An initial attempt at a sex-disaggregated assessment for the South African hake resource, fitting directly to age-length keys

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INTRODUCTION

Geromont *et al*. (1995) estimated a female proportion in the south coast longline catches of 83%. Furthermore, there are very clear sex-specific differences in somatic growth for both *M. paradoxus* and *M. capensis*, in fact more so than between species (see Fig. 1). Routine application of age-length keys to obtain catch-at-age proportions is conducted without attention to sex-specific differences, but sex-differential growth means that larger sized of males are not well represented in the catch. This could confound estimates based on catch-at-age data developed from a sex-aggregated age-length key, which might consequently underrepresent the number of older hake present (and therefore affect the estimates of natural mortality).

This document presents a first attempt at modelling the sexes separately, which requires fitting directly to age-length keys (ALKs) and length frequencies (e.g. Punt *et al*. 2006).

THE MODEL

The model is sex-specific; however, apart from sex-specific age-length keys, all the data available are sex-aggregated. Some assumptions have therefore to be made.

As it is not possible to estimate a sex-specific selectivity-at-age, it is rather assumed that the selectivity-at-length is the same for both males and females. The model therefore needs to keep track of the numbers in each length class. Rather than move to a length-based model, the option being pursued is to keep the model age-structured and convert numbers-at-age into numbers-at-length using a length-at-age distribution (assumed to remain constant over time).

The catches cannot be disaggregated by sex, and there seems no reason to suppose that there is any preferential targeting by sex; thus, we assume that the annual fishing mortality generated by each fleet is the same on both males and females.

Note: for ease of reading, the 'species' superscript has been omitted below.

The numbers-at-age are converted to numbers-at-length as follows:

$$N^{g}_{y,a,l} = N^{g}_{y,a} P^{g}_{a,l} \qquad (1)$$

where $P^g_{a,l}$ is the proportion of fish of age *a* and sex *g* that fall in the length group *l* (i.e., $\sum_l P^g_{a,l} = 1$ for all ages *a*). The matrix *A* is calculated under the assumption that length-at-age is normally distributed about a mean given by the von Bertalanffy equation, i.e.:

$$L_a \sim N\left[L_\infty\left(1-e^{-\kappa(a-t_0)}\right);\theta_a^2\right] \tag{2}$$

where θ_a is the standard deviation of length-at-age *a*, which is modelled as a function of the expected length at age *a*, i.e.:

$$\theta_a = \beta\left[L_\infty\left(1-e^{-\kappa(a-t_0)}\right)\right]^\gamma \tag{3}$$

<u>Population dynamics</u>:

$$N^g_{y+1,a+1,l} = \left(N^g_{y,a,l}\, e^{-M_a/2} - \sum_f C^{g,f}_{y,l}\right) e^{-M_a/2} \quad \text{for } 0 \le a \le m-2 \tag{4}$$

$$N^g_{y+1,m,l} = \left(N^g_{y,m-1,l}\, e^{-M_{m-1}/2} - \sum_f C^{g,f}_{y,l}\right) e^{-M_{m-1}/2} + \left(N^g_{y,m,l} e^{-M_m/2} - \sum_f C^{g,f}_{y,l}\right) e^{-M_m/2} \tag{5}$$

where

$N^g_{y,a,l}$ is the number of fish of sex *g*, age *a* and length *l* at the start of year *y*,

M_a denotes the natural mortality rate on fish of age *a* (assumed – for the moment - to be the same for males and females),

$C^{g,f}_{y,l}$ is the estimated number of hake of sex *g* and length *l* caught in year *y* by fleet *f*, and

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

A Beverton-Holt stock-recruitment relationship is assumed, with the recruitment (R^g_y) dependent on the female component of the spawning biomass and assuming a 50:50 sex-split at recruitment.

$$R^g_y = 0.5\frac{\alpha B^{sp,\,females}_y}{\beta + B^{sp,\,females}_y}\, e^{(\varsigma_y - \sigma_R^2/2)} \tag{6}$$

where

α and β are spawning biomass-recruitment relationship parameters,

ς_y reflects fluctuation about the expected recruitment for year *y*, which is assumed to be normally distributed with standard deviation σ_R;

$B^{sp,g}_y$ is the spawning biomass of sex *g* at the start of year *y*, computed as:

$$B^{sp,g}_y = \sum_a \sum_l f_a w^g_l N^g_{y,a,l} \tag{7}$$

where

w^g_l is the mass of fish of sex *g* and length *l* and f_a is the proportion of fish of age *a* that are mature.

