The 2018 Operational Management Procedure for the South African *Merluccius paradoxus* and *M. capensis* resources[1]

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Summary

Specifications and projection results for the 2018 Operational Management Procedure used for setting South African hake Total Allowable Catches are provided along with various background information, including details of the metarule processes.

Introduction

The algorithm for the 2018 Operational Management Procedure (OMP) to provide TAC recommendations for the South African *Merluccius paradoxus* and *M. capensis* resources is empirical. It calculates an increase or decrease of the TAC in relation to the level of an index combining recent CPUE and survey abundance estimates compared to a target level for that index. The basis for the associated computations is set out below, with the tuning parameters given in Table 1.

The 2018 OMP

The species-combined TAC in year *y*+1 is given by:

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

with

$$C_{y+1}^{spp} = b^{spp}\left(J_y^{spp} - J_0^{spp}\right) \tag{2}$$

where

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

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

J_0^{spp} and b^{spp} are tuning parameters (see Table 1), and

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

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[1] This document is an update of FISHERIES/2014/OCT/SWG-DEM/64 for OMP-2014, and borrows from the text by the authors thereof. Additionally, Appendix E has been updated from what was presented in the original FISHERIES/2018/OCT/SWG-DEM/73 document with results for the updated Reference Set (see FISHERIES/2019/MAR/SWG-DEM/03 for information on the update of the 2018 Reference Set). At the time of the compilation of this document, two further updates to the Reference Set Models still need to be made: (1) a correction of a coding glitch that that effectively resulted in data corresponding to juvenile (i.e. <20cm) fish being excluded from the age-length key negative log-likelihood calculation and (2) a re-evaluation of assumption made regarding the length-distribution for fish in the plus-group. Both updates will likely have minimal impact on the assessment results.

Measure of recent abundance level

The measures of the immediate past level J_y^{spp} for the abundance indices are computed as follows (note that these *J* indices reflect averages over the most recent three years for which the data in question are available):

$$J_y^{para} = \frac{1.0J_y^{WC\_CPUE,para} + 0.75J_y^{SC\_CPUE,para} + 0.5J_y^{WC\_surv,para} + 0.25J_y^{SC\_surv,para}}{2.5} \tag{3}$$

$$J_y^{cap} = \frac{1.0J_y^{WC\_CPUE,cap} + 0.75J_y^{SC\_CPUE,cap} + 0.5J_y^{WC\_surv,cap} + 1.0J_y^{SC\_surv,cap}}{3.25} \tag{4}$$

with

$$J_y^{WC/SC\_CPUE,spp} = \sum_{y'=y-3}^{y-1} I_y^{WC/SC\_CPUE,spp} \Big/ \sum_{y=2010}^{2012} I_y^{WC/SC\_CPUE,spp} \tag{5}$$

$$J_y^{WC/SC\_surv,spp} = \sum_{y'=y-2}^{y} I_y^{WC/SC\_surv,spp} \Big/ \sum_{y=2011}^{2013} I_y^{WC/SC\_surv,spp} \tag{6}$$

Thus, the weighting of the different indices (denoted by *I*) is taken to be the same as for OMP-2010 and OMP-2014, and the normalization is such that a value of *J*=1 reflects resource abundance about the same as in 2011/2012.

Constraints on TAC change

The maximum allowable annual increase in TAC is 10%, and the maximum allowable annual decrease in TAC is 5% unless the *M. paradoxus* average biomass index falls too low, in which case the maximum allowable annual decrease becomes:

$$MaxDecr_y = \begin{cases} 5\% & if\ J_y^{para} < J^{thresh1,para} \\ \text{linear between } x\% \text{ and } 5\% & if\ J^{thresh2,para} < J_y^{para} < J^{thresh1,para} \\ x\% & J_y^{para} < J^{thresh2,para} \end{cases} \tag{7}$$

x, $J^{thresh1,para}$ and $J^{thresh2,para}$ are tuning parameters (see Table 1).

Further, if J_y^{cap} drops below $J^{thresh,cap}$, then action will be taken to reduce the anticipated catch of *M. capensis* further, probably through measures to have the offshore trawl fishery more in deeper waters as a further TAC drop in these circumstances might reduce the catch of *M. paradoxus* unnecessarily.

Two further constraints are included in OMP-2018:

i. An upper cap on the TAC is imposed, so that the TAC cannot exceed 160 000 tons.
ii. The TACs for 2019 and 2020 are fixed at 146 431 tons.

Procedures in the 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 for one survey at most two years of the most recent three have been missed, the computations continue as indicated, with the missing data omitted from computation of the measures of the immediate past level (equation 6).

b) If all of the most recent three years have been missed (i.e. no data available to compute $J_y^{WC/SC\_surv,spp}$), the level for that index will be ignored in computing the average recent level (equations 3 and 4), but an OMP review will commence immediately.

c) The development of OMP-2018 assumed that the surveys will be conducted by the *Africana* from 2019 onwards, and that for recent pre-2019 surveys conducted by the commercial vessels, those vessels were equivalent to *Africana* in terms of trawling efficiency (catchability coefficient *q*). However, if the *Africana* is unable to conduct some future demersal surveys which provide OMP input, abundance estimates from commercial vessels for those surveys will be multiplied by 1.25 prior to input to equations 3 and 4. (This calibration factor, with its standard error, was estimated from assessments, and the OMP checked for robustness to such a replacement.)

Acknowledgements

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Table 1: Tuning parameters for OMP-2018

	M. paradoxus	*M. capensis*
J_0	0.132	0.240
b	88.02	35.00
$J^{thresh1,para}$	0.75	
$J^{thresh2,para}$	0.65	
$J^{thresh,cap}$		0.60
x	25	

Appendix A

Extraction and processing of demersal trawl catch and effort data

A1. Data extraction

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 were 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. The extraction of the drag data (scaled to reflect the landed catches) may result in certain data being excluded, particularly with respect to the data post-2000. Such exclusions arise for the following reasons:

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 for which items a – c above did not apply, 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 latitude (or longitude) 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.

