5319	2721	10889	1271											
Duration t	34														
Average catch over time t	5290.29412														
Depletion over time t	NA														
M	0.3														
FMSY/M	1.08														
BMSY/B0	0.35														
MSY	NA														
BMSY	NA														
Age at 50% maturity	2.8														
Length at first capture	15														
Length at full selection	33														
Current stock depletion	NA														
Current stock abundance	NA														
Von Bertalanffy K parameter	0.318														
Von Bertalanffy Linf parameter	46.5														
Von Bertalanffy t0 parameter	0														
Length-weight parameter a	1.04E-05														
Length-weight parameter b	3.043														
Steepness	0.8														
Maximum age	16														
CV Catch	0.2														
CV Depletion over time t	0.5														
CV Average catch over time t	0.221														
CV Abundance index	0.45														
CV M	0.4														
CV FMSY/M	0.3														
CV BMSY/B0	0.045														
CV current stock depletion	0.5														
CV current stock abundance	1														
CV von B. K parameter	0.1														
CV von B. Linf parameter	0.1														
CV von B. t0 parameter	0.1														
CV Age at 50% maturity	0.25														
CV Length at first capture	0.25														
CV Length at full selection	0.25														
CV Length-weight parameter a	0.1														
CV Length-weight parameter b	0.1														
CV Steepness	0.3														
Sigma length composition	0.2														
Units	metric tons														
Reference OFL	NA														
Reference OFL type	NA														
CAA_bins	1	2	3	4	5	6	7								
CAA 1981	1380	14183	14401	3608	666	182	111								
CAA 1982	575	14153	12374	3713	608	212	202								
CAA 1983	616	7232	13273	6111	1791	695	544								
CAA 1984	493	11470	13940	4890	1770	873	803								
CAA 1985	274	7342	12771	6013	2922	1819	1404								
CAA 1986	216	6327	9101	4218	1053	442	357								
CAA 1987	74	5265	8988	3084	2690	751	424								
CAA 1988	85	3946	9401	3963	1206	978	303								
CAA 1989	468	5275	7208	3541	861	226	214								
CAA 1990	36	2110	6276	2933	768	196	142								
CAA 1991	52	3029	7146	3349	860	252	113								
CAA 1992	25	1507	4460	2582	673	162	53								
CAA 1993	292	2200	3520	1897	714	188	138								
CAA 1994	251	2612	2339	1280	337	97	39								
CAA 1995	88	654	3112	2202	506	83	20								
CAA 1996	171	1050	3289	2181	556	129	40								
CAA 1997	88	1841	3488	2252	584	96	39								
CAA 1998	16	1371	3043	1788	555	185	74								
CAA 1999	5	2146	4062	1577	375	82	18								
CAA 2000	43	1336	3436	2473	822	146	72								
CAA 2001	35	1689	3503	2274	883	231	124								
CAA 2002	14	478	1897	1830	925	324	115								
CAA 2003	15	498	1802	1199	501	223	136								
CAA 2004	36	378	999	858	331	223	167								
CAA 2005	32	417	765	755	328	134	81								
CAA 2006	39	758	1598	686	277	133	108								
CAA 2007	7	335	1460	1010	290	84	42								
CAA 2008	34	243	699	725	278	126	66								
CAA 2009	83	195	271	268	211	66	30								
CAA 2010	67	87	150	159	87	52	35								
CAA 2011	222	169	222	216	106	73	53								
CAA 2012	33	158	336	305	141	56	55								
CAA 2013	45	209	386	561	201	123	91								
CAA 2014	34	50	223	242	196	154	137								

Table A6. Input values used in the DLMtool R package for pollock. This file shows the model run using the fall index of abundance with all available years. For runs calculating the catch following GARM 1, 2, and 3, the dataset was truncated using data through 2001, 2004, and 2007, respectively.

