

Specifications of the South African Hake 2018 Reference Case Assessment

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This document is an update of FISHSERIES/2017/MAY/SWG-DEM/11, which provides the specifications for the 2017 Reference Case (RC) assessment model. Non-trivial changes made to the 2017 model and specifications have been retained in track changes to ease their identification by the reader. These changes relate to the mortality-at-age vectors used and the methodology for incorporating proportion-at-length data into the negative log-likelihood. More details on these changes are provided in MARAM/IWS/2018/Hake/P2. Note that this document is a minor revision of the one presented at the 2018 workshop, containing a correction to a typo in the original equation 14.

Introduction

This paper gives full algebraic specifications of the 2018 South African hake Reference Case assessment. The data used as input to the Reference Case are listed in Appendix A. Parameter estimates and detailed values for different contributions to the negative log-likelihood are also included. The Reference Case results are given in Appendix B.

The Statistical Catch-at-Length model

The model used is a gender-disaggregated Statistical Catch-at-Length (SCAL), which is fitted directly to age-length keys (ALKs) and length frequencies. The model also assesses the two species as two independent stocks and is fitted to species-disaggregated data as well as species-combined data. A distinction is made between the west and the south coasts, with hake movement surrogated using the “areas-as-fleets” approach. “Fleet” below therefore refers to a combination of gear type (offshore trawl, inshore trawl, longline and handline) and area (west and south coasts). The general specifications and equations of the overall model are set out below, together with some key choices in the implementation of the methodology. Details of the contributions to the log-likelihood function from the different data considered are also given. Quasi-Newton minimisation is used to minimise the total negative log-likelihood function (implemented using AD Model Builder™, Otter Research, Ltd. (Fournier *et al.* 2011)).

1 Population Dynamics

1.1 Numbers-at-age

The resource dynamics of the two populations (*Merluccius capensis* and *M. paradoxus*) of the South African hake are modelled by the following set of equations.

Note: for ease of reading, the ‘species’ subscript *s* has been omitted below where equations are identical for the two species.

$$N_{y+1,0}^g = R_{y+1}^g \quad (1)$$

$$N_{y+1,a+1}^g = \left(N_{ya}^g e^{-M_a^g/2} - \sum_f C_{fya}^g \right) e^{-M_a^g/2} \quad \text{for } 0 \leq a \leq m-2 \quad (2)$$

$$N_{y+1,m}^g = \left(N_{y,m-1}^g e^{-M_{m-1}^g/2} - \sum_f C_{f,y,m-1}^g \right) e^{-M_{m-1}^g/2} + \left(N_{ym}^g e^{-M_m^g/2} - \sum_f C_{fym}^g \right) e^{-M_m^g/2} \quad (3)$$

where

N_{ya}^g is the number of fish of gender *g* and age *a* at the start of year *y*¹;

R_y^g is the recruitment (number of 0-year-old fish) of fish of gender *g* at the start of year *y*;

¹In the interests of less cumbersome notation, subscripts have been separated by commas only when this is necessary for clarity.

- m is the maximum age considered (taken to be a plus-group);
 M_a^g denotes the natural mortality rate on fish of gender g and age a ; and
 C_{fya}^g is the number of hake of gender g and age a caught in year y by fleet f .

A penalty is added to the negative log-likelihood to prevent $N_{y,a}^g$ from going below 10 for $a \leq 10$, and below 1 for $a \geq 11$.

1.2 Recruitment

The number of recruits (i.e. new zero-year old fish) at the start of year y is assumed to be related to the corresponding female spawning stock size (i.e., the biomass of mature female fish). The underlying assumptions are that female spawning output can limit subsequent recruitment, but that there are always sufficient males to provide adequate fertilisation. The recruitment and corresponding female spawning stock size are related by means of the Beverton-Holt (Beverton and Holt 1957) or a modified (generalised) form of the Ricker stock-recruitment relationship. These forms are parameterized in terms of the “steepness” of the stock-recruitment relationship, h , the pre-exploitation equilibrium female spawning biomass, $K^{\otimes sp}$, and the pre-exploitation recruitment, R_0 , with a 50:50 sex-split at recruitment being assumed:

$$R_y^g = \frac{4hR_0 B_y^{\otimes sp}}{K^{\otimes sp}(1-h) + (5h-1)B_y^{\otimes sp}} e^{(\varsigma_y - \sigma_R^2/2)} \quad (4a)$$

for the Beverton-Holt stock-recruitment relationship and

$$R_y^g = \alpha B_y^{\otimes sp} \exp\left(-\beta (B_y^{\otimes sp})^\gamma\right) e^{(\varsigma_y - \sigma_R^2/2)} \quad (4b)$$

with

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

for the modified Ricker relationship (for the true Ricker, $\gamma=1$) where

ς_y reflects fluctuation about the expected recruitment in year y ;

σ_R is the standard deviation of the log-residuals, which is input ($\sigma_R = 0.45$ and is taken to decrease linearly from this value to 0.1 over the last five years to statistically stabilise estimates of recent recruitment).

Note: $e^{(\varsigma_y - \sigma_R^2/2)}$ is included only for the years for which the residuals are estimated, i.e. 1985 to 2016.

$B_y^{\otimes sp}$ is the female spawning biomass at the start of year y , computed as:

$$B_y^{\otimes sp} = \sum_{a=1}^m f_a^{\otimes} w_a^{\otimes} N_{ya}^{\otimes} \quad (5)$$

where

w_a^g is the begin-year mass of fish of gender g and age a ;

f_a^g is the proportion of fish of gender g and age a that are mature (converted from maturity-at-length, see equation 46); and

$$R_0 = K^{\otimes sp} / \left[\sum_{a=0}^{m-1} f_a^{\otimes} w_a^{\otimes} e^{-\sum_{a'=0}^{a-1} M_{a'}^g} + f_m^{\otimes} w_m^{\otimes} \frac{e^{-\sum_{a'=0}^{m-1} M_{a'}^g}}{1 - e^{-M_m^g}} \right] \quad (6)$$

For the Beverton-Holt form, h is bounded above by 0.98 to preclude high recruitment at extremely low spawning biomass, whereas for the modified Ricker form, h is bounded above by 1.5 to preclude extreme compensatory behaviour. *The Reference Case uses the modified Ricker form to model recruitment.*

1.3 Total catch and catches-at-age

The fleet-disaggregated catch by mass, in year y is given by:

$$C_{fy} = \sum_g \sum_{a=0}^m \tilde{w}_{fy,a+1/2}^g C_{fya}^g = \sum_g \sum_{a=0}^m \tilde{w}_{fy,a+1/2}^g N_{ya}^g e^{-M_a^g/2} F_{fy} S_{fya}^g \quad (7)$$

where

C_{fya}^g is the catch-at-age, i.e. the number of fish of gender g and age a , caught in year y by fleet f ;

F_{fy} is the fished proportion of a fully selected age class by fleet f in year y .

F_{fy} is independent of g for all fleet except the longline fleet, for which male proportions are available. Therefore for the longline fleet:

$$F_{fy}^g = C_{fy}^g / \left(\sum_{a=0}^m \tilde{w}_{fy,a+1/2}^g N_{ya}^g e^{-M_a^g/2} S_{fya}^g \right) \quad (8)$$

where $C_{fy}^g = L_{fy}^g C_{fy}$

with L_{fy}^{males} given in Table 1 below.

Table 1: Male proportion in the longline catches. For years prior to 2000 and post 2010, the 2000-2010 average is used.

	West coast		South coast	
	<i>M. paradoxus</i>	<i>M. capensis</i>	<i>M. paradoxus</i>	<i>M. capensis</i>
2000	0.35699	0.09755	0.46030	0.29340
2001	0.05378	0.13431	0.52645	0.38234
2002	0.26296	0.13852	0.46030	0.36548
2003	0.22694	0.22288	0.46030	0.31665
2004	0.12542	0.10752	0.46030	0.26581
2005	0.05788	0.14946	0.46030	0.16476
2006	0.04562	0.10308	0.28792	0.27210
2007	0.03721	0.34383	0.46030	0.29340
2008	0.22329	0.29265	0.34573	0.27928
2009	0.22402	0.33734	0.61493	0.21179
2010	0.05378	0.13431	0.52645	0.38234

Note: a penalty is added so that $F_{fy} < 0.95$ and another so that $\sum_f S_{fya}^g F_{fy} < 1$ for each age.

$$S_{fya}^g = \sum_l S_{fyl}^g P_{a+1/2,l}^g \quad (9)$$

S_{fya}^g is the commercial selectivity of gender g at age a for fleet f and year y ;

S_{fyl}^g is the commercial selectivity of gender g at length l for year y , and fleet f , normalised to have a maximum of 1;

$$\tilde{w}_{fy,a+1/2}^g = \sum_l S_{fyl}^g w_l^g P_{a+1/2,l}^g / \sum_l S_{fyl}^g P_{a+1/2,l}^g \quad (10)$$

$\tilde{w}_{fy,a+1/2}^g$ is the selectivity-weighted mid-year weight-at-age a of gender g for fleet f and year y ;

w_l^g is the weight of fish of gender g and length l ;

$P_{a+1/2,l}^g$ is the mid-year proportion of fish of age a and gender g that fall in the length group l (thus $\sum_l P_{a+1/2,l}^g = 1$ for all ages a).

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

$$\ln l_a \sim N \left[\ln \left(l_\infty (1 - e^{-\kappa(a-t_0)}) \right); \left(\frac{\theta_a}{l_\infty (1 - e^{-\kappa(a-t_0)})} \right)^2 \right] \quad (11)$$

where θ_a is the standard deviation of length-at-age a , which is estimated directly in the model fitting for age 0, and for ages 1 and above a linear relationship applies:

$$\theta_a = \begin{cases} \theta_0 & \text{for } a = 0 \\ \left((a-1) \frac{\theta_{14} - \theta_1}{13} + \theta_1 \right) & \text{for } 1 \leq a \leq m \end{cases}$$

with species and gender-specific θ_0 , θ_1 and θ_{14} estimated in the model fitting procedure. A penalty is added to ensure that θ_a is increasing with age, i.e. $\theta_{14} > \theta_0$.

