Reliability of stock-recruitment function estimation in state space assessment models

Gregory L. Britten[1], Elizabeth Brooks[2], and Timothy Miller[2]

[1]Woods Hole Oceanographic Institution
[2]Northeast Fisheries Science Center

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Abstract

Stock-recruitment functions are important but difficult to estimate.

Many assessment models do not estimate stock-recruitment functions.

Maybe state space models help.

Here we ...

We find ...

This has implications for ...

Introduction

Methods

We used the WHAM package (ref, commit 77bbd94)

We performed a simulation study with 96 operating models that differed in the stock recruitment function used to simulate the population and a variety of additional variance parameter settings. Variance parameter settings were determined by a review of the range of estimates from recent applications of WHAM in management of stocks of haddock, butterfish, and American plaice in the NE US.

We simulated 100 data sets for each operating model.

For each simulated data set we fit a set of 4 estimating models.

Operating Models

The general operating model structure follows that of Project 0, reviewed briefly here. The population model tracks 10 age classes: ages 1 to 10+, assuming spawning occurs 1/4 of the way through the year. The maturity at age was a logistic curve with a50 = 2.89 and slope = 0.88, assumed known in all estimation models.

Weight at age was generated with a LVB growth function

$$L_a = L_{\text{inf}} \left(1 - e^{-k(a-t_0}\right)$$

with $t_0 = 0$, $L_{\text{inf}} = 85$, and $k = 0.3$. The length-weight relationship is

$$W_a = \theta_1 L_a^{\theta_2}$$

with $\theta_1 = e^{-12.1}$ and $\theta_2 = 3.2$.

We assume a Beverton-Holt stock-recruitment of the form

$$N_{1,y} = \frac{\alpha \text{SSB}_{y-1}}{1 + \beta \text{SSB}_{y-1}}$$

where α is referred to as the density-independent recruitment and β sets the strength of density-dependence. We specified unfished recruitment at $R_0 = e^{19}$ and $F_{MSY} = F_{\%40} = 0.348$ which corresponds to a steepness of 0.69, $\alpha = 0.60$, and $\beta = 2.4 * 10^{-5}$.

Estimating Models

Analysis

Metrics of interest:

1. Ability to correctly identify a stock recruitment relationship
2. Ability correctly identify the functional form of the stock recruitment relationship
3. Differences in estimation error (SSB, R) when SR relationships are correctly/incorrectly identified

