

8. REVISED MODEL FOLLOWING THE PANEL REVIEW

8.1 Requested changes to the model: The review panel requested a number of changes. For greater resolution of the size distributions, we recalculated the length composition data so that instead of binning all lengths above 50 cm, we examined 2 cm bins for the entire range of observed lengths (18 cm to 78 cm). The panel also requested that we use an externally estimated coefficient of variation of size at age. We used the error bars from the mean size at age data for Catalina Island reported in Warner (Figure 3.2 1975) to estimate the coefficient of variation in growth (CV) by taking the average of the CV across all age groups ($CV_1=CV_2=0.11$). This was done because the length composition data did not show any clear modal progression of cohorts that would allow the model to reliably estimate the variation in individual growth around the growth equation. We therefore used the best available data to estimate CV_1 and CV_2 externally.

The panel also requested that we consider alternative estimates of natural mortality (M) because the Catalina-based estimate of mortality was probably an overestimate of natural mortality due to fishing in the area. Given that the best documented maximum observed age of a fish was 20 years (Cowen 1990), we used the Hoenig relationship (Hoenig 1983) to estimate a baseline natural mortality of 0.20. We also considered the possibility that the actual natural mortality was lower ($M=0.15$) because the maximum observed age could be reduced due to exploitation. A single fish that was reported to be 53 years old based on its opercles (Fitch 1974) was not used to estimate maximum age since all other reported samples gave much lower estimates of maximum ages, between 15 and 30 years (Limbaugh 1955; Warner 1975; Cowen 1985; Cowen 1990). We also examined the effect of a higher natural mortality ($M=0.3$) on the results of the model based on empirical estimates of mortality (Warner 1975; Cowen 1990). Published estimates of mortality for California Sheephead range from 0.29 to 0.55 (see Table 3.1). However to use these values in the model as natural mortality assumes that fishing mortality at these sites was negligible and hence that estimated mortality could be equated with natural mortality. Thus, $M=0.3$ should be considered the higher end of the reasonable range of estimates for natural mortality.

As requested by the panel, we explored the treatment of recruitment and added a low emphasis (likelihood weight of 0.01) on the stock recruitment curve. Estimates of recruitment in the early years are tenuous because length composition data was only available starting in 1975. A low emphasis on the stock recruitment curve allows recruitment to be based on the stock-recruitment relationship when there is not much data available but to be determined by the data when available. Because the stock-recruitment curve was estimated, we used this relationship to estimate recruitment in 2001-2003 for the final model. The length composition data could not estimate recent recruitment events because it takes at least 3-4 years for individuals to recruit to the fishery. We also fixed the steepness parameter of the stock-recruitment relationship at the previously estimated value of 0.99. The standard deviation parameter of the stock-recruitment curve was fixed at 0.8 as requested by the panel. During the review, we determined that the absence of Sheephead larvae in the CalCOFI survey was due to the fact that labrid larvae were not identified to species until 1961 (Moser et al. 1994). Therefore the CalCOFI

abundance index for Sheephead started in 1961 for the final version of the model. Finally, to stabilize the model, the initial age composition was changed from using the background recruitment level to the virgin recruitment level.

Due to the changes made to the model, we also reexamined the selectivities of the fisheries. Although the model could fit a descending limb for the trap and recreational fisheries, this did not significantly improve the fit of the model. Therefore, the final model allowed the selectivities for all four fisheries to be ascending only. Model selection also explored the effect of the model changes on the root mean square error of the surveys and the effective sample size as described in section 6. Although small changes in the estimated effective sample size and standard error did occur, they were not significant and therefore the standard error of the surveys and effective sample sizes were left the same as in the previous version of the model.

