Commission for the Conservation of
Southern Bluefin Tuna

みなみまぐろ保存委員会

Report of the First Meeting of the Management Procedure Workshop

3-4 & 6-8 March 2002
Tokyo, Japan

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1. Opening, Terms of Reference and Adoption of Agenda

1. Mr Penney, independent Chair of the Scientific Committee and Chair of the Workshop, opened the workshop. The Executive Secretary, Mr B. Macdonald, thanked Japan as host country for providing the venue and logistic support for the Workshop.

2. The Workshop participants briefly presented themselves. The list of participants is shown in **Attachment A**. Administrative arrangements for the meeting were presented by Mr Kaneko, the Deputy Executive Secretary.

3. Participants accepted an offer by the Chair to act as rapporteur during general discussions, and to collate the report of the meeting. Dr Parma, Technical Coordinator of the management procedure development process, would coordinate technical discussions, and members of the Advisory Panel would be called upon to draft technical sections of the Workshop report. It was noted that certain technical details (such as mathematical specifications for operating models) may have to be finalised by e-mail exchange after the meeting.

4. The draft agenda was adopted with minor changes, and is shown in **Attachment B**. The document list for the meeting (shown in **Attachment C**) was presented by the Executive Secretary. It was noted that three papers (numbers MP/02030/5, 6 and 7), had not been presented at previous meetings. All the other papers had been presented previously.

5. The Terms of Reference for the Workshop (see agenda in Attachment B) were derived directly from those proposed at the 6th Scientific Committee meeting see CCSBT-MP/0203/Rep2) which had, in turn, been developed in response to initial recommendations by the 2000 Management Strategy Workshop (see CCSBT-MP/0203/Rep1).

2. Overview of the Proposed Process to Develop a Management Procedure for SBT

6. Dr Parma presented an overview of the proposed process to develop a management procedure for SBT. This is scheduled to be completed in three workshops. This first workshop needed to focus on specification of operating models for simulating future population trajectories. This will include a process of conditioning the models on past fisheries data. The code to be developed by Ms Haist (the programming Consultant) will be used by national scientists to evaluate candidate management procedures in future. The results of these evaluations will be reviewed at the second workshop. At this stage there was no need to be comprehensive, and

the focus should be on developing a simple operating model (OM) and candidate management procedure (MP) for testing purposes. These would be improved, and would become more complex, at future workshops.

7. Prof Butterworth presented paper CCSBT-MP/0203/6 and Dr Ianelli presented paper CCSBT-MP/0203/7 as overview examples of how operating models and management procedures have been developed, conditioned and used in other fisheries. These papers illustrate many of the principles and characteristics of operating models and management procedures. It was noted that background paper CCSBT-MP/0203/BGD3 presented an example of an effort to develop a management procedure for SBT, illustrating some of the problems specific to SBT management.

3. Structure of Operating Models for SBT

3.1 Population Model

8. The initial formulation sets simple assumptions recognizing that, in the 2^{nd} phase of the analysis, much more uncertainty and stochasticity will be considered in the model parameters and state variables. The main concern at present is to make sure that the model formulation is flexible enough to allow for these changes, but to keep initial assumptions simple for demonstration of the process and ease of interpretation. The assumptions are summarized in the table at the bottom of Section 3.1. The following comments pertain to the discussion surrounding the elements of this table.

3.1.1 Stock Structure

9. It was agreed that the simplest hypothesis is that there is a single unit stock of SBT and that there was no need to consider sex or geographic structure in an initial model. It is possible that there could be some form of spatial stock structure and this could be examined at a later stage of the analysis.

3.1.2 Natural Mortality

10. It was proposed to initially consider 3 age-specific mortality vectors, but not to estimate these values in the conditioning phase. However, to promote flexibility it is suggested that the computer code be set up so that these vectors are parameterized and it would be possible, at a later stage, to set priors on the parameters of these vectors, and during conditioning allow for estimation of the vectors.

3.1.3 Age/Length Structured Dynamics

11. All state variables in the model will be age based. The numbers at age will be the key variables, and any selectivities will be age rather than length based. It is recognized that selectivity could be length based, but it was not felt important to consider it at this point.

3.1.4 Trends in Growth

12. The historical data shows a change in growth rate over time and this has been estimated from tagging, not within any assessment models. It will initially be assumed that the currently assumed age/length relationship will stay constant for future projection, but it was recognized that other hypotheses, including temporal trends in growth, that may be density related, might be considered later.

3.1.5 Stock-Recruitment Relationship

13. Steepness and R_0 (average unexploited recruitment) will be estimated directly in the conditioning. The recruitment variance and temporal autocorrelation for forward projection will be estimated from the year classes estimated in the conditioning. For the first year trials, it will be assumed that there is no depensation in both conditioning and forward simulation. At a later phase, regime shifts n parameters and depensation may be explored.

3.1.6 Weight-Length Relationship

14. The weight length relationship is assumed to be fixed at current estimates. Some allowance may be made for changes at future points.

3.1.7 Maturity Schedules and Relative Spawning Potential

15. Knife-edged maturity is initially assumed at age 10, but in later stages alternative maturity ogives may be considered, as well as allowing for age specific reproductive output per kilogram to represent the possibility that older fish spawn more frequently or produce better eggs.

3.1 8 Catchabilities

16. It will be assumed that catchabilities are constant, both in conditioning and in forward simulation under management procedures. However, it is recognized that catchabilities may well change over time and this may be included in future analyses.

Item	Initial Operating Model	How Treated in Conditioning Estimation	Possibly Incorporated in Next Step
Stock Structure	Single stock	Single stock	Site specific feeding
Natural mortality rate	Age specific vectors fixed	Fixed age specific vectors assumed, but parameterized in functional form	Consider a prior on parameters and including estimation uncertainty
Age/ length structured dynamics	Everything kept by age	Everything kept by age	

Item	Initial Operating Model	How Treated in Conditioning Estimation	Possibly Incorporated in Next Step
Trends in growth	Fixed growth relationships for initial modeling	Use historical data and fix pattern in time	Other formulations for growth
Stock recruitment	Steepness, R_0 variance and correlation estimated in conditioning	Steepness, R_0, sigma, autocorrelation estimated, depensation fixed	Temporal trends such as regime shift. Prior on depensation
Weight-length	Fixed	Fixed	Change with density or time
Catchabilities	Assumed constant	Assumed constant	Allow for randomness
Maturity schedule	Knife edged Function of age	Fixed	Age specific egg production per kg. Maturity possibly function of length
List of fisheries	For future 4 selectivities Surface, LL1, LL2 and, spawning ground. Alternative scenarios of how future catch is split among selectivities	Surface, LL 1 (Primarily JPN 4-9), LL 2 (primarily non-target), LL 3 (JPN 2) spawning fishery. When changing is allowed will be in 4 year blocks	
Selectivities for each fishery	Fixed based last block in estimation	Estimated for each fishery with 4 year blocks. No change for LL2 or LL3. Change in selectivity in spawning fishery occurs during break between old LL 1 and current Indonesia.	Hypotheses regarding changing selectivities
Unreported removals	Alternative amounts allowed for by fishery, but assumed to be 0 for initial trials	Assumed for each fishery	Allow for alternative amounts
Calendar of events	Indonesian, surface Jan 1 pulse. Then ½ mortality, then LL and non target LL		

3.2 Fishery Model

3.2.1 Fisheries Identified

17. After extensive discussion, it was concluded that the historical data could be analyzed with five specific fisheries. These are; (1) The Australian surface fishery, (2) LL 1, which is primarily the Japanese LL fishery in areas 4-9, but covers all longline fisheries other than those listed in 3 - 5 below; (3) LL 2, which is primarily Taiwanese catches targeted on albacore showing SBT selectivity at younger ages than LL 1; (4) LL 3, which is primarily the Japanese data from area 2, which is different in selectivity from other LL fisheries and not the same as the

spawning area fisheries and (5) LL 4, which are spawning ground fisheries consisting of the Japanese area 1 fishery in early times and the Indonesian spawning ground fishery in recent times.

