An update of the catchability calibration factor between the *Africana* with the old and the new gear, with an attempt to estimate its length-dependence

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The 2004 analysis providing a catchability ratio for the *Africana* with the new compared to the old gear is refined and extended given additional data. The results of 1.18 (SE 0.10) for this ratio for *M. paradoxus* and 0.72 (SE 0.05) for *M. capensis* are both somewhat higher than obtained previously, primarily as a result of the additional data now available. An attempt is made at estimating the length dependence of these calibration factors, but the data are found to have insufficient information content to justify this.

Introduction,

The survey vessel *Africana* has been used for the demersal surveys on the south and west coasts since 1984. In June 2003, the fishing gear used on this vessel was changed and a different value for the catchability coefficient *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 catchabilities 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 (Brandão *et al*. 2004) provided the following estimates:

$\Delta\ell nq^{capensis} = -0.494$ with $\sigma_{\Delta\ell nq^{capensis}} = 0.141$ i.e. $\left(q^{new}/q^{old}\right)^{capensis} = 0.610$ and

$\Delta\ell nq^{paradoxus} = -0.053$ with $\sigma_{\Delta\ell nq^{paradoxus}} = 0.117$ i.e. $\left(q^{new}/q^{old}\right)^{paradoxus} = 0.948$

where

$\ell nq^{s}_{new} = \ell nq^{s}_{old} + \Delta\ell nq^{s}$ with *s* = *capensis* or *paradoxus*

No plausible explanation was found for the particularly large extent to which catch efficiency for *M. capensis* was estimated to have decreased for the new research survey trawl net. It was therefore recommended (BENEFIT 2004) that for assessments the ratio of the catchability of the new to the previous *Africana* net be set below 1, but not as low as the ratio estimated from the calibration experiments. $\Delta\ell nq^{capensis}$ has therefore subsequently been taken as -0.223, i.e. $\left(q^{new}/q^{old}\right)^{capensis} = 0.8$ in assessments.

The model used by Brandão *et al*. (2004) has been improved here by. a more careful examination of residual variance and its dependence on expected catch (see Appendix 1). Furthermore an attempt is made to estimate length-dependent calibration factors. If the old and new gear catch fish of different sizes at different rates, then the constant ratios estimated by the earlier analyses would smooth through those differences and would be pulled towards lengths for which most data are available. Of key interest is whether neglect of possible length dependence in the Brandão *et al*. (2004) approach might have led to the surprisingly low estimate for $\left(q^{new}/q^{old}\right)^{capensis}$.

Data

142 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. These include 33 old *Africana*/Nansen pairs of trawls carried in 2006 which were not included in the original Brandão *et al*. (2004) analysis. For each species, a pair of trawls for which one of the catch was zero was excluded from the analysis.

Methods

Details of the model used are given in Appendix 1. Rather than assume negative binomially distributed errors as in Brandão *et al*. (2004), alternative fitting criteria were explored to see for which the residuals were closest to homoscedastic when their standard deviations were plotted as a function of model-predicted catch. The outcome which is shown in Fig. A1.1 indicates that fitting to sqrt(*C*) provides results closest to homoscedasticity. Homoscedasticity was then further improved by modeling this relation of the standard deviation to model-predicted catch by the power relationship of equation A1.7, with the parameters of that relationship estimated the likelihood maximization process.

Initially the models did not converge. For eight pairs of trawls however, the β (relative density) estimated for one or the other species was particularly small (<-50) (five pairs for *M. paradoxus* and three for *M. capensis*), due to very low catches for both trawls for a particular species. When the data for a particular species for these eight pairs of trawls were excluded from the analysis, convergence was obtained. The results presented below exclude the data for those eight pairs of trawls.