Catch

$$C^{g,f}_{y,a,l} = N^{g}_{y,a,l}\ e^{-M_a/2}\ S^{f}_{y,l}\ F^{f}_{y} \tag{8}$$

where

$S^{f}_{y,l}$ is the commercial selectivity,

F^{f}_{y} is the fished proportion of a fully selected length class, for fleet *f*, assumed to be the same for males and females.

Note: *S* and *F* are assumed to be independent of *g*.

The estimated sex-aggregated catches-at-length to be compared with observations of length frequencies are:

$$C^{f}_{y,l} = \sum_g \sum_a C^{g,f}_{y,a,l} \tag{9}$$

The (known) annual catch-by-mass of fleet *f* is given by:

$$C^{f}_{y,l} = \sum_g \sum_a \sum_l w^{g}_{l} C^{g,f}_{y,a,l} \tag{10}$$

So that:

$$F^{f}_{y} = C^{f}_{y} \Bigg/ \left(\sum_g \sum_a \sum_l N^{g}_{y,a,l} e^{-M_a/2} S^{f}_{y,l} \right) \tag{11}$$

The likelihood function

The model is fitted to CPUE and survey abundance indices, commercial and survey catch-at-length data, as well as to the stock-recruitment curve to estimate model parameters, as in the baseline assessment. The contributions by each of these to the negative log-likelihood are not repeated here.

For years for which ALKs are available, the baseline assessment is also fitted to commercial and survey catch-at-age data. Here however, the model is fitted to the data underlying the ALKs directly, so that catch-at-length are used throughout. The ALKs are the only data that are available in sex-disaggregated form. The contribution of the ALKs to the negative log-likelihood is as follows.

Under the assumption that fish are sampled randomly with respect to age within each length-class, the contribution to the negative log-likelihood for the ALK data (ignoring constants) is:

$$-\ln L^{ALK} = -\sum_i \sum_l \sum_a \left[A^{obs}_{i,l,a} \ln\left(\rho_{i,l,a}\right) - A^{obs}_{i,l,a} \ln\left(A^{obs}_{i,l,a}\right) \right] \tag{12}$$

were

$A^{obs}_{i,a,l}$ is the observed number of fish of age *a* that fall in the length class *l*, for ALK *i* (a specific combination of survey (or commercial fleet), year, species and gender)

$\rho_{i,a,l}$ is the model estimate of $A^{obs}_{i,a,l}$, computed as:

$$\rho_{i,a,l} = W_{i,l} \frac{C_{i,l} A_{a,l}}{\sum_a C_{i,l} A_{a,l}} \tag{13}$$

where $W_{i,l}$ is the number of fish in length class *l* that were aged for ALK *i*.

DISCUSSION

With the addition of the length dimension, the model now runs extremely slowly and results have not yet been obtained.

REFERENCES

Geromont HF, Butterworth DS, Japp D and Leslie RW. 1995. Preliminary assessment of longline experiments: south coast hake. Unpublished document, Marine and Coastal Management, South Africa. WG/11/95/D:H:28. 12pp.

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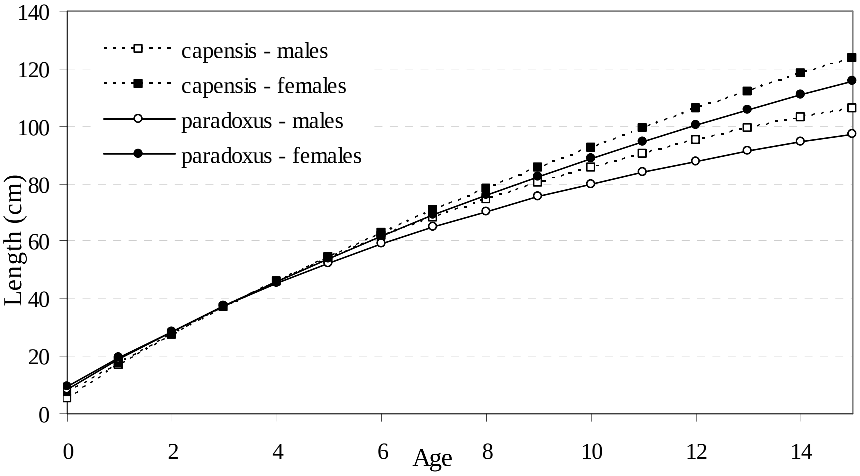

Fig. 1: Estimated mean length-at-age from the von Bertalanffi equation for males and females *M. capensis* and *M. paradoxus*