Exploration of Bayesian Stock Reduction Analysis for Assessment of West Coast Groundfish

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1. Introduction

We evaluate performance of a Bayesian Stock Reduction Analysis (SRA) model by fitting indicies of abundance from age-structured, data-rich stock assessments and comparing SRA results to output from the full assessments. The SRA model allows for a simple transition from catch-based DB-SRA, for which stock status is an input, to a full assessment, updating the prior distributions for stock status and other productivity parameters. Annual variances for abundance indices are assumed known, with uncertainty in an additive variance component and catchability parameters propagated through the model.

2. Darkblotched Rockfish

2.1. Review of Assessment Model

The 2011 assessment, utilizing Stock Synthesis, was conducted by Stephens et al. (2011) and is available at <http://www.pcouncil.org/wp-content/uploads/Darkblotched_2011_Assessment.pdf>. The assessment utilized a fixed M = 0.07 and a fixed value of steepness (h = 0.76) based on the mean of the most recent Dorn prior. Alternative steepness values of 0.54 and 0.95 were used to explore uncertainty. The model considered data from four surveys (Triennial, AFSC slope, NWFSC slope, and NWFSC shelf), all of which were represented by dome-shaped selectivity curves (cf. the recent widow rockfish review requirement for at least one asymptotic selectivity pattern).

We explored some configurations of the assessment that may be useful for comparisons with the new SRA model (Figure 1). The bottom panel of the figure shows abundance relative to the estimated unfished level. In all alternative configurations of SS, rec devs are turned off and all selectivity and growth parameters are fixed at the values estimated in the base model. The assessment trajectory shows a depletion to near 10% of unfished ca. 2000 and a strong rebuilding to near 30% in 2012. The PSA-based depletion prior (2009 relative abundance is 0.229, SE=0.118, dot in lower panel of Figure 1) is close to the value from the assessment. When the comps are removed from the assessment, the assessment produces a much higher ending biomass; if h is estimated (h = 0.94), the result is similar. It appears that there is tension in the assessment where abundance data favor a higher steepness and comp data favor a lower steepness, with ending biomass varying accordingly.

Comparing the survey likelihood components for fixed-h and estimated-h cases, the Triennial data had the strongest influence on the fit (largest delta log-likelihood). The AFSC slope values covered only 4 years, and had negligible influence, and the NWFSC slope survey had small influence. To produce a model roughly comparable with the SRA results, we included only the Triennial and the NWFSC shelf surveys. To simulate the PSA-based depletion prior, we added an “artificial” survey with precise unit value in 1892, and a value of 0.229 (SE = 0.118) in 2009 (note: this approach was discouraged for assessment use at the 2011 review, and is included only as a rough approximation for purposes of comparison). Under the influence of the depletion value the assessment produces an intermediate trajectory, passing 1.35 SE from the depletion value, and has an estimated steepness (h = 0.41). The fit results from a slightly lower estimated value of Bunfished, and a much lower estimated value of steepness.

2.2. Results of the Bayesian SRA Model

The median trajectory from the Bayesian SRA model (note; this is the year-by-year median, and does not correspond exactly to a single realized trajectory) is remarkably similar to the base assessment by Stephens et al. (2011). The stock-recruitment relationship implicit in the SRA model differs from the

Beverton-Holt curve used in the SS assessment. The expected value of Bmsy/Bunfished used in the SRA is 0.4 and is higher than the Beverton-Holt-based value of 0.24 that appears in the assessment, given the fixed value of h = 0.76. Consequently the assessment has higher per-capita productivity at low biomasses than does the SRA. This is most clearly seen in the estimated rate of recovery since rebuilding began about 10 years ago. Using an "eyeball extrapolation" the assessment suggests that the rebuilding target may be reached in 5 years whereas the SRA indicates that it will take much longer, probably more than a decade.

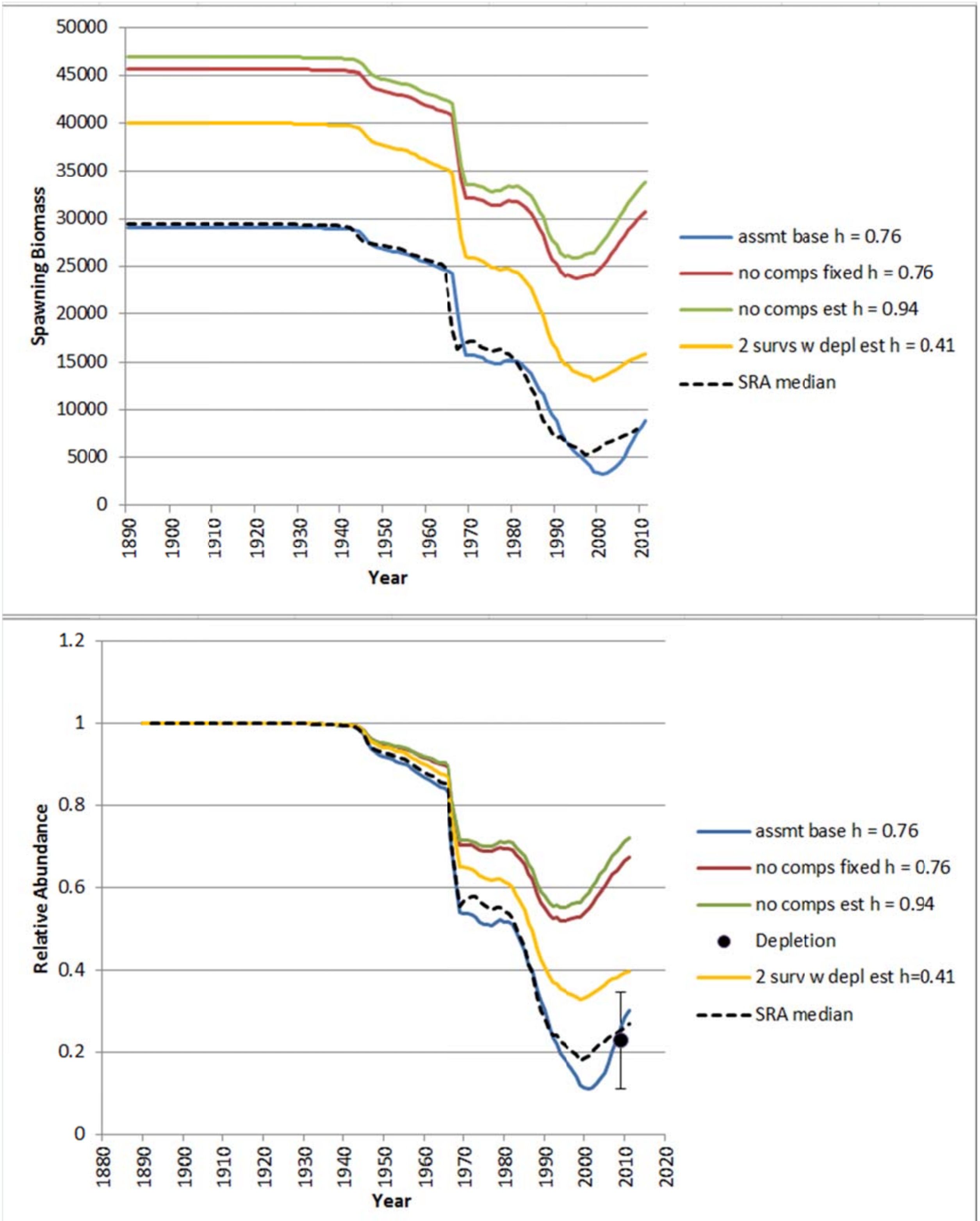

Figure 2.1. Comparison of model trajectories for darkblotched rockfish.

