The 2010 Operational Management Procedure for the South African *Merluccius paradoxus* and *M. capensis* Resources

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Introduction

The algorithm for the 2010 Operational Management Procedure (OMP) to provide TAC recommendations for the South African *Merluccius paradoxus* and *M. capensis* resources is empirical. It combines an increase or decrease of the TAC in relation to a) the magnitude of recent trends in CPUE and survey abundance estimates for both species and b) the relative level of recent CPUE and survey abundance estimates compared to a target level. The basis for the associated computations is set out below, with the tuning parameters given in Table 1. Details of the computation procedures for the CPUE and catch data are provided in Appendix A, and for the survey estimates of Biomass in Appendix B.

The 2010 OMP

The formula for computing the TAC recommendation is as follows:

$$TAC_{y+1} = C_{y+1}^{para} + C_{y+1}^{cap} \tag{1}$$

with

$$C_{y+1}^{spp} = w_y C_y^{*spp}\left[1 + \lambda_{up/down}\left(s_y^{spp} - T_y^{spp}\right)\right] + \left(1 - w_y\right)\left[a^{spp} + b^{spp}\left(J_y^{spp} - 1\right) - Pen_y^{spp}\right] \tag{2}$$

where

TAC_{y+1} is the total TAC recommended for year *y*+1, (year *y* being the current year),

C_{y+1}^{spp} is the intended species-disaggregated TAC for year *y*+1,

C_y^{*spp} is the achieved catch[1] of species *spp* in year *y*~~-1~~,

w_y is a year-dependent tuning parameter,

$\lambda_{up/down}$ are tuning parameters; λ_{up} is used if $s_y^{spp} \geq 0$ and λ_{down} is used if $s_y^{spp} < 0$,

T_y^{spp} is the year-dependant target rate of increase for species *spp*,

s_y^{spp} is a measure of the immediate past trend in the abundance indices for species *spp* as available to use for calculations for year *y*,

a^{spp}, b^{spp}, c^{spp} and p^{spp} are tuning parameters, and

[1] Implemented by applying the species ratio of the catch in year *y*-2 to the TAC for year *y*-1, as the species ratio for year *y*-1 would not yet be known by the time at which a recommendation for the TAC for year *y* would be required.

$$Pen_y^{spp} = \begin{cases} 0 & \text{if } J_y^{spp} \geq p^{spp} \\ c^{spp}\left(J_y^{spp} - p^{spp}\right)^2 & \text{if } J_y^{spp} < p^{spp} \end{cases} \qquad (3)$$

where

J_y^{spp} is a measure of the immediate past level in the abundance indices for species *spp* as available to use for calculations for year *y.*

Measure of recent trend

The trend measure s_y^{spp} is computed as follows from the species- and coasts- disaggregated GLM-CPUE ($I_y^{WC\_CPUE,spp}$ and $I_y^{SC\_CPUE,spp}$), west coast summer survey ($I_y^{WC\_surv,spp}$) and south coast autumn survey ($I_y^{SC\_surv,spp}$) indices:

- linearly regress $\ln I_y^{WC\_CPUE,spp}$ and $\ln I_y^{SC\_CPUE,spp}$ *vs* year *y'* for $y' = y - p$ to $y' = y - 1$, to yield two regression slope values $s_y^{WC\_CPUE,spp}$ and $s_y^{SC\_CPUE,spp}$,
- linearly regress $\ln I_y^{WC\_surv,spp}$ and $\ln I_y^{SC\_surv,spp}$ *vs* year *y'* for $y' = y - p + 1$ to $y' = y$, to yield two regression slope values $s_y^{WC\_surv,spp}$ and $s_y^{SC\_surv,spp}$,

where *p*=6 is the length of the periods considered for these regressions. Note that the reason the trend for surveys is calculated for a period moved one year later than for CPUE is that by the time of year that the TAC recommendation would be computed for the following year, survey results for the current year would be known, but not CPUE as fishing for the year would not yet have been completed. Note also that surveys carried out using the old gear are made comparable to those carried out using the new gear by multiplying them by a species specific calibration factor (0.95 for *M. paradoxus* and 0.8 for *M. capensis*).

Then:

$$s_y^{para} = \left(s_y^{WC\_CPUE,para} + 0.75 s_y^{SC\_CPUE,para} + 0.5 s_y^{WC\_surv,para} + 0.25 s_y^{SC\_surv,para}\right)/2.5 \qquad (4)$$

$$s_y^{cap} = \left(s_y^{WC\_CPUE,cap} + 0.75 s_y^{SC\_CPUE,cap} + 0.5 s_y^{WC\_surv,cap} + s_y^{SC\_surv,cap}\right)/3.25 \qquad (5)$$

Measure of recent level

The measure of the immediate past level J_y^{spp} in the abundance indices is computed as follows:

$$J_y^{para} = \frac{1.0 J_y^{WC\_CPUE,para} + 0.75 J_y^{SC\_CPUE,para} + 0.5 J_y^{WC\_surv,para} + 0.25 J_y^{SC\_surv,para}}{2.5} \qquad (6)$$

$$J_y^{cap} = \frac{1.0 J_y^{WC\_CPUE,cap} + 0.75 J_y^{SC\_CPUE,cap} + 0.5 J_y^{WC\_surv,cap} + 1.0 J_y^{SC\_surv,cap}}{3.25} \qquad (7)$$

with

$$J_y^{WC\_CPUE,spp} = \frac{\sum_{y'=y-3}^{y-1} I_y^{WC\_CPUE,spp}}{\theta^{spp} \sum_{y=2006}^{2008} I_y^{WC\_CPUE,spp}} \tag{8}$$

$$J_y^{SC\_CPUE,spp} = \frac{\sum_{y'=y-3}^{y-1} I_y^{SC\_CPUE,spp}}{\theta^{spp} \sum_{y=2006}^{2008} I_y^{SC\_CPUE,spp}} \tag{9}$$

$$J_y^{WC\_surv,spp} = \frac{\sum_{y'=y-2}^{y} I_y^{WC\_surv,spp}}{\theta^{spp} \sum_{y=2007}^{2009} I_y^{WC\_surv,spp}} \tag{10}$$

and

$$J_y^{SC\_surv,spp} = \frac{\sum_{y'=y-2}^{y} I_y^{SC\_surv,spp}}{\theta^{spp} \sum_{y=2007}^{2009} I_y^{SC\_surv,spp}} \tag{11}$$

with

θ^{para}= 1.67 and θ^{cap} = 1.50,

Maximum allowable change in TAC

While the maximum allowable annual increase in TAC is 10%, the maximum allowable decrease in TAC from one year to the next is:

$$MaxDecr_y = \begin{cases} 5\% & \text{if } J_y > Q_{\min} \\ \text{linear between } 5\% \text{ and } 25\% & \text{if } Q_{\min} - 0.2 \le J_y \le Q_{\min} \\ 25\% & \text{if } J_y < Q_{\min} - 0.2 \end{cases} \tag{12}$$

where

$$J_y = \frac{J_y^{para} + J_y^{cap}}{2} \tag{13}$$

and

$Q_{\min}$ is a tuning parameter.

Procedure in event of missing data

CPUE data

Non-availability of data to compute the GLM-standardised CPUE series for each species is not anticipated.

Survey data

a) If at most two of the four survey estimates are not available in a given year, the computations continue as indicated, with the missing data omitted from the regression estimates of *slope.*

b) If more than two such estimates are missing, or if for more than one survey two years have been missed, computations will continue on the basis in a), but an OMP review will commence immediately.

Table 1: Tuning parameters for OMP-2010

	M. paradoxus	*M. capensis*
λ_{up}	1.25	
λ_{down}	1.50	
T_y^{spp}	0.75% if $y < 2015$ linear between 0.75% and 0% $2015 \le y \le 2018$ 0% if $y \ge 2019$ i.e. 0.75, 0.5, 0.25 and 0% for years 2015 to 2018 respectively	0%
w_y	1 if $y \le 2011$ linear between 1 and 0.5 $2012 \le y \le 2015$ 0.5 if $y \ge 2016$	i.e. w_{2012}=1, w_{2013}=5/6, w_{2014}=4/6, w_{2015}=0.5
a^{spp}	104.5	40
b^{spp}	60	20
c^{spp}	180	20
p^{spp}	0.75	0.75
$Q_{\min}$	0.75	

Appendix A

A summary of the General Linear Modelling approach applied to standardize the CPUE data for the offshore trawl fishery for *Merluccius capensis* and *M. paradoxus* off the coast of South Africa for input to the hake OMP.

A1. Introduction

The models applied to standardize the CPUE data of *Merluccius capensis* and *M. paradoxus* caught offshore off the coast of South Africa are summarised here. This is not straightforward because CPUE indices are required at the species level, but the offshore trawl commercial catch data are recorded only for both species combined. Consequently algorithms developed by Gaylard and Bergh (2009), which make use of species proportions by size at depth, as estimated from research surveys, have been applied to split the hake catches by species at a coast level (west and south) before combining the data from both coasts to perform coast-combined species-specific analyses. Note that this approach can be used from 1978 onwards only, as prior to that the depth of drags was not recorded.

The data used in the analyses are obtained from the Marine and Coastal Management (MCM) demersal database. Appendix B provides a description of the information contained in this database and the process followed to ready the data for analysis purposes.

A2. Separating the species

The algorithms from Gaylard and Bergh (2009) that are used to split the catches by species are summarized below. These splits are made for each trawl.

The proportion of *M. capensis* in trawl *i* and coast/size class component *j* is calculated by:

$$\overline{p}_{i,j} = \frac{1}{1+e^{B_{i,j}}} \qquad \text{(A1)}$$

with $$B_{i,j} = \kappa_j \left[d - \left(d_j^* + \alpha_{y,j} + \beta_{L,j} \right) \right] \qquad \text{(A2)}$$

where:

κ_j	is the slope parameter for and size/coast component *j;*
d	is the trawl depth in metres;
d_j^*	is a the shift for and size/coast component *j;*
$\alpha_{y,j}$	is the year parameter for year *y* and size/coast component *j;*
$\beta_{L,j}$	is the alongshore parameter for alongshore category *L* and size/coast component *j;*

The parameter values estimated are shown in Tables A1 and A2. These will not be updated over time while the OMP is being implemented.

