A Metamodel Based Clustering of Fisheries Model Parameter Estimation Behavior.

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Introduction

Integrated fisheries models are based upon differential equations which model stock dynamics through time. Fisheries are largely managed based upon quantities derived from the equilibrium equations of these dynamics, known as Reference Points (RP). RP behavior is primarily driven by the functional form of the productivity assumed in the differential equations. Mangel et al. (2013) demonstrate that the most commonly used models of productivity limit the domain of RPs due to a lack of flexibility induced by their two-parameter functional forms. Three-parameter models of production release this theoretical RP limitation (Punt & Cope, 2019). Nonetheless, two-parameter models of productivity are overwhelmingly used in practice. When RP model misspecification of this type is present in population dynamics models, what are the useful limits of statistical inference with respect to estimating these RPs? Here, a simulation environment is designed which explores how misspecified two-parameter production models bias RP inference. Using a Gaussian Process metamodel of the inferred RPs (under two-parameter productivity), the full theoretical space of RP bias behavior is explored. This structured simulation setting allows for clustering of RP failure modes which use the metamodel to predict when a given species is most likely to be subject to catastrophic model failure.

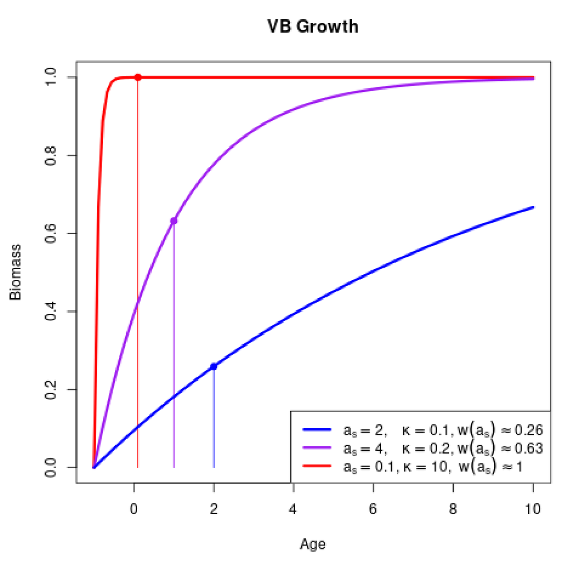
1. Fisheries Model

$$I_t = qB_te^{\epsilon} \qquad \epsilon \sim N(0,\sigma^2)$$

$$\frac{dB}{dt} = \overbrace{w(a_s)R(B;\theta)}^{\text{Recruitment}} + \overbrace{\kappa\left[w_\infty N - B\right]}^{\text{Net Growth}} - \overbrace{(M+F)B}^{\text{Mortality}}$$

