The 2006 Operational Management Procedure for the South African *Merluccius paradoxus* and *M. capensis* Resources

R.A. Rademeyer* and J.P. Glazer+

*MARAM (Marine Resource Assessment and Management Group), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch 7701, South Africa

+MCM (Marine and Coastal Management), Department of environmental Affairs and Tourism, Private Bag X2, Roggebaai 8012, South Africa

November 2006

Introduction

The algorithm for the 2006 Operational Management Procedure (OMP) to provide TAC recommendations for the South African *Merluccius paradoxus* and *M. capensis* resources is empirical, increasing or decreasing the TAC in relation to the magnitude of recent trends in CPUE and survey abundance estimates for both species. The basis for the associated computations is set out below.

The 2006 OMP

The formula for computing the TAC recommendation is as follows:

$$TAC_y = C_y^{para} + C_y^{cap} \tag{1}$$

with

$$C_y^{spp} = C_{y-1}^{*spp}\left[1+\lambda_y\left(s_y^{spp} - target^{spp}\right)\right] \qquad \text{if } y \le 2006+\text{Y} \quad \text{and}$$

$$C_y^{spp} = C_{y-1}^{*spp}\left[1+\lambda_y\left(s_y^{spp}\right)\right] \qquad \text{if } y > 2006+\text{Y} \tag{2}$$

where

TAC_y is the total TAC recommended for year *y*,

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

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

λ_y is a year-dependent tuning parameter,

Y=15 is a tuning parameter,

[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.

target^{spp} is the target rate of increase for species *spp*, with *target*^{para}=2.4% and *target*^{cap}=0 and,

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*.

This trend measure is computed as follows from the species-disaggregated GLM-CPUE ($I_y^{CPUE,spp}$), west coast summer survey ($I_y^{surv1,spp}$) and south coast autumn survey ($I_y^{surv2,spp}$) indices:

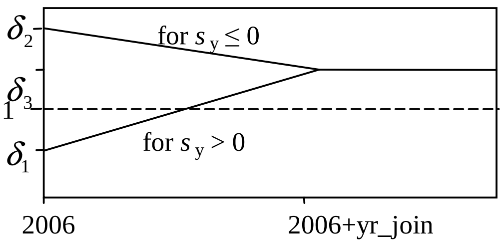
- linearly regress $\ln I_y^{CPUE,spp}$ *vs* year *y*' for $y' = y - p - 1$ to $y' = y - 2$, to yield a regression slope value $s_y^{CPUE,spp}$,
- linearly regress $\ln I_y^{surv1,spp}$ and $\ln I_y^{surv2,spp}$ *vs* year *y*' for $y' = y - p$ to $y' = y - 1$, to yield two regression slope values $s_y^{surv1,spp}$ and $s_y^{surv2,spp}$,

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 (in bold in Table 1) by multiplying them by a species specific calibration factor (0.95 for *M. paradoxus* and 0.8 for *M. capensis*)

Then

$$s_y^{spp} = \left(\frac{s_y^{CPUE,spp}}{2} + \frac{s_y^{surv1,spp}}{4} + \frac{s_y^{surv2,spp}}{4} \right) \qquad (3)$$

The function for the year-dependent tuning parameter, λ_y, which is a measure of how responsive the candidate OMP is to change in trend, is shown below:



With: yr_join=10, δ_1=0.5, δ_2=2.0 and δ_3=1.1, so that:

If $y < 2016$: $$\lambda_y = \begin{cases} 0.06(y-2006)+0.5 & \text{if } s_y > 0 \\ -0.09(y-2006)+2.0 & \text{if } s_y \leq 0 \end{cases} \qquad (4)$$

If $y \geq 2016$: $\lambda_y = 1.1$.

Furthermore, the maximum allowable change in TAC from one year to the next is ±10%, i.e.:

$$\left|TAC_y - TAC_{y-1}\right| \leq 0.9TAC_{y-1} \quad (5)$$

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 b), but an OMP review will commence immediately.

Data

The offshore CPUE data and survey estimates of abundance used in the OMP calculations for the 2007 TAC are given in Table 1. The species-disaggregated GLM-standardised CPUE data for the offshore fleet for the associated period 1978 to 2005 are from Glazer (2006). Details of how these series have been computed are given in Appendix A. These same processes will be used to specify CPUE data for future years for input to the OMP.

