INTERNATIONAL REVIEW PANEL REPORT FOR THE 2015 INTERNATIONAL FISHERIES STOCK ASSESSMENT WORKSHOP
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Introduction
The Panel recognised the very high quality of the research presented at the 2015 International Fisheries Stock Assessment Review Workshop. This included research on Southern African hake and sardine, the impact of area closures near islands on the pelagic fishing industry, and whether it is possible to detect the effects of these closures on penguin population growth rate. The Panel thanked the workshop participants for their hard work preparing and presenting the workshop papers, for the extra analyses undertaken during the workshop, and for the informative input provided during discussions.

This report starts with observations from the Panel on some general issues for the species / programmes reviewed, and then focuses on the more detailed technical review and recommendations concerning each. The current workshop differed somewhat from those in previous years in that a substantial amount of time was spent in "workshop mode", considering model outputs and results, and given this, those discussions are recorded only to the extent that they led to broad conclusions or research recommendations. The recommendations are annotated by their priorities (H, M, L and conclusions are indicated by: *).

Summary of general issues
Penguins

<u>Detection of closure effects</u>

The work since the 2014 International Workshop which was reported to the 2015 event had focused on one aspect of understanding, and ideally reversing, the declining trend in the numbers of African penguins, namely whether fishing near islands impacts penguin population growth rate negatively. A considerable amount of work was undertaken by the Penguin Technical Team in preparation for the workshop. The Panel focused on the development of a method to evaluate statistical power, although the Panel recommendations are also relevant to how conclusions may be drawn on the impact of fishing near islands on penguin population growth rate.

The Panel has provided revised specifications for the power analyses, focusing on the key considerations likely to impact the power to detect biologically meaningful impacts caused by the fishery. It has also identified a reference set of specifications for the operating model and estimation methods that should form the basis for final conclusions. The work needed to complete this exercise is substantial, but the Panel warns against attempts to draw conclusions on the effects of fishing near islands and of the power to detect such efforts prematurely (i.e. without completing all of the suggested calculations).

<u>Impact of closures on industry</u>

The Panel reviewed the Opportunity Based Model (OBM) that has been developed to quantify lost fishing opportunities when an area around an island is closed to pelagic fishing. This model considers the catches that were taken historically in closure areas around the islands and estimates the proportion of those that would have been lost had these areas been

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closed. The Panel identified various aspects of the methodology that could have a substantial impact on predictions, noting that it was requested to address the question of whether lost opportunity could be less than about one fifth or one-tenth of the estimate of 40% from MARAM/IWS/DEC15/PengI/P1.

The Workshop identified an alternative "base-case" model to that provided in MARAM/IWS/DEC15/PengI/P1. This model led to lower estimated values for the proportion of the catch in closure areas that would be lost. The method provides an empirical broad brush way to evaluate lost catch. However, the range of estimated losses remains large, with range from 23% to -3%. More work is needed before the range of estimates can be narrowed. This work would require input from those familiar with vessel behaviour and data at fine spatial scales for individual vessels (including data on vessel tracks), as well as the development of new models to use the input and additional data.

Sardine

The Panel was pleased to note the increased number of fish for which parasite data are available. The increased sample sizes allowed a more accurate estimate of the prevalence of parasites in the south coast stock sardines. The Panel supports efforts to formally include the parasite data in the assessment, but also emphasizes the importance of identifying and resolving some software development issues that may be hampering the ability to fit the model to the data.

Hake

The predation model is still unable to fit all of the available data adequately. The Panel provided suggestions for giving the model more flexibility to simultaneously fit the time-trend in catch-rate as well as data on the fraction of hake in the diet of the two hake species, the split of the diet of *Merluccius. capensis* between *M. capensis* and *M. paradoxus*, and the size-structure of the hake in the diet of hake predators of various ages.

The Panel noted that only limited progress had been possible on the hake SCAA spatial box model during 2015, but that it is planned to address the Panel's recommendations B.18 to B.21 from the 2014 workshop early during 2016. The Panel re-endorsed those recommendations, and looked forward to furtherance of this work.

General considerations

The Panel reiterates the recommendation from past panels that for each species being reviewed, a document should be produced that provides an overview of the fishery, its history of exploitation, and a summary of the data available. This "fishery description" document should be provided to the Panel well in advance of the review meeting, as it would help Panel members unfamiliar with South African fisheries and fisheries management techniques to become better prepared for the review.

African penguins

Detection of closure effects on birds

A.1 (*) The work since the 2014 International Workshop that was reported to the 2015 event has focused on one aspect of understanding, and ideally reversing, the decline in the numbers of African penguins, namely whether pelagic fishing near islands impacts penguin population growth rate negatively. This is, however, only one aspect of the overall problem. The Panel therefore reiterates its high priority recommendation from the 2014 workshop: "Develop and implement a comprehensive research program that aims to identify the core reasons for the reduction in penguin population numbers, and identify any potential mitigation measures" in the absence of any detailed update on this in the information provided to it.

A.2 (H) In relation to next steps for a power analysis to evaluate closure effects on penguins[5]:

1. Analyses should be conducted for multiple effect sizes for each response variable. The models for the response variables should be designed so the values for the effects of fishing, λ (and/or δ), are such that a larger value means a greater negative impact of fishing near islands on penguin population growth rate . The lowest effect size to be evaluated (the "threshold") (e.g., 0.1 in Fig. 1) should be computed using a population dynamics model such as the simple model in MARAM/IWS/DEC15/PengD/BG4 or the penguin population dynamics developed by Robinson *et al.* (2015) given a management objective of a pre-specified change in population growth rate following elimination of fishing near islands (and assuming that fishing impacts only one population dynamics parameter).

2. The power analysis should be based on an evaluation of the probability that the value for the effects of fishing, λ (and/or δ), is greater than or equal to the threshold. This is not the same test as whether the value for λ (or δ) is statistically different from zero under a two-sided test. The Panel recommends that "support for the hypothesis that λ (or δ) exceeds the threshold" be defined as the probability that λ (or δ) is greater than or equal to the threshold exceeds the value P_{MIN}, i.e. $P(\lambda > \text{Threshold}) > P_{\text{MIN}}$ [6]. Full details of the power analysis and for computing the probability that λ (and/or δ) is greater than or equal to the threshold are given in Appendix A.

3. There should be a reference set of specifications for the operating models and for the estimation models (see Panel recommendations in Table 1) and an examination of robustness should be conducted (see Panel recommendations in Table 2). Final conclusions should be based on the reference set.

4. (**1**, *Response variables*) All six response variables should be assessed with respect to how reliably they are sampled and how informative they are regarding potential fishery effects on population growth rates. One of these variables (fledgling success) is directly related to the net reproduction rate, while the other five response variables are related only indirectly. It may still prove challenging to develop thresholds for the indirect response variables because it may be unclear how to quantify how changes in the variables impact biological processes and hence population growth rate (e.g. the relationship between trip duration and population growth rate). A response variable should not be considered further if there is no (objective) way to determine a threshold for it. In addition, if a particular response variable is sub-ordinate or directly correlated with another then there may be little to be gained by considering it further.

