APPENDIX B12: Simulator testing of CASA and rescaled *F* models

We conducted simulation testing to detect potential bugs, check accuracy and assess robustness of the CASA, rescaled *F*, and Beverton and Holt (1956) stock assessment models for sea scallops. CASA is a new and relatively complex stock assessment approach for sea scallops that uses a wide range of data, involves a number of assumptions, and estimates fishing mortality, abundance, biomass and other population characteristics by maximum likelihood (Appendix B10). The rescaled *F* model is a very simple approach used in previous sea scallop assessments (NEFSC 2004) that estimates fishing mortality based on survey data shell height composition, landings data and some information about growth and natural mortality. The Beverton-Holt (1956) model is a simple, equilibrium approach often used for "data poor" stocks. It uses survey size (e.g., shell height) composition data to estimate fishing mortality.

Software

Four independently coded programs were used in testing: a simulator program, the CASA and rescaled F/Beverton-Holt estimation programs, and an interface program to link them. The first program (SAMS model, Appendix B11) simulates a potentially realistic (e.g. spatially structured) population and saves "true" simulated population information (e.g. abundance at size and catch at size without observation errors) for use by the estimation programs.

The interface program links SAMS output to the three assessment models and summarized test results. The interface constructed data files required to run each assessment model with user specified amounts of observation errors in simulated landings, fishing effort, survey records, LPUE observations and survey and fishery length composition data. All models use the same data (same observation errors) in each iteration.

The interface program runs each assessment model with simulated data, and collects and stores biomass, fishing mortality and other estimates from each model. After a specified number of iterations, the interface summarizes information from each model and iteration. Output from the interface program includes tables that compare estimates of biomass and fishing mortality from each model to the "true" values based on a number of statistics that measure model performance.

The statistics used to measure model performance include the CV, %bias (bias/true value), and %RMSE (root means squared error/true value) for biomass and fishing mortality. CV measures the relative precision of estimates (variability around their mean). The %bias statistic measures the relative difference between the truth and the average estimate. The %RMSE statistic measures relative accuracy, considering both precision and bias. The three measures are related because mean squared error MSE = bias^2 + variance.

Simulated landings and survey abundance data were assumed in simulations to be gamma random variables, with mean equal to their true values and a specified variance. Simulated shell height composition data were multinomial random variables based on a user specified number of samples from the true shell height composition. LPUE data were a nonlinear function of stock biomass and abundance calculated from simulated landings and fishing effort data assuming that observation errors for landings and fishing effort were independent

Simulations for sea scallops

Results are presented below for example simulations of particular relevance to this assessment. Similar to patterns in the real scallop fishery, simulations were for 30 years with true fishing mortality starting at a moderate level (F = 0.5), increasing to a high level of F = 1.0, and then fell decreasing to a relatively low level (F = 0.3) near the end of the simulation. The simulated population assumed some variability in growth among six areas within a single region.

Simulated data ranged from very precise to imprecise. A single survey abundance index with a flat selectivity curve and LPUE data as a nonlinear index of average fishable abundance was available in each simulated year. There were three sets of sets of simulated data with CVs and multinomial sample sizes listed in the table below. The assessment models were all run 20 times for each set of observation errors.

Scenario (magnitude of observation errors)	CV survey & landings data	CV for effort data	Sample size survey and fishery shell height data
Low	10%	2%	800
Medium	20%	2%	400
High	30%	2%	200

Other than observation errors in simulated data, all of the assessment models were generally configured for optimal model performance. In particular, assumptions about natural mortality and growth assumed in modeling were accurate. Size ranges assumed in tabulating survey data for the rescaled F model and the assumed critical length in Beverton-Holt model were reasonable choices. The growth transition matrix supplied to CASA was the average transition matrix for all area in the simulations. In CASA modeling, assumptions about the survey selectivity pattern (flat) and the general shape of the fishery selectivity pattern (logistic) were correct. There were no changes in fishery selectivity patterns that might have complicated interpretation of results from any of the models.