Due to the plasticity of life history characteristics and seeming inconsistencies between the fitted models and empirical data, at the request of the panel, we reestimated and refitted the length and maturity data from Cowen (1990) and Warner (1975). Warner's length data and Cowen's maturity and length data had to be read off of the published figures which led to imprecision in the data entered into the model. Further imprecision in the Cowen data resulted from the conversion of age based maturity data to size based maturity data. Errors in calculating the Cabo Thurloe maturity data, as well as in converting between standard, total, and fork lengths were corrected from the version presented to the panel and we improved the method of converting age-based data to length-based data by switching from binned lengths to actual lengths (Table 8.1, Figure 8.1).

The large variation in life history characteristics between locations leads to difficult management questions in choosing the best policy for the population as a whole when many of our biological reference points are dependent on our understanding of such characteristics. Given that we know very little about the triggers of sex change and maturity, only that it tends to be size based, it is difficult to say how density and sex ratio affect sex change. Many fish species show density dependent somatic growth (Lorenzen and Enberg 2002), suggesting an interaction between population density and age at maturity or sex change, given the length-sex change-or-maturity relationship. A possible manifestation of this interaction could be that variation in size at maturity or sex change in the different populations are driven by density resulting in these seemingly population specific life history characteristics. To our knowledge there are no data addressing sex ratio and size or age at sex change for Sheephead.

Because maturity and sex-change schedules are likely to interact strongly with growth curves, we treat the existing sets of recalculated life history parameters corresponding to Table 3.1, now in Table 8.1 as "packages." Accordingly, we compared SPR relationships for the sets of life history parameters at the four mainland Sheephead study areas: Cabo Thurloe and San Benitos Islands in Mexico, and San Nicolas and Santa Catalina Islands off southern California (Figure 8.17). The Catalina Island pattern used as the basis of this assessment is quite similar to the results for Cabo Thurloe. In contrast, the life history

parameters for San Nicolas Island and the San Benitos Islands indicate that severe depression of the female SPR would occur at the current exploitation rate. The reason for the latter responses can be seen in Figure 8.1. Maturity and sex change at San Nicolas Island occurred at much larger sizes, and few fish would reach maturity or sex-change. For the parameters obtained from the San Benitos Islands, sex change happens so soon after maturity that overall production of females is low and would be less able to withstand exploitation. With the exception of Catalina Island, these cases are not intended to reflect actual conditions, but rather are intended to answer “what-if” kinds of questions.

8.2 Results of the final model: We present the results of the final Sheephead stock assessment model for the scenario where natural mortality $M=0.2$ as well as to alternative cases where $M=0.15$ and $M=0.3$ for comparison. The likelihood components and final parameter values for the model are given in Tables 8.2 and 8.3. The parameter and data files for the final model are given in Appendix 3 and 4. The fishery selectivities estimated by the model indicate that smaller fish are taken by the recreational and trap fishery compared to the hook and line and setnet commercial fisheries (Figure 8.2). However, all fisheries target mature individuals while the hook and line and setnet fishery select mainly males (Figure 8.2). When natural mortality $M=0.2$, the historical total biomass and spawning biomass was estimated to start out low, increase during the late 1970s and early 1980s and then decline starting in the late 1980s (Figure 8.3a). In contrast, a natural mortality of $M=0.15$ led to the interpretation that the total and spawning biomass were high in the 1950s but declined before rising again in the late 1970s and early 1980s (Figure 8.4a). When natural mortality $M=0.3$, the changes in historical total and spawning biomass are similar to the case when $M=0.2$ except that the overall estimates of biomass are higher (Figure 8.5a). Estimates of recruitment also depend slightly on the estimate of natural mortality (Figure 8.3b-8.5b). Although the stock-recruitment relationship estimated by the model differs among the alternative estimates of natural mortality (Figures 8.3c-8.5c), a clear stock-recruitment relationship does not exist for any case. The fit between the observed and predicted abundance indices is good for all three natural mortality estimates and all three versions of the final model lead to the interpretation that the abundance of Sheephead has declined in the last 15-20 years (Figures 8.6-8.8). The fit between the predicted and observed length compositions were also relatively good and almost identical among the three estimates of natural mortality (Figure 8.9). Exploitation rate is also estimated to have increased in recent history regardless of the estimate of natural mortality (Figure 8.10).

