Obtaining a multiplicative bias calibration factor between the *Africana* with the old and the new trawl gear

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December 2004

Introduction

The survey vessel *Africana* has been used for the demersal surveys on the south and west coasts of South Africa since 1984. In June 2003, the fishing gear used on this vessel was changed and a different value for the multiplicative bias factor q needs to be applied to the surveys conducted with the new gear in the assessments of the South African hake resource. Calibration experiments have been conducted between the *Africana* with the old gear (hereafter referred to as the "old *Africana*") and the *Nansen*, and between the *Africana* with the new gear ("new *Africana*") and the *Nansen* in order to provide a basis to relate the multiplicative biases of the *Africana* with the two types of gear (q_{old} and q_{new}). A Generalised Linear Model (GLM) analysis assuming a negative binomial distribution for the catches made in the experiments has been applied to provide the calibration factor.

Data

110 pairs of trawls from the old *Africana* and the *Nansen* and 95 pairs of trawls from the new *Africana* and the *Nansen* are available for this calibration exercise. For each pair of trawls, the catch (by mass) of *M. capensis* and *M. paradoxus* is reported separately.

Methods

The GLM considered allows for possible differences in "catchability" between survey vessel-gear combinations (i.e. different multiplicative bias factors q) as well as for varying spatial and temporal distribution of hake density. It has been suggested that the difference in catch rate between the old and the new gear might be a function of depth. A depth factor is therefore included in the GLM analysis. The mean weight of the fish is also included as a factor. There are two likely sources of variation present in catch rate observations from the trawl surveys: sampling error (assumed to be proportional to the expected catch) and some extraneous source of variability in CPUE (assumed to have a constant CV). This implies that the distribution of hake catches has a (quadratic) variance function, for example of the form: $mean + mean^2 / k$, where k is the overdispersion parameter ($k = \infty$ depicting no overdispersion). This form of variance function follows under the assumption that the catches of hake follow a negative binomial distribution. The model for hake catch is thus given by:

$$C_{sp} = E\exp\left(\mu + \alpha_q + \beta_{pair} + \gamma_{depth} + \eta_{mweight} + \omega_{q\times depth}\right) + \varepsilon\,, \qquad (1)$$

where:

C_{sp} is the total catch (kg) for a species (*M. capensis* or *M. paradoxus*),

E is an offset which represents the effort extended by a trawl measured here as the swept-area trawled,

μ is the intercept,

q is a factor with 3 levels associated with the survey vessel-gear combination ("old *Africana*", "new *Africana*" or "*Nansen*"),

pair is a factor with 205 levels associated with trawl pairs between the old *Africana* and the *Nansen* and between the new *Africana* and the *Nansen* survey vessels (capturing the different areas and times that the experiments took place, for each of which the underlying hake density may have been different),

depth is a factor with 5 levels associated with depth ranges ("100" for depths 100–199m, "200" for 200–299 m, "300" for 300–399 m, "400" for 400–499 m and "500" for 500–599 m),

mweight is a factor with 6 levels in the case of *M. paradoxus* associated with the mean weight of the fish (each level representing mean weight of fish for every 0.2 kg, ranging from 0 to 2.99 kg) and 8 levels in the case of *M. capensis* associated with the mean weight of the fish (each level representing mean weight of fish for every 0.5 kg, ranging from 0 to 4.5 kg),

$q \times depth$ is the interaction between the survey vessel-gear combination (q) and depth, and

ε is the error term assumed to be negative binomial distributed.

The logarithmic link function is assumed in this case so that the expected value of hake catches is given by:

$$E(\ln(C_{sp})) = \ln(E) + \mu + \alpha_q + \beta_{pair} + \gamma_{depth} + \eta_{mweight} + \omega_{q\times depth} \,. \qquad (2)$$

Several variations of the model given by equation (1) were investigated in which some of the factors were omitted from the GLM.

Results and discussion

Table 1 shows some parameter estimates obtained by fitting the model given by equation (1) and some variants of it for *M. paradoxus* and *M. capensis*. For the multiplicative bias q factor, the GLM is standardised to the old *Africana*. Fig. 1 shows the residuals for the fit of the GLM to the data plotted against effort when no depth or mean weight of fish factors are taken into account in the GLM. There is no obvious evidence of systematic trends or heteroscedasticity.

It follows that:

$\ell n q_{new}^{paradoxus} = \ell n q_{old}^{paradoxus} - 0.053$ and

$\ell n q_{new}^{capensis} = \ell n q_{old}^{capensis} - 0.494$

for the simplest GLM fitted. These estimates can be used to provide a "prior" on the difference in q occasioned by changing gear on the *Africana*, for incorporation into assessments of the hake resource. The large difference for *M. capensis* is surprising.

There is little by way of obvious trends in the depth and mean-weight factors. For *M. capensis* with the surprisingly low *q* for new *Africana*, the inclusion of the depth factor makes little change, but with incorporation of mean weight the difference in *q* is exacerbated. Inclusion of interactions of *q* with depth shows low *q*'s for *M. capensis* for the new *Africana* for the deeper depths, especially if the mean weight of the fish is not included in the GLM.

A possible extension to this approach would be to treat the location factor β_{pair} as a random effect, which might give more discrimination power by adding degrees of freedom.