$$\frac{dN}{dt} = R(B;\theta) - (M+F)N$$

2. Individual Growth $w(a)$

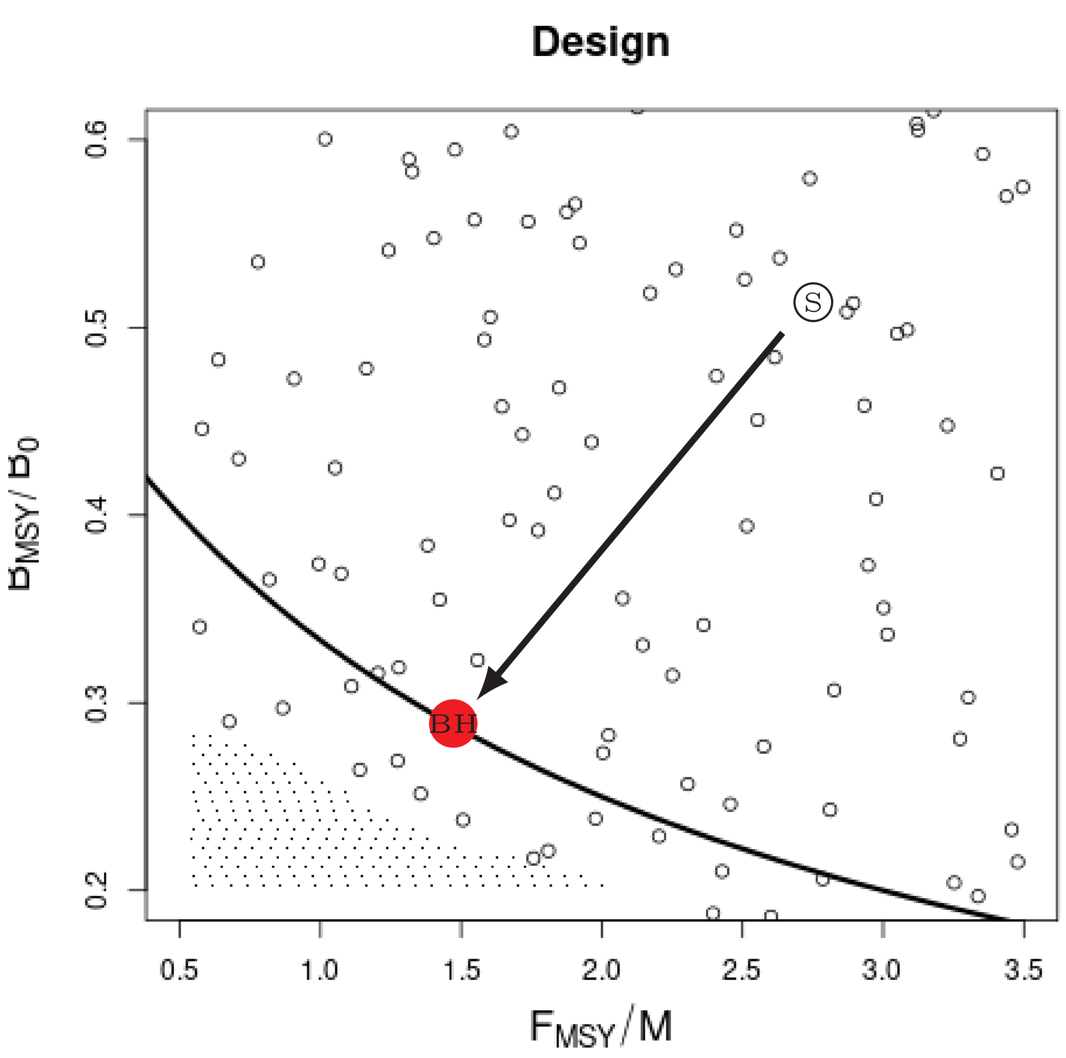


Flatten; High, Medium, Low; Individual Biomass; Title

3. $R(B;\theta)$ & RPs

$$\text{Reference Points}: \frac{F_{MSY}}{M},\ \frac{B_{MSY}}{B_0}$$

two v. three parameter R, Relation to RPs, Make picture smaller



4. Simulation

$$\underbrace{\left(\frac{F_{MSY}}{M},\frac{B_{MSY}}{\bar{B}(0)}\right)}_{\text{Schnute Truth}} \overset{\text{GP}}{\mapsto} \underbrace{\left(\frac{\hat{F}_{MSY}}{M},\frac{\hat{B}_{MSY}}{\bar{B}(0)}\right)}_{\text{BH Estimate}}$$

$$\hat{y}(\mathbf{x}) = \beta_0 + \mathbf{x}\boldsymbol{\beta} + \mathbf{r}(\mathbf{x})'\boldsymbol{R}_{\boldsymbol{\ell}}^{-1}\Big(\mathbf{y} - \big(\beta_0 + \boldsymbol{X}\boldsymbol{\beta}\big)\Big) \quad (1)$$

$$\hat{\sigma}^2(\mathbf{x}) = \mathbf{R}(\mathbf{x},\,\mathbf{x}) - \mathbf{r}(\mathbf{x})'\boldsymbol{R}_{\boldsymbol{\ell}}^{-1}\mathbf{r}(\mathbf{x}). \quad (2)$$

$$\log(\hat{F}_{MSY}) \sim N(\hat{y}(\mathbf{x}), \hat{\sigma}^2(\mathbf{x})) \quad (3)$$

5. Clustering

We want a small percent error in RP estimation:

$$\frac{\frac{F_{MSY}}{M} - \frac{\hat{F}_{MSY}}{M}}{\frac{F_{MSY}}{M}} \le P$$

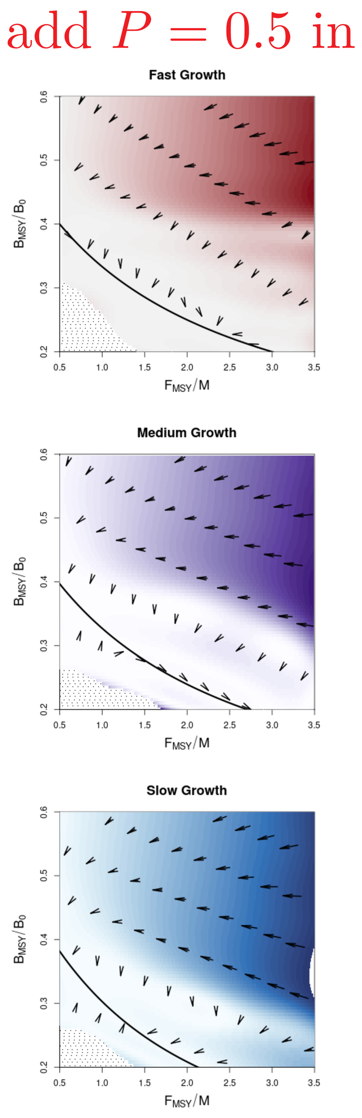
$$\hat{F}_{MSY} \ge (1-P)F_{MSY}$$

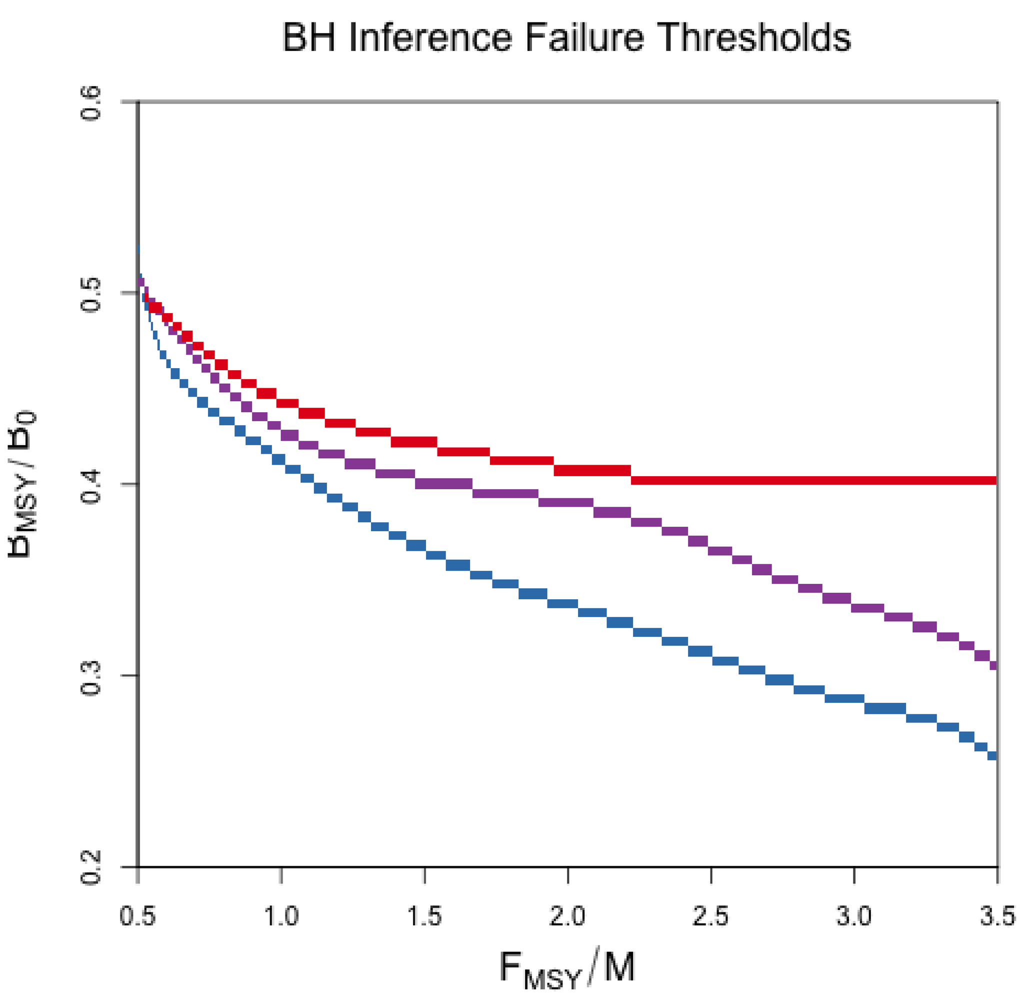
Declare model failure when:

$$e^{\hat{y}(\mathbf{x}) + \sqrt{2\hat{\sigma}^2(\mathbf{x})}\Phi^{-1}\left(\frac{1}{10}-1\right)} < (1-P)F_{MSY}$$

6. Results

add $P = 0.5$ in title? somewhere.





7. Conclusion

References

References

Mangel, M., MacCall, A. D., Brodziak, J., Dick, E., Forrest, R. E., Pourzand, R., & Ralston, S. (2013, April). A perspective on steepness, reference points, and stock assessment. *Canadian Journal of Fisheries and Aquatic Sciences*, *70*(6), 930–940.

Punt, A. E., & Cope, J. M. (2019, September). Extending integrated stock assessment models to use non-depensatory three-parameter stock-recruitment relationships. *Fisheries Research*, *217*, 46–57.