Appendix III, Variable Selectivity SYM Reference Point Model

Deborah R Hart and Jui-Han Chang
Northeast Fisheries Science Center

Introduction

Reference point calculations are typically based on the assumption that (fully recruited) fishing mortality F_{Full} and fishery selectivity are separable, so that changes in fishing mortality does not affect selectivity. As will be shown, this assumption may often be incorrect. At high fishing mortalities, the fishery may target smaller animals than when the fishing mortality is low. The purpose of this Appendix is to present an extension of the SYM reference point model (Hart 2013, NEFSC 2018) where fishery selectivity is allowed to vary with fishing mortality.

Methods

Logistic fishery selectivity S as a function of shell height h was modeled as:

$$S(h) = \frac{1}{1 + \exp(\alpha - \beta h)} \tag{1}$$

To evaluate changes in selectivity with fishing mortality, the parameter β was fixed at its estimated value (from the base CASA models) for the period since 4" rings have been implemented (2005-2019; 2005-2017 for GB Closed Area because of the unusual 2018-19 fishery), and α was estimated for each year. The logistic curve can also be parameterized using L_{50}, the value of h where selectivity is 0.5. A simple calculation shows that $\alpha = \beta L_{50}$, so that with β fixed, estimating α is equivalent to estimating L_{50}. Thus, fixing β while varying α fixes the steepness of the logistic curve while L_{50} varies.

We then regressed the L_{50}s estimated from the CASA model with a four-year lagged moving averaged F_{Full}, or alternatively, the mean exploitable weight of the population as estimated in the CASA model (Figure 1; in the Georges Bank Closed Area model, 2015-16, when there was little fishing in this area, as well as 2018-19, were excluded). Regressions were performed separately for Mid-Atlantic and Georges Bank. The meat weight regressions fit better (Figure 1, $R^2 = 0.76$ for Georges Bank and $R^2 = 0.41$ for Mid-Atlantic; in both cases the slopes were significantly different from zero, $p < 0.01$), and therefore were used in the subsequent analysis.

The use of the meat weight regression creates a complication, because at equilibrium, the mean exploitable meat weight $W(F)$ depends on selectivity as well as F_{Full}, while selectivity is a function of meat weight. To get around this circularity, for the purposes of estimating L_{50} from the regression, $W(F)$ was estimated in the per recruit simulations from $W(F - 0.01)$ and $W(F - 0.02)$ (which have already been calculated), using the linear approximation:

$$W(F) \simeq W(F - 0.01) + [W(F - 0.01) - W(F - 0.02)] = 2W(F - 0.01) - W(F - 0.02) \tag{2}$$

Mean weights for $F = 0.01$ and 0.02 were directly input, based on simulations. The resulting $W(F)$ were used to determine Ł50 and α, and hence the selectivity curve Eq (1) as a function of F_{Full}, using the regression equations. This variable selectivity was used to perform per recruit calculations in the SYM model, which were combined with stock-recruit relationships to obtain yield curves and MSY-based reference points.

Results and Discussion

When employing variable selectivity, the distribution of most reference points tended to be more concentrated, and so were more certain (Figures 2, 3, 4). This is because the variable selectivity reduces yields at both very low and very high fishing mortalities, resulting in steeper yield curves (Figures 5,6). The combined fishing mortality reference point is slightly lower than the fixed selectivity model ($F_{\text{MSY}} = 0.55$ compared to $F_{\text{MSY}} = 0.61$ using the fixed selectivity model), but MSY is slightly greater B_{MSY} and slightly less using the variable selectivity approach (Table 1). Because the two models give similar reference points, it is recommended to keep the present approach for this assessment, but develop further the variable selectivity model for use in future assessments.

References

Hart, DR. 2013. Quantifying the tradeoff between precaution and yield in fishery reference points. ICES Journal of Marine Science, 70:591-603.