A3. The General Linear Models

The following two models (equations A3 and A4) are applied to the *M. capensis* and *M. paradoxus* CPUE data respectively:

$$\ell n(\mathrm{CPUE}_{\mathrm{capensis}}+\delta)=\alpha+\beta_{year}+\gamma_{depth}+\eta_{area}+\kappa_{seas}+\lambda_{vessel}+\nu(\mathrm{snoek\,CPUE}) \\ +\nu'(\mathrm{snoek\,CPUE})^2+\varpi(\mathrm{hmack\,CPUE})+\varpi'(\mathrm{hmack\,CPUE})^2 \quad \text{(A3)} \\ +interactions+\varepsilon$$

$$\ell n(\mathrm{CPUE}_{\mathrm{paradoxus}}+\delta)=\alpha+\beta_{year}+\gamma_{depth}+\eta_{area}+\kappa_{seas}+\lambda_{vessel}+\nu(\mathrm{snoek\,CPUE}) \\ +\nu'(\mathrm{snoek\,CPUE})^2+\varpi(\mathrm{hmack\,CPUE})+\varpi'(\mathrm{hmack\,CPUE})^2 \quad \text{(A4)} \\ +interactions+\varepsilon$$

(Note: to avoid clutter, the subscripts "*capensis*" and "*paradoxus*" for the parameters of equations A3 and A4 have been omitted.)

where: $\mathrm{CPUE}_{\mathrm{capensis}}$ is the catch of *M. capensis* per unit of (hake-directed – the recorded data specifies the target species for each trawl) effort,

$\mathrm{CPUE}_{\mathrm{paradoxus}}$ is the catch of *M. paradoxus* per unit of (hake-directed) effort,
α is the intercept,

year is a factor with 32 levels (1978-2009) associated with the year effect,

depth is a factor with 8 levels in both the *M. capensis* and *M. paradoxus* models:

$d1_{wc}$: 0 - 100m
$d2_{wc}$: 101 - 200m
$d3_{wc}$: 201 – 300m
$d4_{wc}$: 301 – 400m
$d5_{wc}$: > 400m
$d6_{sc}$: 0 - 100m
$d7_{sc}$:101 - 200m
$d8_{sc}$: > 200m

area is a factor with 6 levels in both the *M. capensis* and *M. paradoxus* models:

$a1_{wc}$: ⍰ 31°00S
$a2_{wc}$: 31°00S - 33°00S
$a3_{wc}$: 33°00S - 34°20S
$a4_{wc}$: > 34°20S
$a5_{sc}$: < 22°00E
$a6_{sc}$: ≥ 22°00E,

seas is a factor with 4 levels in both the *M. capensis* and *M. paradoxus* models:

Summer: December - February
Autumn: March - May
Winter: June - August
Spring: September - November,

vessel is a factor associated with each individual vessel in the dataset being analyzed (detailed in Appendix B). Note that for the same vessel, different values of this factor may be estimated for *M. capensis* and *M. paradoxus*.

snoek CPUE and hmack CPUE refer to the CPUE of the bycatch species snoek and horse-mackerel respectively (unlike other major by-catch species, these two species tend **not** to co-occur with hake, so that trawls with proportionally larger catches of these two are reflective of some redirection of fishing effort away from hake, of which account needs to be taken in the GLM),

interactions refer to *year×depth*, *year×area* and *depth×area* interactions which allow for spatial density patterns which have changed over time, and ε is the error term, assumed to follow a normal distribution.

δ is a (usually small) constant added to the CPUE of the species being modelled to allow for the occurrence of zero CPUE values - here δ is taken to be 10% of the average nominal CPUE of the species being modelled in the respective datasets, and will change each year as the CPUE database is augmented given new data.

A4. Standardizing the CPUE

The introduction of interactions with year requires that the standardized CPUE (assumed to provide an index of local density) be integrated over area to determine an index of abundance. The boundary separating the west and south Coasts is shown in Figure A1 as being from Cape Agulhas to the tip of the Agulhas Bank so that the whole of the major fishing area of Brown's Bank is included in the west coast. The sizes for depth/latitude (west coast) and depth/longitude (south coast) combinations are shown in Tables A2 and A3.

The formula applied to standardize the CPUE for *M. capensis* and *M. paradoxus* is therefore:

$$CPUE_y = \sum_{strata} \left[e^{\{\alpha + \beta_{year} + \gamma_{depth} + \eta_{area} + \text{autumn} + \text{median vessel estimate} + \nu(\text{snoek } \overline{CPUE}) + \nu'(\text{snoek } \overline{CPUE^2}) + \varpi(\text{hmack } \overline{CPUE}) + \varpi'(\text{hmack } \overline{CPUE^2}) + \text{interactions}\}} - \delta \right] * \frac{A_{stratum}}{A_{total}} \qquad \text{(A5)}$$

where $A_{stratum}$ is the size of the area of the stratum in nm^2 (e.g. depth 200-300m and latitude 31 - 33°), and

A_{total} is the total size of the area considered (it is not strictly necessary to divide by A_{total}, but this keeps the units and size of the standardised CPUE index comparable with those of the basic CPUE data).

For the west coast the standardised CPUE is calculated for depths > 200m since very little fishing takes place at depths below 200m. The majority of hauls within the 0 - 200m depth range occur very close to the 200m depth contour, and accordingly are of questionable representativeness of densities within the whole depth-latitude stratum to which the above equation would take them to refer. Similarly, the standardized CPUE for the south coast is calculated for depths > 100m only.

Reference

Gaylard, J.D. and M.O. Bergh. 2009. Update of the hake species split models in the light of more recent survey data and a revision of the large/medium/small size classification. Unpublished document: MARAM IWS/DEC09/HP/14. 13pp.

Table A1: Parameter values related to the West Coast for substitution into equations (A1) and (A2) (Gaylard and Bergh, 2009).

		Large	Medium	Small
	κ[2]	0.03724	0.03707	0.04694
	d*	379.66	300.93	217.98
longshore (latitude) factors β_L	North of 29° S	0.00	0.00	0.00
	29° to 30° S	-30.50	-47.35	-49.81
	30° to 31° S	-27.77	-43.69	-51.74
	31° to 32° S	-21.33	-52.04	-41.81
	32° to 33° S	-40.72	-57.25	-30.87
	33° to 34° S	-68.62	-60.83	-28.85
	34° to 35° S	-47.40	-39.53	-18.12
	South of 35° S	-47.31	-58.96	-25.60
year parameters α_y	≤1984	-15.91	53.20	35.54
	1985	-5.96	76.11	31.57
	1986	17.51	71.78	3.44
	1987	-1.27	61.00	-3.03
	1988	8.34	25.49	37.50
	1989	-23.43	52.14	31.55
	1990	2.05	2.87	1.26
	1991	-49.43	46.96	12.79
	1992	-15.61	39.84	2.97
	1993	-15.65	42.00	-9.63
	1994	0.00	0.00	0.00
	1995	-13.57	48.88	-1.14
	1996	-15.49	-5.49	-13.98
	1997	-3.83	5.68	-0.04
	1998[3]	***0.92***	***33.52***	***9.96***
	1999	14.67	39.43	33.98
	2000	8.31	94.44	19.88
	2001	69.08	43.73	-4.83
	2002	13.87	1.61	-19.71
	2003	-5.62	68.69	22.69
	2004	33.74	54.98	-12.66
	2005	12.85	28.49	-17.11
	2006	-3.32	23.53	24.87
	2007	-11.61	73.50	-8.69
	2008	-12.34	0.00	0.00
	2009	0.00	0.00	0.00

[2] Note that the κ values were erroneously reported as negative values in Gaylard and Bergh (2009).
[3] The average of the parameter estimates for 1996, 1997, 1999 and 2000.

Table A2: Parameter values related to the South Coast for substitution into equations (A1) and (A2) (Gaylard and Bergh, 2009).

		Large	Medium	Small
	κ[4]	0.03457	0.05547	0.15184
	d*	346.75	238.82	206.64
longshore (longitude) factors β_L	West of 21° E	0.00	0.00	0.00
	21° to 22° E	60.40	44.52	11.04
	22° to 23° E	-107.35	-65.27	-31.23
	23° to 24° E	-102.50	-81.32	-30.82
	24° to 25° E	-72.34	-74.22	-36.81
	25° to 26° E	15.10	24.78	-23.91
	East of 26° E	44.10	-8.17	-22.50
year parameters α_y	≤1986	88.72	31.47	-21.40
	1987	44.63	32.34	-29.00
	1988	66.22	46.35	-13.28
	1989	406.96	63.06	-24.05
	1990	28.50	66.32	-21.82
	1991	68.98	202.05	41.78
	1992	66.43	69.58	-21.71
	1993	78.08	28.07	-41.73
	1994	42.03	48.27	-30.41
	1995	29.59	60.06	-39.47
	1996	-35.72	21.34	-26.58
	1997	-33.04	22.47	-33.48
	1998[5]	***-11.97***	***16.63***	***-27.00***
	1999	8.79	8.97	-30.56
	2000	12.09	13.72	-17.38
	2001	74.09	79.25	-25.22
	2002[6]	***14.16***	***33.99***	***-23.19***
	2003	-46.28	13.49	-35.70
	2004	16.73	29.50	-14.46
	2005	-35.95	29.52	-23.38
	2006	18.67	12.64	-33.46
	2007	12.18	34.67	-24.76
	2008	62.53	48.34	-26.02
	2009	0.00	0.00	0.00

[4] Note that the κ values were erroneously reported as negative values in Gaylard and Bergh (2009).
[5] The average of the parameter estimates for 1996, 1997, 1999 and 2000.
[6] The average of the parameter estimates for 2000, 2001, 2003 and 2004.

Table A3: The sizes of the areas (nm^2) covered by each of the latitude/depth combination strata on the West Coast.

	Depth (m)				
Latitude (S)	0-100	101-200	201-300	301-400	401-500
31^{o}00	906.84	6712.13	3597.79	800.68	657.12
31^{o}00-33^{o}00	1179.97	3383.32	2842.35	2382.84	1426.62
33^{o}00-34^{o}20	1052.23	93.57	882.33	458.3	500.59
>34^{o}20	933.14	2869.8	751.5	507.76	438.24

TABLE A4: The size of the area (nm^2) covered by longitude/depth combinations on the South Coast.

	Depth (m)			
Longitude (E)	0 - 50	51 - 100	101 - 200	201 - 500
< 22^{o}	441.63	3734.59	6910.87	839.05
22^{o}	1051.58	3861.35	8469.5	2534.82