1.4 Exploitable and survey biomasses

The model estimate of the mid-year exploitable (“available”) component of biomass for each species and fleet is calculated by converting the numbers-at-age into mid-year mass-at-age and applying natural and fishing mortality for half the year:

$$B_{fy}^{ex} = \sum_g \sum_{a=0}^m \tilde{w}_{fy,a+1/2}^g S_{fya}^g N_{ya}^g e^{-M_a^g/2} \left(1 - \sum_f S_{fya}^g F_{fy} / 2 \right) \quad (12)$$

The model estimate of the survey biomass is given by:

$$B_y^{surv} = \sum_g \sum_{a=0}^m \tilde{w}_a^{g,surv} S_a^{g,surv} N_{ya}^g e^{-M_a^g \frac{t^{surv}}{12}} \left(1 - \frac{t^{surv}}{12} \sum_f S_{fya}^g F_{fy} \right) \quad (13)$$

where

- t^{surv} is the month (on average) in which survey *surv* took place (1, 7, 9 and 4 for summer, winter, spring and autumn surveys respectively),
- $S_a^{g,surv}$ is the survey selectivity of gender g for age a , converted from survey selectivity-at-length in the same manner as for the commercial selectivity (equation 9);
- $\tilde{w}_a^{g,surv}$ is the survey selectivity-weighted weight-at-age a of gender g for survey i , computed in the same manner as for the commercial selectivity-weight-at-age (equation 10) and taking account of the timing of the survey ($\tilde{w}_{y,a}^{g,surv}$ from $P_{a,l}^g$ if t^{surv} is less or equal to 6 and from $P_{a+1/2,l}^g$ otherwise).

1.5 Initial conditions

It is assumed that the resource is at the deterministic equilibrium that corresponds to an absence of harvesting at the start of the initial year considered, i.e., $B_1^{g,sp} = K^{g,sp}$, and the year $y=1$ corresponds to 1917 when catches commence.

2. MSY and related quantities

The equilibrium catch for a fully selected fishing proportion F^* is calculated as:

$$C(F^*) = \sum_g \sum_a \tilde{w}_{a+1/2}^g S_a^g F^* N_a^g(F^*) e^{-\frac{(M_a^g)}{2}} \quad (14)$$

where

S_a^g is the average selectivity across all fleets, for the most recent five years:

$$S_a^g = \frac{\sum_{y=2012}^{2016} \sum_f S_{fy}^g F_{fy}}{\max \left(\sum_{y=2012}^{2016} \sum_f S_{fy}^g F_{fy} \right)} \quad (15)$$

where the maximum is taken over ages;

and $\tilde{w}_{a+1/2}^g$ is the average selectivity-weighted weight-at-age, for the most recent five years:

$$\tilde{w}_{a+1/2}^g = \frac{\sum_{y=2012}^{2016} \sum_f \tilde{w}_{f,y,a+1/2}^g F_{fy}}{\sum_{y=2012}^{2016} \sum_f F_{fy}} \quad (16)$$

and with

$$N_a^g(F^*) = \begin{cases} R_0(F^*) & \text{for } a = 0 \\ N_{a-1}^g(F^*) e^{-M_{a-1}^g (1 - S_{a-1}^g F^*)} & \text{for } 0 < a < m \\ \frac{N_{m-1}^g(F^*) e^{-M_{m-1}^g (1 - S_{m-1}^g F^*)}}{(1 - e^{-M_m^g (1 - S_m^g F^*)})} & \text{for } a = m \end{cases} \quad (17)$$

where

$$R_0(F^*) = \frac{\alpha B^{\otimes sp}(F^*)}{\beta + B^{\otimes sp}(F^*)} \quad (18a)$$

for a Beverton-Holt stock-recruitment relationship, and

$$R_0(F^*) = \alpha B_y^{\otimes sp}(F^*) \exp(-\beta (B_y^{\otimes sp}(F^*))^\gamma) \quad (18b)$$

for a modified Ricker stock-recruitment relationship.

The maximum of $C(F^*)$ is then found by searching over F^* to give F_{MSY}^* , with the associated female spawning biomass given by:

$$B_{MSY}^{\otimes sp} = \sum_a f_a^{\otimes} w_a^{\otimes} N_a^{\otimes}(F_{MSY}^*) \quad (19)$$

3. The likelihood function

The model is fit to CPUE and survey biomass indices, commercial and survey length frequencies, survey age-length keys, as well as to the stock-recruitment curve to estimate model parameters. Contributions by each of these to the negative of the log-likelihood ($-\ell nL$) are as follows².

3.1 CPUE relative biomass data

The likelihood is calculated by assuming that the observed biomass index (here CPUE) is log-normally distributed about its expected value:

²Strictly it is a penalised log-likelihood which is maximised in the fitting process, as some contributions that would correspond to priors in a Bayesian estimation process are added.

$$I_y^i = \hat{I}_y^i e^{\varepsilon_y^i} \quad \text{or} \quad \varepsilon_y^i = \ln(I_y^i) - \ln(\hat{I}_y^i) \quad (20)$$

where

I_y^i is the biomass index for year y and series i (which corresponds to a specified species and fleet);
 $\hat{I}_y^i = \hat{q}^i \hat{B}_{fy}^{ex}$ is the corresponding model estimate, where $\hat{B}_{fy}^{ex}$ is the model estimate of exploitable resource biomass, given by equation 11;
 $\hat{q}^i$ is the constant of proportionality for biomass series i ; and
 ε_y^i from $N(0, (\sigma_y^i)^2)$.

In cases where the CPUE series are based upon species-aggregated catches (as available pre-1978), the corresponding model estimate is derived by assuming two types of fishing zones: z1) an “*M. capensis* only zone”, corresponding to shallow-water and z2) a “mixed zone” (see diagrammatic representation in Figure 1).

The total catch of hake of both species (*BS*) by fleet f in year y ($C_{BS, fy}$) can be written as:

$$C_{BS, fy} = C_{C, fy}^{z1} + C_{C, fy}^{z2} + C_{P, fy} \quad (21)$$

where

$C_{C, fy}^{z1}$ is the *M. capensis* catch by fleet f in year y in the *M. capensis* only zone (z1);
 $C_{C, fy}^{z2}$ is the *M. capensis* catch by fleet f in year y in the mixed zone (z2); and
 $C_{P, fy}$ is the *M. paradoxus* catch by fleet f in year y in the mixed zone.

Catch rate is assumed to be proportional to exploitable biomass. Furthermore, let γ_c be the proportion of the *M. capensis* exploitable biomass in the mixed zone ($\gamma_c = B_{C, fy}^{ex, z2} / B_{C, fy}^{ex}$) (assumed to be constant throughout the period for simplicity) and ψ_{fy} be the proportion of the effort of fleet f in the mixed zone in year y ($\psi_{fy} = E_{fy}^{z2} / E_{fy}$), so that:

$$C_{C, fy}^{z1} = q_C^{i, z1} B_{C, fy}^{ex, z1} E_{fy}^{z1} = q_C^{i, z1} (1 - \gamma_c) B_{C, fy}^{ex} (1 - \psi_{fy}) E_{fy} \quad (22)$$

$$C_{C, fy}^{z2} = q_C^{i, z2} B_{C, fy}^{ex, z2} E_{fy}^{z2} = q_C^{i, z2} \gamma_c B_{C, fy}^{ex} \psi_{fy} E_{fy} \quad \text{and} \quad (23)$$

$$C_{P, fy} = q_P^i B_{P, fy}^{ex} E_{fy}^{z2} = q_P^i B_{P, fy}^{ex} \psi_{fy} E_{fy} \quad (24)$$

where

$E_{fy} = E_{fy}^{z1} + E_{fy}^{z2}$ is the total effort of fleet f , corresponding to combined-species CPUE series i which consists of the effort in the *M. capensis* only zone (E_{fy}^{z1}) and the effort in the mixed zone (E_{fy}^{z2});
 $q_C^{i, zj}$ is the catchability for *M. capensis* (C) for biomass series i , and zone zj ; and
 q_P^i is the catchability for *M. paradoxus* (P) for biomass series i .

It follows that:

$$C_{C, fy} = B_{C, fy}^{ex} E_{fy} [q_C^{i, z1} (1 - \gamma_c) (1 - \psi_{fy}) + q_C^{i, z2} \gamma_c \psi_{fy}] \quad (25)$$

$$C_{P, fy} = B_{P, fy}^{ex} E_{fy} q_P^i \psi_{fy} \quad (26)$$

From solving equations 25 and 26:

$$\psi_{fy} = \frac{q_C^{i,z1}(1-\gamma_C)}{\left\{ \frac{C_{C,fy} B_{P,fy}^{ex} q_P^i}{B_{C,fy}^{ex} C_{P,fy}} - q_C^{i,z2} \gamma_C + q_C^{i,z1}(1-\gamma_C) \right\}} \quad (27)$$

Note: a penalty is included so that $0 < \psi_{fy} < 1$.

and:

$$\hat{I}_y^i = \frac{C_{fy}}{E_{fy}} = \frac{C_{fy} B_{P,fy}^{ex} q_P^i \psi_{fy}}{C_{P,fy}} \quad (28)$$

Zone 1 (z1): <i>M. capensis</i> only	Zone 2 (z2): Mixed zone
<i>M. capensis</i> : biomass (B_C^{z1}), catch(C_C^{z1})	<i>M. capensis</i> : biomass (B_C^{z2}), catch(C_C^{z2})
	<i>M. paradoxus</i> : biomass (B_P), catch(C_P)
Effort in zone 1 (E^{z1})	Effort in zone 2 (E^{z2})

Figure 1: Diagrammatic representation of the two conceptual fishing zones.

Two species-aggregated CPUE indices are available: the ICSEAF West Coast and the ICSEAF South Coast series. For consistency, q 's for each species (and zone) are forced to be in the same proportion:

$$q_s^{SC} = r q_s^{WC} \quad (29)$$

The contribution of the CPUE data to the negative of the log-likelihood function (after removal of constants) is then given by:

$$-\ln L^{CPUE} = \sum_i \sum_y \left[\ln(\sigma_y^i) + (\varepsilon_y^i)^2 / 2(\sigma_y^i)^2 \right] \quad (30)$$

where

σ_y^i is the standard deviation of the residuals for the logarithms of index i in year y .

Homoscedasticity of residuals for CPUE series is customarily assumed³, so that $\sigma_y^i = \sigma^i$ is estimated in the minimisation process. To correct for possible negative bias in estimates of variance (σ^i) and to avoid according unrealistically high precision (and so giving inappropriately high weight) to the CPUE data, lower bounds on the standard deviations of the residuals for the logarithm of the CPUE series have been enforced: for the historical ICSEAF CPUE series (separate West Coast and South Coast series) the lower bound is set to 0.25, and to 0.15 for the recent GLM-standardised CPUE series, i.e.: $\sigma^{ICSEAF} \geq 0.25$ and $\sigma^{GLM} \geq 0.15$.