Results and discussion

The results of the following different models are compared in Tables 1 (for length independent calibration) and Table 2 (for length dependent calibration):

a) Brandão *et al*. (2004);

b) "Model 1": a length-independent model as described in equation A1.1;

c) "Model 1-RE": as for "Model 1" above, but the β parameters which reflect the different hake densities at the positions where paired trawls took place, are treated as random effects;

d) “Model 1 (excluding 2006 data)”: as for Model 1 but excluding the 2006 data;

e) "Model 2": length-dependent model as described in equation A1.5, for which the α_L^v parameters are estimated for each 10cm length bin from the minus to the plus group;

f) "Model 3": as for "Model 2" above, but the length dependency was simplified by grouping some of the 10 cm length bins together. The choice of the simplification was based on AIC. A single α_L^v was therefore estimated for each of the following length ranges: ≤29cm, 30-39cm, 40-49cm, 50-79cm and ≥80cm for *M. paradoxus* and ≤39cm and ≥40cm for *M. capensis*.

g) "Overall direct ratio": a length-independent ratio computed using equation A1.12 applied to all length groups;

h) "Overall direct ratio (excluding 2006 data)": as for g) but excluding the 2006 data;

i) "Direct ratio - 3": a length-dependent ratio computed using equation A1.12 applied to the length groups selected for "Model 3";

j) "Direct ratio - 3 (excluding 2006 data)": as for i), but excluding the 2006 data.

The results in Table 1 for *M. paradoxus* are broadly consistent. The Model 1 estimate of 1.18 (SE 0.10) for the *Africana* new/old gear catchability ratio is hardly changed if the *β* parameters are treated as random effects, and the direct ratio approach used as a check yields a very similar though less precise estimate of 1.22. The Model 1 estimate for *M. capensis* is 0.72 (SE 0.05), which again changes little if the *β* parameters are treated as random effects. The direct ratio estimate is rather larger at 0.96, but has a high standard error.

These estimates are both higher than obtained by Brandão *et al*. (2004). Table 1 entries make clear that the primary reason for the change is the addition of further data from 2006. All the new data relate to *Nansen/Old Africana* comparisons, suggesting that the reason for the low *M.capensis* ratio found earlier lies in the 2004 *Nansen/Old Aficana* pair trawls. Fig. 1 shows that the previous estimates barely lie within the 95% confidence intervals for the updated estimates.

Results for analyses which attempt the introduction of length dependence in the calibrations are given in Table 2 and plotted in Figs 2 and 3. In short, length dependency estimates can vary considerably depending on the method used, and Fig. 2 suggests that these estimates are scarcely significantly different from estimates from a length-independent analysis. It seems that there is insufficient information content in these data to estimate length dependence in catchability ratios satisfactorily, so that the best approach for the time being is to maintain use of length-independent ratios for input to assessments.

Discussion is needed on whether the two updated estimates for the new/old *Africana* net catchability ratios of 1.18 for *M.paradoxus* and 0.72 for *M. capensis* should replace the values of 0.984 and 0.8 respectively from BENEFIT (2004) which are currently used as inputs to hake assessments.

References

BENEFIT. 2004. Formal report: BENEFIT/NRF stock assessment workshop, Cape Town, 12-17 January 2004.

Brandão A, Rademeyer RA and Butterworth DS. 2004. First attempt to obtain a multiplicative bias calibration factor between the *Africana* with the old and the new gear. Unpublished report, Marine and Coastal Management, South Africa WG/11/04/D:H:26

Miller TJ, Das C, Politis PJ, Miller AS, Lucey SM, Legault CM, Brown RW, and Rago PJ. 2010. Estimation of Albatross IV to Henry B. Bigelow Calibration Factors. NAFO SCR Doc. 10-05.

Table 1: Estimates of catchability ratios for *Africana* new compared to old gear, with their associated standard errors in parenthesis, for the length-independent models.

	M. paradoxus		*M. capensis*	
Brandão *et al.* (2004)	0.948	(0.111*)	0.610	(0.086*)
Model 1	1.176	(0.097)	0.718	(0.054)
Model 1-RE	1.160+	-	0.725+	-
Model 1 (excluding 2006 data)	0.938	(0.085)	0.597	(0.050)
Overall direct ratio	1.215	(0.306)[1]	0.964	(0.337)[1]
Overall direct ratio (excluding 2006 data)	1.209	-	0.685	-

* The standard errors on the log(ratio) given in Brandão *et al.* (2004) have been taken to reflect the CVs on the estimates here to provide the se estimates quoted.
+ There were convergence problems for this run, and consequently no Hessian, thus precluding the provision of Hessian-based standard errors.

