C.I.E. Review Report
of
STAR Meeting
Stock Assessment of Pacific Whiting in U.S. and Canadian waters in 2001

N. G. Hall
Murdoch University, South Street, Murdoch, Western Australia 6150, Australia
normhall@central.murdoch.edu.au

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Seattle, February 20-22, 2002
CIE Review Report

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Murdoch University, South Street, Murdoch, Western Australia, 6150, Australia
normhall@central.murdoch.edu.au

March 3, 2002

Executive summary of findings and/or recommendations

- Although final figures are still to be computed and incorporated by the chairmen of the STAR Panel into its report, it is expected that the results will be very similar to those reported within the background document for the base-run. For this, the estimated biomass of the stock in 2001 was approximately 21% of that of the unfished stock, and was at the lowest level yet encountered for the fishery. The biomass was expected to increase to around 26% and 31% in 2002 and 2003, respectively, as the strong 1999 year class increased its contribution. The level of exploitation in 2001 was estimated to be around 31%.
- The 1999 year class has only partially recruited to the fishery, and the strength of the recruitment of this year class will only be confirmed when it is three to four years old.
- The age composition data from the surveys and catches should be examined to investigate the cause of the anomalous patterns that are apparent in the plots of the catch curves for the early 1990s.
- An investigation should be undertaken to assess the proportion of the Pacific whiting stock that is not detected by the acoustic surveys.
- Currently, the selection of alternative model specifications to be examined by the STAR Panel is determined by the need to investigate lack of fit or to examine the potential benefit of giving greater emphasis to an additional data set. A more orderly approach is required if the stock assessment is to cover the full range of uncertainty relating to alternative model specifications. It is suggested that, following an examination of an explicit list of model assumptions, a comprehensive set of alternative model specifications, and weighting factors, should be identified as candidate model runs to be investigated during the stock assessment.
- It is recommended that, rather than selecting a preferred model on the basis of subjective criteria, the results from the assessments for a set of alternative candidate models should be considered and reported.
- The appropriate level of model complexity should be determined on the basis of a statistical criterion, such as the likelihood ratio test or the Akaike or Bayesian Information Criteria.

Background

The stock assessment for 2002 of the Pacific whiting (hake), (*Merluccius productus*), fishery was reviewed by a STAR panel that met at the NMFS North Western Fishery Science Center in Seattle during February 20-22, 2002.

A background document (Hesler *et al*., 2002) was distributed prior to the meeting. This described the data used in the stock assessment, the model that had been applied and had been used to investigate uncertainty associated with the model specification, and the results of Bayesian analyses of the projected stock status within the constraints of a variety of harvest strategies. The model that has been developed for the Pacific whiting, the data collection and analysis and the stock assessments represent the contribution of a considerable number of scientists. Their considerable input is acknowledged.

In attempting to provide an external review of the stock assessment of the Pacific whiting fishery, it is noted that the recommendations, which are proposed, may already have been considered by the stock assessment team in previous analyses of which I am unaware. Further, it should be noted that the recommendations that I have made are not intended as criticisms of the stock assessment or process, but are suggested as possible improvements that might be considered by the stock assessment team. I should also acknowledge the intellectual contribution of participants of the meeting, arising from the group discussions, which have provided the basis for my report. However, I accept full responsibility for any erroneous statements or conclusions that are reported below.

Description of review activities

Details of the 2002 assessment were described by Hesler *et al*. (2002). The STAR Panel reviewed the data sets that were used in the assessment, noting the additional data that were now available for the Pacific whiting fishery. These data include the results of the 2001 AFSC acoustic and shelf surveys, catch and catch at age data till 2001, and the results of the SWFSC recruit survey. The estimate of biomass resulting from the latest triennial AFSC acoustic survey, which is the primary source of information on the abundance of the stock, had declined by 38% from that of the 1998 survey. The data indicated a shift in the spatial distribution of the stock towards the south of the fishery. Cross-calibration in 2001 of the ages read from 29 otoliths had revealed inconsistencies in the ages assigned by the different centers, suggesting that further work is required to ensure that readings are consistent. It was also noted that otoliths collected in the more recent years had an additional false check that appeared to be related to an El Niño event, suggesting that aging errors might have become of increasing prevalence in the associated data sets.

The different patterns of the trends in the time series of biomass estimated from the acoustic and trawl surveys had been investigated by the stock assessment team and appeared to relate to a shift in the spatial distribution of the stock between 1995 and 2001. In the more recent surveys, a greater proportion of the stock was located in those depths covered by the trawl survey, thus accounting for the greater consistency between the trends shown by these two surveys since 1995 (Helser *et al*., 2002, Fig. 12).

Details of the age-structured model, which had been used to undertake an integrated analysis of the various data sets and assess the status of the fishery for Pacific whiting, were presented to the STAR

panel. The changes that had been introduced into the model since the previous assessment were relatively minor, and the model still maintains its strong links to the stock synthesis model that had originally been developed for the fishery. The base-run of the model (Model 1) assumed that the acoustic survey data were less precise in 1977-1989 than in subsequent surveys. It also assumed that the parameters of the selectivity functions for the two fisheries varied among years, undertaking a random walk which reflected the changing annual distribution of the different year classes, and applied a prior probability to the slope parameter of the ascending portion of the selectivity curve for the acoustic survey.