In the case of the species-disaggregated CPUE series, the catchability coefficient q^i for biomass index i is estimated by its maximum likelihood value, which in the more general case of heteroscedastic residuals is given by:

$$\ln \hat{q}^i = \frac{\sum_y (\ln I_y^i - \ln \hat{B}_{fy}^{ex}) / (\sigma_y^i)^2}{\sum_y 1 / (\sigma_y^i)^2} \quad (31)$$

³There are insufficient data in any series to enable this to be tested with meaningful power.

In the case of the species-combined CPUE, $q_C^{WC,z1}$, $q_C^{WC,z2}$, q_P^{WC} , r and γ_C are estimated directly in the fitting procedure.

3.2 Survey biomass data

Data from the research surveys are treated as relative biomass indices in a similar manner to the species-disaggregated CPUE series above, with survey selectivity function $S_a^{g, sum/win}$ replacing the commercial selectivity S_{fya}^g (see equation 13 above, which also takes account of the timing of the survey).

An estimate of sampling variance is available for most surveys and the associated σ_y^i is generally taken to be given by the corresponding survey CV. However, these estimates likely fail to include all sources of variability, and unrealistically high precision (low variance and hence high weight) could hence be accorded to these indices. The contribution of the survey data to the negative log-likelihood is of the same form as that of the CPUE biomass data (see equation 30). The procedure adopted takes into account an additional variance $(\sigma_A)^2$ which is treated as another estimable parameter in the minimisation process, i.e:

$$-\ln L^{Survey} = \sum_i \sum_y \left[\ln \left(\sqrt{(\sigma_y^i)^2 + (\sigma_A)^2} \right) + (\varepsilon_y^i)^2 / 2 \left((\sigma_y^i)^2 + (\sigma_A)^2 \right) \right] \quad (32)$$

This procedure is carried out enforcing the constraint that $(\sigma_A)^2 > 0$, i.e. the overall variance cannot be less than its externally input component.

In June 2003, the trawl gear on the *Africana* was changed and a different value for the multiplicative bias factor q is taken to apply to the surveys conducted with the new gear. Calibration experiments have been conducted between the *Africana* with the old gear (hereafter referred to as the “old *Africana*”) and the *Nansen*, and between the *Africana* with the new gear (“new *Africana*”) and the *Nansen*, in order to provide a basis to relate the multiplicative biases of the *Africana* with the two types of gear (q_{old} and q_{new}). A recent calibration analysis based on “Model 1” (see Table 1, “Model 1” of Smith *et al.*, 2013) provided the following estimates:

$$\begin{aligned} (q_{new}/q_{old})^{capensis} &= 0.652 && \text{with SE}=0.073 \text{ and} \\ (q_{new}/q_{old})^{paradoxus} &= 0.883 && \text{with SE}=0.082. \end{aligned}$$

The following contribution is therefore added as a penalty (or a log prior in a Bayesian context) to the negative log-likelihood in the assessment:

$$-\ln L^{q-ch} = \sum_i (\ln q_{new} - \ln q_{old} - \Delta \ln q)^2 / 2\sigma_{\Delta \ln q}^2 \quad (33)$$

A different length-specific selectivity is estimated for the “old *Africana*” and the “new *Africana*”, see section 4.1.2 below. The commercial vessel recently used in place of the *Africana* is assumed to have the same q and same selectivity as the *Africana* with the new net.

For the surveys, the q ’s are estimated directly in the model fitting procedure.

3.3. Commercial proportions at length

Commercial proportions at length from the offshore trawl fleet cannot be disaggregated by species and gender as the data collected did not distinguish these. The model is therefore fit to the proportions at length as determined for both species and gender combined. The catches made by the inshore trawl fleet are assumed to consist of *M. capensis* only, and species and sex information is available over the 2000-2010 period for the longline fleet.

The catches at length are computed as:

$$C_{fyl}^{sg} = \sum_{a=0}^m N_{sya}^g F_{sfl}^g S_{sfl}^g P_{s,a+1/2,l}^g e^{-M_{sa}^g/2} \left(1 - \sum_l S_{sfl}^g F_{fl}^g / 2 \right) \quad (34)$$

Where appropriate, the catches at length are summed over species and gender.

The predicted proportions at length are computed as:

$$\hat{p}_{fyl} = \sum_s \sum_g C_{fyl}^{sg} / \sum_s \sum_g \sum_{l'} C_{fyl'}^{sg} \quad (35a)$$

for species- and sex-aggregated series (offshore trawl data),

$$\hat{p}_{fyl}^s = \sum_g C_{fyl}^{sg} / \sum_g \sum_{l'} C_{fyl'}^{sg} \quad (35b)$$

for sex-aggregated series (inshore trawl data and some longline data), and

$$\hat{p}_{fyl}^{sg} = C_{fyl}^{sg} / \sum_{l'} C_{fyl'}^{sg} \quad (35c)$$

for sex-disaggregated series (2000-2010 longline data).

The commercial proportions at length are grouped into 2cm length classes.

Due to the sex-imbalance of some of the catch data, some of the sex-disaggregated catch proportions are very small for all lengths for a particular gender (e.g. males *M. paradoxus* in the west coast longline catches). To deal with these small numbers, a modified “*sqrt(p)*” method is used to compute the contribution to the CAL data to the negative of the log-likelihood function instead of the Punt-Kennedy method (Punt and Kennedy, 1997) used previously. The formulation mimics a multinomial form for the error distribution by forcing a near-equivalent variance-mean relationship for the error distributions. The modification made to the method is to use a power of 0.35 instead of 0.50 to address homoscedasticity of the residuals (see Appendix B of MARAM/IWS/2018/Hake/P2).

$$-\ell n L^{CAL} = 0.1 \sum_y \sum_l \left[\ell n(\sigma_{len}^i) + \left((p_{yl}^i)^{0.35} - (\hat{p}_{yl}^i)^{0.35} \right)^2 / 2(\sigma_{len}^i)^2 \right] \quad (36)$$

where

the superscript ‘i’ refers to a particular series of proportions at length data which reflect a specified fleet, species and sex (or combination thereof); and

σ_{len}^i is the standard deviation associated with the proportion at length data, which is estimated in the fitting procedure by:

$$\hat{\sigma}_{len}^i = \sqrt{\sum_y \sum_l \left((p_{yl}^i)^{0.35} - (\hat{p}_{yl}^i)^{0.35} \right)^2 / \sum_y \sum_l 1} \quad (37)$$

In the case of sex-disaggregated CAL data, the standard deviation is computed for each gender separately.

The initial 0.1 multiplicative factor in equation 34 reflects a somewhat arbitrary downweighting to allow for correlation between proportions in adjacent length groups. The coarse basis for this adjustment is the ratio of effective number of age-classes present to the number of length groups in the minimisation, under the argument that independence in variability is likely to be more closely related to the former.

3.4. Survey proportions at length

The survey proportions at length are incorporated into the negative of the log-likelihood in an analogous manner to the commercial catches-at-age, using the modified *sqrt(p)* formulation (equation 34).

$p_{sylv}^{g,surv} = \frac{C_{sylv}^{g,surv}}{\sum_g \sum_{l'} C_{sylv}^{g,surv}}$ is the observed proportion of fish of species *s*, gender *g* and length *l* from survey *surv* in year *y*; and

$\hat{p}_{syl}^{g,surv}$ is the expected proportion of fish of species s , gender g and length l in year y in the survey $surv$, given by:

$$\hat{p}_{syl}^{g,surv} = \frac{\sum_a S_{sl}^{g,surv} P_{s,a+1/2,l}^g N_{sya}^g e^{-M_{sa}^g \frac{t^{surv}}{12}} \left(1 - \frac{t^{surv}}{12} \sum_f S_{fya}^g F_{fy} \right)}{\sum_g \sum_{l'} \sum_a S_{sl'}^{g,surv} P_{s,a+1/2,l'}^g N_{sya}^g e^{-M_{sa}^g \frac{t^{surv}}{12}} \left(1 - \frac{t^{surv}}{12} \sum_f S_{fya}^g F_{fy} \right)} \quad (38)$$

All juveniles fish (<21cm) are assumed to be of unknown sex, so that the numerator in equation 38 above is also summed over g and similarly for surveys for which sex-disaggregation is not available.

The survey proportions at length are grouped into 2cm length classes.

The 2017 model did not make use of any minus and plus groups for the commercial and survey proportions-at-length data. However, the presence of many near-zero cells for residuals resulted in negatively biased CAL sigma values, which in turn resulted in very large negative log-likelihood contributions for the CAL data (see MARAM/IWS/2018/Hake/P2). To address this issue, new plus-minus groups were imposed that are data-type dependent, but year-independent. The plus and minus groups that have been used in the RC assessment are listed in the Table below.

1. Commercial sex-aggregated	Minus group	Plus group
West Coast offshore	19	81
South Coast offshore	19	81
South Coast inshore	19	81
West Coast longline	37	101
South Coast Longline	37	101
2. Commercial sex-disaggregated	Minus group	Plus group
WC longline <i>M. paradoxus</i>	37	101
WC longline <i>M. capensis</i>	37	101
SC longline <i>M. paradoxus</i>	37	101
SC longline <i>M. capensis</i>	37	101
3. Survey sex-aggregated	Minus group	Plus group
WC summer <i>M. paradoxus</i>	5	75
WC winter <i>M. paradoxus</i>	5	75
SC spring <i>M. paradoxus</i>	11	75
SC autumn <i>M. paradoxus</i>	11	75
WC summer <i>M. capensis</i>	5	75
WC winter <i>M. capensis</i>	5	75
SC spring <i>M. capensis</i>	5	75
SC autumn <i>M. capensis</i>	5	75
4. Survey sex-disaggregated	Minus group	Plus group
WC summer <i>M. paradoxus</i>	5	75
SC spring <i>M. paradoxus</i>	11	75
SC autumn <i>M. paradoxus</i>	11	75
WC summer <i>M. capensis</i>	5	75
SC spring <i>M. capensis</i>	5	75
SC autumn <i>M. capensis</i>	5	75

3.5. Age-length keys

Under the assumption that fish are sampled randomly with respect to age within each length-class, the contribution to the negative log-likelihood for the ALK data (ignoring constants) is:

$$-\ln L^{ALK} = -w \sum_i \sum_l \sum_a [A_{ial}^{obs} \ln(\hat{A}_{ial}) - A_{ial}^{obs} \ln(A_{ial}^{obs})] \quad (39)$$

where

- w is a downweighting factor to allow for overdispersion in these data compared to the expectation for a multinomial distribution with independent data; this downweighting factor is somewhat arbitrarily set to 0.01 to avoid these data overriding trend information in the indices of biomass;
- A_{ial}^{obs} is the observed number of fish of size class l that have been read as of age a for ALK i (a specific combination of survey, year, species and gender);
- $\hat{A}_{ial}$ is the model estimate of A_{ial}^{obs} , computed as:

$$\hat{A}_{ial} = W_{il} \frac{\tilde{C}_{ial}}{\sum_{a'} \tilde{C}_{ia'l}} \quad (40)$$

where

$$\tilde{C}_{ial} = N_{sya}^g \tilde{P}_{a,l} S_l^i e^{-M_{sa}^g \frac{t^i}{12}} \left(1 - \frac{t^i}{12} \sum_f S_{fya}^g F_{fy}\right) \quad (41)$$

S_l^i is the selectivity-at-length l for ALK i ,

t^i is the month (on average) in which the ALK was sampled ($= t^{surv}$ (equation 13) for surveys and $=6$ for commercial)

$W_{i,l}$ is the number of fish in length class l that were aged for ALK i ,

$\tilde{P}_{a,l} = \sum_a Y(a'|a) P_{a,l}$ is the ALK for age a and length l after accounting for age-reading error,

with

$Y(a'|a)$ the age-reading error matrix, representing the probability of an animal of true age a being aged to be that age or some other age a' .