18. The specification of the historical catch data to be included within each of these five fishery components is shown in the table below:

Fishery Component	Catch Data to be Included
1	Australian surface fishery catches (purse seine, pole and line, and troll from all areas)
2	Japanese longline catches except from Areas 1 and 2 Taiwan targeted SBT longline catches Australia domestic longline catches Australian joint venture longline catches New Zealand charter catches New Zealand domestic catches All other nations longline catches not included below (estimated from Japanese import statistics)
3	SBT caught in the Taiwanese albacore longline fishery Taiwanese gillnet catches
4	Japanese longline catches in Area 2
5	Japanese longline catches in Area 1 Indonesian longline catches

19. For forward projections of management procedures, the same fisheries will be included, with the exception of LL 3. Thus there will be 4 fisheries. Alternative projection scenarios will allocate different amounts of the catch to these fisheries. Thus if it is required to consider a scenario in which an increased proportion of catch was harvested by longline, then more the catch would be “added” to the LL 1 fishery and some removed from the surface fishery.

3.2.2 Selectivity for Each Fishery

20. Selectivity patterns will be estimated in the conditioning phase by four year blocks for the surface and LL1 fisheries. The selectivity patterns will be assumed constant in the LL2 and LL3 fishery. The selectivity in the spawning fishery will be broken into two blocks during the break between the Japanese Area 1 fishery and the recent Indonesian spawning ground fishery.

21. In the initial analysis, future changes in selectivity will not be considered, but it is recognized that there are a number of hypotheses about how selectivity might change in the future. These may be considered at a later phase of the analysis.

3.2.3 Unreported Removals

22. It is recognized that there are undoubtedly some unreported removals in historical fisheries, and that there will be some in future fisheries. The initial analysis will have the potential to allow for both historical and future levels by fishery, but no

attempt was made to agree on values to be used. The default assumption in the initial trials will be zero.

3.3 Technical Details: Annual Calendar

23. As an approximation, fishing will be assumed to take place in two pulses. In the first pulse (1st January), the surface and spawning ground catches will be removed. In the second pulse (1st July), the other LL fisheries catches will be removed. The allocation of fishery LL 3 to the most appropriate pulse requires further investigation. Natural mortality will take place continuously throughout the year.

24. Details of the mathematical specifications for the agreed conditioning model for SBT MP testing are shown in **Attachment D**.

4. Conditioning on Historical Data: Identification of Data and Error Structure used for Estimating Model Parameters

25. The workshop discussed a wide range of inter-related issues related to the following agenda sub-items in a combined, broad-ranging discussion:

4.1 Total Catch
4.2 Catch at Age and Catch at Length
4.3 Abundance Indices:
- **CPUE (by age/length/aggregate) vs effort**
- **Tagging**
- **Aerial surveys**

4.4 Method Used for Conditioning
4.5 Likelihood Structure for Each Data Component
4.6 Priors, Penalties and Constraints
4.7 Others

26. The workshop discussion on these agenda items is summarised in the table below, showing agreements reached on the initial model construction, together with notes on the justification for these agreements:

	Item	Initial Specifications	Notes
1.	Total catch	Assume values as reported. Countries should provide best available estimates.	Alternatives for sensitivity-(e.g., values thought to reflect unreported catch).

	Item	Initial Specifications	Notes
2.	Catch at age	Indonesian (only available) As reliable age-estimates from the surface fishery may become available, these will be preferred over size compositions for this fishery.	Ages out to at least 30 for the Indonesian data. We may wish to carry out modelling with fewer ages (20) for full time frame. Omitting the Indonesian length data was considered reasonable because a) the selectivity will be assumed constant for this fishery, b) estimates of selectivity are age-based hence age data most appropriate; and c) the information for year-class variability is negligible from older length data.
3.	Catch at length	All others (omitting initially Indonesian data and likely Australian surface fishery).	Future alternatives may evaluate sets estimated with different substitution algorithms.
4.	Growth	Begin-year and mid-year length-age matrices for fitting catch at length are pre-specified (and vary over time). i.e., not estimated internally. Having two matrices for each year is consistent with the way fisheries will be organized (i.e., begin-year fisheries and mid-year fisheries).	Issues on the number and width of length groups to be explored and advised with consultant feedback. Data are to be prepared on the finest length-increments available so that collapsing can be done consistently for all fisheries. Future analyses to perhaps consider uncertainty in growth.
5.	CPUE by age and effort	Aggregated CPUE values, standardized using GLM (or method selected from CPUE Modeling Workshop). As fallback, use nominal, but modeled with appropriate errors within main model.	Future analyses for conditioning model may include explicit time-trends in catchability, density dependence, and possibly other process errors.
6.	Tagging	To be used in aggregate. Assume one set of reporting rates from previous assessments. Pulse-fishing model to be used (non-Baranov) (see initial specifications in Attachment D)	Future possibility is to consider uncertainty in reporting rates. Also possibly splitting out by fishery.
7.	Aerial surveys	Do not include at this time	Information likely to be low, difficult to interpret.
8.	Acoustic surveys	Do not include at this time	Explore possible future use.

	Item	Initial Specifications	Notes
9.	Method for conditioning	Bayesian approach was selected. This primarily means that the option to use the posterior distribution as the basis of simulation trials is available and requires conditioning from currently available data.	Retain the option for approximating conditioned runs for projections. E.g., evaluating profile likelihoods or Hessian approximations to the posterior distribution in order to perform a reduced number of projection scenarios (instead of integrating over estimates of the posterior distribution).
10.	Likelihood structure for each data component	In general, the likelihood structure will follow those outlined from statistical approaches presented to the CCSBT (e.g., Commission for the Conservation of Southern Bluefin Tuna-MP/0203/4).	The minimum variance values for abundance indices (and analogously, upper limits for effective sample sizes for multinomial-type data) will be initially specified.
11.	Priors, penalties, constraints	Prior distributions to be clearly specified in the initial conditioned model, with initial specification to follow reasonable guidelines from previous CCSBT assessment work. I.e., these will be specified at the discretion of the Consultant and steering committee.	We anticipate that modifications to prior distribution specification will occur at subsequent MP workshops.
12.	Others	The time frame of the model was discussed and the suggestion was to extend the catch time series back to (1951–A) where here A is the number of ages that are modeled in 1951 (A = 20 for initial trials).	This point is considered important to establish a reasonable begin-year abundance level consistent with subsequent estimates of the stock-recruitment relationship.

5. Candidate Management Procedures

5.1 General Issues

5.1.1 Simple vs Complex

27. Initially, the candidate MPs to be evaluated should be simple, rather than complex. These will not only be more easily understandable when interacting with industry and managers during evaluation, but will be easier to code and test. However, MPs will be developed by national scientists, and the intention is not to place any constraints on what candidate MPs may be developed and evaluated. The performance of all developed initial candidate procedures will be evaluated and reviewed at the second MP Workshop in March 2003.

