

An Alternative View of Widow Rockfish Productivity

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In west coast groundfish stock assessments, biological productivity is largely defined by a single parameter, i.e., steepness (h) of the Beverton-Holt spawner-recruit curve, which ranges from 0.20 (no compensation) to 1.00 (complete compensation). A steepness of 0.20 implies no latent surplus production and a total lack of resilience to the effects of exploitation, whereas a value of 1.0 implies a very strong density-dependent response and strong resilience to perturbations.

Previous experience on the west coast has shown that groundfish stock assessments conducted for the Pacific Fishery Management Council have difficulty in estimating h with acceptable precision. As a consequence, the SSC and the Council have adopted the use of a Bayesian prior estimate of the distribution of h that is based on the work of Dorn (2002), but which is recalculated biannually to ensure that it is up to date. We note that a Bayesian approach to stock assessment “determines the probabilities of alternative hypotheses using information for the stock in question and from inferences for other stocks/species” and this is useful because “it facilitates representing and taking account of the full range of uncertainties related to models and parameter values” (Punt and Hilborn 1997). In principle we support the application of the prior distribution of steepness developed by Dorn to rockfish stocks managed by the Council, which is depicted in Figure 1. Note that the prior distribution of rockfish steepness places more weight on higher values, with the mode at 0.94 and a mean equal to 0.76 (labeled “average” in the figure). Even so, the Dorn rockfish prior allows for steepness values at least as low as 0.30, albeit with low probability.

This year the widow rockfish (*Sebastes entomelas*) stock assessment was referred to the mop-up panel after a STAR panel concluded it did not meet the standard of best available science. In particular, three issues were identified for further exploration by the STAT team, which included: (1) development of a complete one-area model, (2) conversion of the model from age-based selection to length-based selection, and (3) incorporation of asymptotic selectivity curves for some fisheries and/or surveys. The STAT team successfully developed such a model in advance of the mop-up panel, and it was refined during the review that occurred the week of September 26-30.

One change recommended by the mop-up panel, which deviated from the analysis that was initially presented by the STAT, was to fix spawner-recruit steepness at the mean of the Dorn prior distribution, i.e., $h = 0.76$. The rationale for this decision was,

“The assessment is unable to produce a reliable estimate of stock-recruit steepness. The model, therefore, uses a fixed value that represents an average value for all rockfish and therefore the extent of uncertainty in model results is underestimated.”

Fundamentally, the rationale of this decision rests on the conclusion of the panel that "... no data currently exist to reliably estimate widow rockfish productivity." We take issue with this assertion and wish to draw the attention of the SSC and Council to our specific concerns.

First we note that the profile likelihood of steepness, when the likelihood contributed by the steepness prior is excluded, indicates that the data do contain information on widow rockfish steepness (Figure 2). Note that we develop a confidence region for the maximum likelihood estimate (MLE) of steepness using the profile likelihood method, evaluating the negative log-likelihood function over the domain of steepness (0.20 – 1.00, in 0.02 increments). For a single parameter, an approximate 95% confidence interval is bounded by 1.92 log-likelihood units above the minimum negative log-likelihood, based on the 95th quantile of the Chi-squared distribution with 1 degree of freedom (Venzon and Moolgavkar 1988; Hilborn and Mangel 1997). In this application we simply added 2 likelihood units for simplicity of presentation, which is equivalent to a 95.4% confidence interval. From this analysis we conclude that *in the absence of the Dorn prior*, for widow rockfish $0.22 \leq h \leq 0.54$ with 95% confidence, which is an informative interval and is much less than the value adopted by the mop-up panel (0.76). We used the likelihood profile presented in Figure 2 to calculate the approximate probability distribution of steepness in the absence of the prior, which is also presented in Figure 1 (labeled no prior). The distribution is strongly skewed to the right, with a mode of $h = 0.30$ and a mean of 0.38.