From the base-run, it was apparent that projections of future catches were highly dependent on the estimated magnitude of the 1999 year class, and that this, in combination with the assessment of the biomass in 2001, would be critical in determining the ratio of the biomass in 2002 to the unfished biomass. Thus, in assessing model uncertainty, these two variables were important and influential indicators of the status of the fishery. It was noted that the observed weights at age were currently greater than had been experienced in recent years, and that these, if carried through into the projections, might result in optimistic estimates of stock size. Results from the base-run indicated that the exploitation rate had increased from around 20% in 1997-98 to 31% in 2001, and that biomass had declined by 20% from 2000 and by 48% from that in 1998. Indeed, since a peak in 1987, there had been a consistent trend of decreasing estimates of biomass to those of the last four years, which are the lowest estimates for the entire data set. It was recognized, however, that the peak biomass estimated for 1987 had resulted from an unusually large recruitment, and that, based on the full set of recruitment levels, the 2001 biomass was estimated to be 21% of that of the unfished stock. This was expected to increase to around 26% and 31% in 2002 and 2003, respectively, as the 1999 year class matured. It should be noted that Helser *et al.* (2002) have not included a description of the method used to calculate the estimate of the unfished biomass, B_0, and its relationship to the average weights at age and levels of recruitment over the whole time series.

Projections of future biomass and yield under different harvest strategies were tabulated by Helser *et al*. (2002, Table 14), breaking the possible recruitment states into quartiles of the posterior distribution determined by MCMC. It was noted that, although this arrangement represented the various states of reality, the CVs presented in Table 14 might underestimate the variance.

Concern was expressed that the fishery was now strongly dependent on the strength of a single year class and the current high level of exploitation. There was also concern that the projections of future catches and stock status under alternative harvest strategies were relying on the 1999 year class, yet the strength of recruitment of this year class was still to be confirmed. While an error based on a conservative projection would have little impact, there would be considerable impact on the stock if it were assumed that the recruitment of the 1999 year class was large but subsequently it was found to be of smaller magnitude. It was suggested to the Panel that it might be preferable to allow the age class to materialize, adopting a more conservative harvest strategy in the interim to allow the age structure to rebuild.

As with earlier assessments, the poor fit of the model to the acoustic survey estimates of biomass (Helser *et al*., 2002, Fig. 16) was a source of concern. However, it should be recognized that the data between 1977 and 1989 were assumed to be less precise than the more recent data (*i.e.*, CV = 0.5 for the earlier data and CV = 0.1 for the recent data). Nevertheless, the survey biomasses in 1980-1992

are consistently overestimated by the model, suggesting either that there is a structural deficiency in the model specification or that one or more of the data sets is a biased measure.

The stock assessment team had examined aspects of uncertainty associated with the emphasis given within the model to the different data sets and resulting from the model specification. The influence of the AFSC shelf trawl data had been examined in Model 2, while the impact of greater emphasis given to the earlier acoustic data had been explored in Model 3. Model 4 had been used to investigate the consequences of relaxing the assumption that q=1 for the acoustic survey biomass estimates, estimating this as an additional parameter of the model. By applying a penalty to the parameters of the ascending limb of the selectivity curve for the acoustic survey age composition data, the team had attempted to allow for an increased representation of younger fish in these data. As expected given the different trends shown by the acoustic and trawl survey indices, the estimates of biomass for 1977-1992 based on Model 2 were reduced from those estimated by Model 1 (Helser *et al*., 2002, Fig. 18). Similarly, with Model 3, the estimates of biomass are more consistent with those observed in the acoustic surveys (Helser *et al*., 2002, Fig. 18). Model 2 produced very optimistic estimates of the biomass in 2001 (65%), but the results from Model 3 were similar to those of Model 1 (26%) and resulted in a greater value of the estimated recruitment for the 1999 year class (Helser *et al*., 2002, Fig. 17). The catchability for the acoustic survey estimated by Model 4 was 0.53, a value that was considered by the STAR panel to be unrealistically low. While the acoustic surveys miss fish within 0.5 m of the bottom or miss fish in the southern regions due to increased backscatter noise, it appears unlikely that such a large proportion of the stock could fail to be detected.

The STAR panel proposed a number of alternative model runs to investigate aspects of the model uncertainty. It was noted that the acoustic surveys in 1977-1989 had been undertaken using a sampling regime that differed from that used since 1992. Although a correction factor had been applied to adjust for the different geographical extent of the earlier survey, and the precision of the earlier data had been assumed to be less than that of the later period, it was suggested that the data might appropriately be separated into two periods, pre-1992 and 1992 onwards. It was therefore proposed that, in Model 6, the catchability of the acoustic survey for the earlier period should be estimated. A further model, Model 7, was also proposed, which estimated the catchability of the acoustic survey in the earlier period and assumed asymptotic selectivity for the acoustic survey in the second period. Noting that the estimates of recruitment derived from the Tiburon survey were included in the determination of projected catches, the Panel also requested that the stock assessment team undertake an investigation of the impact of increased emphasis being given to the Tiburon survey when fitting the model (Model 8).

