CONSULTANT'S REPORT: STAR PANEL, NEWPORT OREGON, MAY 2000

1. Introduction

This report describes work undertaken by the external consultant, Robin Cook, in connection with the STAR panel review of assessments of Bank Rockfish, *Sebastes rufus* and Darkblotched Rockfish, *Sebastes crameri*. The review took place at the Hatfield Marine Science Center, Newport, Oregon from 15-19th May 2000. The work to be undertaken by the Consultant is set out in Annex 1.

The report is divided into three main parts which deal with work undertaken, observations on the assessments and observations on the STAR process itself. Recommendations are given at the end of the report. These need to be interpreted with appropriate scepticism given that the Consultant is not intimately familiar will all stages of the assessment and advisory process.

2. Work Undertaken

Annex 2 outlines the itinerary and the main activities undertaken. The draft assessment documents were received in good time before the meeting and provided sufficient time for the Consultant to review them. During the meeting the Consultant participated actively in the discussion. Particular points contributed related to:

- The use of priors in the darkblotched rockfish assessment
- The interpretation of survey catchability in the assessments
- Assumptions about the stock recruit relationship
- Summary presentations of assessment results to indicate stock status in relation to reference points
- Presentation of stock projection information
- Evaluation of F50% over-fishing definitions

Annexes 3-5 contain specific text and analyses contributed to the STAR panel report. In addition conventional age structured spawner per recruit analyses were performed on both stocks to calculate F50% for comparison with the Synthesis estimates. In both cases the SPR calculated values were almost identical to the Synthesis values.

Following return to the UK, the Consultant offered comments on the draft STAR report text prepared by the Panel chair.

3. Observations on the stock assessments

3.1 Assessment Models

Both assessments are based on Stock Synthesis as the primary analytical tool. It is a very versatile tool which can make use of a variety of different data types and can fit a wide range of different models. Synthesis is well suited to the kind of data available for these assessments and appears to be a very effective approach. I have three main concerns about Synthesis, some of which may simply be mis-understandings on my part. These are:

1. There does not appear to be a definitive version of the software which has been independently tested or a manual to describe it.
2. The software author appeared to be the only practitioner in the STAT team fully able to run and interpret the model.
3. The precise model being fitted is not always transparent

Item (1) is primarily a quality control issue. It is important that any software used in assessment is properly tested and fully documented. I am sure that the author has tested the program, but I do not know if independent testing has been done. This is highly desirable to build confidence in those outside NMFS who are affected by the assessments. It is also essential to have a manual describing exactly what the software is does. As a reviewer, it is very difficult to know precisely what is going on without access to such information. I was under the impression that the software author was the only source of such information.

I was also under the impression that the software author was the only member of the STAT team who was fully able to run and interpret the analysis. This makes the process vulnerable to loss of expertise. Clearly some members of the STAT team are very new to these assessments and their expertise will grow. However, it is undesirable to have the definitive expertise concentrated in one mind. It is essential that this expertise is more

widely distributed

The versatility of Synthesis makes it an immensely powerful tool. However, with this sophistication comes problems of interpretation for the non-expert. Most managers will not be experts in modelling and therefore may be mislead by model output. Depending on the data, Synthesis may, for example, do a stock reduction analysis for the early data where information is limited, and then go on to fit a CAGEAN type model for the more plentiful age structured data in recent years. For the output, the layman will simply see a stream of annual biomass, recruitment and fishing mortality estimates covering a span of perhaps 30 years. However, the recruitment stream for the early years may be purely forced values from an assumed stock recruitment curve while the later ones are driven mainly by real data. How recruitment has changed over the decades can have an important effect on the perception of the stock status so it is crucial that the reader understands the veracity of the estimates. In my view the precise model being fitted needs to be made much more transparent, even to the extent of writing down the likelihood function for each model. For the layman, commentary needs to be included in the assessment report which explains how the estimates should be interpreted.

