Evaluating the Precision and Accuracy of the Yellowtail flounder Movement-Mortality Model via simulation

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Relevance to the GARM Data Meeting

In this study we begin to address the uncertainty of the yellowtail flounder movement-mortality model (GARM WP 3F) by simulating a population that emulates the yellowtail flounder population and tagging study. Within this purview, results of this exercise are expected to provide some insights on the properties of the model with application to the yellowtail tagging study (TOR C).

Background

A simulation study was developed in association with the yellowtail tagging study to test the performance of the movement-mortality model with datasets of similar characteristics under varying assumptions of measurement and process errors. The operating model concept described by Hilborn and Walters (1992) form the basis for developing the simulation tool for yellowtail movement-mortality model and application. Within this framework, the simulation study assumes that population processes (i.e. mortality, survival, movement etc) are applicable to the subpopulation tagged for the study. Here, we present the model simulation design and preliminary results on the precision and accuracy estimates of fishing mortality and movement rates, under different assumptions regarding spatial structure in the population and stochastic processes.

Simulation Approach

Simulated Population

We simulated an age-structured model of a single cohort of yellowtail flounder recruits. Initial numbers of recruits to the population were drawn directly from the assessments and subsequent abundances were generated using age and year specific instantaneous fishing mortality rates with an assumed natural mortality rate of 0.2. Additionally, these abundances were simulated with some assumed fixed movement rate consistent with the movement rates defined for the simulated tagged population. Hence, we make the

assumption that the movement processes occurring at the subpopulation level (i.e. tagged population) is also operating on the population level in general. In this study, movement is modeled as a discrete process and assumed to be conditioned by survival from the previous year.

Movement-Mortality Simulation

Stochastic simulations were developed in which tagged "virtual" fish were released and subsequently recaptured in the model. To emulate the patterns of releases from the tagging study, proportions of tags to be allocated in the simulation were taken directly from the field study and applied to the simulated total abundances by year. Datasets of simulated tag releases were generated with observation errors around true releases by randomly sampling a lognormally distributed measurement errors with a 5% coefficient of variation (CV). Using the movement-mortality model, predicted tag recaptures were generated assuming a fixed natural mortality of 0.2 and a global reporting rate of 0.57. Datasets of simulated recaptures were generated by also randomly sampling a lognormally distributed measurement and process error around the true value with a series of different precisions (10%, 25%, 50% and 75% CV). Reporting rates were estimated consistent with yellowtail flounder tagging analyses, based on the ratio of returns from standard tag to high reward tags, assuming a 100% reporting rate for the high rewards. Model simulations were repeated 100 times with mortality and movement parameters estimated by comparing the simulated datasets of recaptures to the "true" recaptures using a least square estimator. Relative model performance was then evaluated by computing the bias and precision between the average of the 100 estimates and "true" values from the reference model.

Simulated model Specifications

Here, we consider a simple base case model specification (Single Fishing mortality rate and six movement rates) and a more complex model configuration (independent fishing mnortality rates and six movement rates) to test model performance with assumed random errors at various levels of precision ranging from 10% - 75% CV. Furthermore, we differentiate between two modes of movement patterns, characterized as symmetric and asymmetric. A symmetric movement simply refers to equal proportion of movement from a release stock to adjacent stocks while asymmetric movement can be considered as disproportional movement patterns to adjacent stocks. The following compares three case scenarios simulated for the movement-mortality model:

1. *Global* Fishing Mortality rates (F = 1.00) simulated with ***no*** movement rates (α = 0.00; residency = 1.00) among the three stocks

2. *Global* Fishing Mortality rates (F = 1.00) simulated with low (α_1 = 0.05 and α_2 = 0.05; residency = 0.90) and moderate (α_1= 0.25 and α_2 = 0.25; residency = 0.50) ***symmetrical*** movement rates among the three stocks

3. Three *Independent* fishing mortality rates (F_{GB} = 1.10, F_{CCGOM} = 0.76, F_{SNEMA} = 1.40) and ***asymmetric*** movement rates (α_1 =0.05 and α_2=0.25; residency = 0.70).

Results

Preliminary results from the simulation exercise suggest that accuracy of fishing mortality and movement rates tend to increase with precision of input data. However, when the model assumes a global fishing mortality rate with zero or low movement rates, estimates of movement tend to be confounded, suggesting that the application of a single population assumption will be an inappropriate specification for the model (Figure 1).

Alternatively, when moderate movement is introduced to the model at precision levels ranging from 10% to 25% CV, fishing mortality rates are relatively accurate (Figures 3 and 4). At 50% CV and above, simulated fishing mortality estimates become unreliable, denoted by low to moderate frequency of non-convergence in the model (Figure 12). Relative to fishing mortality rates, estimates of movement rates were generally accurate with low to moderate bias (1% - 13%) from the true value. However, caution should be taken when interpreting these movement rates at CV's of 50% and higher as the model structure is designed to simultaneously estimate rates of fishing mortality and movement (Figures 5, 6, 7 and 8).

Analysis of the independent fishing mortality and asymmetric movement rate model performed relatively well, mostly at error levels ranging between 10% - 25% CV. However at 50% CV error level, simulated estimates of fishing mortality for Cape Cod-Gulf of Maine tends to be fairly accurate with moderate precision. Estimates of movement rates on the other hand, tend to be moderately accurate at all levels of simulated errors. The exception was noticed with movement rates from Georges Bank when simulated with measurement errors greater than 25% CV and movement rates from Cape Cod-Gulf of Maine with process errors greater than 25% CV. At these levels of error, the model produced relatively inaccurate estimates of movement (Figures 9, 10 and 11).