The Panel examined the results of these runs and noted that the catchability for the acoustic survey had been estimated in Model 6 as 0.4 for the first period. The model had continued to predict a declining trend in biomass in recent years and had produced a better fit to the earlier acoustic survey biomass data. When the selectivity in the second period was constrained to an asymptotic form, in Model 7, the catchability of the acoustic survey biomass data in the first period was estimated as 0.53. Models 6 and 7 were re-run, shifting 1992 into the first period, but this resulted in no improvement to the fit. On reflection, the Panel preferred the earlier specification as there was an *a priori* reason for the 1992 data to be included in the second stanza. When results from Model 8 were considered, it appeared that the fit to the age data was relatively poor. However, the Tiburon data did influence the estimates of predicted recruitment for the more recent year classes, which had yet to materialize fully in the catches

or the survey. The Panel considered that there might be merit in including these data in future runs with a CV of 0.5.

Subsequently, after reviewing the results of these analyses, the Panel requested that the catchabilities of the acoustic survey should be estimated in both periods, with asymptotic selectivity of the acoustic survey in the second period, and the CV of the Tiburon survey being set to 0.5 (Model 9). A similar run was proposed (Model 10), in which the catchabilities of the acoustic surveys were estimated in both periods, the CV of the Tiburon survey being set to 0.5, and with the dome-shaped double logistic function describing the selectivity of the acoustic survey in the second period.

The results from Models 9 and 10 indicated that the improvement to the fit of the acoustic survey biomass data had been achieved at the expense of the fit to the age structure. The estimated catchabilities in both periods appeared too low, with the resulting estimates for Model 10 being 0.32 and 0.66 for the first and second stanzas, respectively.

Examination of the age composition data from the acoustic surveys, in the form of plots of the catch curves associated with each year class, suggested that the younger year classes had been absent from the 1992 survey. That is, the survey had failed to detect the presence of these year classes in the quantities that must have been present, as demonstrated by the subsequent contribution that these year classes made to the age composition. Further, there appeared to be an anomalous decline of some of the older age classes in the 2001 acoustic survey, suggesting that aging errors might have affected the age composition that was determined for the 2001 acoustic survey. However, apart from the 1992 year class, the catch curves before and after 1992 were relatively consistent and appeared to have a slight curvature which would tend to support the use of a dome-shaped selectivity function. Examination of similar catch curves generated from the age compositions of the US catches produced a similar unusual pattern in the late 1980s, with a pattern of decline in the earlier period that was relatively consistent with the pattern of decline observed in the more recent years. The panel concluded that the separation of the data into two stanzas, pre-1992 and from 1992, was probably inappropriate, but that further investigation of the anomalous patterns in the data around 1992 was required. The Panel therefore concluded that, for the current assessment, it was appropriate to examine alternative harvest strategies using the base-run model with the CV for the Tiburon survey being modified to 0.5.

The stock assessment team was requested to prepare a decision table based on three alternative states (low, medium and high) of the size of the 1999 year class, tabulating the assumed state against the true state in a 3×3 table, where, for each cell of this table, values of the available catch and ratio of B/B_0 should be reported for each of the three harvest strategies, F40%, F45% and F50%. As generation of this table would require a re-run of the MCMC run, it would not be possible for the results to be reported back to the full STAR panel. However, the inclusion of the results in the final report of the STAR Panel was considered a relatively minor modification of the draft report that the Panel had prepared. Accordingly, the chairmen who had led the STAR Panel undertook to incorporate these results when they became available.

Summary of findings

The analyses presented to the STAR Panel demonstrated that biomass estimates derived from the ASFC bottom trawl surveys represented only that portion of the Pacific whiting stock in the depth

range covered by the bottom trawl survey, whereas the acoustic survey data estimated the biomass over a wider spatial extent. Thus, the ASFC bottom trawl surveys produced biased estimates of the biomass of the total stock. It was therefore appropriate that these data should be de-emphasized when fitting the model.

The lack of fit of the model estimates to the acoustic survey biomass data demonstrates that there is inconsistency between the different data sets when viewed in the context of the model specification. Thus, either the model specification is inappropriate or one or more of the data sets provides a biased measure of the time series of values for the underlying variables. Visual examination of the plots of catch curve data for the different year classes, derived from the age composition data both for the acoustic surveys and U.S. catches, suggests that the observed data were anomalous in the early 1990s. Further analyses of these data might reveal appropriate modifications to the model specifications.

Exploration of alternative model specifications supported the view that the catchability of the acoustic survey biomass data might be less than 1.0, however the parameter estimates that were obtained when the model was fitted to the data appeared infeasible in the opinion of those scientists responsible for the acoustic surveys. Further examination, and possibly field investigation, of the proportion of the stock detected by the acoustic surveys is warranted.

Further development of the methods used to determine the age of fish from examination of the annuli on otoliths is required, to achieve greater consistency among readers and to determine the extent of aging errors that exist within the age composition data. While the stock synthesis model allowed for the existence of aging errors in the age composition data, the AD Model Builder version of the model currently does not include such a capability. Enhancement of the AD Model Builder version of the Pacific whiting model to allow for aging errors is recommended.