5. (**1**, *Islands*) The analyses should consider both Dassen and Robben islands.

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[5] The first three points are general and the remaining points pertain to the specific issues raised in MARAM/IWS/DEC15/PengD/P4. Points 4-22 indicate the section and topic in MARAM/IWS/DEC15/PengD/P4 where the issue concerned was raised (e.g. (**1**, Islands) indicates this relates to the "islands" section in MARAM/IWS/DEC15/PengD/P4. Also, these "next steps" apply to Daasen and Robben Islands only given that the material provided to the Panel related to these islands.

[6] P_{MIN} could be set *a priori* (e.g. to 0.5) or tuned given knowledge about estimator bias (see Appendix A).

6. (**1**, *Conditioning and Estimation methods*) The primary analyses should be based on the sub-regional model (equation 1 in MARAM/IWS/DEC15/PengD/ALL1). The regional biomass model has the disadvantage that it requires that an appropriate "regional biomass" be defined. Sensitivity should be conducted to the use of the regional biomass model, but this should be a secondary priority.

7. (**1**, *Allowance for sample size in estimator*) There is no need to account for sample size when generating data in any simulations given the low observation error relative to process error (MARAM/IWS/DEC15/PengD/P2). However, it is also reasonable to exclude data points based on very small sample sizes (perhaps < 5 points) when conditioning the operating model or to estimate the sample size component of the observation error.

8. (**1**, *Fish species considered*) For operating models that include catches, focus should be on anchovy given it constitutes the largest fraction of the diet of penguins during the reproductive period.

9. (**1**, *Areas considered around islands to define catches*) There is no *a priori* way to eliminate any of the options for defining catches, but C_{20} and $C_{closure}$ should be sufficiently similar so only one of the two need be included in the reference case analyses. The Panel recommends that the analyses use C_{10}, C_{30} and $C_{closure}$. C_{20} could be considered in the sensitivity analyses. Options can be removed from consideration if this is agreed by the local scientists.

10. (**1**, *Allocation of catches given closure to areas outside*) The two options for the spatial allocation of catches that would otherwise have been taken from a closed area which are proposed in MARAM/IWS/DEC15/PengD/P1 are extreme. The OBM should be used to compute the average proportion of the catch in the closure area that would have occurred in other areas.

11. (**1**, *Biomass series considered*) The choice of biomass series is not essential to conducting a power analysis for the proposed reference case analysis.

12. (**1**, *Catch-biomass correlation*) The assumption m=0 (where *m is* the correlation between the catch in the vicinity of the islands and regional biomass) should be restricted to evaluating the potential bias of estimation methods. Continue with the current non-zero options.

13. (**1**, *Autocorrelation in residuals*) The impact of autocorrelation in residuals (Equation 8 in MARAM/IWS/DEC15/PengD/P4) is likely to be inconsequential so the Panel recommends that this factor be ignored.

14. (**1**, *Biomass and catch autocorrelation*) Temporal autocorrelation in biomass and catches is evident in the data. However, how to model this has yet to be sufficiently well developed to warrant inclusion in the reference case.

15. (**2**, *Data to used*) Conduct the proposed standardization of individual observations to yield revised annual summary values. Use the standardized values in further analyses if only the time-series of standardized values is statistically different from that for the unstandardized (raw) values (for example if the coefficients for the covariates are

statistically significant). Conditioning of the operating model should be based on the largest data set possible irrespective of whether the raw or standardized indices are used.

16. (**3**, *Conditioning issues*) For the catch+closure models, the total effect sizes should be split equally between λ and δ.

17. (**3**, *Conditioning issues*) Set the value for σ_α as the mean of the sampling (or posterior) distribution for this value when the point estimate of σ_α is zero.

18. (**4**, *Issues related to generating pseudo-data for simulation testing*) These issues have been largely resolved so it is necessary to consider only approach A in section 4 of MARAM/IWS/DEC15/PengD/P2 in future analyses.

19. (**5**, *Procedure for adjusting initial estimates for bias*) There is no need to adjust the effect sizes in the operating model, but candidate estimation methods could be adjusted for estimation bias (see Appendix A). Any process for adjusting for bias for an estimation method must be the same for all operating model variants.

20. (**6**, *Aggregating results*) See recommendation A.3 below.

21. (**7**, *Miscellaneous*) The proposed simple estimator should continue to be explored as an alternative to GLMM estimators.

22. (**7**, *Miscellaneous*) The proposed set of analyses (Table 1) allow for crossing of factors.

A.3 (*) The Panel consider that it is ill advised to attempt to draw conclusions regarding the biological effects on penguins of fishing near islands at this stage, in particular because biologically-important thresholds for λ and δ have yet to be established and the power analysis has not yet been conducted. However, when such thresholds have been established and power analyses conducted, if such conclusions are to be drawn, the process should involve the following steps:

- Construct a table that has columns for each response variable and rows for each estimation model, with entries indicating whether the data indicate support for the hypothesis that the value for λ (or δ) is greater than the predetermined effect size.
- Eliminate columns from the table to avoid response variables that are *a priori* correlated through causation (e.g. longer trip durations may decrease fledgling success). If two response variables are thought to be correlated, keep the variable that is most directly related to penguin population growth rate.
- Explore and quantify the probability of the estimation method concluding that there is a fishery effect when the fishery effect is substantially less than the threshold.
- Use the results of the power analysis to assess whether there are values for λ (or δ) that are no longer plausible given current data (i.e., as the power to detect them, given the current stage of the experiment, is already very high).
- The value of the P_{MIN} can be adjusted so that if the estimation method is "biased" (i.e., the probability that the value for λ (or δ) is greater than the threshold differs

from 0.5 when the value for λ (or δ) equals the threshold). See Appendix A for further details.

The Panel recognizes that a key difficulty in drawing conclusions regarding the biological effects of fishing near islands on penguins is how to combine the results from multiple estimation methods that only differ slightly. This can usually be achieved though model averaging methods, but there is no clear way to do that in this case. The Panel's recommended approach for the power analysis is that only four estimation models (one closure-only model and three catch-only models) are included in the reference set.

A.4 (M) Conduct analyses where the effect sizes are zero (using simulated data only). This should provide a fuller understanding of the behaviour of the estimators (i.e., the Type I error rate). Knowing the Type I error associated with proposed estimation methods is essential to interpreting the current results as well as those of the power analysis (see the third bullet point of recommendation A.3).