Prior to the application of the procedure to allow for non-mapped landings to be included in the GLM analyses, a number of data exclusions are applied. These 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 dd 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.

A2. 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 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.
- 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 $\geq$ 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.

A3. Identifying potential errors

It is possible that recording errors (typo's) may occur in the DAFF demersal catch database, and an objective means of identifying and excluding erroneous records from the analyses is required. This is achieved by applying a "99% quantile rule". Within the accumulated data, any records (days) where the hake CPUE or by-catch CPUE values exceeded the annual 99% quantile for each CPUE respectively are excluded from the analysis. In addition, any effort values that exceed 1090 minutes on the West Coast and 865 minutes on the South Coast are considered to be potential "mistakes" and are 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.

[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.

TABLE A1: 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 are assigned to 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 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. as ribbon fish (*Lepidopus caudatus*) and 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

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[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 by-catch 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 by-catch.

[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 by-catch. The new logbooks (phased in during 2004) provide for the recording all possible species caught per drag.

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)

TABLE A2: The company codes of the offshore companies included in the GLM analyses.

Company Codes			
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	

Appendix B

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.

B1. 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 routinely recorded only as generic "hake", rather than on a species disaggregated basis. This is because the species are very similar in appearance and can be distinguished only by a trained scientific observer. Consequently algorithms developed by OLRAC (2017), which make use of species proportions by size at depth, as estimated from research surveys and observer records from commercial trips, 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 demersal database of the Fisheries Branch of the Department of Agriculture, Forestry and Fisheries (DAFF). Appendix A provides a description of the information contained in this database and the process followed to ready the data for analysis purposes.

B2. Separating the species

OLSPS (2017) revised the algorithm utilized in OMP-2014 based upon research and observer data over the period 1985-2017. A GLMM with a logit link function and a binomial distribution was applied. Both west and south coast data were modelled using the equation:

$$P = \frac{1}{1+e^{-\psi}} \qquad \text{(B1)}$$

where:

$$\psi = \mu + \alpha \times depth + \lambda_{position} + \varphi_{sizeclass} + \tau_{sizeclass \times depth} + \theta_{sizeclass \times position} \qquad \text{(B2)}$$

and:

P is the observed proportion of ***M. paradoxus*** by mass for a given trawl,
μ is the model intercept,
$depth$ is the mean depth of the trawl in metres, and α is the associated parameter for the covariate,
$\lambda_{position}$ is a categorical variable, being the latitude bin on the West Coast and the longitude bin on the South Coast,
$\varphi_{sizeclass}$ is a categorical variable for small, medium or large size classes, and
$\tau_{sizeclass \times depth}$ is the interaction between size class and depth
$\theta_{sizeclass \times position}$ is the interaction between size class and position.

This model (Model A6b of Glazer *et al.,* 2018) and was selected from a suite of models that differed in terms of input data and explanatory variables (Glazer *et al.*, 2018). The parameter values estimated for this model are provided in Table B1. These will not be updated during the implementation period of the OMP.

The GLMM was run without any record specific weighting. This means that the dependent value for each record is the observed mass proportion of *M. paradoxus*.

B3. The General Linear Models

The following two models (equations B3 and B4) are applied to the *M. capensis* and *M. paradoxus* CPUE data respectively:

$$\ell n\left(CPUE_{M.cap} + \delta\right) = \alpha + \beta_{year} + \gamma_{depth} + \eta_{Area} + \kappa_{season} + \lambda_{vessel} + \upsilon(CPUE_{snoek}) + \upsilon'(CPUE_{snoek})^2 + \omega(CPUE_{hmack}) + \omega'(CPUE_{hmack})^2 + interactions + \varepsilon \tag{B3}$$

$$\ell n\left(CPUE_{M.par} + \delta\right) = \alpha + \beta_{year} + \gamma_{depth} + \eta_{Area} + \kappa_{season} + \lambda_{vessel} + \upsilon(CPUE_{snoek}) + \upsilon'(CPUE_{snoek})^2 + \omega(CPUE_{hmack}) + \omega'(CPUE_{hmack})^2 + interactions + \varepsilon \tag{B4}$$

(Note: to avoid clutter, the subscripts "*capensis*" and "*paradoxus*" for the parameters of equations B3 and B4 have been omitted.)

where:

$CPUE_{M.cap}$is the catch of *M. capensis* per unit of (hake-directed – the recorded data specifies the target species for each trawl) effort,
$CPUE_{M.par}$ is the catch of *M. paradoxus* per unit of (hake-directed) effort,
α is the intercept,
$year$ is a factor with 40 levels (1978-2017) 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 A). Note that for the same vessel, different values of this factor may be estimated for *M. capensis* and *M. paradoxus*.

$CPUE_{snoek}$ and $CPUE_{hmack}$ 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 $year \times depth$, $year \times area$ and $depth \times area$ 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.

B4. 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 B1 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 B2 and B3.

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

$$CPUE_y = \sum_{strata} [e^{\{\alpha + \beta_{year} + \gamma_{depth} + \eta_{area} + \text{autumn} + \text{median vessel estimate} + \nu(\text{snoek } \overline{CPUE}) + \nu'(\text{snoek } \overline{CPUE^2}) + \varpi(\text{hmack } \overline{CPUE}) + \varpi'(\text{hmack } \overline{CPUE^2}) + \text{interactions}\}} - \delta] * \frac{A_{stratum}}{A_{total}} \qquad \text{(B6)}$$

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

Glazer JP, Bergh MO, Butterworth DS, Durholtz D and A. Ross-Gillespie. 2018. Further hake specie-splitting algorithm results. Unpublished DAFF Working Group Document: FISHERIES/2018/JULY/SWG-DEM/27. 9pp.