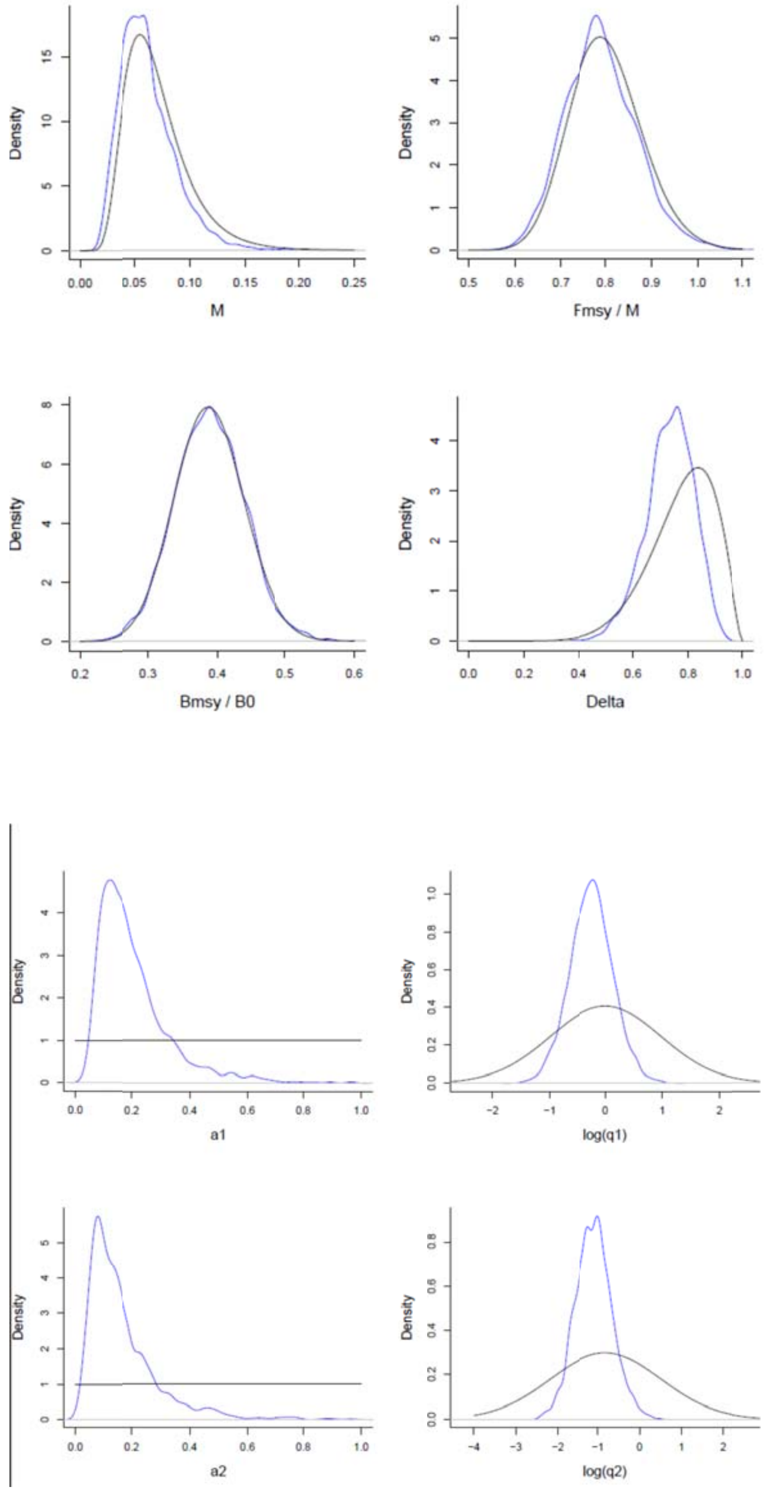

Figure 2.2. Prior and posterior density of SRA parameters for darkblotched rockfish. Upper panel shows leading parameters, lower panel shows nuisance parameters. Survey 1 is Triennial index, and Survey 2 is shelf portion of NWFSC trawl survey.

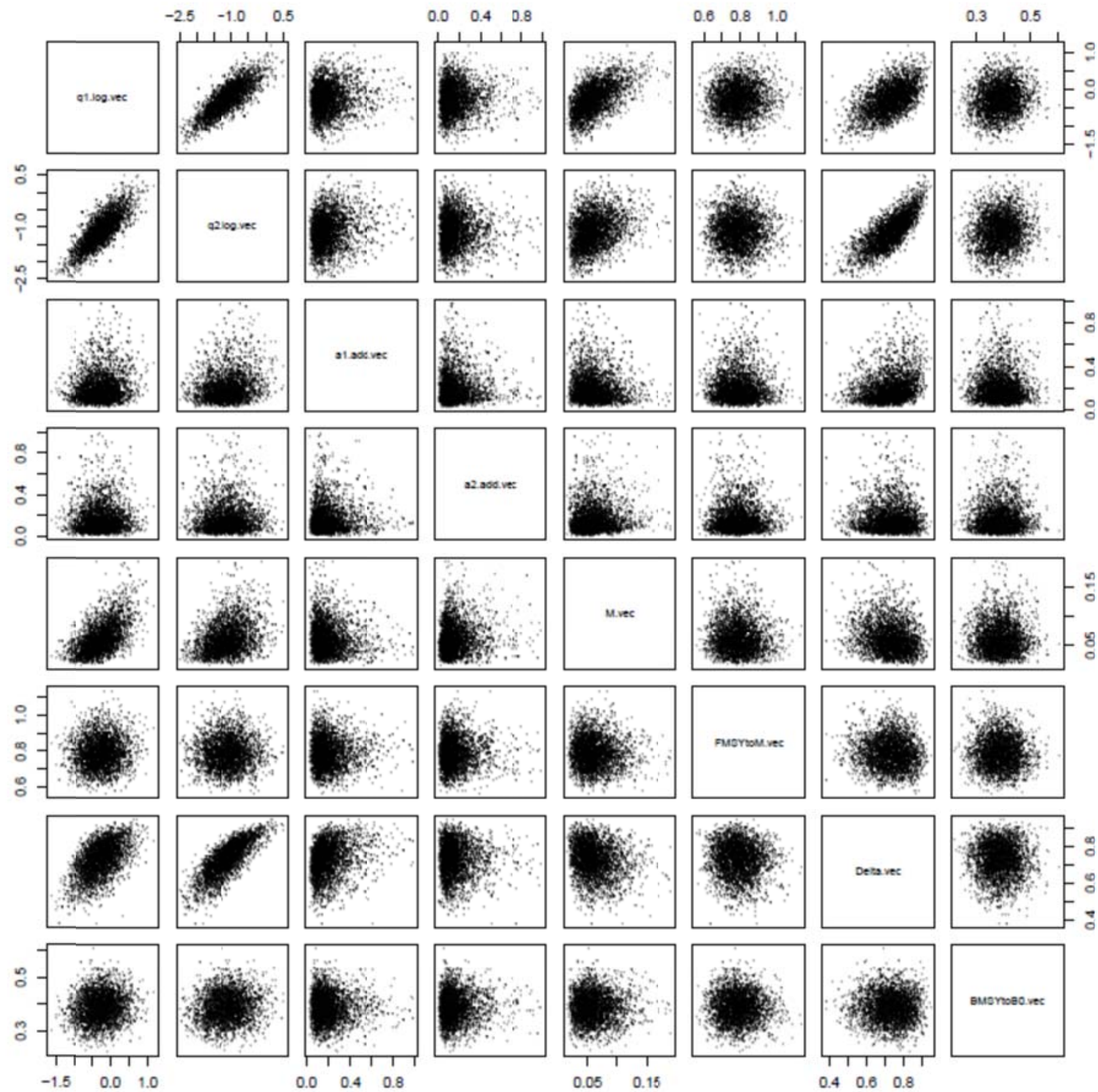

Figure 2.3. Scatterplots of parameter values for darkblotched rockfish.

3. Widow Rockfish

3.1. Review of Assessment Model

The 2011 assessment, utilizing Stock Synthesis, was conducted by He et al. (2011) and is available at http://www.pcouncil.org/wp-content/uploads/Widow_2011_Assessment.pdf (may need to check with PFMC on this). The assessment utilized fixed M = 0.124 for females and 0.129 for males, and a fixed value of steepness (h = 0.76) based on the mean of the most recent Dorn prior. Alternative steepness values of 0.41 and 0.90 were used to explore uncertainty. In addition to an index of juvenile abundance, the assessment considered multiple data sources for adult fish abundance (Oregon bottom trawl logbooks, Triennial survey, NWFSC trawl survey, and by-catch rates in foreign, joint venture and domestic hake fisheries AFSC slope). Although the comp data favored dome-shaped selectivity curves, asymptotic curves were adopted for the final assessment in order to improve model stability. The data favored a low steepness, while the Dorn prior favored a high steepness, so that the posterior likelihood was relatively flat over a wide range of steepness values. The final assessment used a steepness fixed at the mean of the Dorn prior (h = 0.76), which resulted in high productivity estimates at lower abundances (maximum productivity would occur at Bmsy/Bunfished = 0.24) and indicated that the resource had increased strongly since rebuilding was initiated.