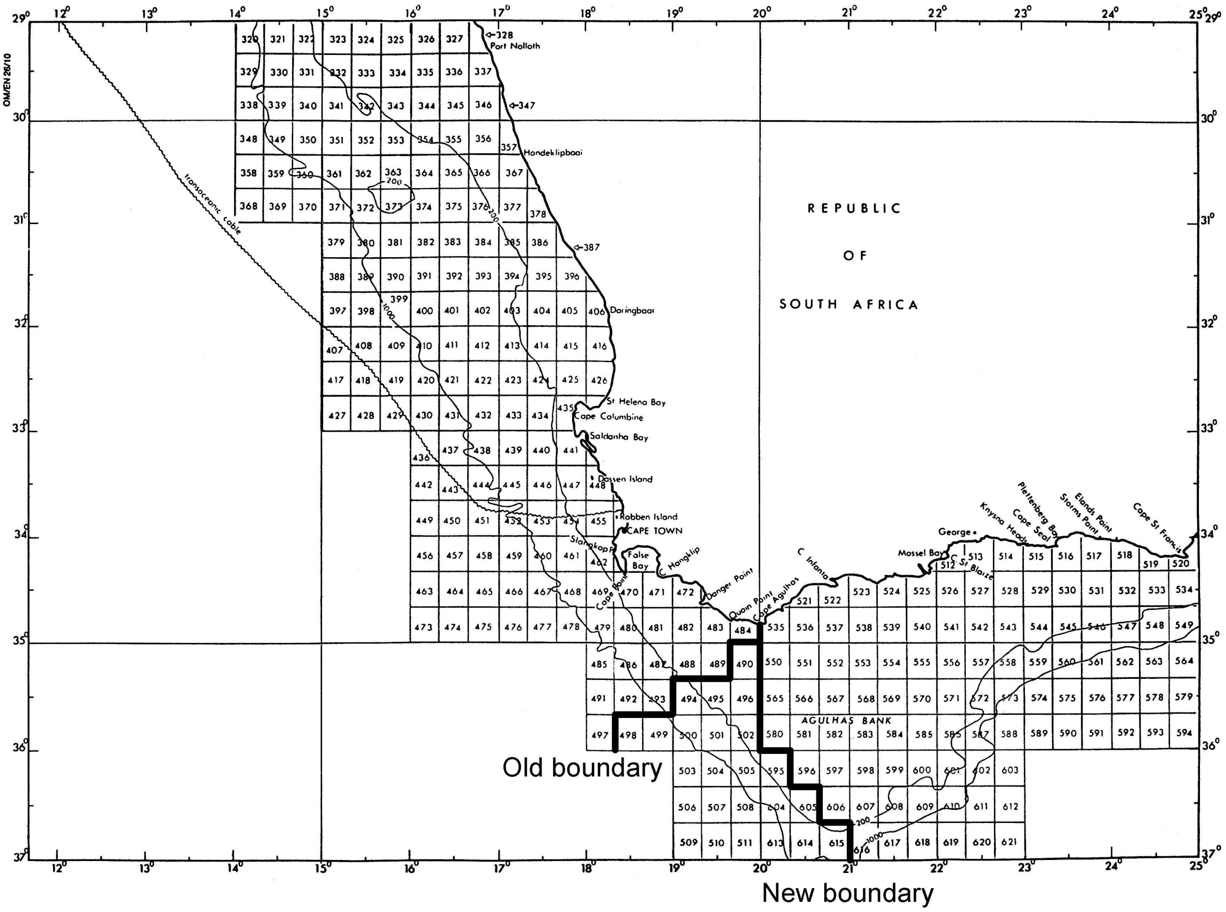

Figure A1: Demarcation of boundaries separating the west and south coasts in the hake fishery. The “Old boundary” was set by ICSEAF and was used to separate coasts until 2004 after which it was agreed by the MCM Demersal Working Group to adopt the “New boundary” for future analyses so that the boundary did not split Brown’s Bank. The depth contours shown are the 200m and 1000m contours respectively.

Appendix B

The database and associated problems

[See MCM/2009/OCT/SWG-DEM/72 for full details]

B1. The database and associated problems

Hake catches are reported in two ways:

i) Fine scale data: On the vessel the skipper estimates the catch for each drag, as well as recording important information on depth, longitude and latitude, time and effort [called the "drag" data].

ii) Onshore when the vessel is offloaded (called a landing), catches are more accurately measured for each product category [called the "landing" data]. Each landing is associated with a number of drags made at sea.

When a hake vessel returns from a fishing trip the vessel lands and the catch is discharged to a shore-based processing establishment. The discharged catch for some product categories is graded by size (weight) into product size categories. The catch per product size category is weighed and the total mass (landed_mass) is recorded on the landing sheet. A landing consists of more than one drag (trawl) and the catch estimates per drag are derived from a skipper's estimate made while at sea. At Branch Fisheries the landing is captured first in order to keep track of how much of the TAC has been caught. The captured landing data are then proof-read before the drags are captured. There are 242 species and category codes used in the database of which 59 are for hake alone. A procedure called *Convert to Real Mass* (CRM) is run at the close of each day and when a landing is updated. This procedure scales actual landed mass values to correspond with cleaned mass estimates (for the trip) and then calculates a nominal mass using a raising factor for each species and category code. If a species and category code exists in the landing but not in any of the drags (e.g. skipper only estimates for catch of large hake but factory produces large and medium) then that category is assigned to a table known as drags-no-effort (dne) as it is essentially fish that was landed but not caught.

The input data set used in the CPUE GLM analysis is based on the drag data which are modified in such a way so that the catches (by tonnage) are scaled to reflect the more accurate measures of catch contained in the landing data.

There are several problems associated with the drag data that are extracted for input into the GLM CPUE analysis, particularly with respect to the data post-2000:

a) some of the landing records could not be matched perfectly with the associated drag files due to mismatched product codes. If this problem occurred, then all drag records associated with that landing were excluded from the GLM input drag data.

b) not all category codes were included in the data extracts.

c) The GLM input drag data often in recent years has excluded drags which had no catch associated with them. In large part this reflects the freezer vessels which generally report what is referred to as "daily tallies" where they report all the catch for one day against the last drag of the day. These drag records are flagged as daily tallies in the database to distinguish from drag tally records. As these fishing trips usually last 30 days with at least 3/4 trawls per day the number of drags without catch can be appreciable. How this came to pass is unclear as not all drags without catch were omitted from the previous GLM input drag data when compared with the full database.

In order to improve the percentage of data included in the GLM input the following was done:

- A file containing all the drags that are omitted from the final input to the GLM was created (called non-input drag file)
- A file containing all the landings that could not be matched to drag files was created (called non-input landing file)
- At the non-input landing level, sum hake to get the total hake catch for that landing (Lhake)
- In the non-input drag file, at the drag level, sum hake to get the total hake per drag
- Apportion Lhake across the drags of the non-input drag file in a pro-rata basis to create a new total hake per drag
- Use size structure proportions per season/area/depth to split the total hake catch per drag into small, medium and large hake. These proportions were derived from the data that are currently included in the GLM analyses (after all exclusions have been applied), and are simply the proportions of small, medium and large hake within a given cell which, for each year, is defined by a depth range, latitude range (for the West Coast) or longitude range (for the South Coast), and quarter (Jan-Mar, Apr-Jun, July-Sept and Oct-Dec). The reason for defining cells at a quarterly level rather than a monthly level was to avoid getting cells which had no or very few samples in them. Even at the quarterly level there was a need to aggregate across lat (or long) within some depth ranges to ensure sample sizes in each cell greater than or equal to 5.

This process allows for the non-mapped landings to be included in the GLM analyses.

The current preparation of data for GLM purposes requires a number of exclusions to be applied before accumulating the catch and effort data on a daily basis before processing. These exclusions are as follows:

1. Exclude all landings where there is only one drag.
2. Exclude all landings where SizedHake = ∑ (HGSml + HGMed + HGLar) = 0
3. Exclude all landings which have fillets in the corresponding dne records
4. Exclude all landings where drag∑HGLar = 0 and dnePQ > 0
5. Exclude all landings where dneSizedHake = 0
   (HakeFillets = FilSml + FilMed + FilUng is calculated but NOT excluded)
6. Exclude all landings where ∑Hake=0
7. Distribute dnePQ into the HGLar column across the drags and add the value to Hake, also add the HakePQ using the formula HGLar + dnePQ * HGLar/∑HGLar +HakePQ
8. Exclude all drags which have SizedHake = 0 and HGUng>0
9. Distribute HGUng over HG Size (e.g. HGSml + HGSml/SizedHake *HGUng)
10. Distribute dneHGUng and dneBroken over HG Size (e.g. HGSml + HGSml/SizedHake *dneHGUng +dneBroken)
11. Exclude all drag_ID where grid > 899
12. Exclude all drag_ID where effort ≤ 0

There were a number of cases in the drag data where ungraded hake was positive, but the small, medium and large size categories all had zeros recorded. These are erroneous and such drags (and not the entire landing) were deleted.

B2. Data accumulation

Because of the practice of daily tallies the data are accumulated on a daily basis for each vessel before attempting GLM analyses.

The following criteria were adopted for accumulating the database.

- If fishing took place in more than one Division (see Table B1 for explanation of Division) within a day for a particular vessel, the data were allocated to the Division in which at least 2/3 of the drags took place. If a 2/3 majority was not achieved, the records were ignored.

- Different net mesh sizes[7] (75mm, 85mm and 110mm) may have been used on a day. If this occurred, the net mesh size which was used on least 2/3 of the drags for any given vessel was allocated to that day. If there was no two thirds majority, the mesh size was recorded as missing. Two records in the database had a mesh size of zero recorded. In both cases, 110mm was used on all other trawls of the day. Therefore a mesh size of 110mm was assumed for those two records.

- If hake was the recorded target species on at least 2/3 of the drags then the day was recorded as hake-targeted, otherwise it was recorded as non-hake targeted.

- If no depth was recorded for a particular drag (i.e. depth = 0 or 999), it was assumed to be the average depth of the other drags on that day for that particular vessel.

- If fishing took place in two Divisions on one day, the average latitude and longitude pertains only to the latitude and longitude recorded for the dominant Division.

- Namibian and foreign vessels (vessel code ≥ 500) were excluded from the accumulated file.

Hence, for a particular vessel, the Demersal database was accumulated over a day, summing over the catches and effort, averaging over depth, latitude and longitude, and including the Division, target species and net mesh size as determined by the decision criteria above.

The analyses are further restricted to offshore companies, a list of which is provided in Table B2.

B3. Identifying potential errors

It is possible that recording errors (typo's) may occur in a database as large as the Demersal one, and an objective means of identifying and excluding erroneous records from the analyses was sought. This was achieved by applying a "99% quantile rule". Within the accumulated data, any records (days) where the hake CPUE or bycatch CPUE values exceeded the annual 99% quantile for each CPUE respectively (see Tables B3 and B4), were excluded from the analysis. In addition, any effort values that exceeded 1090 minutes on the West Coast and 865 minutes on the South Coast were considered to be potential "mistakes" and were also excluded from the analysis.

A number of records in the accumulated database had positive effort, but zero total catch (i.e. hake + all bycatch species) recorded. It was assumed that these records reflected an aborted drag for some reason or another, and they were therefore excluded from the analyses.

Since the analyses are concerned with the hake stocks, only those days on which hake was recorded as the target species were included in the analyses.

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[7] The net mesh size reported in the database refers to the net mesh size that was legally allowed, and not the size that was actually used. New log books that were phased in during 2004 makes allowance for skippers to record the actual mesh size used. Some skippers however continue to record the legal limit for their permit, and not the actual mesh size used. Industry made extensive use of liners in the late 1970s and in the 1980s (and perhaps even in the 1990s), thereby greatly reducing the mesh size. Although Industry recently provided a range of possible years over which the use of liners was believed to have been phased out, the diversity of this range precludes this information from being used in any quantitative manner.

Reference

Fairweather, T., Glazer, J., Leslie R., De Decker M., Johnston S and Butterworth D.S. 2009. Hake Data: problems, solutions and GLM CPUE sensitivity to alternate scenarios. Unpublished Working Group Document, MCM/2009/OCTOBER/SWG-DEM/72. 26pp.

TABLE B1: The drag information extracted from the demersal database to be used in the GLM analysis.