Table B1: Coast-specific parameter values for substitution into equations (B1) and (B2).

	WEST COAST		
	Fish Size		
Parameter	**Small**	**Medium**	**Large**
Intercept	-3.8467	-6.7956	-6.9164
Mean depth	0.0175	0.0206	0.0189
lat<3000	0.0000	0.0000	0.0000
3000≤lat<3100	0.4625	0.6913	0.3755
3100≤lat<3200	0.3872	1.0850	0.9694
3200≤lat<3300	0.3685	1.1997	1.0839
3300≤lat<3400	0.2336	1.2579	1.1591
3400≤lat<3500	-0.0583	0.9015	0.9161
lat≥3500	0.2276	1.0643	0.7884

	SOUTH COAST		
	Fish Size		
Parameter	**Small**	**Medium**	**Large**
Intercept	-6.2389	-6.4230	-6.5111
Mean depth	0.0176	0.0167	0.0149
long<2100	0.0000	0.0000	0.0000
2100≤long<2200	1.4186	1.3607	1.0231
2200≤long<2300	1.2845	1.1622	1.0650
2300≤long<2400	2.5010	2.0649	1.5846
2400≤long<2500	2.4171	2.2306	1.8074
2500≤long<2600	2.1252	1.6150	1.4271
long≥2600	1.6083	0.6589	0.8975

Table B2: The sizes of the areas (nm^2) covered by each of the latitude/depth combination strata on the West Coast.

	Depth (m)		
Latitude (S)	201-300	301-400	401-500
≤31^{o}00	3598 (10.3)	801 (2.3)	657 (1.9)
31^{o}00-33^{o}00	2842 (8.1)	2383 (6.8)	1427 (4.1)
33^{o}00-34^{o}20	882 (2.5)	458 (1.3)	501 (1.4)
>34^{o}20	1357 (3.9)	726 (2.1)	586 (1.7)

TABLE B3: The size of the area (nm^2) covered by longitude/depth combinations on the South Coast.

	Depth (m)	
Longitude (E)	101-200	201-500
< 22°	6911 (19.8)	839 (2.4)
≥22°	8470 (24.2)	2535 (7.2)

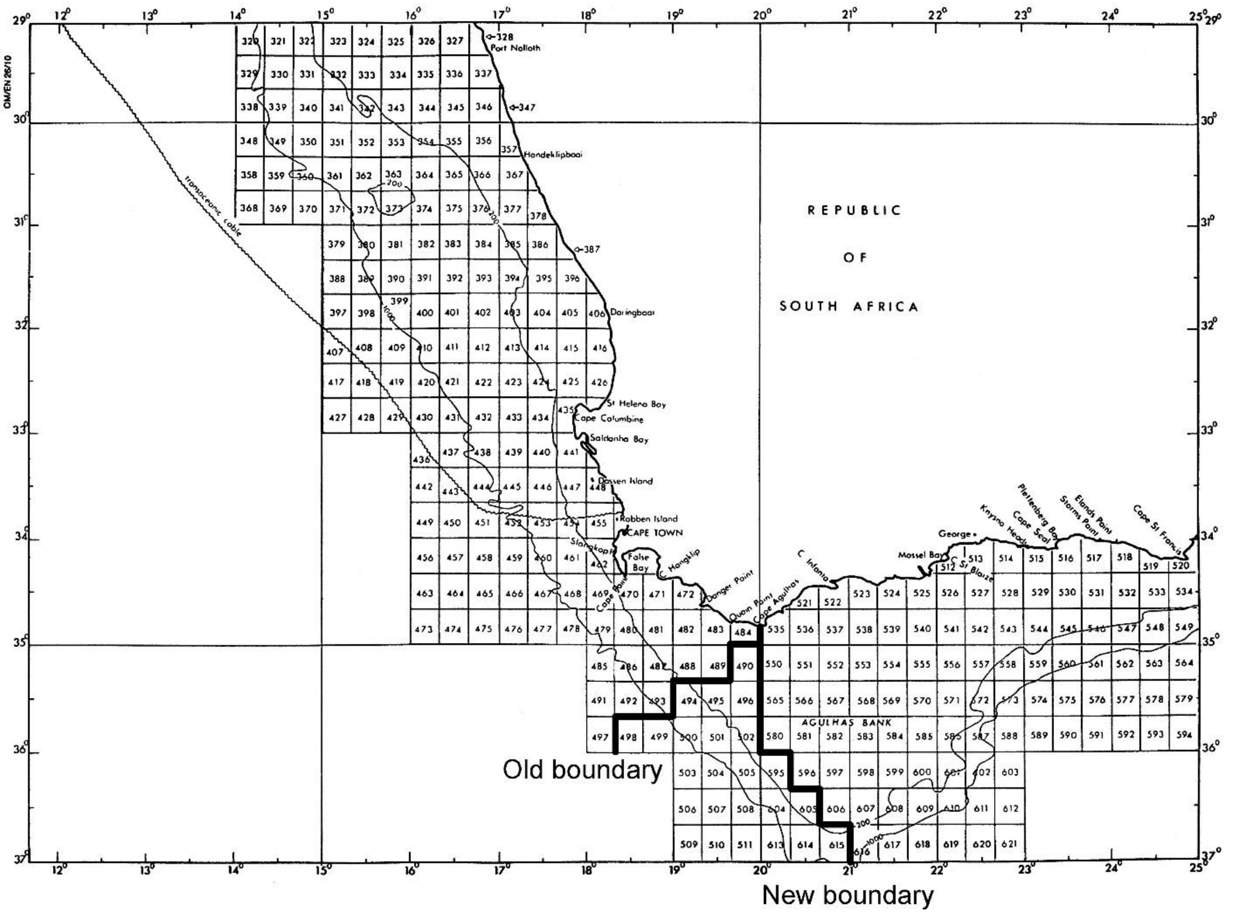

Figure B1: Demarcation of boundaries separating the west and south coasts in the hake fishery. The "Old boundary" was set by ICSEAF and was used to separate coasts until 2004 after which it was agreed by the Demersal Working Group to adopt the "New boundary" for future analyses so that the boundary did not split Brown's Bank. The depth contours shown are the 200m and 1000m contours respectively.