3.2. Results of the Bayesian SRA Model

A2 is beign downweighted

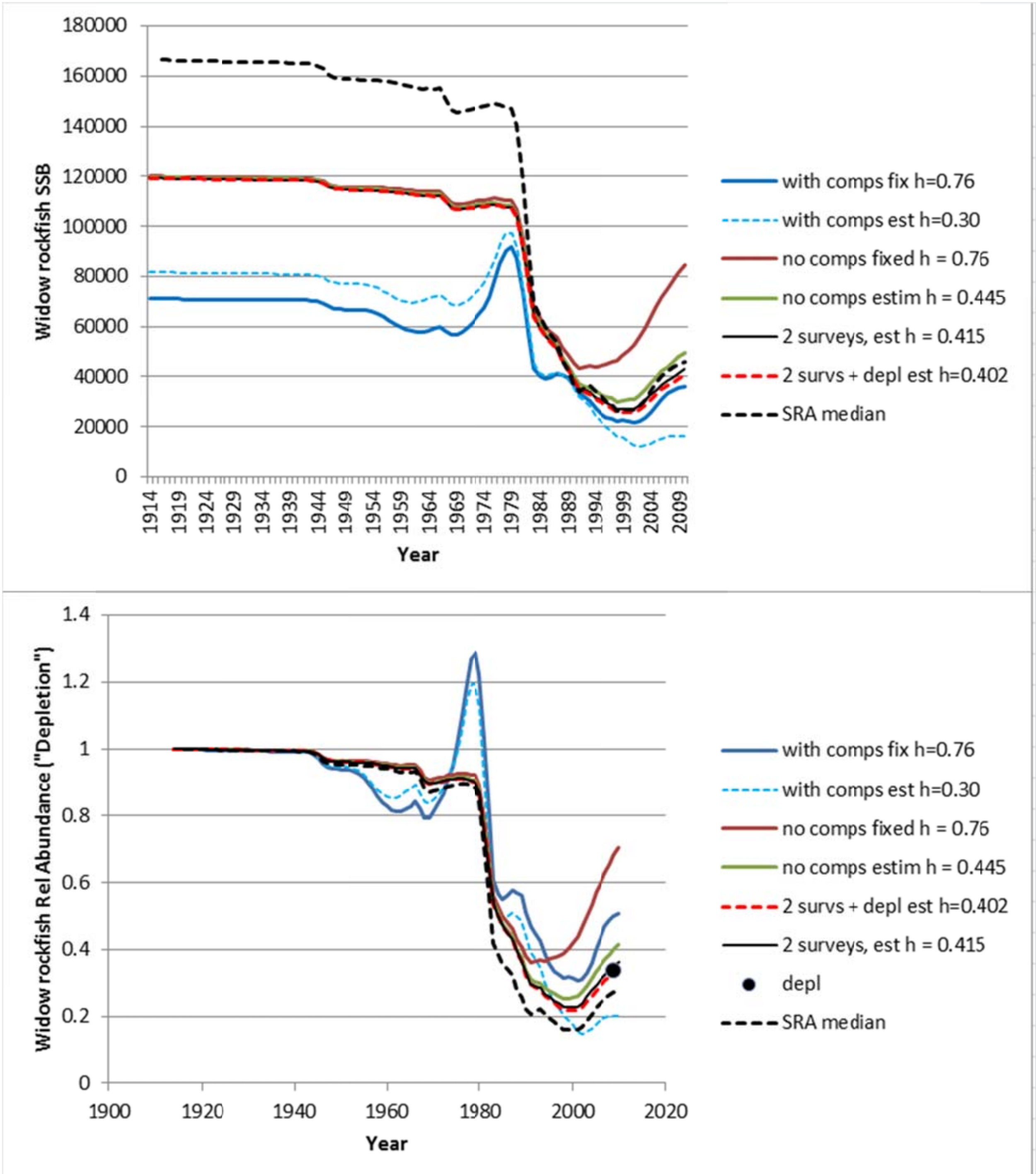

Figure 3.1. Comparison of model trajectories for widow rockfish.

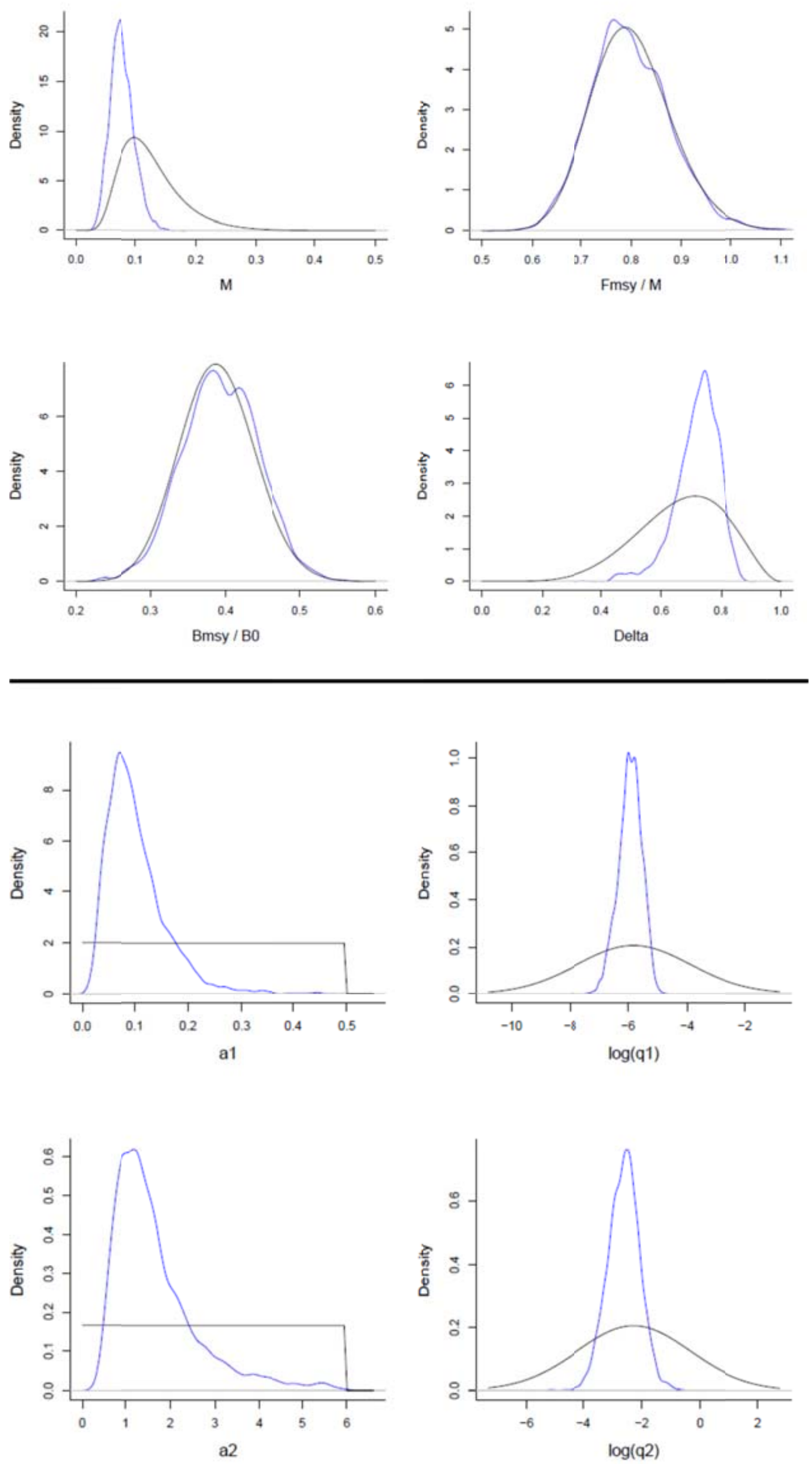

Figure 3.2. Prior and posterior density of SRA parameters for widow rockfish. Upper panel shows leading parameters, lower panel shows nuisance parameters. Survey 1 is Oregon bottom trawl index, and Survey 2 is Triennial.

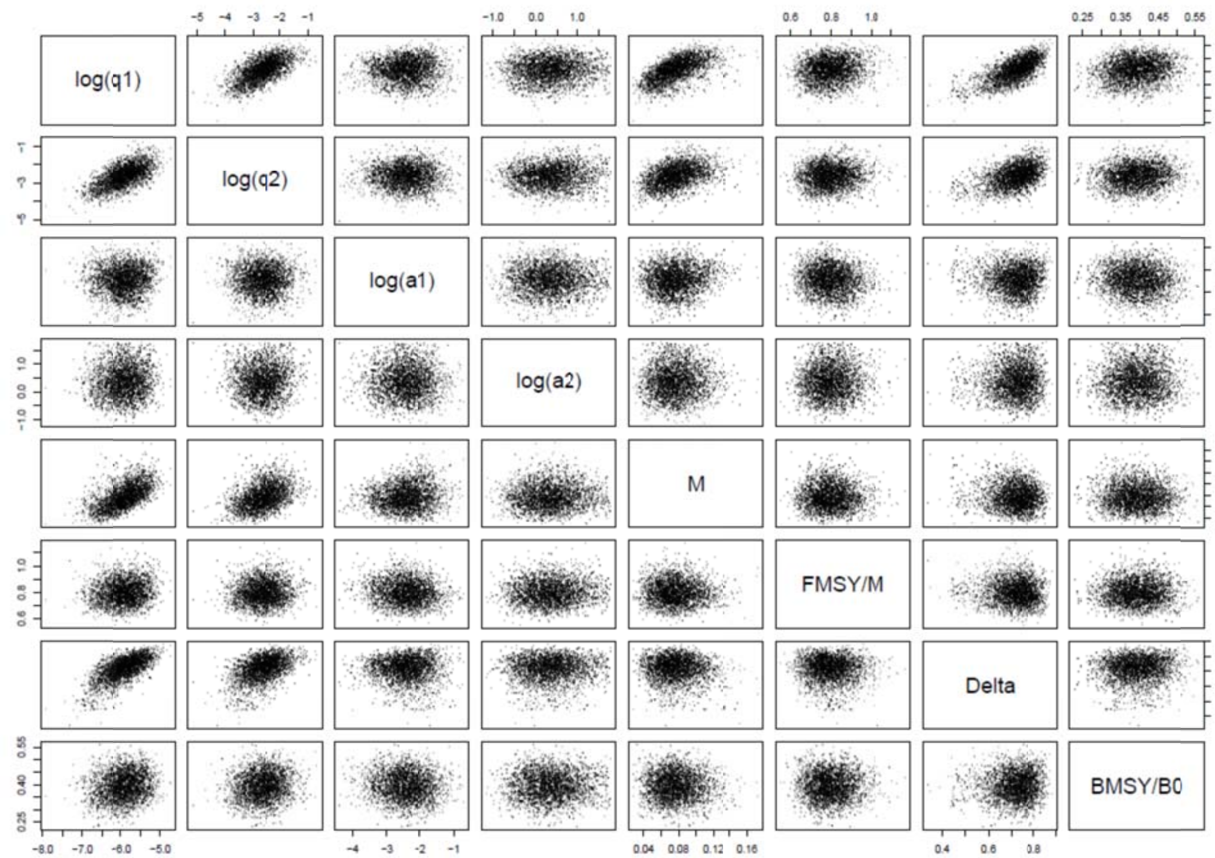

Figure 2.3. Scatterplots of parameter values for widow rockfish.