When the profile likelihood of steepness is recalculated to include the contribution of the steepness prior, a much different picture is presented (Figure 3). In this instance there is no significant difference between the maximum likelihood estimate and the value of steepness adopted by the mop-up panel (0.76). This is not surprising, given the strongly divergent probability distributions of the prior and the data, given the model (no prior) presented in Figure 1. Note that the blended Bayesian posterior distribution of steepness, based on the likelihood profile shown in Figure 3, has a mode at $h = 0.36$ and a mean of 0.54 ("posterior" in Figure 1). We believe that the posterior distribution of steepness shown in Figure 1 more adequately characterizes the uncertainty in this key biological parameter and is consistent with the philosophy of the Bayesian approach (Punt and Hilborn 1997).

Why is the estimate of steepness important to the PFMC? These findings are crucial to determination of resource status relative to the rebuilding target (Figure 4). If the value of h adopted by the mop-up panel is used, the estimated depletion is 51% of B_0 ; if the MLE is used, estimated depletion is 26%; using the posterior mean for steepness, estimated depletion is 40%. The conclusion that rebuilding of the widow rockfish stock has occurred depends directly on the estimated value of steepness. We note that to conclude that the stock has rebuilt, i.e., 2011 depletion $\geq 40\%$, a steepness value of $h \geq 0.54$ is required.

We advocate a consideration of the posterior distribution of steepness to inform the SSC and Council in decision-making. In particular, results presented in Figure 5 depict the

approximate cumulative probability distribution of steepness from the blended Bayesian result, i.e., the rockfish steepness prior is included in the profile likelihood. The figure illustrates that there is a 78% probability that steepness exceeds the MLE. The median of the distribution is $h = 0.49$ and the conditional expected value is $h = 0.54$. A summary of the mean, median, and mode of the three distributions presented in Figure 1 is provided in the table below:

Distribution	Central Tendency		
	mode	median	mean
prior	0.94	0.80	0.76
no prior (model+data)	0.30	0.33	0.38
posterior	0.36	0.49	0.54

Lastly, we draw attention to the estimated time series of recruitment deviations from the base model that was accepted by the mop-up panel, which is illustrated in Figure 6. Note that only one year-class in the last nine exceeds expectation (2004) and the last five year-classes have been particularly weak. We recommend that the Council consider the lack of evidence of successful recruitment in recent years and substantial uncertainty with respect to stock status in 2011 when establishing catch levels for widow rockfish.

References

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Venzon, DJ, and SH Moolgavkar. 1988. A method for computing profile-likelihood-based confidence intervals. *Applied Statistics* 37(1):87-94.

Hilborn, R, and M Mangel. 1997. *The Ecological Detective: Confronting Models with Data*. Monographs in Population Biology, 28. Princeton University Press, New Jersey, 315 p.