Results

For convenience, model performance statistics were averaged over all years for each model and level of observation error (Table 1). In terms of average percent bias, fishing mortality estimates from the rescaled F model were consistently biased low (-11 %). CASA model fishing mortality estimates were consistently biased high to a modest extent (< 5%). CASA model abundance and biomass estimates were biased high, usually by less than 10%. CASA estimates of landings were relatively unbiased (-0.3 to -2%). More simulations with larger numbers of iterations are required to make definite conclusions, but %bias was not strongly dependent on the magnitude of observation errors.

CASA model F estimates were most precise (lower CV, Table 1) than estimates from alternative models unless observation errors were high. CVs for CASA model fishing mortality, abundance, biomass and landings estimates increased almost proportionally with CVs for simulated observation errors assumed in survey and landings data.

Results for %RMSE (Table 1) were similar to results for CVs because bias was modest in all cases and changes in accuracy were due primarily to differences in precision.

Comparison of the mean fishing mortality estimates for each year from the three models gives insights into their performance (Figure 1). The negative bias in the rescaled F mortality estimates was due to underestimation of fishing mortality during years when true fishing mortality rates were highest. The positive bias of the CASA model was due to a consistent overestimation of mortality during the first four years of the simulation. CASA estimated fishing mortalities that were essentially unbiased after the initial years. The strong oscillations in the Beverton-Holt estimator are due to recruitment variability in the underlying simulation.

In comparing results for individual years, fishing mortality estimates from the rescaled *F* seem more variable than from CASA (Figure 2 to 3). In addition, CASA estimates seem to track trends in true fishing mortality better than estimates from other models. CASA estimates appear to track abundance and biomass with a reasonably well (Figure 3 to 4).

Conclusions

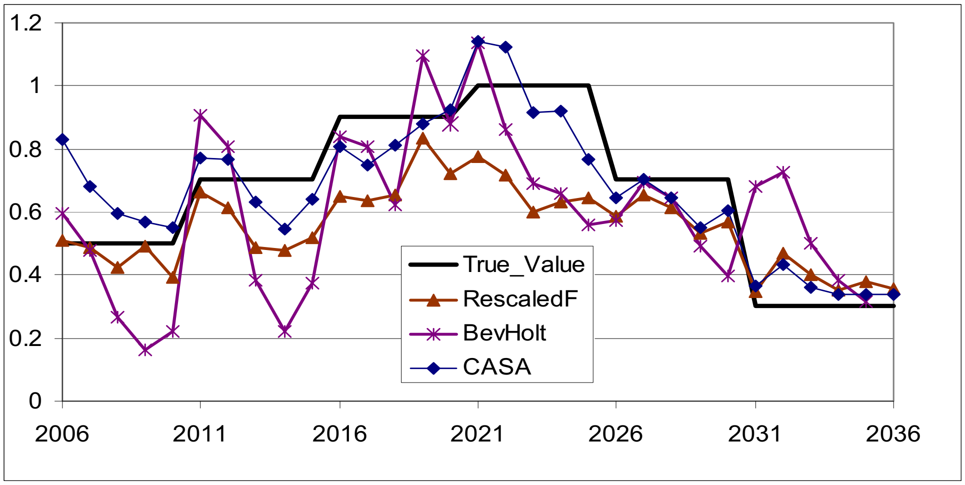
More testing is required, but simulation tests support use of CASA in this assessment for sea scallops. Results indicate that the CASA model is working properly and estimating abundance and biomass reasonably well. The CASA model generally performed better than the rescaled *F* and Beverton-Holt models. With the exception of the first few years, fishing mortality estimates from CASA was nearly unbiased.

CASA estimates were the most precise and accurate, except at the highest (30%) observation error levels. For sea scallops, low to medium (10-20%) observation errors in survey data are probably more realistic because the dredge and video surveys are relatively precise.