Appendix 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*)

C1. 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 C1a) and 1° longitude substrata on the South Coast (Table C1b). 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 C1a: 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 C1b: 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**

C2. Gear Type

Surveys conducted on the research vessel *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 that consisted of a 4-panel German 180 ft trawl net with a modified rockhopper footrope, 150kg lift and 1500kg Morgere multi-purpose doors. The "new" gear has subsequently been used as standard on *Africana* (with the exception of 2006 and 2010, where the old gear was used to facilitate a gear "cross-calibration") and on the fishing vessels *Andromeda* and *Compass Challenger*.

C3. 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 C2). 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 un-trawled. 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 portions of the inshore strata were not adequately surveyed) and 1998 (during which year no surveys were completed as the *Africana* was undergoing a complete re-fit). In 2000 and 2001 the Norwegian research vessel *Dr Fridjtof Nansen* was used to conduct the surveys but these data are not currently used in hake assessments or OMPs.

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 C2). 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 *Dr Fridjtof Nansen* was used in 2000). In 2002 the *Africana* resumed operations, completing all surveys until April 2012. The commercial fishing vessel *Andromeda*, was used in 2013 (summer), 2014 (summer and autumn) and 2015 (summer and autumn). The *Andromeda* was unavailable in 2016 and was replaced by the *Compass Challenger* for the summer and autumn surveys. The *Africana* was operational for spring 2016 and summer 2017 before undergoing further major repairs. No demersal surveys were completed in 2018.

Table C2: Summary of abundance estimate surveys completed since 1985. Surveys AFR069, AFR109 and AFR281 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 *Dr Fridjof Nansen* are underlined, *Africana* surveys using "new" gear are in bold and *Andromeda* surveys are both bold and underlined.

	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* NOT OPERATIONAL			
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**	
2010	AFR259		AFR261	
2011	**AFR270**		**AFR273**	
2012	**AFR279**		**AFR281**	
2013	**AND001**			
2014	**AND002**		**AND003**	
2015	**AND004**		**AND005**	
2016	**CCH008**		**CCH009**	
2017	**AFR291**			
2018	NO SURVEYS COMPLETED AS *AFRICANA* NOT OPERATIONAL			

C4. Data collection

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 (>2 500kg) 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. Catch of mainly pelagic species – small sizes: 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.

Once sorted to species (and gender and size category where necessary), the total weight of each species (and category where relevant) is recorded. Length frequency data are then recorded for each species (and category) where feasible (in some cases, a count of the number of individuals in the sample is recorded, rather than length measurements). Sub-samples of the "commercial" species, namely hake, monk, kingklip, squid and sole are dissected to determine individual length, weight, sex, maturity, stomach contents and otoliths (or illicia or statoliths) are removed for age determination purposes.

C5. 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 n_i is the number of trawls in the *i*-th stratum and d_{ij} is the observed density in the *j*-th trawl of the *i*-th stratum;

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

4. Estimate abundance per stratum B_i (tons) where $\overline{d_{i.}}$ is the mean density (kg/nm^2) 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 (tons) for the survey area B is the sum of the abundance per stratum B_i over all strata n_s;

$$B = \sum_{i=1}^{n_s} B_i$$

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

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

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

$$SE(B) = \sqrt{\sum_{i}^{n_s} SE(B_i)^2}$$

where

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

Survey abundance indices and standard errors are presented in Table C3 for *M. paradoxus* and Table C4 for *M. capensis* – note for both tables the values in bold represent surveys when *Africana* used new gear; surveys conducted on the *Andromeda* and *Compass Challenger* are underlined and bold values and shaded surveys either only extended to 200m or were incomplete and have therefore been omitted.

C6. 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 C3: Survey abundance estimates and associated standard errors (in thousand tons) for *Merluccius paradoxus*. *Africana* surveys using "new" gear are in bold, *Andromeda* and *Compass Challenger* surveys are both bold and underlined and surveys marked in grey were inadequately sampled.

Year	WEST COAST				SOUTH COAST			
	Summer (Jan)		Winter (July)		Autumn (April/May)		Spring (Sept)	
	Abundance	SE	Abundance	SE	Abundance	SE	Abundance	SE
1985	168.989	37.765	290.281	63.295				
1986	202.334	37.745	147.378	21.667			11.280	3.111
1987	284.434	54.165	180.158	39.047			16.381	3.033
1988	138.534	20.303	252.121	71.246	28.293	8.673		
1989			434.092	142.716				
1990	307.615	87.841	205.704	43.607				
1991	331.177	81.633			27.570	8.153		
1992	225.755	33.711			25.036	6.650		
1993	340.079	51.427			162.375	81.691		
1994	333.499	56.259			108.179	38.369		
1995	317.104	76.709			70.890	39.330		
1996	474.270	92.744			68.859	19.929		
1997	543.615	96.043			121.707	51.507		
1998								
1999	542.830	110.541			263.256	59.439		
2000								
2001							16.668	7.159
2002	251.820	32.690						
2003	386.321	63.565			185.345	82.188	**98.434**	**42.249**
2004	**271.540**	**55.710**			**39.822**	**22.153**	**70.001**	**22.156**
2005	**296.065**	**42.409**			**26.691**	**6.017**		
2006	316.247	57.332			34.868	5.843	68.507	18.283
2007	**407.377**	**77.222**			**102.195**	**53.688**	**66.267**	**21.966**
2008	**238.143**	**37.018**			**33.034**	**9.340**	**25.661**	**8.324**
2009	**310.760**	**27.768**			**45.030**	**15.551**		
2010	576.848	88.202			46.938	12.160		
2011	**380.185**	**128.013**			**21.054**	**6.531**		
2012	**405.865**	**59.099**						
2013	**136.260**	**25.116**						
2014	**269.482**	**37.492**			**62.925**	**24.802**		
2015	**207.583**	**24.057**			**111.411**	**51.852**		
2016	**312.876**	**33.250**			**94.177**	**51.731**	**22.520**[6]	**6.700**
2017	**319.024**	**58.766**						
2018								

