Appendix to: Evidence for the precautionary principle from POMDP solutions for ecological management

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Appendix

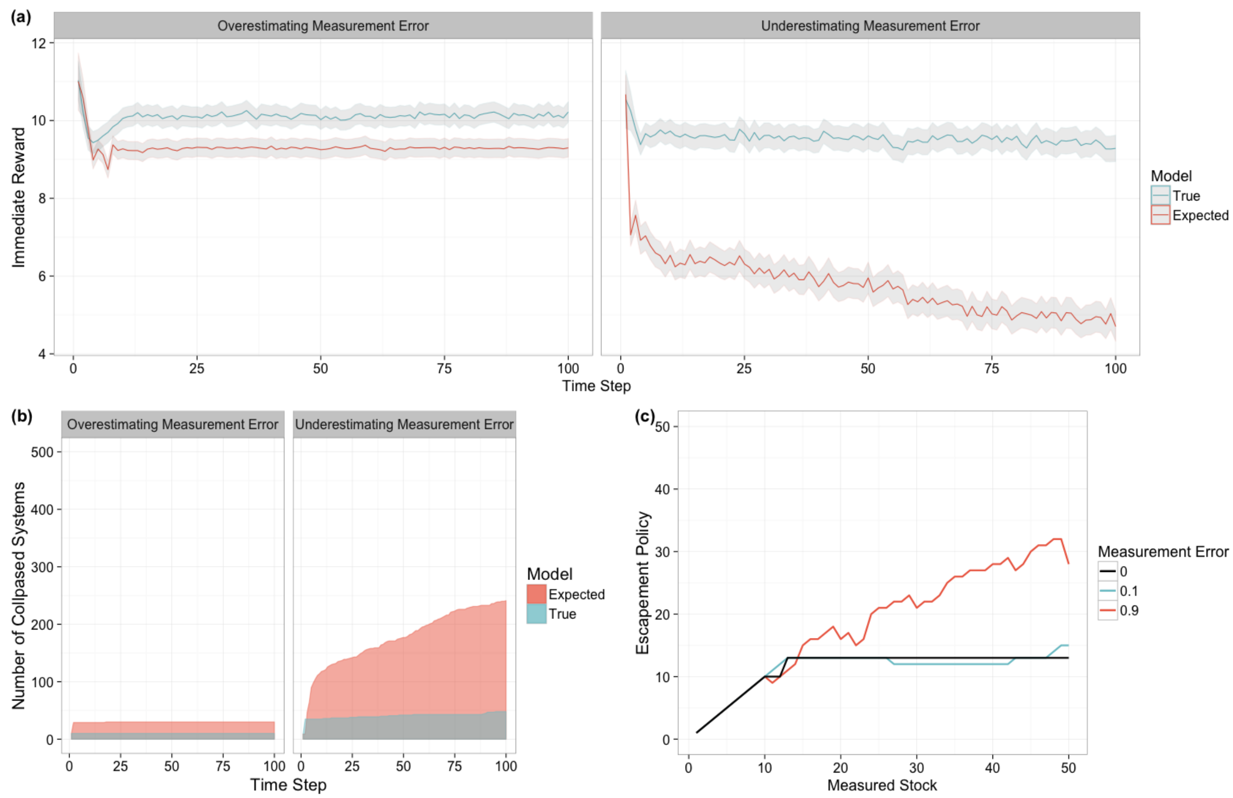

Figure A1: Results of 500 independent forward simulations of managing a marine ecosystem comparing overestimating measurement error with underestimating it: (a) immediate reward that agent receives through the management process, (b) number of collapsed systems in time, and (c) optimal escapement policies for different measurement errors. The growth model is Ricker model in this figure, the noise is uniformly distributed, the carrying capacity of the system is $K = 33$, the maximum per capita growth rate is $r = 1$, and the discount factor is $\gamma = 0.95$.