Examination of several two-stanza versions of the model suggested that these traded off the improvement of fit of the earlier acoustic survey biomass data with a reduction in the quality of the fit to the age composition data. Further, examination of the catch curve plots suggested that the two-stanza assumption was unjustified as the patterns displayed by the catch curves in the earlier period were very similar with those displayed in more recent years. However, the data in the early 1990s appeared anomalous. Accordingly, the STAR Panel accepted that Model 1, which reduced the emphasis of the acoustic survey biomass data in the earlier years, was the preferred model in the current assessment for use in assessing the fishery and projecting the state of the stock under alternative harvest strategies. However, the Panel considered that it was appropriate to use the Tiburon data to improve the assessment of the strength of the 1999 year class, as the projections of future catches are sensitive to this variable. While results of the final assessment runs are to be incorporated into the STAR Panel's report by the Chairmen of the Panel, following the completion of the MCMC run and generation of the specified decision table, the resulting assessment is likely to be similar to that produced for Model 1. That is, the estimated biomass of the stock in 2001 was approximately 21% of that of the unfished stock, and was at the lowest level yet encountered for the fishery. The biomass was expected to increase to around 26% and 31% in 2002 and 2003, respectively. The level of exploitation in 2001 was estimated to be around 31%.

Conclusions/recommendations

Stock assessments of the fishery for Pacific whiting (*Merluccius productus*), or, as it is alternatively known, Pacific hake, have been based on an age-structured model of the fishery. Inevitably, as with all fisheries assessments, considerable uncertainty exists both in the stock assessment and in the resulting projections of the future stock status. Such uncertainty derives principally from inadequacies of the data (bias, imprecision and lack of contrast) and from the uncertainty of the model specification that arises from alternative sets of assumptions regarding both the data and the processes that relate those data.

Although the STAR Panel examined a number of alternative model specifications for the Pacific whiting fishery, it is likely that these failed to cover the full range of uncertainty. From a list of the assumptions relating to the base-run model, Model 1, for the Pacific whiting, which is presented in Appendix 3, it appears that the emphasis given to the different data sets through the specification of their CVs or effective sample sizes is subjective. The exploration of the different models undertaken for the STAR review demonstrated that changes in the emphasis of different data sets would produce alternative assessments of the current state and of alternative projections that might result from the different harvest strategies (*e.g.* Models 1 and 3). Further, changes in the functions describing the relationships between those data sets produced changes to the interpretation of the available data that was reflected in the estimates of the current and future states that are derived from the new model (*e.g.* Models 1 and 4). Moreover, for each change in the emphasis of the different data sets or in the functional relationships between those data sets, there will be a distribution of estimates of the current and future states of the fishery, which arises from the uncertainty of the parameter estimates obtained from the model and the stochasticity of the system. It should be noted, however, that all models are not equally likely (*e.g.* Model 2 increases the emphasis of the AFSC bottom trawl survey data set, which, through survey design and methodology, is likely to provide a biased estimate of the biomass of the coastal stock).

A more orderly approach is required if the stock assessment is to cover the full range of uncertainty relating to alternative model specifications. The current selection of alternative models has been focused on the investigation of the lack of fit of the model to the acoustic survey biomass data and to the question of whether use of the ASFC bottom trawl survey might improve the accuracy of the stock assessment. If the full range of uncertainty is to be investigated, the list of assumptions might be examined and a comprehensive set of alternative model specifications, and weighting factors, might be identified as candidate model runs. While a single preferred model, that best fits the data, may be desirable to ease the task of communication of the results of the assessment, it is unlikely that the selection of such a model could be made objectively. Furthermore, it is unlikely that a single preferred model could adequately expose the range of uncertainty that exists for the full range of alternative candidate models.

The STAR Panel focused attention on the failure of the integrated model to provide an adequate fit to the acoustic survey biomass data, investigating alternative models that were considered likely to resolve the problem. Such lack of fit to one or more data sets may relate to either inconsistency between those different data sets or inadequacy of the model structure. In the former case, it is possible that the measures in one or more of the data sets are biased, or that observation error is of a magnitude such that unusually high or low values of the variables are having too great an influence on

the resulting parameter estimates. Correction of the problem may require re-specification of the model or more appropriate statistical analysis of the data within the data sets. De-emphasis of one or more of the data sets for particular subsets of those data may reduce the influence of one of the inconsistent data sets, however specification of the emphasis to be given to each data set should not be subjective. It should be recognized that, with such de-emphasis, inadequacy of the model fit will be evident in the trends shown by the residuals for the de-emphasized data.

The model, which has been developed to represent the Pacific whiting fishery, utilizes the available data in a sophisticated but effective manner, avoiding many of the strong assumptions that have been required in age-structured models for other fisheries. By introducing parameters to describe the initial age composition, the levels of recruitment of the different year classes and the random walk undertaken by the selectivity functions for the two fisheries, the modelers have created an extremely flexible representation of the Pacific whiting fishery. However, it should be noted that, according to Helser *et al.* (2002), the model now requires the estimation of 303 parameters. Using AD Model Builder, such estimation is possible, however the necessity for including such a large number of parameters has not been demonstrated. A simpler model, with fewer parameters, might provide more robust estimates of future stock status. It would be useful to examine, using statistical tools such as the likelihood ratio test, AIC and BIC, whether model complexity should be reduced.