5.2 Data Inputs to Management Procedures

28. Different types of data were considered as candidates for input to management procedures. These would provide information on:
    - Abundance trends (CPUE and tagging)

- Recruitment trends (aerial surveys, acoustic)
- Age-comp, size-comp

29. The relative importance of these data types was debated. It was concluded that while simple procedures have advantages, the choice of an MP would be based on performance on simulation trials. While tagging may assume an increasing importance in the future, in the short to mid term the greatest influence will be on CPUE to index abundance trends.

5.3 Split of Catches

30. Two levels of control of splitting of catches will be provided. The control file for the OM will allow the split in catches to be determined before evaluations. However, this does not allow for control of catch split by MPs. Certain management procedures may wish to control the amount of catch removals by fishery. The code will therefore be designed with the option to have fishery-specific allocation of the total catch adjusted dynamically by the MP.

31. Once initial testing is complete, this will be activated (after review of the first OM code at the 2002 SAG meeting). For the initial simulation trials conducted by the Consultant, fishery-specific catches will be split out using historical proportions (averaged over 1998 - 2000). Future options will also include implementation errors (such as total removals differing from recommended catch levels).

5.4 Candidate Estimation Models
5.5 Candidate Decision Rules

32. These two items were discussed together. Only one or two simple candidate MPs are required to enable the programming consultant to test the OM before providing the code to national scientists for their own evaluations. A simple empirical rule will be implemented by the consultant to check code performance and for demonstration purposes. Total removals will be specified by:

$$C_{t+1} = (1-v)C_t + v\, kC_t(1+l)$$

where l is the slope of the regression of log(CPUE) versus time over the last ten years, using CPUE data up to time (t-1), and k is an adjustable control parameter.

33. Three options will be explored:
    1) Zero catch
    2) Constant catch (v =0)
    3) Variable catch (v =0.5)

6. Testing Management Procedures

6.1 Implementation of MP

6.1.1 Error Structure for Simulating Data Inputs for MP

34. Specifications for the sampling model used to generate future data for input in the MP are given in the table below. More complex models will be used after the first stage of trials.

Data type	Assumptions for Simulating Data in First Phase	Possibly Later
Aggregate CPUE in numbers and weight.	Lognormal i.i.d. with variance estimated in conditioning.	Proposals for incorporating bias will be developed by national scientists and CPUE workshop to be considered during the 2002 SAG meeting and Workshop II.
Catch at age for surface and Indonesian fisheries.	Multinomial using sample sizes determined empirically based on conditioning to past data.	Add higher variance than multinomial or consider alternative assumptions.
Catch at age for LL fisheries.	Generate size composition data with multinomial using sample sizes determined in conditioning, then apply cohort slicing.	Add higher variance than multinomial and consider alternatives.
Tagging	Not implemented.	Proposals for future implementation will be considered during the 2002 SAG meeting and Workshop II.

35. Proposals for the issues listed in the final column above (and also those indicated in section 4) should be in the form of specific, motivated and written submissions to the 2002 SAG meeting or Workshop II.

6.1.2 Implementation Uncertainty

36. No implementation uncertainty will be incorporate during the first stage of trials.

6.2 Approaches for Dealing with Uncertainty in Simulation Trials

37. Trials of MPs will be conducted according to a pre-specified hierarchy, going from the simplest and incorporating progressive levels of uncertainty as follows:

Hierarchy of MP trials

1) Fully Deterministic
Historic:

- use a few cases: (i) maximum likelihood estimates for h and B_0 plus fits of B_0 to upper/lower 5%-ile of h and vice versa. Hence each case has a fixed starting B/B_0 value.

Future Projections:

- no observation error in data
- no process error (e.g. no fluctuations about S-R curve)

2) Noise in Future Data

Future Projections:

- random observation error in data simulation (e.g. fluctuations in CPUE vs biomass relationship)
- no process error (e.g. no fluctuations about stock-recruitment curve)

3) Full Stochasticity in Future Projections

Future Projections:

- random observation error in data simulation as in (2)
- process error (e.g. add fluctuations about stock-recruitment curve)

4) Fully Stochastic per Scenario

Historic:

- Use full posterior distribution of parameters and state variable estimates in conditioning process.

Note: starting B/B_0 is now a distribution so interpretation of results is more difficult.

Future Projections:

- As in (3)

5) Partial Scenario Combination

It may be helpful to “integrate out” scenarios which the available data are scarcely able to distinguish, e.g. scenarios corresponding to different inputs for the natural mortality-at-age schedule (M_a), so as to reduce the number of robustness trials overall. This could be done either by combining across a set of discrete choices for M_a (for example) by choosing between them with equal probability for each projection replicate, or integrating over informative priors for the parameters in question in a Bayesian estimation procedure to implement conditioning.

The natural next stage in the hierarchy would be a ***Fully Stochastic Overall*** stage, where stage (4) would be integrated over all scenarios, weighting different scenarios (robustness trials) by relative probabilities. The workshop considered that reaching this last stage was unlikely and that the evaluation process would likely stop at stage (5).

6.3 Preliminary Set of Robustness Trials

38. The set of robustness trials to be used for the first stage of the MP evaluations (first year) will be decided at the next September meeting when results of the

conditioning will be available. Four series of CPUE data will be made available for the conditioning:

- B-Ratio proxy
- GeoStat-proxy
- Spline-based
- ST-window

39. Quality of fits and sensitivity of results will be examined using standard goodness-of-fit diagnostics. Conditioning will be done using a range of parameter values for M_a (vectors V2, V6 and V9), s_R (0.4, 0.6), r (0, 0.4, 0.8), sample sizes and/or variances used for weighting likelihood components (different data types), and variances of prior distributions corresponding to stochastic variables such as those that control changes in selectivity. For further robustness trials, emphasis will be placed on those sources of uncertainty that have a stronger effect on performance of candidate MPs.

6.4 General Issues about Weighting Alternative Hypotheses

40. A process will need to be developed for assigning weights to alternative hypotheses. The issue will be addressed during the second MP workshop, when results from the conditioning of different operating models to historical data will be available. The workshop anticipated that although goodness of fit criteria would be one component influencing the relative probabilities assigned to the different scenarios, expert judgment would need to be exercised, particularly for alternatives for which little or no informative data exists.

7. Initial Identification of Objectives and Related Performance Measures

41. The basic time horizon for evaluation of management procedures should be agreed as being 20 years. The major concern is that this time horizon is short in terms of number of SBT generations and won't reflect the longer term impact on spawning stock. For instance, reporting only spawning stock size and catch could allow policies that harvest young fish hard in the last 10 years to have higher catch and little impact on spawning stock, yet the consequences beyond 20 years would be adverse. This will be accounted for by tracking spawning potential and immature biomass in addition to spawning biomass.

7.1 Maximizing Catches

42. The management procedure evaluations will output catch and exploitation rate for each year and fishery. Initial summary statistics will be average catch over next 5 years and next 20 years.