A.5 (M) Fit the operating models (not necessarily the estimation models) using Bayesian methods (perhaps using JAGS: Just Another Gibbs Sampler) assigning uninformative priors to the parameters. This will provide vectors of parameters (setting λ and δ to alternative values) for all parameters, including σ_ε. An advantage of using JAGS (or a similar method) is that it would become possible to weight each data point by its sample size when conditioning the operating model.

A.6 (M) Report error distributions for the estimates of the parameters related to fishery impacts and of other key parameters (such as the variance of the random effects).

Impact of closures on industry

B.1 (*) The Panel considered the Opportunity Based Model (OBM) (MARAM/IWS/DEC15/PengI/P1) in terms of the whether it might substantially overestimate the proportion of the catch of anchovy and other industrial fishes that could have been caught, but would remain uncaught owing to the closure of Dassen and Robben Islands (the "unreplaceable catch"). There were aspects of the OBM, such as ignoring the impact of implausibly many vessels being assigned to the same grid, which would lead to the OBM underestimating the effects of closures, but these aspects were not examined in any detail during the workshop.

Issues that might lead to incorrect estimation of the impacts of closures on industry catches include: (a) the assumption that the catch from a grid to which a set is reassigned due to a closure (the "alternative grid") cannot exceed the actual catch for that set, (b) selecting a grid cell from the set of possible alternative grid cells with equal probability rather than accounting for factors such as expected catch and/or distance from port, and (c) selecting an alternative grid only from the first group for which there is a viable alternative grid, rather than an alternative grid from all possible alternative grids.

The Panel developed a set of alternative model runs. These model runs were not considered the most likely, but were chosen to bound the impacts of the above effects. The results of the alternative model runs (Table 3) indicated that the estimate of unreplaceable catch is strongly dependent on the assumptions. The workshop identified five model runs to further explore the sensitivity of the estimate of the unreplaceable catch to the assumptions of the OBM.

Run	7a (max of all	7b (capped at	Hierarchy (in	Alternative opportunities.	Set

	opportunities or randomly selected)	actual set, or no cap or boat cap or boat x year cap)	groups or all lumped together)	ALL = ADJ, ADJ2, OTHER, GANSBAAI, ST HELENA BAY, EXTRA	selection
BC	RANDOM weighted by set	BOAT X YEAR cap	IN GROUPS	ADJ, ADJ2, ST HELENA BAY, OTHER	ALL
Alt-A	RANDOM weighted by set	BOAT X YEAR cap	LUMPED	ADJ, ADJ2, ST HELENA BAY, OTHER	ALL
Alt-B	MAX	BOAT X YEAR cap	IN GROUPS	ADJ, ADJ2, ST HELENA BAY, OTHER	ALL
Alt-C	MAX	BOAT X YEAR cap	LUMPED	ADJ, ADJ2, ST HELENA BAY, OTHER	ALL
Alt-D	RANDOM	BOAT X YEAR cap	IN GROUPS	ADJ, ADJ2, ST HELENA BAY, OTHER	ALL

The “RANDOM weighted by set” option involves identifying the sets that occurred in possible alternative grids on a given day and selecting a set at random from those sets. This option differs from “RANDOM”, which involves selecting a grid at random from the possible alternative grids (ignoring the number of sets in each grid). A BOAT-X-YEAR cap was considered as part of the base-case analysis to reflect that each boat will have a limit on the size of its possible catch. The order in which groups are selected was modified from that in MARAM/IWS/DEC15/PengI/P1 to reflect industry information on search strategies.

The results suggested that the predicted proportion of the catch in closure areas that is not replaceable for BC, Alt-B and Alt-D ranged between 23% and -3%. The Panel considered the “MAX” and “RANDOM” options to be implausible, but without additional data analysis (see recommendation A.2 below) it is not possible to refine these estimates further. Removing “St Helena Bay” as an option, based on industry observations that it would be an unlikely alternative location for vessels fishing near Dassen and Robben Islands, has a marked effect on the estimated unreplaceable proportion.

B.2 (H) Extend the OBM so that the selection of alternative grids from the set of possible alternative grids accounts for covariates such as expected catch-rate and distance from port. The impact of each covariate on the choice of grid could be based on fitting a finite choice model to the data. The selection of to which grid to go to after fishing a particular grid on a particular day will depend on (i) where fishing occurred previously, (ii) the distance of each alternative grid from the current grid or from port, and (iii) prior information about catches and schools in the alternative grids available.

B.3 (M) Develop an approach to validate the OBM. The OBM is based on heuristics regarding how the distribution of fishing effort will change following closures, and a formal model validation (e.g., assessing how well the model is able to predict the spatial and temporal distribution of catches for years during which closures actually occurred historically) should be conducted.

B.4 (M) Extend the OBM to include defining alternative grids for a given day as those grids that were fished on the following day. This scenario allows consideration that a day of fishing to replace a day lost owing to a closure could occur on a subsequent day rather than be lost completely.

B.5 (M) Develop an algorithm to identify situations in which some grids have no catch, but are close to several grids with catch and set the expected catch for such grids using an interpolation algorithm (such as a spatial GAMM). At present, the model implicitly assumes that no catches could be taken from such grids because it assumes that there is sufficient fishing that all grids that could lead to catches on a day were fished at least once that day.

Hake

Predation modelling

C.1 (*) The Panel notes that the some of the runs of the model that included inter-species predation and cannibalism led to poor fits to the historical (ICSEAF) catch-rate series.

C.2 (H) The model should be set up to mimic the trend in the historical (ICSEAF) catch-rate data because major reductions in catch-rates are an important characteristic of southern African hake fisheries between the early- to mid-1960s and mid-1970s.

C.3 (H) The data on the proportion of the diet of each hake species by length-class should be based on the predicted relative weight of *Merluccius capensis*, *M. paradoxus* and other species in the diet, rather than on the number of stomachs with more than 50% hake. Appendix B outlines an approach based on the methods of Punt and Leslie (1995) for predicting the mass of hake and other species at ingestion. The diets should be calculated by hake species length-class, and using depth and latitude strata, with the results by strata weighted by numbers inferred from surveys.

C.4 (M) Select appropriate weights in the likelihood function for the proportions of hake prey in the diets of hake predators of various lengths if there is evidence for overdispersion. The approach of Francis (2011) could be considered (but only one iteration of the algorithm needs to be conducted).

C.5 (H) The model is unable to predict the species and age composition of the diet of hake predators adequately. The model should therefore be modified as follows:

- allowance should be made for predation rate to differ between prey species and ages in the predation function;
- the preference function should be normalized to sum to 1 across all hake prey species;
- the plus-group should be extended from 10+ to 15+; and
- the weights assigned to the diet data should be explored as it appears that the diet data are overweighted relative to the quality of the fits to those data (see recommendation C.4 above).

C.6 (M) Develop the diet data based on predator age rather than predator length, given that most hake for which stomach content data are available are aged. Use of such data in the model should simplify the fitting process (because the model computes predation by predator age).