Company code (a code assigned to each fishing company for identification purposes)
Vessel code (a unique code assigned to each fishing vessel for identification purposes)
Power factor (as crudely calculated in the early 1970s)
Vessel class (vessels were separated into broad categories according to their gross registered tonnage)
Landing date (Date on which the catch was landed at port)
Drag date (Date on which a drag took place)
Start time (Time (hour and minutes) at which drag started)
Effort (the amount of time net was dragged; recorded in minutes)
ICSEAF Division (identifying the Division in which the catch took place – Division 1.6 refers to the West Coast, and Divisions 2.1 and 2.2 refer to the South Coast)
Grid block in which catch was taken (the fishing grounds are divided into 20 minute squares so that catch positions can be reported accurately)
Depth at which catch was taken
Mesh size used (75mm, 85mm or 110mm)
Species targeted[8]
Total hake[9] catch (kg)
Total horse mackerel[3] (*Trachurus trachurus capensis*) catch (kg)
Total monk[3] (*Lophius vomerinus*) catch (kg)
Total kingklip[3] (*Genypterus capensis*) catch (kg)
Total East Coast sole[3] (*Austroglossus pectoralis*) catch (kg)
Total West Coast sole[3] (*Austroglossus microlepis*) catch (kg)
Total snoek[3] (*Thyrsites atun*) catch (kg)
Total mackerel[3] (*Scomber japonicus*) catch (kg)
Total white squid[3] (*Loligo vulgaris reynaudii*) catch (kg)
Total red squid[3] (*Todapopsis eblanae*/*Todarodes angolensis*) catch (kg)
Total catch (kg) of other species[10] (e.g. ribbon fish (*Lepidopus caudatus*), panga (*Pterogymnus laniarius*))
Amount of hake (kg) which make up the large hake size category
Amount of hake (kg) which makes up the medium hake size category
Amount of hake (kg) which makes up the small hake size category
Amount of hake (kg) which makes up the ungraded hake category
Amount of hake (kg) which makes up the small fillets hake category
Amount of hake (kg) which makes up the medium hake fillets category
Amount of hake (kg) which makes up the ungraded hake fillets category
Amount of hake (kg) which makes up PQ hake category
Latitude position at which catch was taken (minutes have been converted to decimalized minutes)
Longitude position at which catch was taken (minutes have been converted to decimalized minutes)

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[8] Analyses are restricted to drags/days indicated as hake-directed. However, this field was not completed consistently, so that many indications of "hake direction" in fact reflected effort directed at other species. Although hake is generally the dominant species in the catch and the primary target in most trawls, fishermen often fish in areas or use methods that maximize the catch of certain bycatch species, with a resultant decrease in the hake catch rate. These drags are usually also recorded as hake directed.

[9] Space is provided in the log books for declaring the amount of each of these species caught. Apart from hake, the other species are referred to as declared bycatch.

[10] Space was not provided in the old log books for declaring the catch of these species. The catch of each of these species was determined only at the landing site, and apportioned across the drags of the trip in the same ratio of the catch of targeted species across drags. These species are therefore referred to as undeclared bycatch. The new logbooks (phased in during 2004) provide for the recording all possible species caught per drag.

TABLE B2: The company codes of the offshore companies included in the GLM analyses.

Company Code			
1	112	144	185
2	113	153	187
3	114	154	188
27	115	155	189
35	117	156	190
36	118	157	191
46	119	158	192
54	120	159	193
55	121	160	194
56	122	161	195
61	123	162	196
62	126	163	197
63	127	164	198
68	128	166	199
69	129	167	200
70	130	168	201
100	131	169	202
101	132	170	203
102	133	171	204
103	134	172	205
104	136	173	206
105	137	174	207
106	138	175	210
107	139	176	211
108	140	178	212
109	141	182	213
110	142	183	
111	143	184	

TABLE B3: Year-specific 99% quantiles for West Coast hake CPUE and bycatch CPUE.

Year	99% Quantile for hake CPUE (kg/min)	99% Quantile for bycatch CPUE (kg/min)
1978	61.71	32.69
1979	75.67	34.51
1980	62.34	28.07
1981	57.22	21.94
1982	70.44	23.61
1983	63.53	24.18
1984	84.05	26.74
1985	80.65	27.89
1986	96.51	29.09
1987	75.08	30.93
1988	93.62	54.64
1989	84.83	85.83
1990	110.74	77.87
1991	107.50	58.89
1992	91.56	52.74
1993	107.97	53.85
1994	152.88	39.62
1995	95.30	39.41
1996	108.28	33.66
1997	92.87	27.20
1998	118.39	36.81
1999	110.66	25.34
2000	118.45	20.09
2001	98.39	12.27
2002	71.61	9.80
2003	82.02	12.86
2004	68.61	21.93
2005	65.33	27.81
2006	68.39	18.63
2007	92.18	23.21
2008	110.77	20.35
2009	117.74	30.43

TABLE B4: Year-specific 99% quantiles for South Coast hake CPUE and bycatch CPUE.

Year	99% Quantile for hake CPUE (kg/min)	99% Quantile for bycatch CPUE (kg/min)
1978	48.41	49.37
1979	63.28	71.91
1980	54.39	58.81
1981	40.04	55.73
1982	74.81	48.44
1983	61.74	73.63
1984	64.93	38.43
1985	71.87	49.73
1986	93.77	52.22
1987	98.62	34.82
1988	80.83	64.58
1989	84.04	65.00
1990	111.03	59.91
1991	146.56	63.68
1992	167.83	59.18
1993	107.22	106.28
1994	100.64	56.05
1995	75.14	85.77
1996	132.83	48.67
1997	100.77	34.50
1998	103.63	40.53
1999	198.11	41.79
2000	124.77	39.83
2001	135.53	48.41
2002	153.20	31.61
2003	83.96	31.46
2004	110.02	24.51
2005	86.62	32.19
2006	103.41	15.21
2007	118.63	25.45
2008	132.25	30.09
2009	214.79	42.55

Appendix C

Demersal Research Surveys – sampling strategy, data collection, raised length frequencies and calculation of abundance estimates as applied to Cape hakes (*Merluccius capensis* & *M. paradoxus*)

[See MCM/2009/JULY/SWG-DEM/53 for further details]

Survey Design

Demersal surveys cover the same geographical range each year. West coast surveys extend from the coast out to the 500 metre isobath and from the international border between South Africa and Namibia to Cape Agulhas (20° E longitude), while South coast surveys cover the same depth range from Cape Agulhas to 27° E longitude. Stations are selected using a pseudo-random stratified sampling design. The area is divided into depth strata and each stratum is further subdivided into 1° latitude substrata on the West Coast (Table 1a) and 1° longitude substrata on the South Coast (Table 1b). Stations within each substratum are selected at random, and the number of target stations per substratum is proportional to the area of the substratum.

Table 1a: Area (nm^2) of depth and latitude strata used on the West coast of South Africa for Demersal Surveys

<table>
<tr><th>Lat\Depth</th><th>000-100</th><th>101-200</th><th>201-300</th><th>301-400</th><th>401-500</th></tr>
<tr><td>28°30-29</td><td>239.27</td><td>312.53</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>29-30</td><td>345.3</td><td>4098.38</td><td>447.49</td><td>173.26</td><td>252.3</td></tr>
<tr><td>30-31</td><td rowspan="2">687.55</td><td>2301.22</td><td>3150.3</td><td>627.42</td><td>404.82</td></tr>
<tr><td>31-32</td><td>2080.96</td><td>1535.9</td><td>1121.03</td><td>1016.07</td></tr>
<tr><td>32-33</td><td>814.69</td><td>1302.36</td><td>1306.45</td><td rowspan="2">1585.85</td><td rowspan="2">824.19</td></tr>
<tr><td>33-34</td><td>678.16</td><td>860.71</td><td>550.25</td></tr>
<tr><td>34-35</td><td>1244.8</td><td>1366.69</td><td>641.22</td><td rowspan="2">709.32</td><td rowspan="2">521.71</td></tr>
<tr><td>35-36°20</td><td>62.41</td><td>1820.77</td><td>896.65</td></tr>
<tr><td>TOTAL</td><td>4072.18</td><td>14143.62</td><td>8528.26</td><td>4216.88</td><td>3019.09</td></tr>
</table>

Table 1b: Area (nm^2) of depth and longitude strata used on the South coast of South Africa for Demersal Surveys

Long\Depth	000-050	051-100	101-200	201-500
20-21	303.57	1804.2	3750.72	454.22
21-22	138.06	1930.39	3804.62	839.05
22-23	230.39	2080.29	3389.52	1206.37
23-24	100.36	651.68	1783.61	533.91
24-25	183.39	231.76	1419.01	347.78
25-26	330.65	385.01	978.24	281.79
26-27	206.79	512.61	899.12	164.97
TOTAL	**1493.21**	**7595.94**	**16024.84**	**3828.09**

It is worth noting that not all trawls completed during the surveys are valid to be used for abundance estimates. In order to be valid, trawls must be 20-35 minutes in duration at a speed of 3 to 3.5 knots. Should the net encounter hard ground, the damage must have compromised the catch composition before the trawl is discounted. There has been considerable variation in the duration of trawls over the years (Figure 1).

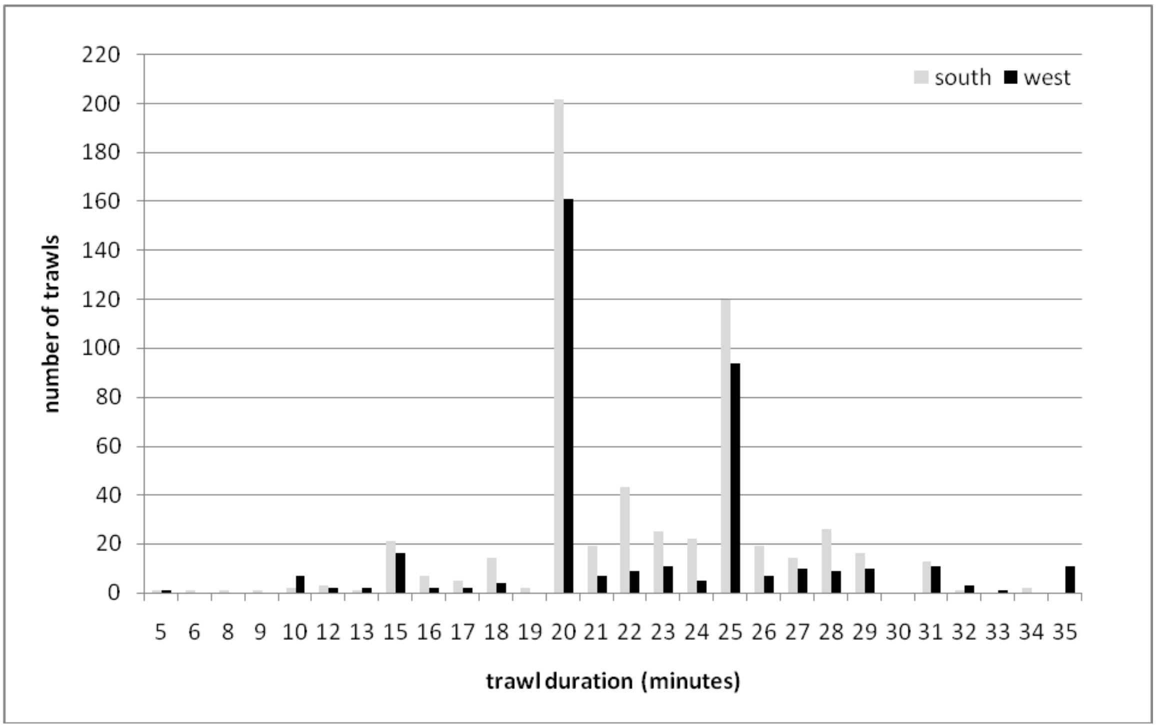

Figure 1: Distribution of trawl durations illustrated for West and South coast demersal abundance surveys

Gear Type

Surveys conducted on the *RV Africana* between 1985 and September 2003 used a 2-panel German 180 ft trawl net with a rope-wrapped chain footrope, 150kg lift and 1500kg WV doors. In 2003 "new" gear was introduced consisting of a 4-panel German 180 ft trawl net with a modified rockhopper footrope, 150kg lift and 1500kg Morgere multi-purpose doors and has been used as standard on RV Africana since with the exception of the surveys completed in 2006. Standard gear on *RV Fridtjof Nansen* is a Modified Gissand shrimp trawl net.