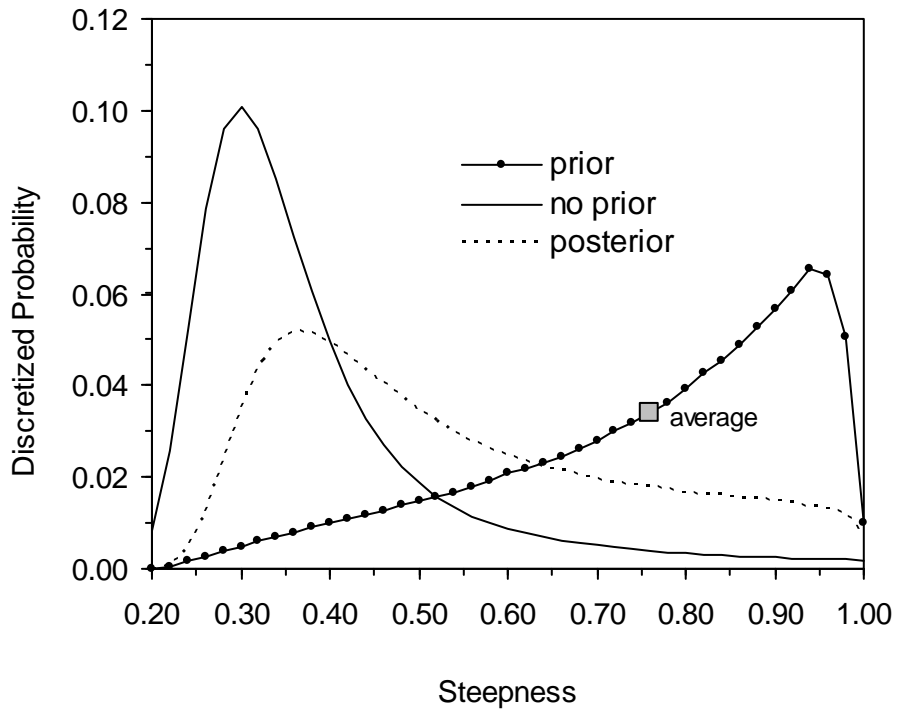


Figure 1. Distributions of widow rockfish steepness (h) based on: (1) the Dorn Prior, (2) the data and model (= no prior), and (3) the combination of the two (= posterior).

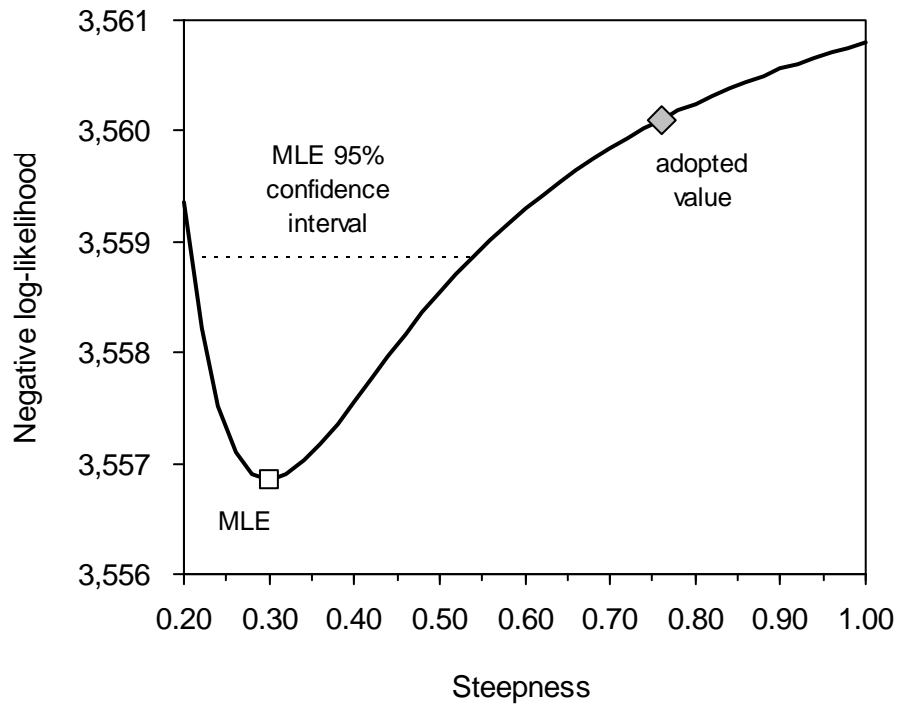


Figure 2. Profile likelihood of widow rockfish steepness when the steepness prior is excluded.