Sardine

D.1 (*) The Panel is concerned that the sardine model was unable to converge (i.e., lead to a positive definite Hessian matrix), which meant that all of the analyses reviewed during the workshop were considered ‘preliminary’. A ‘best practices’ guide for developing and fitting models is needed. This could be developed by collaborating with researchers (including current and past Panel members) who are using AD Model Builder. Appendix C summaries some initial deliberations on how the code could be improved and some principles for setting up ADMB models

D.2 (H) The updated base-case model for sardine should be based on the specifications in MARAM/IWS/DEC15/Sardine/P1, with the following modifications:

- the log-normal commercial selectivity function should be replaced by one that allows more flexibility on the right-hand descending limb (including the possibility of an asymptotically flat selectivity function);
- the parasite prevalence data for the south coast from the November survey should be based on animals sampled east of 22^0E (this is to exclude age-1 animals that may be from the west coast);
- estimate all the west to east movement parameters based on a normal prior for transformed movement rate that has the same variance as the current U[0,1] prior (in principle it should be possible to estimate movement parameters for all years even if the estimates are close to 0, as might be expected given the low November biomass estimates for the years prior to 1993);
- as needed, adjust the likelihood for the parasite data to account for overdispersion; and
- estimate the annual infection rates from 2006 as a random effect (although data are available from 2010 onwards only, the population in 2010 comprised animals spawned from 2006) (estimate the mean of the distribution for the infection rates, but pre-specify the variance of this distribution).

D.3 (H) Conduct the following sensitivity analyses once a base-case model has been selected:

- base the parasite prevalence data for the south coast from the November survey on animals sampled east of 20^0E;
- ignore the recruitment survey data for the south coast (these data are very noisy and the model fails to mimic the current indices); and
- consider a model in which the south coast stock consists of two cohorts.

D.4 (M) Improve the fits to the survey and catch length-composition data. The residuals about the fits to these data (MARAM/IWS/DEC15/Sardine/P3) show patterns suggestive of model mis-specification. Consider (a) “blocking” of selectivity, (b) time-varying growth, and (c) random effects for length-specific selectivity deviations over time.

D.5 (M) Progress has been made on conducting a meta-analysis of stock and recruitment data for sardine to examine whether the pattern of an initial linear relationship between recruitment and spawning stock occurs for other stocks. At least one stock (Pacific sardine) exhibited this pattern. Further data sets should be obtained from the RAM Legacy Database when available, and their results collated and summarized.

References

Francis, R.I.C.C., 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68: 1124–1138.

Punt, A.E. and R.W. Leslie. 1995. The effects of future consumption by the Cape fur seal on catches and catch rates of the Cape hakes. 1. Feeding and diet of the Cape hakes *Merluccius capensis* and *M. paradoxus*. *South African Journal of Marine Science* 16: 37-55.

Robinson, W., Butterworth, D.S. and É.E Plagányi. 2015. Quantifying the projected impact of the South African sardine fishery on the Robben Island penguin colony. *ICES Journal of Marine Science* 72: 1822-1833.

Table 1. Specifications of the reference case analyses related to the power to detect fishery effects on penguins. All analyses should be conducted for each response variable and results should be provided for both islands.

Factor	Operating model variants	Estimation model variants
Variants of the sub-regional biomass approach	3[1]	2[3]
Catch	Anchovy only	Anchovy only
Areas around islands	3 (C_{10}, C_{30}, $C_{closure}$)[2]	C_{10}, C_{30}, $C_{closure}$
Allocation of catches given closure to areas outside	New option	N/A
Catch-biomass correlation	2 (0.2, 0.4)[2]	N/A
Total number of options	13	4

1 catch-only, closure-only, catch+closure
2 relevant for catch-only and catch+closure operating models only
3 catch-only, closure-only

Table 2. Specifications of further analyses to explore the robustness of the results from the reference case
(a) Operating model (to be run for the reference set of estimation methods)

Factor	Operating model variants
Regional Biomass model	10 ([sardine catch, anchovy catch, anchovy + sardine catch] x [biomass=anchovy, biomass =sardine (May-June), biomass= sardine(Oct-Dec) x [catch-only and closure-only])[1]
Catch	sardine, anchovy + sardine
Areas around islands to define catches	C_{20}
Catch allocation	Options i) and ii) in MARAM/IWS/DEC15/PengD/P1.
Biomass and catch auto-corelation[1]	$\alpha_{y+1} = \chi\alpha_y + \sqrt{1-\chi^2}\omega_y; C_y = \bar{C} + m/\kappa\alpha_y + \eta_y$ [2]

1 strawperson suggestion – this needs to be expanded.
2 $\omega_y \sim N(0;\sigma_\alpha^2)$; χ is the extent of auto-correlation in prey biomass in the sub-regional model. The remaining symbols are defined in MARAM/IWS/DEC15/PengD/P1.

(b) Estimation method (to be run for the reference set of operating models)

Factor	Estimation model variants
Regional Biomass model	9 [one for sardine, anchovy, anchovy + sardine biomass] x [C_{10}, $C_{Closure}$, C_{30} anchovy catch]
Bias correction	As developed by the analysts

Table 3. Further calculations as requested on 1 December 2015 for the Opportunity Based Model

Fig #	7a (max of all opportunities or randomly selected)	7b (capped at actual set, or no cap or boat cap or boat x year cap)	Hierarchy (in groups or all lumped together)	Alternative opportunities. ALL = ADJ, ADJ2, OTHER, GANSBAAI, ST HELENA BAY, EXTRA	Set selection	% Lost
B.C.	RANDOM	CAPPED	IN GROUPS	ALL	ALL	40.52%
2b	RANDOM	NO CAP	IN GROUPS	ALL	ALL	23.68%
2b'	RANDOM	NO CAP	IN GROUPS	ALL	>=2008	29.23%
2b''	RANDOM	BOAT x YEAR CAP	IN GROUPS	ALL	ALL	24.48%
$2b^{III}$	RANDOM	BOAT x YEAR CAP	IN GROUPS	(All - Gansbaai and Extra) Adj, Adj2, Other Island, St Helena Bay	ALL	23.09%
$2b^{IV}$	MAX	BOAT x YEAR CAP	IN GROUPS	(All - Gansbaai and Extra) Adj, Adj2, Other Island, St Helena Bay	ALL	-3.28%
$2b^{V}$	RANDOM WEIGHTED BY SETS	BOAT x YEAR CAP	IN GROUPS	(All - Gansbaai and Extra) Adj, Adj2, Other Island, St Helena Bay	ALL	9.31%
$2b^{V'}$	RANDOM WEIGHTED BY SETS	BOAT x YEAR CAP	IN GROUPS	Adj, Adj2, Other Island, ~~St Helena Bay~~	ALL	20.1%
$2b^{VI}$	RANDOM	BOAT x YEAR CAP	LUMPED	(All - Gansbaai and Extra) Adj, Adj2, Other Island, St Helena Bay	ALL	18.2%
$2b^{VII}$	MAX	BOAT x YEAR CAP	LUMPED	(All - Gansbaai and Extra) Adj, Adj2, Other Island, St Helena Bay	ALL	-15.05%
$2b^{VIII}$	RANDOM WEIGHTED BY SETS	BOAT x YEAR CAP	LUMPED	(All - Gansbaai and Extra) Adj, Adj2, Other Island, St Helena Bay	ALL	18.11%