[6] Note that this survey estimate was inadvertently omitted for the updated assessments on which OMP-2018 is based, but would have had little impact on the results

Table C4: Survey abundance estimates and associated standard errors (in thousand tons) for *Merluccius capensis*. *Africana* surveys using "new" gear are in bold, *Andromeda* and *Compass Challenger* surveys are both bold and underlined and surveys marked in grey were inadequately sampled.

Year	**WEST COAST**				**SOUTH COAST**			
	Summer (Jan)		**Winter (July)**		**Autumn (April/May)**		**Spring (Sept)**	
	Abundance	**SE**	**Abundance**	**SE**	**Abundance**	**SE**	**Abundance**	**SE**
1985	102.929	18.888	159.198	18.982				
1986	113.154	23.474	115.218	19.733			96.768	10.737
1987	75.438	9.709	83.050	10.306			137.008	13.057
1988	66.365	9.930	48.046	9.574	154.548	23.984		
1989			294.740	67.495				
1990	400.142	97.102	156.337	22.507				
1991	67.565	9.656			276.607	25.274		
1992	95.401	11.892			124.495	13.600		
1993	93.613	14.390			144.551	12.379		
1994	124.497	37.845			153.790	20.310		
1995	193.292	24.270			222.464	31.245		
1996	87.969	9.866			222.176	23.144		
1997	252.606	42.721			163.163	17.274		
1998								
1999	188.624	31.362			171.946	13.330		
2000								
2001							117.590	20.093
2002	105.093	16.130						
2003	73.020	12.518			117.538	17.192	**73.604**	**9.142**
2004	**194.294**	**30.714**			**92.796**	**11.318**	**96.933**	**13.936**
2005	**63.363**	**11.498**			**68.672**	**5.302**		
2006	73.655	17.255			116.298	11.931	92.831	8.998
2007	**73.230**	**9.306**			**65.935**	**5.303**	**67.937**	**6.553**
2008	**52.577**	**7.069**			**102.169**	**9.681**	**87.836**	**9.723**
2009	**140.437**	**26.486**			**111.191**	**10.832**		
2010	162.402	34.891			170.261	33.235		
2011	**89.095**	**23.574**			**105.424**	**10.688**		
2012	**84.746**	**8.331**						
2013	**30.383**	**4.575**						
2014	**219.756**	**60.342**			**63.389**	**6.415**		
2015	**65.086**	**9.178**			**76.059**	**6.873**		
2016	**115.058**	**30.400**			**83.197**	**6.600**	**110.301**[7]	**13.436**
2017	**69.289**	**14.486**						
2018								

[7] Note that this survey estimate was inadvertently omitted for the updated assessments on which OMP-2018 is based, but would have had little impact on the results

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

D1. 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 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 DAFF BRANCH FISHERIES [Demersal] Scientific 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.

D1.1 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 DAFF BRANCH FISHERIES 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 the core Reference Case model 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 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 full Reference Set of assessment models and conducting 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/or 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 affect 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, DAFF BRANCH FISHERIES 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.

D1.2 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 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 5%ile and 95%ile of projections under the Reference Set (RS) of operating models.
- Whether the proportions of *M. capensis* in the west and south coast offshore trawl catches are within the bounds indicated in operating model projections.
- Whether future recruitment levels are within the bounds projected by the RS operating models.
- 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 for *M. paradoxus*; the target objective for the fishery is to keep this stock somewhat above its MSY level so that a relatively high CPUE value is maintained (this last for reasons of economic viability).
- Whether updated assessments suggest that the spawning biomass for the *M. paradoxus* population has fallen below its median 2007 level, which will be considered a limit reference point for the fishery.

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

D1.3 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, DAFF BRANCH FISHERIES that exceptional circumstances exist and provide advice on the action to take.

The Chief Director Research, DAFF BRANCH FISHERIES 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.

