Report on progress made on the hake cannibalism and inter-species predation model

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Brief background

The hake cannibalism and inter-species predation model was presented to the International Stock Assessment Workshop (IWS) for the first time in 2011 and was reviewed again in 2013 and 2014. A list of past panel recommendations for the cannibalism model is provided in Table 1.

In summary, this work aims to build on that undertaken by Punt and Leslie (1995) and Punt and Butterworth (1995) in the development of a multispecies model for the two Cape hake species, *Merluccius capensis* and *M. paradoxus*. There, the authors aimed to construct a model which included hake, seals and "other predatory fish" and then to use this model to assess the consequences of different levels of consumption of hake by seals on the hake fishery in the context of the change in the size of sustainable hake TACs and catch rates. They also aimed to investigate the effect of seal culling on the fishery. In the years that have passed since, more data have become available, and the hake assessment models have been continuously developed. The aim is to update the work done by Punt and Leslie (1995) with new data, and to extend the model to the level of the current hake assessment model.

At the time of IWS 2013, the most notable problems surrounding the cannibalism model were extremely slow model runs as well as instability arising from the manner in which the initial population equilibrium setup was structured in the model. Suggestions made by the panel as well as interim modifications to the model have helped to resolve these issues. At IWS 2014, the greatest area of concern was that the model battled to fit all of the proportion of hake in diet, daily ration and trend data simultaneously, although the methodology and preliminary results showed promise for a reasonable base case model that takes hake predation and cannibalism into account.

The purpose of this report is to provide an update on work done since IWS 2014 and to highlight areas where input from the panel would be useful. Full model specifications and results will be provided in a separate document as soon as possible.

Time frame of the work

There is a hard deadline for this work in January 2016. Since it will not be possible to explore all aspects of the cannibalism model before then, priorities presented in this report refer to Phase 1 (before January 2016) and Phase 2 (post January 2016).

Summary of work done since December 2014

Alongside more subtle model improvements and development, there are three main aspects in which the model has changed from last year.

1. The model now fits directly to catch-at-length data rather than catch-at-age data as before.

2. In 2014, the model fit to diet data by age, and diet data were converted from counts-at-length to counts-at-age using von Bertalanffy growth curve parameters. The model now fits to diet data by length directly.

3. Earlier this year, the hake cannibalism and inter-species predation model still failed to reflect both a biologically feasible estimate of daily ration and the proportion of hake in the diet of hake predators indicated by the diet data obtained during surveys. Andre Punt made a suggestion to investigate the sampling strategy used to obtain the diet data, in order to ascertain whether this strategy might be giving rise to biases in the estimates for the population as a whole in terms of both the length distributions and the proportions of hake in the diet of hake predators. This led to an examination of the raw survey catch-at-length data and the methods used to analyse these data, and a few suggestions were made for alternative approaches to weighting the length probability distributions from individual trawls in order to obtain aggregated distributions for each stratum. Details of this investigation are provided in FISHERIES/2015/AUG/SWG-DEM/STT02 (workshop document number to be confirmed). Findings of this investigation include:

    - Weighting of the catch-at-length data by depth stratum density has minimal impact on the population trajectory for the no-predation hake model.
    - There seems to be a general trend of a relatively large proportion of biological samples coming from deeper strata where the survey estimates of the population density are small, indicating that weighting the diet data by stratum density would be justified.
    - Weighting the diet data by stratum density substantially lowers the estimates of proportion of hake in the diet of *M. paradoxus* predators. Various iterations of the model are still in the process of being run, but preliminary results indicate that the model is more consistent with this lower proportion of hake in the diet of *M. paradoxus* predators.

Preliminary thoughts on where panel input would be useful

1. Prioritisation of work in Table 1: what critically needs to be done in Phase 1 as opposed to later in Phase 2?

2. Suggestions for other considerations not included in Table 1

References

Punt, A.E. and Butterworth, D.S. 1995. Modelling the biological interaction between Cape fur seals *Arctocephalus pusillus pusillus* and the Cape hakes *Merluccius capensis* and M. paradoxus. *South African Journal of Marine Science, 16:1, 255-285.*

Punt, A.E. and Leslie, R.W. 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 hake *Merluccius capensis* and M. paradoxus. *South African Journal of Marine Science, 16:1, 37-55.*

Table 1: Recommendations made by the panel of the 2011, 2013 and 2014 International Stock Assessment workshops. The recommendations have been sorted by category, and a status for each has been provided. Preliminary priorities have been allocated as follows:

H: to be implemented as soon as possible (Phase 1)

M: to be implemented later in Phase 2

L: to be implemented in Phase 2 only if time permits

"-": completed

Q: Query regarding either the recommendation or the priority of the recommendation