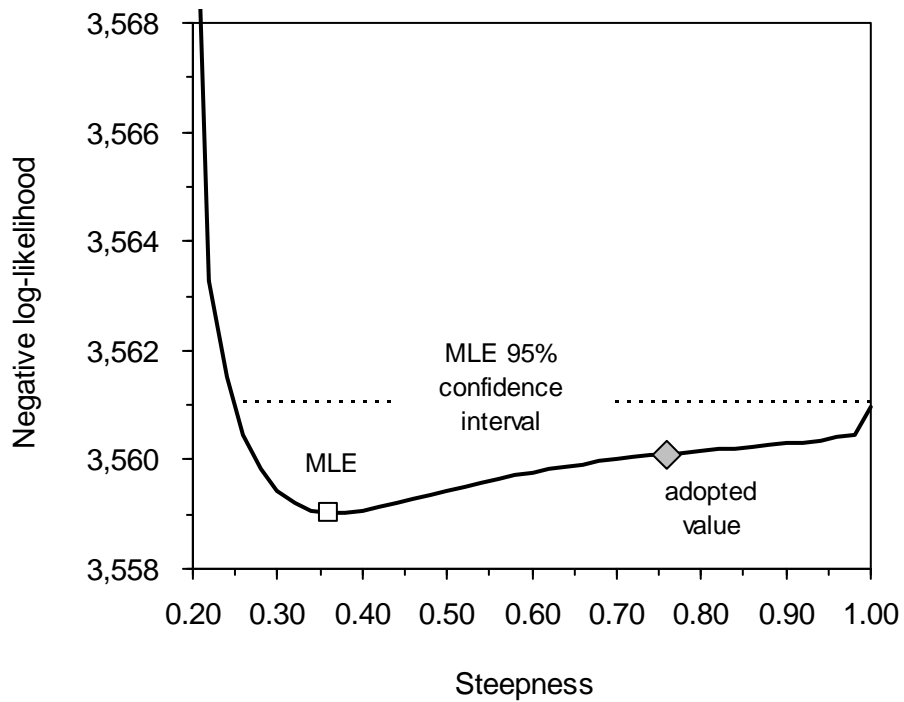


Figure 3. Profile likelihood of widow rockfish steepness when the steepness prior is included.

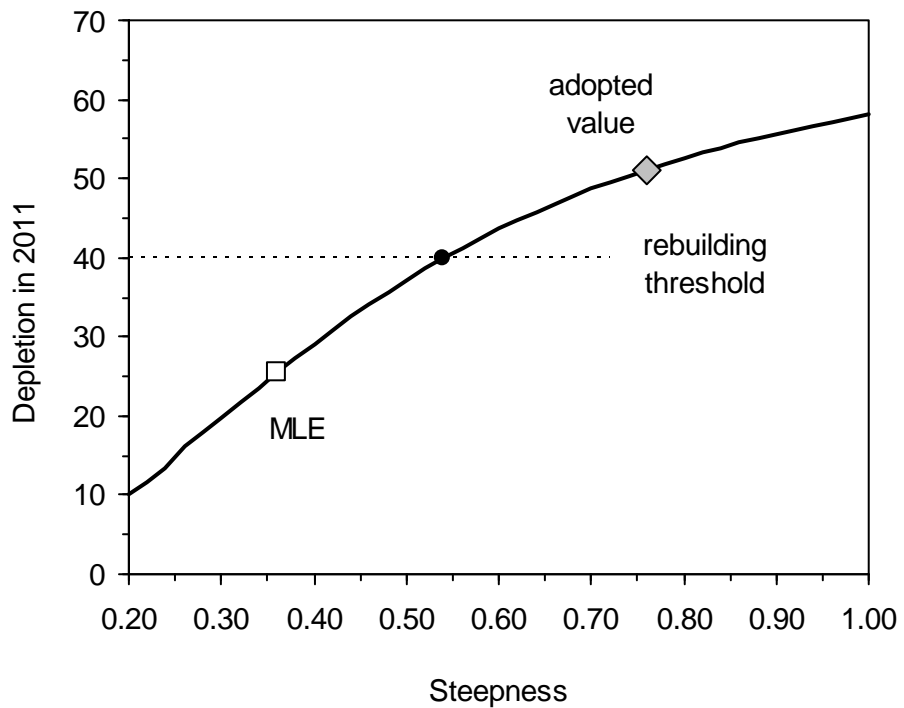


Figure 4. Relationship between estimated stock status and steepness when the steepness prior is included, i.e., the fully Bayesian result.