Consideration should also be given to exploring the use of a stock-recruitment relationship, possibly fitted to the estimated biomasses of mature females and the estimated recruitment strengths for the associated year classes. This might overcome a limitation of the current model formulation, allowing the development of projections for a greater number of years and the possible development of operating models to explore alternative harvest strategies within a closed-loop framework.

References

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Helser, T. E., Dorn, M. W., Saunders, M. W., Wilson, C. D., Guttormsen, M. A., Cooke, K. and Wilkins, M. E. (2002). Stock assessment of Pacific whiting in U.S. and Canadian waters in 2001. Background document presented to STAR Panel, Seattle, WA, Feb 20-22, 2002.

Appendices

Appendix 1. Bibliography of materials provided

1. Groundfish stock assessment and review process during 2002
2. Helser *et al*. (2002) Stock assessment of Pacific whiting in U.S. and Canadian waters in 2001.
3. Table: Parameter estimates and standard errors from models 1-5.
4. Figures showing comparisons of the acoustic and trawl surveys.
5. Listing of HK2001.TPL, the AD Model Builder code for the Pacific whiting model
6. Data file for AD Model Builder hake model
7. Overheads describing the 2001 AFSC acoustic survey
8. Overheads describing the 2001 west coast bottom trawl survey
9. 2001 PWCC prerecruit survey cruise report by Vidar Wespestad
10. Review of Helser *et al*. (2002) stock assessment by A. R. Kronlund

Appendix 2. Statement of work

STATEMENT OF WORK

Consulting Agreement Between The University of Miami and Dr. Norman Hall

February 14, 2002

General

The consultant will participate in the Stock Assessment and Review (STAR) Panel of the Pacific Fishery Management Council (PFMC) in Seattle, Washington, from February 20-22, 2002. The STAR panel will review the stock assessment for Pacific whiting, a joint assessment between the Department of Fisheries and Oceans (DFO) of Canada and the Northwest Fishery Science Center (NWFSC) of the National Marine Fishery Service (NMFS), which is expected to provide the basis for management of the fishery.

The consultant's duties shall not exceed a maximum total of 12 days: Several days prior to the meeting for document review; the three-day meeting; and several days following the meeting to complete the written report. The report is to be based on the consultant's findings, and no consensus report shall be accepted.

The consultant will be provided with the most recent assessment report and electronic copies of the data, parameters, and model used for the assessment (if requested).

Specific

1) Become familiar with the current Pacific Whiting stock assessment;

2) Understand the primary sources of uncertainty in the assessment;

3) Comment on the strengths and weaknesses of current approach

4) Recommend alternative model configurations or formulations as appropriate during the STAR panel

5) No later than March 8, 2002, the consultant will submit a written report of his review activities and assessment of the STAR process. The consultant will send the report to David Die, UM/RSMAS, 4600 Rickenbacker Causeway, Miami, FL 33149 (email: ddie@rsmas.miami.edu).

Signed_____ Date_____

Appendix 3. Assumptions of the age-structured model for Pacific whiting

A number of the assumptions of the base-run model, *i.e.* model 1, as described by Helser *et al*. (2002), are listed in the table below. It should be noted that this list is incomplete as, for example, those assumptions relating to future recruitment strength required for projecting the model under the alternative harvest strategies have not been included. By treating the initial age structure and the levels of annual recruitment as free parameters, to be estimated by the model, the requirement to introduce a specific functional relationship between spawning biomass and subsequent recruitment has been avoided. The annual fishing mortality rates for fully-selected fish within each fishery are also estimated as free parameters of the model. The information concerning the levels of annual recruitment and annual fishing mortality rates are determined from the total annual catches in each fishery and estimates of biomass derived from acoustic surveys, in combination with data describing the age compositions of those catches and of those fish sampled during acoustic surveys. The latter data are interpreted using dome-shaped selection curves that describe the proportions of the year classes that are caught by the fishery or sampled in the acoustic surveys.

Identifier	Assumption	Comment	Concerns
1.	The coastal population of Pacific whiting is comprised of a single stock	Assumption appears sound.	• It is unclear from Helser *et al.* (2002) whether the for catch data, survey data and biological samples relate to the fish from the coastal stock or to a mixture of the coastal, Strait of Georgia, Puget Sound and Gulf of California stocks. If the former, the method by which the catches are allocated among stocks, etc., has not been described.
2.	For both the U.S. and Canadian fisheries, catch data from 1972 to 2001 are assumed to be accurate measures of all fish removed from the stock as a consequence of fishing activity. For each fishery, measurement errors of the total catch are assumed to be log-normally distributed, with a standard deviation of the logarithm of the total catches (approximate CV of the total catch) = 0.05.	According to Helser *et al.* (2002), Bailey *et al.* (1982) suspected that the reported catches from 1968 to 1976 may have been under-reported. The assumption of a log-normal measurement error for total catch appears reasonable. However, the assumption that the CV=0.05 appears subjective.	• Catches by the foreign fishery in the U.S. zone were not monitored using observers until the late 1970s. • The proportion of trips with observers, the data that are captured, and the methods of analysis used to estimate total annual catches have not been described sufficiently to assess whether catch data are accurate. • Estimates of the precision of the estimates of total catch should be derived from the analysis of the catch and observer data. • There might be value in considering the variance in the model to be the sum of the input variance and an estimate of additional variance derived from the fit to the data (suggested by Punt, pers. comm., for the assessment of another fishery).