Details of the surveys are in Appendix C.

Application for 2007

TAC_{2007} computations as set out above yield 135 000 tons.

References

Glazer JP. 2006. Updated hake GLM-standardized CPUE series. Unpublished MCM Demersal Working Group Document, WG/08/06 D:H:25.

Table 1: Species-disaggregated offshore trawl GLM-standardised CPUE (in kg/min), as well as south coast autumn and west coast summer survey biomass estimates (in '000 tons) for *M. paradoxus* and *M. capensis*. Results for surveys that have been carried out using the new gear on the *Africana* are in bold.

	M. paradoxus	*M. capensis*	*M. paradoxus*				*M. capensis*			
	offshore trawl	offshore trawl	South coast		West coast		South coast		West coast	
Year	GLM-CPUE	GLM-CPUE	Autumn		Summer		Autumn		Summer	
	(kg/min)	(kg/min)	Biomass	(s.e.)	Biomass	(s.e.)	Biomass	(s.e.)	Biomass	(s.e.)
1978	5.81	3.18								
1979	5.64	3.58								
1980	5.90	4.06								
1981	5.39	3.62								
1982	5.70	3.60								
1983	6.14	4.26								
1984	6.28	4.93								
1985	7.52	6.06			168.139	(36.607)			124.652	(22.709)
1986	7.03	4.90			196.151	(36.366)			117.829	(23.639)
1987	6.13	4.39			284.859	(53.108)			75.705	(10.242)
1988	5.60	4.35	30.236	(11.084)	158.796	(27.390)	165.184	(21.358)	66.737	(10.767)
1989	5.79	4.80								
1990	6.46	5.33			282.225	(78.956)			455.861	(135.253)
1991	7.16	5.32	26.604	(10.431)	327.105	(82.209)	273.897	(44.363)	77.369	(14.997)
1992	6.89	5.23	24.305	(15.197)	234.699	(33.963)	137.798	(15.317)	95.568	(11.753)
1993	6.52	4.27	198.403	(98.423)	321.782	(48.799)	156.533	(13.628)	94.564	(17.346)
1994	6.67	4.97	111.354	(34.622)	329.927	(58.332)	158.243	(23.607)	120.206	(35.885)
1995	5.07	5.17	44.618	(19.823)	324.626	(80.370)	233.359	(31.862)	199.173	(26.816)
1996	6.83	5.03	85.530	(25.485)	430.971	(80.614)	243.934	(25.035)	83.347	(9.287)
1997	6.66	4.41	134.656	(50.922)	570.091	(108.230)	182.157	(18.601)	257.332	(46.062)
1998	6.74	4.62								
1999	6.29	4.62	321.328	(113.520)	562.988	(116.322)	190.864	(14.929)	198.748	(32.471)
2000	6.08	5.29								
2001	5.64	4.56								
2002	4.92	5.01			272.172	(35.586)			108.025	(16.086)
2003	5.75	4.81	108.756	(37.529)	405.457	(68.882)	126.749	(20.079)	74.771	(12.989)
2004	5.59	4.14	**55.914**	(23.926)	**259.566**	(56.034)	**103.356**	(12.688)	**205.976**	(33.221)
2005	5.30	3.23	**25.834**	(8.547)	**281.991**	(40.328)	**77.024**	(5.977)	**71.272**	(13.861)
2006			35.038	(8.981)	313.457	(47.265)	132.082	(14.891)	88.357	(22.748)

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 (2004), 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 (2004) 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 size category *s* (where *s* = small, medium or large) in each trawl is given by :

$$\overline{p}_s = \frac{1}{1+e^{B_s}} \tag{A1}$$

The size classifications are as follows: small 21-42cm, medium 43-57cm and large 58+cm. Fillets are assumed to comprise 23% large, 62% medium and 15% small fish and the size categories are thus adjusted accordingly.

For the west coast:

$$B_s = \kappa_s[d-(d_s^* + \alpha_y + \beta_L + 0.5\gamma_{summer})] \tag{A2}$$

For the south coast:

$$B_s = \kappa_s[d-(d_s^* + \beta_L)] \tag{A3}$$

where: κ_s is the coast-specific slope parameter for size category *s*,

d is the trawl depth in metres,

d_s^* is the coast-specific shift parameter for size category *s*,

α_y is the coast-specific year parameter for year *y*,

β_L is the coast-specific long-shore parameter for long-shore category *L*, and

$0.5\gamma_{summer}$ is the average of the west coast summer and winter season factors estimated in the fit to the survey data.