Generalized linear models

Generalized linear mixed models

Classification trees

Results

Discussion

Appendix A

References

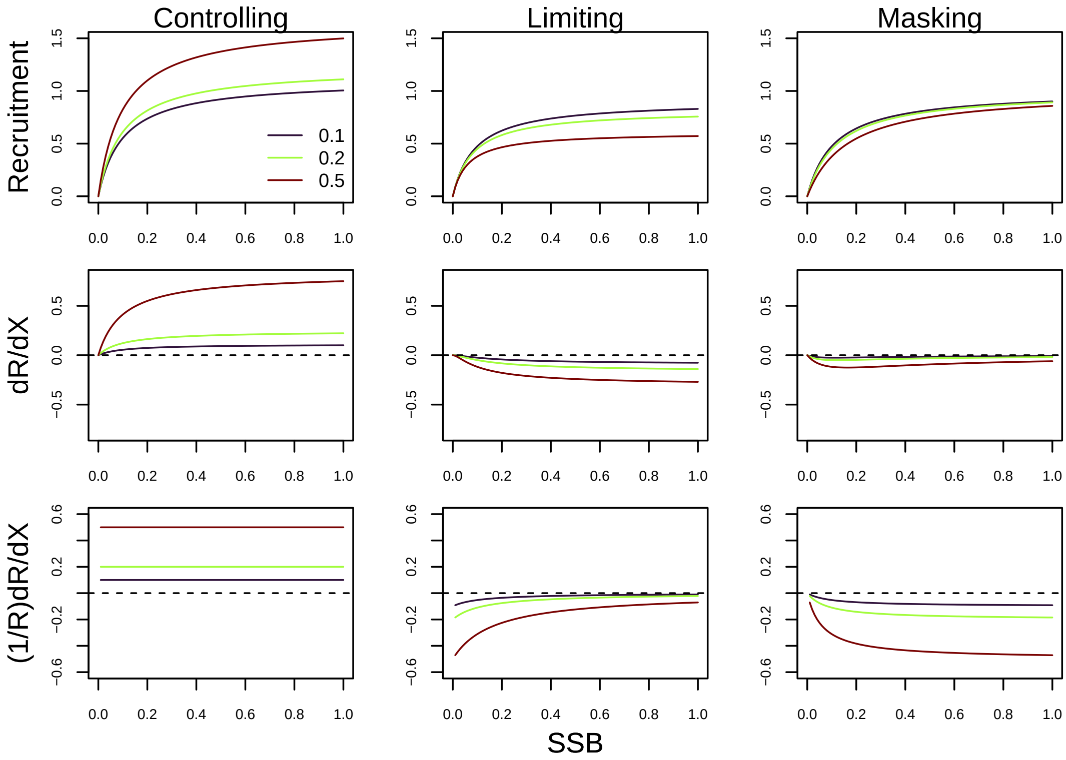

Figure 1: Sensitivity of recruitment to environmental covariates for the three functional forms considered in this study.

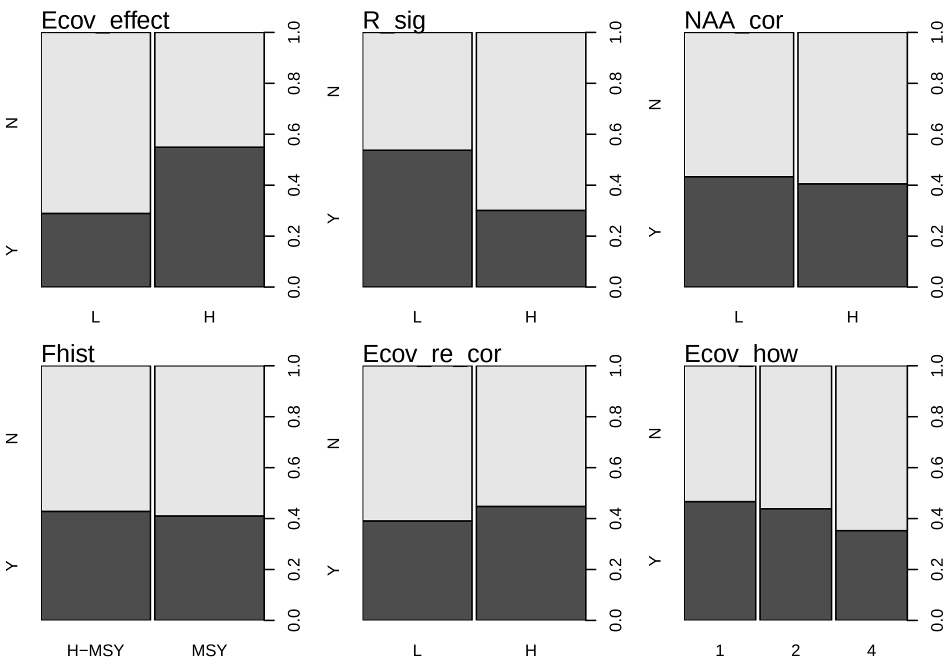

Figure 2: Model selection results for whether a stock recruitment relationship was correctly identified, expressed as marginal proportions against individual covariates.