3.	Catch at age data from 1973 to 2001 for the U.S. fishery and from 1977 to 2000 for the Canadian fishery, are accurate measures of the age composition of those fish removed from the stock as a consequence of fishing activity. For each fishery, catch at age data are assumed to represent random samples from multinomial distributions, where the effective sample size is assumed to be 80 fish.	The assumption that each sample is drawn from a multinomial distribution appears reasonable. However, the assumption that the effective sample size is 80 fish appears subjective.	• The accuracy of the age composition data, particularly for foreign vessels in the U.S. zone during the earlier period, may have been affected by changes in sampling regimes, methods of ageing, and methods of analysis. • There was no information provided by Helser *et al.* (2002) to confirm that the use of counts of the annuli on otoliths as a measure of the age of the fish had been validated. • Insufficient details of the sampling regime and methods of analysis were provided in Helser *et al.* (2002) to allow an assessment of whether age composition data were accurate. • Inconsistencies among the readings of otoliths at different research centers suggests that the resulting age data may be imprecise (and possibly biased), particularly for the older fish.
4.	Biomass estimates from the AFSC acoustic/midwater trawl surveys provide accurate estimates of the total biomass of Pacific whiting at the time of the survey, adjusted for the age-dependent selectivity and catchability of the survey method. Measurement errors of the estimates of biomass are assumed to be log-normally distributed with a standard deviation of the logarithm of the biomass estimate (approximate CV) of 0.5 from 1977 to 1989 and 0.1, subsequently.	The assumption of a log-normal measurement error for total catch appears reasonable. However, the assumptions that the CV=0.5 from 1977 to 1989 and 0.1 from 1992 to 2001 appear subjective.	• The surveys from 1977 to 1989 had limited geographic cover of the deep water and northern regions, and a correction factor was applied by Dorn (1996), as cited by Helser et al. (2002). • Because of increased acoustic backscatter noise in the south, off California, estimates become more uncertain when the stock has a more southerly distribution. • The survey "misses" fish that are located close to the bottom. • The different CVs for 1977-89 and 1992-2001 acknowledge the limited geographic extent of the earlier surveys. • There might be value in considering the variance in the model to be the sum of the input variance and an estimate of additional variance derived from the fit to the data (suggested by Punt, pers. comm., for the assessment of another fishery).
5.	Age compositions of the Pacific whiting recorded in the AFSC acoustic/midwater trawl survey provide accurate estimates of the age	The assumption that each sample is drawn from a multinomial distribution appears	•

	composition of the stock at the time of the survey, adjusted by the age-dependent selectivity of the survey method. These age composition data represent random samples from multinomial distributions, with an effective sample size of 80 fish.	reasonable. However, the assumption that the effective sample size is 80 fish appears subjective.	
6.	Biomass estimates from the AFSC bottom trawl surveys provide accurate estimates of the total biomass of Pacific whiting at the time of the survey, adjusted for the age-dependent selectivity and catchability of the survey method. Measurement errors of these estimates of biomass are assumed to be log-normally distributed with a standard deviation of the logarithm of the biomass estimate (approximate CV) of 100.	The assumption of a log-normal measurement error for the biomass estimates appears reasonable. However, the assumption that the CV=100 is subjective, but effectively causes these data to be ignored.	• Depth range and latitudinal extent of the surveys has varied. • Estimates of biomass from this survey are considered to be biased as the survey does not cover the full depth range and latitudinal extent of the stock.
7.	Age compositions of the Pacific whiting recorded in the AFSC bottom trawl survey provide accurate estimates of the age composition of the stock at the time of the survey, adjusted by the age-dependent selectivity of the survey method. These age composition data represent random samples from a multinomial distribution, with an effective sample size of 0.01 fish.	The assumption that each sample is drawn from a multinomial distribution appears reasonable. The assumption that the effective sample size is 0.01 fish is subjective but causes these data to be ignored.	• Estimates of age composition from this survey are considered to be biased as the survey does not cover the full depth range and latitudinal extent of the stock.
8.	Biomass estimates from the DFO surveys provide accurate estimates of the total biomass of Pacific whiting at the time of the survey, adjusted for the age-dependent selectivity and catchability of the survey method. Measurement errors of these estimates of biomass are assumed to be log-normally distributed with a standard deviation of the logarithm of the biomass estimate (approximate CV) of 100.	The assumption of a log-normal measurement error for the biomass estimates appears reasonable. However, the assumption that the CV=100 is subjective, but effectively causes these data to be ignored.	• The survey covers only the Canadian zone • The proportion of the total biomass that migrates into Canada varies annually. • The survey is unlikely to provide accurate estimates of the total stock.
9.	Age compositions of the Pacific whiting recorded in the DFO survey provide accurate estimates of the age composition of the stock at the time of the survey, adjusted by the age-dependent selectivity of the survey method. These age composition data represent random samples from multinomial distributions, with an effective sample size of 0.01 fish.	The assumption that each sample is drawn from a multinomial distribution appears reasonable. The assumption that the effective sample size is 0.01 fish is subjective, but causes these data to be ignored.	• The survey covers only the Canadian zone