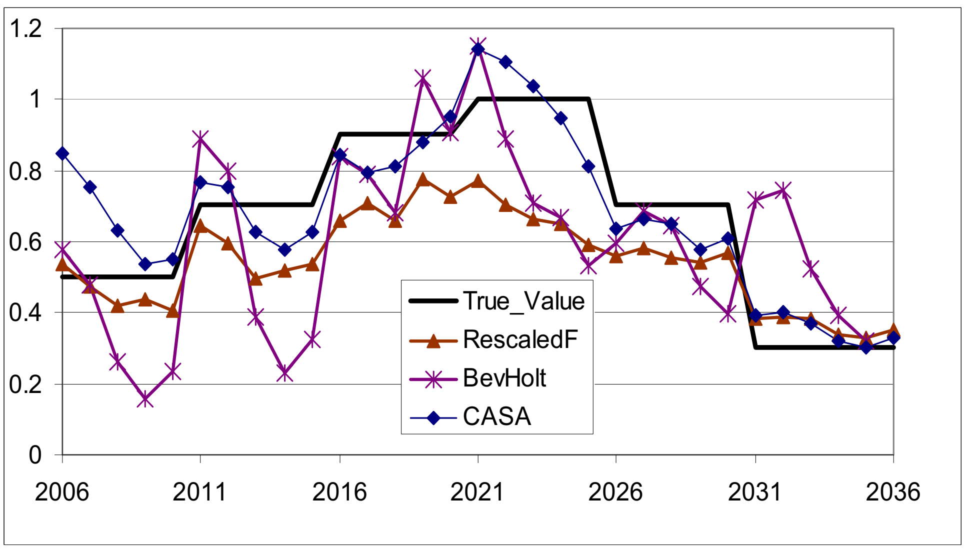
APPENDIX B12 Table 1. Performance measures (%bias, CV and %RMSE) for fishing mortality, abundance, biomass and landings estimates based on simulation testing (20 iterations each). Figures for each model are averages performance measures averaged over 30 simulated years. Performance during individual years may have been better or worse than indicated in the table. The CASA model failed to converge in one iteration with high observation errors. Effects of this run on performance measures for CASA with high levels of observation error were minimized by using medians, instead of means, in the table. When all runs converged, means and medians were similar.

Model / estimate	%Bias			CV			%RMSE		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Rescaled F	-0.13	-0.11	-0.11	0.15	0.28	0.46	0.26	0.35	0.49
Beverton-Holt F	-0.07	-0.01	0.05	0.11	0.12	0.14	0.23	0.40	0.42
CASA-F	0.05	0.05	0.03	0.20	0.20	0.30	0.20	0.28	0.32
CASA-Abundance	0.08	0.07	0.12	0.04	0.09	0.49	0.17	0.20	0.58
CASA-Biomass	0.04	0.03	0.07	0.05	0.10	0.57	0.09	0.13	0.61
CASA-Landings	0.00	0.00	-0.02	0.10	0.20	0.29	0.10	0.20	0.29

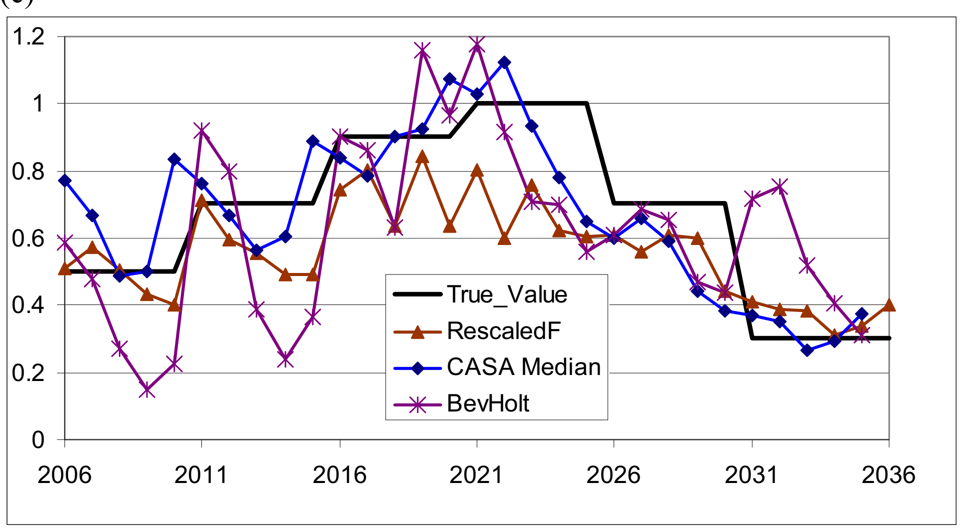
(a)