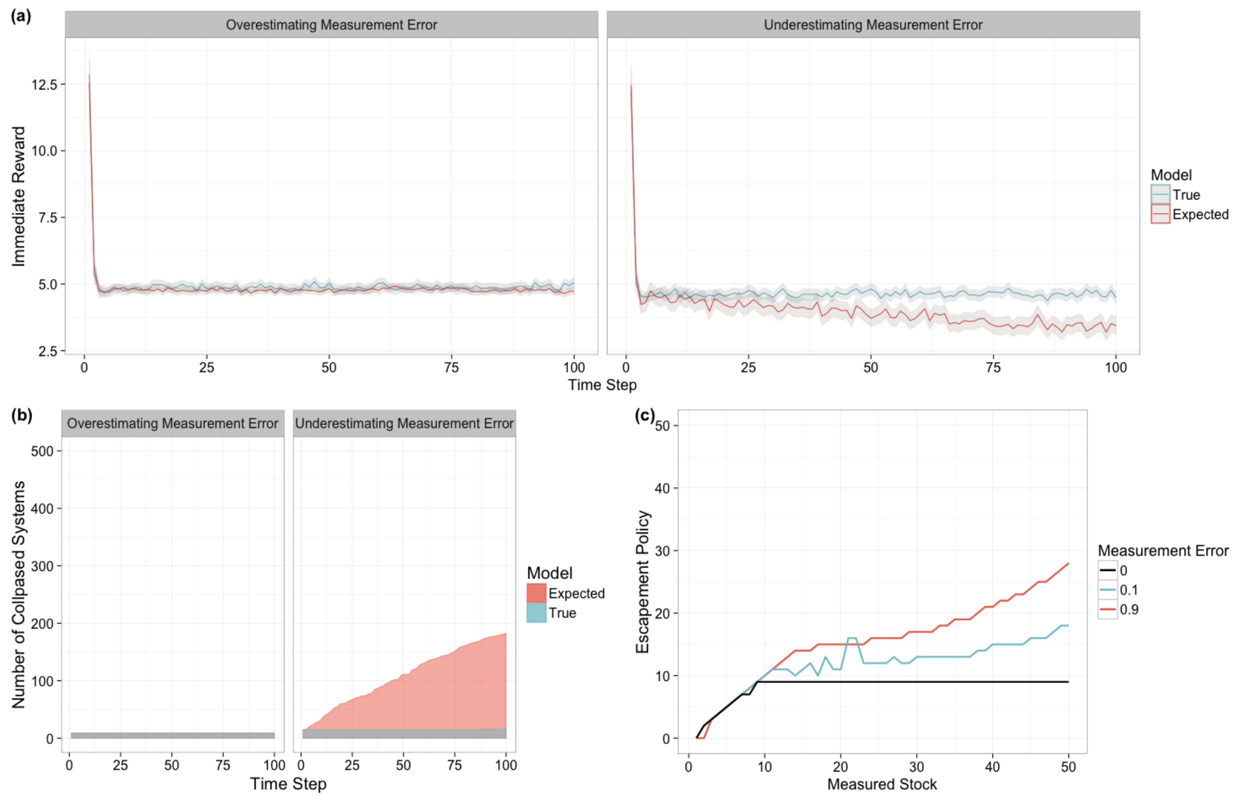

Figure A2: Results of 500 independent forward simulations of managing a marine ecosystem comparing overestimating measurement error with underestimating it: (a) immediate reward that agent receives through the management process, (b) number of collapsed systems in time, and (c) optimal escapement policies for different measurement errors. The growth model is Beverton-Holt model in this figure, the noise is lognormally distributed, the carrying capacity of the system is $K = 33$, the maximum per capita growth rate is $r = 1$, and the discount factor is $\gamma = 0.95$. Here we see the same pattern as shown in the main text for the Ricker model: overestimating measurement error avoids collapse.