[1] Standard errors obtained using the jackknife approach: the ratio is systematically recomputed, leaving out one month's data at a time from the sample set. From this new set of ratios, the estimate of variance can be calculated. If instead days are used as the sampling unit, the respective se's are 0.194 and 0.179 respectively.

Table 2: Fit statistics and estimates of catchability ratios for *Africana* new compared to old gear, with their associated standard errors in parenthesis, for the length-dependent models.

	Model 2		Model 3		Direct ratio - 3
M. paradoxus					
-lnL	3077.2		3078.0		
AIC	6632.4		6624.0		
<=29cm	0.593	(0.135)	0.599	(0.136)	1.090
30cm-39cm	0.455	(0.094)	0.462	(0.094)	1.783
40cm-49cm	2.322	(0.463)	2.360	(0.418)	1.413
50cm-59cm	1.106	(0.220)	1.250	(0.166)	0.784
60cm-69cm	1.348	(0.279)	1.250	(0.166)	0.784
70cm-79cm	1.280	(0.272)	1.250	(0.166)	0.784
>=80cm	3.961	(0.981)	3.960	(0.978)	0.352
M. capensis					
-lnL	2380.9		2390.5		
AIC	5177.8		5177.1		
<=39cm	1.677	(0.438)	1.440	(0.330)	1.477
40cm-49cm	0.704	(0.164)	0.701	(0.086)	0.786
50cm-59cm	0.873	(0.193)	0.701	(0.086)	0.786
60cm-69cm	0.491	(0.108)	0.701	(0.086)	0.786
70cm-79cm	0.562	(0.128)	0.701	(0.086)	0.786
80cm-89cm	1.121	(0.267)	0.701	(0.086)	0.786
>=90cm	0.470	(0.138)	0.701	(0.086)	0.786

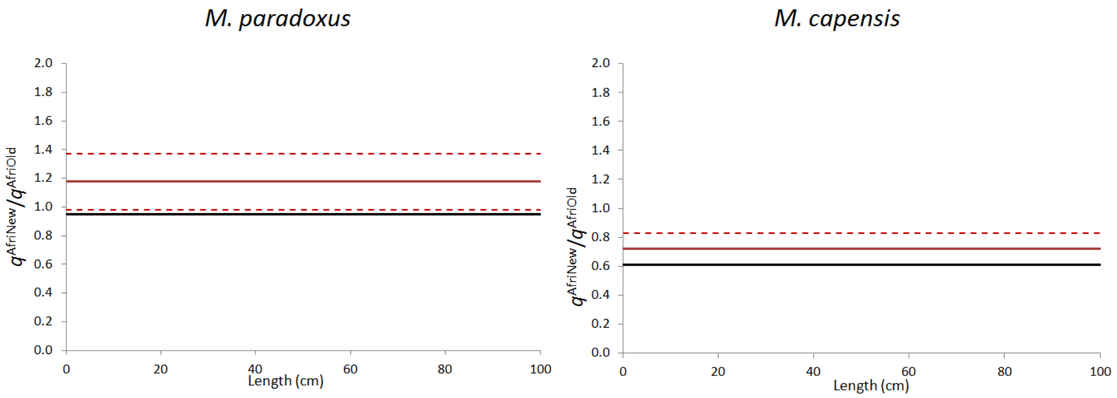

Fig. 1: Catchability ratios for the Africana New and Old gear for the length-independent model (red lines) ("Model 1"), compared to the results obtained by Brandão *et al*. (2004) (black lines). The dashed lines are +- 2 s.e.