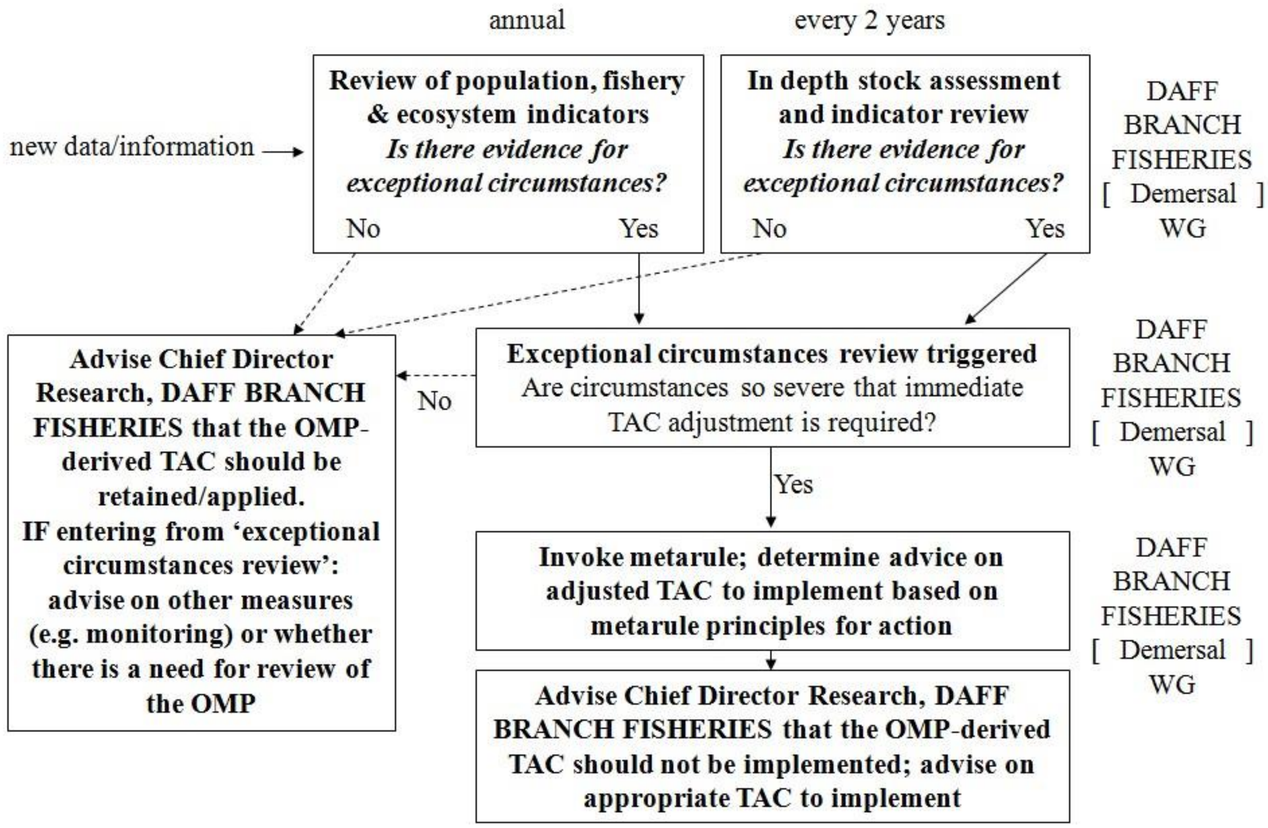

Figure D1: Flowchart for Metarules Process

D2. 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.

D2.1 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 DAFF BRANCH FISHERIES 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, DAFF BRANCH FISHERIES that a review/revision of the OMP is required, giving details of the proposed work plan and timeline.
- Advise the Chief Director Research, DAFF BRANCH FISHERIES 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, DAFF BRANCH FISHERIES that a review/revision of the OMP is not yet required.

The Chief Director Research, DAFF BRANCH FISHERIES will:

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

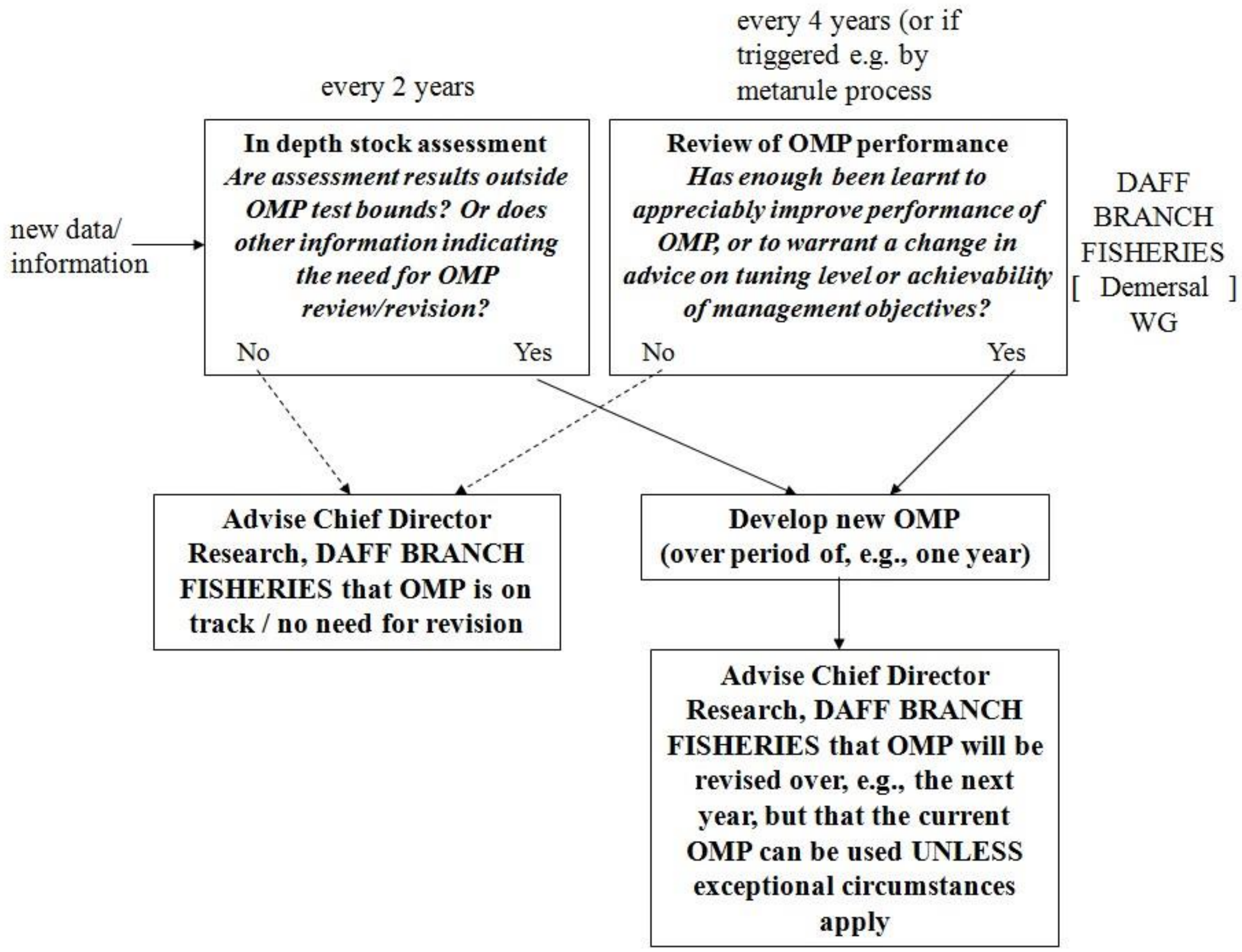

Figure D2: Flowchart for Regular Review and Revision Process

Appendix E

Projected future CPUE, survey abundance indices and recruitment

Figures E1-E2 plot the projected GLM-standardised CPUE and the survey abundance indices used in the OMP computations for each species for the updated RS under OMP-2018 respectively while Table E1 gives the 90% PI for each of these for the next four years. Note that the GLM-standardised CPUE series have been re-normalised by dividing by the 2016 value. This is done because the whole series changes when the GLM is rerun.

Figure E3 plots the projected proportion of *M. capensis* catch in the offshore trawl catch, with the 90% PIs for this proportion for the next four years are given in Table E3.

Table E1: 90% PI for the projected GLM-standardised CPUE and survey abundance indices (five-year running averages) for *M. paradoxus* and *M. capensis* for the updated RS under OMP-2018. Note: the new gear is assumed to be used on the *Africana* for all future surveys; if an industry vessel is used instead, the resultant estimates must be multiplied by 1.25 before comparison with the bounds in this table.

Year	West Coast CPUE ($CPUE_y/CPUE_{2016}$)	South Coast CPUE ($CPUE_y/CPUE_{2016}$)	West Coast summer survey	South Coast autumn survey
M. paradoxus				
2017	(0.68; 1.25)	(0.46; 1.27)		
2018	(0.63; 1.45)	(0.44; 1.48)	(124.9; 731.7)	(22.9; 168.6)
2019	(0.59; 1.68)	(0.43; 1.71)	(124.2; 796.1)	(22.6; 185.4)
2020	(0.58; 1.84)	(0.43; 1.88)	(125.8; 832.5)	(22.6; 202.2)
2021			(129.1; 856.1)	(23.2; 214.0)
M. capensis				
2017	(0.84; 1.60)	(1.06; 2.65)		
2018	(0.87; 1.90)	(1.10; 3.07)	(52.1; 248.2)	(64.5; 271.9)
2019	(0.88; 2.19)	(1.13; 3.47)	(51.7; 264.2)	(63.4; 295.5)
2020	(0.89; 2.50)	(1.14; 3.89)	(51.6; 279.0)	(61.9; 318.7)
2021			(51.9; 296.6)	(60.7; 344.7)

Table E2: 90% PI for the projected proportion of *M. capensis* in the offshore trawl catch.

Year	West Coast	South Coast
2018	(0.07; 0.36)	(0.04; 0.40)
2019	(0.07; 0.37)	(0.04; 0.41)
2020	(0.08; 0.38)	(0.04; 0.42)
2021	(0.08; 0.38)	(0.04; 0.42)
2022	(0.08; 0.39)	(0.04; 0.43)

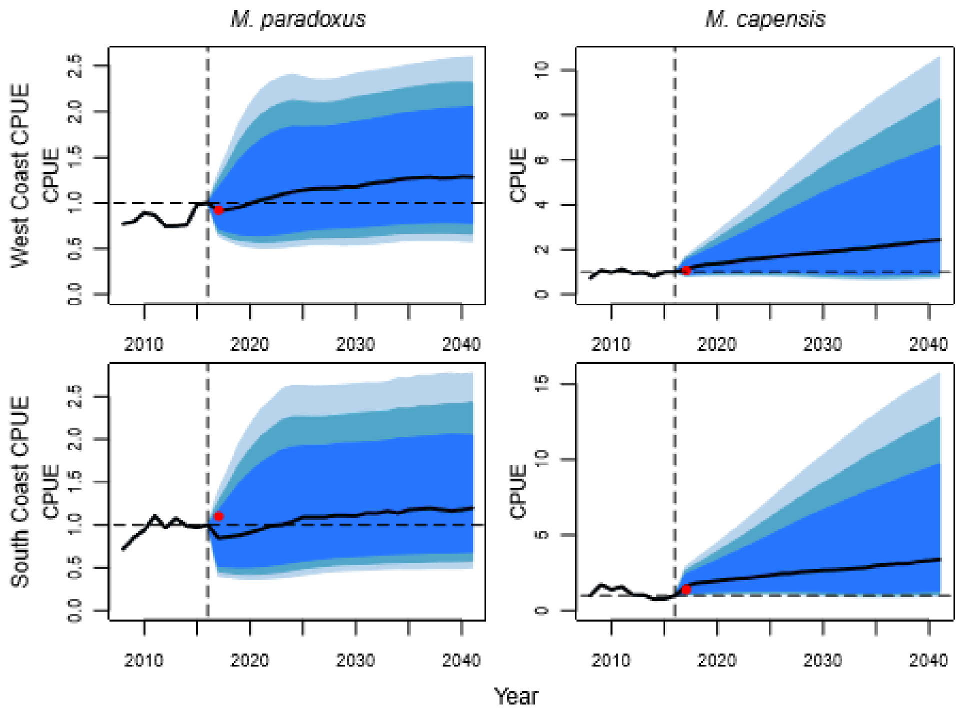

Fig. E1: 95, 90, 80% PE and median for the projected GLM-standardised CPUE for *M. paradoxus* and *M. capensis* for the updated RS under OMP-2018. The red dots show the 2017 CPUE indices, standardised relative to the 2016 value in the updated GLM series.