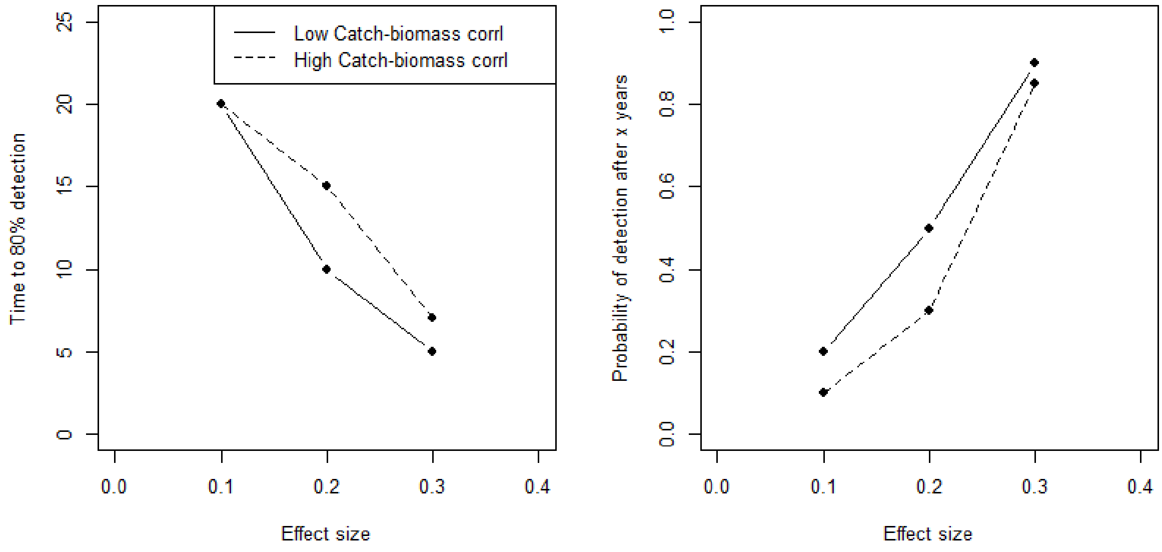

Figure 1. An illustrative example of the expected shape of the relationship between time to 80% detection (left) and the probability of detection of an effect size greater (i.e., larger effect) than a selected threshold after a given number of years (right) as a function of actual effect size. Results are shown for two levels of catch-biomass correlation.

APPENDIX A
OUTLINE OF THE PROCESS OF CONDUCTING A POWER ANALYSIS FOR AFRICAN PENGUINS

Step 1. Identify and review the response variables.

Step 2. Select quantitative thresholds for the parameter (λ and/or δ) for each response variable. This will involve inferences using population dynamics models.

Step 3. Conduct projections for each combination of an operating model and an estimation model in the reference set (Table 1) to estimate for each case the probability of detection that the value of λ (or δ) is larger than the threshold.

A. Specify a set (3-7) of values for the parameter (λ and/or δ) to be used in the operating model. The values should include the threshold and several values larger than this (the actual values will need to be selected based on initial analyses for widely different values; the objective of this selection is to get sufficient information to indicate the shape of the relationships of detection probability to λ and δ for the range over which the former changes most).
B. Set an initial value (0.5 is suggested) for P_{MIN}, the cut-off value used to decide for a given replicate that the data support the hypothesis that λ (or δ) is larger than the threshold.
C. For each value of the parameter (λ and/or δ) apply steps D –F.
D. Condition the operating model and hence specify the values for parameters such as the standard deviation (σ_α) of the sub-regional biomass surrogate random effect (α) (see comments 7, 14, 16 and 17 under recommendation A.2 for issues related to conditioning).
E. Conduct a set of simulations
    a. Simulate future data for 20 years and add these data to the data actually available (see comments 10, 13, and 18 for issues related to conditioning).
    b. One year at a time, fit the estimation model to the simulated data and record (*inter alia*, see recommendation A.6) the estimate of λ (or δ) and its standard error (denoted here as $\hat{\lambda}_i$ and $\sigma_{\hat{\lambda}_i}$).
    c. Compute $P(\lambda > \text{Threshold})$ as:

$$\int_T^\infty \frac{1}{\sqrt{2\pi}\sigma_{\hat{\lambda}}} e^{-(x-\hat{\lambda}_i)/(2\sigma^2_{\hat{\lambda}_i})} dx$$ [7]

    d. From the distribution of $P_i(\lambda > \text{Threshold})$ over the realizations, the detection probability is the number of times $P_i(\lambda > \text{Threshold})$ is larger than P_{MIN}.
F. Set the detection probability as the number of times $P_i(\lambda > \text{Threshold})$ was larger than P_{MIN}. (see Fig. A.1)
G. Plot the outcomes from Step E against the values for λ and/or δ for each projection year.

[7] This can be computed using pnorm in R.

Estimator “bias” can be defined as the extent to which the detection probability computed with P_{MIN}=0.5 differs from 0.5 when the value for the λ and/or δ equals the threshold (Fig. A.2a). For a single operating model, one way to correct this “bias” is by changing the value of P_{MIN} (see Fig. A.2b). The “bias” will differ among operating models for a single estimation method so the “bias correction” procedure will need to be an integral over operating models (e.g., giving the closure-only model a weight of 1, each of the catch-only models a weight of 1/6[8] and each of the catch-and-closure models a weight of 1/6). This process will involve computing a “integrated” detection probability and then selecting P_{MIN} so that the detection probability is close to the desired value (e.g. 0.5) at the threshold (see Fig. A.3).