4. Cowcod

4.1. Review of Assessment Model

The 2009 update assessment, utilizing Stock Synthesis, was conducted by Dick et al. (2009) and is available at <http://www.pcouncil.org/wp-content/uploads/cowcod_update_assessment_2009.pdf>. The cowcod assessment has long been problematic, with estimated Beverton-Holt steepness falling to 0.2 (indicating no net productivity) if it is freely estimated. Under the assumption that there must be some productivity, the update used a fixed value of steepness (h = 0.6), and explored alternative steepness values of 0.4 and 0.8. The model used no comps (or rec devs) and considered abundance data from two sources, a long time series (1963-2000) of the southern California partyboat (a.k.a., commercial passenger fishing vessels) CPUE, and a single fishery-independent estimate of abundance from a submersible survey conducted in 2002. The model was unable to resolve a conflict between the two data sources (the submersible survey was too high to reach), and there was difficulty in obtaining abundance trajectories that declined as rapidly as the partyboat CPUE (Figure 4.1). In order to generate a rapid decline of abundance in the presence of relatively high underlying stock-recruitment productivity associated with the assumed steepness, the model estimated extremely high fishing intensities, peaking at a 92% exploitation rate in 1988 (Figure 4.1, bottom).

4.2. Results of the Bayesian SRA Model

The SRA model is able to reconcile all major problems with the assessment. The depletion trajectory is nearly indistinguishable from that produced by the previous assessment, but passes near the depletion prior (prior relative abundance in 2009 has mean 0.128, sd = 0.092; SRA median is 0.072, see lower right graph in Figure 4.2). Figure 4.2 shows that the data support several other changes to the prior distributions. SRA prefers a much lower natural mortality rate (M), a slightly lower Fmsy to M ratio (posterior mean is 0.76) and perhaps most importantly a higher Bmsy to Bunfished ratio (mean is 0.53). This indicates that SRA favors a solution that cannot be obtained under the constraints of a Beverton-Holt SRR (Figure 4.3). By shifting the biomass at peak productivity to a higher level relative to Bunfished, the estimated productivity of the stock is lower in the 1980s, and the model is not forced to estimate implausible exploitation rates (Figure 4.1, bottom). Unlike the assessment, the SRA model agrees well with the submersible survey (passing at 1.4 se above the estimate), and there is no conflict between the two sources of abundance information. Scatterplots of parameters are shown in Figure 4.4.

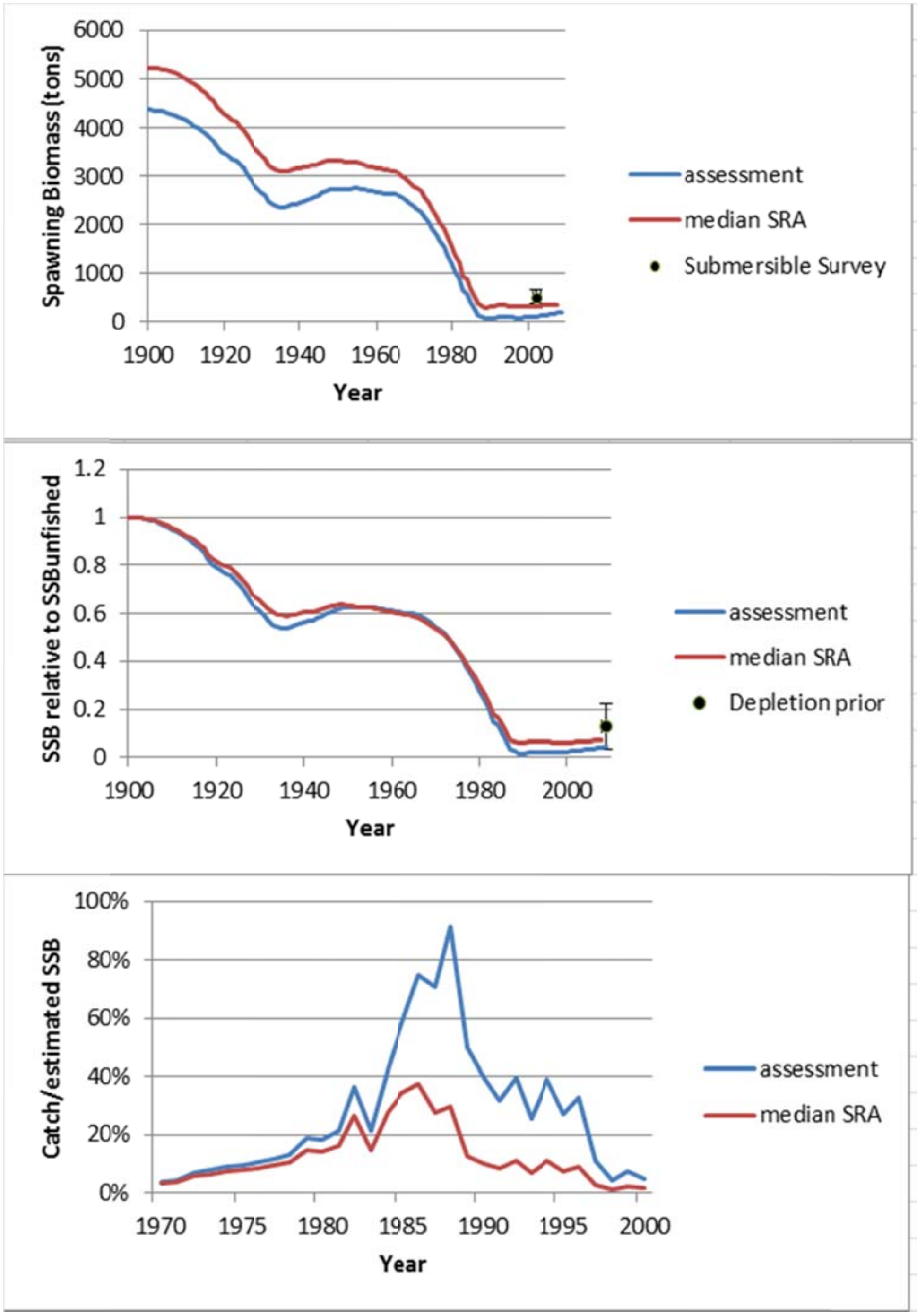

Figure 4.1. Comparison of model trajectories for cowcod (upper panel is spawning biomass, middle panel is SSB relative to estimated unfished). Lower panel shows the ratio of catch to estimated spawning biomass.

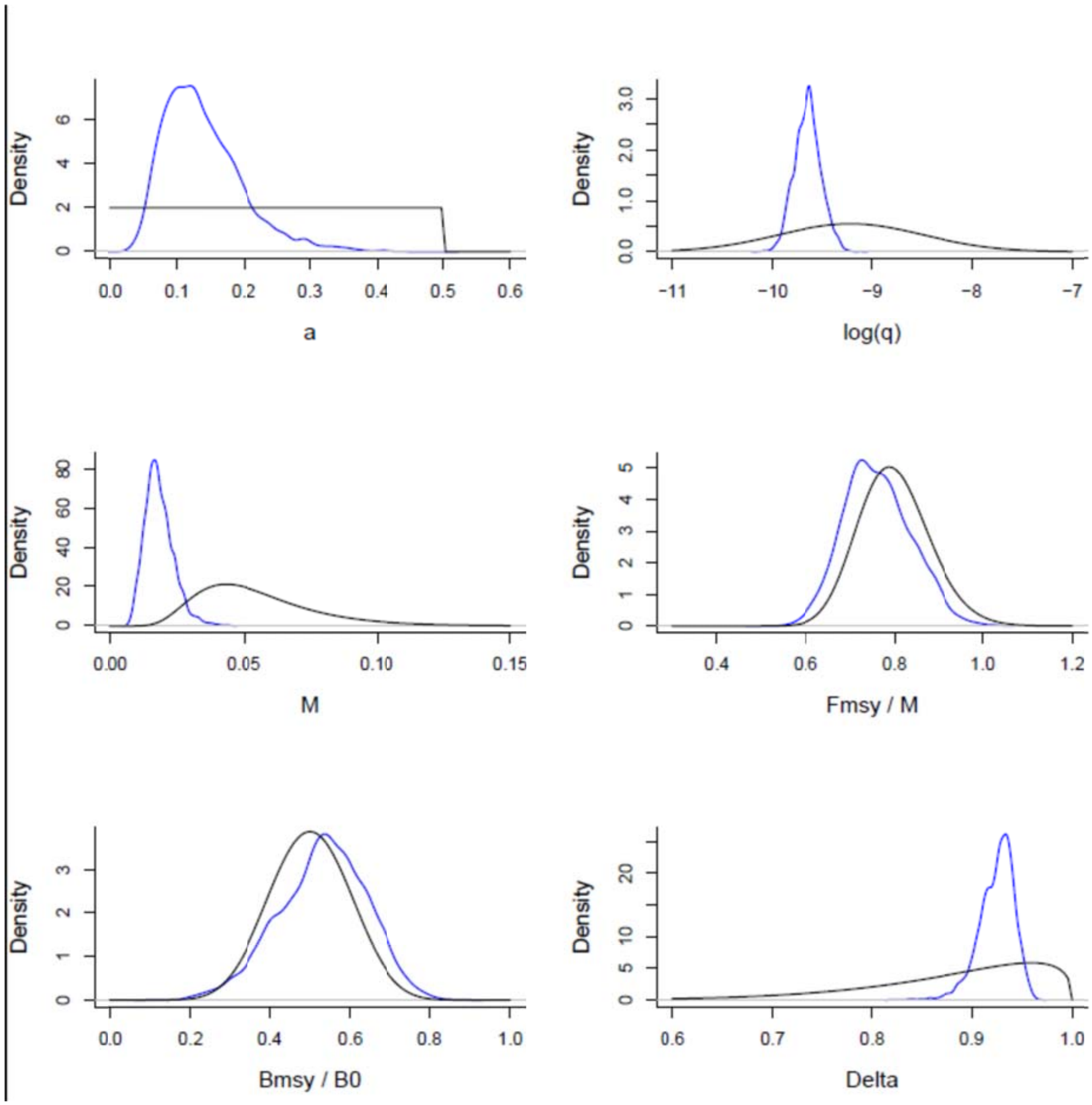

Figure 4.2. Prior and posterior density of SRA parameters for cowcod.