7.2 Safeguarding of the Resource

43. Three quantities of interest will be calculated and output each year:

1) Spawning biomass,

$$B_t = \sum_a N_{t,a} m_a w_a$$

2) Non spawning biomass

$$NB_t = \sum_a N_{t,a} (1 - m_a) w_a$$

3) Spawning potential

$$SP_t = \sum_a \left(N_{t,a} \sum_{j=a}^{A} \left[m_j w_j e^{-(j-a)M} \right] \right)$$

It will also be necessary to calculate the unfished spawning biomass *(B_0)*

$$B_0 = R_0 \left[\sum_{a=1}^{a=A-1} \left(m_a w_a e^{-(a-1)m} \right) + m_A w_A e^{-(A-1)M} \left(\frac{e^{-M}}{1 - e^{-M}} \right) \right]$$

4) Recruitment

R_y

For these computations, $A = 30$.

44. Similar calculations for non-spawning biomass and spawning potential can be calculated for the unfished state, where:

B_t	is the spawning biomass at time t
B_0	is the average unfished spawning biomass
R_0	is the average unfished recruitment
$N_{t,a}$	is the numbers alive at time t age a
NB_t	is the non spawning biomass at time t
SP_t	is the spawning potential at time t
m_a	is the proportion mature at age a
w_a	is the mass of individuals age a
A	is the oldest age considered

45. Three ratios, B_t / B_0, NB_t / NB_0 and SP_t / SP_0 will all be output at 1980, y, y+5, y+10, 2020 and y+20 where y is the first year of projection under management policy.

46. As initial summary statistics, the following will also be computed and output:B_{2020}/B_{1980},

1. B_{2020}/B_{1980}
2. B_{y+20}/B_y
3. B_{y+5}/B_y,
4. SP_{y+n}/SP_y,
5. Proportion of years spawning potential is less than current

47. Finally, the current surplus production or a suitable approximation will be calculated and output, noting that the exact solution may be difficult to compute for the multi-fishery model.

7.3 Minimizing Inter-Annual Variation in Catch and Effort

48. It is recognized that year to year variation in catch is of considerable interest to the fishing industry and summary statistics will be difficult to compute that will capture all characteristics of interest. It is expected that examination of full distributions of catch change will ultimately be considered.

49. For each realization, the average annual deviation in catch will be calculated and output as:

$$AAV = \frac{1}{n}\sum_t \frac{|C_t - C_{t-1}|}{C_t}$$

50. Inter-annual change will also be computed as:

$$d_t = \frac{C_t - C_{t-1}}{C_t}$$

where C_t is the catch in year t

51. The distribution of d across years, within a single realization and across all realizations, will then be summarized for a management procedure as the 10^{th} and 90^{th} percentiles.

7.4 Others

52. No other classes of indicators were identified for the initial trials.

8. Mechanics for Conducting the Evaluation Tests

8.1 Roles of Computer Programmer and National Scientists

53. National scientists will design, code and evaluate management procedures (MP) of their choice using the simulation program developed by the Consultant. .

8.2 Computer Languages and Protocols for Linking OMs with User MPs

54. The simulation code, as well as the code used for the conditioning, will be written using AD Model Builder. The workshop agreed on the approach for implementing the management procedure within the operating model for specific conditioning cases (scenarios). To allow flexibility in computer coding languages for the management procedure side, a simple executable (or batch file) could be used rather than passing variables to a subroutine.

55. Users of the code will have control of a number of choices by variables contained in a file. These variables by changing their values on a control file. The specific control variables were listed as:

- Case number (fully describe the scenario)
- Name of MP code
- Hierarchy of trial (level of uncertainty incorporated in the trial- from 1 to 4)
- Number of historical replicates
- Number of projection replicates per historical replicate
- Length of forward projection (years)
- Types of data inputs expected by the MP
- Options for splitting total removals among fisheries
- Output specifications (control whether long output containing time series of variables is desired as opposed to only descriptive statistics)

56. A request was made at the workshop to allow control of parameters used for generating data (e.g. the CV used for generating CPUE). It was concluded that for the process of evaluating MPs, those variables would be part of what defines the case. This flexibility will be added later so that the code can be used for evaluating things such as quality of future data needs.

8.3 Protocols for Exchange of Code and Results

57. "Communication" between the operating model (OM) and the MP model may be done in two ways, both of which will be allowed for:

1) The most flexible option is to allow exchange through input/output of ASCII files. In one direction (OM →MP), simulated data used as input to the MP will be written/read; in the other (MP →OM), the catches computed by the MP will be exchanged. The advantage of this approach is that it broadens the type of software that can be used for developing management procedures, with some cost in efficiency (due to repeatedly reading and writing data).

2) The second option would require MPs to be written in AD Model Builder (or C++) and linked directly to the OM executable file. Data and results will be exchange as data objects between the subroutines. This is more efficient, but requires experience in coding in ADMB or C++, and use of the same compiler.

58. It was agreed to use the simple test-case MP used for testing by the consultant programmer to check comparability of results on different user machines (resulting, for example, from different variable precision or implementation of random number generation). Dr Parma agreed to provide instructions and guidelines regarding OM →MP exchange file formats and structures during the course of the year.

9. Workplan and Timetable

59. The following was agreed to be the workplan and timetable for completion of the scientific tasks related to development and testing of SBT OM's and MP's. This timetable does not attempt to address the need for iterative consultation with industry and managers during this process, which is recognised as being essential.

	Task:	**Completion by:**
9.1	Compile conditioning data	May 1, 2002
9.2	Prepare/debug computer code	August, 2002
9.3	Estimate model parameters by conditioning on historical data	August, 2002
9.4	Conduct first set of simulation trials using a few simple MP candidates	August, 2002
9.5	Meet inter-sessionally to examine model fits and consider the choice of operating models	SAG meeting, September 2002
9.6	Make code and input parameters (for different operating models) available to national scientists so that they can test different MPs using chosen set of operating models	2 weeks after SAG meeting (may not include the posterior distributions for Step 4 initially)
9.7	Continue with MP trials and document results	
9.8	Hold Workshop II – update data for final conditioning estimations, produce final specifications of operating models (robustness tests), and consider results for initial candidate MPs	Feb/March, 2003
9.9	Continue with MP trials and document results	
9.10	Inter-sessional meeting – evaluate conditioning and assign weights to alternate hypotheses (new Step 5, old step 4.5) and consider results for penultimate candidate MPs	SAG meeting, September 2003?
9.11	Continue with MP trials and document results	
9.12	Hold Workshop III – consider results for final candidate MPs and evaluate results, formulate conclusions and provide advice	March 2004

60. It was noted that this is a very full work schedule, particularly for those national scientists involved in preparation of data and development and testing of candidate MPs.

9.1 Data and Other Information Required for SBT Conditioning Model

61. The following data will need to be prepared by the identified responsible persons, and provided to the OM development process.

Data/Information Required	Provided By
Total catch (biomass or numbers) for 6 fisheries to 2001	Bob Kennedy to co-ordinate with input from member countries
Catch-at-length (2 cm bins) for LL1, LL2, LL3, and Japan spawning ground fisheries	Bob Kennedy to co-ordinate with input from member countries
Catch-at-age (ages 0 – 30) for Australia surface and Indonesia spawning ground fisheries	Bob Kennedy to co-ordinate with input from member countries
CPUE series (4)	Laslett Core – Australia ST Window – Japan Geo-proxy – Japan B-Ratio-proxy – Japan
Tag releases/recoveries	Australia (Tom Polacheck)
Reporting rates	Australia (Tom Polacheck)
Mean length-at-age by year and season	Jim Ianelli to co-ordinate with Dale Kolody
CV of length-at-age	from Dale Kolody – described in Attachment D
Weight – length relationship	Sachiko Tsuji
Natural mortality vectors	from previous stock assessment reports
Cohort slicing algorithm	Sachiko Tsuji

62. Fisheries falling in the first season (Australian surface, Indonesian spawning ground, Japanese spawning ground will use a September 1 to December 31 period for compiling statistics. Fisheries falling in the second season (LL1, LL2, LL3) will use a January 1 to August 31 period for compiling statistics.