Summary of Demersal Abundance Surveys

West coast surveys were completed bi-annually (summer and winter) from 1983 to 1990, and in summer only from 1991 onwards (Table 2). The data from the first survey (summer 1983) are not used as this is regarded as a learning or "shake-down" survey. Extensive use was made of bobbin-gear during the 1983 and 1984 surveys, as many of the stations were in areas that were previously untrawled. From 1985 onwards, bobbin-gear was no longer used (Payne *et al*. 1986). Consequently the abundance estimates from the first two years may not be compatible with the rest of the time-series, as the selectivity of the bobbin-gear differs from that of the footrope-trawl gear used from 1985 onwards. During the summer survey of 1989, the vessel broke down after only 25 stations were completed and the survey was aborted. All surveys subsequent to this were successfully completed with the exception of 1993 where portion of the inshore strata was not adequately surveyed and in 1998 no surveys were completed as the *RV Africana* broke down and had to be completely re-fitted. In 2000 and 2001 the *RV Fridtjof Nansen* was used to conduct the surveys. In 2002 the time series continues with the *Africana* but in 2004.

The first of the south coast surveys was completed in spring (September) 1986 and the first autumn (April/May) survey was completed in 1988 (Table 2). The following two autumn surveys were only completed within the 200m depth contour, as were the spring surveys from 1990 to 1995. With the exception of 2001 and 2002, surveys of the entire south coast shelf up to 500m have been completed every autumn since 1999 (although the *Nansen* was used in 2000). Spring surveys have been conducted intermittently during this period (Table 2).

Table 2: Summary of abundance estimate surveys completed since 1985. Surveys 069 and 109 were inadequately sampled and several south coast surveys were completed within the 200m depth contour as opposed to the entire 500m area. Surveys completed on the *RV Fridjof Nansen* are underlined and *RV Africana* surveys using "new gear" are in bold.

	WEST COAST		**SOUTH COAST**	
year	**Summer (Jan)**	**Winter (July)**	**Autumn (April/May)**	**Spring (Sept)**
1985	AFR 028	AFR 033		
1986	AFR 039	AFR 046		AFR 048
1987	AFR 050	AFR 054		AFR 056
1988	AFR 059	AFR 066	AFR 063	
1989	AFR 069	AFR 075	AFR 072 <200m	
1990	AFR 079	AFR 084	AFR 082 <200m	AFR 086 <200m
1991	AFR 088		AFR 093	AFR 095 <200m
1992	AFR 100		AFR 102	AFR 106 <200m
1993	AFR 109		AFR 111	AFR 116 <200m
1994	AFR 118		AFR 122	AFR 125 <200m
1995	AFR 127		AFR 129	AFR 131 <200m
1996	AFR 133		AFR 135	
1997	AFR 139		AFR 144	
1998	NO SURVEYS COMPLETED AS AFRICANA BROKE DOWN			
1999	AFR 150		AFR 152	
2000	NAN 001		NAN 003	
2001	NAN 004			AFR 160
2002	AFR 165			
2003	AFR 173		AFR 177	**AFR 182**
2004	**AFR 188**		**AFR 191**	**AFR 200a**
2005	**AFR 203**		**AFR 206**	
2006	AFR 214		AFR 217	AFR 224
2007	**AFR 228**		**AFR 232**	**AFR 236**
2008	**AFR 238**		**AFR 241**	**AFR 246**
2009	**AFR 249**		**AFR 252**	

Data collection

At each station, either before or after the trawl a CTD is deployed to measure hydrographic variables (e.g. temperature, salinity, turbidity). These values are captured as the average value measured over every second and binned into defined depths. On occasion, time constraints or bad weather may have precluded the completion of a CTD dip. In the past (and currently) the ship has, where possible, returned to the start position of the trawl and the CTD has been completed. *It is difficult to determine how often this has occurred at present but whether or not this is worthwhile needs to be decided and documented, particularly in terms of time constraints or other limiting factors which would make the dip redundant.*

Once the trawl is hauled and emptied onto the deck the catch is sorted depending on species and size composition:

1. Catch of mainly demersal species: sort into species to weigh, if necessary the hake (and occasionally other species) are separated into size categories when the catch is bimodal. This is done because the reality of sorting fish is that people are inclined to pick up the bigger fish first and thus the first few bins, if not sorted, would be mainly large fish whereas the last would be mainly small fish and neither will be suitable for a length frequency measurement. In addition, either a sub-sample of or all the hake is sexed, within each size category and the sexed hake are also measured.
2. Catch of mainly pelagic species – mixed sizes: occasionally the trawl will encounter a school of pelagic fish – usually redeye, anchovy or horse mackerel. If the catch is large (>1500kg) and includes a varied

size range of demersal species then the demersal species are picked out and separated as discussed above and the pelagic species are weighed and dumped with a sub-sample measure. If the catch is exceptionally large (>2500kg) then the whole catch will be sub-sampled with half or the majority being dumped as “mix” and a reasonable number of bins sorted and used to scale up the catch amount.

3. <u>Catch of mainly pelagic species – small sizes</u>: catches of small pelagic and demersal fish, usually made in shallower water, are sub-sampled (usually one or two bins) and the ratio is used to scale up to the weight of the dumped mix.

This sampling strategy may not have been applied consistently over the duration of the surveys as for a lengthy period the surveys were run entirely by technical staff. For example: the number of hake sexed has increased in recent years but this is also a reflection of different sampling to resolve current questions.

In addition to sorting and weighing all the species in the catch, all possible species are measured or at least counted (*note that the current data system does not allow entry of this number so they will still have to be captured*). The “commercial” species, namely hake, monk, kingklip, squid and sole are dissected to determine individual length, weight, sex, maturity, stomach contents and otoliths (or elisia or statoliths) are removed to allow the fish to be aged.

<u>During the April 2009 survey the following “Hake Sampling Strategy” protocol was officially introduced</u>:

A. If the hake catch is small (less than ca 400kg) or the size range is restricted (ca 40 cm between smallest and largest) then don’t grade the hake.
   1. Take a random sample and sort to male, female, FOG and juvenile
   2. Use the sex ratio from the sexed sample to apportion the unsexed catch into estimated weight of male, female, FOG and juvenile (13*M, 13*F 13*E and 13*J)
   3. Capture length frequency data on a subsample of each of the 4 “sex”-categories

B. If the catch is large and the size range is large (or if there are distinct cohorts eg baby hake) then grade the hake catch into large, small, and baby.
   1. Take a random sample of the large hake
      i. Sort into male, female and FOG
      ii. Use the observed sex ratio to apportion any unsexed large hake into estimated total catch by sex (13*Y, 13*Z, 13*EL)
      iii. Capture length frequency data for each category
   2. Take a random sample of the small hake and sort into male, female, FOG and juvenile
      i. Sort into male, female, FOG and juvenile. If all the small fish are regarded as “juvenile” i.e. a subsample of smalls is not sexed, then these data must be captured as unsexed small (13*B)
      ii. Use the observed sex ratio to apportion any unsexed small hake into estimated total catch of each of the 4 “sex”-categories (13*W, 13*X, 13*J, 13*ES)
      iii. Capture length frequency data for each sex-category
   3. Capture length frequency on a subsample of baby (13*D) hake.

C. Biological data must NOT be split across the different sex/size codes. All fish from a single biological sample must be captured together under any one of the available sex/size codes.

If the hake catch is unsexed for whatever reason then capture the data as ungraded (13*A) or as unsexed large and small (13*B and 13*C). Reserve the code for juveniles (13*J) to refer to juvenile fish that are part of the subsample sorted for sexing. If the catch was such that all the small fish are regarded as too small to sex, then capture as unsexed small (13*B).

Survey abundance indices
Catch data collected during the surveys is used to calculate an abundance estimate by the swept-area survey method. Two basic assumptions of the swept area method are that all fish in the path of the net are caught, and that the fish are distributed homogeneously over the survey area. Both of these assumptions are open to criticism and are difficult to defend. However, it is reasonable to assume that the effects of these two assumptions will not vary much from year to year. Therefore abundance estimates obtained using the swept area method are not regarded as absolute estimates, but rather as relative abundance indices.

The assumption is that each trawl (*j*) within a stratum (*i*) gives an independent estimate of the density in that stratum. Then the average density for all trawls in a stratum will be an estimate of the average density in the stratum. Therefore multiplying the average density (kg/nm^2) by the area of the stratum (nm^2) gives an estimate of the total abundance in that stratum.

1. Calculate the area swept (nm^2) a_{ij} for each trawl: where s_{ij} is the towing speed (knots, nm/hr), t_{ij} is the duration (minutes) and w_{ij} is the horizontal mouth width (m) i.e. the width of the trawl track in the *j*-th trawl of the *i*-th stratum;

$$a_{ij} = s_{ij} \times \frac{t_{ij}}{60} \times \frac{w_{ij}}{1852}$$

2. Calculate the observed density (kg/nm^2) d_{ij} in the *j*-th trawl of the *i*-th stratum for each trawl where C_{ij} is the observed catch weight (kg) of the species and a_{ij} is the area swept (nm^2);

$$d_{ij} = \frac{C_{ij}}{a_{ij}}$$

3. Calculate the mean density (kgs/nm^2) $\overline{d_{i.}}$ per stratum and its standard error $SE(\overline{d_{i.}})$ where d_{ij} is the observed density and n_{ij} is the number of trawls in the *j*-th trawl of the *i*-th stratum;

$$\overline{d_{i.}} = \frac{\sum_{j=1}^{n_{ij}} d_{ij}}{n_{ij}}; \; SE(\overline{d_{i.}}) = \frac{1}{\sqrt{n_{ij}}} \sqrt{\frac{n_{ij} \sum_{j=1}^{n_{ij}} d_{ij}^2 - \left(\sum_{j=1}^{n_{ij}} d_{ij} \right)}{n_{ij}\left(n_{ij} - 1\right)}}$$

4. Estimate abundance per stratum B_i where $\overline{d_{i.}}$ is the mean density and A_i is the area (nm^2) of the i-th stratum, division by 1000 is to get from kg to tons;

$$B_i = \frac{\overline{d_{i.}} \times A_i}{1000}$$

5. The total abundance estimate for the survey area B is the sum of the abundance per stratum B_i over all strata n_s;

$$B = \sum_{i}^{n_s} B_i$$

6. Multiply the standard error of the mean density mean density per stratum by the area of the stratum area to get estimated standard error per stratum;

$$SE(B_i) = \sqrt{\left(SE\left(\overline{d_{i.}}\right) \times A_i\right)}$$

7. Sum the abundance per stratum over all strata to get the total abundance estimate for the survey area.

$$SE(B_i) = \sqrt{\sum_{i}^{n_s} SE(B_i)^2} = \sqrt{\sum_{i}^{n_s} \left(SE(\overline{d_{i.}}) \times A_i\right)}$$

Where *B* is the abundance index for the total survey area, $SE(B_i)$ is the standard error of the abundance index for the *i*-th stratum and $SE(B)$ is the standard error of the overall abundance index.