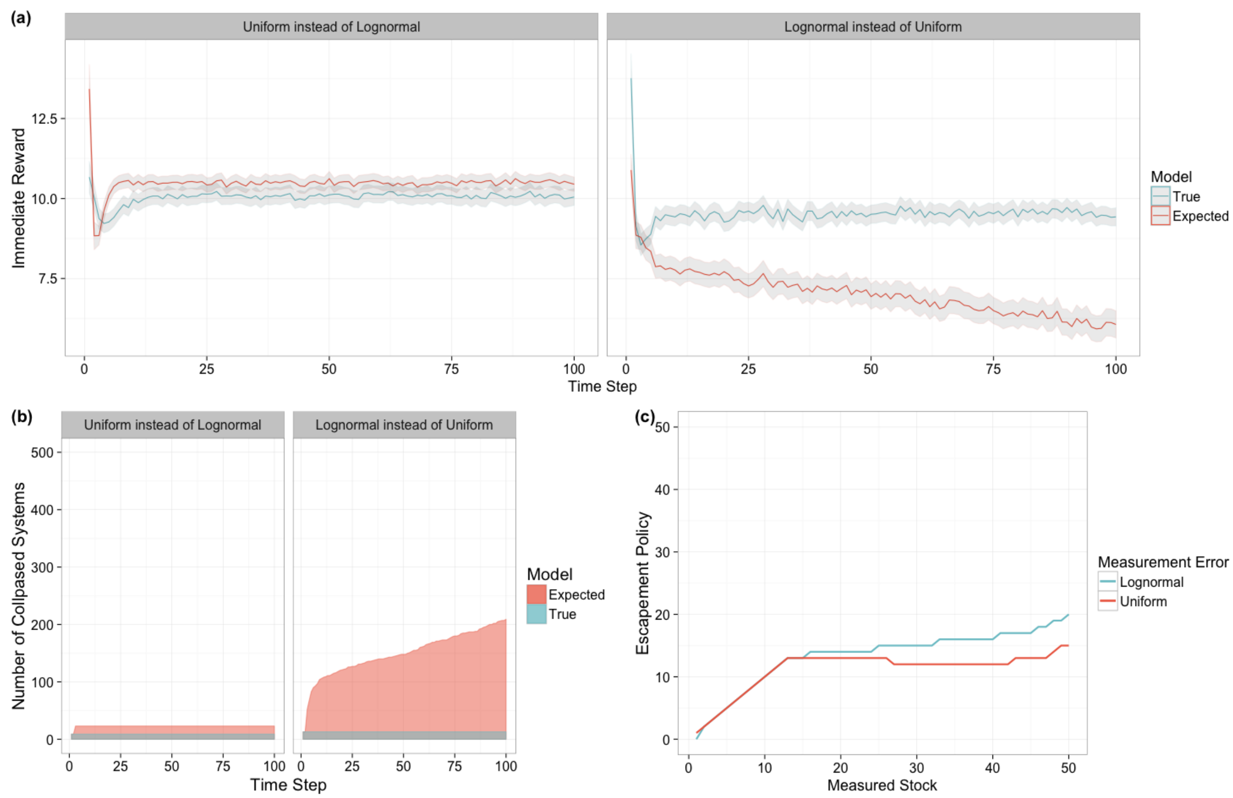

Figure A3: Results of 500 independent forward simulations of managing a marine ecosystem comparing using lognormally distributed noise or uniform one: (a) immediate reward that agent receives through the management process when true model is uniform (left), or when true model is log-normal. (b) number of collapsed systems in time, and (c) optimal escapement policies for different measurement errors. The growth model is Ricker model in this figure, the carrying capacity of the system is $K = 33$, the maximum per capita growth rate is $r = 1$, and the discount factor is $\gamma = 0.95$. Incorrectly using a log-normal noise model when the true model is uniform causes few collapses and yields nearly the economic optimum value. On the other hand, using the uniform model when the underlying noise is log-normal leads to both poor economic returns and ecological collapse.