The results in this paper only provide a snapshot of the several possibilities for simulation and analyses. Based on the presented simulations, input recapture data with precision around 10% - 25% tends to provide the most accurate estimates of fishing mortality and movement rates. While exploratory simulations continue to determine the general properties of the model, the results in this paper should be viewed as demonstrations of the several alternatives to be simulated. Some of the future next steps in the simulation involve evaluating the effect of sample size on variance estimates, simulating a design that assumes proportional releases, time varying mortality rates and stock-specific reporting rate. Additionally, a simulation exercise that evaluates the effect of recapture sample size on the precision of natural mortality estimates will be considered as potential basis to relax this assumption in the model.

References:

Hilborn, R. and C.J. Walters. 1992. Quantitative Fisheries Stock Assessment: choice, dynamics and uncertainty. Chapman and Hall, New York

NEFSC (Northeast Fisheries Science Center). 2002. Final report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. Northeast Fisheries Science Center Reference Doc. 02-04. 249 p. + appendices.

NEFSC (Northeast Fisheries Science Center). 2005. Assessment of 19 Northeast Groundfish stocks through 2004. Northeast Fisheries Science Center Reference Doc. 05-13.

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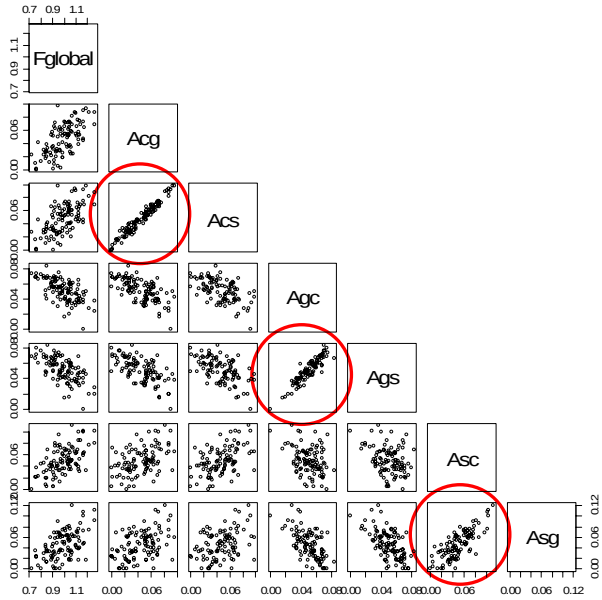

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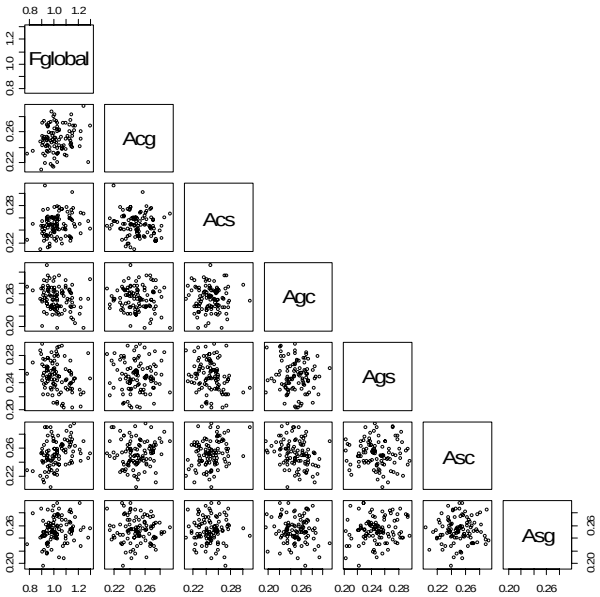

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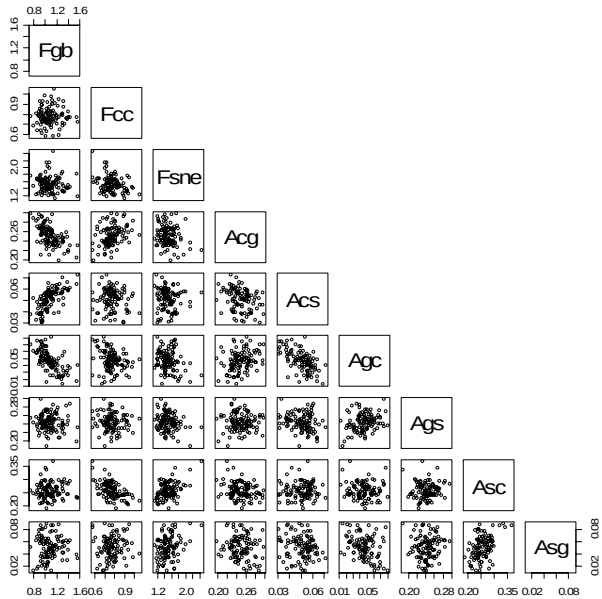

**Note:* Covariance analyses is based on the simulations with the highest precision in combined measurement and process errors (10% CV)

Figure 1: Covariance between estimates of movement and fishing mortality rates based on model specifications #1 (Global Fishing Mortality with no movement); #2a (Global Fishing Mortality rates and low symmetric movement) #2b (Global Fishing Mortality rates and moderate symmetric movement); #3 (Independent fishing mortality rates and Asymmetric movement). Each panel represents 100 estimates from the simulation run. Strong correlations among parameter estimates are depicted in the red circles.