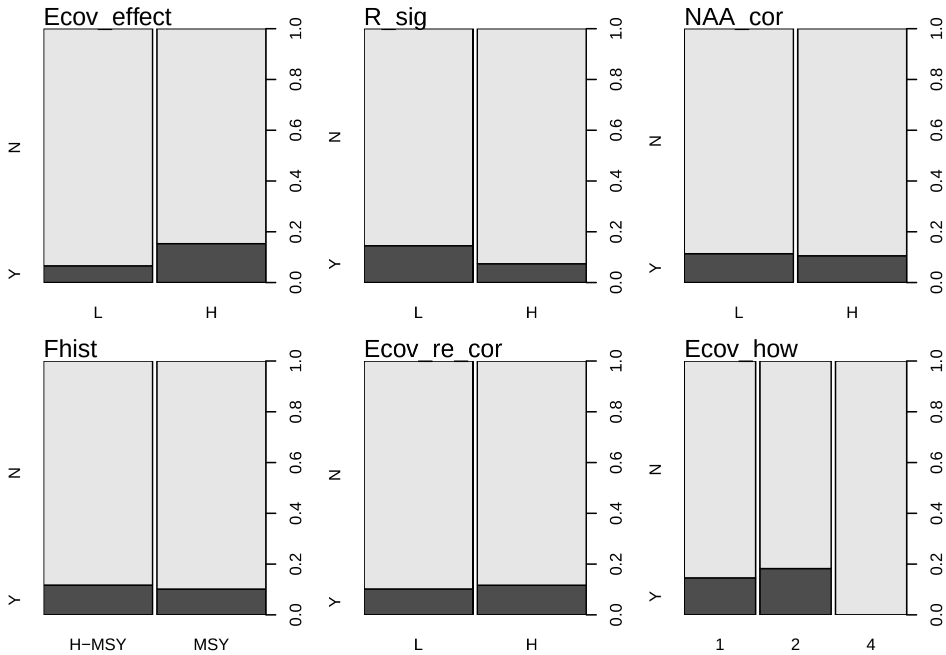

Figure 3: Model selection results for whether the correct stock recruitment functional form was identified, expressed as marginal proportions against individual covariates.

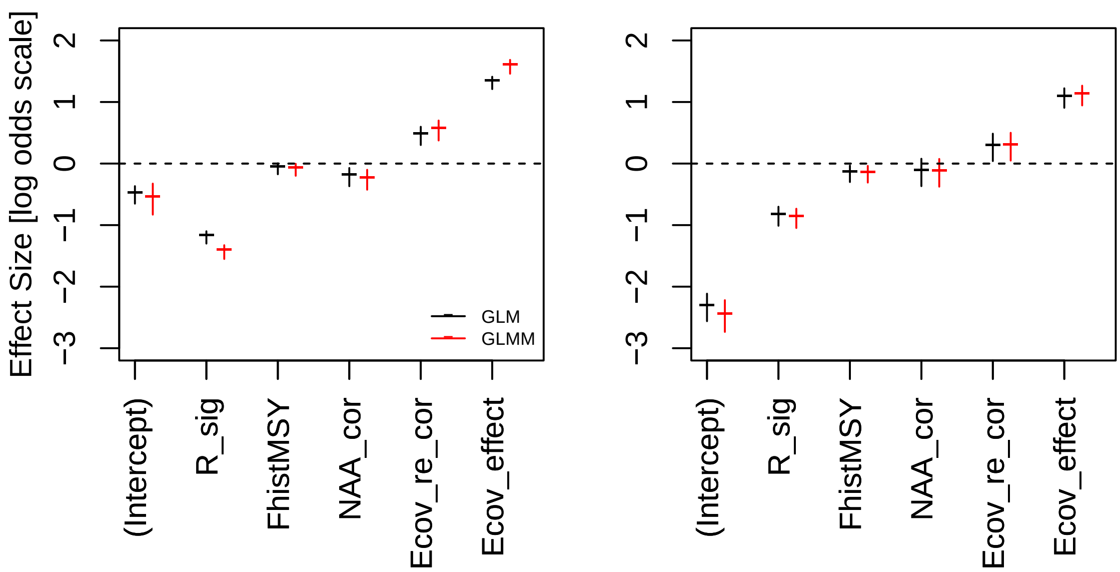

Figure 4: Effect sizes for predicting estimated via a binomial generalized linear model and a binomial generalized linear mixed model with simulation random number seed as a random intercept.