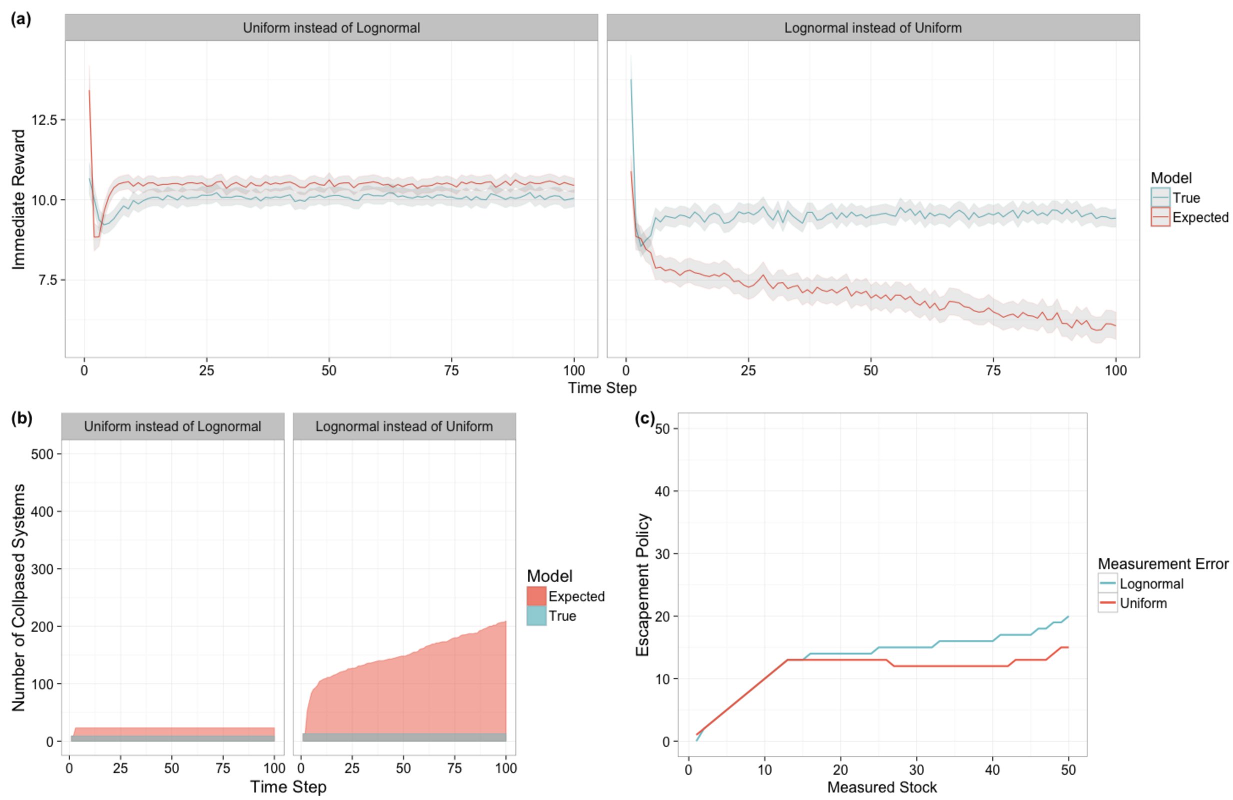

Figure A4: Results of 500 independent forward simulations of managing a marine ecosystem comparing using lognormally distributed noise or uniform one: (a) immediate reward that agent receives through the management process, (b) number of collapsed systems in time, and (c) optimal escapement policies for different measurement errors. The growth model is Beverton-Holt model in this figure, the carrying capacity of the system is $K = 33$, the maximum per capita growth rate is $r = 1$, and the discount factor is $\gamma = 0.95$.