Figures for Model Specification #2

Global Fishing Mortality simulated with Moderate (25%) Movement rate

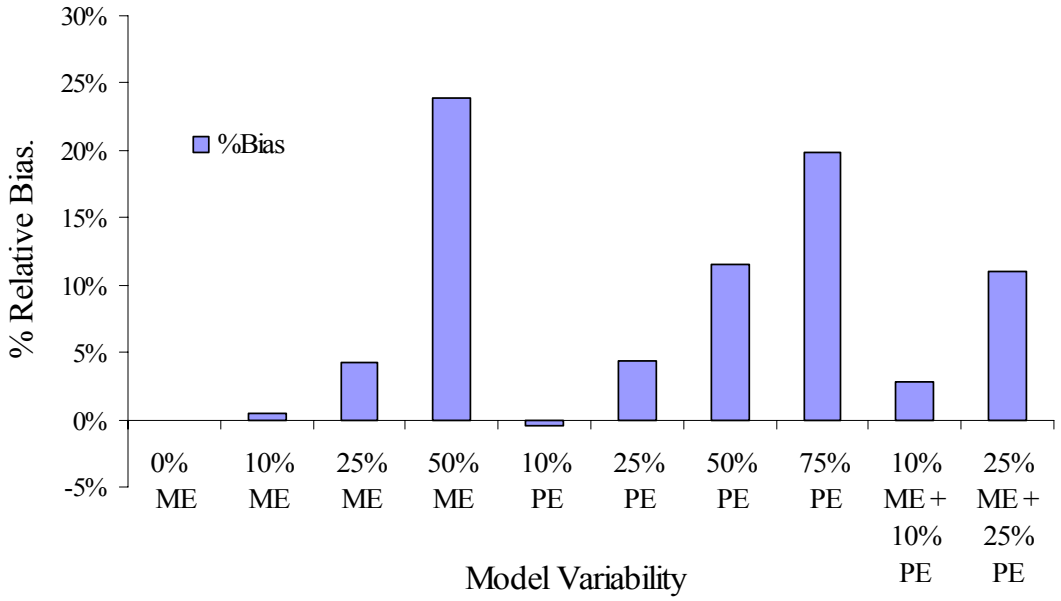

Figure 3: Accuracy of mean global fishing mortality rate with no movement at 10% and 25% CV. Each bar represents 100 simulations with ME representing measurement errors in recaptures and PE is the process error in the survival-movement process

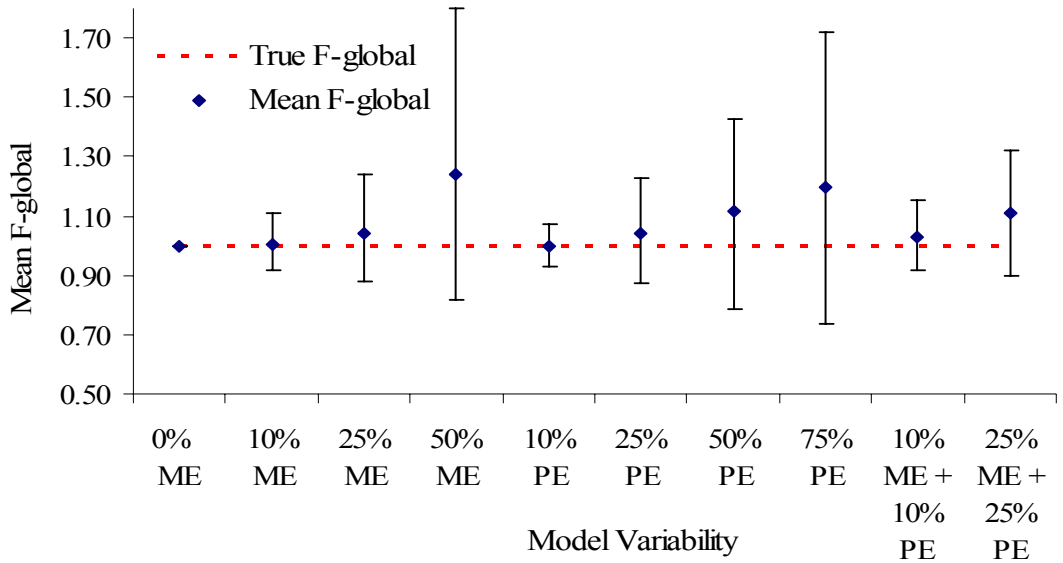

Figure 4: Precision estimates of mean global fishing rate and 80 % percentile confidence Interval, simulated with 25% movement at 10%, 25%, 50% & 75%CV. Simulated true value for F-global from the reference model = 1.00