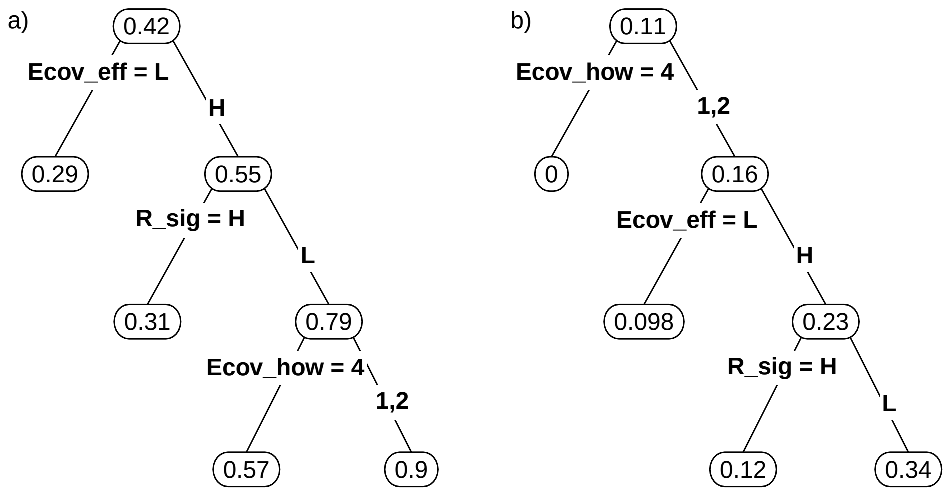

Figure 5: Classification tree analysis of model selection results. R package 'rpart' was used for the model fit and visualization. Following default settings in rpart, the complexity parameter is set at $c_p = 0.01$ which represents the minimum classification improvement required for any split.