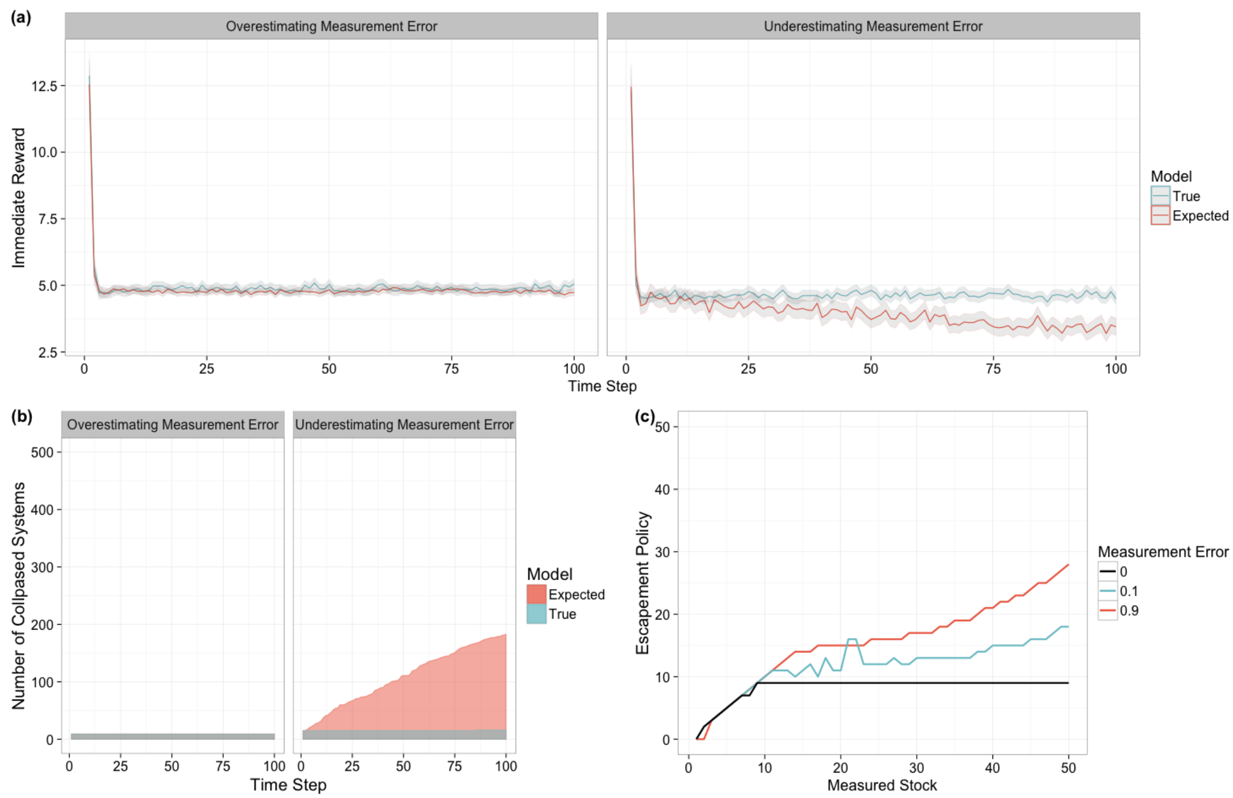

Figure A5: Results of 500 independent forward simulations of managing a marine ecosystem comparing overestimating measurement error with underestimating it: (a) immediate reward that agent receives through the management process, (b) number of collapsed systems in time, and (c) optimal escapement policies for different measurement errors. The growth model is Allen model in this figure, the noise is lognormally distributed, the carrying capacity of the system is $K = 33$, the maximum per capita growth rate is $r = 1$, and the discount factor is $\gamma = 0.95$.