(A) Spatial structure			
Recommendation	**Date**	**Status**	**Priority**
A1. Start with South Africa only, and perhaps incorporate Namibian data later if possible.	IWS DEC 2011	The model considers South Africa only. Incorporation of Namibian data is unlikely to occur within the time frame of even Phase 2.	Q
A2. Exclude South Coast initially, but implement coastal segregation later if possible since feeding will likely differ on the two coasts.	IWS DEC 2011	The current model has no coastal segregation, and the model uses diet data from the West Coast only.	M
A3. Explicitly account for spatial structure, either using a movement model or by treating predation on the west and south coasts as separate 'fleets' (base initial analyses on diet data for the West Coast only)	IWS DEC 2014	Coastal segregation is a high priority for Phase 2.	
A4. No depth segregation.	IWS DEC 2011	The model does not have depth segregation.	Q
(B) Population structure			
Recommendation	**Date**	**Status**	**Priority**
B1. Ignore sex structure initially. Only later extend model to something similar to the current hake assessment model.	IWS DEC 2011	The model is sex-aggregated. Sex-disaggregation is a high priority for Phase 2.	M
B2. Disaggregate the model by sex to better fit, for example, the longline catch-at-age data. It should be possible to disaggregate the diet data by predator sex but not by prey sex.	IWS DEC 2014		

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B3. Do not fit to catch-at-length (CAL) and age-length-key (ALK) data initially.	IWS DEC 2011	The model does not fit to CAL or ALK data. Could be considered during Phase 2, time-permitting.	M/L
B4. Implications of whether recruitment is taken to occur before or after predation should be explored.	IWS DEC 2013	This has not been explored yet, but can be looked at either as a sensitivity in Phase 1 or in Phase 2.	M/H
B5. Consider alternate formulations of stock-recruit models for hake that incorporate cannibalism, both directly as a covariate and indirectly in how spawning stock biomass is defined (e.g., Link et al., 2012)	IWS DEC 2014	This may be investigated in Phase 2, time permitting.	L
(C) Diet data			
Recommendation	**Date**	**Status**	**Priority**
C1. Scale hake prey-by-species information upwards to account for unidentified hake prey.	IWS DEC 2013	This is an immediate priority along with general checking of how diet data were extracted and summarized from the database.	H
C2. Difference in feeding relationship between West and South Coast should be investigated.	IWS DEC 2013	This has not yet been undertaken, but will be investigated in conjunction with recommendations A2 and A3 in Phase 2.	M
C3. Plan, and then implement, a review of the sampling strategy for diet data given the results of the current model as well as other needs for diet data.	IWS DEC 2014	This recommendation has been noted for the record.	M
(D) Other predators			
Recommendation	**Date**	**Status**	**Priority**
D1. Do not include other predators (seals) initially, but if there is an increase/decrease in seal population try take this into account in the mortality rates.	IWS DEC 2011	The model currently does not include predators other than hake, but the possibility of including seal predators will be explored in Phase 2.	M

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D2. Include other predators (re-evaluate sources of hake mortality to identify which predators to add to the model).	IWS DEC 2014	Apart from seal predators, the inclusion of other predators has a medium to low priority for Phase 2.	L
(E) Technical modelling aspects of the predation and cannibalism model			
Recommendation	**Date**	**Status**	**Priority**
E1. Test different values for basal mortality, particularly lower values.	IWS DEC 2014	This is a high priority before the December 2015 workshop.	H
E2. A Holling Type II functional form should be implemented initially, but other forms (as in Kinzey and Punt 2009) could be explored, including Holling Type III or Foraging Arena.	IWS DEC 2011	The model uses a Holling Type II functional form. Other forms could be explored in Phase 2.	M
E3. Use the "Hybrid" method with a Baranov catch formulation for catches.	IWS DEC 2013	This has been implemented.	-
E4. Daily ration should not be prespecified but rather included as a likelihood component.	IWS DEC 2013	This has been implemented, and daily ration is no longer a fixed quantity in the model.	-
E5. The feeding functional response should be parameterised to simplify the equilibrium setup.	IWS DEC 2013	This has been implemented.	-
E6. Include an "other food" component as in Kinzey and Punt (2009).	IWS DEC 2013	This has been implemented.	-
E7. Apply the model ignoring the spatial availability matrix (Appendix A of MARAM/IWS/DEC14/Hake/P8) to assess whether this feature of the model is needed to allow the model to mimic the observed diet compositions by age.	IWS DEC 2014	This has been implemented. The model seems to cope without the spatial availability matrix, and this feature has been discontinued.	-