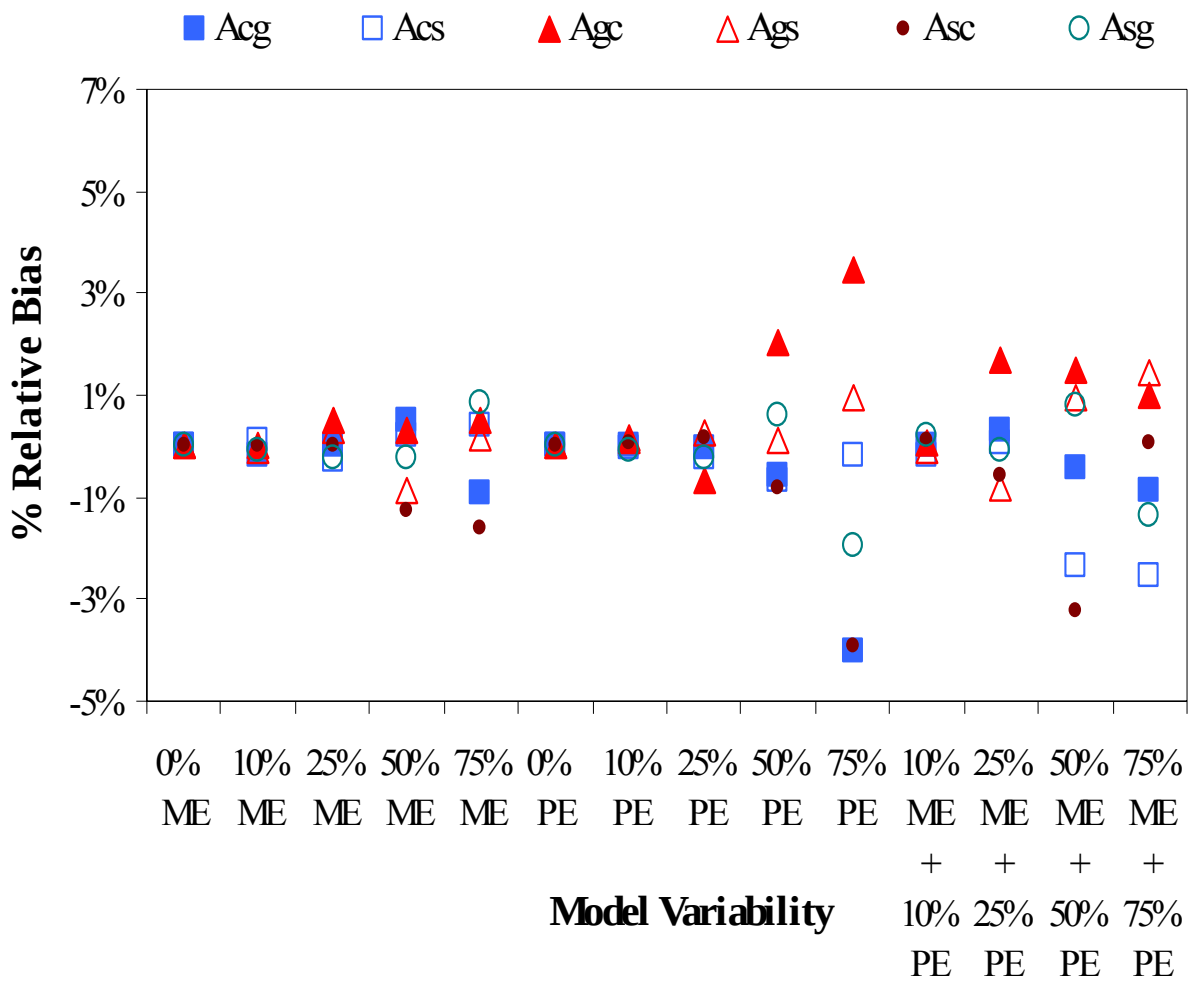

Figure 5: Accuracy of movement rates simulated with global fishing mortality at 10%, 25%, 50% & 75% CV levels of precision. Simulated true value for movement from the reference model = 0.25. Blue squares represent movements from Cape Cod Gulf of Maine to adjacent stocks (Acg = Cape Cod Gulf of Maine to Georges Bank; Acs = Cape Cod Gulf of Maine to Southern New England); Red Triangles indicate movement from Georges Bank to adjacent stocks (Agc = Georges Bank to Cape Cod Gulf of Maine; Ags = Georges Bank to Southern New England Mid Atlantic) and the green circles are movements from Southern New England to other stock regions (Asc = Southern New England-Mid Atlantic to Cape Cod-Gulf of Maine; Asg = Southern New England-Mid Atlantic to Georges Bank).