3.2 Assessment Reports

I found the reports well presented and thorough. Clearly the report structure follows a pre-agreed format to which the STAT teams had adhered. The comprehensive and careful description of the input data was extremely useful in understanding what information could usefully be gained from any analysis. The model runs were well documented and the various approaches covered the range of uncertainty appropriately. Where I would suggest improvements is in the presentation of summary information. The present report format effectively stops at model diagnostics whereas once the estimation stage is complete, what people need to know is how can the status of the stock be described. I would suggest a number of standard tables and figures which summarise the population dynamics. Since the underlying population dynamics model in Synthesis is age structured, I would include tables of estimated numbers at age and fishing mortality at age. Tables and figures showing trends in catch, spawning stock biomass, fishing mortality and recruitment should also be given. I would also suggest that these tables and figure follow an agreed fixed format so that the information can be readily located and interpreted. It is also important to produce standardised figures which show the present stock status in relation to biological reference points. This could be done by presenting a spawner per recruit vs F plot with the relevant biological reference points indicated. Where an adequate stock-recruitment curve exists, this could be done on an equilibrium SSB vs F plot.

3.3 Scope of the Assessments

The analyses presented consist of what many practitioners refer to as the “stock assessment”. This is essentially a reconstruction of historical population and mortality rate estimates. It is this analysis which the STAR panel reviewed. In my view this is rather limiting and has some important disadvantages because there is a tendency to consider the stock assessment analysis as an end in itself without considering the context in which it is being performed. Clearly the stock assessment is being performed in order, ultimately, to generate management advice. How the assessment is done therefore needs to consider the final end use. The problem is perhaps best illustrated with examples. Managers need to be given some insight into how the stock might respond to a given action, such as a catch control designed to reduce fishing mortality. Scientists might exemplify the effect of this by running a forward projection for a number of years. To do this usually requires modelling the stock recruitment relationship. However, in the Synthesis analyses, quite strong assumptions are often made about the stock recruitment relationship at the population estimation stage. These assumptions may be appropriate for estimation purposes but may not be credible for forward simulation.

Another example concerns the estimates of populations in the ending year which form the base populations for projections. In the case of the darkblotched rockfish, it is clear that large year classes which recruited in the mid nineties have a profound effect on the forward projection yet are estimated from some of the least reliable data. Thus while Synthesis might provide objective measures of the these year classes, there may be good reasons to consider using estimates with a lower mean squared error but with some additional bias, such as a value shrunk towards the mean. Since the projections are done only after the Panel has reviewed the stock assessment, these problems do not appear to be adequately considered, yet may have a substantial effect on the efficacy of any management measure. I would suggest that the STAT team’s assessment should be more comprehensive and include forward projections, both for the short and medium term, as well as an equilibrium analysis. Only when these are included will it be possible to evaluate all the potential weaknesses which contribute to the ultimate advice.

4. Observations on the STAR panel process

I found the STAR process a valuable and effective means of reviewing assessments. It is certainly superior to its European equivalent where the stock assessment review and advice formulation are done by the same group of experts. The latter not only limits the amount of time given to the review but means that not all the appropriate expertise is present and it offers an opportunity to manipulate the assessment to give the advice desired. The STAR process therefore has major strengths in being able to allocate sufficient time for the review, mobilise the relevant review expertise and maintain independence from the advice formulation. Of course this makes the STAR panel an expensive exercise and thought needs to be given to ensure that it makes best use of resources.

I my view, the time allocated to the two stocks involved was overly generous and that an equally good review could be completed in less time. Because all assessments contain large amounts of uncertainty, it is always possible to fill any time allocated with discussion. However, there comes a point when it is more important to ensure that uncertainty has been addressed properly rather than spend time in discussion in the mistaken belief that further dissection of something unknown will lead to enlightenment. I would suggest that as a rule of thumb, one might allocate one working day per assessment so that minds are focussed on the important issues. This would require firm action by the STAR panel chair.

One issue which arose on this STAR panel, but which fortunately was contained, was the question of Bayesian statistics. One panel member was implacably opposed to Bayesian approaches. The question of their use in these particular assessments never really arose in earnest so the controversy was avoided, but it is clearly an issue which has occurred on other panels and is potentially a major problem. In view of the strongly held opinions in different centres, it is very important that controversies of this kind, which have no place in STAR panels, are avoided. The issue for the STAR panel is not whether Bayesian or frequentist statistics are “right” but whether the assessment conforms to the highest standards. To some degree this raises the question as to the precise remit of the STAR panel. In my view the review should be conducted as a review and not to provide an opportunity for panellists to undertake alternative assessments using their own favourite methods which are likely to be different, but no better. Such analyses may be enlightening but they should not be used by panellists to get their own way. If they do then the STAR panel effectively becomes part of the assessment team without the benefit of independent review. The present system does seem to be prone to this danger. I would prefer the review to proceed on the basis that the STAT team assessment is acceptable unless it can be shown to need changes.

