Candidate Management Procedures for the South African Hake Resource: Draft Objectives and Testing Methodology

RA Rademeyer and DS Butterworth
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Objectives

The objectives for the previous hake OMP adopted in 2006 were:

a) Improve catch rates in the short term, considered operationally as increase the expected CPUE for the offshore trawlers by 50% over its average for the 2003-2005 period by 2016.

b) Limit inter-annual TAC variations, with an operational implementation that these not exceed 10% p.a.

c) Recover the *M. paradoxus* resource, taken operationally to mean to reach its MSYL by 2027.

d) Have a low probability of further decline in the *M. paradoxus* resource, taken operationally to mean that the lower 5%-ile of the *M. paradoxus* spawning biomass should be above the corresponding 2007 level in 2027.

Note that projected probability distributions for associated performance statistics were evaluated over the Reference Set of Operating Models (OMs).

Though revised operational objectives should only be finalised through an iterative process as the results of simulation tests of Candidate Management Procedures (CMPs), and hence their trade-off implications, become available, this process merits initiation at the present time.

Questions the DWG needs to address at its next meeting include:

i. Are there any reasons to modify any of the existing objectives?

ii. Some scenarios in the updated Reference Set reflect a *M. capensis* resource that is also depleted below its MSYL at present – what recovery targets should be set for those scenarios?

iii. The recent MSC re-certification of the trawl fishery includes a condition as follows:

> **"Condition 7. Appropriate limit and target reference points for *M. paradoxus* based on stock biomass and/or fishing mortality**
> **Action required:** The limit reference point is the lower 95% confidence interval of the recovery trajectory in the 2006 OMP meaning the limit reference point is not a constant, but a level that will vary over time. At its lowest point, a *M. paradoxus* spawning biomass might not be low enough to trigger management override of the default OMP response, risking recruitment failure.
> SG 80 states: 'Limit and target/precautionary reference points should be justified based on stock biology (e.g. a stock-recruitment relationship) and measurable given data and assessment limitations. Reference points may be probability based'.
> It is anticipated that the OMP will undergo revision during 2010. This condition could be addressed within this planning process and thereby formally linked to the harvest control rules (OMP) that will be used to set TACs for the period of certification. The OMP revision process in 2010 should explicitly consider limit control rules with that planning evaluation.
>
> **Timescale:** Appropriate limit and target reference points enacted within one year of certification."

What is meant by a limit reference point, and what action is implied if a resource falls below an associated abundance level, varies internationally, and specific guidance is needed from the MSC regarding exactly how they require this interpreted in circumstances where the CMPs under consideration are already feedback-control based and so will (in expectation at least) pull TACs down if abundance drops. However the sense intended may be of the nature of an additional rule implying more conservative decisions coming into play if some monitoring index drops below a threshold level. Possibilities to consider might be along the lines of using some coast-combined offshore trawler standardised CPUE index (I) for a species for the last three years as the monitoring index in question. Fix two associated thresholds I1 and a lower value I2: if I drops below I2, then the TAC is reduced by a further 5% than would have been the case without this further rule; for I between I1 and I2, the extent of this further reduction changes linearly from 0% at I1 to 5% at I2.

Projection methodology

Projections into the future under a specific Candidate Management Procedure (CMP) are proposed to be evaluated using the following steps for the component Operating Model (OM) of the Reference Set under consideration.

Step 1: Begin-year numbers at age

The components of the numbers-at-age vector for each gender and species at the start of 2010 ($N^g_{2010,a}$: a = 1,…, m – here and below the species superscript has been omitted for ease of reading) are obtained from the MLE of an assessment of the resource, assuming a total catch in 2009 equal to the TAC set for that year and split between species, coast and fleet using the 2008 catch ratio.

Error is included for ages 0 to 3 because these are poorly estimated in the assessment given limited information on these year-classes, i.e.:

$$N^g_{2010,a} \rightarrow N^g_{2010,a} e^{\varepsilon_a} \qquad \varepsilon_a \text{ from } N\left(0,(\sigma_R)^2\right) \tag{1}$$

where σ_R is the standard deviation of the stock-recruitment residuals estimated by the OM for the years 1985 to 2005 (last year before shrinking of SR residuals). Note that the residuals each year are assumed to be gender-independent. Equation 1 is approximate in that it omits to adjust for past catches from the year-class concerned, but these are so small that the differential effect is negligible.