[8] Three catch series x two catch-biomass correlation values

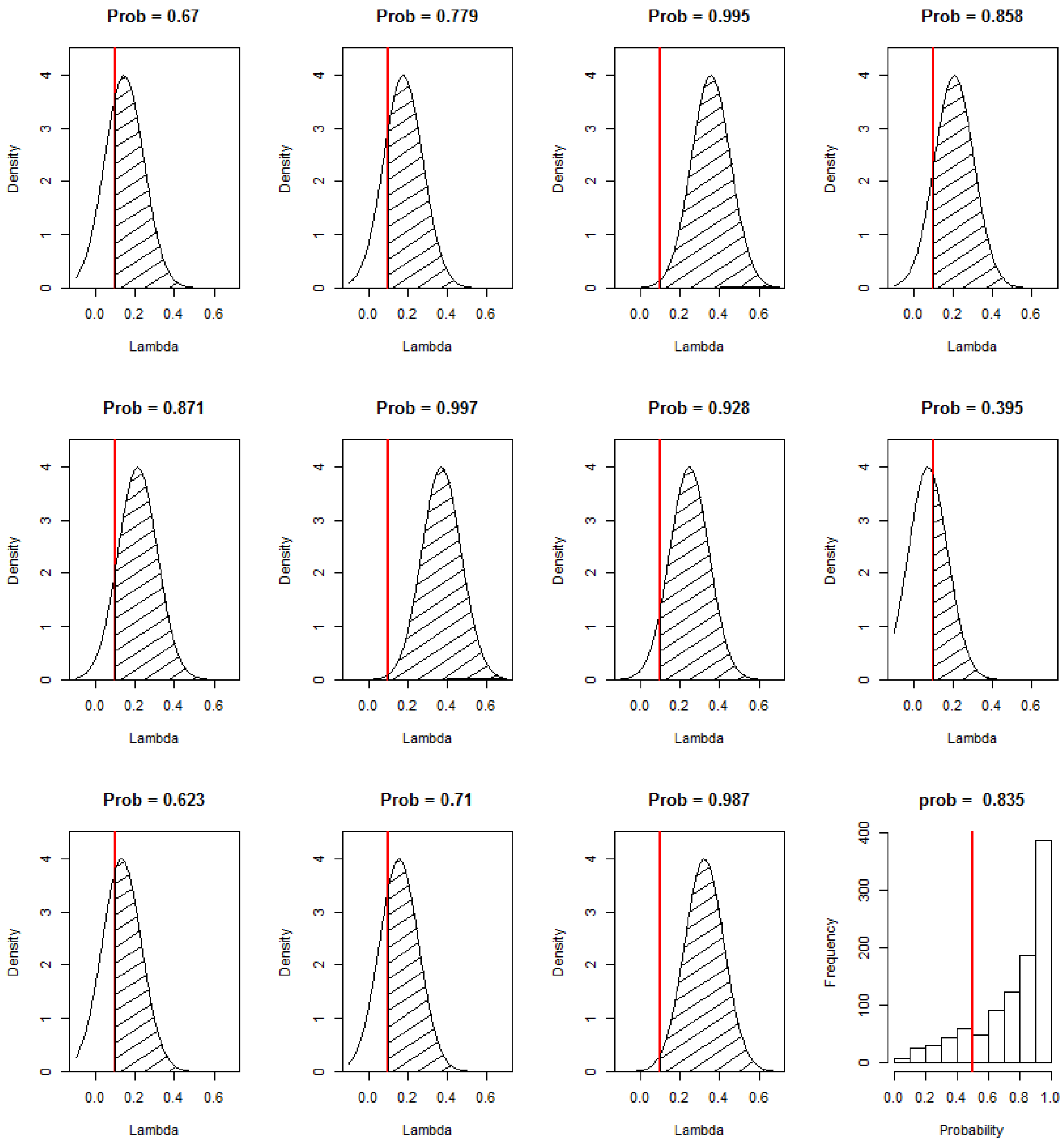

Figure A.1. Illustrative example application of steps E-F of the algorithm. For this case, the threshold is at 0.1 and the true value of λ is 0.2. The estimates of λ are assumed to be unbiased with a standard error of 0.1. The shaded area is $P_i(\lambda > \text{Threshold})$ for i=1,2,..,11 (treating the sampling distribution as a probability distribution) and this leads to the values above each panel. The lower right panel shows the distribution for $P_i(\lambda > \text{Threshold})$. The detection probability in this case is 0.835 (given 1,000 replicates) for a P_{MIN} = 0.5.

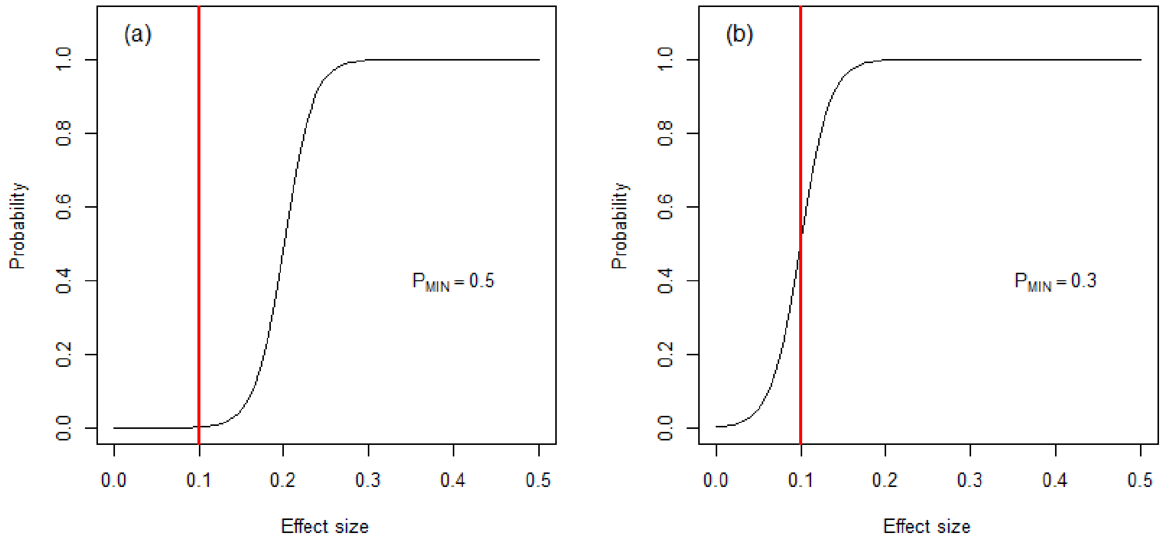

Figure A.2. Probability of detection vs effect size when the threshold is 0.1 (vertical line). Panel (a) shows a case in which the estimation method is "biased" because the effect size at 50% detection probability differs substantially from 0.1 when P_{MIN}=0.5. (b) shows how the rule is "bias corrected" by setting P_{MIN}=0.3 to get a probability of 0.5 when the effect size is 0.1 (i.e. by making it easier to conclude that $P(\lambda > \text{Threshold})$).