(b)

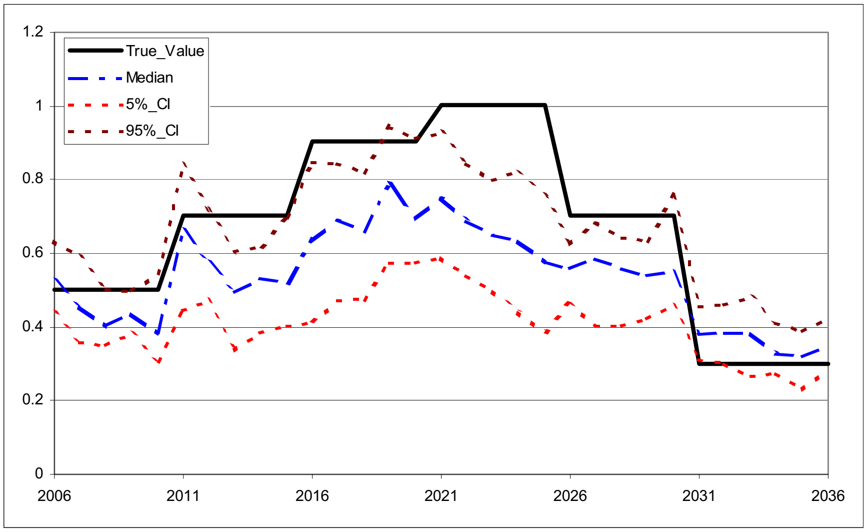


(c)



APPENDIX B12 Figure 1. Mean annual fishing mortalities for fishing mortality estimates from three models using data with (a) low, (b) medium, and (c) high observation errors.

(a)



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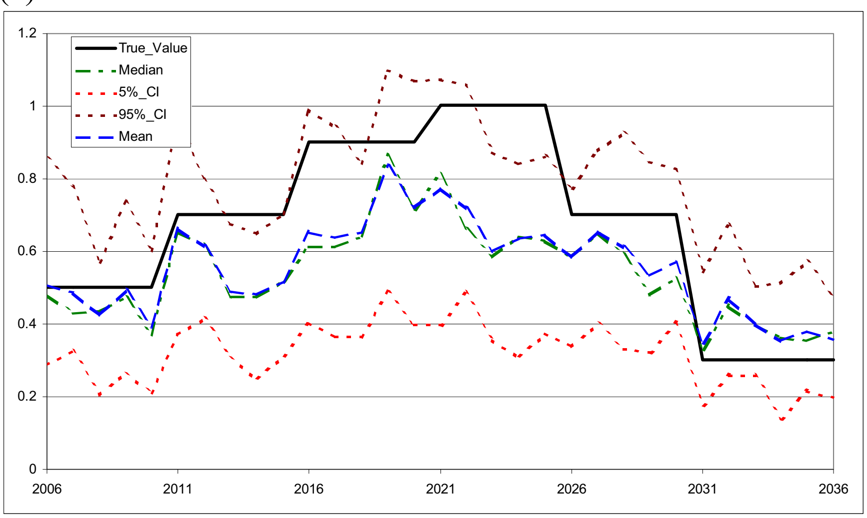
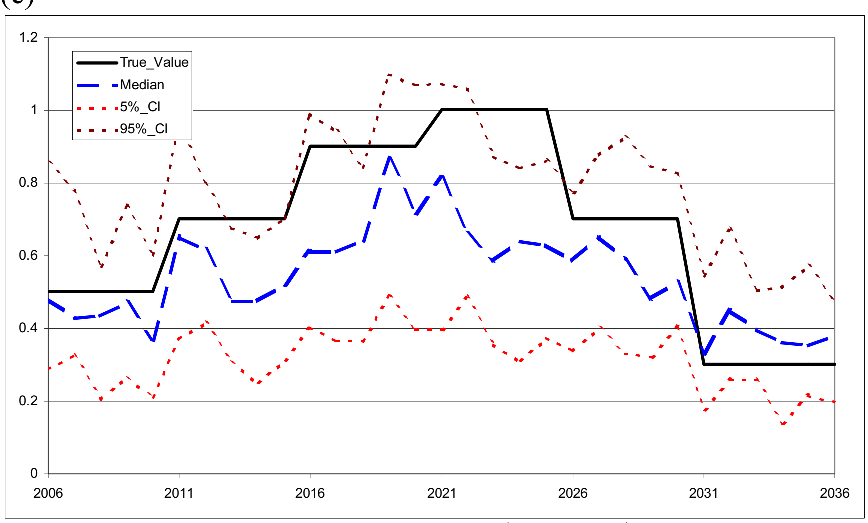
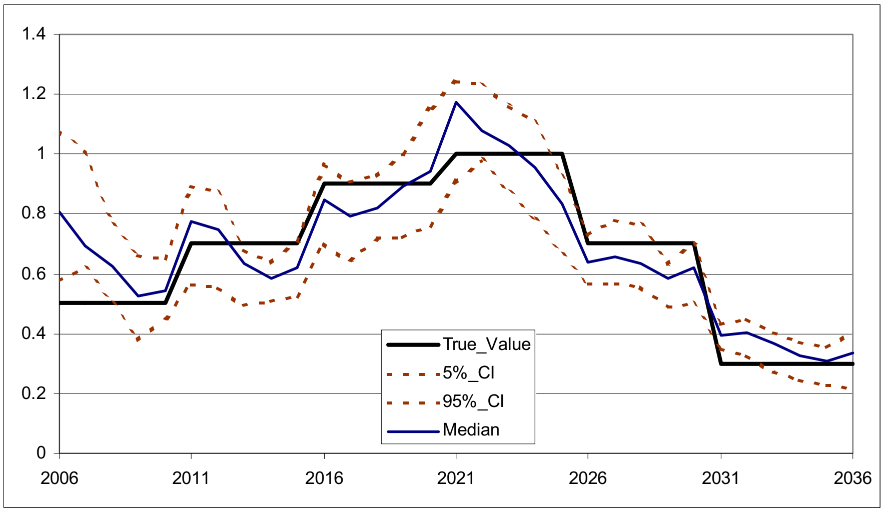