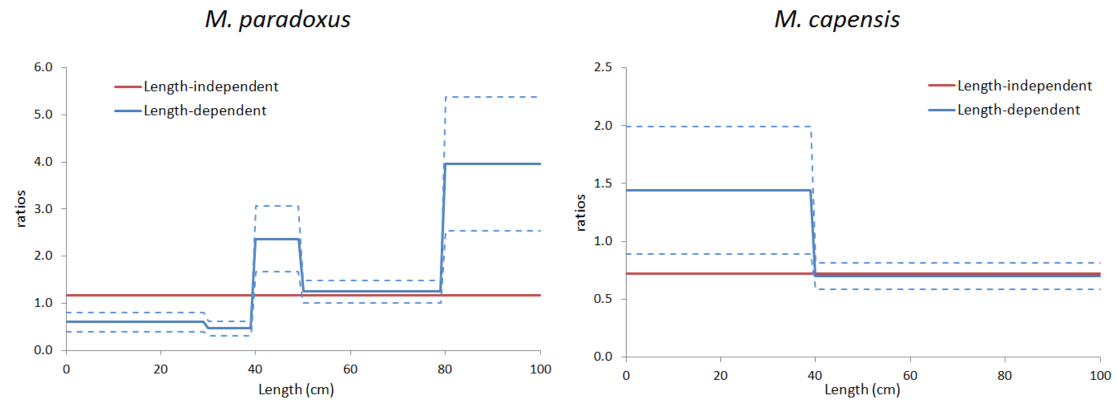

Fig. 2: Catchability ratios for the Africana New and Old gear for the length-independent ("Model 1") and length-dependent models ("Model 3"). The dashed lines are +-2 s.e.

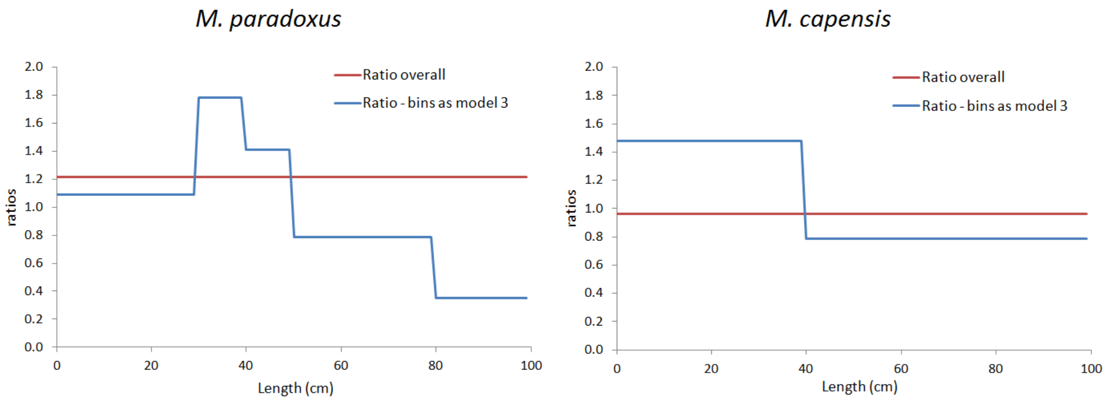

Fig. 3a: Ratios of the sum of the catches over all lengths ("Overall direct ratio"), and by length bins as selected for Model 3 ("Direct ratio - 3").

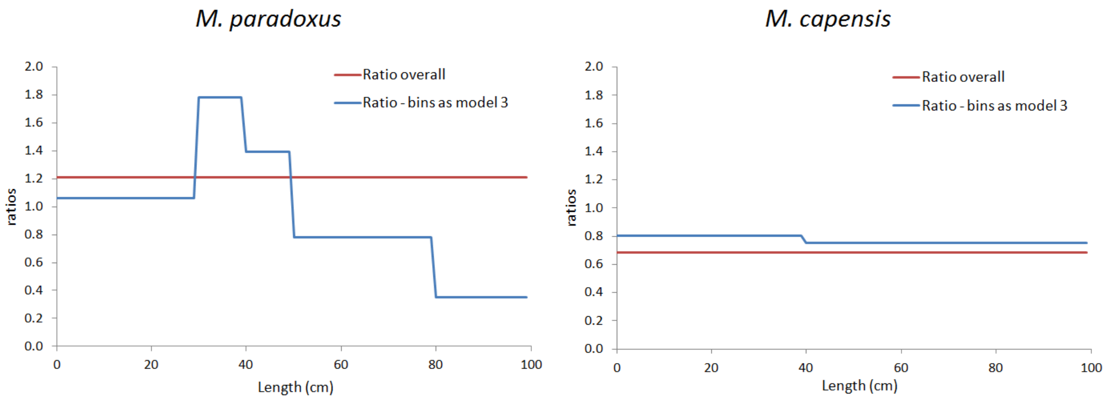

Fig. 3b: As for Fig. 3a above but excluding the 2006 data.