Step 2: Catch

These numbers-at-age are projected one year forward at a time given a catch for the year concerned.

C_y is as specified by the CMP.

This requires specification of how the catch is disaggregated by species, fleet, gender and age to obtain C^g_{fya}, and of how future recruitments are generated.

Step 3: Catch-at-age by species, gender and fleet

Catch by species:

Although the annual catch (TAC) generated by the CMP can be species-disaggregated, the TAC recommended by the MP will be an overall figure for the two species combined given the difficulties that would be encountered in trying to set species-specific hake TACs. To disaggregate the total catch by species, previous practice when projecting forward was to assume for each fleet that the ratio of the fishing mortality (F) for the two species (F_{para}/F_{cap}) remains the same, i.e. that the current pattern of fishing remains approximately unchanged over the projection period — although some robustness tests explored sensitivity to this). Figure 1 shows plots of estimates of this ratio for the three fleets concerned, together with averages over recent periods, for the central OM within the Reference Set (the OM RS1 – see Table 2 of Rademeyer and Butterworth, 2010). It is proposed that the averages over the last five years (2005–2009) be used for this purpose, However given that there is variability from year to year evident in these plots, it is proposed that in each future year the ratio be drawn from a Normal distribution with mean and variance as estimated from the values over the last five years, except that these distributions be truncated at +2 and -2 standard deviations to avoid generation of outlying values.

Catch by gender:

The fishing mortality on males and females is assumed to be equal for each species and fleet, as assumed in the assessment, except for the south coast offshore fishery for which the female downscaling factor estimated in the OM is used in the projection.

Catch by fleet:

The total TAC recommended by the CMP is divided in fixed proportions among the various fleets, with the following values used for the sector allocations as in the last rights re-allocation process for the fishery: offshore trawl — 84%, inshore trawl — 6%, longline — 7% and handline — 3%. The offshore trawl and longline fleet catches are further split between the West and South Coasts using the average proportion over the last five years data (2004-2008) (see Figure 2). This should make little difference in practice as the stocks each cover both coasts.

Catch by age:

C^g_{fya} is obtained by assuming that S^g_{fyl}, w^g_l and $P^g_{a+1/2,l}$ stay constant in the future as estimated in the OM, and therefore that:

$$\tilde{S}^g_{fya} = \left[\sum_l S^g_{fyl} w^g_l P^g_{a+1/2,l}\right] \Big/ w^g_{a+1/2} \tag{2}$$

the effective commercial selectivity functions, also stay constant in the projections.

The matrix P is calculated under the assumption that length-at-age is log-normally distributed about a mean given by the von Bertalanffy equation, i.e.:

$$l_a \sim N\left[\ln(l_\infty(1-e^{-\kappa(a-t_0)}));\left(\frac{\theta_a}{l_\infty(1-e^{-\kappa(a-t_0)})}\right)^2\right] \tag{3}$$

where θ_a, l_∞, t_0 and κ are as estimated in the OM for each species and gender.

From this it follows that:

$$C_{fy} = \sum_g \sum_{a=0}^{m} w^g_{a+1/2}\, C^g_{fya} = \sum_g \sum_{a=0}^{m} w^g_{a+1/2}\, N^g_{ya} e^{-M^g_a/2} F_{fy} \tilde{S}^g_{fya} \tag{4}$$

$$F^{cap}_{fy} = \frac{C^{tot}_{fy}}{\left[F_{ratio} \sum_g \sum_{a=0}^{m} w^{para,g}_{a+1/2}\, N^{para,g}_{ya} e^{-M^{para,g}_a/2} \tilde{S}^{para,g}_{fya} + \sum_g \sum_{a=0}^{m} w^{cap,g}_{a+1/2}\, N^{cap,g}_{ya} e^{-M^{cap,g}_a/2} \tilde{S}^{cap,g}_{fya}\right]} \tag{5}$$

$$F^{para}_{fy} = F^{cap}_{fy} F_{ratio}$$

and hence that:

$$C^g_{fya} = N^g_{ya} e^{-M^g_a/2} F_{fy} \tilde{S}^g_{fya} \tag{6}$$

The numbers-at-age can then be computed for the beginning of the following year (y+1):

$$N^g_{y+1,0} = R^g_{y+1} \tag{7}$$

$$N^g_{y+1,a+1} = \left(N^g_{ya} e^{-M^g_a/2} - \sum_f C^g_{fya}\right) e^{-M^g_a/2} \qquad \text{for } 0 \le a \le m-2 \tag{8}$$

$$N^g_{y+1,m} = \left(N^g_{y,m-1} e^{-M^g_{m-1}/2} - \sum_f C^g_{f,y,m-1}\right) e^{-M^g_{m-1}/2} + \left(N^g_{ym} e^{-M^g_m/2} - \sum_f C^g_{fym}\right) e^{-M^g_m/2} \tag{9}$$

The procedure above can however lead to problems in situations where the catch specified is not small relative to the resource abundance, and may lead to certain numbers-at-age going negative. To avoid such a situation arising, and indeed further to ensure that in any one year no more than 90% of any cohort can be taken by the fishery as a whole (as this would require an unrealistically large level of effort), the following procedure is then followed. First to see whether this situation has arisen, for each species and age, check that:

$$\left[N^g_{ya}e^{-M^g_a/2}-\sum_f C^g_{fya}\right]\geq\left[0.1N^g_{ya}e^{-M^g_a/2}\right] \qquad (10)$$

if $\left[N^g_{ya}e^{-M^g_a/2}-\sum_f C^g_{fya}\right]<\left[0.1N^g_{ya}e^{-M^g_a/2}\right]$ for any age a then:

$$N^{*g}_{y,a}=N^g_{y*a}e^{-M^g_a/2} \qquad (11)$$

For each fleet in the following order: west coast longline, south coast longline, west coast offshore, south coast offshore, south coast inshore and south coast handline, go through equations 12 to 18:

A]. if $F^{para}_{fy}>0.9$ and $F^{cap}_{fy}\leq 0.9$, otherwise go to **B**]

$$F'^{para}_{fy}=0.9 \qquad (12)$$

$$F'^{cap}_{fy}=\frac{C_{fy}-0.9\sum_g\sum_{a=0}^m w^{para,g}_{a+1/2}\ N^{*para,g}_{ya}\tilde{S}^{para,g}_{fya}}{\sum_g\sum_{a=0}^m w^{cap,g}_{a+1/2}\ N^{*cap,g}_{ya}\tilde{S}^{cap,g}_{fya}} \qquad (13)$$

if $F'^{cap}_{fy}>0.9$ then go to **C**].

B]. if $F^{cap}_{fy}>0.9$ and $F^{para}_{fy}\leq 0.9$

$$F'^{cap}_{fy}=0.9 \qquad (14)$$

$$F'^{para}_{fy}=\frac{C_{fy}-0.9\sum_g\sum_{a=0}^m w^{cap,g}_{a+1/2}\ N^{*cap,g}_{ya}\tilde{S}^{cap,g}_{fya}}{\sum_g\sum_{a=0}^m w^{para,g}_{a+1/2}\ N^{*para,g}_{ya}\tilde{S}^{para,g}_{fya}} \qquad (15)$$

if $F'^{para}_{fy}>0.9$ then go to **C**].

C]. if $F^{para}_{fy}>0.9$ and $F^{cap}_{fy}>0.9$

$$F'^{para}_{fy}=0.9 \text{ and } F'^{cap}_{fy}=0.9 \qquad (16)$$

$$C^g_{fya}=N^{*g}_{ya}F'_{fy}\tilde{S}^g_{fya} \qquad (17)$$

$$N'^g_{y,a}=N^{*g}_{ya}-C^g_{fya} \qquad (18)$$

In equations 13, 15 and 17, $N^{*g}_{y,a}$ is replaced by $N'^g_{y,a}$.