(c)

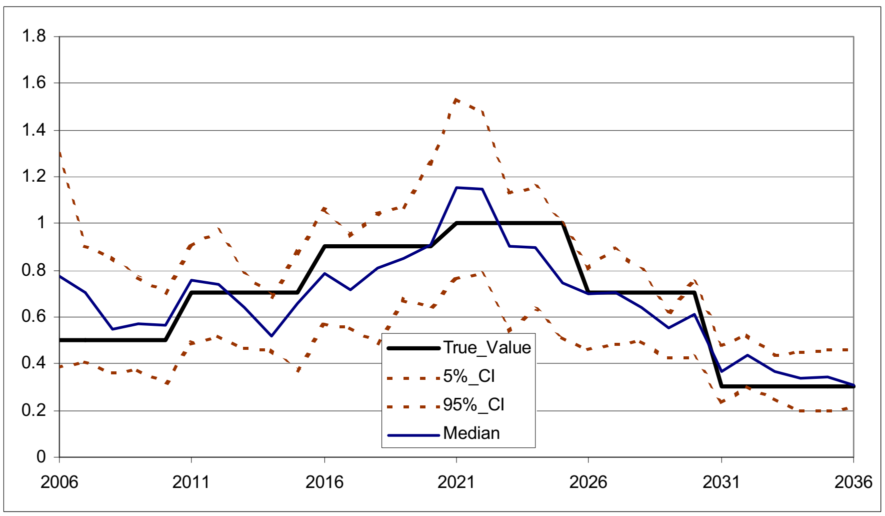


APPENDIX B12 Figure 2. Median, 5^{th} and 95^{th} percentiles for rescaled *F* estimates of annual fishing mortality using data with (a) low, (b) medium, and (c) high observation errors.