10.	The abundance of juvenile whiting derived from analysis of data from the Tiburon larval rockfish survey is an accurate index of (*i.e.*, is proportional to) the year-class abundance. The measurement errors are assumed to be log-normally distributed, with a standard deviation of the logarithm of the index of 10.	The assumption that the abundance of juvenile whiting determined from the survey is proportional to the year-class abundance appears to be true based on the significant correlation described by Dorn *et al.* (1999), as cited by Helser *et al.* (2002). The assumption of a log-normal measurement error for the index appears reasonable. However, the assumption that the CV=10 is subjective but de-emphasizes these data.	•
11.	The age-1 index from the AFSC shelf trawl survey is an accurate index of (*i.e.*, is proportional to) year-class abundance. Measurement errors are assumed to be log-normally distributed, with a standard deviation of 10.	The assumption that the abundance of juvenile whiting determined from the survey is proportional to the year-class abundance may be appropriate but should be tested. The assumption of a log-normal measurement error for the index appears reasonable. However, the assumption that the CV=10 is subjective but de-emphasizes these data.	•
12.	The sexes may be combined within the assessment model.		• Bailey et al. (1982) reports that growth and weight-length relationships differ between male and female Pacific whiting • By using observations of weight at age and a function to describe selectivity at age, the model may have avoided the need to separate the sexes. • Calculations of mature female biomass may require an assumption of a constant proportion of females to males, however it is possible that these calculations made use of sex ratios observed for the biological samples.

13.	Weights at age derived from biological samples are assumed to be accurate estimates of the weight at age of the fish within the stock. It is assumed that the measurement error for these observations is negligible.		• The description of the sampling regime and the methods of analysis in Helser *et al.* (2002) was not sufficient to assess whether this assumption is likely to be valid.
14.	The proportion of female fish of each age that are mature is assumed to be accurately determined from the table derived by Dorn and Saunders (1997), as reported by Helser *et al.* (2002).	Reasonable assumption.	• Within other fisheries, the age at which female fish first achieve maturity has been found to vary.
15.	Natural mortality is constant for all ages and for all years, and is equal to 0.23 $year^{-1}$.	The assumption considerably simplifies the analysis, but the value is likely to be an inaccurate estimate of the true mortality.	• Estimates of natural mortality have low precision and are often biased.
16.	Pacific whiting recruit to the fishery, first becoming vulnerable to capture, at age 2.		• There has been a shift towards younger ages in more recent years.
17.	Fish greater than 15 years of age have the same selectivity and weight at age as the 15 year-old fish, and may be combined with these fish in the analysis.	Reasonable assumption	•
18.	Within each fishery, a constant level of annual fishing mortality is applied throughout the year to the fish within each age class		• The estimate of fishing mortality will adjust to achieve the required catches in order to compensate for failure of this assumption.
19.	All of the fish within each age class are exposed simultaneously to the fishing mortality imposed by the U.S. and Canadian fisheries.		•
20.	Within each fishery, the fishing mortality is estimated as the product of an age and fishery-dependent selectivity and a year and fishery-dependent annual fishing mortality rate.		• Environmental factors that influence the distribution of the fish are therefore assumed to be reflected, on average, by the estimate of the annual fishing mortality rate for each fishery.
21.	The age-dependent selectivity is assumed to be represented by a scaled double-logistic function of age, where the maximum selectivity at age is set to 1.		• This equation may take the form of a logistic function if the slope of the descending portion of the curve is set to zero, but provides the flexibility to allow for reduced selectivity of the older fish.
22.	The catchability of the acoustic survey was assumed to be 1.	Strong but subjective assumption	• Unlikely to be correct as fish within 0.5 m of the bottom are missed, as are fish in the southern region where noise in backscatter apparently results in an underestimate of the biomass of fish.

23.	The four parameters of the age-dependent selectivity function for the U.S. fishery, and the two parameters of the ascending portion of the selectivity function for the Canadian fishery, were assumed to undertake a random walk, with annual changes of the slope that were log-normally distributed (and with a mean of logarithms of the changes of zero) and annual changes of the inflection age that were normally distributed (with a mean of zero). The CV of the changes in the slope was assumed to be 0.25, and the standard error of the changes in the inflection age was assumed to be 1.	The selections of the CV and standard error were subjective.	• Environmental changes in the spatial distribution of fish of different ages, as reflected in the age composition of those catches, will be reflected in the changes in the parameters of the selectivity functions for the fisheries.
24.	The slope of the ascending portion of the AFSC acoustic survey is assumed to be selected from a log-normal prior probability distribution, with a mean of 0.9 and a CV of 0.2	Appears to be subjective.	•
25.	The proportions observed or estimated to lie within marginal age groups were combined in a number of specific instances, to avoid "obvious instances of ageing error from affecting the model fit" (Helser *et al*., 2002).	Subjective, but appropriate.	• This reduces the impact of these age classes
26.	The selectivities for the 1994 year class in the U.S. fishery and the1997 year class in the Canadian fishery are not estimated using the double-logistic function but are estimated as free parameters of the model.		• Unusually large numbers of 2 and 3 year old fish from the 1997 year class were observed in Canadian catches in 1999 and 2000, which could not be accommodated using the random walk • Similar problems were encountered for the 1994 year class in the U.S. fishery (Dorn *et al.*, 1999, as cited by Helser *et al.*, 2002)
27.	The method used to age the fish is accurate and the age of each fish is read without error	The assumption of the accuracy of age reading may be appropriate for more recent data, however it is unlikely that ages are read without error.	• Aging method does not appear to have been validated. • Results of otolith readings at different Centers are inconsistent, particularly for older fish (Helser *et al*., 2002).