$\tilde{P}_{a,l}$ takes account of the timing of the age-length sampling (from $P_{a+1/2,l}$ for commercial samples and survey samples if t^{surv} is greater than 6 and from $P_{a,l}$ otherwise).

Note: All aged animals less than 21cm in length are assumed to be juveniles, i.e. of unknown gender. Outliers, defined as the data points lying outside the mean ± 3 s.d. for each age (mean and s.d. calculated across all years and surveys) have been discarded.

The age-length information is grouped into 2cm length classes.

Age-reading error matrices have been computed for each reader and for each species. When multiple readers age the same fish, these data are considered to be independent information in the model fitting.

3.6 Stock-recruitment function residuals

The stock-recruitment residuals are assumed to be log-normally distributed. Thus, the contribution of the recruitment residuals to the negative of the log-likelihood function is given by the penalty function:

$$-\ln L^{SR} = \sum_s \left[\sum_{y=y1}^{y2} \zeta_{sy}^2 / 2\sigma_R^2 \right] \quad (42)$$

where

- ζ_{sy} is the recruitment residual for species s , and year y , which is assumed to be log-normally distributed with standard deviation σ_R and which is estimated for year $y1$ to $y2$ (see equation 4) (estimating the stock-recruitment residuals is made possible by the availability of catch-at-age data, which give some indication of the age-structure of the population); and
- σ_R is the standard deviation of the log-residuals, which is input.

The stock-recruitment residuals are estimated for years 1985 to 2016, with recruitment for other years being set deterministically (i.e. exactly as given by the estimated stock-recruitment curve) as there is insufficient catch-at-age information to allow reliable residual estimation for earlier years. A limit on the recent recruitment fluctuations is set by having the σ_R (which measures the extent of variability in recruitment) decreasing linearly from 0.45 in 2012 to 0.1 in

2016 (or more generally over the last five years of the assessment), thereby effectively forcing recruitment over the last years to lie closer to the stock-recruitment relationship curve.

The detailed contributions to the negative log-likelihood are given in **Table 2** for the Reference Case.

4. Model parameters

4.1 Estimable parameters

The primary parameters estimated are the species-specific female virgin spawning biomass ($K_s^{\varnothing_p}$) and steepness (h_s) and γ (for the modified Ricker curve used in the Reference Case, see equation 4b) of the stock-recruitment relationship. The standard deviations σ^i for the CPUE series residuals (the species-combined as well as the GLM-standardised series) as well as the additional variance $(\sigma_A^i)^2$ for each species and survey q 's are treated as estimable parameters in the minimisation process. Similarly, in the case of the species-combined CPUE, $q_C^{WC,z1}$, $q_C^{WC,z2}$, q_P^{WC} , ρ and γ_C are directly estimated in the fitting procedure.

The species- and gender-specific von Bertalanffy growth curve parameters (l_∞ , κ and t_0) are estimated directly in the model fitting process, as well as the θ_0 , θ_1 and θ_4 , values used to compute the standard deviation of the length-at-age a .

Stock-recruitment residuals ς_{sy} are estimable parameters in the model fitting process. They are estimated separately for each species from 1985 to the present, and set to zero pre-1985 because there are no catch-at-length data for that period to provide the information necessary to inform estimation.

All the estimable parameters apart from the selectivity parameters are listed in **Table 3**, with the bounds enforced and their values as estimated for the Reference Case.

The following parameters are also estimated in the model fits undertaken (if not specifically indicated as fixed).

4.1.1 Natural mortality:

The natural mortality-at-age vectors are fixed at the values estimated in the hake predation model see MARAM/IWS/2018/Hake/BG7), and are listed in the Table below.

Age	<i>M. paradoxus</i>	<i>M. capensis</i>
0	0.839	0.907
1	0.820	0.803
2	0.792	0.648
3	0.710	0.494
4	0.659	0.344
5	0.608	0.319
6	0.548	0.291
7	0.457	0.263
8	0.362	0.237
9	0.286	0.218
10	0.237	0.207
11	0.213	0.202
12	0.203	0.200
13	0.200	0.200
14	0.200	0.200
15	0.200	0.200

4.1.2 Survey fishing selectivity-at-length:

The survey selectivities are all modelled by a double normal shape as recommended by the International Panel (Smith *et al.*, 2013). Thus the selectivity-at-length for each species, sex, gear and survey is estimated by the following functional form:

$$S_l = \begin{cases} \exp\left(-\frac{(l-l_{\max})^2}{2\sigma_{\text{Left}}^2}\right) & \text{for } l \leq l_{\max} \\ \exp\left(-\frac{(l-l_{\max})^2}{2\sigma_{\text{Right}}^2}\right) & \text{for } l > l_{\max} \end{cases} \quad (45)$$

where σ_{Left} , σ_{Right} and $l_{\max}$ are estimable parameters.

For the surveys, different selectivities can potentially be estimated for all of the following “effects”:

- Species (*M. paradoxus*/*M. capensis*),
- Coasts (West coast/South coast),
- Seasons (Summer/Winter/Spring/Autumn),
- Gear (*Africana* old/new gear), and
- Gender (males/females).

Note that selectivity is always 1 for $l=l_{\max}$ except for females *M. paradoxus* on the South Coast, for which the maximum female selectivity is always set at an estimable proportion of the maximum of 1 for the males.

To select an appropriate combination, several runs have been carried out, estimating the selectivities including one or more different effects. The final run selected involves maintaining the same parameters for each sex and gear across other effects, except for estimating a fixed multiplicative change to the σ_{Right} parameter if sex is female (Δ_{fem}) and also if new gear is used (Δ_{gear}). This multiplicative change is species and coast dependent, i.e.:

$$\sigma_{\text{Right},f,g} = \begin{cases} \sigma_{\text{Right}} & \text{if } f = \text{old gear, and } g = \text{males} \\ \sigma_{\text{Right}}\Delta_{\text{fem}} & \text{if } f = \text{old gear, and } g = \text{females} \\ \sigma_{\text{Right}}\Delta_{\text{gear}} & \text{if } f = \text{new gear, and } g = \text{males} \\ \sigma_{\text{Right}}\Delta_{\text{fem}}\Delta_{\text{gear}} & \text{if } f = \text{new gear, and } g = \text{females} \end{cases} \quad (46)$$

With σ_{Right} , Δ_{fem} and Δ_{gear} estimated separately for each for each species and coast combination.

Details of the survey selectivities (including the values estimated in the Reference Case) are shown in **Table 4**.

Selectivities-at-length are converted to selectivities-at-age using the begin-year age-length matrix for the summer and autumn surveys, and the mid-year age-length matrix for winter and spring surveys.

4.1.3 Commercial fishing selectivity-at-length:

As for the survey selectivities, the commercial fishing selectivity-at-length for each species and fleet, S_{sfl} , is estimated in terms of a double normal curve.

Periods of fixed and changing selectivity have been assumed for the offshore trawl fleet to take account of the change in the selectivity at low ages over time in the commercial catches, likely due to the phasing out of the (illegal) use of net liners to enhance catch rates.

Two selectivity periods are also assumed for the longline fleet.

On the South Coast, for *M. paradoxus*, the female offshore trawl selectivity (only the trawl fleet is assumed to catch *M. paradoxus* on the South Coast) is scaled down by a factor taken as the average of those estimated for the South Coast spring and autumn surveys. Although there is no gender information for the commercial catches, the South Coast spring

and autumn surveys catch a much higher proportion of male *M. paradoxus* than female (ratios of about 7:1 and 3.5:1 for spring and autumn respectively). This is assumed to reflect a difference in distribution of the two genders which would therefore affect the commercial fleet similarly.

Details of the fishing selectivities (including the number of parameters estimated and their values as estimated in the Reference Case) are shown in **Table 5**.

4.2 Input parameters and other choice for application to hake

4.2.1 Age-at-maturity:

The proportion of fish of species *s*, gender *g* and length *l* that are mature is assumed to follow a logistic curve with the parameter values given in **Table 6**:

$$f_{sl}^g = \left(1 + e^{\frac{l_{50}^{s,g} - l}{\Delta^{s,g}}} \right)^{-1} \quad (45)$$

Maturity-at-length is then converted to maturity-at-age as follows:

$$f_{sa}^g = \sum_l f_{sl}^g P_{a,l}^g \quad (46)$$

with maturity at age 0 set to 0.

4.2.2 Weight-at-length:

The weight-at-length for each species and gender is calculated from the mass-at-length function, with values of the parameters for this function listed in **Table 7**:

$$w_l = \alpha l^\beta \quad (47)$$

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Table 2: Negative log-likelihood contributions for the 2018 Reference Case.

		Total	Both spp.	<i>M. paradoxus</i>	<i>M. capensis</i>
-lnL total		-3154.1			
ICSEAF CPUE	WC	-37.7	-28.5		
	SC		-9.3		
GLM CPUE	WC	-202.9		-60.7	-52.4
	SC			-50.5	-39.3
Survey	WC summer	-34.5		-15.1	-2.0
	WC winter			-3.0	-0.8
	SC spring			2.4	-4.9
	SC autumn			4.9	-16.0
Commercial sex-aggregated CAL	WC offshore	-825.6	-255.5		
	SC offshore		-226.3		
	SC inshore				-264.0
	WC longline		-42.2		
Commercial sex-disaggregated CAL	SC longline	-681.6			-37.7
	WC longline			-230.0	-175.1
Survey sex-aggregated CAL	SC longline	-413.3		-208.7	-67.7
	WC summer			-96.7	-70.9
	WC winter			-51.0	-44.0
	SC spring			-30.5	-42.6
Survey sex-disaggregated CAL	SC autumn	-1090.0		-36.5	-41.2
	WC summer			-314.1	-241.3
	SC spring			-44.6	-54.7
Age-length keys		122.0			
SR residuals		9.4		3.1	6.4

Table 3: Parameters estimated in the model fitting procedure, excluding selectivity parameters, with bounds enforced and values as estimated for the Reference Case.