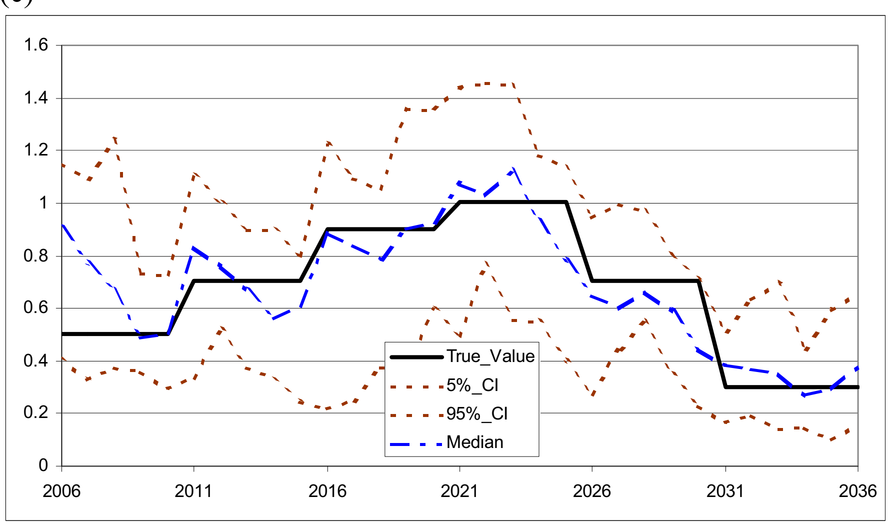
(a)



(b)

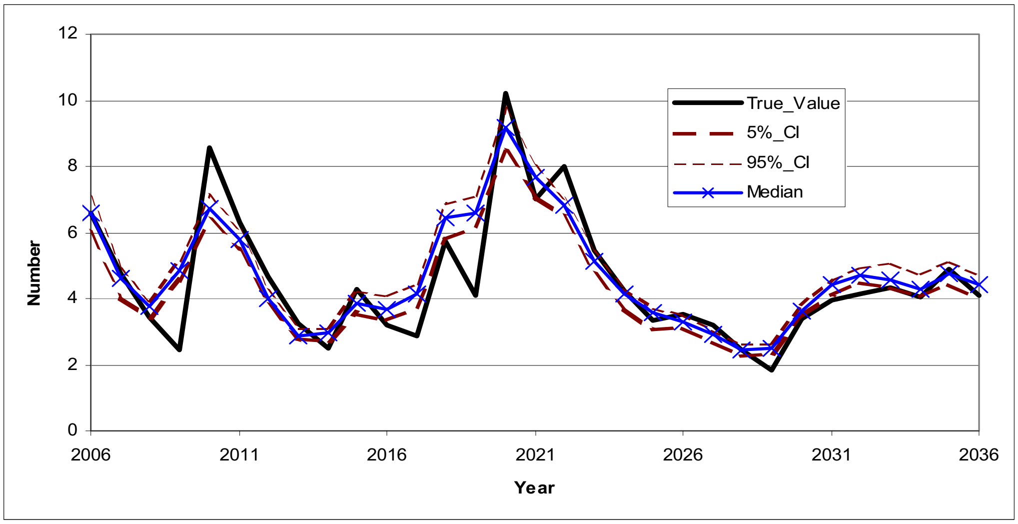


(c)