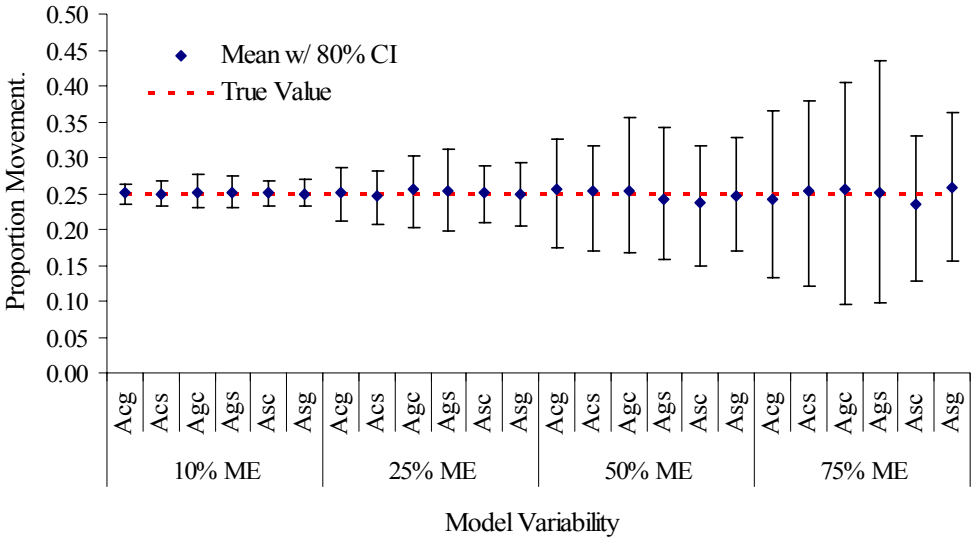

Figure 6: Precision of movement rates and 80% percentile CI, simulated at 10%, 25%, 50% & 75% CV levels of precision with random measurement errors. Simulated true value for movement from the reference model = 0.25

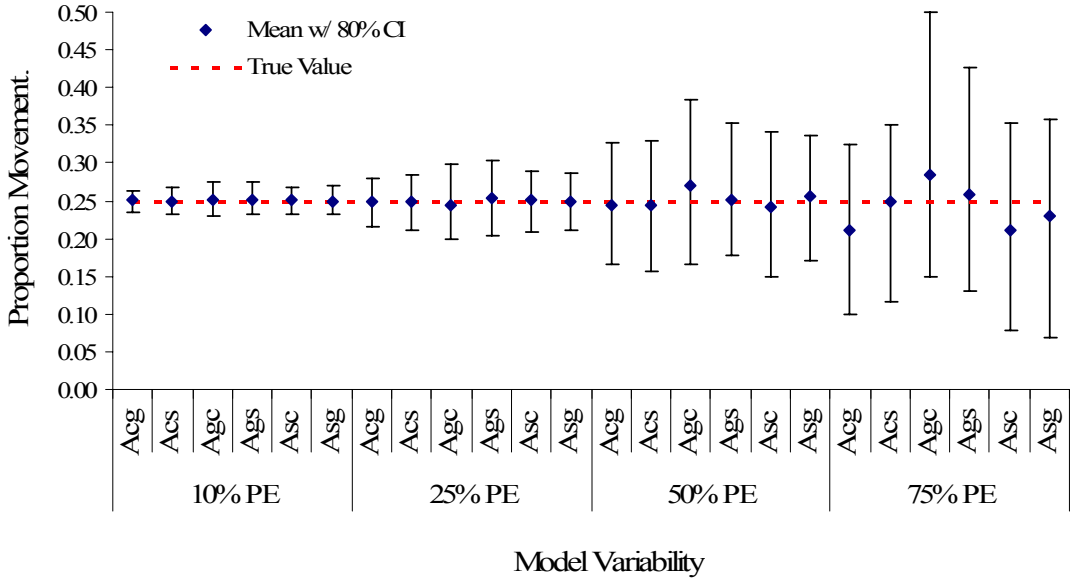

Figure 7: Precision of movement rates and 80% percentile CI, simulated at 10%, 25%, 50% & 75% CV levels of precision with random process errors. Simulated true value for movement from the reference model = 0.25

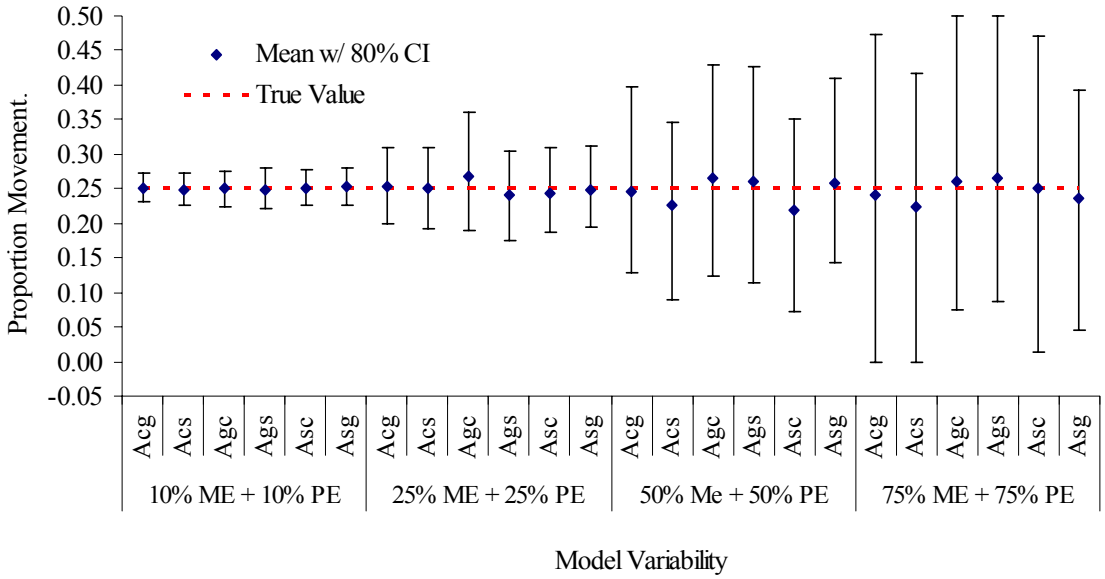

Figure 8: Precision of movement rates and 80% percentile CI, simulated at 10%, 25%, 50% & 75% CV levels of precision with random measurement and process errors. Simulated true value for movement from the reference model = 0.25