Estimable parameter	Bounds enforced	Reference Case estimates			
			<i>M. paradoxus</i>	<i>M. capensis</i>	
$\ln(K)$	(3.5;10)		5.763	5.671	
h	(0.5;2)		1.618	2.000	
γ	(0;2)		0.419	0.854	
ζ	(-5;5)	1985	-0.446	-0.065	
		1986	-0.144	0.187	
		1987	0.269	0.527	
		1988	0.016	0.564	
		1989	0.091	0.551	
		1990	0.059	0.376	
		1991	0.073	0.186	
		1992	-0.139	0.041	
		1993	0.270	0.280	
		1994	0.183	0.196	
		1995	0.272	-0.023	
		1996	-0.231	0.124	
		1997	-0.079	0.105	
		1998	-0.229	-0.114	
		1999	-0.293	-0.117	
		2000	0.048	0.046	
		2001	0.128	-0.174	
		2002	-0.352	-0.355	
		2003	-0.129	-0.150	
		2004	0.292	-0.015	
		2005	0.169	-0.048	
		2006	-0.104	-0.204	
		2007	-0.034	-0.217	
		2008	0.168	-0.246	
		2009	-0.174	-0.612	
		2010	0.003	-0.471	
		2011	-0.191	-0.357	
		2012	0.113	-0.358	
		2013	0.191	0.097	
		2014	0.248	0.050	
		2015	0.007	0.188	
		2016	-0.034	0.011	
		2017	-0.018	-0.004	
$(\sigma_A)^2$	(0;0.5)		0.179	0.144	
σ_{ICSEAF}^{WC}	(0.25;1)	0.25			
σ_{ICSEAF}^{SC}	(0.25;1)	0.25			
σ_{GLM}^{WC}	(0.15;1)		0.150	0.158	
σ_{GLM}^{SC}	(0.15;1)		0.166	0.221	
ICSEAF CPUE					
$q_C^{WC,z1}$	(0;10)			0.114	
$q_C^{WC,z2}$	(0;10)			2.975	
q_p^{WC}	(0;10)		0.032		
r	(0;10)		0.073		
γ_c	(0;2)			0.013	
survey lnq	(-5;2)		Old gear	New gear	New gear
WC summer			0.501	0.381	0.031
WC winter			0.126		0.101
SC spring			-0.031	-0.207	-0.098
SC autumn			-0.031	-0.189	0.158
Age-length dbn			Males	Females	Males
θ_0	(0.1;100)		2.460	0.100	2.344
θ_1	(0.01;100)		4.571	4.290	4.544
θ_{14}	(0.01;100)		9.687	12.470	6.707
$\ln(\kappa)$	(-20;2)		52.303	50.064	53.607
$t0$	(-10;0)		-19.500	-19.423	-18.882
					-19.603

Table 4: Details for the survey selectivities-at-length for each species for the Reference Case. All selectivities are assumed to have a double normal shape. The Reference Case values are given, with the values estimated shown in bold.

	<i>M. paradoxus</i>			No. of est. parameters	<i>M. capensis</i>			No. of est. parameters
	σ_{left}	σ_{right}	l_{max}		σ_{left}	σ_{right}	l_{max}	
West Coast summer	$\Delta_{len} =$	2.256	$\Delta_{NG} =$	0.922	$\Delta_{len} =$	1.690	$\Delta_{NG} =$	1.074
Males, old gear	22.547	4.162	14.058	5	14.338	1.974	19.942	22.547
Females, old gear	22.547	9.388	14.058		14.338	3.336	19.942	22.547
Males, new gear	22.547	3.836	14.058		14.338	2.120	19.942	22.547
Females, new gear	22.547	8.653	14.058		14.338	3.582	19.942	22.547
West coast winter	$\Delta_{len} =$	2.256	$\Delta_{NG} =$	-	$\Delta_{len} =$	1.690	$\Delta_{NG} =$	-
Males, old gear	24.360	4.541	22.951	3	21.834	2.873	15.282	3
Females, old gear	24.360	10.242	22.951		21.834	4.855	15.282	
Males, new gear	-	-	-		-	-	-	
Females, new gear	-	-	-		-	-	-	
South Coast spring	$\Delta_{len} =$	18355.573	$\Delta_{NG} =$	1.458	$\Delta_{len} =$	1.559	$\Delta_{NG} =$	0.793
Males, old gear	32.309	3.316	4.620	6	55.526	22.473	10.453	5
Females, old gear	32.309	60866.582	4.620		55.526	412501.753	10.453	
Males, new gear	32.309	4.836	4.620		55.526	17.810	10.453	
Females, new gear	32.309	88763.801	4.620		55.526	27.762	10.453	
Female selectivities multiplicatively scaled by 0.084								
South coast autumn	$\Delta_{len} =$	18355.6	$\Delta_{NG} =$	1.458	$\Delta_{len} =$	1.559	$\Delta_{NG} =$	0.793
Males, old gear	33.529	3.408	6.691	4	48.666	14.969	12.643	3
Females, old gear	33.529	62552.9	6.691		48.666	274760.9	12.643	
Males, new gear	33.529	4.970	6.691		48.666	11.863	12.643	
Females, new gear	33.529	91223.1	6.691		48.666	18.492	12.643	
Female selectivities multiplicatively scaled by 0.242								

Table 5: Details for the commercial selectivities-at-length for each fleet and species combination for the Reference Case. All selectivities are assumed to have the double normal shape. The Reference Case values are given, with the values estimated shown in bold.

	<i>M. paradoxus</i>			No. est. param.	<i>M. capensis</i>			No. est. param.
	σ_{left}	σ_{right}	l_{max}		σ_{left}	σ_{right}	l_{max}	
1. WC off. trawl				6				0
1917-1976	As 1989 selectivity				As 1989 selectivity			
1977-1984	Estimated	Estimated	Estimated		As 1993-2016	As 1993-2016 - Δ_{para}		
	32.475	3.880	1547545.8		39.485	13.434	=20.149-(-1547521.739)=1547541.9	
1985-1992	Linear change between 1984 and 1993				Linear change between 1984 and 1993			
1993-2016	Estimated	Estimated	Estimated		As inshore	As inshore*3	As inshore+5	
	33.657	3.370	24.094		39.485	13.434	20.149	
	$\Delta_{para}=24.094-1547545.8=-1547521.739$							
2. SC off. trawl				3				0
1917-1976	As 1989 selectivity				As 1989 selectivity			
1977-1984	As 1993-2016		As 1993-2016 - Δ_{para}		As 1993-2016	As 1993-2016 - Δ_{para}		
	34.362	3.252	=2114504-(-1547521.739)=3662025.7		39.485	13.434	=20.149-(-1547521.739)=1547541.9	
1985-1992	Linear change between 1984 and 1993				Linear change between 1984 and 1993			
1993-2016	Estimated	Estimated	Estimated		As inshore	As inshore*3	As inshore+5	
	34.362	3.252	2114504.0		39.485	13.434	20.149	
3. SC insh. trawl					0	Estimated	Estimated	
					39.485	4.478	15.149	
4. WC longline				8				8
1984-1999	Males		Estimated		Males		Estimated	
2000-2005	same for all periods	same for all periods	78.561		same for all periods	same for all periods	63.788	
			est-shift 1				est-shift 1	
			=78.561-5.451=73.110				=63.788-(-1.359)=65.146	
2006-2016	8.716	8.134	est-shift2		7.378	10.241	est-shift2	
			=78.561-7.100=71.461				=63.788-0.258=63.529	
1984-1999	Females		Estimated		Females		Estimated	
2000-2005	same for all periods	same for all periods	77.437		same for all periods	same for all periods	69.356	
			est-shift 1				est-shift 1	
			=77.437-5.451=71.986				=69.356-(-1.359)=70.715	
2006-2016	7.516	8.595	est-shift2		8.110	9.337	est-shift2	
			=77.437-7.100=70.377				=69.356-0.258=69.095	
5. SC longline				8				8
1984-1999	Males		Estimated		Males		Estimated	
2000-2005	same for all periods	same for all periods	46.539		same for all periods	same for all periods	65.075	
			est-shift 1				est-shift 1	
			=46.539-(-20.000)=66.539				=65.075-2.383=62.692	
2006-2016	6.770	7.841	est-shift2		6.378	9.422	est-shift2	
			=46.539-(-15.805)=62.344				=65.075-3.444=61.631	
1984-1999	Females		Estimated		Females		Estimated	
2000-2005	same for all periods	same for all periods	51.602		same for all periods	same for all periods	70.728	
			est-shift 1				est-shift 1	
			=51.602-(-20.000)=71.602				=70.728-2.383=68.345	
2006-2016	8.398	5.193	est-shift2		7.683	9.737	est-shift2	
			=51.602-(-15.805)=67.407				=70.728-3.444=67.284	
5. SC handline				0	Average of inshore and SC longline female			0
	-	-	-		23.584	7.108	41.216	

Table 6: Female maturity-at-length ogive (equation 44) parameter estimates (from Singh *et al.* 2013).

	l_{50} (cm)	Δ (cm)
<i>M. paradoxus</i>	41.526	2.979
<i>M. capensis</i>	53.825	10.144

Table 7: Length-weight relationship estimates (from Singh 2013).

	α (gm/cm $^{\beta}$)	β
<i>M. paradoxus:</i>		
Males	0.007750	2.977
Females	0.005700	3.071
<i>M. capensis:</i>		
Males	0.006750	3.044
Females	0.005950	3.075

Appendix A: Reference Case data

The data listed below correspond to the data in the master data file “20181109 V1.0 Input Data Master File.xlsx”.

Table App.A.1a: Species-disaggregated catches (in thousand tons) by fleet of South African hake from the south and west coasts for the period 1917-1977. The offshore catches have been split between species using the Model A6b species splitting algorithm (MARAM/IWS/2018/Hake/BG6).