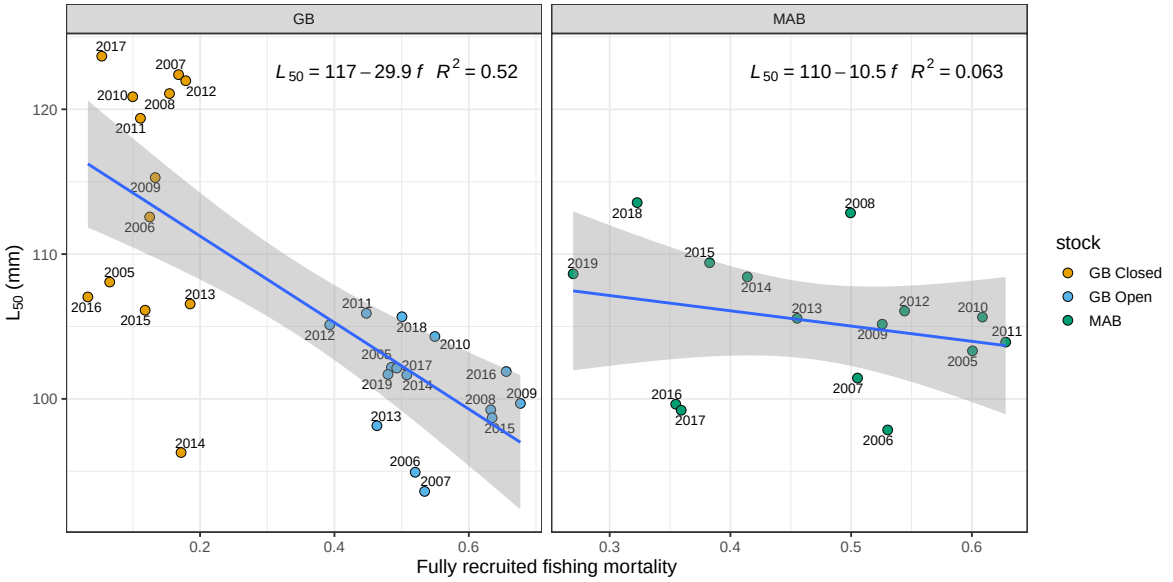
Northeast Fisheries Science Center (NEFSC). 2018. 65th Northeast Regional Stock Assessment Workshop (65th SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 18-11; 659 p.

Table

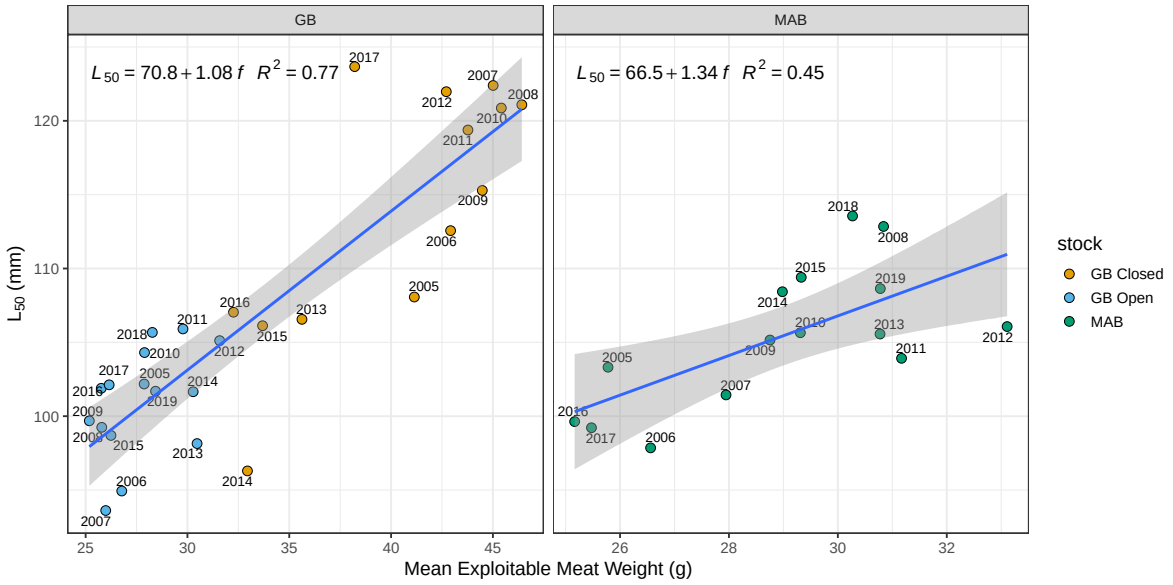
Table 1. Summary of reference points for Georges Bank, Mid-Atlantic and combined for the variable selectivity SYM model. Med. $\text{Yield}_{0.55}$ and Med. $\text{SSB}_{0.55}$ are the yield and SSB from the median curves at the combined $F_{\text{MSY}} = 0.61$.