Appendix 1:

Length-independent model

$$\hat{C}^{spp} = E\exp\left(\mu + \alpha^{v} + \beta_{pair}\right) + \varepsilon \qquad \text{(A1.1)}$$

where:

$\hat{C}^{spp}$ is the expected total catch (kg) for a species (*M. capensis* or *M. paradoxus*),

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

μ is the intercept,

α^{v} is the log-catchability relative to "old Africana" (i.e. $\alpha^{oldAfr} = 0$),

β_{pair} is linked to the fish density, capturing the differences in this density in the areas and times that the adjacent trawling experiments took place, and

ε is the error term.

The negative log-likelihood is given by:

$$-\ln L = \sum_{spp}\sum_{i=1}^{n}\left[\ln\sigma_i^{spp} + \left(\varepsilon_i^{spp}\right)^2 / 2\left(\sigma_i^{spp}\right)^2\right] \qquad \text{(A1.2)}$$

with

$$\sigma_i^{spp} = \phi^{spp} + \theta^{spp}\left(\hat{C}_i^{spp}\right)^{\varphi^{spp}} \qquad \text{(A1.3)}$$

where

σ_i^{spp} is the standard deviation for species *spp* and trawl and vessel/gear combination *i*, with ϕ^{spp}, θ^{spp} and φ^{spp} taken as estimable parameters, and

$$\varepsilon_i^{spp} = \sqrt{C_i^{spp}} - \sqrt{\hat{C}_i^{spp}} \qquad \text{(A1.4)}$$

Length-dependent model

$$\hat{C}_L^{spp} = E\exp\left(\mu + \alpha_L^{v} + \beta_{pair}\right) + \varepsilon_L \qquad \text{(A1.5)}$$

where:

$\hat{C}_L^{spp}$ is the expected catch (kg) for species *spp* and length bin L,

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

μ is the intercept,

α_L^{v} is the log-catchability taken as relative to "old Africana", length bin 50-59cm,

β_{pair} is linked to the fish density, capturing the differences in density in the areas and times that the adjacent trawling experiments took place, and

ε_L is the error term.

The negative log-likelihood is given by:

$$-\ln L = \sum_{spp} \sum_{L=minus}^{plus} \sum_{i=1}^{n} \left[\ln \sigma_{L,i}^{spp} + \left(\varepsilon_{L,i}^{spp}\right)^2 \Big/ 2\left(\sigma_{L,i}^{spp}\right)^2 \right] \quad \text{(A1.6)}$$

with

$$\sigma_{L,i}^{spp} = \phi^{spp} + \theta^{spp} \left(\widehat{C}_{L,i}^{spp}\right)^{\varphi^{spp}} \quad \text{(A1.7)}$$

where

$\sigma_{L,i}^{spp}$ is the standard deviation for species *spp* and trawl and vessel combination *i*, with ϕ^{spp}, θ^{spp} and φ^{spp} taken as estimable parameters, and

$$\varepsilon_{L,i}^{spp} = \sqrt{C_{L,i}^{spp}} - \sqrt{\widehat{C}_{L,i}^{spp}} \quad \text{(A1.8)}$$

The observed catch in length bin L is taken as:

$$C_{L,i}^{spp} = \sum_{l=l_1}^{l_2} C_{l,i}^{spp} w_l^{spp} \quad \text{(A1.9)}$$

with l_1 and l_2 the minimum and maximum length in length bin *L*,

$C_{l,i}^{spp}$ is the estimated catch in numbers at length *l* for species *spp* and trawl and vessel/gear combination *i*, and

w_l^{spp} is the weight (kg) of species *spp* at length *l*.

10 cm length bins have been used. For *M. paradoxus*, the minus and plus group lengths are 29 cm and 80 cm respectively, while for *M. capensis*, these are 39 cm and 90 cm respectively.

