A comparison between the hake cannibalism and inter-species predation models presented in Bergh *et al.* (2016) and Ross-Gillespie (2016)

A. Ross-Gillespie[1]

Note that the Ross-Gillespie (2016) predation model allows for the *M. capensis* preference for hake prey to shift from primarily *M. capensis* to primarily *M. paradoxus* prey as the predators grow larger. Further, this model incorporates a competition component that effectively limits the predation mortality rate at 0.06 per month or 0.72 per annum.

<table>
<tr><th>Bergh et al. (2016)</th><th>Ross-Gillespie (2016)</th></tr>
<tr><td colspan="2">Maximum age considered (plus-group): 15 years</td></tr>
<tr><td colspan="2">Natural mortality is higher than for the conventional stock assessment model</td></tr>
<tr><td>M. paraodxus (pristine): 1.5* at age 0 to 0.35* at age >5
M. capensis (pristine): 1.0* at age 0 to 0.90* at age >5</td><td>M. paradoxus (pristine): 0.92 at age 0 to 0.2 at age >11
M. capensis (pristine): 0.92 at age 0 to 0.2 at age >11</td></tr>
<tr><td colspan="2">Pristine spawning biomass is lower than for the conventional stock assessment model
(the Rademeyer and Butterworth 2014 K^{sp} estimates are 1504 for M. paradoxus, and 491 for M. capensis).</td></tr>
<tr><td>M. paradoxus K^{sp}: 387
M. capensis K^{sp}: 122</td><td>M. paradoxus K^{sp}: 497
M. capensis K^{sp}: 280</td></tr>
<tr><td colspan="2">M. paradoxus exhibits competitive release</td></tr>
<tr><td colspan="2">Bsp/Ksp for M. paradoxus</td></tr>
<tr><td>Max: 1.32* (1958*)
2013: 50%
predation off: 28%</td><td>Max: 1.32 (1956)
2013: 14%
predation off ~15%</td></tr>
<tr><td colspan="2">Species- and age-disaggregated</td></tr>
<tr><td>Sex-disaggregated</td><td>Sex-aggregated</td></tr>
<tr><td>Diet information from Punt and Leslie (1995).

Hake ration and dietary percentages are fixed on input. Aim is to develop method to reflect the relationship between hake diet and prey availability.

Diet data are not formally included in the likelihood. Aim is to develop methods for including the data in the likelihood function.</td><td>Diet information from DAFF 1999-2013 dataset.

Hake ration and dietary percentages vary with predator and prey abundances.

Diet data are formally included in the likelihood.</td></tr>
<tr><td>Preference function is a beta function, informed by data in Butterworth and Harwood (1991) and BEP (1991).</td><td>Preference function is a gamma function, informed by the DAFF 1999-2013 dataset.</td></tr>
<tr><td colspan="2">No coast-disaggregation</td></tr>
<tr><td>Biannual time-step</td><td>Monthly time-step</td></tr>
<tr><td>Initial pristine natural mortality vector is taken to be a logistic function of age, and the pristine predation mortality rates are constrained to not exceed this total natural mortality through a posfun function. The basal mortality is the total pristine natural mortality less the pristine predation mortality, and assumed to be time invariant.</td><td>A time- and age-invariant basal mortality is assumed. The initial population structure is calculated in a step-wise manner starting from the age plus-group (under the assumption that these large hake are not preyed upon by other hake) and moving systematically to the new recruits, calculating predation rates along the way. Total pristine natural mortality is the sum of the predation mortality and basal mortality.</td></tr>
</table>

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Pope's approximation for the catch equation	Baranov formulation of the catch equation
Notation: s,a = predator, sp,ap=prey	sp,ap = predator, s,a =prey
Hake consumed = ration x prop_hake x number_predators, where ration and prop_hake are fixed on input Hake consumed is calculated as the sum over all hake predator species, genders and ages and then distributed across these predator groups through a preference function	Hake consumed = Holling Type II function of hake predator and prey numbers, other prey numbers and predator-prey preference
No other prey component	Other prey component included
No other predator component	
Daily ration	
Daily ration is modelled as a function of species and age with exponential functions from the Punt and Leslie (1995) results, converted to ration by age and re-fitted with polynomials. 0.12%-0.86% for *M. paradoxus*, and 1.38%-2.25% for capensis	Model output 0.1%-0.7% for paradoxus, 0.5%-4.0% for capensis
Proportion of hake in the diet	
Year invariant. Fit polynomial to Punt and Leslie (1995) proportions by age, convert to length and fit logistic. par on par: 0.03-0.50 cap on par: 0.00-0.23 cap on cap: 0.00-0.14	Model output par on par: 0.00-0.51 cap on par: 0.00-0.21 cap on cap: 0.02-0.10
Preference	
Optimum prey/predator length 51-57% Maximum prey/predator length 75-80%	Optimum prey/predator length 39%-50% Maximum prey/predator length 65-70%

* Inferred from the graphical output in Bergh *et al.* (2016).

Rademeyer and Butterworth (2014)	**Bergh *et al.* (2016)**	**Ross-Gillespie (2016)**
Sex-disaggregated Fits to age-length keys Modified Ricker stock-recruitment relationship Pope's approximation for the catch equation Annual time-step	Sex-disaggregated Fits to age-length keys Modified Ricker stock-recruitment relationship Pope's approximation for the catch equation Biannual time-step	Sex-aggregated Does not fit to age-length keys Beverton-Holt stock-recruitment relationship Baranov formulation of the catch equation Monthly time step

References

Bergh, M., Fourie, A. and Joselson, N. 2016. Modification of the prevailing species, sex, age and size disaggregated hake stock assessment model to incorporate hake cannibalism and inter-species predation. Document FISHERIES/2016/MAR/SWG-DEM/06.

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 hakes *Merluccius capensis* and *M . paradoxus*. *South African Journal of Marine Science*, 16(1), 37(55).

Rademeyer, R. A. and Butterworth, D. S. 2014b. Speci_cations of the South African hake 2014 Reference Case assessment. Document MARAM/IWS/DEC14/Hake/P2 reviewed at the International Stock Assessment Workshop, Cape Town, December 2014.

Ross-Gillespie, A. 2016. Modelling cannibalism and inter-species predation for the Cape hake species *Merluccius capensis* and *M. paradoxus.* PhD thesis, University of Cape Town, submitted.