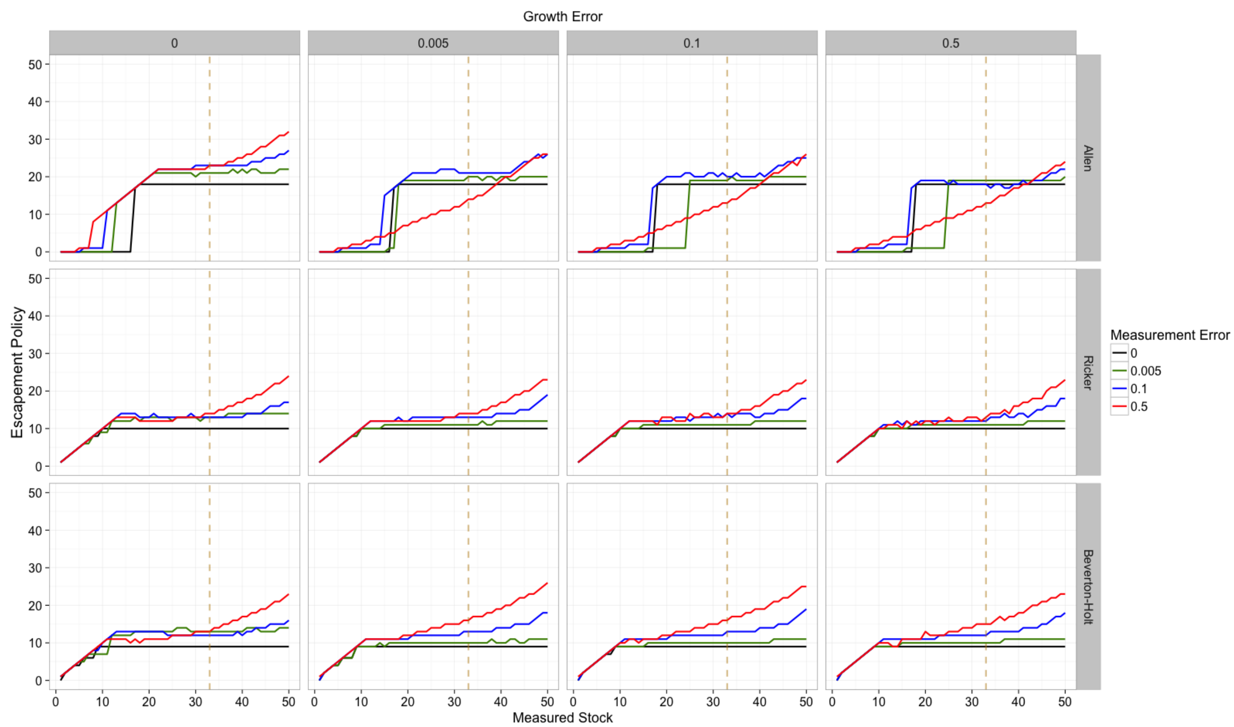

Figure A6: Optimal escapement policy for different growth models, growth error, and measurement errors (log-normal noise) with the modified reward function with $alpha = 0.1$. The dashed vertical line represents the carrying capacity of the system, $K = 33$. State space is discretized into $|S| = 50$ states, the maximum per capita growth rate is $r = 1$, and the discount factor is $\gamma = 0.95$.