Figures for Condition #3:

Independent Fishing Mortality simulated with Asymmetric Movement

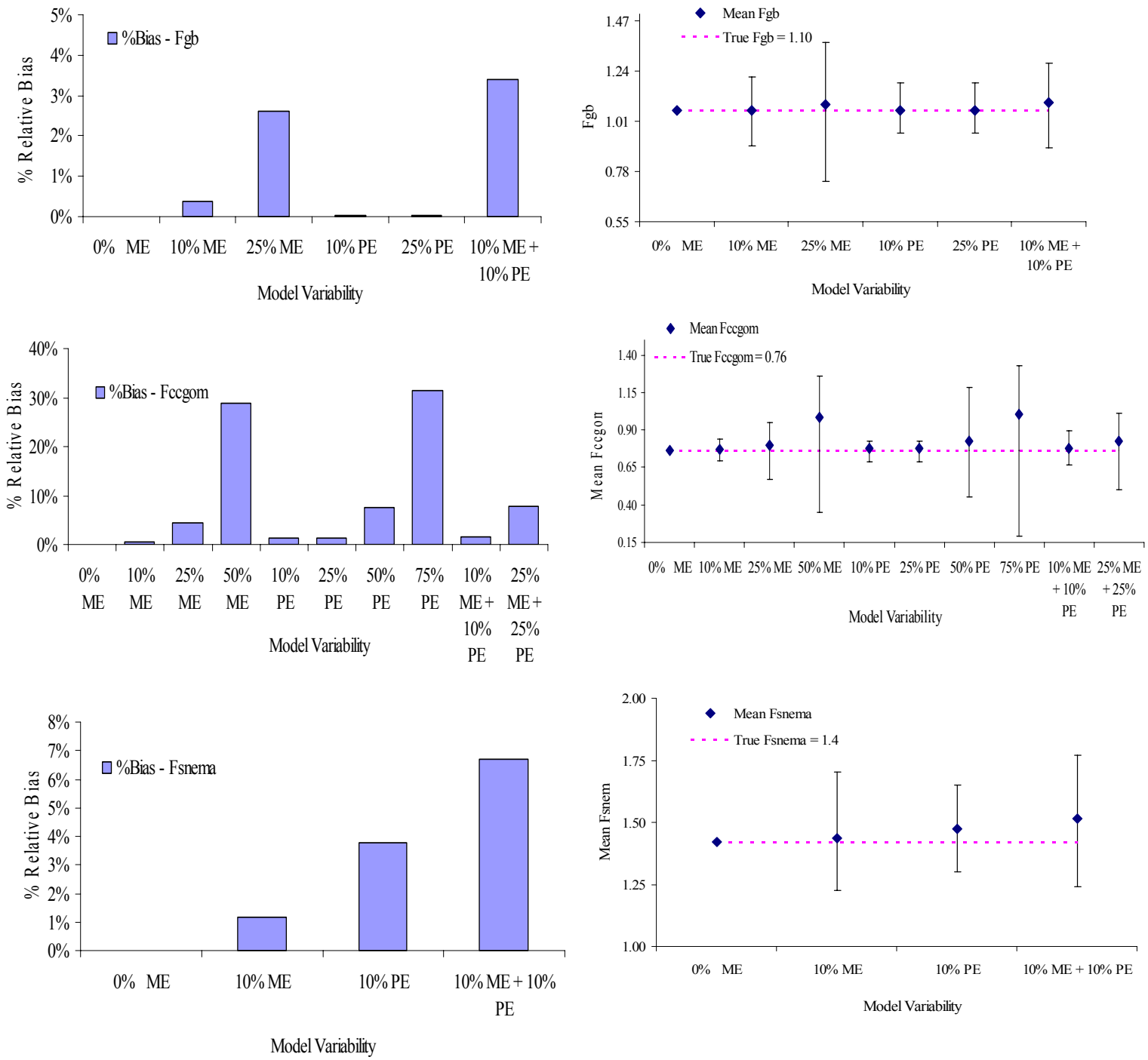

Figure 9: Accuracy and precision of reliable estimates of fishing mortality rates for Georges Bank (GB), Cape Cod-Gulf of Maine (CCGOM) and Southern New England-Mid Atlantic (SNEMA) simulated with measurement and process errors at 10%, 25%, 50% & 75% CV