Region	F_{MSY}	MSY	B_{MSY}	Med. $\text{Yield}_{0.55}$	Med. $\text{Bms}_{0.55}$
GB	0.46	14219	52044	14081	43786
MA	0.60	18717	53205	18678	57440
Combined	0.55	32760	101227	32760	101227

Figures



(a)



(b)

Figure 1. Regressions of L_{50} vs. (a) fully recruited 4-year lagged moving average fishing mortality and vs. (b) mean exploitable meat weight. Separate regressions were performed for Georges Bank and the Mid-Atlantic.

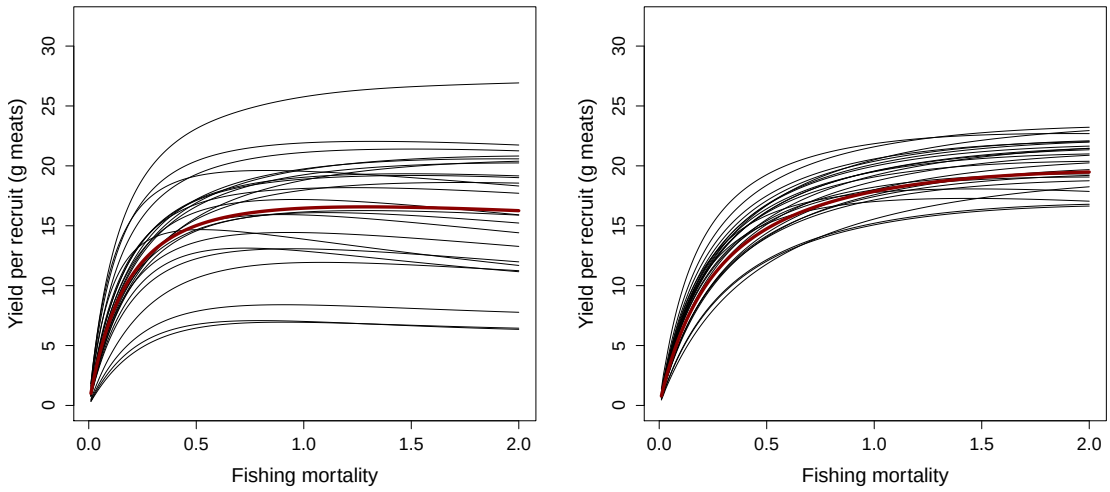


Figure 2. Mean yield per recruit plot (dark red line) together with 25 example yield per recruit plots (thin black lines) from the variable selectivity SYM model for Georges Bank (left) and the Mid-Atlantic (right).