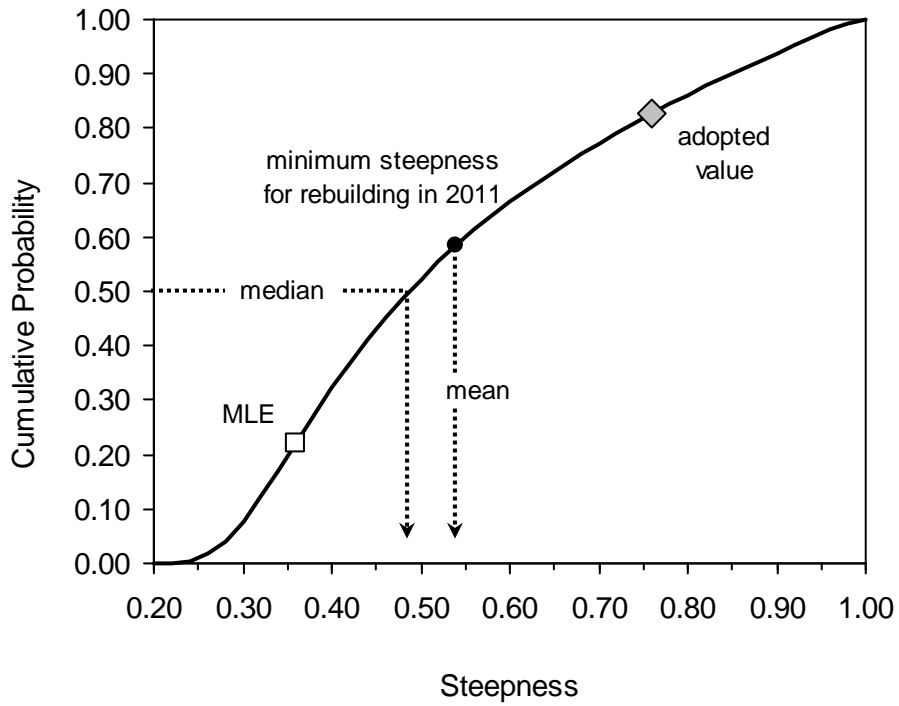


Figure 5. Cumulative probability distribution of steepness from the posterior.

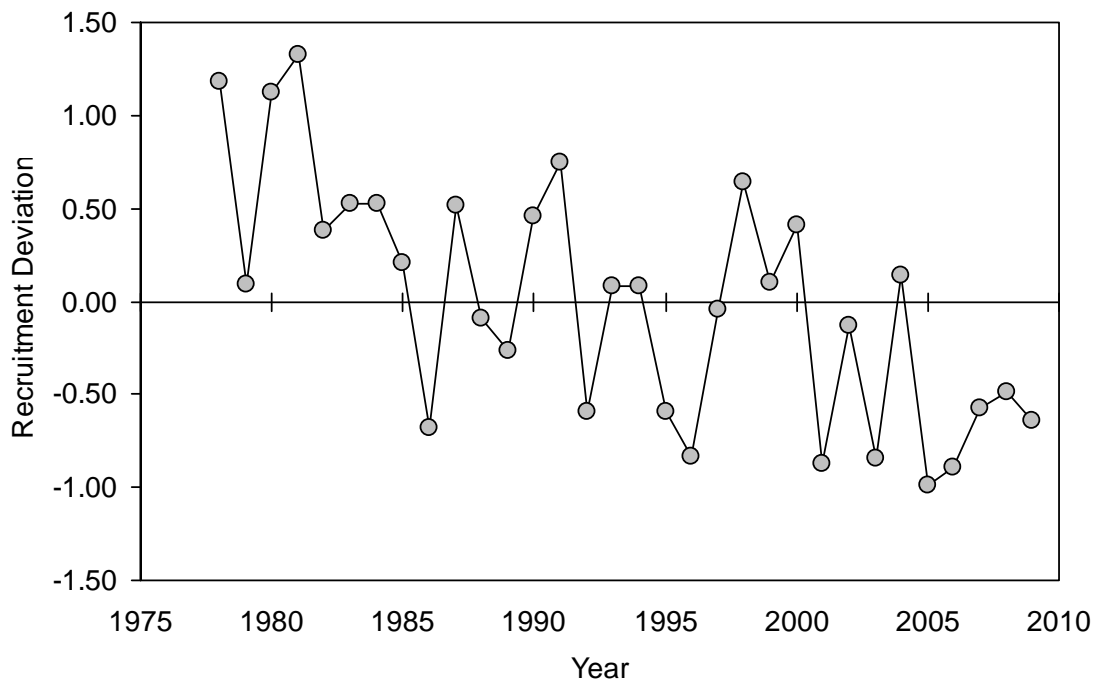


Figure 6. Time series of estimated recruitment deviations from the base model.