Note that the α, β and γ parameters are estimated taking them to be independent of size category. Season and year factors are omitted for the south coast, as they were not significant in the Gaylard and Bergh (2004) GLM analyses of the survey data. The parameter values estimated are shown in Table A1. These will not be updated over time while the OMP is being implemented.

A3. The General Linear Models

The following two models (equations A4 and A5) are applied to the *M. capensis* and *M. paradoxus* CPUE data respectively:

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

$$\ell n(\text{CPUE}_{\text{paradoxus}} + \delta) = \alpha + \beta_{year} + \gamma_{depth} + \eta_{area} + \kappa_{seas} + \lambda_{vessel} + \nu(\text{snoek CPUE}) + \nu'(\text{snoek CPUE})^2 + \varpi(\text{hmack CPUE}) + \varpi'(\text{hmack CPUE})^2 + interactions + \varepsilon \quad \text{(A5)}$$

(Note: to avoid clutter, the subscripts "*capensis*" and "*paradoxus*" for the parameters of equations A4 and A5 have been omitted.)

where:

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

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

year is a factor with 26 levels (1978-2003) 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:

$$CPUE_y = \sum_{strata} \left[e^{\{\alpha + \beta_{year} + \gamma_{depth} + \eta_{area} + \text{autumn} + \text{median vessel estimate} + \nu(\text{snoek } \overline{CPUE}) + \nu'(\text{snoek } \overline{CPUE^2}) + \varpi(\text{hmack } \overline{CPUE}) + \varpi'(\text{hmack } \overline{CPUE^2}) + \text{interactions}\}} - \delta \right] * \frac{A_{stratum}}{A_{total}} \qquad \text{(A6)}$$

where $A_{stratum}$ is the size of the area of the stratum in nm^2 (e.g. depth 200-300m and latitude 31 - 33^o), 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. 2004. **A species splitting mechanism for application to the commercial hake catch data 1978 to 2003**. Unpublished MCM Demersal Working Group Document, WG/09/04 D:H:21.

Table A1: Parameter values for substitution into equations (A2) and (A3): the coast-and size-specific algorithms used to split the hake catches by species (Gaylard and Bergh, 2004).

West coast		South coast	
Size category values (κ_s)		**Size category values (κ_s)**	
κ_{small}	0.04722	κ_{small}	0.09074
κ_{medium}	0.03325	κ_{medium}	0.03786
κ_{large}	0.02784	κ_{large}	0.02085
Depth parameter values (d_s^*)		**Depth parameter values (d_s^*)**	
d_{small}^*	177.46		181.62
d_{medium}^*	282.76		257.29
d_{large}^*	325.60		386.85
Year parameter α_y			
< 1985	14.04		
1985	21.95		
1986	13.52		
1987	8.02		
1988	0.50		
1989	11.34		
1990	32.73		
1991	11.45		
1992	21.14		
1993	16.31		
1994	4.84		
1995	26.70		
1996	-6.6		
1997	7.22		
1998	5.25		
1999	4.07		
2000	5.25		
2001	5.25		
2002	21.51		
2003	0.00		
Longshore (latitude) factors (β_L)		**Longshore (longitude) factors (β_L)**	
North of 29°S	0.00	West of 21°E	0.00
29-30°S	-4.02	21-22°E	18.92
30-31°S	4.81	22-23°E	-20.74
31-32°S	1.99	23-24°E	-33.63
32-33°S	5.75	24-25°E	-34.00
33-34S	14.93	25-26°E	-11.64
34-35°S	34.81	East of 26°E	44.51
South of 35°S	36.27		
Season factor			
γ_{summer}	-17.02		