63. The following provides an example of the convention that will be used for coding "year".

Year Code	Fishing Season 1	Fishing Season 2
1990	September 1, 1989 to August 31, 1990	January 1, 1990 to December 31, 1990

64. In addition to the required scientific work in developing and testing MPs, it was recognised that specific provision will have to be made for regular interaction with industry and managers in order to take account of their views. This was particularly important with relation to identification of objectives, identification and testing of performance measures and evaluation of output from candidate management procedures. Although the first OM code would only be available for the next SAG

meeting, progress could already be made in discussing management objectives (such as limits on inter-annual catch variation) with industry and managers.

65. A number of options were recognised for this iterative interaction with industry and managers:

- National scientists should initiate immediate consultation with their own industry and managers when developing their first candidate MPs for evaluation.

- Specific provision should be made for including industry and management representatives at SC meetings, and particularly at the next MP Workshop, to involve them directly in review of candidate MPs at those meetings.

- Specific presentations of OM and MP evaluation results should be arranged for the annual Commission Meetings in 2002 and 2003.

66. In the interest of initiating such consultation as soon as possible, it was agreed that industry and management representatives should be invited to a specific session at the September 2002 SC meeting, where first discussions regarding objectives could be held, and some initial test results shown. Regarding future interaction processes, it was agreed that further detailed proposals in this regard should be developed at the September 2002 SC meeting.

10. Appointment of Steering Committee

67. A Steering Committee will be required to coordinate the tasks outlined in the agreed workplan above, to ensure that unexpected problems or unnecessary delays do not jeopardise the proposed OM and MP development and testing schedule. The following were proposed as members of the Committee:

Ana Parma	- Technical Coordinator
Vivian Haist	- Development Programmer
Jim Ianelli	- Data Preparation Coordinator
Sachiko Tsuji	- Japan
Tom Polachek	- Australia
Talbot Murray	- New Zealand
Eric Chang	- Taiwan
(To be decided)	- Korea

68. Dr Hiramatsu was proposed as a substitute for Dr Tsuji, and Dr Kolody as a substitute for Dr Polachek, when they are unavailable. Substitutes may also be nominated for other national representatives.

69. Steering Committee representatives will be required to respond to communications and requests within time periods specified by the Coordinator.

11. Acceptance of Report

70. Following inclusion of the agreed revisions, the report of the Management Procedure Workshop was accepted. The Chair thanked all participants for their constructive and cooperative contributions.

LIST OF ATTACHMENTS

Attachment A: List of Participants

Attachment B: Agenda

Attachment C: List of Documents

Attachment D: Conditioning Model for SBT MP Testing

Attachment A

List of Participants
CCSBT
The 1st Meeting of Management Procedure Workshop
3-4 & 6-8 March 2002
Tokyo, Japan

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Attachment B

Terms of Reference
Agenda and the Annotation
The 1st Meeting of Management Procedure Workshop
3-4 & 6-8 March 2002
Tokyo, Japan

Draft Terms of Reference

1. Identification of an initial set of operating models for SBT, including estimation procedures for conditioning on past data.
2. Identification of future data that will be assumed available for possible input to Management Procedures.
3. Identification of a few simple Management Procedures (MPs) to be used for code development and demonstration.
4. Initial identification of performance indicators used to evaluate candidate MPs.
5. Definition of a workplan and timetable.
6. Appointment of a steering committee to coordinate inter-sessional work.

Proposed Agenda

1. **Opening, Terms of Reference and Adoption of Agenda**
   Chair: Andrew Penny

2. **Overview of the proposed process to develop a MP for SBT**
   Technical Coordinator: Ana Parma

3. **Structure of Operating Models for SBT**

The aim is at this stage is not to be comprehensive but to choose an initial set of operating models to be used for the first round of trials to be conducted during the first year. Material from past papers will be used as reference for this discussion.

- 3.1 Population model
  - 3.1.1 Stock structure
  - 3.1.2 Natural mortality
  - 3.1.3 Age/length- structured dynamics
  - 3.1.4 Trends in growth (historical trends estimated internally vs provided as input)
  - 3.1.5 Stock-recruitment relationship
  - 3.1.6 Weight/length relationship
  - 3.1.7 Maturity schedule and relative spawning potential

3.2 Fishery model

    3.2.1 Fisheries identified
    3.2.2 Selectivity for each fishery
    3.2.3 Non-retain catch

3.3 Technical detail: Annual calendar (quarters 1-2-3-4 vs 4-1-2-3)

3.4 Others

4. Conditioning on historical data: Identification of data and error structure used for estimating model parameters

4.1- Total catch

4.2- Catch at age and catch at length

4.3- Abundance indices: CPUE (by age/length/aggregate) vs effort
Tagging
Aerial surveys

4.4- Method used for conditioning

4.5- Likelihood structure for each data component

4.6- Priors, penalties and constraints

4.7- Others

5. Candidate Management Procedures

Items 5.1 and 5.4-5.5 will be discussed only briefly and to the extent that they satisfy ToR 3. It will be up to national scientists to develop and test candidate MPs once the simulation program and input parameters are made available. Item 5.2 is critical to satisfy ToR 2; the computer program will simulate the chosen sets of future data.

5.1. General issues

    5.1.1. Simple vs complex
    5.1.2. Empirical vs model-based

5.2. Input data

    5.2.1. CPUE or effort
    5.2.2. Tagging
    5.2.3. Aerial surveys
    5.2.4. Others? (catch at age, catch at length)

5.3. Split of catches between fisheries

5.4. Candidate estimation models

5.5. Candidate decision rules

6. Testing Management Procedures

6.1 Implementation of MP

    6.1.1 Error structure for simulating data inputs for MP

6.1.2 Implementation uncertainty

6.2 Approaches for dealing with uncertainty in the simulation trials
How much uncertainty will be integrated within each simulation trial
6.3 Preliminary set of robustness trials
6.4 General issues about weighting alternative hypotheses

7. Initial identification of objectives and related performance measures

An initial set of performance measures will be identified so that they can be used to evaluate results of preliminary tests. Input from managers and industry will be sought on those after the March meeting.

7.1. Maximizing catches
7.2. Safeguard of resource
7.3. Minimizing inter-annual variation in catch and effort
7.4. Others

8. **Mechanics for conducting the evaluation tests**

In order for national scientists to develop and evaluate their own MPs using the simulation code prepared by the programmer, the two pieces of code will need to exchange data while the programs run. Details will be discussed under this agenda item.