Start the next fleet and continue through all the fleets.

$$N^{g}_{y+1,a+1} = N'^{g}_{ya} e^{-M^{g}_{a}/2} \qquad \text{for } 0 \le a \le m-2 \tag{19}$$

$$N^{g}_{y+1,m} = N'^{g}_{y,m-1} e^{-M^{g}_{m-1}/2} + N'^{g}_{y,m} e^{-M^{g}_{m}/2} \tag{20}$$

Step 4: Recruitment

Future recruitments are provided by a Beverton-Holt or a modified (generalised) form of the Ricker stock-recruitment relationship, as specified for the OM and assuming a 50:50 sex-split at recruitment.

$$R^{g}_{y} = \frac{4hR_0 B^{♀,sp}_{y}}{K^{♀,sp}(1-h) + (5h-1)B^{♀,sp}_{y}} e^{(\varsigma_y - \sigma^2_R/2)} \tag{21}$$

for the Beverton-Holt stock-recruitment relationship and

$$R^{g}_{y} = \alpha B^{♀,sp}_{y} \exp\left(-\beta\left(B^{♀,sp}_{y}\right)^{\gamma}\right) e^{(\varsigma_y - \sigma^2_R/2)} \tag{22}$$

with

$$\alpha = R_0 \exp\left(\beta\left(K^{♀,sp}\right)^{\gamma}\right) \qquad \text{and} \qquad \beta = \frac{\ln(5h)}{\left(K^{♀,sp}\right)^{\gamma}\left(1-5^{-\gamma}\right)}$$

for the modified Ricker relationship.

Log-normal fluctuations are introduced by generating ς_y factors from $N(0,\sigma^2_R)$ where σ_R is estimated from the residuals of the model fit for years 1985 to 2004. K^{sp}, h (and γ with the modified Ricker) are as estimated for that OM.

$B^{♀,sp}_{y}$ is the female spawning biomass at the start of year y, computed as:

$$B^{♀,sp}_{y} = \sum_{a=1}^{m} f^{♀}_{a} w^{♀}_{a} N^{♀}_{ya} \tag{23}$$

Step5:

The information obtained in Steps 1 to 4 is used to generate values of the abundance indices in the form of species-disaggregated CPUE series (one for each coast and species) and survey indices of abundance (one for each coast and species). These abundance indices (CPUE and surveys) are generated from the OM, assuming the same error structures as in the past, as follows:

(a) Coast- and species-disaggregated CPUE series are generated from model estimates for corresponding mid-year exploitable biomass and catchability coefficients, with multiplicative lognormal errors incorporated where the associated variance is estimated within the OM concerned from past data. When computing the TAC for year y+1, such data are available to year y–1.

$$I^{i}_{y} = \hat{q}^{i} \hat{B}^{ex}_{fy} e^{\varepsilon^{i}_{y}} \tag{24}$$

where

$$B^{ex}_{fy} = \sum_{g}\sum_{a=0}^{m} w^{g}_{a+1/2} \tilde{S}^{g}_{fya} N^{g}_{ya} e^{-M^{g}_{a}/2}\left(1 - \sum_{f} S^{g}_{fya} F_{fy} \Big/ 2\right) \tag{25}$$

$$\hat{\sigma}^i = \sqrt{1/n_i \sum_{y=1978}^{2008} \left(\ell n(I_y^i) - \ell n(\hat{I}_y^i)\right)^2} \quad \text{and} \tag{26}$$

$$\ell n\, \hat{q}^i = \frac{\sum_{y=1978}^{2008} \left(\ell n I_y^i - \ell n \hat{B}_{fy}^{ex}\right)}{\sum_{y=1978}^{2008} 1} \tag{27}$$

$$\varepsilon_y^i \quad \text{from } N\left(0, \left(\sigma^i\right)^2\right) \tag{28}$$

(b) Species-disaggregated biomass estimates from the West Coast summer and South Coast autumn surveys are generated from model estimates of mid-year survey biomass. Because the research survey vessel, the RV *Africana*, has used new gear in 2003/2004, estimates from that date are adjusted by a multiplicative bias when the new gear is used. For future projections it is assumed that each year the new gear is used (this is no restriction is practice, because even if gear is varied in future, a calibration factor assumed to be known exactly would be applied). Lognormal error variance includes the survey sampling variance with the CV set equal to the average historical value, plus survey additional variance (the variability that is not accounted for by sampling variability) as estimated within the OM concerned from past data. For the TAC for year y+1, such data are available for year y.