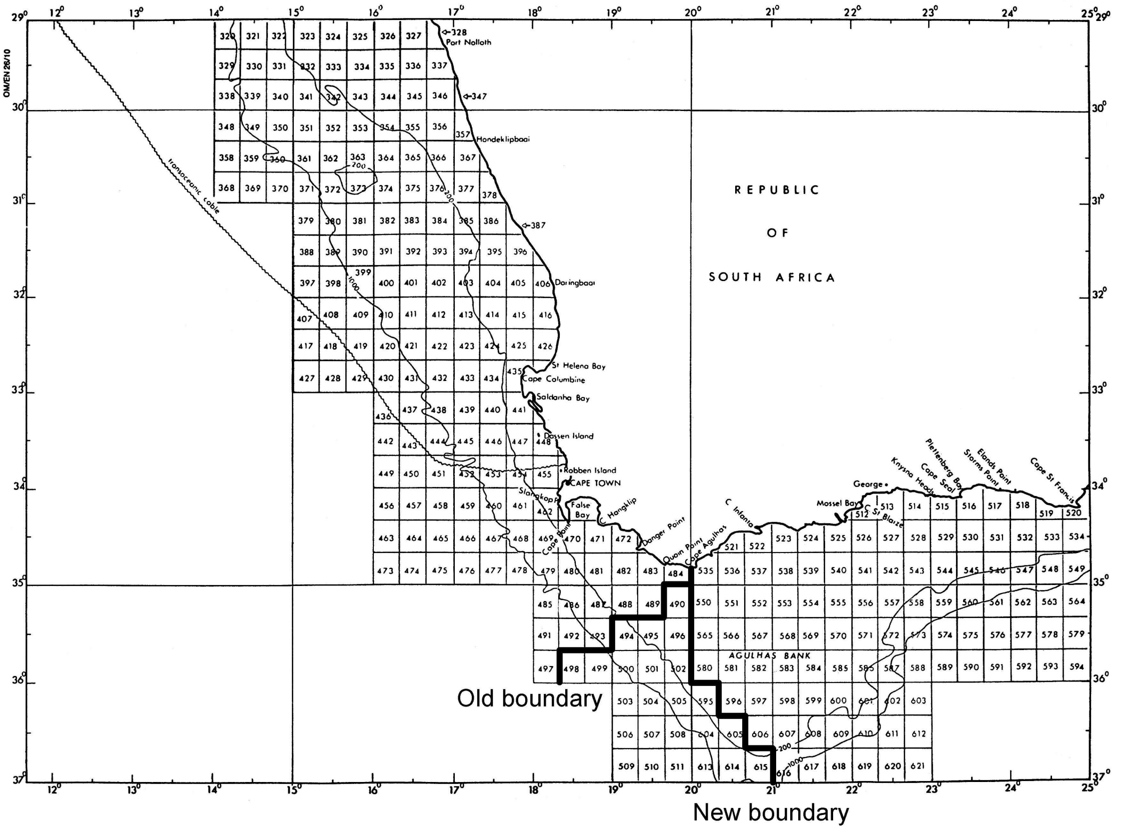
Table A2: The sizes of the areas (nm^2) covered by each of the latitude/depth combination strata on the West Coast.

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

TABLE A3: The size of the area (nm^2) covered by longitude/depth combinations on the South Coast.

Longitude (E)	Depth (m) 0 - 50	51 - 100	101 - 200	201 - 500
< 22°	441.63	3734.59	6910.87	839.05
≥ 22°	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

The demersal database was designed to capture catch and effort information on a haul-by-haul (drag) basis, each record containing the position, duration and landed catch per species of a single demersal trawl (Table A1). Skippers are obliged to fill in log books recording such information. However, due to operational constraints (e.g. vessels with factories on board prefer to keep the factories running continuously and therefore often empty their catch into the hold before the catch from the previous haul has been completely processed), it is not always possible to record the catch per trawl. In such cases the effort and position is recorded per trawl, whereas the catch for the day is logged against the effort of only one of the trawls (usually the last) for the day. Zero catch is recorded against the other trawls completed during that day. The Demersal database therefore contains catch information reported at two levels of resolution, *viz* daily and drag tallies.

When a vessel discharges its catch, the catch is weighed and recorded on a landing sheet. The landing record is therefore considered to be a true reflection of the catch, whereas the catch reported in the log books is considered to be an estimate. In addition, the catch is recorded as processed (cleaned) weight. It is necessary to convert the processed mass to nominal (green or live) mass and to adjust the log book (drag) estimates so that the sum of the masses recorded at the drag level matches the landing mass. These calculations are performed by the convert-to-real-mass (CTRM) procedure. In some cases a species or product category is recorded on the landing sheet, but not on any of the drags. The CTRM is then unable to apportion the catch of that species or product across drags. In the pre-2000 database, such catches were apportioned across drags in the proportion of the hake. Therefore the catch per drag for most species in the old database is suspect. To avoid this problem in the new database (post-1999), a “dummy drag” record is attached to each landing and all catches that cannot be mapped to drags are written to this record.