8.1. Roles of computer programmer and national scientists in conducting the evaluation tests over the first year
8.2. Computer languages and protocols for linking the operating models with the user-developed management procedures
8.3. Protocols for exchanges of code and results

9. Workplan and timetable

9.1. Compile conditioning input data
This corresponds to historical data that will be used to estimate parameters of the operating models. Initially we would want to use data that has been already compiled for the 2001 assessments. However, some of the data may need to be recompiled to match specifications of the operating models (e.g. 1.1-1.3).
9.2. Prepare/debug computer code
9.3. Estimate model parameters by conditioning on historical data
9.4. Meet intersessionally (at SAG? SC? earlier?) to examine model fits and reconsider the choice of operating models
9.5. Conduct first set of simulation trials using a few simple MP candidates
9.6. Make code and input parameters (for different operating models) available to national scientists so that they can test different MPs using chosen set of operating models

9.7. Continue with trials and document results
9.8. Hold Workshop II

10. Appointment of Steering Committee

11. Acceptance of report

Attachment C

List of Documents
The 1st Meeting of Management Procedure Workshop (MPWS)

(CCSBT-MP/0203/)

1. Terms of Reference, Draft Agenda and the Annotation
2. List of Participants
3. List of Documents
4. A Statistical Model for Stock Assessment of Southern Blue fin Tuna with Temporal Changes in Selectivity, 6 January 2002. : Doug S. Butterworth, James N. Ianelli, Ray Hilborn.
5. (Japan) Overview of characteristics of SBT stock, fisheries, and assumptions used in historical assessments and some consideration toward d eveloping SBT Management Procedures. :Sachiko Tsuji.
6. (Japan) Management procedure development for the Namibian hake resource. :R.A.Rademeyer and D.S. Butterworth.
7. Management of Long-Lived Marine Resources: A Comparison of Feedback-Control Management Procedures. :Andre E. Punt and Anthony D.M.Smith

(CCSBT-MP/0203/BGD)

1. (Australia) An Integrated Statistical Time Series Assessment of the Southern Bluefin Tuna Stock based on Catch at Age Data. CCSBT-SC/0108/19, Polacheck, T. and A. Preece. 2001.
2. (Australia) Application of a Statistical Catch-at-Age and -Length Integrated Analysis Model for the Assessment of Southern Bluefin Tuna Stock Dynamics 1951-2000. CCSBT-SC/0108/13. Kolody, D. and Tom Polacheck.
3. (Australia) Development and evaluation of management strategies for the southern bluefin tuna fishery. AFFA-FRRF Final Report. CCSBT-MS/0005/13. Polacheck, T., N. Klaer, C. Millar, and A. Preece. 1999.
4. (Japan) Exploration of cohort analysis based on catch at length data for southern bluefin tuna. CCSBT-SC/0108/32. H. Kurota et al.
5. (Japan) Review of history in recognition of stock status and some consideration on principles in developing management procedures. CCSBT-SC/0108/34. S. Tsuji.

(CCSBT-MP/0203/Info)

(CCSBT-MP/0203/Rep)

1. The Report of the Management Strategy Workshop
2. The Report of the Sixth Meeting of the Scientific Committee

Classification of List of Documents

(CCSBT-MP/0203/)
Documents to be discussed at the meeting and not yet given a document number of CCSBT, to be classified into this category.

(CCSBT-MP/0203/BGD)
Documents to be discussed at the meeting and already given a document number of CCSBT in the previous meeting, to be classified into this category.

(CCSBT-MP/0203/Info)
Documents not to be discussed at the meeting but presented for information and reference, to be classified into this category.

(CCSBT-MP/0203/Rep)
The previous report of CCSBT to be classified into this category.

(CCSBT-MP/0203/WP)
The draft of the document and report developed through the discussion of the meeting and documents of informal meetings, to be classified into this category.

CONDITIONING MODEL FOR SBT MP TESTING

THE AGE-STRUCTURED POPULATION MODEL

Population Model

The SBT dynamics are modeled with age-specific dynamics. Fishing and natural mortality are treated as discrete events and two seasons are modeled for each year.

$$N_{y+1,a+1} = N_{y,a}\left(1-\sum_{f\in f^1} H_{f,y,a}\right)\left(1-\sum_{f\in f^2} H_{f,y,a}\right)e^{-M_a} \quad \text{for } 0 \le a \le m\text{-}2$$

$$N_{y+1,m} = N_{y,m-1}\left(1-\sum_{f\in f^1} H_{f,y,m-1}\right)\left(1-\sum_{f\in f^2} H_{f,y,m-1}\right)e^{-M_{m-1}} + N_{y,m}\left(1-\sum_{f\in f^1} H_{f,y,m}\right)\left(1-\sum_{f\in f^2} H_{f,y,m}\right)e^{-M_m}$$

$$N_{y+1,0} = R_{y+1}$$

$$N^*_{y,a} = N_{y,a}\left(1-\sum_{f\in f^1} H_{f,y,a}\right)e^{-M_a/2}$$

$$H_{fya} = s_{fya}F_{fy}$$

$$F_{f,y} = C_{f,y} \Big/ \left(\sum_{f\in f^1} w^1_{y,a} s_{f\,y,a} N_{y,a}\right) \quad ; \quad F_{f,y} = C_{f,y} \Big/ \left(\sum_{f\in f^2} w^2_{y,a} s_{f\,y,a} N^*_{y,a}\right)$$

where
- $N_{y,a}$ is the number of fish of age a at the start of year y,
- $N^*_{y,a}$ is the number of fish of age a at mid-year y,
- M_a denotes the natural mortality rate on fish of age a,
- $C_{f,y}$ is the biomass of fish caught in fishery f in year y,
- $F_{f,y}$ is the age-averaged fishing proportion of fishery f in year y,
- $H_{f,y,a}$ is the fishing proportion of fishery f in year y for fish of age a,
- $s_{f,y,a}$ is the standardized selectivity of fish of age a in fishery f in year y,
- $w^1_{y,a}, w^2_{y,a}$ are the average weights of fish of age a in year y in seasons 1 and 2,
- R_y is the age-0 recruitment in year y,
- f^1 is the set of fisheries that occur in the first season,
- f^2 is the set of fisheries that occur in the second season, and

m is the maximum age considered (taken to be a plus-group).

Stock-Recruitment

The number of recruits at the start of year y is related to the spawning stock size by a stochastic Beverton-Holt stock-recruitment relationship with auto-correlation in the residuals:

$$R_y = \frac{a \quad S_y}{b + S_y} \quad \exp\left(t_y - s_R^2/2\right)$$

$$t_y = r\,t_{y-1} + \sqrt{1 - r^2}\,w_y$$

where S_y is the spawning stock biomass in year y, r is the serial correlation in the recruitment residuals ($r = \mathrm{Cor}(t_y, t_{y-1})$) and $v_y \sim \mathrm{N}\left(0, s_R^2\right)$. The recruitment residuals are estimated also for 20 years prior to the onset of fishing, so as to allow the 1951 population age distribution to differ from that for pre-exploitation equilibrium to the extent that the data suggest. Thus, effectively, the analyses provide population trend estimates from an assumed deterministic equilibrium situation in 1931, rather than 1951. Spawning stock biomass is estimated as:

$$S_y = \sum_{a=1}^{m} b_a w_{y,a}^1 N_{y,a}$$

where b_a is the proportion of fish of age a that are mature.

In order to work with estimable parameters that are more meaningful biologically, the stock-recruitment relationship is re-parameterised in terms of the pre-exploitation equilibrium spawning biomass, B_0, and the "steepness", h, of the stock-recruitment relationship (recruitment at 20% of the pre-exploitation level as a fraction of recruitment at the pre-exploitation level):

$$a = \frac{4hR_0}{5h - 1}$$

and

$$b = \frac{B_0(1-h)}{5h - 1}$$

where

$$R_0 = B_0 \Bigg/ \left[\sum_{a=1}^{m-1} b_a w_{1951,a}^1 \quad \exp\left(-\left(\sum_{a'=0}^{a-1} M_{a'}\right)\right) + b_m w_{1951,m}^1 \frac{\exp\left(-\left(\sum_{a'=0}^{m-1} M_{a'}\right)\right)}{1 - \exp\left(-M_m\right)} \right]$$

Note that a depensation function may be added to the stock-recruitment relationship in the operating model at a later stage, but is not estimated in the conditioning model.