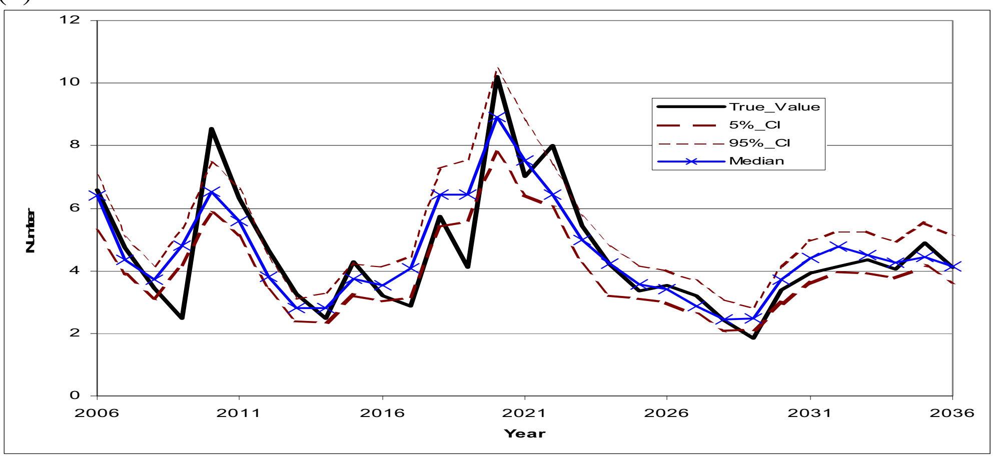


APPENDIX B12 Figure 3. Median, 5th and 95th percentiles for CASA annual fishing mortality estimates using data with (a) low, (b) medium, and (c) high observation errors.

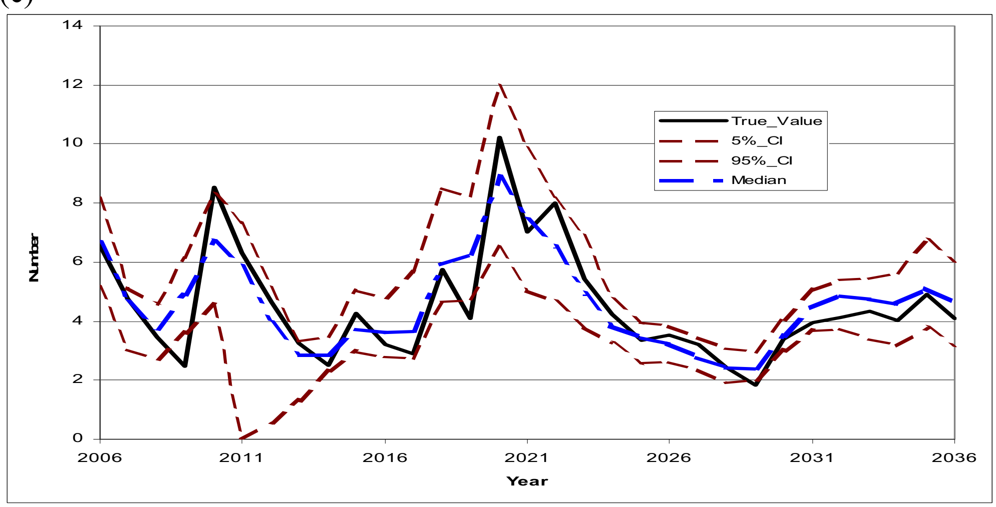
(a)



(b)

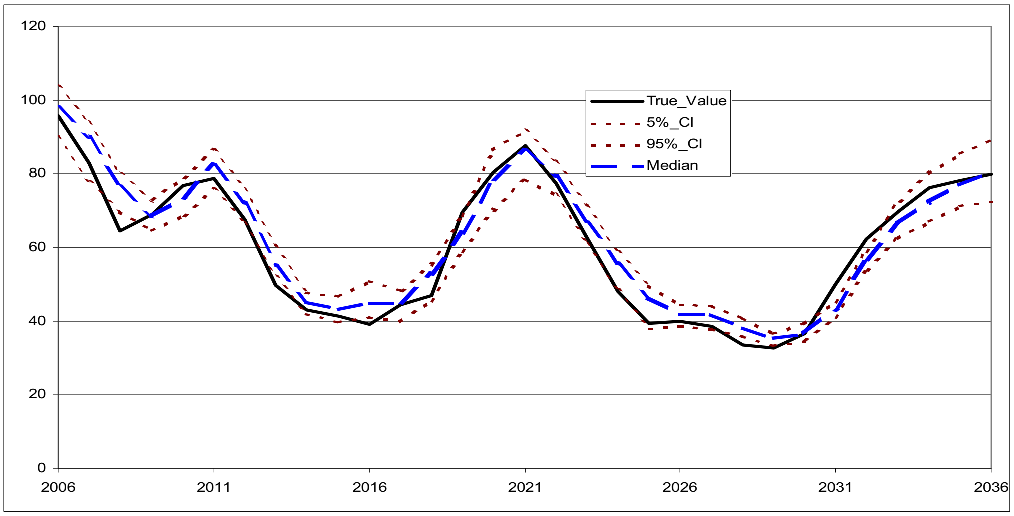


(c)