There are perhaps two ways in which the problem above may be ameliorated. Firstly as indicated earlier, less time (and hence less opportunity to indulge) and strong chairing will help. Secondly there is a need to establish a set of agreed assessment techniques which are acceptable. This might include both Bayesian and frequentist approaches. It would mean that where a STAT team used a Bayesian approach, Bayesians and neutral experts should review the assessment. Likewise, if a frequentist approach was used by a STAT team, the review would be by frequentists and neutrals. Having Bayesians review frequentists and vice versa is entertaining, but not helpful

5. Recommendations

1. The STAT teams appear to be vulnerable to loss of expertise. It is essential that appropriate expertise is more widely distributed among the scientists involved. (Section 3.1)

1. The precise model being fitted within Synthesis needs to be made more transparent, even to the extent of writing down the likelihood function for each model. For the layman, commentary should be included in the assessment report which explains how the estimates should be interpreted.(Section 3.1)

1. The stock assessment reports would benefit from a number of standard tables and figures which summarise the population dynamics of the stock. These should include tables of estimated numbers at age and fishing mortality at age. Standardised tables and figures showing trends in catch, spawning stock biomass, fishing mortality and recruitment should also be given. If at all possible all input data should be presented in a standard and accessible format.(Section 3.2)

1. The STAT teams assessment report should be more comprehensive and include forward projections, both for the short and medium term, as well as an equilibrium analysis. Only when these are included will it be possible to evaluate all the potential weaknesses which contribute to the ultimate advice. (Section 3.3)

1. The STAR panel is an expensive exercise and thought needs to be given to ensure that it makes best use of resources. As a rule of thumb, one might allocate one working day per assessment so that minds are focussed on the important issues. This would require firm intervention from the STAR panel chair.(Section 4)

1. There is a need to establish a set of agreed assessment techniques which are acceptable to the relevant agencies to reduce methodological discussion by STAR panels. These methods need to be fully tested and documented.(Sections 3.1 and 4)

1. STAR panels should avoid advocating alternative assessments of their own unless very clear and sound reasons support them. If they do so then the STAR panel effectively becomes part of the assessment team without the benefit of independent review, which is self defeating.(Section 4)

Annex 1:STATEMENT OF WORK

Consulting Agreement Between The University of Miami and Robin Cook

August 14, 2002

General

The consultant will participate in the Stock Assessment and Review (STAR) Panel of the Pacific Fishery Management Council (PFMC) in Newport, Oregon from May 15-19, 2000. The STAR panel will review assessments for two species, bank and dark blotch rockfish, during this meeting.

The consultant is expected to participate actively in the panel, offering advice and constructive criticism of the assessments. The consultant is also expected to assist in the preparation of two panel reports, documenting the technical quality and completeness of these assessments. Finally, the consultant is expected to provide an additional written report describing the consultant's review activities and an assessment of the review.

Specific

1) Read and become familiar with the assessment reports, and any anonymous reviews of the previous assessment, provided in advance to the consultant. These documents will be provided directly to the consultant by PFMC.

2) Participate actively in the discussions during the STAR panel meeting.

3) Offer constructive criticisms on technical aspects of all the assessments, in accordance with the terms of reference.

4) Under the leadership of the STAR panel chair, assist in the drafting of the STAR panel reports (one per species).

5) No later than June 30, 2000, 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).

Annex 2: Outline of Visit

3-4 May. Draft assessments received by email

4-13 May. Assessments reviewed by the Consultant

13 May. Departed Aberdeen, UK and arrived in Portland Oregon at 22:00

14 May. Arrived Newport. Meeting with Cyreis Schmidt of the Hatfield Science Center to discuss the STAR panel process

15-19 May. STAR panel meeting

19 May. Depart Newport 12:00 and arrived Portland 16:00

20 May. Departed Porland 12:05

21 May. Arrived Aberdeen, UK 16:00

22 May onwards. Follow up to STAR panel (report finalising by email) and preparation of consultant's report.

Annex 3: Does Catchability Matter?