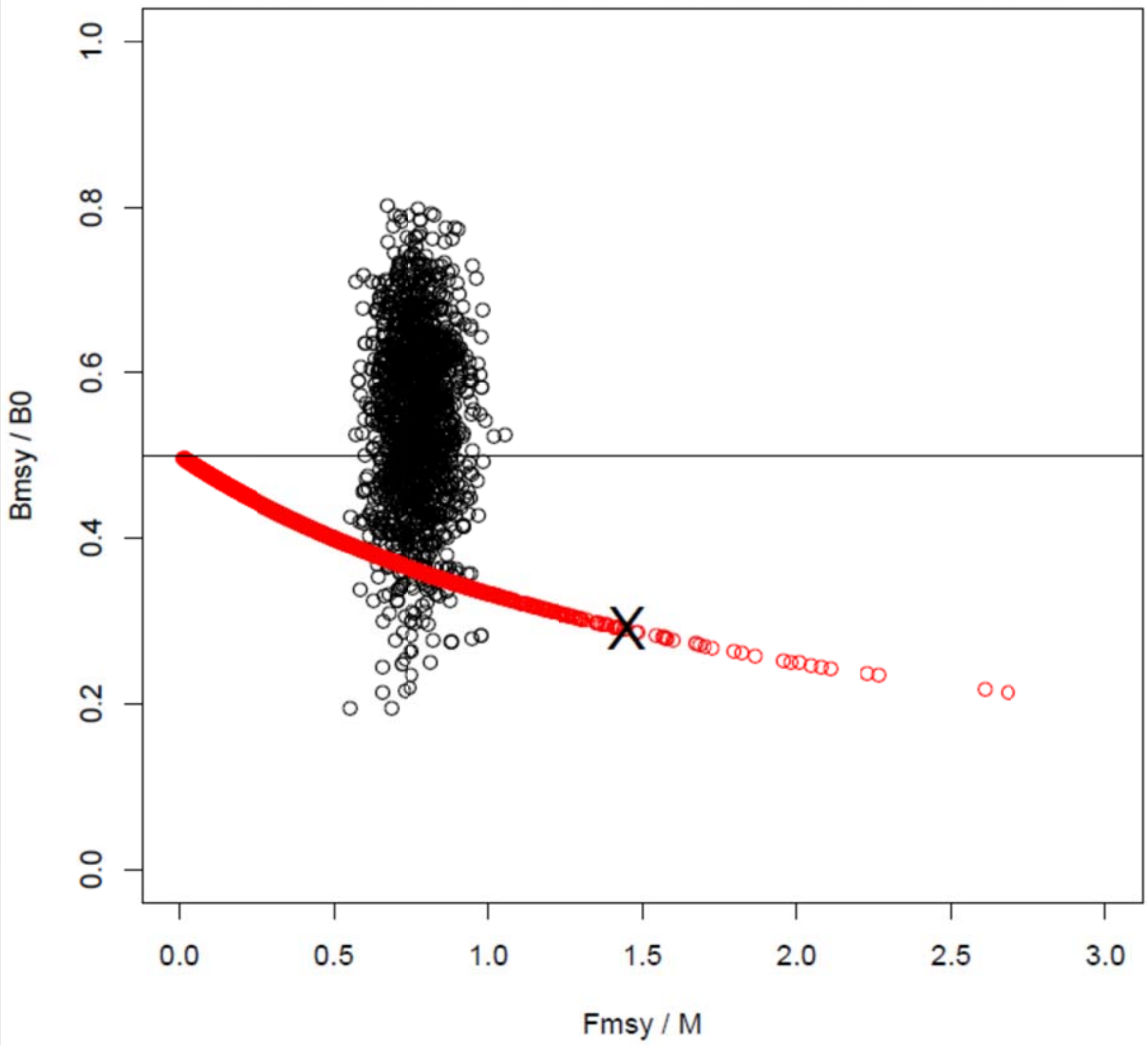

Figure 4.3. Comparison of SRA posterior parameter estimates drawn from a generalized production model (black) and those drawn from a Beverton-Holt SRR (red, falling along a line). The X marks the location of the h = 6 assumed in the assessment.

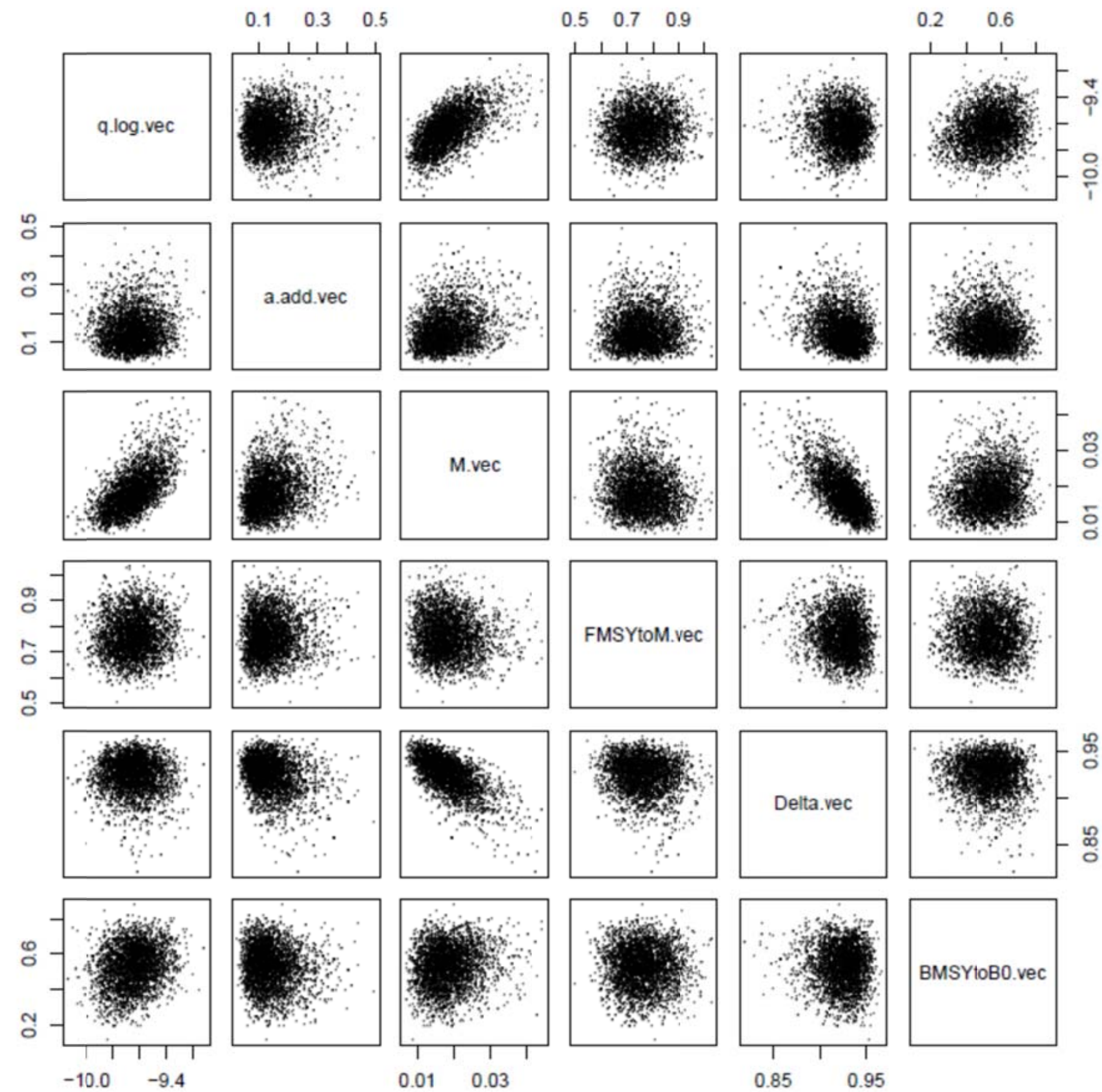

Figure 4.4. Scatterplots of parameter values for cowcod.

5. Bocaccio

5.1. Review of Assessment Model

<http://www.pcouncil.org/wp-content/uploads/Bocaccio_Final_Jan15_2010.pdf>

5.2. Results of the Bayesian SRA Model

TBD

6. Gopher Rockfish

6.1. Review of Assessment Model

The 2007 assessment, utilizing Stock Synthesis, was conducted by Key et al. (2005) and is available at <http://www.pcouncil.org/wp-content/uploads/GOPHER_rf_Key_August05.pdf>. The assessment utilized fixed M = 0.2, and a fixed value of steepness (h = 0.65) based on the mean of the then-current Dorn prior. The assessment initially considered two abundance indexes based on recreational fishery catch-per-unit-effort data, one from the MRFSS/RecFIN time series of dockside samples 1983-2003, and the other from the site-specific on-board sampling conducted by CDFG from 1987 to1998. Both indexes showed an increase in recent years, but otherwise were not in close agreement, and were not well fit by any configuration of the model because the comp information favored a declining trend. In response to a STAR Panel recommendation, the longer RecFIN series (which included the problematic 1997-98 observations) was discarded, and the CDFG time series was up-weighted by a lambda (data weighting multiplier) of 5 while comp data remained at lambda of 1. The resulting fit to the abundance data is shown in Figure 6.1. Manipulation of lambda was treated as the main axis of uncertainty, with alternative values of 1 and 10, which produced a range of 2003 relative abundances from 59 to 110%, with the base model giving a value of 97%. Because all scenarios indicated a healthy stock, the risk appeared to be minor despite the relatively large uncertainty.