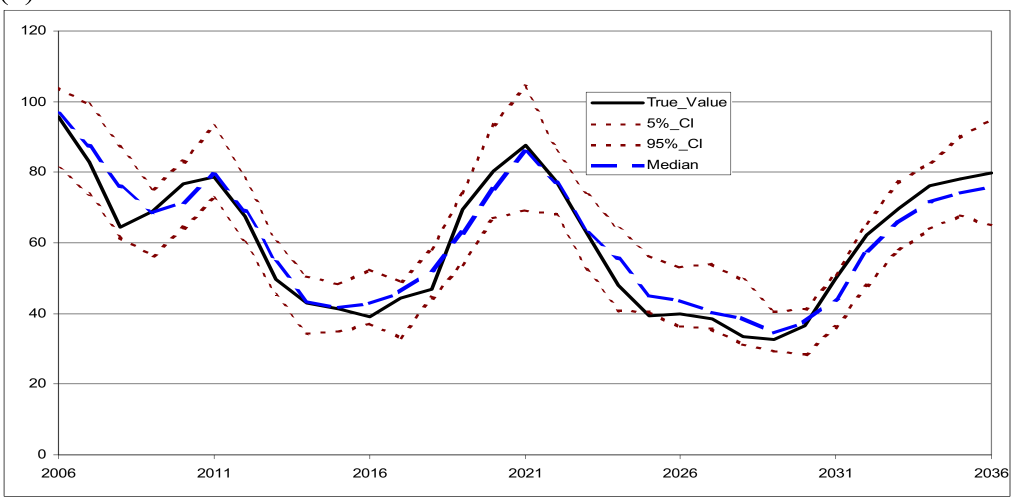


APPENDIX B12 Figure 4. Median, 5th and 95th percentiles of CASA annual abundance estimates using data with (a) low, (b) medium, and (c) high observation errors.

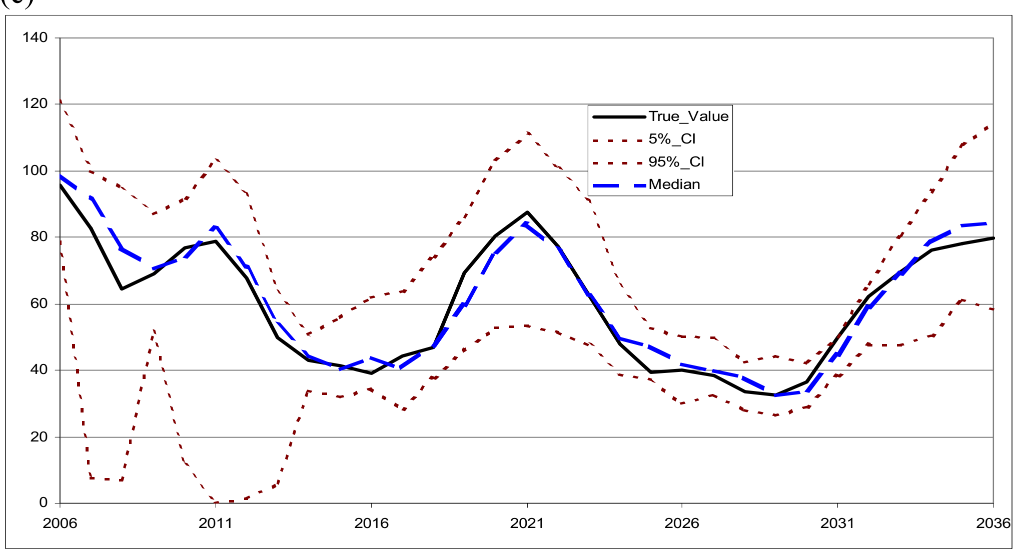
(a)



(b)



(c)



APPENDIX B12 Figure 5. Median, 5th and 95th percentiles for CASA annual biomass estimates using data with (a) low, (b) medium, and (c) high observation errors.