Table 1: Distinguishing characteristics of the operating models

	Model	NAA_re	Ecov_obs_sig	Ecov_re_sig	obs_error	R_sig	Fhist	NAA_cor	Ecov_re_cor	Ecov_effect	Ecov_how
1	om_1	rec	0.10	0.10	L	0.10	H-MSY	0.20	0.20	0.10	1
2	om_2	rec	0.10	0.10	L	1.00	H-MSY	0.20	0.20	0.10	1
3	om_3	rec	0.10	0.10	L	0.10	MSY	0.20	0.20	0.10	1
4	om_4	rec	0.10	0.10	L	1.00	MSY	0.20	0.20	0.10	1
5	om_5	rec	0.10	0.10	L	0.10	H-MSY	0.80	0.20	0.10	1
6	om_6	rec	0.10	0.10	L	1.00	H-MSY	0.80	0.20	0.10	1
7	om_7	rec	0.10	0.10	L	0.10	MSY	0.80	0.20	0.10	1
8	om_8	rec	0.10	0.10	L	1.00	MSY	0.80	0.20	0.10	1
9	om_9	rec	0.10	0.10	L	0.10	H-MSY	0.20	0.80	0.10	1
10	om_10	rec	0.10	0.10	L	1.00	H-MSY	0.20	0.80	0.10	1
11	om_11	rec	0.10	0.10	L	0.10	MSY	0.20	0.80	0.10	1
12	om_12	rec	0.10	0.10	L	1.00	MSY	0.20	0.80	0.10	1
13	om_13	rec	0.10	0.10	L	0.10	H-MSY	0.80	0.80	0.10	1
14	om_14	rec	0.10	0.10	L	1.00	H-MSY	0.80	0.80	0.10	1
15	om_15	rec	0.10	0.10	L	0.10	MSY	0.80	0.80	0.10	1
16	om_16	rec	0.10	0.10	L	1.00	MSY	0.80	0.80	0.10	1
17	om_17	rec	0.10	0.10	L	0.10	H-MSY	0.20	0.20	1.00	1
18	om_18	rec	0.10	0.10	L	1.00	H-MSY	0.20	0.20	1.00	1
19	om_19	rec	0.10	0.10	L	0.10	MSY	0.20	0.20	1.00	1
20	om_20	rec	0.10	0.10	L	1.00	MSY	0.20	0.20	1.00	1
21	om_21	rec	0.10	0.10	L	0.10	H-MSY	0.80	0.20	1.00	1
22	om_22	rec	0.10	0.10	L	1.00	H-MSY	0.80	0.20	1.00	1
23	om_23	rec	0.10	0.10	L	0.10	MSY	0.80	0.20	1.00	1
24	om_24	rec	0.10	0.10	L	1.00	MSY	0.80	0.20	1.00	1
25	om_25	rec	0.10	0.10	L	0.10	H-MSY	0.20	0.80	1.00	1
26	om_26	rec	0.10	0.10	L	1.00	H-MSY	0.20	0.80	1.00	1
27	om_27	rec	0.10	0.10	L	0.10	MSY	0.20	0.80	1.00	1
28	om_28	rec	0.10	0.10	L	1.00	MSY	0.20	0.80	1.00	1
29	om_29	rec	0.10	0.10	L	0.10	H-MSY	0.80	0.80	1.00	1
30	om_30	rec	0.10	0.10	L	1.00	H-MSY	0.80	0.80	1.00	1
31	om_31	rec	0.10	0.10	L	0.10	MSY	0.80	0.80	1.00	1
32	om_32	rec	0.10	0.10	L	1.00	MSY	0.80	0.80	1.00	1
33	om_33	rec	0.10	0.10	L	0.10	H-MSY	0.20	0.20	0.10	2
34	om_34	rec	0.10	0.10	L	1.00	H-MSY	0.20	0.20	0.10	2
35	om_35	rec	0.10	0.10	L	0.10	MSY	0.20	0.20	0.10	2
36	om_36	rec	0.10	0.10	L	1.00	MSY	0.20	0.20	0.10	2
37	om_37	rec	0.10	0.10	L	0.10	H-MSY	0.80	0.20	0.10	2
38	om_38	rec	0.10	0.10	L	1.00	H-MSY	0.80	0.20	0.10	2
39	om_39	rec	0.10	0.10	L	0.10	MSY	0.80	0.20	0.10	2
40	om_40	rec	0.10	0.10	L	1.00	MSY	0.80	0.20	0.10	2
41	om_41	rec	0.10	0.10	L	0.10	H-MSY	0.20	0.80	0.10	2
42	om_42	rec	0.10	0.10	L	1.00	H-MSY	0.20	0.80	0.10	2
43	om_43	rec	0.10	0.10	L	0.10	MSY	0.20	0.80	0.10	2
44	om_44	rec	0.10	0.10	L	1.00	MSY	0.20	0.80	0.10	2
45	om_45	rec	0.10	0.10	L	0.10	H-MSY	0.80	0.80	0.10	2
46	om_46	rec	0.10	0.10	L	1.00	H-MSY	0.80	0.80	0.10	2
47	om_47	rec	0.10	0.10	L	0.10	MSY	0.80	0.80	0.10	2
48	om_48	rec	0.10	0.10	L	1.00	MSY	0.80	0.80	0.10	2