6.2. Results of the Bayesian SRA Model

The SRA model faced data fitting problems similar to those encountered in the original assessment. Because catches were high during the 1990s, the SRA model is constrained to portraying declining trends during the period covered by the abundance indexes, and its influence is analogous to that of the comps in the original assessment. The SRA model also detected an incompatibility between the two abundance indexes, and assigned a large additive variance to the RecFIN index which greatly reduces its influence on the resulting SRA estimates: The means of the additive variances were 0.1 for the CDFG observer index, and 1.5 for the RecFIN index. In reducing the influence of the RecFIN index, the SRA analysis objectively reached the same conclusion as was reached in the original assessment. Consequently, this SRA also rejects use of the RecFIN index, and results are given only for an analysis using only the CDFG observer index, making it comparable to the assessment. Although the fitted trajectories are quite different, the assessment and SRA are in agreement that recent abundance levels are high relative to estimated unfished levels (Figure 6.2). The posterior distribution of delta (Figure 6.3) indicates that the abundance data are strongly informative relative to the prior. Scatterplots of leading SRA parameters are shown in Figure 6.4.

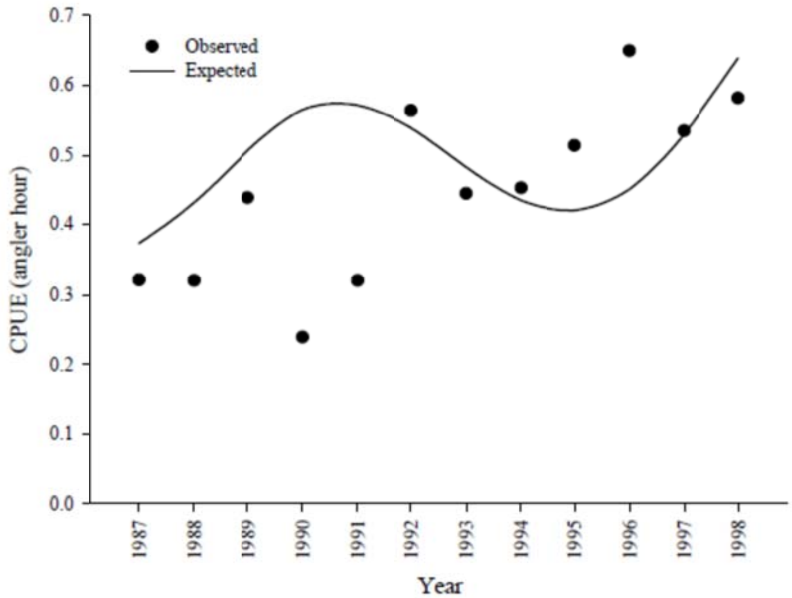

Figure 6.1. Original assessment fit to CDFG observer index of gopher rockfish abundance. Observations had standard errors of about 0.1, and no variance was added.

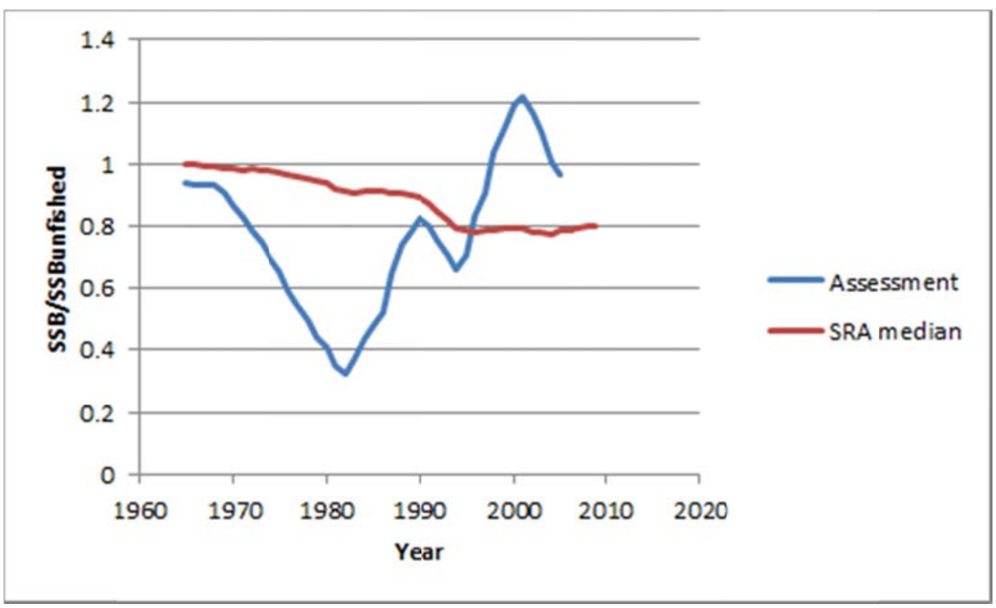

Figure 6.2. Comparison of estimated trajectories of relative spawning biomass (SSB) from the gopher rockfish assessment and the median SRA result using on the CDFG abundance index.

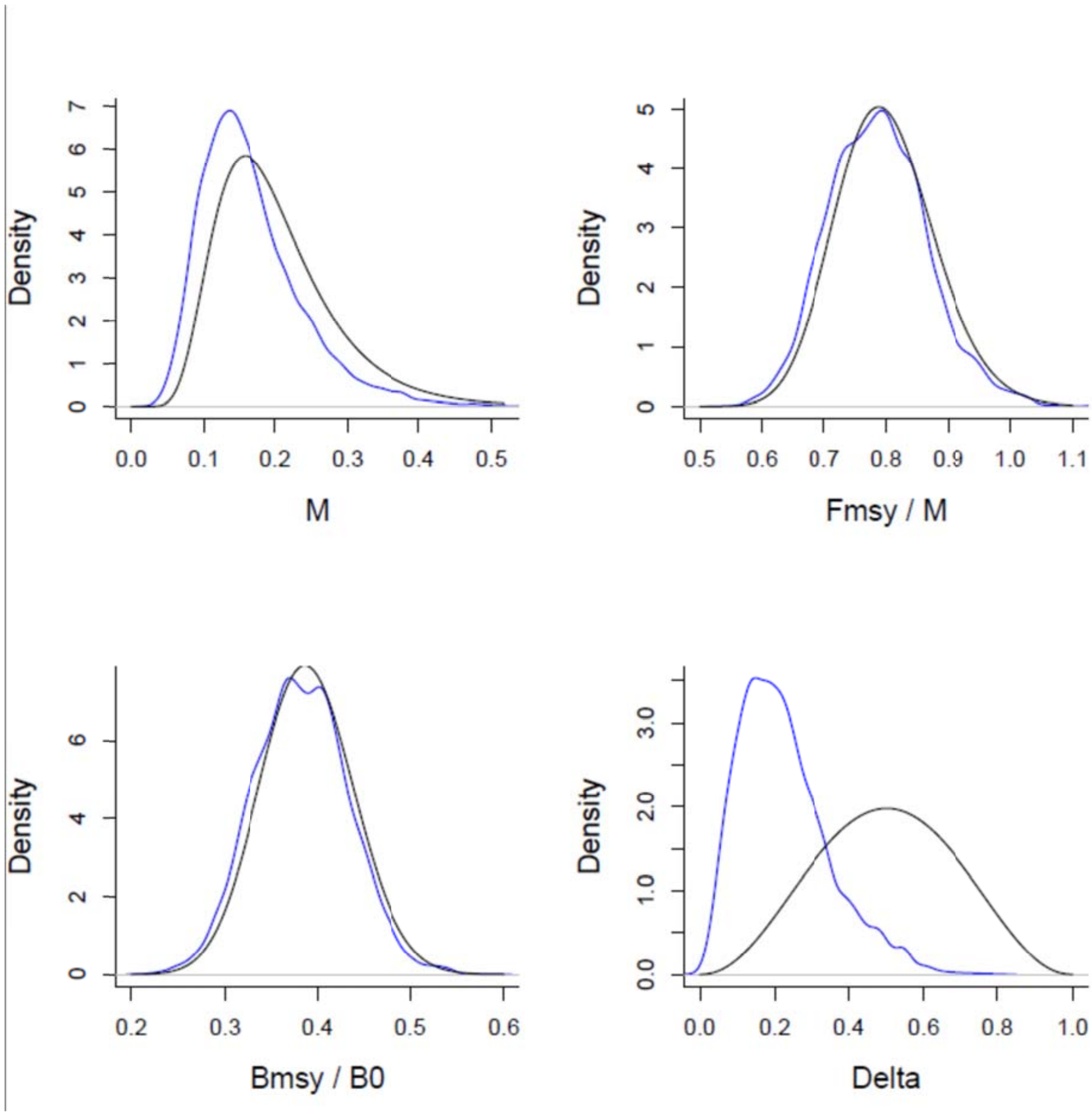

Figure 6.3. Prior and posterior density of SRA parameters for gopher rockfish.