	<i>M. paradoxus</i>	<i>M. capensis</i>	<i>M. paradoxus</i>			<i>M. capensis</i>		
	Offshore	Offshore	Offshore			Offshore		Inshore
	WC	WC	WC	SC		WC	SC	SC
1917	0.000	1.000	1948	0.056	-	58.744	-	-
1918	0.000	1.100	1949	0.106	-	57.294	-	-
1919	0.000	1.900	1950	0.257	-	71.743	-	-
1920	0.000	0.000	1951	0.620	-	88.880	-	-
1921	0.000	1.300	1952	1.188	-	87.612	-	-
1922	0.000	1.000	1953	2.395	-	91.105	-	-
1923	0.000	2.500	1954	5.092	-	100.308	-	-
1924	0.000	1.500	1955	10.229	-	105.171	-	-
1925	0.000	1.900	1956	18.335	-	99.865	-	-
1926	0.000	1.400	1957	31.885	-	94.515	-	-
1927	0.000	0.800	1958	48.593	-	82.107	-	-
1928	0.000	2.600	1959	71.733	-	74.267	-	-
1929	0.000	3.800	1960	94.095	-	65.805	-	1.000
1930	0.000	4.400	1961	97.390	-	51.310	-	1.308
1931	0.000	2.800	1962	102.622	-	44.978	-	1.615
1932	0.000	14.300	1963	121.695	-	47.805	-	1.923
1933	0.000	11.100	1964	118.512	-	43.788	-	2.231
1934	0.000	13.800	1965	149.541	-	53.459	-	2.538
1935	0.000	15.000	1966	144.301	-	50.699	-	2.846
1936	0.000	17.700	1967	131.066	4.260	45.634	9.926	3.154
1937	0.000	20.200	1968	106.642	8.391	36.958	19.517	3.462
1938	0.000	21.100	1969	122.685	11.412	42.415	26.518	3.769
1939	0.000	20.000	1970	105.925	7.140	36.575	16.583	4.077
1940	0.000	28.600	1971	150.177	9.065	51.823	21.050	4.385
1941	0.000	30.600	1972	181.368	14.057	62.565	32.639	4.692
1942	0.001	34.499	1973	117.318	21.782	40.464	50.574	5.000
1943	0.001	37.899	1974	91.458	27.351	31.542	63.502	10.056
1944	0.002	34.098	1975	66.637	20.310	22.980	47.153	6.372
1945	0.004	29.196	1976	106.996	15.634	36.898	36.296	5.740
1946	0.010	40.390	1977	76.089	11.131	26.239	25.841	3.500
1947	0.020	41.380						

Table App.A.1b: Species-disaggregated catches (in thousand tons) by fleet of South African hake from the south and west coasts for the period 1978-present. The recent offshore trawl catches are from MARAM/IWS/2018/Hake/BG6, the recent inshore and handline catches are from Rob Cooper (pers. commn) and the new longline catches from Sobahle Somhlaba (pers. commn).

	<i>M. paradoxus</i>				<i>M. capensis</i>					
	Offshore		Longline		Offshore		Inshore	Longline		Handline
	WC	SC	WC	SC	WC	SC	SC	WC	SC	SC
1978	101.042	3.220	-	-	26.470	4.365	4.931	-	-	-
1979	94.331	1.924	-	-	39.192	4.995	6.093	-	-	-
1980	99.654	2.206	-	-	33.873	4.254	9.121	-	-	-
1981	88.883	0.910	-	-	32.048	4.575	9.400	-	-	-
1982	83.618	3.353	-	-	29.732	8.005	8.089	-	-	-
1983	71.238	4.723	0.126	-	23.195	7.792	7.672	0.104	-	-
1984	82.358	3.796	0.200	0.005	28.897	7.139	9.035	0.166	0.011	-
1985	94.428	8.059	0.638	0.091	30.642	11.957	9.203	0.529	0.201	0.065
1986	103.756	8.580	0.753	0.094	30.049	7.385	8.724	0.625	0.208	0.084
1987	93.517	7.459	1.952	0.110	24.008	8.225	8.607	1.619	0.243	0.096
1988	79.913	5.876	2.833	0.103	26.669	8.640	8.417	2.350	0.228	0.071
1989	82.230	6.182	0.158	0.010	25.029	12.730	10.038	0.132	0.022	0.137
1990	81.996	9.341	0.211	-	21.640	13.451	10.012	0.175	-	0.348
1991	87.093	12.448	-	0.932	19.357	9.626	8.206	-	2.068	1.270
1992	84.768	17.297	-	0.466	18.519	9.165	9.252	-	1.034	1.099
1993	102.125	9.880	-	-	15.940	4.380	8.870	-	-	0.278
1994	103.541	6.726	0.882	0.194	20.327	4.326	9.569	0.732	0.432	0.449
1995	100.268	4.004	0.523	0.202	20.629	3.146	10.630	0.434	0.448	0.756
1996	107.381	8.966	1.308	0.568	21.794	4.323	11.062	1.086	1.260	1.515
1997	100.654	10.509	1.410	0.582	16.500	5.327	8.834	1.170	1.290	1.404
1998	111.154	9.742	0.505	0.457	16.499	4.411	8.283	0.419	1.014	1.738
1999	88.581	11.420	1.532	1.288	15.179	3.926	8.595	1.272	2.856	2.749
2000	96.587	7.700	2.706	3.105	21.114	5.830	10.906	2.000	1.977	5.500
2001	101.247	7.850	1.417	0.084	16.349	8.306	11.836	2.394	1.527	7.300
2002	91.207	12.443	4.469	1.585	13.724	6.141	9.581	2.391	2.546	3.500
2003	93.711	17.397	3.305	1.252	11.665	7.636	9.883	2.526	3.078	3.000
2004	85.722	26.065	2.855	1.196	12.510	8.704	10.004	2.297	2.731	1.600
2005	85.869	21.778	3.091	0.472	9.398	7.468	7.881	2.773	3.270	0.700
2006	81.513	18.050	3.241	0.485	11.984	6.578	5.524	2.520	3.227	0.400
2007	92.724	13.488	2.512	3.021	16.145	3.757	6.350	2.522	2.522	0.400
2008	85.538	13.191	2.255	0.809	13.838	4.316	5.496	1.937	1.893	0.231
2009	68.202	10.895	2.410	1.069	12.296	4.806	5.639	2.828	2.520	0.265
2010	69.709	15.457	2.394	1.527	10.186	4.055	5.472	3.086	3.024	0.275
2011	76.576	17.904	2.522	0.140	15.673	4.086	6.013	3.521	3.047	0.186
2012	81.411	16.542	4.358	0.306	12.928	4.584	3.223	2.570	1.737	0.008
2013	74.341	28.859	6.056	0.060	8.761	4.475	2.920	2.606	1.308	0.000
2014	73.251	40.863	6.879	0.008	9.672	6.579	2.965	2.123	0.315	0.002
2015	77.521	31.713	5.223	0.021	12.728	4.067	3.077	2.935	0.064	0.001
2016	92.242	18.641	2.806	0.001	14.797	2.851	3.973	4.360	0.002	0.001

Table App.A.2: GLM standardized CPUE data for *M. paradoxus* and *M. capensis*, corresponding to the Model A6b species splitting algorithm (MARAM/IWS/2018/Hake/BG6).

Year	GLM CPUE (kg min ⁻¹)			
	<i>M. paradoxus</i>		<i>M. capensis</i>	
	West Coast	South Coast	West Coast	South Coast
1978	8.74	1.41	2.33	4.05
1979	8.78	1.13	3.22	4.50
1980	8.22	2.13	2.88	5.49
1981	8.06	1.33	3.02	4.73
1982	7.87	2.01	2.61	4.98
1983	8.73	2.03	3.27	5.85
1984	8.94	2.25	3.33	6.81
1985	10.51	3.04	3.73	8.56
1986	9.08	3.08	3.09	7.03
1987	7.58	2.83	2.61	6.46
1988	7.37	2.27	2.38	6.59
1989	8.00	2.37	2.56	7.34
1990	8.47	3.13	2.29	8.84
1991	9.45	3.47	2.76	7.90
1992	8.41	3.86	3.16	7.43
1993	8.49	3.20	3.05	5.44
1994	9.09	2.84	3.57	6.52
1995	8.06	2.11	3.42	5.95
1996	8.86	3.18	3.92	6.02
1997	7.86	3.43	3.32	5.01
1998	8.95	3.24	3.79	4.95
1999	7.35	3.83	3.38	5.34
2000	6.62	2.90	3.15	5.92
2001	5.32	2.86	2.25	4.45
2002	5.21	2.56	2.14	4.75
2003	5.99	3.01	1.92	5.15
2004	4.91	2.50	1.79	4.27
2005	4.78	2.17	1.36	3.66
2006	5.05	2.28	1.55	2.89
2007	6.15	2.40	1.62	2.83
2008	6.78	2.48	2.01	3.73
2009	7.00	2.95	2.98	6.42
2010	7.85	3.25	2.68	5.18
2011	7.63	3.83	3.13	5.90
2012	6.56	3.35	2.59	3.91
2013	6.57	3.73	2.67	3.91
2014	6.68	3.43	2.21	2.83
2015	8.67	3.36	2.73	2.84
2016	8.80	3.47	2.77	3.74

Table App.A.3: Survey abundance estimates and associated standard errors in thousand tons for *M. paradoxus* for the depth range 0-500m for the South Coast and for the West Coast (Fairweather, 2016a). Values in bold are for the surveys conducted by the *Africana* with the new gear, while underlined values are for the surveys conducted by the *Andromeda* and in 2016 by the *Compass Challenger*.

Year	West coast				South coast			
	Summer		Winter		Spring (Sept)		Autumn (Apr/May)	
	Biomass	(s.e.)	Biomass	(s.e.)	Biomass	(s.e.)	Biomass	(s.e.)
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)	-	-	98.434	(42.249)	185.345	(82.188)
2004	271.540	(55.710)	-	-	70.001	(22.156)	39.822	(22.153)
2005	296.065	(42.409)	-	-	-	-	26.691	(6.017)
2006	316.247	(57.332)	-	-	68.507	(18.283)	34.868	(5.843)
2007	407.377	(77.222)	-	-	66.267	(21.966)	102.195	(53.688)
2008	238.143	(37.018)	-	-	25.661	(8.324)	33.034	(9.340)
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	<u>136.260</u>	(25.116)	-	-	-	-	-	-
2014	<u>269.482</u>	(37.492)	-	-	-	-	<u>62.925</u>	(24.802)
2015	<u>207.583</u>	(24.057)	-	-	-	-	<u>111.411</u>	(51.852)
2016	<u>312.876</u>	(33.250)	-	-	-	-	<u>94.177</u>	(51.731)
2017	319.024	(58.766)	-	-	-	-	-	-

Table App.A.4: Survey abundance estimates and associated standard errors in thousand tons for *M. capensis* for the depth range 0-500m for the South Coast and for the West Coast (Fairweather, 2016a). Values in bold are for the surveys conducted by the *Africana* with the new gear, while underlined values are for the surveys conducted by the *Andromeda* and in 2016 by the *Compass Challenger*.