We calculated the spawning potential ratio of Sheephead based on the total mature biomass since both male and female biomass contribute to spawning potential. This leads to the interpretation, independent of natural mortality, that Sheephead have declined below target levels (Figure 8.11 CDFG 2002). For the most likely scenario ($M=0.2$), the spawning potential ratio based on mature biomass is estimated to be (at the current exploitation rate of 0.23) approximately 20% of the unfished spawning potential ratio. A lower estimate of natural mortality leads to an even greater estimated reduction in the spawning potential ratio of California Sheephead.

We also projected the expected distribution of total biomass in the absence of fishing and following the 60/20 policy of the Nearshore Fishery Management Plan (CDFG 2002). These projections indicate that the expected distribution of total biomass is variable (Figure 8.12) in all scenarios. Although estimates of future biomass do depend on the estimate of natural mortality, all scenarios indicate that Sheephead biomass can be expected to vary through time even in the absence of fishing (Figures 8.12 and 8.13). In the presence of fishing, total biomass will depend on actual natural mortality (Figure 8.14). However for the most plausible scenario, the allowable catch following the NFMP policy is low at the present time when $M=0.2$ (Figure 8.15) as well for lower estimates of natural mortality. Even higher estimates of natural mortality lead to the prediction that catch may have to be reduced substantially under the NFMP policy.

The decline in the catch per unit effort (CPUE) index is reflected in the model output, and indicates a decline in abundance since the mid-1980s. The model results indicate two combined causes for the decline, increased fishing pressure, and reduced recruitment. It is unclear whether the reduced recruitment is associated with the effects of increased fishing pressure, but the recruitment levels during the intense fishing since 1993 are clearly lower than were seen at similar population level earlier when fishing was less intense (Figures 8.3c, 8.4c and 8.5c). Any decline in abundance that is directly due to fishing pressure is quickly reversible, and abundance and associated CPUE should recover quickly, to the extent allowed by recent recruitment levels. If the decline in recruitment is due to fishing effects, recruitment levels also should increase quickly with a reduction in fishing intensity. However if the decline in recruitment is due to a prolonged change in environmental conditions, a reduction in fishing pressure would not result in recovery to earlier levels of abundance, but catch levels must nonetheless be reduced because the lower recruitments would be incapable of supporting historical catch levels.

In our projections, we assume that decline in CPUE is due solely to fishing pressure, i.e., recruitment will return to previous levels under reduced fishing pressure. Yield (Figure 8.15) and biomass (Figure 8.16) projections use the same scenario as Figure 8.14 and are separated into females only (a) and all mature biomass (b). If average recruitment has declined, equivalent catch levels will be proportionally lower than are given by the projections.

8.3 Sources of Uncertainty: Natural and density-dependent variation in life history characteristics between localities is a key source of uncertainty for management. We have no new information on life history parameters for Sheephead, and as requested by CDFG, we used the four mainland study areas as possible alternative scenarios (Figure 8.17). Results were discussed at the end of Section 8.1. Appropriate management is strongly dependent on the life history parameters of the population, and it is possible that those parameters differ from place to place. Despite those potential differences, note that for all populations, relative mature SPR approaches $SPR_{50\%}$ at an exploitation rate around 0.08, suggesting that this may be invariant, and therefore may be a generally useful reference point for management.

The most important source of uncertainty in the model is the estimate of natural mortality. Independent of the natural mortality scenario, however, Sheephead appear to have been declining in abundance and have exhibited a decline in the spawning potential ratio below target levels with zero or substantially decreased catch allowed under projections following the NFMP (Figures 8.10 and 8.15 CDFG 2002). Another source of uncertainty includes the lack of data on the abundance and exploitation of Sheephead in Mexico. Although our data included some fish from Mexico landed in the U.S., data were not available to indicate the status of the stock in Mexico. However, recruitment probably occurs between Mexican and U.S. and the populations are probably linked demographically. This leads to some uncertainty which should be considered when determining management strategies for Sheephead in California.