The mapping problem in the post-99 data has necessitated screening of the data before performing the GLM analyses, particularly given that the size data are to be included in the analyses. The following scenarios were considered problematic and the landings associated with these were subsequently excluded from the analyses:

1. Large+Medium+Small hake for the entire landing = 0 in the drag file (i.e. no size information available at the drag level).
2. Fillets in the dummy drag record > 0 (i.e. fillets could not be apportioned among drags)
3. Positive PQs recorded in the dummy drag record, but zero large hake recorded for the landing in the drag file (i.e. no size data available to enable the PQ catch being apportioned across drags)
4. Large+Medium+Small hake > 0 in the dummy drag record (If hake is in the dummy drag record, then the hake catch for some or all of the drags in the landing is underestimated).

Once the above landings had been identified and excluded from the dataset to be analysed, PQ hake captured for the landings that remain in the dummy drag file were apportioned across drags for that landing in ratio of large hake to total large hake for that landing and then added to the large hake. PQ hake recorded at the drag level were also added to the large hake category, i.e.

$$L_i^* = L_i + (PQ_{dummy} \times \frac{L_i}{\sum L_i}) + PQ_i \qquad \text{(B1)}$$

where L_i^* is the adjusted mass of large (large + PQ) hake in the *i*th trawl

L_i is the mass of large hake recorded for the *i*th trawl

PQ_{dummy} is the mass of PQ hake recorded in the dummy drag record

PQ_i is the mass of PQ hake recorded for the *i*th trawl

The broken and ungraded hake in the dummy drag record are then apportioned across drags for the landing in the ratio of total hake per drag:

$$A_i = (brok + ungr)_{dummy} \times (\frac{S_i + M_i + L_i^*}{\sum_{landing} S_i + M_i + L_i^*}) \quad \text{(B2)}$$

A_i is then allocated between small (S_i), medium (M_i) and large(L_i^*) hake per drag as follows:

$$S_i^* = S_i + A_i \times (\frac{S_i}{S_i + M_i + L_i^*}) \quad \text{(B3)}$$

$$M_i^* = M_i + A_i \times (\frac{M_i}{S_i + M_i + L_i^*}) \quad \text{(B4)}$$

$$L_i^{**} = L_i^* + A_i \times (\frac{L_i^*}{S_i + M_i + L_i^*}) \quad \text{(B5)}$$

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.

Data accumulation

Because of the practice of the daily tallies as explained above, the data were accumulated on a daily basis for each vessel before attempting GLM analyses. Failure to do so would have led to effort being allocated erroneously. For example, the effort exerted on the last drag of the day would be allocated to the total catch of the day if the daily tally method of reporting was employed and the data were not accumulated; this would result in an artificially high CPUE for that particular drag, and erroneous zero CPUE values for the other drags.

Another complication that required the accumulation of the data over a day is that skippers often average the catch taken on a day over the number of drags completed on that day, with rounding error (if any) included in the catch allocated to the last trawl of the day.

The following criteria were adopted for accumulating the database.

! If fishing took place in more than one Division (see Table A1 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[2] (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.

[2] 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.

- The target species were broadly separated into two categories; hake (H) and other (O). The species that was targeted in at least 2/3 of the drags was the target species allocated to that day. If there was no 2/3 majority, the target species was recorded as missing.

- 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 A2.

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 A3 and A4), 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.

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[3]
Total hake[4] 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[5] (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)

[3] 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.

[4] 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.

[5] 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. These correspond to those companies that were included in the initial development of the GLMs used to provide inputs when fitting the operating models used for OMP testing; future analyses for OMP inputs are to be restricted to these companies for the sake of consistency.

Code
1
2
3
35
36
54
56
61
62
63
65
66
67
68
69
70
102
103
104
107
108
109
110
111
112
113
114
115
117
118
119
120
121

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	130.70	39.59
2001	108.62	24.82
2002	78.94	34.36
2003	81.38	26.09
2004	92.58	31.97
2005	126.38	41.64

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	143.97	43.07
2001	209.91	66.32
2002	299.16	64.48
2003	104.12	39.15
2004	429.27	56.64
2005	266.54	54.01

Appendix C

Details of the survey biomass estimates

[TO COME FROM ROB LESLIE]