Year	West coast				South coast			
	Summer		Winter		Spring (Sept)		Autumn (Apr/May)	
	Biomass	(s.e.)	Biomass	(s.e.)	Biomass	(s.e.)	Biomass	(s.e.)
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)	-	-	73.604	(9.142)	117.538	(17.192)
2004	194.294	(30.714)	-	-	96.933	(13.936)	92.796	(11.318)
2005	63.363	(11.498)	-	-	-	-	68.672	(5.302)
2006	73.655	(17.255)	-	-	92.831	(8.998)	116.298	(11.931)
2007	73.230	(9.306)	-	-	67.937	(6.553)	65.935	(5.303)
2008	52.577	(7.069)	-	-	87.836	(9.723)	102.169	(9.681)
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	<u>30.383</u>	(4.575)	-	-	-	-	-	-
2014	<u>219.756</u>	(60.342)	-	-	-	-	<u>63.389</u>	(6.415)
2015	<u>65.086</u>	(9.178)	-	-	-	-	<u>76.059</u>	(6.873)
2016	<u>115.058</u>	(30.400)	-	-	-	-	<u>83.197</u>	(6.600)
2017	69.289	(14.486)	-	-	-	-	-	-

Table App.A.5a: West coast commercial offshore trawl, species combined, sex-aggregated, catch-at-length data given as proportions (Fairweather, 2016b). Here and below, the blue bars represent the sizes of the proportions, with the shortest bar representing the lowest proportion in the matrix and the longest bar representing the highest proportion.

Length	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81+
1981	0.006	0.026	0.059	0.119	0.168	0.159	0.120	0.086	0.065	0.047	0.031	0.023	0.019	0.013	0.011	0.009	0.007	0.006	0.005	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.001
1982	0.003	0.025	0.076	0.120	0.153	0.166	0.130	0.093	0.059	0.046	0.028	0.018	0.015	0.012	0.012	0.010	0.008	0.006	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
1983	0.000	0.005	0.018	0.054	0.088	0.104	0.126	0.127	0.110	0.087	0.065	0.044	0.034	0.028	0.024	0.020	0.015	0.012	0.009	0.007	0.005	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001
1984	0.000	0.003	0.009	0.057	0.113	0.127	0.139	0.111	0.092	0.082	0.062	0.036	0.029	0.025	0.023	0.019	0.014	0.010	0.009	0.008	0.007	0.006	0.005	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.000	0.001
1985	0.000	0.000	0.001	0.004	0.015	0.043	0.115	0.146	0.132	0.119	0.096	0.071	0.052	0.036	0.029	0.025	0.018	0.017	0.014	0.013	0.011	0.009	0.007	0.006	0.005	0.005	0.004	0.003	0.002	0.001	0.001	0.001
1986	0.000	0.000	0.002	0.008	0.029	0.050	0.094	0.136	0.147	0.134	0.111	0.075	0.050	0.033	0.026	0.019	0.015	0.011	0.009	0.008	0.006	0.006	0.006	0.005	0.005	0.004	0.004	0.003	0.002	0.001	0.001	0.002
1987	0.000	0.000	0.004	0.027	0.071	0.119	0.140	0.137	0.107	0.072	0.058	0.046	0.039	0.036	0.029	0.026	0.019	0.016	0.012	0.010	0.008	0.006	0.004	0.003	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001
1988	0.000	0.000	0.009	0.036	0.107	0.141	0.157	0.129	0.102	0.074	0.050	0.038	0.028	0.020	0.017	0.015	0.012	0.011	0.009	0.009	0.007	0.007	0.006	0.004	0.003	0.002	0.002	0.001	0.001	0.000	0.000	0.001
1989	0.000	0.003	0.018	0.055	0.115	0.158	0.161	0.122	0.088	0.065	0.045	0.033	0.026	0.020	0.017	0.013	0.010	0.008	0.007	0.007	0.006	0.006	0.005	0.004	0.003	0.002	0.001	0.001	0.001	0.000	0.000	0.000
1990	0.000	0.001	0.005	0.013	0.058	0.106	0.131	0.141	0.127	0.115	0.081	0.055	0.042	0.030	0.023	0.016	0.011	0.010	0.007	0.006	0.004	0.004	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.000	0.000	0.000
1991	0.000	0.001	0.006	0.022	0.049	0.077	0.092	0.099	0.088	0.088	0.075	0.066	0.063	0.052	0.041	0.032	0.024	0.019	0.014	0.014	0.011	0.012	0.011	0.010	0.008	0.007	0.005	0.004	0.003	0.002	0.001	0.002
1992	0.000	0.002	0.010	0.041	0.092	0.122	0.124	0.107	0.082	0.068	0.053	0.045	0.036	0.031	0.032	0.026	0.023	0.023	0.017	0.015	0.011	0.009	0.007	0.006	0.005	0.004	0.003	0.002	0.002	0.001	0.001	0.001
1993	0.000	0.001	0.003	0.015	0.041	0.075	0.095	0.085	0.071	0.069	0.073	0.064	0.065	0.063	0.066	0.051	0.038	0.034	0.023	0.019	0.012	0.009	0.006	0.005	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.001
1994	0.000	0.000	0.001	0.005	0.027	0.077	0.118	0.131	0.080	0.080	0.069	0.053	0.042	0.042	0.044	0.046	0.046	0.041	0.029	0.021	0.012	0.011	0.006	0.005	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.001
1995	0.000	0.003	0.019	0.035	0.054	0.071	0.122	0.118	0.119	0.109	0.085	0.048	0.032	0.036	0.023	0.013	0.016	0.015	0.014	0.015	0.014	0.010	0.009	0.006	0.004	0.003	0.003	0.001	0.001	0.000	0.000	0.001
1996	0.000	0.004	0.017	0.043	0.057	0.096	0.116	0.121	0.110	0.097	0.082	0.062	0.042	0.031	0.021	0.019	0.011	0.012	0.009	0.009	0.008	0.007	0.005	0.005	0.003	0.003	0.002	0.001	0.001	0.001	0.000	0.001
1997	0.000	0.003	0.018	0.040	0.060	0.096	0.130	0.118	0.111	0.097	0.080	0.052	0.036	0.033	0.021	0.014	0.012	0.013	0.011	0.012	0.010	0.008	0.007	0.005	0.003	0.003	0.002	0.001	0.001	0.000	0.000	0.001
1998	0.000	0.002	0.012	0.028	0.045	0.073	0.112	0.119	0.120	0.109	0.088	0.060	0.043	0.039	0.025	0.017	0.015	0.016	0.014	0.015	0.012	0.010	0.008	0.005	0.004	0.003	0.002	0.001	0.001	0.000	0.000	0.001
1999	0.000	0.002	0.011	0.026	0.044	0.076	0.116	0.117	0.115	0.103	0.084	0.056	0.040	0.037	0.025	0.018	0.017	0.018	0.016	0.017	0.015	0.012	0.010	0.007	0.005	0.004	0.004	0.002	0.001	0.001	0.001	0.001
2005	0.000	0.000	0.008	0.068	0.172	0.170	0.150	0.116	0.064	0.042	0.026	0.020	0.024	0.021	0.022	0.016	0.012	0.012	0.011	0.010	0.008	0.007	0.005	0.005	0.003	0.003	0.002	0.001	0.001	0.000	0.000	0.001
2006	0.000	0.001	0.008	0.038	0.075	0.116	0.146	0.144	0.137	0.095	0.041	0.031	0.024	0.022	0.019	0.017	0.015	0.014	0.012	0.010	0.006	0.006	0.005	0.005	0.003	0.003	0.002	0.002	0.001	0.001	0.000	0.001
2007	0.000	0.000	0.002	0.015	0.062	0.115	0.157	0.167	0.141	0.099	0.048	0.028	0.022	0.022	0.020	0.019	0.015	0.014	0.013	0.010	0.007	0.006	0.004	0.004	0.002	0.002	0.002	0.002	0.001	0.000	0.000	0.001
2008	0.000	0.000	0.000	0.004	0.023	0.060	0.111	0.155	0.129	0.107	0.085	0.044	0.050	0.043	0.029	0.026	0.028	0.023	0.019	0.015	0.012	0.009	0.008	0.007	0.004	0.003	0.002	0.002	0.002	0.001	0.000	0.001
2009	0.000	0.001	0.008	0.024	0.050	0.095	0.103	0.122	0.103	0.072	0.047	0.043	0.047	0.036	0.036	0.039	0.037	0.032	0.025	0.019	0.015	0.011	0.011	0.008	0.005	0.003	0.003	0.002	0.002	0.001	0.000	0.001
2010	0.000	0.002	0.002	0.005	0.018	0.067	0.131	0.137	0.112	0.090	0.063	0.045	0.043	0.045	0.047	0.045	0.032	0.031	0.019	0.016	0.012	0.010	0.007	0.007	0.004	0.004	0.003	0.002	0.002	0.001	0.000	0.001
2011	0.000	0.005	0.002	0.002	0.014	0.056	0.101	0.125	0.117	0.112	0.087	0.060	0.052	0.044	0.041	0.036	0.024	0.023	0.019	0.016	0.012	0.012	0.009	0.008	0.005	0.004	0.004	0.003	0.002	0.001	0.001	0.001
2012	0.000	0.003	0.007	0.015	0.028	0.080	0.117	0.096	0.097	0.088	0.067	0.063	0.061	0.050	0.047	0.041	0.033	0.028	0.018	0.015	0.011	0.009	0.007	0.005	0.004	0.003	0.003	0.002	0.001	0.001	0.001	0.001
2013	0.000	0.003	0.005	0.010	0.026	0.060	0.090	0.099	0.087	0.075	0.064	0.066	0.058	0.055	0.055	0.053	0.048	0.040	0.028	0.024	0.015	0.013	0.007	0.006	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.001
2014	0.000	0.001	0.004	0.015	0.071	0.106	0.131	0.124	0.104	0.060	0.055	0.040	0.033	0.039	0.044	0.041	0.030	0.023	0.018	0.016	0.012	0.008	0.007	0.005	0.003	0.002	0.002	0.001	0.001	0.001	0.002	0.002
2015	0.002	0.005	0.017	0.033	0.097	0.165	0.138	0.102	0.100	0.088	0.050	0.028	0.027	0.021	0.027	0.025	0.020	0.018	0.013	0.008	0.004	0.004	0.002	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000

Table App.A.5b: South coast commercial offshore trawl, species combined, sex-aggregated, catch-at-length data (Fairweather, 2016b).