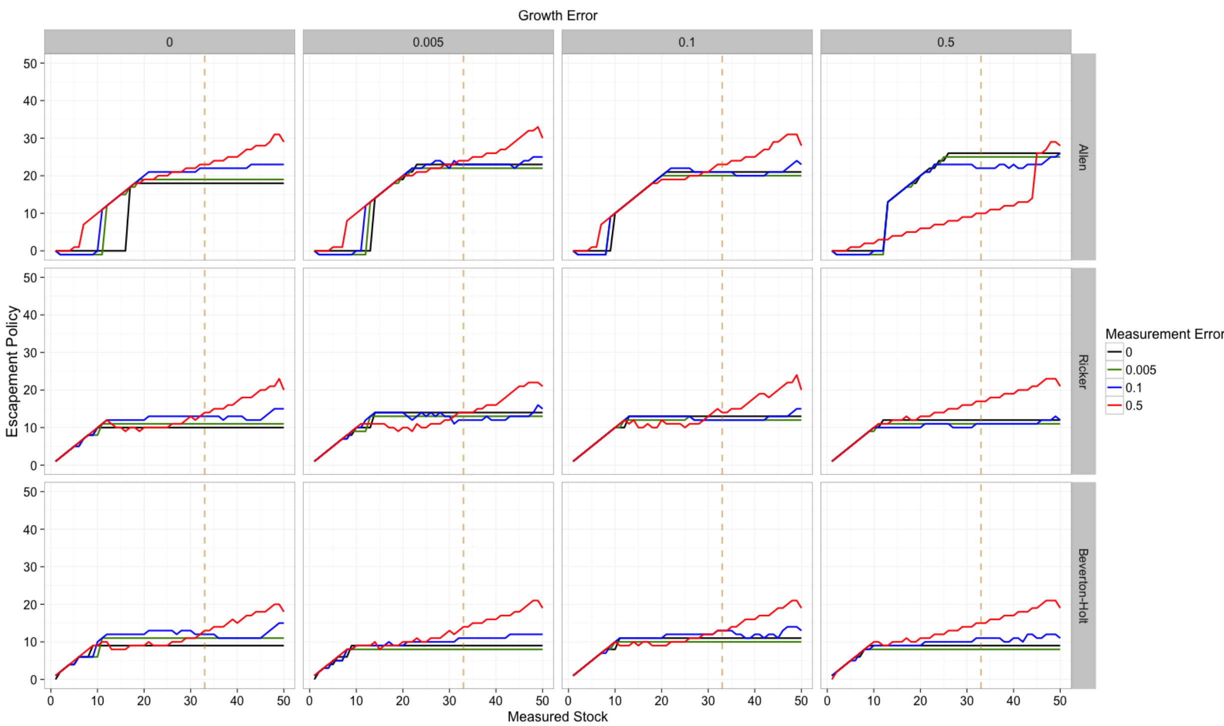

Figure A7: Optimal escapement policy for different growth models, growth error, and measurement errors (uniform noise). The dashed vertical line represents the carrying capacity of the system, $K = 33$. State space is discretized into $|S| = 50$ states, the maximum per capita growth rate is $r = 1$, and the discount factor is $\gamma = 0.95$.