When survey data are included in the model a catchability parameter is required which relates the survey abundance index to stock abundance. This can be fixed externally, or estimated within the model. The usual assumption is that the survey index is proportional to stock abundance. The principal need for the survey information is to determine the relative change in stock abundance so that the survey index needs only to be on a relative scale. Sometimes assumptions are made about the value of the catchability based on the area swept by the survey gear and the vulnerability of fish to the gear. Concerns therefore can arise if the catchability estimated within the model differs from the assumed value. In practice, this need not be a concern since the population sampled by the survey need not be the same as the population sampled by the fishery. If for example, the survey gear cannot be deployed where commercial gears operate, or if the commercial fishery operates in a more restricted area then the area covered by the survey, then the value of the catchability parameter could take values both less than or greater than unity. Furthermore, in calculating a survey abundance estimate to represent absolute abundance, assumptions have to be made about the behaviour of the fish being sampled and the area swept by the gear. All these factors mean that it is almost impossible to arrive at an *a priori* estimate of catchability. This means it is unwise to constrain catchability when fitting the model since an inappropriate choice may be inconsistent with other data in the model and lead to distorted estimates of important population parameters. Essentially, catchability is a nuisance parameter whose value should not be regarded as having particular significance beyond quantifying the relative scales of different data sets.

Annex 4: EQUILIBRIUM ANALYSIS OF DARK BLOTCHED ROCKFISH

An equilibrium analysis of Darkblotched rockfish was performed to examine the long term implications of the present fishing mortality rate and the target value of 50%F. The methodology is based on work by Shepherd(1982), Sissenwine and Shepherd(1987) and Cook (1998). The approach uses a stock recruit relationship to calculate population equilibria at different fishing mortality rates.

Stock-recruit data are shown in Figure 1 and are taken from the base run assessment in Rogers *et al* (2000). Rather than fit a parametric stock recruitment function which may make restrictive assumptions, a non-parametric smoother has been used to summarise the relationship between stock and recruitment. This is based on the approach of Evans and Rice (1988).

Biological information on weight at age, maturity and selectivity are taken from Rogers *et al* (2000) and have been used to calculate spawner per recruit values and hence identify the population equilibria at different fishing mortality rates.

Figure 2 shows the expected spawning biomass at different fishing mortality rates. The figure illustrates how the population might be expected to change for a given set of starting conditions. Included in Figure 2 are the observed spawning biomasses each year at the prevailing fishing mortality rates. These are identified by year and show the stock trajectory over time as the mortality has increased. Over time, the stock has declined and is presently close to the equilibrium value expected at current fishing mortality rates. Given the variability in recruitment, this means that as the population fluctuates around the equilibrium it is likely to fall below the lowest observed spawning biomasses in some years, even if fishing mortality rate does not increase.

In this case fishing mortality rates below F=0.09 are required to avoid further stock decline and much lower values are necessary to ensure a high probability of avoiding low stock biomass. The analysis supports the view that 50%F would be a safe target for this stock. This is because the estimated value (~0.032) lies well to the left of the expected equilibrium line. This would mean that if 50%F could be achieved, the expected equilibrium spawning biomass would be substantially higher than recent values.

References

Cook, R.M. 1998. A sustainability criterion for North Sea Cod. *ICES Journal of Marine Science*, 55: 1061-1070.

Evans, G.T. and Rice, J.C. (1988). Predicting recruitment from stock size without the mediation of a functional relation. *Journal du Conseil pour l' Exploration de la Mer*. 44:111-122.

Rogers, J.B., Methot, R.D., Builder, T.L., and Piner, K. 2000. Status of the darkblotched rockfish (Sebastes crameri) Resource in 2000. Draft stock assessment document presented to STAR panel, Newport OR, May 2000.

Shepherd, J.G. (1982). A versatile new stock-recruitment relationship for fisheries and the construction of sustainable yield curves. *Journal du Conseil pour l' Exploration de la Mer*. 40: 67-75.

Sissenwine, M.P. and Shepherd, J.G. (1987). An alternative perspective on recruitment overfishing and biological reference points. *Canadian Journal of Fisheries and Aquatic Sciences*. 44:913-918.

Figure 1. The number of one-year-old recruits produced each year by the spawning biomass of Dark blotched rockfish. The line shows the expected recruitment derived from a nom-parametric smoother. Biomass figures are in thousands of tonnes. The year in which the recruitment occurred is indicated in the data labels.

Figure 2. A plot of the expected equilibrium spawning biomass for different values of fishing mortality rate. The solid line shows the locus of expected equilibrium. Super-imposed on the graph are the spawning biomasses observed each year beginning in 1963. These are joined in a time sequence.