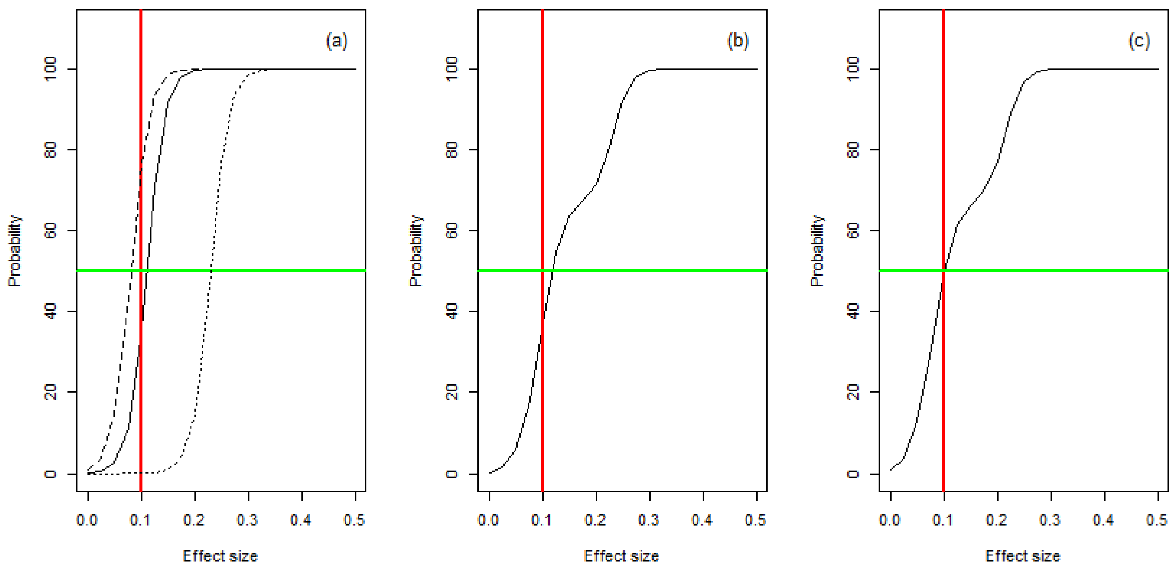

Figure A.3. Illustrative example of the bias correction approach. Panel (a) shows detection probability curves for three operating models (and one estimation method), and panel (b) the combined detection probability curve (giving each operating model equal weight). Panel (c) shows the detection probability curve after P_{MIN} has been adjusted.

APPENDIX B
APPROACH FOR COMPUTING DIET IN MASS (BASED ON PUNT AND LESLIE, 1995)

André E. Punt

The hake population dynamics model requires estimates of the proportion of the diet of each hake species by length-class that are *Merluccius paradoxu*s, *M. capensis* and "other". The following algorithm can be used to provide these estimates (and, with some work, their standard errors). The proportions are taken to be weighted averages of the estimates of the proportions by stratum (depth zone x latitudinal band):

$$\hat{P}^{s_p,l_p}_{y,s} = \sum_q \hat{P}^{s_p,l_p}_{y,q,s} N^{s_p,l_p}_{y,q} / \sum_s N^{s_p,l_p}_{y,q} \qquad (1)$$

where $\hat{P}^{s_p,l_p}_{y,s}$ is the proportion of animals of (prey) species *s* (including other) in the diet of (predator) species s_p and length-class l_p during year *y*, $\hat{P}^{s_p,l_p}_{y,q,s}$ is the proportion of animals of species *s* in the diet of species s_p and length-class l_p during year *y* in stratum *q*, and $N^{s_p,l_p}_{y,q}$ is the estimate of the number of species s_p and length-class l_p during year *y* in stratum *q*.

The values for the $N^{s_p,l_p}_{y,q}$ can be obtained from the survey results. $\hat{P}^{s_p,l_p}_{y,q,s}$ on the other hand needs to be computed from the diet data:

$$\hat{P}^{s_p,l_p}_{y,q,s} = (\Omega^{s_p,l_p}_{y,q,s} / T_s) / \sum_{s'} (\Omega^{s_p,l_p}_{y,q,s'} / T_{s'}) \qquad (2)$$

where $\Omega^{s_p,l_p}_{y,q,s}$ is the total mass (at ingestion – and over all hauls) of species *s* in the diet of species s_p and length-class l_p during year *y* in stratum *q*, and T_s is the evacuation time for prey species *s*. Calculation of $\Omega^{s_p,l_p}_{y,q,s}$ requires that the observed mass in the stomach for each prey item (i.e., the mass of the partially digested stomach contents) be converted to mass-at-ingestion. Punt and Leslie (1995) provide suggestions in this regard:

1. If the number of items and their lengths are recorded, and if length-mass relationships are available for the prey species concerned (see Table B.1) then the length-mass relationship is used to estimate ingested mass. If the estimate of ingested mass obtained by means of this approach is smaller than the actual mass of the stomach contents, the latter is used instead as an estimate of ingested mass - this problem occurs regularly only when a prey item is in digestion stages 1 (very fresh) or 2 (partially digested) .
2. If the prey item is a crustacean or a cephalopod, then the ingested mass is estimated by multiplying the observed mass of stomach contents by two. This is equivalent to assuming that, on average, the stomach contents reflect material half-way through the digestion cycle and that digestion is a linear process.
3. If the prey item is a fish, but either the length-mass relationship has yet to be determined, or the number of prey items or the length was not recorded, then the following equation is solved for ingested mass (note that the temperature *T* is assumed to be 9^0 C):

$$S(t)^{1-\beta} = S(0)^{1-\beta} - \alpha_1 e^{\alpha_2 9}(1-\beta)(BW/600)^{\alpha_3}(S(0)/BW)^{\alpha_4} t_{\text{half}} \qquad (3)$$

where t_{half}	is set to half the time to evacuate 90% of a fish prey item for the predators in the length-class concerned (Table B.2),
BW	is the body weight of the predator,
S(t)	is the observed mass in the stomach,
S(0)	is the ingested mass, and
$\beta, \alpha_1, \alpha_2, \alpha_3, \alpha_4$	are parameters (see Table B.3 for two scenarios regarding estimates for these parameters)

Step 2 could be refined by making use of the recorded digestion state (DS). The codes for DS are:

0. No signs of digestion or of damage (i.e. no teeth marks or other signs of injury that would be expected when the prey item was captured by the predator). Possibly ingested during the trawl.
1. Very fresh. No or only slight signs of digestion. If no signs of digestion, differs from "0" in that there are signs of injuries received during capture by the predator, i.e. unlikely to have been ingested during the trawl.
2. Partially digested.
3. Well digested.
4. So well digested that unrecognisable, e.g. mush with some hard parts such as bits of carapace, bones, otoliths, beaks.

DS = 0 exclude from analysis
DS = 1 then use observed mass
DS = 2 or 3 then multiply by 2
DS = 4 multiply by a number larger than 2 (check sensitivity to alternative values)

Table B.1: Relationships between length (ℓ) in cm and mass (*w*) in grams for a number of prey species (source: Table II of Punt and Leslie, 1995).