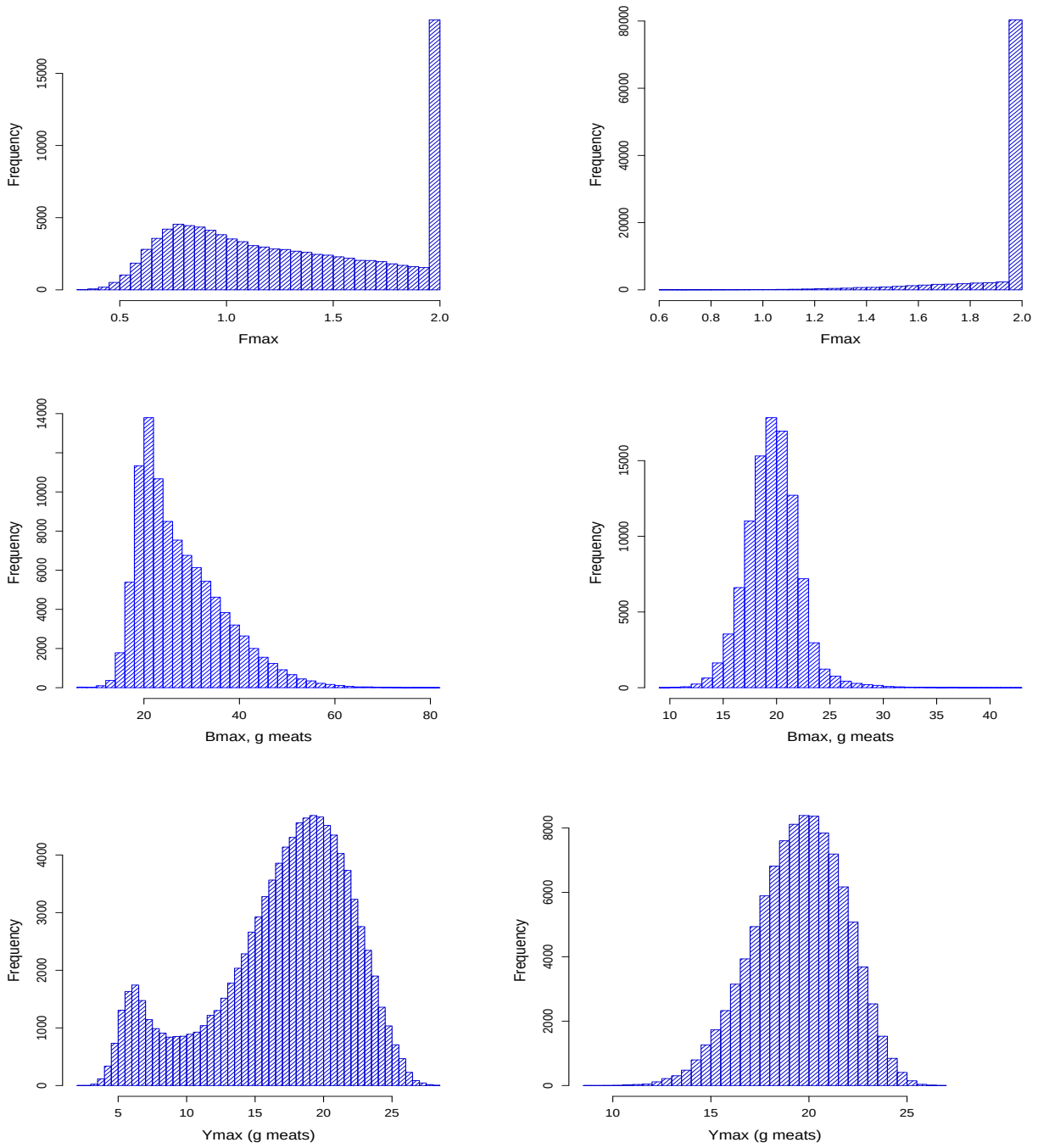


Figure 3. Distribution of the variable selectivity yield per recruit reference point F_{MAX}, B_{MAX} and Y_{MAX} for the Georges Bank (left), and the Mid-Atlantic (right).