Name	Pollock_fall												
Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Catch	11555	14319	12995	13080	12014	13482	12731	15516	21512	17645	22201	22879	20787
Abundance index	0.551	0.949	1.483	0.969	1.007	0.704	4.296	2.342	1.062	0.873	0.494	1.1	0.793
Year (cont.)	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Catch (cont.)	19443	21112	21244	25155	20533	15365	11483	9916	8473	7470	5876	4337	4254
Abundance index (cont.)	1.001	0.28	1.107	0.424	0.541	3.963	1.642	0.699	0.696	0.907	1.096	0.374	0.856
Year (cont.)	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Catch (cont.)	3709	4728	5932	4945	4717	5436	4721	5736	6064	7228	7078	9280	12216
Abundance index (cont.)	1.011	1.704	2.058	2.282	2.449	2.113	3.179	7.742	3.106	5.064	1.672	0.332	1.01
Year (cont.)	2009	2010	2011	2012	2013	2014							
Catch (cont.)	8755	7373	9738	8277	8594	6071							
Abundance index (cont.)	0.25	1.134	4.391	1.577	1.322	11.335							
Duration t	45												
Average catch over time t	11466												
Depletion over time t	NA												
M	0.2												
FMSY/M	1												
BMSY/B0	0.35												
MSY	NA												
BMSY	NA												
Age at 50% maturity	3.7												
Length at first capture	30												
Length at full selection	56												
Current stock depletion	NA												
Current stock abundance	NA												
Von Bertalanffy K parameter	0.16												
Von Bertalanffy Linf parameter	108												
Von Bertalanffy t0 parameter	-0.44												
Length-weight parameter a	0.00000743												
Length-weight parameter b	3.09												
Steepness	0.8												
Maximum age	20												
CV Catch	0.2												
CV Depletion over time t	0.5												
CV Average catch over time t	0.221												
CV Abundance index	0.45												
CV M	0.4												
CV FMSY/M	0.3												
CV BMSY/B0	0.045												
CV current stock depletion	0.5												
CV current stock abundance	1												
CV von B. K parameter	0.1												
CV von B. Linf parameter	0.05												
CV von B. t0 parameter	0.1												
CV Age at 50% maturity	0.2												
CV Length at first capture	0.2												
CV Length at full selection	0.2												
CV Length-weight parameter a	0.1												
CV Length-weight parameter b	0.1												
CV Steepness	0.1												
Sigma length composition	0.2												
Units	metric tons												
Reference OFL	NA												
Reference OFL type	NA												
CAA_bins	1	2	3	4	5	6	7	8	9				
CAA 1970	0	645	436	990	884	563	392	243	213				
CAA 1971	0	1044	1487	1267	1019	796	276	117	6				
CAA 1972	0	286	777	1013	746	331	173	39	270				
CAA 1973	0	566	864	2715	1493	204	82	29	149				
CAA 1974	0	87	2414	1110	968	411	127	70	86				
CAA 1975	0	107	530	1871	809	791	337	95	114				
CAA 1976	0	79	905	1234	1948	466	354	81	29				
CAA 1977	0	23	471	1259	870	1058	400	297	378				
CAA 1978	0	91	824	1056	1141	810	1085	373	695				
CAA 1979	0	200	1553	2225	1311	635	278	293	288				
CAA 1980	0	194	415	2040	2189	1355	653	218	357				
CAA 1981	0	587	1545	697	2014	1140	603	322	411				
CAA 1982	0	120	1616	894	366	1005	683	437	636				
CAA 1983	0	36	1047	3252	814	222	428	283	623				
CAA 1984	0	44	574	2172	3609	697	123	180	423				
CAA 1985	0	196	1854	758	1794	2043	334	87	411				
CAA 1986	0	54	940	3120	927	1650	1208	182	427				
CAA 1987	0	81	950	856	2703	546	637	413	396				
CAA 1988	0	0	360	803	848	1614	441	262	281				
CAA 1989	53	111	321	1352	801	457	504	190	215				
CAA 1990	13	13	645	911	1142	375	201	146	224				
CAA 1991	152	66	186	798	610	664	164	77	194				
CAA 1992	197	112	78	459	754	440	347	81	100				
CAA 1993	413	40	108	136	320	546	273	148	63				
CAA 1994	8	4	3	62	181	283	240	95	86				
CAA 1995	21	12	30	107	174	233	208	86	54				
CAA 1996	96	40	66	166	224	258	141	75	29				
CAA 1997	1	9	24	160	451	366	193	75	44				
CAA 1998	1	2	15	45	322	696	335	93	25				
CAA 1999	1	12	23	171	253	402	326	107	44				
CAA 2000	0	1	26	118	376	334	175	93	61				
CAA 2001	0	2	32	161	292	399	222	90	66				
CAA 2002	4	8	27	97	259	166	230	111	78				
CAA 2003	1	16	8	101	289	373	221	165	106				
CAA 2004	43	11	23	12	170	432	386	172	146				
CAA 2005	1	8	8	32	75	570	646	286	148				
CAA 2006	1	2	9	6	106	202	679	367	165				
CAA 2007	7	13	24	56	89	610	397	636	356				
CAA 2008	24	42	48	48	97	205	1014	367	706				
CAA 2009	5	39	38	163	102	316	306	517	582				
CAA 2010	5	5	25	122	269	161	254	167	437				
CAA 2011	4	12	21	190	383	515	244	293	436				
CAA 2012	5	19	30	93	393	540	412	161	346				
CAA 2013	3	41	56	113	145	457	370	189	220				
CAA 2014	5	25	107	203	277	238	394	185	140				