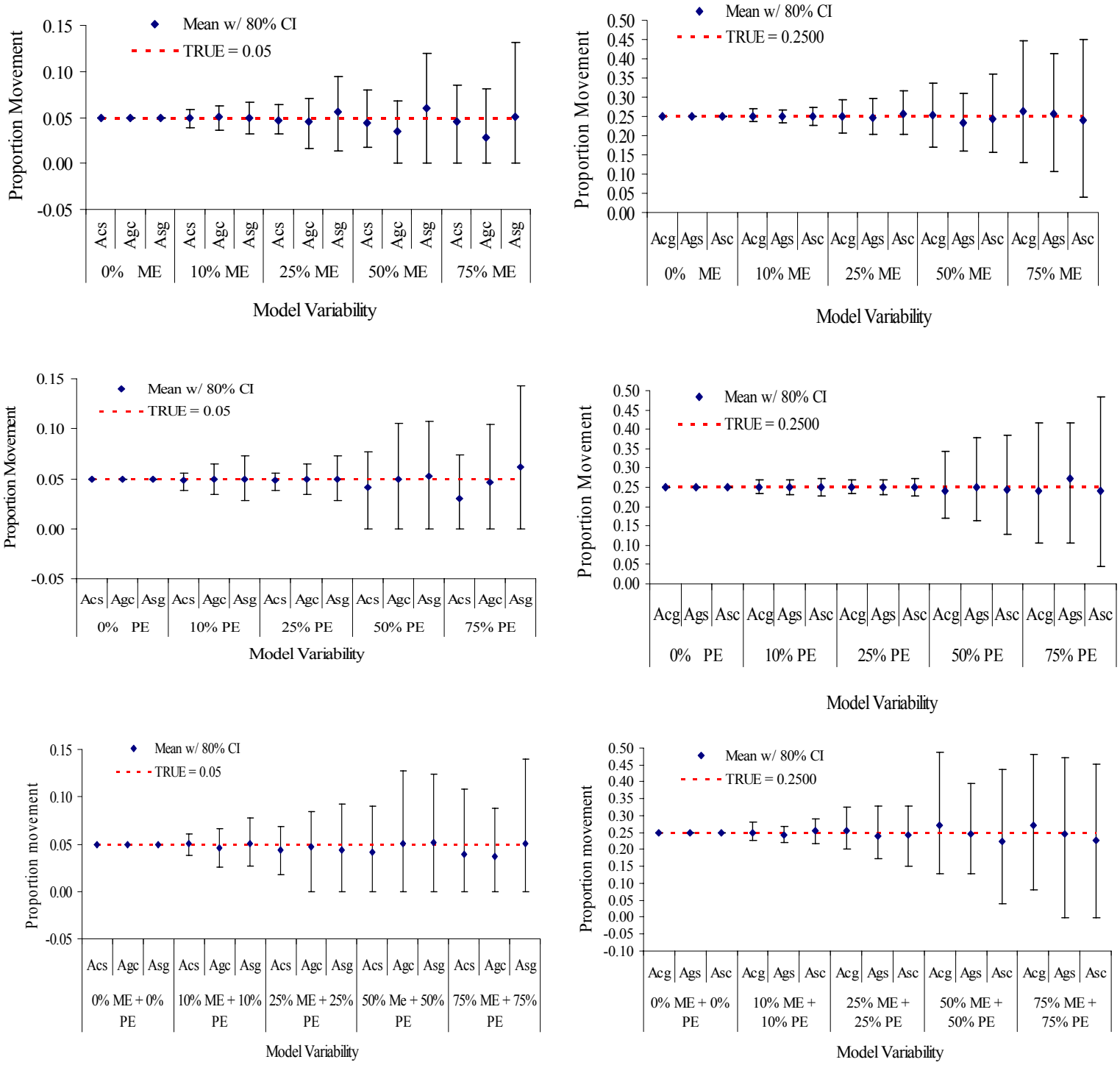

Figure 10: Precision estimates of mean movement rates and 80% CI, simulated at 10%, 25%, 50% & 75% CV with random, measurement, process and combined error processes. Simulated true value for movement from the reference model = 0.05 and 0.25.