Survey abundance indices and standard errors for the entire survey is presented in Table 3 for *M. paradoxus* and Table 4 for *M. capensis* – note for both tables the values in bold represent surveys when *RV Africana* used new gear; underlined values were surveys conducted on the *RV Fridtjof Nansen* and shaded surveys only extended to 200m and have therefore been omitted.

References

Payne, A.I.L., C.J. Augustyn and R.W. Leslie 1986 -- Results of the South African hake biomass cruises in Division 1.6 in 1985. *Colln scient. Pap. int. Commn SE. Atl. Fish.* 13(2): 181-196.

Table 3: Survey abundance estimates and associated standard errors (in thousand tons) for *Merluccius paradoxus*

year	WEST COAST				SOUTH COAST			
	Summer (Jan)		Winter (July)		Autumn (April/May)		Spring (Sept)	
	Abundance	SE	Abundance	SE	Abundance	SE	Abundance	SE
1985	169.959	36.680	264.839	52.949				
1986	196.111	36.358	172.477	24.122			13.758	3.554
1987	284.805	53.101	195.482	44.415			21.554	4.605
1988	158.758	27.383	233.041	64.003	30.316	11.104		
1989			468.780	124.830				
1990	282.174	78.945	226.862	46.007				
1991	327.020	82.180			26.638	10.460		
1992	226.687	32.990			24.304	15.195		
1993	334.151	50.234			198.849	98.452		
1994	330.270	58.319			111.469	34.627		
1995	324.554	80.357			55.068	22.380		
1996	430.908	80.604			85.546	25.484		
1997	569.957	108.200			135.192	51.031		
1998								
1999	562.859	116.302			321.478	113.557		
2000	328.773	36.910			14.880	4.256		
2001	276.539	34.826					19.929	9.956
2002	267.487	35.068						
2003	411.177	69.431			108.857	37.528	**88.442**	**36.051**
2004	**259.527**	**56.021**			**48.898**	**20.343**	**63.900**	**17.894**
2005	**286.416**	**39.849**			**26.605**	**7.952**		
2006	315.310	49.490			34.799	8.325	72.415	15.500
2007	**392.812**	**70.043**			**129.646**	**60.661**	**52.287**	**19.231**
2008	**246.542**	**51.973**			**39.505**	**11.408**	**24.816**	**8.775**
2009	**330.235**	**28.526**			**102.834**	**28.670**		

Table 4: Survey abundance estimates and associated standard errors (in thousand tons) for *Merluccius capensis*

year	WEST COAST				SOUTH COAST			
	Summer (Jan)		Winter (July)		Autumn (April/May)		Spring (Sept)	
	Abundance	SE	Abundance	SE	Abundance	SE	Abundance	SE
1985	124.647	22.707	181.487	27.476				
1986	117.810	23.636	119.587	18.489			121.197	16.625
1987	75.693	10.241	87.391	11.198			159.088	17.233
1988	66.725	10.765	47.120	9.568	165.939	21.871		
1989			323.833	67.295				
1990	455.798	135.237	157.800	23.561				
1991	77.357	14.995			274.298	44.395		
1992	95.407	11.744			138.085	15.357		
1993	92.598*	14.589			158.340	13.733		
1994	121.257	35.951			160.555	23.701		
1995	199.142	26.812			236.025	31.840		
1996	83.337	9.285			244.410	25.107		
1997	257.293	46.056			183.087	18.906		
1998								
1999	198.716	32.467			191.203	14.952		
2000	318.557	42.568			200.912	16.046		
2001	189.490	25.622					133.793	20.858
2002	106.253	15.813						
2003	75.960	13.314			128.450	20.062	**82.928**	**9.010**
2004	**205.939**	**33.216**			**99.902**	**12.027**	**106.119**	**15.596**
2005	**70.983**	**13.845**			**76.932**	**5.965**		
2006	88.420	22.851			130.900	14.816	99.867	9.803
2007	**82.270**	**11.441**			**70.940**	**5.615**	**74.615**	**7.383**
2008	**50.877**	**5.355**			**108.195**	**9.978**	**94.232**	**11.456**
2009	**175.289**	**39.920**			**124.004**	**11.808**		

Appendix D

Procedures for deviating from OMP output for the recommendation for a TAC, and for initiating an OMP review

1. Metarule Process

Metarules can be thought of as "rules" which pre-specify what should happen in unlikely, exceptional circumstances when application of the TAC generated by the OMP is considered to be highly risky or highly inappropriate. Metarules are not a mechanism for making small adjustments, or 'tinkering' with the TAC from the OMP. It is difficult to provide firm definitions of, and to be sure of including all possible, exceptional circumstances. Instead, a process for determining whether exceptional circumstances exist is described below (see Fig. D1). The need for invoking a metarule should be evaluated by the MCM [Demersal] Working Group (hereafter indicated by WG), but only provided that appropriate supporting information is presented so that it can be reviewed at a WG meeting.

1.1 Description of Process to Determine Whether Exceptional Circumstances Exist

While the broad circumstances that may invoke the metarule process can be identified, it is not always possible to pre-specify the data that may trigger a metarule. If a WG Member or Observer, or MCM Management, is to propose an exceptional circumstances review, then such person(s) must outline in writing the reasons why they consider that exceptional circumstances exist, and must either indicate where the data or analyses are to be found supporting the review, or must supply those data or analyses in advance of the WG meeting at which their proposal is to be considered.

Every year the WG will:

- Review population and fishery indicators, and any other relevant data or information on the population, fishery and ecosystem, and conduct a simple routine updated assessment (likely no more than core reference set models used in the OMP testing refitted taking a further year's data into account).
- On the basis of this, determine whether there is evidence for exceptional circumstances.

Examples of what might constitute an exceptional circumstance in the case of [hake] include, but are not necessarily limited to:

- [Survey estimates of abundance that are appreciably outside the bounds predicted in the OMP testing.
- CPUE trends that are appreciably outside the bounds predicted in the OMP testing.
- Catch species composition in major components of the fishery or surveys that differ markedly from previous patterns (and so may reflect appreciable changes in selectivity).]

Every two years the WG will:

- Conduct an in depth stock assessment (more intensive than the annual process above, and in particular including the conduct of a range of sensitivity tests).
- On the basis of the assessment, indicators and any other relevant information, determine whether there is evidence for exceptional circumstances.

The primary focus for concluding that exceptional circumstances exist is if the population assessment/indicator review process provides results appreciably outside the range of simulated population and/other other indicator trajectories considered in OMP evaluations. This includes the core (Reference case or set of) operating models used for these evaluations, and likely also (though subject to discussion) the operating models for the robustness tests for which the OMP was considered to have shown adequate performance. Similarly, if the review process noted regulatory changes likely to effect appreciable modifications to outcomes predicted in terms of the assumptions used for projections in the OMP evaluations (e.g. as a result, perhaps, of size limit changes or closure of areas), or changes to the nature of the data collected for input to the OMP beyond those for which allowance may have been made in those evaluations, this would constitute grounds for concluding that exceptional circumstances exist in the context of continued application of the current OMP.

(Every year) IF the WG concludes that there is no or insufficient evidence for exceptional circumstances, the WG will:

- Report to the Chief Director Research, MCM that exceptional circumstances do not exist.

IF the WG has agreed that exceptional circumstances exist, the WG will:

- Determine the severity of the exceptional circumstances.
- Follow the "Process for Action" described below.

1.2 Specific issues that will be considered annually (regarding Underlying Assumptions of the Operating Models (OMs) for the OMP Testing Process)

The following critical aspects of assumptions underlying the OMs for [hake] need to be monitored after OMP implementation. Any appreciable deviation from these underlying assumptions may constitute an exceptional circumstance (i.e. potential metarule invocation) and will require a review, and possible revision, of the OMP:

- [Whether over recent years the species splits of catches from the major fisheries differ substantially from the species splits considered in projections in the OMP testing.
- Whether selectivities-at-length for the major fisheries differ substantially from assumptions made to generate operating model projections.
- Whether standardised CPUE and survey abundance estimates are within the bounds indicated in operating model projections, where bounds here and in similar cases following shall be taken to be the 2.5%ile and 97.5%ile of projections under the Reference Set a (RSa) of operating models.
- Whether future recruitment levels are within the bounds projected by the RSa operating models.
- Whether new data suggest appreciably increased plausibility of the RSb scenarios which reflect a much more depleted *M. capensis* population than is the case under RSa.
- Whether the "survey-standardised-CPUE discrepancy statistic" defined below for each species as:

$$D_y^{WC\_surv,spp} = \Delta I_y^{WC\_surv,spp} - \frac{\left(\Delta I_y^{WC\_CPUE,spp} + \Delta I_y^{SC\_CPUE,spp}\right)}{2}$$

$$D_y^{SC\_surv,spp} = \Delta I_y^{SC\_surv,spp} - \frac{\left(\Delta I_y^{WC\_CPUE,spp} + \Delta I_y^{SC\_CPUE,spp}\right)}{2}$$

where

$$\Delta I_y^i = \frac{\left(I_{y+1}^i - I_y^i\right)}{I_y^i}$$

falls outside the bounds indicating in the OMP testing.

- Whether updates of major data sets or ageing practices indicate substantial differences from what were used to condition the operating models for the OMP testing.
- Whether there have been a series of substantial differences between TACs allocated and the catches subsequently made.
- Whether fishing regulations and/or strategies have changed substantially, and in a manner such that continuing use of the agreed GLM-standardisation procedures would likely introduce substantial bias in resource abundance trend estimates based on CPUE indices.
- Whether new data or information suggest a substantial revision of estimates of stock status or of the spawning biomass at MSY which is the target reference point for the fishery.
- Whether updated assessments suggest that the spawning biomass for the *M. paradoxus* population has fallen below its 2007 level, which will be considered a limit reference point for the fishery. Given that the OMP intends recovery of this population, an upward revision of this reference point will be considered at the next four-yearly OMP review.

A guide as to what constitutes "substantial" is a change that would alter the recommended TAC by more than 3%.]