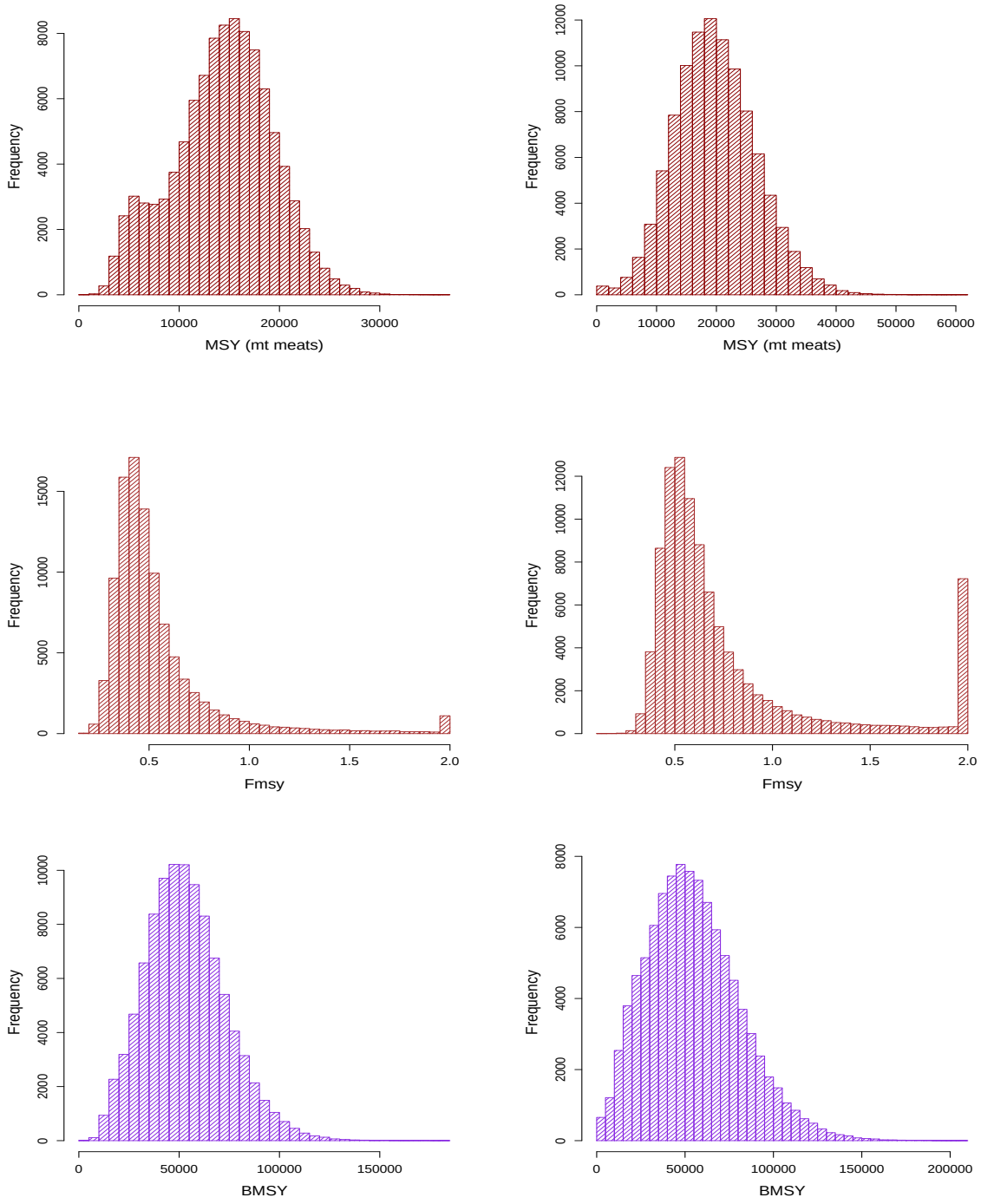


Figure 4. Distributions of variable selectivity MSY, F_{MSY} and B_{MSY} for Georges Bank (left) and Mid-Atlantic (right).