Selectivities

The parameterization of selectivity is age-specific, and for some fisheries the model structure allows the selectivities to change slowly over time. For fisheries with time-invariant selectivity,

$$s'_{f,y,a} = l_{f,a} \qquad \text{for } 1 \le a \le m^f$$

$$s'_{f,y,a} = l_{f,m^f} \qquad \text{for } a > m^f$$

$$s_{f,y,a} = s'_{f,y,a} \Big/ \sum_{a=1}^{m} s'_{f,y,a}$$

where we assume that selectivity is constant for all age classes older than m^f in fishery f. For fisheries with time-variant selectivity the formulation is:

$$s'_{f,1951,a} = l_{f,a} \qquad \text{for } 1 \le a \le m^f$$

$$s'_{f,1951,a} = l_{f,m^f} \qquad \text{for } a > m^f$$

$$s_{f,1951,a} = s'_{f,1951,a} \Big/ \sum_{a=1}^{m} s'_{f,1951,a}$$

$$s'_{f,y+b,a} = s_{f,y,a} \exp\left(g_{f,y,a}\right) \qquad g_{f,y,a} \sim N\left(0, s^2_{s^f}\right)$$

$$s_{f,y+b,a} = s'_{f,y+b,a} \Big/ \sum_{a=1}^{m} s'_{f,y+b,a}$$

where $g_{f,y,a}$ reflects the amount of change (over time period b) in the age effect of fishing by fleet f

for age a, and b is the period length (years) over which the age effect of fishing is constant.
The stochastic error terms, $g_{f,t,a}$ are treated as free parameters subject to the constraints of their input variances, $s^2_{s^f}$. If the age effects of fishing ($s_{f,y,a}$) are constant over time, this results in a decomposition of the fleet-specific fishing mortality rate into an age component and a year component. This assumption creates what is known as a separable model. If the age effect of fishing in fact changes over time, then the separable model can mask important changes in fish abundance. In our analyses, we impose constraints through the variance term that allow selectivity to change only slowly over time – thus improving our ability to estimate the $g_{f,y,a}$'s. Also, to provide smoothness in the age component, we place a curvature penalty on the age-specific coefficients using squared third-differences, i.e., the following term was added to the negative log-likelihood function for each fishery:

$$\sum_{y=1951}^{Y} \sum_{a=0}^{m^f-3} \frac{\left(\ln s_{f,y,a+3} - 3\ln s_{f,y,a+2} + 3\ln s_{f,y,a+1} - \ln s_{f,y,a}\right)^2}{2s^2_{b^f}} = g^f\left(s_{f,y,a}; 2s^2_{b^f}\right)$$

This prevents irregular shifts between adjacent age classes. The reason for the choice of third differences is that the data indicate selectivity to usually be dome-shaped with age, so that selecting either first differences (which penalizes all but independence with age), or second differences (which favors linear behavior with age) would be inappropriate.

Growth

We do not attempt to estimate growth in the model but rather assume known mean lengths-at-age that change over time. Also, we assume a known length-weight relationship. For catch-at-length prediction we require estimates of the length frequency distribution for each age. We use a simple approach, for initial estimation, in which normal distributions are assumed, with standard deviation (sigma) of length-at-age linearly related to the mean length-at-age (mu) by the relationship used in Kolody and Polacheck (2001): sigma(age) = 2.0 + (1/30)*mu(age) cm, where mu(age,time) was the age-length relationship agreed for the 2001 stock assessment. The linear relationship can provide a very reasonable approximation of the standard deviations of instantaneous length-at-age estimated in a comprehensive growth study (Paige Eveson, CSIRO, pers comm.). However, in the relationship above, sigma(a) is intentionally increased (particularly for younger ages), relative to the growth study estimates, to admit within-year growth in the observed CL distribution. The degree of increase was arbitrarily chosen, and the effects of the decision were not subsequently examined, so a better choice could probably be made at a later stage.

Tagging Model

We assume the same dynamics for fish that are tagged and released as for the general population. The tag releases have generally occurred near the beginning of the calendar year (January) so we treat the releases as discrete events occurring between the two fishing seasons. Because the tagged fish will not be completely mixed during the fishing season following their release we do not assume they have the same vulnerability to this seasons fisheries as the general population. Rather adjust the number of tag releases for the recoveries during the fishing season following their release. The dynamics for the tagged fish are described by:

$$T_{1951,a} = 0 \qquad \text{for} \quad a \le 10$$

$$T_{y+1,a+1} = T_{y,a}\left(1-\sum_{f\in f^1} H_{f,y,a}\right)\left(1-\sum_{f\in f^2} H_{f,y,a}\right)e^{-M_a} + \left(G_{y,a} - {r_{y,a}}/{l_{y,a}}\right)e^{-M_a/2} \qquad \text{for } 1951 \le y \le 2000 \text{ and } 0 \le a \le 10$$

$$T^*_{y,a} = T_{y,a}\left(1-\sum_{f\in f^1} H_{f,y,a}\right)e^{-M_a/2}$$

where $T_{y,a}$ is the number of tagged fish of age a at the start of year y,

$T^*_{y,a}$ is the number of tagged fish of age a at the middle of year y,

$G_{y,a}$ is the number of fish of age a tagged and released at the start of year y,

$r_{y,a}$ is the number of fish of age a recovered in year y,

$l_{y,a}$ is the reporting rate for fish of age a in year y.

PREDICTED QUANTITIES

Catch-at-age and Catch-at-length

Observations of either catch-at-age or catch-at-length are available for each of the fisheries and are fitted in the model. The predicted catch-at-age *a* in fishery *f* and year *y* is:

$$\hat{C}_{f,y,a} = s_{f,y,a} F_{f,y} N_{y,a} \quad \text{for} \quad f \in f^1$$

$$\hat{C}_{f,y,a} = s_{f,y,a} F_{f,y} N^*_{y,a} \quad \text{for} \quad f \in f^2$$

For fisheries with length-based data, the predicted catch-at-length *l* in fishery *f* and year *y* is given by:

$$\hat{L}_{f,y,l} = \sum_a p^t_{y,a,l} \hat{C}_{f,y,a} \qquad \text{for } f \in f_1, t=1\,; \quad \text{for } f \in f_2, t=2$$

where $p^t_{y,a,l}$ is the proportion of fish of age *a* that are length *l* in season *t*. The $p^t_{y,a,l}$ are calculated assuming normal distributions for length-at-age with known means and variances.

CPUE

Catch per unit effort (CPUE) is fitted as an aggregate index (i.e. not age based) for the LL1 fishery only. The predicted CPUE is:

$$\hat{I}_y = q \sum_a \left(s_{f,y,a} N^*_{y,a} \right) \qquad \text{where } f = \text{LL1}$$

where *q* is a proportionality constant that is time invariant for the current analyses. Alternate structural assumptions about the form of *q* will be considered in future work.