Direct ratio

To provide results from an alternative approach to be able to compare with the results from the length-independent and -dependent models described above, a "direct ratio" calibration factor (as in Miller *et al*. 2010) was computed for each species as follows:

$$\rho_L^{Old/Nansen} = \frac{\sum_{i=1}^{Nstation} \sum_{l=l_1}^{l_2} C_{l,i}^{AfriOld} w_l^{spp}}{\sum_{i=1}^{Nstation} \sum_{l=l_1}^{l_2} C_{l,i}^{Nansen} w_l^{spp}} \quad \text{(A1.10)}$$

$$\rho_L^{New/Nansen} = \frac{\sum_{i=1}^{Nstation} \sum_{l=l_1}^{l_2} C_{l,i}^{AfriNew} w_l^{spp}}{\sum_{i=1}^{Nstation} \sum_{l=l_1}^{l_2} C_{l,i}^{Nansen} w_l^{spp}} \quad \text{(A1.11)}$$

$$\rho_L^{New/Old} = \rho_L^{New/Nansen} \Big/ \rho_L^{Old/Nansen} \quad \text{(A1.12)}$$

This was computed for the overall ratio (l_1=1, l_2=100cm) and for length bins selected for model 3, i.e.

≤29cm, 30-39cm, 40-49cm, 50-79cm and ≥80cm for *M. paradoxus* and ≤39cm and ≥40cm for *M. capensis* (chosen based on AIC).

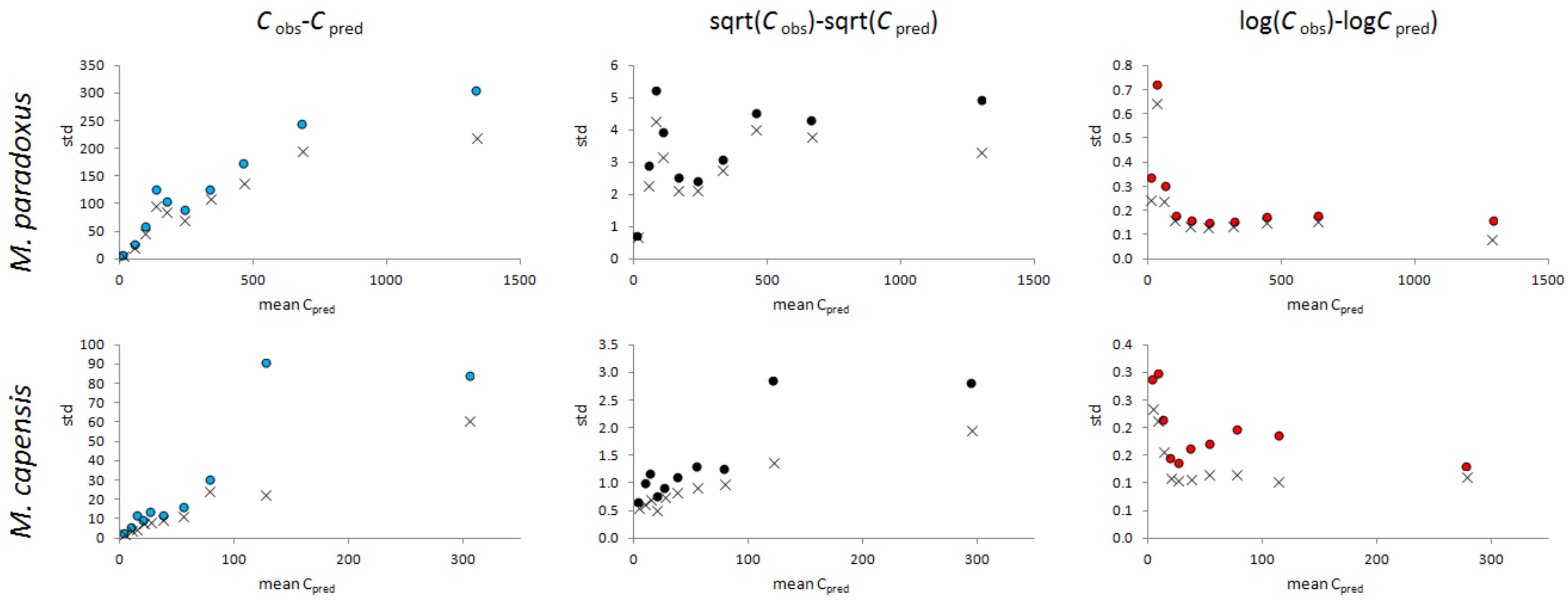

Fig. A1.1: Plot of the residual standard deviation (st d) against predicted catch for different choices to define residuals..