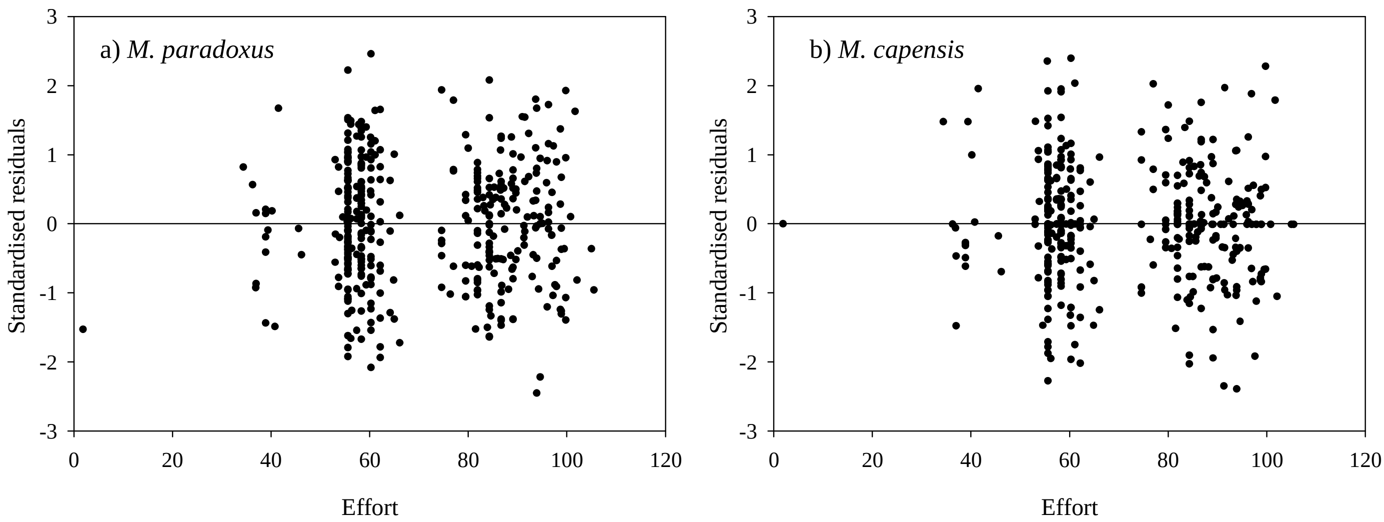

Figure 1. Standardised residuals plotted against effort for a) *M. paradoxus* and b) *M. capensis* when no depth and no mean weight of fish effects are taken into account.

Table 1: Parameter estimates for a) *M. paradoxus* and b) *M. capensis* multiplicative bias calibration factor analyses. The values in bold are statistically significant at the 5% level.

a) *M. paradoxus*

Parameters			Estimates				
			No depth/mean weight effect (CV)	**With depth effect**	**With mean weight effect**	**With q–depth interaction (no mean weight)**	**With q–depth interaction (with mean weight)**
μ			1.107 (0.412)	0.391	1.121	0.647	0.658
q	**old *Africana***		1.000	1.000	1.000	1.000	1.000
	Nansen	**< 200 m**	0.881 (0.030)	0.903	**0.820**	**0.745**	**0.738**
		200–299 m				**0.541**	**0.556**
		300–399 m				**1.072**	**1.002**
		400–499 m				**1.679**	**1.391**
		> 500 m				**1.428**	**1.661**
	new *Africana*	**< 200 m**	0.948 (0.117)	0.964	0.950	0.811	0.842
		200–299 m				0.786	0.796
		300–399 m				1.233	1.132
		400–499 m				1.078	1.095
		> 500 m				1.186	1.258
Depth	**< 200 m**		—	**3.695**	—	2.277	2.225
	200–299 m		—	1.000	—	1.000	1.000
	300–399 m		—	0.824	—	0.591	0.573
	400–499 m		—	1.147	—	0.507	0.611
	> 500 m		—	1.571	—	0.604	0.772
Mean weight	**< 0.2 kg**		—	—	1.000	—	1.000
	0.2–0.39 kg		—	—	1.210	—	1.338
	0.4–0.59 kg		—	—	0.632	—	0.760
	0.6–0.79 kg		—	—	**0.383**	—	0.662
	0.8–0.99 kg		—	—	**0.225**	—	0.520
	> 1.0 kg		—	—	0.485	—	1.008

b) *M. capensis*

Parameters			Estimates				
			No depth/mean weight effect (CV)	**With depth effect**	**With mean weight effect**	**With q–depth interaction (no mean weight)**	**With q–depth interaction (with mean weight)**
μ			**0.389** (0.461)	**0.345**	**0.398**	0.415	**30.02**
q	**old *Africana***		1.000	1.000	1.000	1.000	1.000
	Nansen	**< 200 m**	**0.809** (0.096)	**0.793**	**0.739**	**1.298**	**0.883**
		200–299 m				**0.681**	**0.456**
		300–399 m				**0.782**	**0.380**
		400–499 m				**0.616**	**0.224**
		> 500 m				**1.403**	**0.456**
	new *Africana*	**< 200 m**	**0.610** (0.141)	**0.603**	**0.566**	**0.702**	**0.764**
		200–299 m				**0.527**	**0.560**
		300–399 m				**0.809**	**0.511**
		400–499 m				**0.310**	**0.378**
		> 500 m				**0.086**	**0.560**
Depth	**< 200 m**		—	1.210	—	0.994	0.978
	200–299 m		—	1.000	—	1.000	1.000
	300–399 m		—	1.018	—	0.899	1.085
	400–499 m		—	1.329	—	1.506	2.003
	> 500 m		—	**13020**	—	8726	—
Mean weight	**< 0.5 kg**		—	—	1.000	—	1.000
	0.5–0.99 kg		—	—	0.889	—	**1.119**
	1.0–1.49 kg		—	—	**1.389**	—	**1.790**
	1.5–1.99 kg		—	—	1.141	—	1.724
	2.0–2.49 kg		—	—	1.074	—	1.483
	2.5–2.99 kg		—		0.712	—	0.961
	3.0–3.49 kg		—		0.973	—	1.397
	> 3.5 kg		—	—	**3.702**	—	**4.287**