1.3 Description of Process for Action

If making a determination that there is evidence of exceptional circumstances, the WG will with due promptness:

- Consider the severity of the exceptional circumstances (for example, how severely "out of bounds" are the recent CPUEs and survey abundance estimates or recruitment estimates).
- Follow the principles for action (see examples below).
- Formulate advice on the action required (this could include an immediate change in TAC, a review of the OMP, the relatively urgent collection of ancillary data, or conduct of analyses to be reviewed at a further WG meeting in the near future).
- Report to the Director Research, MCM that exceptional circumstances exist and provide advice on the action to take.

The Chief Director Research, MCM will:

- Consider the advice from the WG.
- Decide on the action to take, or recommendations to make to his/her principals.

Examples of 'Principles for Action'

If the risk is to the resource, or to dependent or related components of the ecosystem, principles may be:

- The OMP-derived TAC should be an upper bound.
- Action should be at least an x% decrease in the TAC output by the OMP, depending on severity.

If the risk is to socio-economic opportunities within the fishery, principles may be:

- The OMP-derived TAC should be a minimum.
- Action should be at least a y% increase in the TAC output by the OMP, depending on severity.

For certain categories of exceptional circumstances, specific metarules may be developed and pre-agreed for implementation should the associated circumstances arise (for example, as has been the case for OMP's for the sardine-anchovy fishery where specific modified TAC algorithms come into play if abundance estimates from surveys fall below pre-specified thresholds). Where such development is possible, it is preferable that it be pursued.

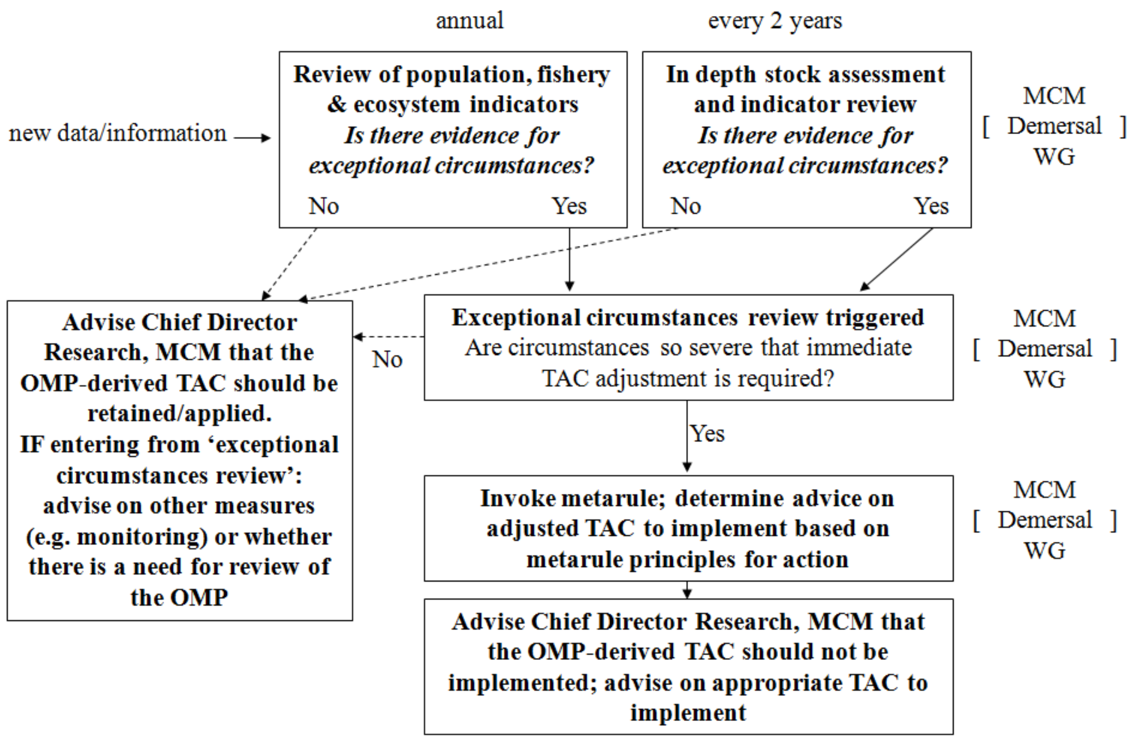

Fig. D1: Flowchart for Metarules Process

2. Regular OMP Review and Revision Process

The procedure for regular review and potential revision of the OMP is the process for updating and incorporating new data, new information and knowledge into the management procedure, including the operating models (OMs) used for testing the procedure. This process should happen on a relatively long time-scale to avoid jeopardising the performance of the OMP, but can be initiated at any time if the WG consider that there is sufficient reason for this, and that the effect of the revision would be substantial. During the revision process the OMP should still be used to generate TAC recommendations unless a metarule is invoked.

2.1 Description of Process for Regular Review (see Fig.D2)

Every year the WG will:

- Consider whether the procedure for Metarule Process has triggered a review/revision of the OMP. Note that if proposals by a WG Member or Observer, or MCM Management, for an exceptional circumstances review include suggestions for an OMP review and possible revision, they must outline in writing the reasons why they consider this necessary, and must either indicate where the data or analyses are to be found supporting their proposed review, or must supply those data or analyses in advance of the WG meeting at which their proposal is to be considered. This includes the possibility of a suggested improvement in the manner in which the OMP calculates catch limitation recommendations; this would need to be motivated by reporting results for this amended OMP when subjected to the same set of trials as were used in the selection of the existing OMP, and arguing that improvements in anticipated performance were evident.

Every two years the WG will:

- Conduct an in depth stock assessment and review population, fishery and related ecosystem indicators, and any other relevant data or information on the population, fishery and ecosystem.
- On the basis of this, determine whether the assessment (or other) results are outside the ranges for which the OMP was tested (note that evaluation for exceptional circumstances would be carried out in parallel with this process; see procedures for the Metarule Process), and whether this is sufficient to trigger a review/revision of the OMP.
- Consider whether the procedure for the Metarule Process triggered a review / revision of the OMP.

Every four years since the last revision of the OMP the WG will:

- Review whether enough has been learnt to appreciably improve/change the operating models (OMs), or to improve the performance of the OMP, or to provide new advice on tuning level (chosen to aim to achieve management objectives).
- On the basis of this, determine whether the new information is sufficient to trigger a review/revision of the OMP.

In any year, IF the WG concludes that there is sufficient new information to trigger a review/revision of the OMP, the WG will:

- Outline the work plan and timeline (e.g. over a period of one year) envisaged for conducting a review.
- Report to the Chief Director Research, MCM that a review/revision of the OMP is required, giving details of the proposed work plan and timeline.
- Advise the Chief Director Research, MCM that the OMP can still be applied while the revision process is being completed (unless exceptional circumstances have been determined to apply and a metarule invoked).

In any year, IF the WG concludes that there is no need to commence a review/revision of the OMP, the WG will:

- Report to the Chief Director Research, MCM that a review/revision of the OMP is not yet required.

The Chief Director Research, MCM will:

- Review the report from the WG.
- Decide whether to initiate the review/revision process.

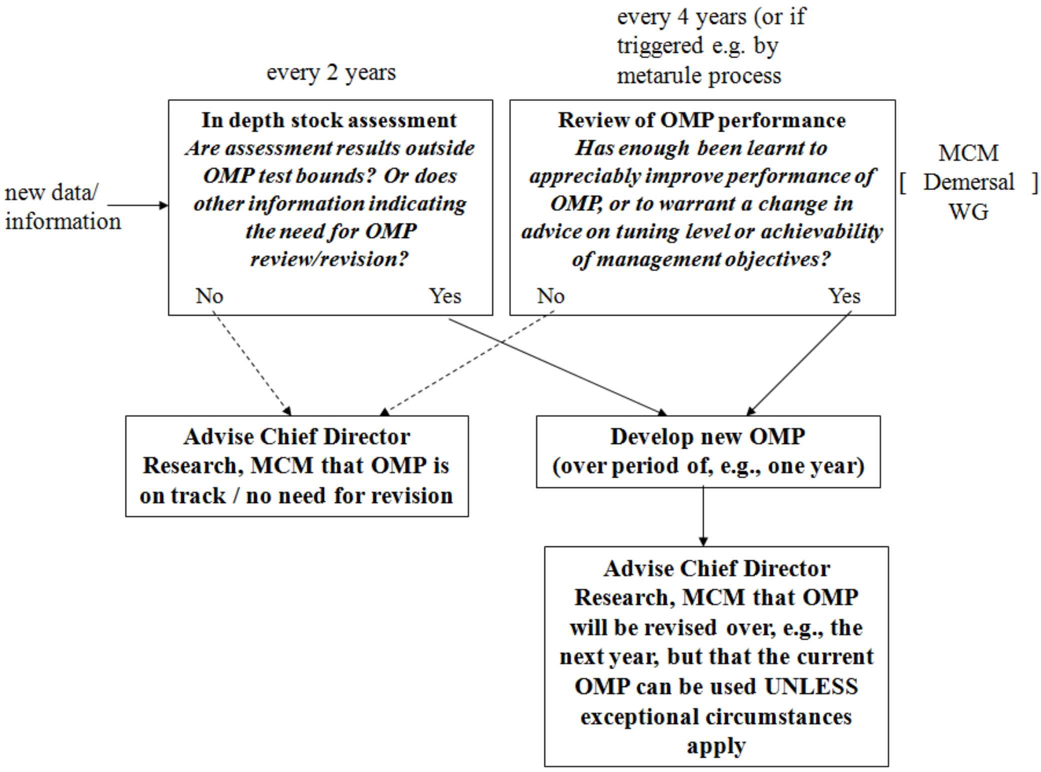

Fig. D2: Flowchart for Regular Review and Revision Process

Appendix E

Projected future CPUE, survey abundance indices, recruitment and survey/CPUE discrepancy statistic

Figs. E1-E2 plots the projected GLM-standardised CPUE and the survey abundance indices used in the OMP computations for each species for RSa under OMP-2010 respectively. Fig. E3 plots the future recruitment under RS1 and Fig. E4 plots the survey/CPUE discrepancy statistic. Table D1 gives the 95% PI for each of these for the next four years. Note that the GLM-standardised CPUE series have been renormalised by dividing by the 2009 value. This is done because the whole series changes when the GLM is rerun.

Table E1: 95% PI for the projected GLM-standardised CPUE, survey abundance indices, and discrepancy statistic for *M. paradoxus* and *M. capensis* for RSa under OMP-2010. Similarly the 95% PI for the projected recruitment are shown, but based on RS1 under OMP-2010. Note: the new gear on the *Africana* is assumed for future surveys. The 2010 surveys, carried out with the old gear, have therefore been calibrated by multiplying them by 0.95 for *M. paradoxus* and 0.8 for *M. capensis*.