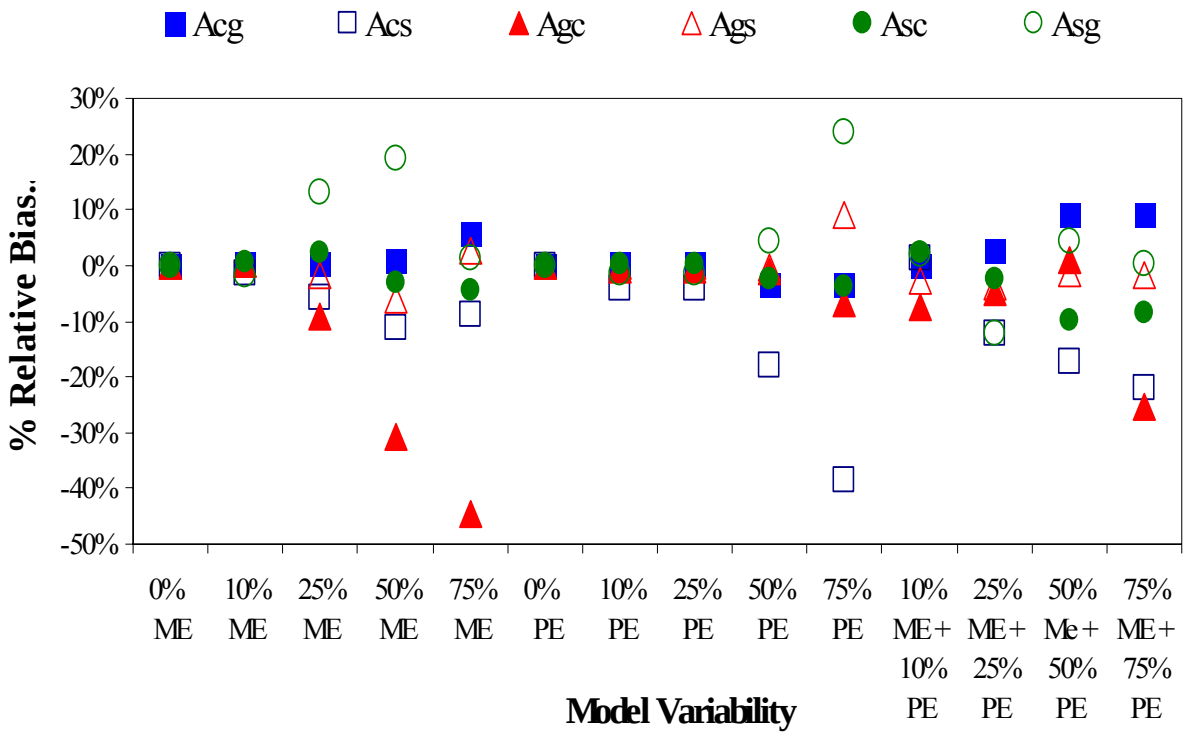

Figure 11: Accuracy of movement rates simulated with global fishing mortality at 10%, 25%, 50% & 75% CV levels of precision. Simulated true values for movement from the reference model = 0.05 and 0.25

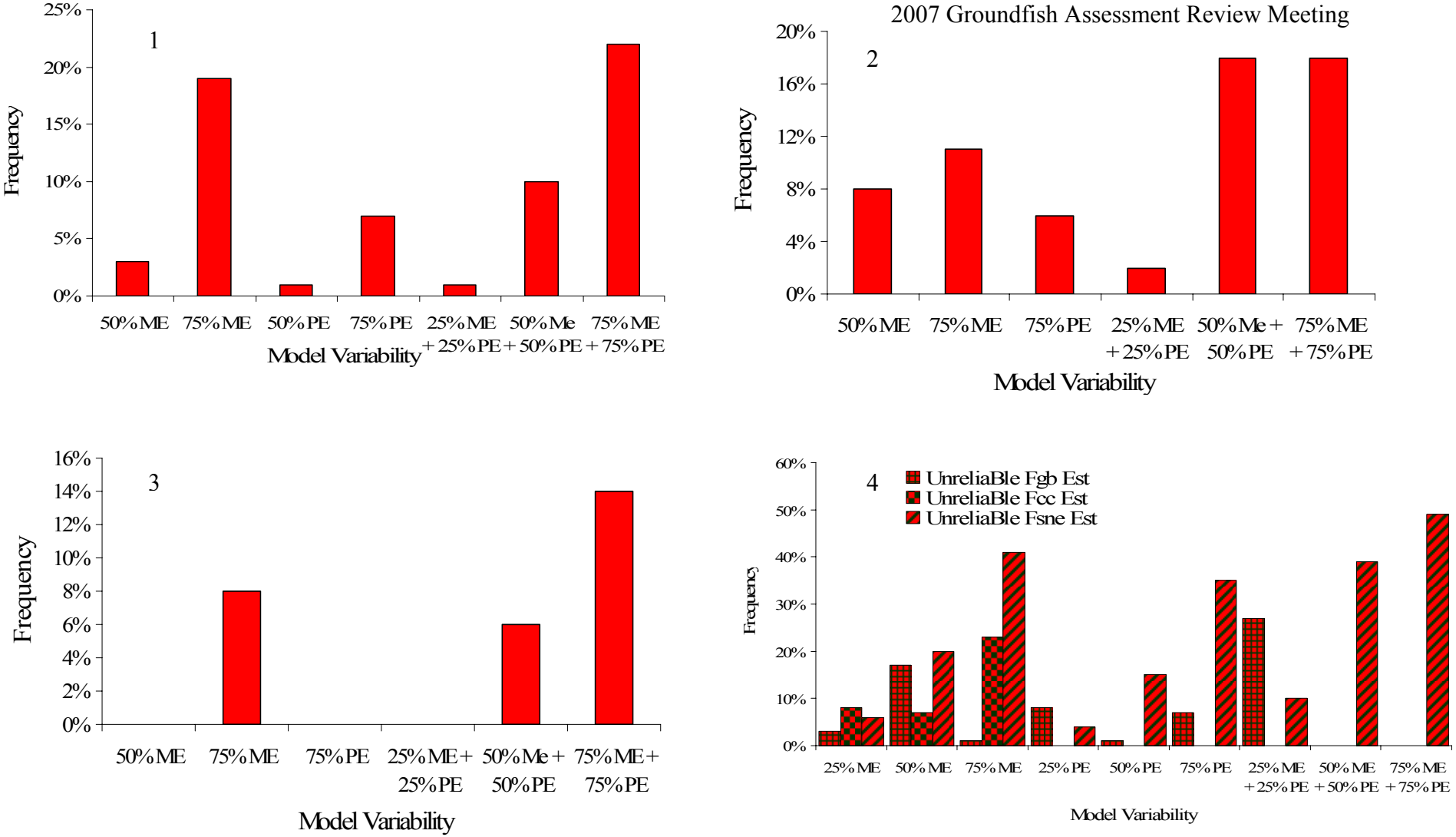

Figure 12: Frequency of unreliable estimates of fishing mortality rates from the simulation runs, defined by F =10.00 in the upper bound constraints in the estimation procedure. (1) Global fishing mortality rates with no movement; (2) Global fishing mortality rates with low symmetric movement ($\alpha = 0.05$); (3) Global fishing mortality rates with moderate symmetric movement ($\alpha = 0.25$) and (4) Independent fishing mortality rates with asymmetric movements.