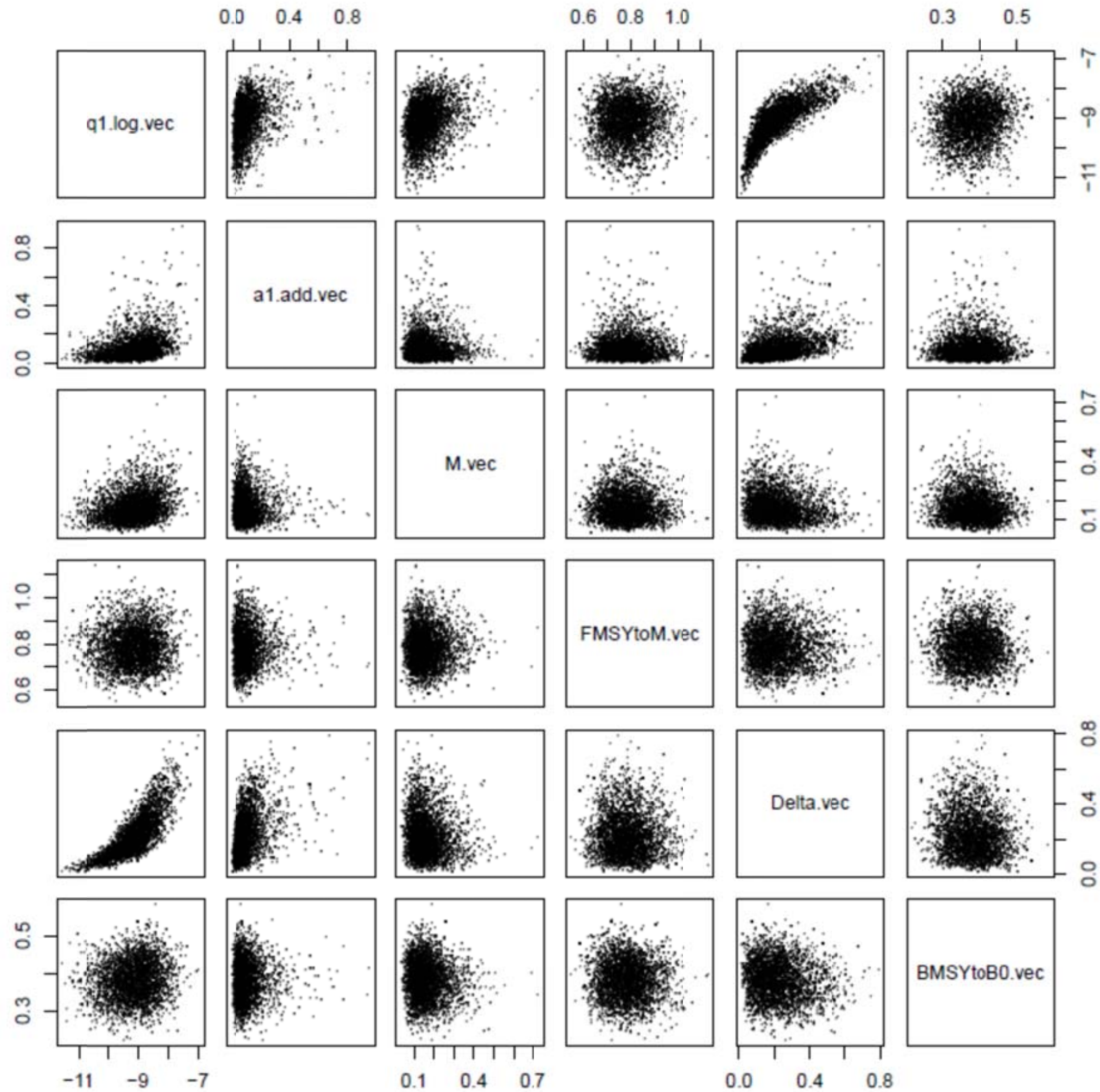

Figure 6.4. Scatterplots of parameter values for gopher rockfish.

7. Blue Rockfish

7.1. Review of Assessment Model

The 2007 assessment, utilizing Stock Synthesis, was conducted by Key et al. (2008) and is available at <http://www.pcouncil.org/wp-content/uploads/KeySAFE_BlueRF_Jan08.pdf>. The assessment utilized fixed M = 0.10 for females and 0.12 for males, and a fixed value of steepness (h = 0.58) based on the mean of the then-current Dorn prior. The model considered data from two recreational fishery sources, a RecFIN trip-based CPUE and the CDFG on-board observer CPUE. Because of a change in bag limits, the RecFIN CPUE for years after 1999 was treated as a third, separate series. The length comps used int he assessment were interepreted by a single growth curve despite stron evidence that growth parameters varied substantially by location and year. However, there were too few age samples to support a detailed growth model. The assessment model tended to be unstable, and the results were not considered to be definitive.

7.2. Results of the Bayesian SRA Model

The posterior distributions (Figure 7.1) show relatively little difference from the prior distributions, indicating that the abundance data are not informative except for delta, where the data indicate a somewhat higher relative ending abundance than was produced by the assessment. Judging by the relatively small additive variances, neither abundance index is rejected by the analysis (Figure 7.2). Scatterplots of parameters are shown in Figure 7.3.

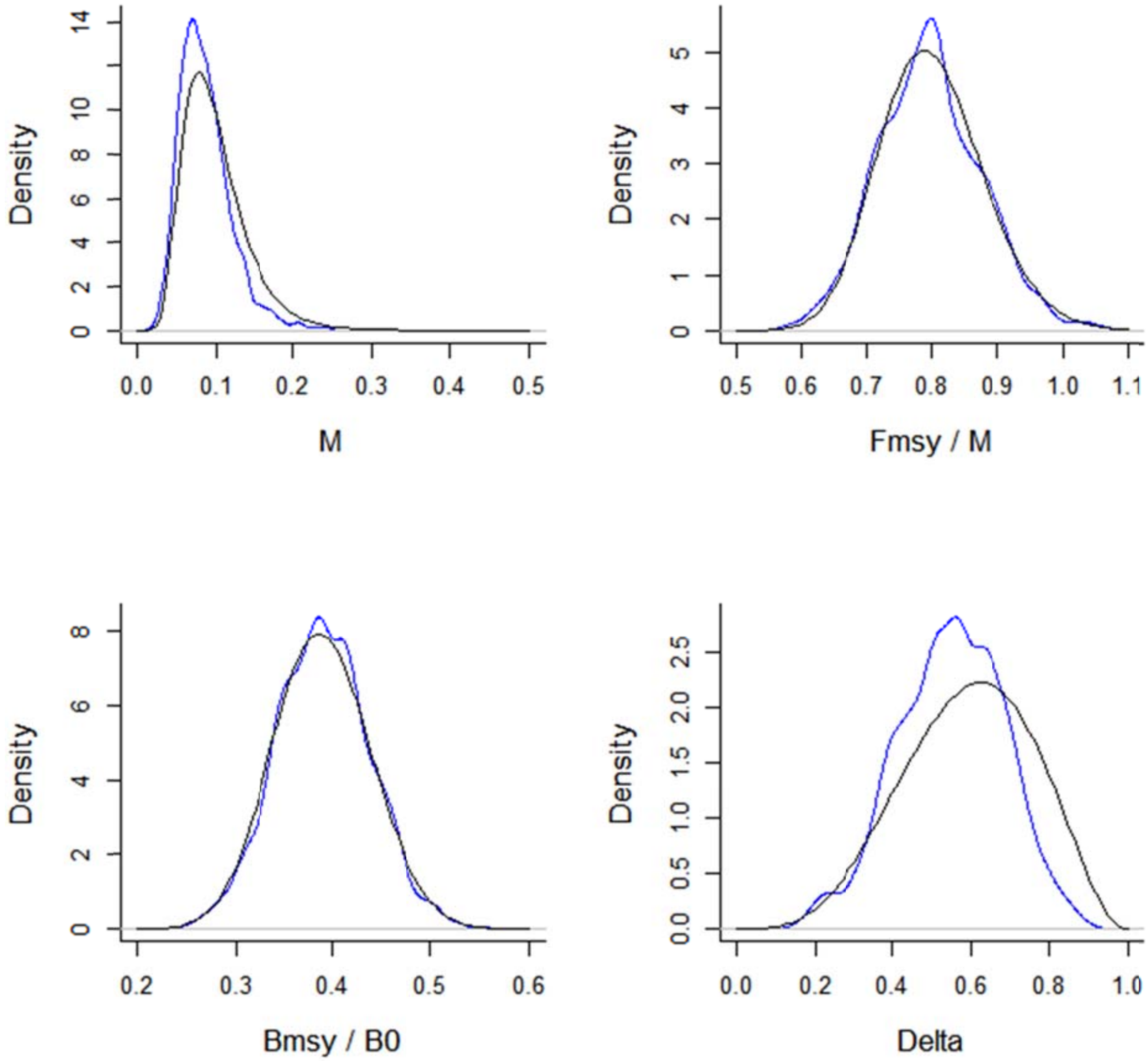

Figure 7.1. Prior and posterior density of SRA parameters for blue rockfish.