(a) Species for which length-mass relationships exist ($w = a\,\ell^b$)

Species	*a*	*b*
Engraulis japonicus	0.00924	3.046
Sardinops sagax ocellatus	0.00957	3.075
Etrumeus whiteheadi	0.0122	2.975
Trachurus trachurus capensis	0.0124	2.903
Merluccius capensis	0.00505	3.113
Merluccius paradoxus	0.00615	3.046
Merluccius spp.	0.0095	2.885
Austroglossus spp.	0.00390	3.119
Chelidonichthys capensis	0.03470	2.678
Sufflogobius bibarbatus	0.0143	3.054
Genypterus capensis	0.00080	3.420
Scomber japonicus	0.00155	3.445

(b) Species for which relationships between length and mass have yet to be determined

Species	Length (cm)	Average mass (g)
Thyrsites atun	all	2200
Galeichthys felicpes	all	600
Helicolenus dactylopterus	15	60
	20	120
	30	450
	35	700
Caelorinchus simorhynchus	25	50
	30	95
Lepidopus caudatus	80	500
	100	900
Malacocephalus laevis	40	300
	60	600

Table B.2: (a) Estimates of the average mass of hake predators, *BW*, and their undigested stomach contents, *S*(0), in grams and (b) estimates of the average time (in hours) taken by hake predators in various length-classes to evacuate 90% of a meal consisting of fish prey. Estimates and standard errors (in parentheses) for the evacuation times are shown for two choices for the form of the evacuation model (source: Table IV of Punt and Leslie, 1995).

(a) Mass

Length-class (cm)	*BW*	*S*(0)	*S(0)/BW*
1-20	40.5	6.3	0.156
20-30	139.2	13.0	0.093
30-40	376.1	40.5	0.108
40-50	768.1	72.1	0.094
50-60	1439.0	149.6	0.104
60-70	2330.7	171.0	0.073
70+	4159.1	362.4	0.087

(b) Time for 90% evacuation

Length-class (cm)	Model	
	α_3=0; α_4=0	α_3, α_4 estimated
1-20	51.6 (3.4)	57.7 (13.1)
20-30	66.9 (4.1)	69.2 (6.6)
30-40	100.7 (8.2)	99.8 (7.8)
40-50	124.1 (10.8)	119.2 (10.3)
50-60	161.7 (17.3)	151.8 (18.7)
60-70	169.7 (18.7)	155.7 (21.8)
70+	222.8 (29.7)	200.6 (34.3)

Table B.3: Estimates and bootstrap *CV*s for the parameters of the evacuation model. Results are presented for (a) analyses in which α_3 and α_4 are estimated, and (b) in which they are fixed to be 0 (source: Table III of Punt and Leslie, 1995).

	Estimate	*CV* (%)*
(a)		
α_1	0.0268	51.7
α_2	0.1	-
α_3	0.054	101.6
α_4	0.000	148.8
β	0.602	8.1
(b)		
α_1	0.0248	5.8
α_2	0.1	-
α_3	0	-
α_4	0	-
β	0.625	5.3

* Bootstrap standard error divided by bootstrap mean

APPENDIX C
SOME NOTES RELATED TO THE CODE FOR THE SARDINE MODEL

The Panel reviewed the sardine ADMB model code, and made the following suggestions for investigation to try to improve model performance and convergence.

1. Ensure that the model is initialised with a large value for the maximum recruitment on the stock-recruitment relationship (parameter *a*) and a minimal value for the inflection point (parameter *b*), so that recruitment is initially scaled about a median value and allows for all historical catches to have been taken.

2. When choosing in which phase to estimate parameters, first estimate key biomass scaling parameters (average recruitment, catchability parameters, and selectivity parameters) before estimating the secondary parameters such as for growth, and for the stock-recruitment relationship.

3. Annual movements: Estimate annual age-1 movements in an early phase and the proportion of adults that move in a later phase.

4. The Panel was uncertain whether the Normal component on the left of the commercial fishery selectivity curve was required to fit the small mode of fish observed at shorter lengths or whether the observations were simply a reflection of the availability of a cohort of recruits. The Panel also queried the use of a rigid dome-shape selectivity function (a reverse log-normal of fixed variance at larger lengths) to fit the commercial fishery catch proportions-at-length, as this may force an inappropriately sharp decrease at larger lengths. The Panel recommends initially assuming a simple (logistic style) selectivity, then using the residual structure from the fits to inform the choice of whether a more complex selectivity pattern – including domed selectivity and the left hand "bump" in the current selectivity, are required. The Panel also notes that instead of using two normal distributions, the same effect can be achieved, in part, by using a double normal (Equation 1) with the right variance set at a large value to assess fit, then freed up in a later run if required.

Equation 1: The double normal selectivity

$$f(x) = 2^{-\left[(x-a_1)/s_L\right]^2}, \qquad (x \le a_1)$$
$$= 2^{-\left[(x-a_1)/s_R\right]^2}, \qquad (x > a_1)$$

5. Since selectivity-at-length is [0,1], change the maximum exploitation rate penalty from

$$S_{j,y,l}F_{j,y,q} < 0.95 \text{ to } F_{j,y,q} < 0.95 .$$

6. Rescale the maximum exploitation rate penalty multiplier to a lower value and change the *eps* parameter used in the AMDB posfun function to be a softer constraint, for example it may be better to set *eps* at 0.01 for the maximum exploitation rate penalty instead of 0.0001.

7. Remove the penalty on N and Nrec (used to penalise cases where the sardine bycatch and recruit catch taken by the fishery before the survey are larger than available

biomass estimated by the model) and rather impose a maximum exploitation rate penalty on the sardine bycatch and recruit catch in the same manner as for the other fisheries.

The Panel also made some additional considerations secondary to the above. These were:

8. With regard to the estimation of $\sigma_R{}^2$, start model runs with a reasonably large value and estimate the value of this parameter only in one of the last phases. Alternatively, consider calculating a closed-form solution for each model run before the prior is added to the objective function.

9. Consider the possibility of an informed prior on the estimated numbers at age in the first year of the model to assist the model minimisation and subsequent MCMC performance.

10. Growth curve parameterisation: re-parametrising the growth curve to estimate mean lengths at reference ages rather than in terms of L_∞ and t_0, as per Schnute and Fournier (1980) may assist minimisation and MCMC performance by reducing the correlations between the von Bertalanffy parameters in estimation.

11. Consider imposing a relationship between age and the CV of the age-length relationship to deal with the problem of the model estimating the age 0 CV close to the upper bound. Possible relationships to consider could include quadratic or negative exponential.

12. Consider assuming a log-normal rather than a normal distribution for the prior for the bias in the estimate of sardine abundance from acoustic surveys (parameter k_{ac}).

Reference

Schnute, J. and D. Fournier. 1980. New approach to length-frequency analysis: Growth structure. *Canadian Journal of Fisheries and Aquatic Sciences* 37: 1337–1351.