Year	West Coast CPUE ($CPUE_y/CPUE_{2005}$)	South Coast CPUE ($CPUE_y/CPUE_{2005}$)	West coast summer survey	South Coast autumn survey	Normalised Recruitment ($N0_y/N0_{2005}$)	West coast survey-std-CPUE discrepancy	West coast survey-std-CPUE discrepancy
M. paradoxus							
2010	(0.96; 1.91)	(0.44; 1.60)					
2011	(0.79; 2.09)	(0.43; 1.53)	(145.4; 657.6)	(19.7; 190.8)	(0.62; 1.84)	(-88.3; 137.7)	(-107.0; 40.3)
2012	(0.89; 2.23)	(0.43; 1.65)	(131.3; 703.9)	(22.3; 189.7)	(0.72; 1.57)	(-94.4; 208.7)	(-89.8; 247.9)
2013	(0.93; 2.46)	(0.46; 1.94)	(167.5; 997.1)	(23.9; 252.3)	(0.64; 1.51)	(-102.4; 222.2)	(-94.3; 346.2)
2014			(174.3; 848.5)	(25.9; 172.3)	(0.65; 1.77)	(-104.8; 288.2)	(-139.4; 383.8)
M. capensis							
2010	(1.22; 3.39)	(0.94; 2.34)					
2011	(1.41; 3.87)	(1.05; 2.71)	(71.2; 274.8)	(70.4; 324.6)	(0.50; 1.51)	(-124.6; 48.7)	(-80.9; 80.6)
2012	(1.46; 4.12)	(1.24; 2.93)	(63.7; 280.8)	(85.9; 365.4)	(0.50; 1.24)	(-96.5; 175.6)	(-98.7; 267.2)
2013	(1.42; 4.84)	(1.20; 3.48)	(60.5; 290.0)	(85.8; 402.8)	(0.44; 1.46)	(-91.2; 162.2)	(-87.9; 158.7)
2014			(61.1; 277.4)	(89.6; 397.5)	(0.39; 1.21)	(-93.1; 225.9)	(-111.0; 137.7)

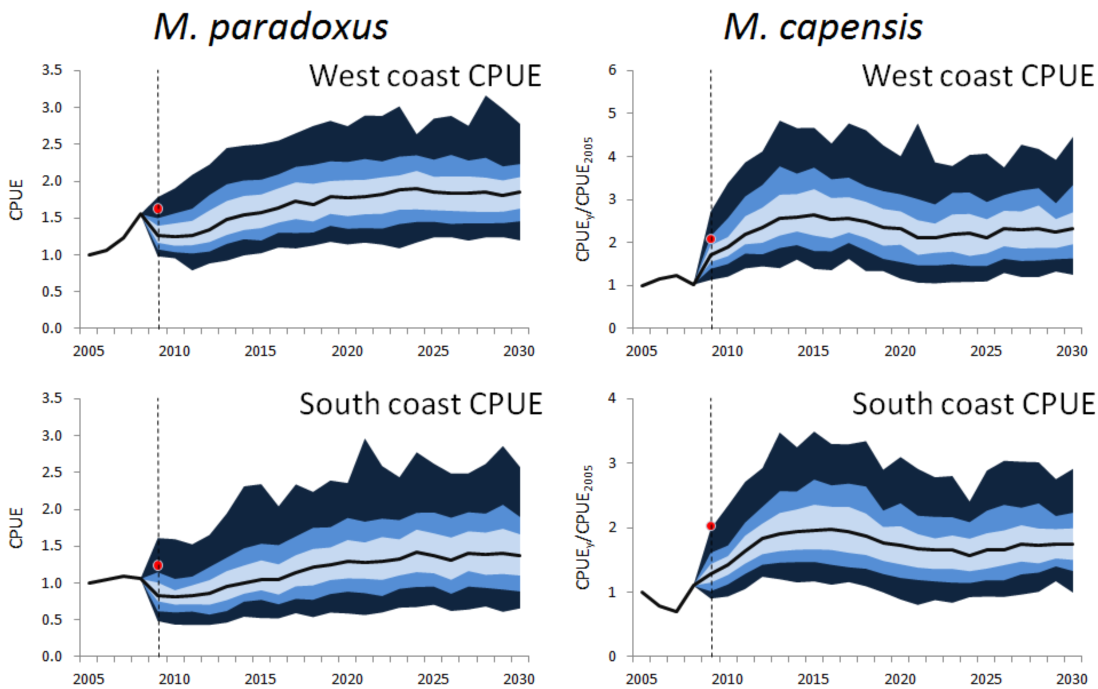

Fig. E1: 95, 75, 50% PI and median for the projected GLM-standardised CPUE for *M. paradoxus* and *M. capensis* for RSa under OMP-2010. The red dots show the values used for the computation of the 2011 TAC.

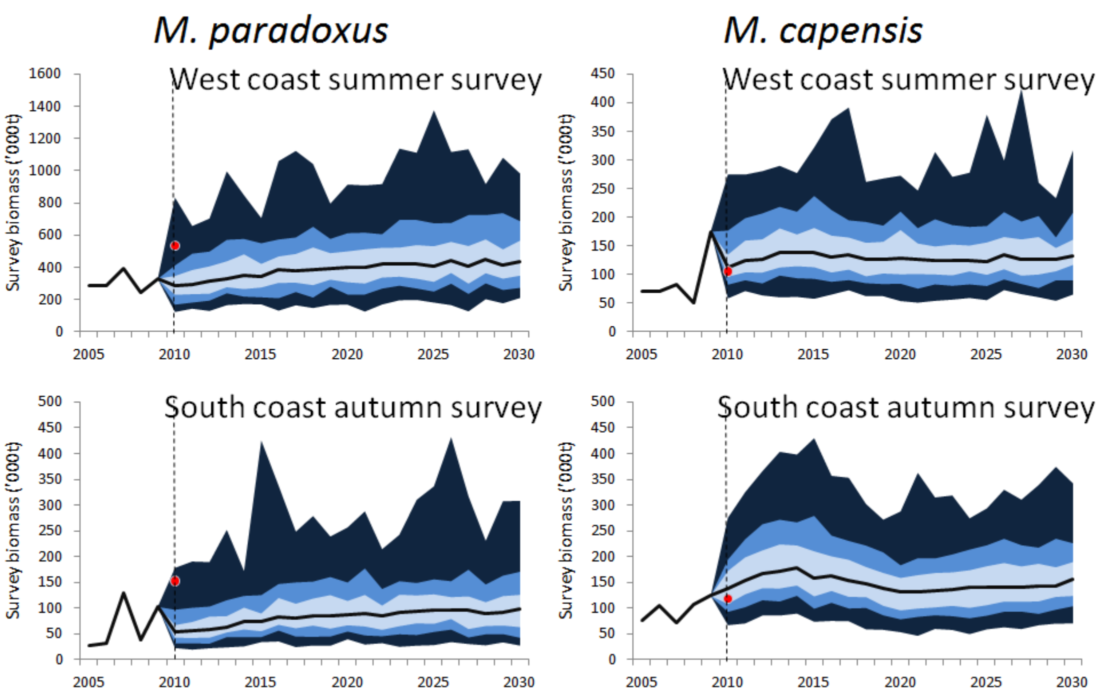

Fig. E2: 95, 75, 50% PI and median for the survey abundance indices for *M. paradoxus* and *M. capensis* for RSa under OMP-2010. The red dots show the values used for the computation of the 2011 TAC. Note: future surveys are assumed to be carried out using the new gear on the *Africana*. The 2010 surveys, carried out with the old gear, have therefore been calibrated by multiplying them by 0.95 for *M. paradoxus* and 0.8 for *M. capensis*.

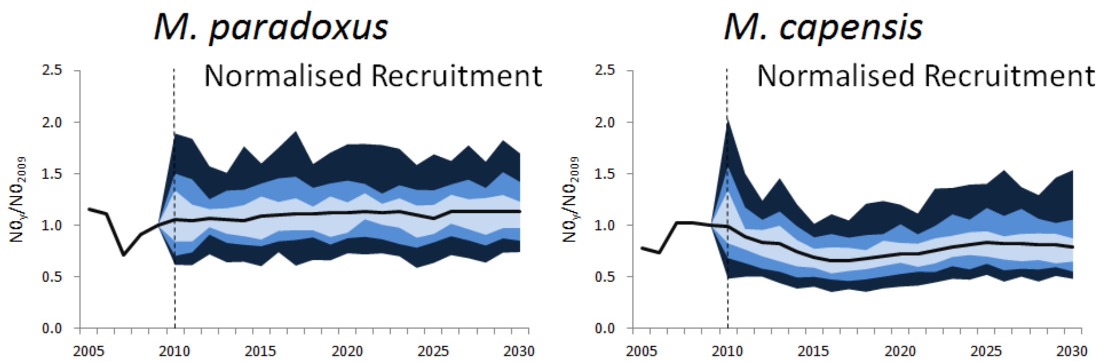

Fig. E3: 95, 75, 50% PI and median for the normalised recruitment ($N0_y/N0_{2009}$) for *M. paradoxus* and *M. capensis* for RS1 under OMP-2010.

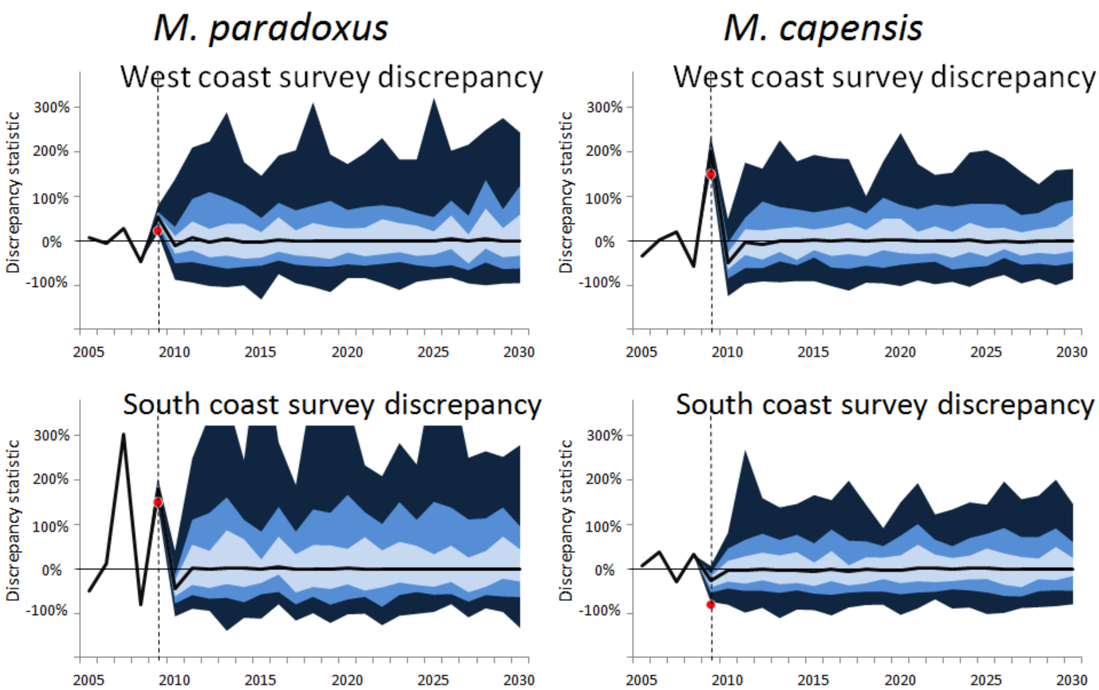

Fig. E4: 95, 75, 50% PI and median for the discrepancy statistic for *M. paradoxus* and *M. capensis* for RSa under OMP-2010.