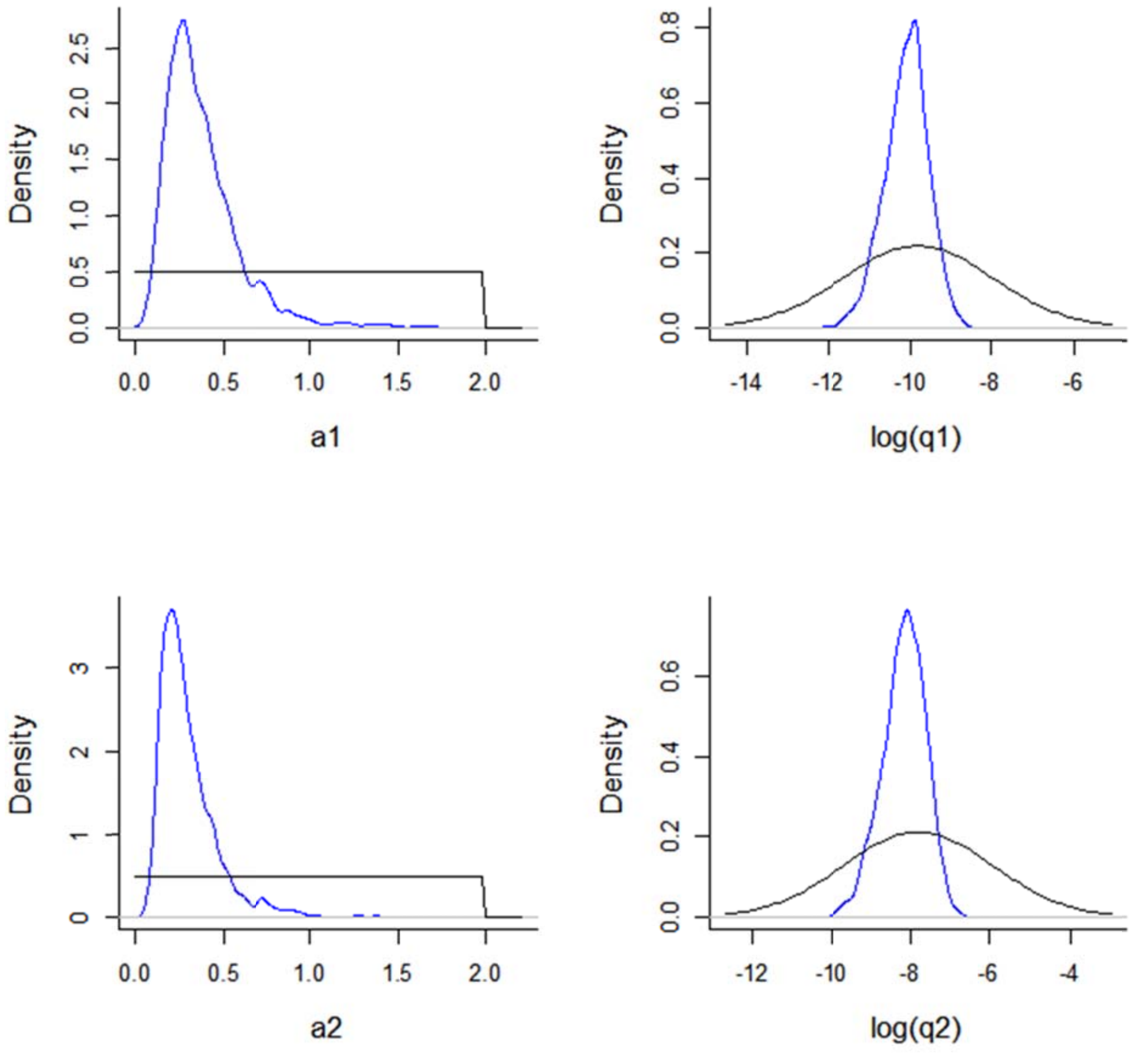

Figure 7.2. Prior and posterior density of SRA nuisance parameters for blue rockfish.

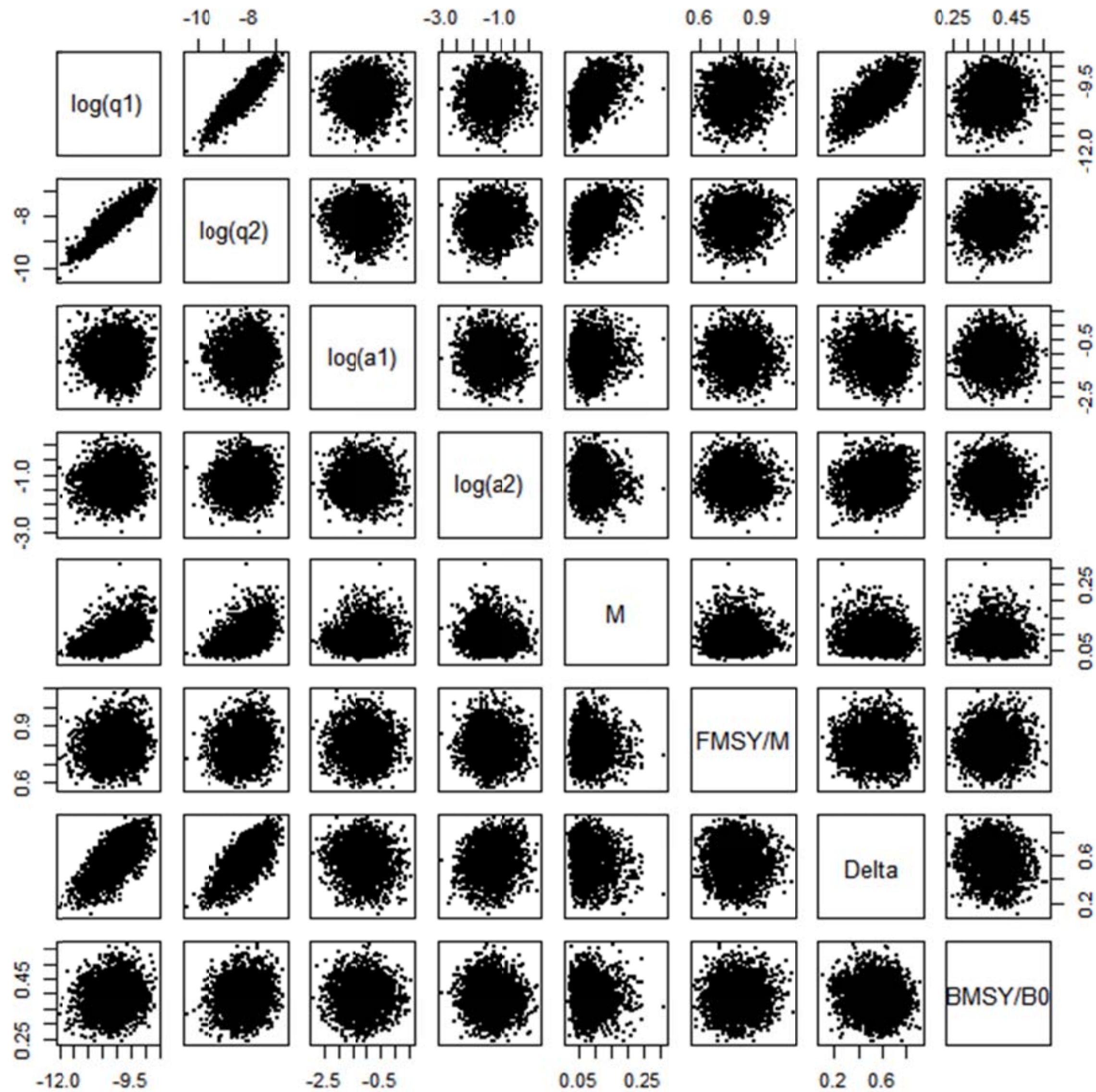

Figure 7.3. Scatterplots of parameter values for blue rockfish.

8. Chilipepper Rockfish

8.1. Review of Assessment Model

The 2011 assessment, utilizing Stock Synthesis, was conducted by Field et al. (2009), and is available at http://www.pcouncil.org/wp-content/uploads/ChilipepperJan2009final.pdf.

8.2. Results of the Bayesian SRA Model

TBD

9. Summary and Discussion

Stock	Darkblotched	Widow RF	Cowcod (Conception)	Gopher RF CDFG obs index "Index 2" only	Blue RF
SRA model diagnostics					
Sample size	5000	5000	5000	5000	5000
Maximium weight	0.0017	0.0023	0.0015	0.0009	0.0036
Relative entropy	0.942	0.946	0.972	0.969	0.947
Reference year	2009	2009	2009	2005	2007
SSB (tons)					
Assessment	7568	35545	195.2	1931	622
median SRA	7594	45093	377.7	3674	5372
Relative difference	0%	+27%	+93%	+90%	+764%
mean SRA (std)	8401 (4049)	48647 (18657)	385.6 (76.3)	5018 (4408)	6422 (3973)
CV	48%	38%	20%	88%	62%
Relative abundance (1-Delta)					
Assessment	0.27	0.50	0.045	0.97	0.30
Prior from PSA (std)	0.229 (0.118)	0.409 (0.165)	0.128 (0.098)	0.499 (0.181)	0.409 (0.165)
median SRA	0.27	0.27	0.072	0.794	0.447
Relative difference	0%	46%	+60%	-18%	49%
mean SRA (std)	0.273 (0.093)	0.280 (0.073)	0.075 (0.018)	0.776 (0.121)	0.452 (0.136)
CV	34%	26%	24%	16%	30%
OFL (tons)					
Assessment	483	3500	7	246	263
median SRA	323	2481	5	386	339
Relative difference	-33%	-29%	-29%	+60%	+29%
mean SRA (std)	352 (173)	2693 (1061)	5 (2)	524 (476)	384 (216)
CV	49%	39%	40%	91%	56%