49	om_49	rec	0.10	0.10	L	0.10	H-MSY	0.20	0.20	1.00	2
50	om_50	rec	0.10	0.10	L	1.00	H-MSY	0.20	0.20	1.00	2
51	om_51	rec	0.10	0.10	L	0.10	MSY	0.20	0.20	1.00	2
52	om_52	rec	0.10	0.10	L	1.00	MSY	0.20	0.20	1.00	2
53	om_53	rec	0.10	0.10	L	0.10	H-MSY	0.80	0.20	1.00	2
54	om_54	rec	0.10	0.10	L	1.00	H-MSY	0.80	0.20	1.00	2
55	om_55	rec	0.10	0.10	L	0.10	MSY	0.80	0.20	1.00	2
56	om_56	rec	0.10	0.10	L	1.00	MSY	0.80	0.20	1.00	2
57	om_57	rec	0.10	0.10	L	0.10	H-MSY	0.20	0.80	1.00	2
58	om_58	rec	0.10	0.10	L	1.00	H-MSY	0.20	0.80	1.00	2
59	om_59	rec	0.10	0.10	L	0.10	MSY	0.20	0.80	1.00	2
60	om_60	rec	0.10	0.10	L	1.00	MSY	0.20	0.80	1.00	2
61	om_61	rec	0.10	0.10	L	0.10	H-MSY	0.80	0.80	1.00	2
62	om_62	rec	0.10	0.10	L	1.00	H-MSY	0.80	0.80	1.00	2
63	om_63	rec	0.10	0.10	L	0.10	MSY	0.80	0.80	1.00	2
64	om_64	rec	0.10	0.10	L	1.00	MSY	0.80	0.80	1.00	2
65	om_65	rec	0.10	0.10	L	0.10	H-MSY	0.20	0.20	0.10	4
66	om_66	rec	0.10	0.10	L	1.00	H-MSY	0.20	0.20	0.10	4
67	om_67	rec	0.10	0.10	L	0.10	MSY	0.20	0.20	0.10	4
68	om_68	rec	0.10	0.10	L	1.00	MSY	0.20	0.20	0.10	4
69	om_69	rec	0.10	0.10	L	0.10	H-MSY	0.80	0.20	0.10	4
70	om_70	rec	0.10	0.10	L	1.00	H-MSY	0.80	0.20	0.10	4
71	om_71	rec	0.10	0.10	L	0.10	MSY	0.80	0.20	0.10	4
72	om_72	rec	0.10	0.10	L	1.00	MSY	0.80	0.20	0.10	4
73	om_73	rec	0.10	0.10	L	0.10	H-MSY	0.20	0.80	0.10	4
74	om_74	rec	0.10	0.10	L	1.00	H-MSY	0.20	0.80	0.10	4
75	om_75	rec	0.10	0.10	L	0.10	MSY	0.20	0.80	0.10	4
76	om_76	rec	0.10	0.10	L	1.00	MSY	0.20	0.80	0.10	4
77	om_77	rec	0.10	0.10	L	0.10	H-MSY	0.80	0.80	0.10	4
78	om_78	rec	0.10	0.10	L	1.00	H-MSY	0.80	0.80	0.10	4
79	om_79	rec	0.10	0.10	L	0.10	MSY	0.80	0.80	0.10	4
80	om_80	rec	0.10	0.10	L	1.00	MSY	0.80	0.80	0.10	4
81	om_81	rec	0.10	0.10	L	0.10	H-MSY	0.20	0.20	1.00	4
82	om_82	rec	0.10	0.10	L	1.00	H-MSY	0.20	0.20	1.00	4
83	om_83	rec	0.10	0.10	L	0.10	MSY	0.20	0.20	1.00	4
84	om_84	rec	0.10	0.10	L	1.00	MSY	0.20	0.20	1.00	4
85	om_85	rec	0.10	0.10	L	0.10	H-MSY	0.80	0.20	1.00	4
86	om_86	rec	0.10	0.10	L	1.00	H-MSY	0.80	0.20	1.00	4
87	om_87	rec	0.10	0.10	L	0.10	MSY	0.80	0.20	1.00	4
88	om_88	rec	0.10	0.10	L	1.00	MSY	0.80	0.20	1.00	4
89	om_89	rec	0.10	0.10	L	0.10	H-MSY	0.20	0.80	1.00	4
90	om_90	rec	0.10	0.10	L	1.00	H-MSY	0.20	0.80	1.00	4
91	om_91	rec	0.10	0.10	L	0.10	MSY	0.20	0.80	1.00	4
92	om_92	rec	0.10	0.10	L	1.00	MSY	0.20	0.80	1.00	4
93	om_93	rec	0.10	0.10	L	0.10	H-MSY	0.80	0.80	1.00	4
94	om_94	rec	0.10	0.10	L	1.00	H-MSY	0.80	0.80	1.00	4
95	om_95	rec	0.10	0.10	L	0.10	MSY	0.80	0.80	1.00	4
96	om_96	rec	0.10	0.10	L	1.00	MSY	0.80	0.80	1.00	4

Table 2: Distinguishing characteristics of the estimating models

	ecov_how	r_mod
1	0	BH
2	1	BH
3	2	BH
4	4	BH