$$I_y^i = \hat{q}^i \hat{B}_{fy}^{surv} e^{\varepsilon_y^i} \tag{29}$$

$$B_y^{surv} = \sum_g \sum_{a=0}^{m} w_a^g \tilde{S}_a^{g,sum} N_{ya}^g \tag{30}$$

for begin-year (summer) surveys, and

$$B_y^{surv} = \sum_g \sum_{a=0}^{m} w_{a+1/2}^g \tilde{S}_a^{g,win} N_{ya}^g e^{-M_a^g/2} \left(1 - \sum_f S_{fya}^g F_{fy} \Big/ 2\right) \tag{31}$$

for mid-year (spring, winter and autumn) surveys,

$$\varepsilon_y^i \quad \text{from } N\left(0, \left(\sigma^i\right)^2\right) \tag{32}$$

where

$$\sigma^i = \sqrt{\ln(1 + \overline{CV^i}^2) + \sigma_a^2} \tag{33}$$

The survey specific average CV (CV^i) is computed over all the years available for that survey as:

$$\overline{CV^i} = \frac{\sum_y se_y^i \big/ I_y^i}{\sum_y 1} \tag{34}$$

For *M. paradoxus*, $\overline{CV^i}$ is 0.185 and 0.372 for the West Coast summer and South Coast autumn surveys respectively and for *M. capensis*, $\overline{CV^i}$ is similarly 0.178 and 0.112.

The reason for this difference in periods for which data are available is that recommendations for a TAC, which applies over a calendar year (y+1), are required by October of the preceding year (y). By that time the results of the surveys conducted during year y will be available, but not for CPUE which pertains to the full calendar year y. Thus, care is taken in developing and testing the OMP that only data that would actually be available at the time a TAC recommendation is required are used. Furthermore, in order to project the resource biomass trajectory forward, the TAC needs to be disaggregated by species and by fleet.

As for the commercial selectivity, the survey selectivities are obtained under the assumption that the selectivity functions estimated for that OM remain constant.

Step 6:

Given the new CPUE indices I^i_{y-1} and the new survey indices I^i_y compute TAC_{y+1} using the CMP.

Step 7:

Steps 1-6 are repeated for each future year in turn for as long a period as desired, and at the end of that period the performance of the candidate MP under review is assessed by considering statistics such as the average catch taken over the period and the final spawning biomass of the resource.

Performance Statistics

The following performance statistics, related to the objectives above, will be computed for the CMP tested. Projections will be conducted over 20 years.

Utilisation-related

- Short, medium and long term average catch: $\frac{1}{5}\sum_{y=2011}^{2015} C_y$, $\frac{1}{10}\sum_{y=2011}^{2020} C_y$ and $\frac{1}{20}\sum_{y=2011}^{2030} C_y$ and (for both species combined and also for each species separately).
- Annual species-combined catch: $C_{2011}, C_{2012}, C_{2013}$ (note that C_{2010} was fixed by the TAC decision already made in 2009, and simulations assumed that this catch would be landed).

Resource status-related

- B^{sp}_{2030} / K^{sp} and $B^{sp}_{2030} / B^{sp}_{2010}$: for each species, the expected female spawning biomass at the end of the projection period, relative to pristine and to current level;
- $B^{sp}_{2020} / B^{sp}_{2007}$, $B^{sp}_{2027} / B^{sp}_{2007}$, $B^{sp}_{2027} / B^{sp}_{MSY}$ and $B^{sp}_{2020} / B^{sp}_{MSY}$: for each species, the expected female spawning biomass in 2020 and 2027, relative to the 2007 level and to B^{sp}_{MSY} ;
- $CPUE_{2016} / CPUE_{2003-2005}$: the change in the expected species-combined offshore trawl CPUE in 10 years time compared to the average over the most recent three years at the time the previous OMP was adopted for the offshore trawl fleet. CPUE for these purposes will be indexed by the sum of the exploitable biomass over both species and over West and South coasts. To provide stakeholders with some sense of how exploitable biomass defined in this way relates to overall offshore trawl CPUE, Fig. 3 compares both nominal CPUE aggregated over species, gender and coasts, and then this CPUE GLM-standardised as for coast- and species-specific data, with such exploitable biomass as estimated for the Reference Case assessment in the past.