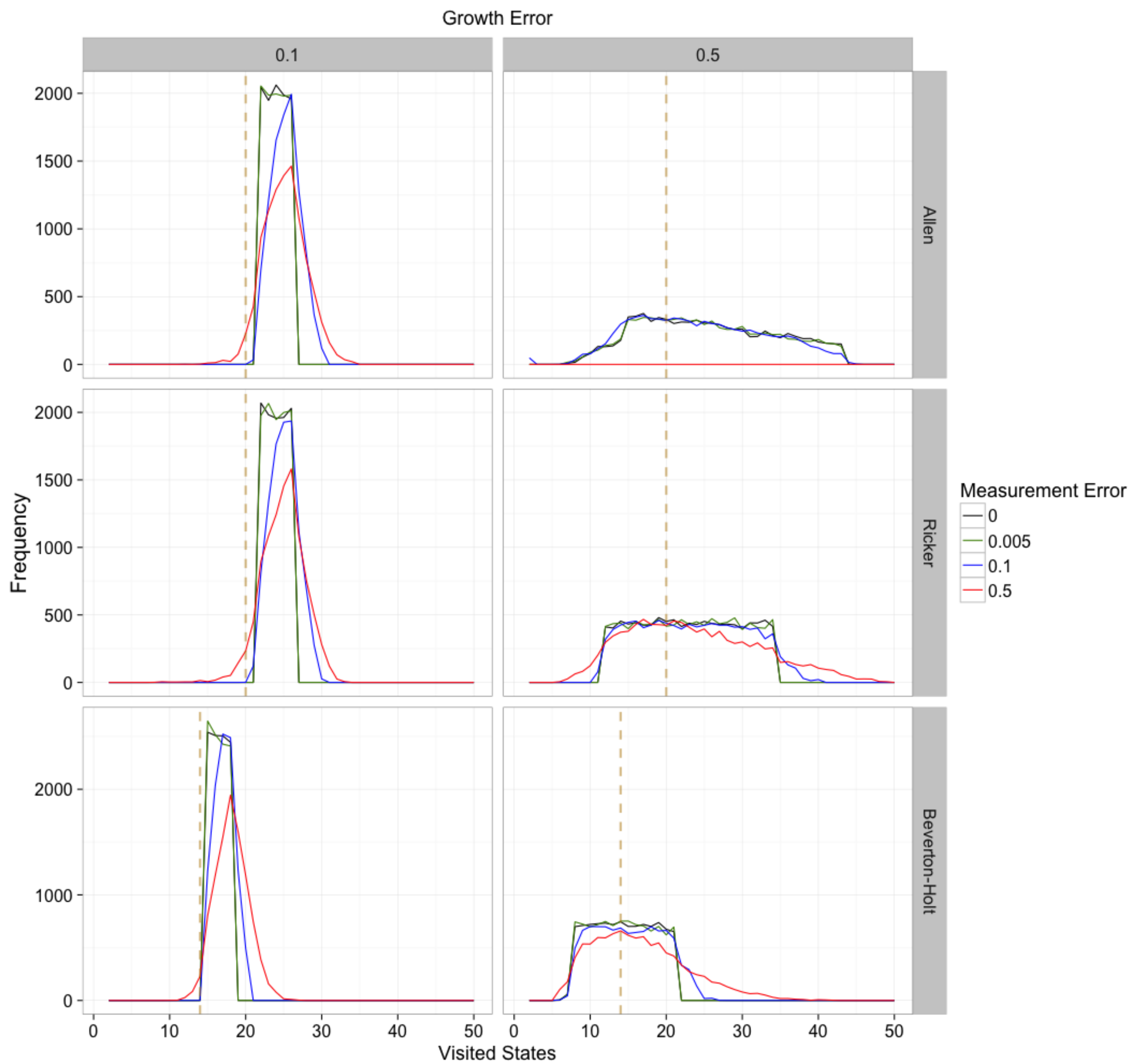

Figure A8: Density of visited states in 1000 independent simulations of managing the mentioned marine ecosystem for different growth models, growth error, and measurement errors (uniform noise). The dashed vertical line represents the stable state that agent keeps the system in for the case of no uncertainty

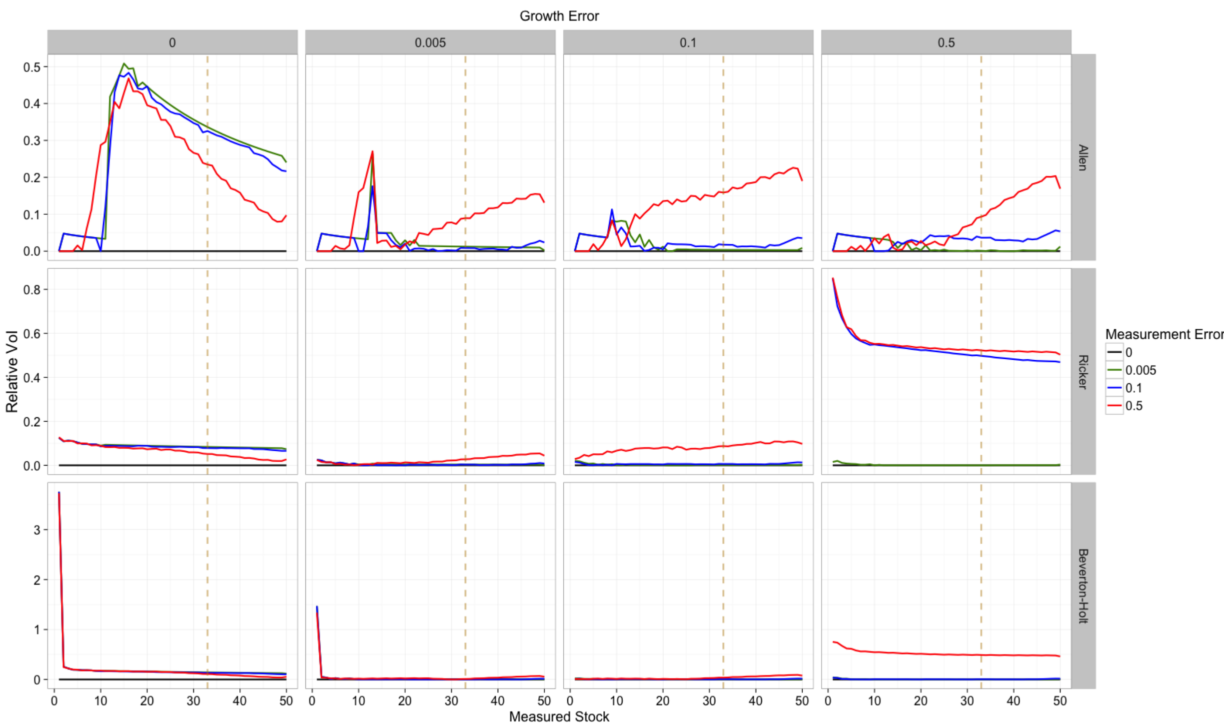

Figure A9: Relative value of information for different growth models, growth error, and measurement errors (uniform noise)