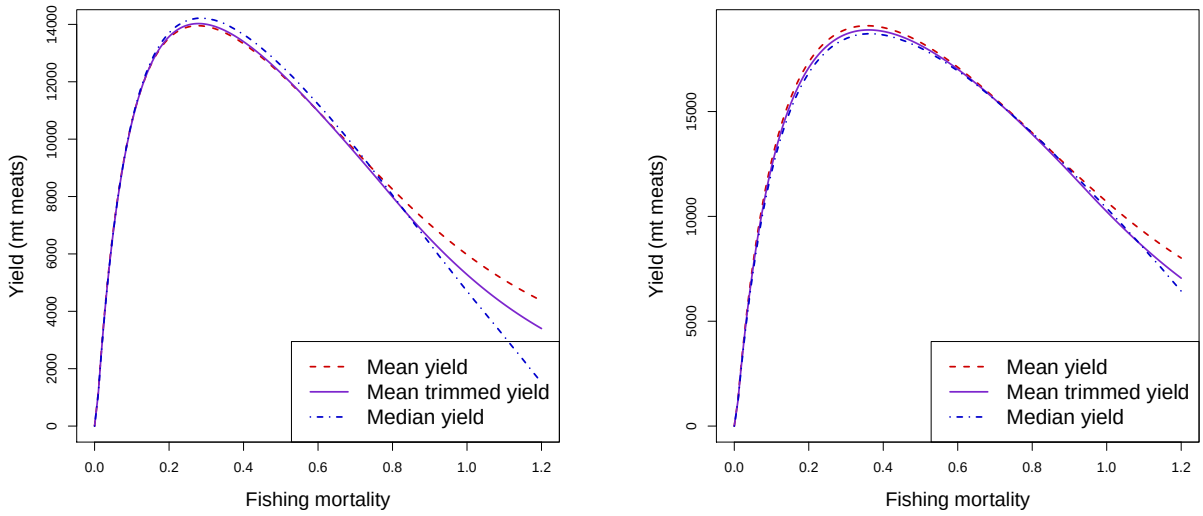


Figure 5. Estimated variable selectivity mean, trimmed mean, and median yield curves Georges Bank (left) and Mid-Atlantic (right).

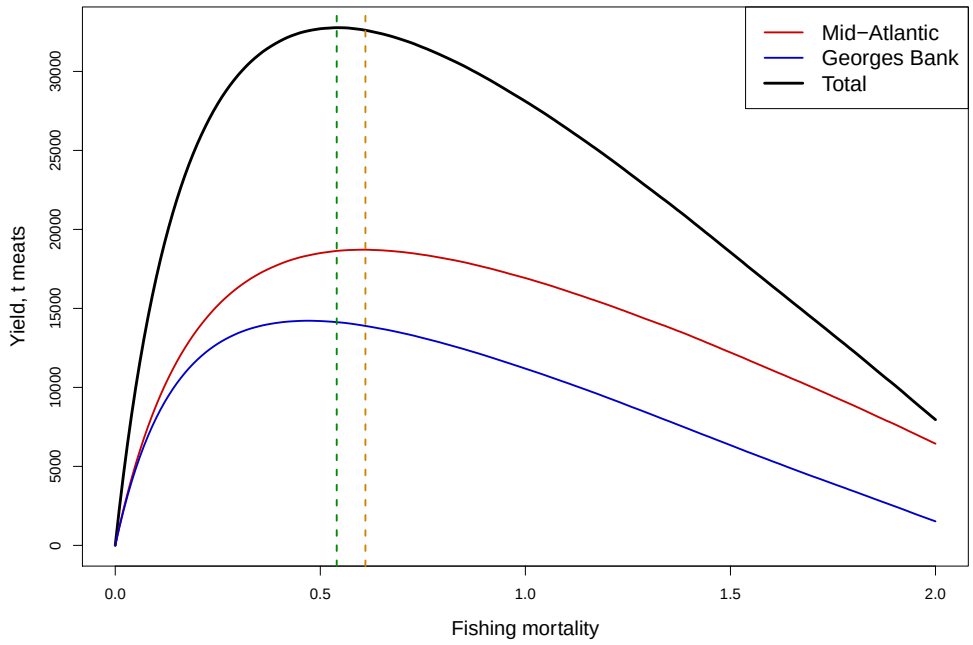


Figure 6. Median yield curves using variable selectivity for Georges Bank (blue), the Mid-Atlantic (red) and combined (black). The vertical lines are at the estimated $F_{\text{MSY}} = 0.55$ for the variable selectivity model (green), and $F_{\text{MSY}} = 0.61$ for the fixed selectivity model.