Tag Returns

The predicted number of tag recoveries for each fishery is a function of the number of tagged fish in the population and fishing mortality:

$$r'_{f,y,a} = s_{f,y,a} F_{f,y} T_{y,a} \quad \text{for} \quad f \in f^1$$

$$r'_{f,y,a} = s_{f,y,a} F_{f,y} T^*_{y,a} \quad \text{for} \quad f \in f^2$$

where $r'_{f,y,a}$ is the predicted number of recoveries of fish of age *a* in fishery *f* in year *y*. The expected number of tag returns in year *y* is:

$$\hat{r}_{y,a} = \frac{\sum_f r'_{f,y,a}}{l_{y,a}}$$

OBJECTIVE FUNCTION

Likelihood Components for Data Fits

The model is fitted to a CPUE index series, fishery catch-at-age and catch-at-length data, and tag return data. The estimates of catch biomass for eash fishery are assumed to be without error. The negative of the log-likelihood (-lnL) for each of the data components are described below.

CPUE data

The likelihood is calculated assuming that the observed abundance index is log-normally distributed about its expected value with variance s_I^2:

$$-\ln L = n_I \ln\left(s_I\right) + \frac{\sum_{n_I}\left(\ln\left(I_y\right) - \ln\left(\hat{I}_y\right)\right)^2}{2s_I^2}$$

where n_I is the number of CPUE observations.

Catch-at-age and catch-at-length

For the fits to catch-at-age and catch-at-length data we assume a multinomial sampling distribution. Under this assumption, the log-likelihood function for the catch-at-age or catch-at-length data (in numbers) from each fishery can be written:

$$-\ln L = n^f \sum_y \sum_k p_{f,y,k} \ln\left(\hat{p}_{f,y,k}\right)$$

where $k = a$ for catch-at-age data, $k = l$ for catch-at-length data, and

$$p_{f,y,a} = \frac{O_{f,y,a}}{\sum_a O_{f,y,a}}, \quad \hat{p}_{f,y,a} = \frac{\hat{C}_{f,y,a}}{\sum_a \hat{C}_{f,y,a}} \quad \text{for age-based data}_1\text{, a nd}$$

$$\hat{p}_{f,y,l} = \frac{\hat{L}_{f,y,l}}{\sum_a \hat{L}_{f,y,l}} \quad \text{for length-based data}$$

The n^f are the effective sample sizes for fisheries f, and the $O_{f,y,a}, \hat{C}_{f,y,a}, \hat{L}_{f,y,l}$ are the observed and predicted catch-at-age or at-length for fishery f.

Tag Returns

The fits to the tag return data is based on an approximation to the Poisson distribution. If the tag recapture process is governed by a Poisson distribution, a square root transformation should produce variables that are approximately normally distributed with a standard deviation of 0.5. The negative log-likelihood we use is:

$$-\ln L = \sum_y \sum_a \frac{\left(\sqrt{r_{y,a}} - \sqrt{\hat{r}_{y,a}}\right)^2}{2s_T^2}$$

where $r_{y,a}$ is the number of tag returns of age a in year y which have been at liberty for more than one year. Note that in practice the distribution of tag recoveries is likely over-dispersed relative to the Poisson assumption, so a standard deviation greater than 0.5 is used in the analysis.

Likelihood Components for Priors

<u>Stock-recruitment relationship</u>

The stock-recruitment relationship that we use implies a number of prior assumptions about the relationship between stock and recruitment, including; steepness, serial correlation in recruitment residuals, and the magnitude of the recruitment residuals. We assume that the steepness parameter and the serial correlation parameter are normally distributed, $N \sim \left[\tilde{h}, s_h^2\right]$ and $N \sim \left[\tilde{r}, s_r^2\right]$, respectively. Then the negative log-likelihoods for these assumptions are:

$$\ln\left(s_h\right) + \frac{\left(h - \tilde{h}\right)^2}{2s_h^2} \quad \text{and} \quad \ln\left(s_r\right) + \frac{\left(r - \tilde{r}\right)^2}{2s_r^2}$$

As described in the stock-recruitment section, the recruitment residuals (in log space) are assumed to be multivariate normal from a stationary AR(1) process with parameters $E\left(t_y\right) = 0$, $\text{Var}\left(t_y\right) = s_R$, $\text{Cor}\left(t_y, t_{y-1}\right) = r$. The negative log-likelihood for this prior is:

$$\frac{\left(t_{y_1}\right)^2}{2s_R^2} + \frac{\sum_{y=y_1+1}^{y=y_n} \left(t_y - r\,t_{y-1}\right)^2}{2s_R^2\left(1-r\right)^2} + n_R \ln\left(s_R\right) + 0.5\left(n_R - 1\right)\ln\left(1 - r^2\right)$$

where y_1 and y_n are the first year and the last year for which recruitment residuals are estimated and n_R is the number of recruitment residuals estimated.

Selectivity

The age-specif ic selectivity parameterization incorporates two assumptions that reflect our prior belief about the form of the selectivity function. For all fisheries we assume a dome-shaped relationship between selectivity and age. The negative log-likelihood for this prior is:

$$\sum_f g^f\left(s_{f,y,a}; 2s_{b^f}^2\right)$$

where the variance term $s^2_{b^f}$ reflects our belief about the degree to which the selectivities should be dome-shaped.

For some of the fisheries we assume that age-specific selectivity changes slowly over time. The negative log-likelihood for this prior assumption is:

$$\sum_{f} \sum_{y \in y^f} \frac{\left(g_{f,y,a}\right)^2}{2s^2_{s^f}}$$

where y^f is the set of years in which selectivity changes for fishery f. Note that for fisheries with time-invariant selectivity this set will be empty.

Table 1. Estimated parameters and prior distributions for initial conditioning of operating models.

Process	Estimated Parameters/States	Fixed Value or Prior Distribution
Natural mortality	M<u>a</u>	Age-specific vectors V2,V6 and V9
Maturity	b_a	b_a=0 for a<10 b_a=1 for a≥10
Recruitment	h $\ln(B_0)$ $v_y \quad y = 1931,\cdots,2000$ s_R^2 r	$U(0.2,\ 1)$ or Gaussian $U(-\infty, \infty)$ $N(0,\ s_R^2)$ fixed at 0.4- 0.6 or estimated fixed at 0, 0.4 and 0.8 (estimated?)
Selectivity:		
f: surface	$l_{f,a} \quad a = 0,\cdots,7$ flexibility on maximum age estimated	Penalized for curvature
f: spawning JA1	$l_{f,a} \quad a = 5,\cdots,20$ flexibility on ages estimated	Penalized for curvature
f: spawning ILL	$l_{f,a} \quad a = 5,\cdots,20$ flexibility on ages estimated	Penalized for curvature
f: LL1	$l_{f,1951,a} \quad a = 3,\cdots,15$ $g_{f,y,a} \quad a = 3,\cdots,15 \quad y = 1951,1955,..$ flexibility of ages	penalized for curvature $N(0, s_{sf}^2)$
f: LL2	$l_{f,1951,a} \quad a = 3,\cdots,15$ $g_{f,y,a} \quad a = 3,\cdots,15 \quad y = 1951,1955,..$ flexibility of ages	penalized for curvature $N(0, s_{sf}^2)$
f: LL3	$l_{f,1951,a} \quad a = 3,\cdots,15$ $g_{f,y,a} \quad a = 3,\cdots,15 \quad y = 1951,1955,..$ flexibility of ages	penalized for curvature $N(0, s_{sf}^2)$
CPUE	$\ln(q_{1951})$ s_I	U(-15,-10) U(0.2, 2)
Other data	n^f s_T	to be explored to be explored