TAC variability

- $AAV = \frac{1}{20}\sum_{y=2011}^{2030} \left|C_y - C_{y-1}\right| / C_{y-1}$

In addition, time trajectories (both worm plots and probability envelopes) will be plotted for certain outputs from the projections, such as C_y and B^{sp}_y .

Summary of data available to CMPs

The data available to a CMP to provide a TAC recommendation for year *y*+1 are**:**

- Catch data by species to year *y*-1

- CPUE indices by coast and species to year *y*-1
- Survey abundance estimates by coast and species to year *y*.

Consideration might be given to whether CMPs might also be provided annual CV estimates for the indices/estimates, either exact values or with estimation error added.

REFERENCES

Rademeyer RA and Butterworth DS. 2010. Proposed Reference Set for the South African hake resource to be used in OMP-2010 testing. Unpublished report, Marine and Coastal Management, South Africa. MCM/2010/FEB/SWG-DEM/05.

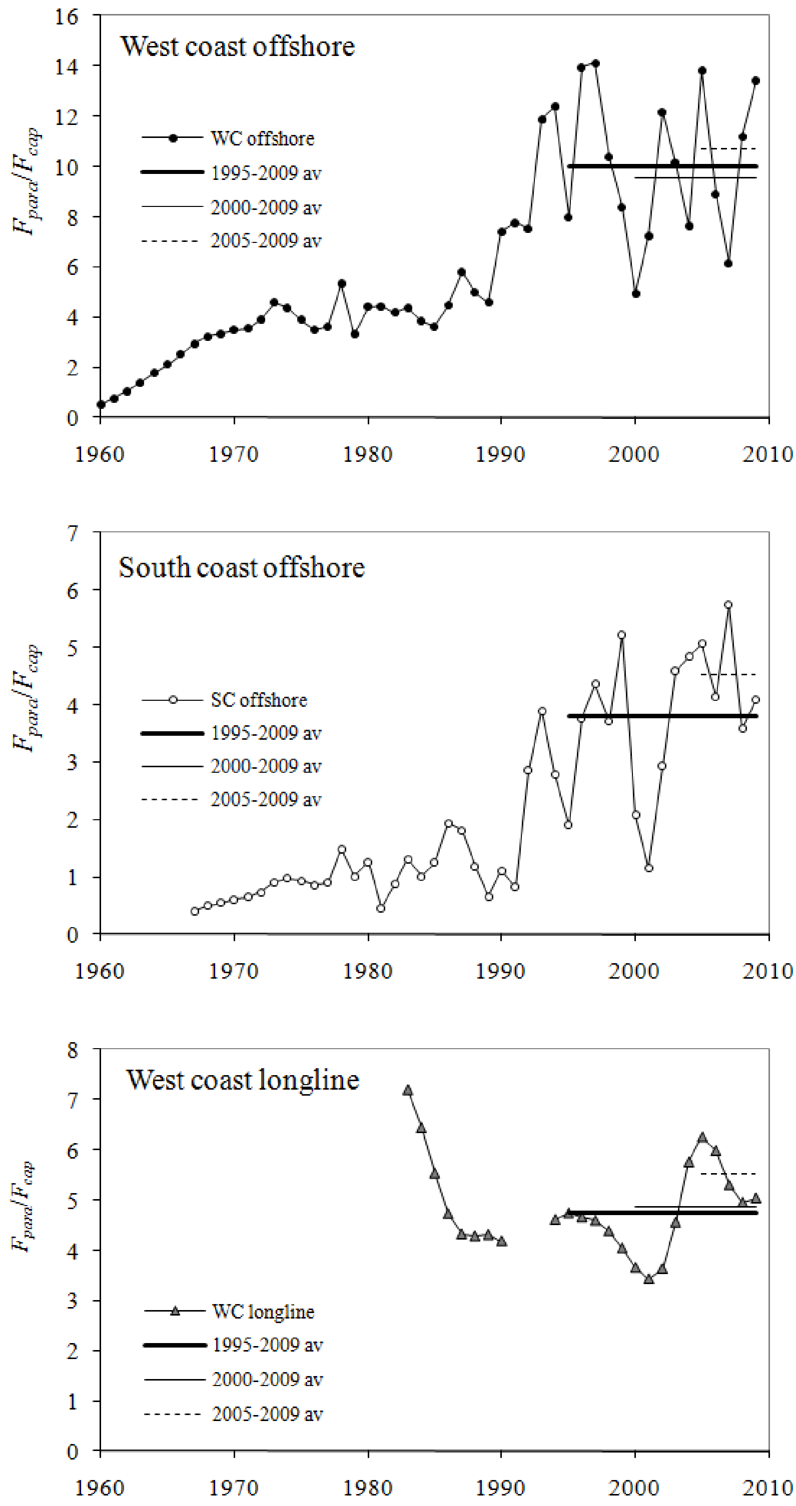

Fig. 1: Trends in past *F*ratio (F_{para}/F_{cap}) for the west and south coast offshore trawl and west coast longline fleet for the Reference Case assessment (RS1) within the Reference Set (see Table 2 of Rademeyer and Butterworth, 2010). The averages over1995-2009, 2000-2009 and 2005-2009 are also shown.

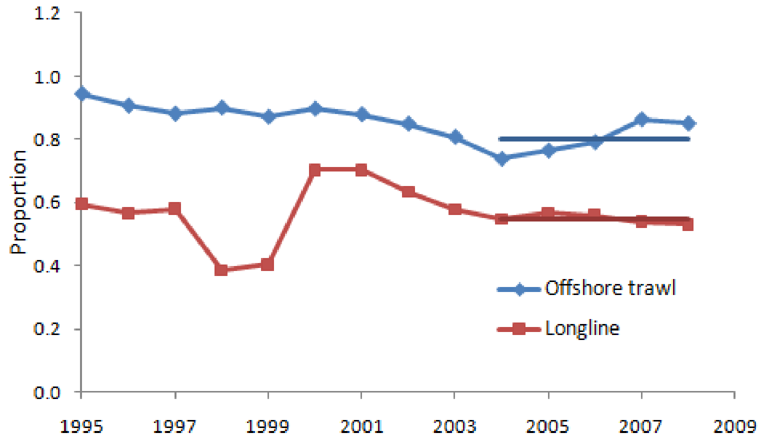

Fig. 2: Proportion of the species combined offshore trawl and longline catches taken on the West Coast. The averages over the last five years are also shown.

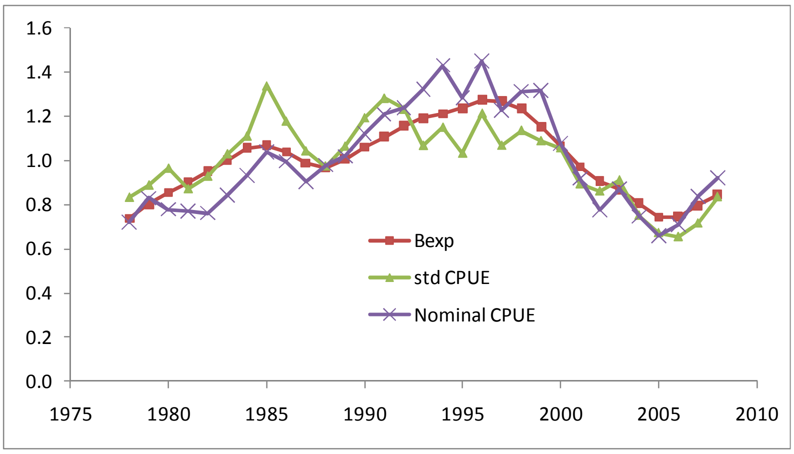

Fig. 3: Comparison of nominal CPUE (aggregated over species, gender and coasts), CPUE GLM-standardised as for coast- and species-specific data, and offshore trawl species- and coast-combined exploitable biomass as estimated for the Reference Case assessment in the past.