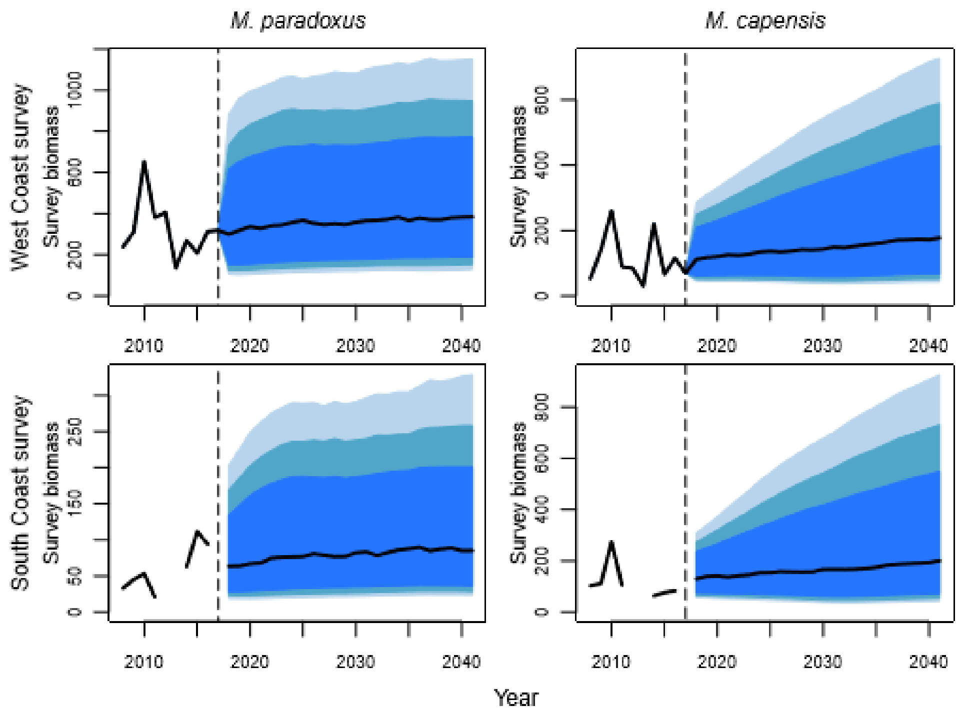

Fig. E2: 95, 90, 80% PE and median for the survey abundance indices for *M. paradoxus* and *M. capensis* for the updated RS under OMP-2018. Gaps in the median trajectory for the South Coast survey indicate surveys that did not take place. Since no surveys took place in 2018, no further data have been added to the projection PEs. Note: future surveys are assumed to be carried out using the new gear on the *Africana*; if an industry vessel is used instead, the resultant estimates must be multiplied by 1.25 before comparison with the bounds in these plots.

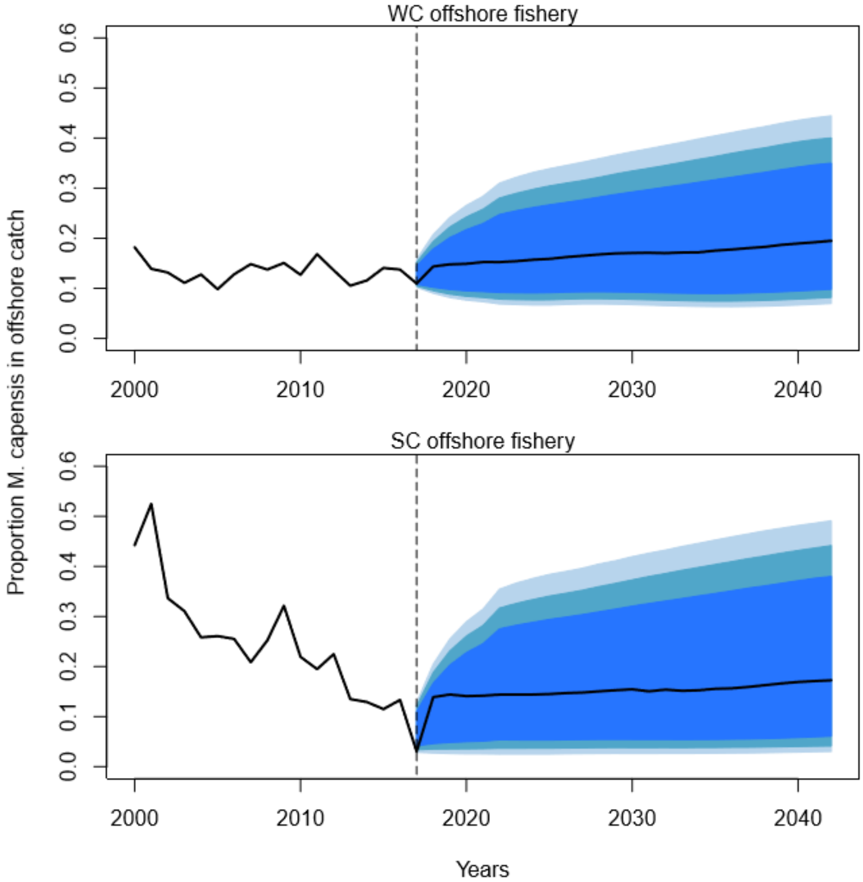

Fig. E3: 95, 90, 80% PE and median for the proportion *M. capensis* in the offshore trawl catch.