Annex 5: SHORT AND MEDIUM TERM PROJECTIONS FOR DARKBLOTCHED ROCKFISH

Short term analysis

There was some discussion on the STAR panel about the form of forward stock projections based on the synthesis assessments. At present, short term deterministic projections are usually performed using the synthesis output for a period of three years. This will give simple point estimates of catches and stock sizes for given fishing mortality rates. While this information is of some use, the approach does not take any account of uncertainty. Given that this and other stocks are managed in relation to a fishing mortality rate target and a minimum biomass reference point, managers really need additional information on the probability of success of a given action under uncertainty. In particular, one might consider two questions in relation to the choice of a management action:

a) For a given catch control in year T, what is the probability that F will exceed the target value?

b) If a given target F is achieved in year T what is the probability that the spawning stock biomass will be below a threshold level in year T+1?

To illustrate how this might be done, an analysis has been performed using the output of the baserun assessment using the methodology described in Cook (1993). This method is a simple age structured model which takes as input starting populations at age, N, fishing selectivity at age, s, weight at age, W, natural mortality M, and maturity at age MT. The population is then rolled forward determinstically to give populations and catches in future years. In order to quantify uncertainty, coefficients of variation (CVs) are assigned to the input values, N, s, W, M and MT. CVs for the output quantities are then derived using a delta method assuming zero covariance between the input values. Table 1 shows the input quantities for the base year of 2000. The values for the CVs are arbitrarily chosen but are likely to reflect the approximate estimation error. In this example it is assumed that fishing mortality from 2000 onwards is 50%F (ie F=0.03). It should also be noted that the software used only copes with 20 ages hence a plus group at age 20 has been applied, and that no distinction is made between males and females. The results, therefore should only be regarded as illustrative.

Figure 1 shows how question (a) may be illustrated. This shows the probability that fishing mortality in 2001 will exceed 50%F for a given catch. If managers want to reduce F to at least 50%F then an ABC will need to be chosen toward the left hand end of the profile. Clearly, a catch control corresponding to the point estimate of the catch in 2001 will have a 50% chance of failure. A stock in a poor state with a strong need for rebuilding should therefore require a catch nearer the left hand tail of the distribution.

Figure 2 shows how question (b) may be illustrated. In this figure the distribution of the spawning stock biomass in the year following the management action is shown. It assumes that fishing mortality in 2000 and 2001 was 50%F. What is shows is the cumulative distribution of spawning stock biomass in 2002. It can be used to identify the probability that SSB is below is given value. Thus, for example, the SSB estimate from synthesis for 1999 was 5200mt which means, given the scenario of 50%F for 2000-2001, that the SSB only stands about a 50% chance of increasing.

Medium term analysis

The short term analysis may be useful for making tactical annual decisions but there is a need to evaluate the longer term stock trajectory given a particular fishing scenario. This is especially important if stock rebuilding is important. One way to do this is to run the short term projections further, for 5-10 years. This requires a model of stock and recruitment, since after a few years, unobserved yearclasses begin to enter the fishery. The analysis presented here attempts to show how the stock trajectory might evolve in relation to a given spawning stock biomass reference value, ie the probability that the SSB in a given year will be below a reference value.

The model is based on a simple age structured forward projection model using the same input values as above. Recruitment is modelled as a stochastic process by bootrapping the observed recruitment series where the probability of observing a given recruitment is conditioned on stock size using the method described in Cook (2000). The projection is run for 10 years with 500 simulations drawing initial populations, N, from the distribution given in Table 1. With the exception of N and recruitment, all other values are assumed fixed. The analysis was repeated for a range of different fishing mortalities, each one fixed for the ten year period.

Figure 3 summarizes the results of the analysis. Initially it can be quite difficult to follow. It shows the probability that the SSB in any particular year is below 5000mt, a value which is approximately the lowest observed value. The right hand Y scale is the fishing mortality rate while the left hand Y scale is the fishing mortality rate relative to 50%F (ie a

value of one corresponds to F=0.03). The lines are contours of probability that SSB will be below 5000mt. The contours begin to rise after a few years indicating that the SSB would be expected to increase even at relatively high fishing mortality rates. This is because of strong recruitment in 1995, evident in the starting populations in Table 1, which enters the spawning stock biomass during the projection period. If reliable the analysis would indicate that stock rebuilding is likely to occur in the medium term even at the fishing mortality rates estimated in the stock assessment for 1999 of about 0.1

Discussion

The examples presented in this report are intended primarily to illustrate how uncertainty might be presented to managers in a way which could help in decision making. Clearly there are significant limitations in the methods applied here which are not tailored for the biology of this species or the stock assessment model. Despite these limitations, the analysis probably does give insight into the uncertainty and the possible stock trajectory of dark-blotched rockfish but it would be highly desirable to develop more appropriate methodology which provided similar information for Pacific rockfish.