Appendix 4. Alternative models

Results of the following models were examined by the STAR Panel. It should be noted that the numbers assigned to the models in the table below differed from those used in referring to the models during the meeting.

Model	Description	Assumptions
1.	Base-run model	• Acoustic survey biomass CV=0.5 in 1977-1989 • Acoustic survey biomass CV=0.1 in 1992-2001 • AFSC shelf trawl survey de-emphasized CV=100 • Acoustic survey *q*=1.
2.	Model 1 with increased emphasis on AFSC shelf trawl survey	• Acoustic survey biomass CV=0.5 in 1977-1989 • Acoustic survey biomass CV=0.1 in 1992-2001 • ***AFSC shelf trawl survey CV=0.1*** • Acoustic survey *q*=1.
3.	Model 1with equal emphasis on earlier acoustic survey biomass estimates	• ***Acoustic survey biomass CV=0.1 in 1977-1989*** • Acoustic survey biomass CV=0.1 in 1992-2001 • AFSC shelf trawl survey de-emphasized CV=100 • Acoustic survey *q*=1.
4.	Model 1 with acoustic survey *q* estimated	• Acoustic survey biomass CV=0.5 in 1977-1989 • Acoustic survey biomass CV=0.1 in 1992-2001 • AFSC shelf trawl survey de-emphasized CV=100 • ***Acoustic survey q freely estimated***
5.	Model 1 with penalty on parameters of ascending limb of selectivity to force a higher selectivity for the younger ages	• Acoustic survey biomass CV=0.5 in 1977-1989 • Acoustic survey biomass CV=0.1 in 1992-2001 • AFSC shelf trawl survey de-emphasized CV=100 • Acoustic survey *q*=1. • ***Penalty on ascending limb selectivity***
6.	Base-run with two stanzas, estimating *q* in first stanza and fixing *q*=1 in the second.	• Acoustic survey biomass CV=0.5 in 1977-1989 • Acoustic survey biomass CV=0.1 in 1992-2001 • AFSC shelf trawl survey de-emphasized CV=100 • ***Acoustic survey, estimating q before 1992 and setting q=1 in 1992-2001***
7.	Model 6, with asymptotic selectivity in stanza 2 and profile likelihood over *M*.	• Acoustic survey biomass CV=0.5 in 1977-1989 • Acoustic survey biomass CV=0.1 in 1992-2001 • AFSC shelf trawl survey de-emphasized CV=100 • ***Acoustic survey, estimating q before 1992 and setting q=1 in 1992-2001*** • ***Asymptotic selectivity in second stanza (i.e. logistic rather than double logistic)***

8.	Model 1, with increased emphasis on Tiburon index of recruitment	• Acoustic survey biomass CV=0.5 in 1977-1989 • Acoustic survey biomass CV=0.1 in 1992-2001 • AFSC shelf trawl survey de-emphasized CV=100 • Acoustic survey *q*=1. • ***Tiburon survey, CV=0.1 and CV=0.5***
9.	Model 7, with estimation of q in second stanza and increased emphasis on Tiburon index of recruitment	• Acoustic survey biomass CV=0.5 in 1977-1989 • Acoustic survey biomass CV=0.1 in 1992-2001 • AFSC shelf trawl survey de-emphasized CV=100 • ***Acoustic survey, estimating q before 1992 and also estimating q in 1992-2001*** • ***Asymptotic selectivity in second stanza (i.e. logistic rather than double logistic)*** • ***Tiburon survey, CV=0.5***
10.	Model 6, estimating q in both stanzas and increasing the emphasis on the Tiburon index of recruitment	• Acoustic survey biomass CV=0.5 in 1977-1989 • Acoustic survey biomass CV=0.1 in 1992-2001 • AFSC shelf trawl survey de-emphasized CV=100 • ***Acoustic survey, estimating q before 1992 and also estimating q in 1992-2001*** • ***Tiburon survey, CV=0.5***
11.	Model 1, increasing the emphasis on the Tiburon index of recruitment	• Acoustic survey biomass CV=0.5 in 1977-1989 • Acoustic survey biomass CV=0.1 in 1992-2001 • AFSC shelf trawl survey de-emphasized CV=100 • Acoustic survey *q*=1. • ***Tiburon survey, CV=0.5***