References

Cook, R.M. (1993). The use of sensitivity analysis to quantify uncertainties in stock projections. ICES C.M.1993/D:66.

Cook, R.M. (2000). A rough guide to population change in exploited fish populations. Ecology Letters, in press.

Table 1. Input data for projections

Label	Value	CV	Label	Value	CV
Number at age			Weight in the stock		
N1	1186	.30	w1	.00	.00
N2	1186	.30	w2	.00	.10
N3	1059	.30	w3	.03	.10
N4	323	.30	w4	.08	.10
N5	2704	.30	w5	.15	.10
N6	4536	.30	w6	.24	.10
N7	743	.30	w7	.34	.10
N8	984	.30	w8	.44	.10
N9	957	.30	w9	.54	.10
N10	479	.30	w10	.64	.10
N11	184	.30	w11	.73	.10
N12	658	.30	w12	.82	.10
N13	547	.30	w13	.89	.10
N14	524	.30	w14	.96	.10
N15	224	.30	w15	1.02	.10
N16	146	.30	w16	1.07	.10
N17	84	.30	w17	1.12	.10
N18	74	.30	w18	1.16	.10
N19	183	.30	w19	1.20	.10
N20	1822	.30	w20	1.23	.10
Selectivity			Weight in the catch		
s1	.00	.00	w1	.00	.00
s2	.00	.00	w2	.00	.10
s3	.00	.00	w3	.03	.10
s4	.00	.10	w4	.08	.10
s5	.00	.10	w5	.15	.10
s6	.00	.10	w6	.24	.10
s7	.00	.10	w7	.34	.10
s8	.01	.10	w8	.44	.10
s9	.02	.10	w9	.54	.10
s10	.02	.10	w10	.64	.10
s11	.03	.10	w11	.73	.10
s12	.03	.10	w12	.82	.10
s13	.03	.10	w13	.89	.10
s14	.03	.10	w14	.96	.10
s15	.03	.10	w15	1.02	.10
s16	.03	.10	w16	1.07	.10
s17	.03	.10	w17	1.12	.10
s18	.03	.10	w18	1.16	.10
s19	.03	.10	w19	1.20	.10
s20	.03	.10	w20	1.23	.10

Table 1. Cont.

Natural mortality			Proportion mature		
M1	.05	.10	MT1	.00	.00
M2	.05	.10	MT2	.00	.00
M3	.05	.10	MT3	.00	.00
M4	.05	.10	MT4	.00	.00
M5	.05	.10	MT5	.00	.00
M6	.05	.10	MT6	.00	.10
M7	.05	.10	MT7	.00	.10
M8	.05	.10	MT8	.02	.10
M9	.05	.10	MT9	.07	.10
M10	.05	.10	MT10	.20	.10
M11	.05	.10	MT11	.38	.10
M12	.05	.10	MT12	.58	.10
M13	.05	.10	MT13	.73	.10
M14	.05	.10	MT14	.82	.10
M15	.05	.10	MT15	.88	.10
M16	.05	.10	MT16	.92	.10
M17	.05	.10	MT17	.94	.10
M18	.05	.10	MT18	.96	.10
M19	.05	.10	MT19	.97	.10
M20	.05	.10	MT20	.97	.10

Relative effort in HC fishery			Year effect for natural mortality		
hf1	1.00	.10	k1	1.00	.10
hf2	1.00	.10	k2	1.00	.10
hf3	1.00	.10	k3	1.00	.10

Figure 1. The probability that fishing mortality in 2001 will exceed 50%F for a given catch

Figure 2. The cumulative distribution of spawning stock biomass in 2002. It shows the distribution of the spawning stock biomass in the year following management action. It assumes that fishing mortality in 2000 and 2001 was 50%F.

Figure 3. The probability that the SSB in any particular year is below 5000mt, a value which is approximately the lowest observed value. The right hand Y scale is the fishing mortality rate while the left hand Y scale is the fishing mortality rate relative to 50%F(F=0.3). The lines are contours of probability that SSB will be below 5000mt.