Length	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81+	
1975	0.000	0.000	0.000	0.002	0.009	0.021	0.046	0.055	0.047	0.056	0.045	0.066	0.068	0.068	0.075	0.067	0.068	0.055	0.055	0.044	0.031	0.024	0.016	0.013	0.013	0.011	0.006	0.006	0.005	0.005	0.005	0.016	
1976	0.000	0.005	0.007	0.017	0.036	0.113	0.208	0.166	0.113	0.066	0.033	0.050	0.037	0.033	0.040	0.032	0.018	0.008	0.005	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000		
1977	0.000	0.000	0.000	0.002	0.003	0.015	0.045	0.050	0.058	0.072	0.073	0.078	0.068	0.061	0.042	0.036	0.030	0.026	0.026	0.022	0.022	0.024	0.018	0.011	0.009	0.061	0.044	0.035	0.045	0.021	0.001	0.002	
1978	0.000	0.003	0.007	0.027	0.063	0.138	0.157	0.138	0.104	0.077	0.052	0.040	0.032	0.026	0.027	0.020	0.016	0.014	0.010	0.007	0.007	0.007	0.004	0.005	0.003	0.002	0.003	0.002	0.002	0.001	0.002	0.004	
1979	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.013	0.036	0.053	0.056	0.048	0.050	0.049	0.063	0.079	0.081	0.063	0.069	0.058	0.050	0.040	0.034	0.027	0.029	0.020	0.019	0.014	0.010	0.008	0.007	0.018	
1980	0.000	0.000	0.004	0.017	0.052	0.084	0.113	0.111	0.101	0.077	0.070	0.060	0.053	0.045	0.037	0.030	0.027	0.019	0.015	0.014	0.014	0.010	0.009	0.008	0.007	0.005	0.005	0.004	0.003	0.002	0.002	0.004	
1981	0.000	0.001	0.006	0.021	0.041	0.098	0.119	0.107	0.107	0.071	0.078	0.065	0.055	0.041	0.039	0.030	0.025	0.020	0.016	0.012	0.012	0.009	0.006	0.005	0.003	0.003	0.003	0.002	0.001	0.001	0.001	0.002	
1982	0.001	0.004	0.012	0.025	0.054	0.097	0.108	0.092	0.078	0.058	0.055	0.055	0.045	0.037	0.036	0.036	0.030	0.027	0.024	0.022	0.021	0.019	0.015	0.012	0.009	0.007	0.006	0.005	0.004	0.003	0.002	0.003	
1983	0.000	0.001	0.003	0.019	0.046	0.076	0.081	0.090	0.108	0.094	0.080	0.053	0.045	0.039	0.042	0.037	0.036	0.031	0.023	0.019	0.017	0.015	0.012	0.010	0.007	0.005	0.003	0.003	0.002	0.002	0.001	0.002	
1984	0.001	0.002	0.013	0.031	0.096	0.126	0.142	0.106	0.075	0.055	0.056	0.043	0.042	0.034	0.026	0.021	0.018	0.019	0.017	0.014	0.011	0.010	0.008	0.007	0.007	0.006	0.004	0.003	0.002	0.002	0.001	0.002	
1985	0.000	0.000	0.001	0.004	0.025	0.063	0.112	0.117	0.104	0.101	0.086	0.060	0.047	0.034	0.029	0.028	0.025	0.026	0.023	0.020	0.017	0.013	0.013	0.013	0.009	0.007	0.007	0.006	0.004	0.003	0.001	0.004	
1986	0.000	0.000	0.000	0.002	0.011	0.044	0.102	0.100	0.105	0.069	0.083	0.064	0.062	0.050	0.042	0.037	0.029	0.028	0.026	0.024	0.025	0.021	0.016	0.016	0.010	0.007	0.008	0.007	0.004	0.004	0.001	0.003	
1987	0.000	0.000	0.001	0.004	0.033	0.084	0.118	0.125	0.090	0.074	0.054	0.037	0.037	0.038	0.038	0.036	0.032	0.029	0.030	0.025	0.023	0.021	0.017	0.012	0.009	0.008	0.007	0.006	0.004	0.003	0.002	0.004	
1988	0.000	0.001	0.005	0.026	0.045	0.081	0.102	0.113	0.110	0.070	0.049	0.041	0.043	0.040	0.038	0.036	0.027	0.026	0.026	0.020	0.022	0.019	0.014	0.014	0.009	0.007	0.005	0.003	0.003	0.002	0.002	0.001	0.002
1989	0.000	0.002	0.003	0.020	0.084	0.132	0.171	0.130	0.071	0.063	0.047	0.037	0.033	0.023	0.021	0.016	0.020	0.023	0.016	0.017	0.015	0.016	0.012	0.010	0.007	0.004	0.003	0.002	0.001	0.001	0.001	0.000	
1990	0.000	0.001	0.004	0.010	0.040	0.073	0.087	0.100	0.092	0.104	0.095	0.076	0.061	0.051	0.040	0.029	0.023	0.022	0.016	0.015	0.011	0.011	0.009	0.008	0.007	0.005	0.004	0.002	0.002	0.001	0.001	0.001	
1991	0.000	0.001	0.005	0.020	0.047	0.081	0.108	0.121	0.108	0.100	0.077	0.061	0.051	0.042	0.031	0.023	0.018	0.017	0.014	0.013	0.010	0.010	0.009	0.007	0.006	0.005	0.003	0.003	0.002	0.001	0.001	0.001	
1992	0.000	0.001	0.005	0.021	0.048	0.070	0.086	0.106	0.107	0.105	0.089	0.078	0.055	0.043	0.035	0.025	0.019	0.018	0.014	0.014	0.010	0.010	0.008	0.007	0.007	0.005	0.004	0.003	0.002	0.002	0.001	0.002	
1993	0.000	0.001	0.004	0.022	0.054	0.088	0.105	0.104	0.098	0.094	0.094	0.068	0.053	0.038	0.033	0.024	0.018	0.017	0.013	0.013	0.010	0.009	0.008	0.006	0.006	0.005	0.004	0.003	0.002	0.001	0.001	0.002	
1994	0.000	0.001	0.002	0.013	0.038	0.082	0.116	0.139	0.104	0.098	0.077	0.055	0.038	0.033	0.031	0.027	0.026	0.023	0.018	0.015	0.010	0.011	0.008	0.007	0.007	0.006	0.006	0.004	0.003	0.002	0.001	0.002	
1995	0.000	0.001	0.011	0.021	0.044	0.061	0.111	0.133	0.129	0.108	0.073	0.042	0.036	0.040	0.022	0.012	0.012	0.014	0.012	0.019	0.016	0.015	0.015	0.013	0.011	0.009	0.009	0.005	0.004	0.002	0.002	0.002	
1996	0.000	0.000	0.002	0.004	0.022	0.050	0.101	0.122	0.142	0.141	0.108	0.080	0.047	0.032	0.023	0.018	0.013	0.015	0.014	0.013	0.010	0.009	0.007	0.006	0.005	0.004	0.003	0.002	0.002	0.001	0.001	0.002	
2008	0.000	0.000	0.001	0.005	0.014	0.069	0.130	0.161	0.137	0.097	0.053	0.042	0.035	0.035	0.036	0.034	0.031	0.031	0.023	0.018	0.014	0.009	0.006	0.006	0.003	0.003	0.002	0.002	0.002	0.000	0.000	0.001	
2009	0.000	0.000	0.000	0.005	0.028	0.073	0.099	0.114	0.096	0.076	0.060	0.053	0.055	0.048	0.044	0.038	0.035	0.039	0.031	0.029	0.015	0.015	0.011	0.007	0.006	0.005	0.004	0.004	0.004	0.001	0.001	0.002	
2010	0.000	0.000	0.000	0.001	0.008	0.035	0.083	0.106	0.109	0.086	0.076	0.053	0.052	0.052	0.047	0.043	0.039	0.035	0.032	0.030	0.023	0.023	0.017	0.013	0.010	0.009	0.005	0.005	0.004	0.002	0.001	0.002	
2011	0.000	0.000	0.001	0.003	0.009	0.040	0.086	0.119	0.117	0.095	0.071	0.054	0.055	0.050	0.038	0.041	0.037	0.036	0.028	0.026	0.018	0.017	0.014	0.011	0.009	0.008	0.005	0.004	0.003	0.002	0.002	0.002	
2012	0.000	0.000	0.000	0.004	0.013	0.036	0.075	0.101	0.101	0.151	0.077	0.056	0.052	0.042	0.042	0.038	0.031	0.033	0.026	0.024	0.019	0.019	0.015	0.012	0.008	0.007	0.005	0.004	0.003	0.003	0.002	0.003	
2013	0.000	0.000	0.001	0.006	0.022	0.064	0.126	0.164	0.139	0.088	0.065	0.043	0.038	0.038	0.037	0.031	0.027	0.029	0.018	0.016	0.011	0.007	0.006	0.004	0.004	0.003	0.003	0.003	0.002	0.001	0.001	0.001	
2014	0.000	0.000	0.009	0.020	0.079	0.102	0.123	0.135	0.120	0.103	0.041	0.037	0.037	0.030	0.029	0.028	0.023	0.019	0.023	0.012	0.006	0.006	0.004	0.002	0.002	0.002	0.002	0.001	0.000	0.001	0.001	0.001	

Table App.A.5c: South coast commercial inshore trawl, *M. capensis*, sex-aggregated, catch-at-length data (Fairweather, 2016b).

Length	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81+
1981	0.000	0.000	0.000	0.001	0.003	0.014	0.037	0.070	0.101	0.117	0.119	0.103	0.094	0.075	0.060	0.049	0.036	0.031	0.021	0.017	0.015	0.011	0.008	0.006	0.004	0.003	0.002	0.001	0.001	0.001	0.001	0.000
1982	0.000	0.000	0.000	0.001	0.006	0.031	0.085	0.133	0.144	0.125	0.112	0.088	0.067	0.052	0.038	0.029	0.023	0.016	0.012	0.010	0.007	0.006	0.004	0.003	0.002	0.002	0.001	0.001	0.000	0.000	0.000	0.000
1983	0.000	0.000	0.000	0.000	0.000	0.004	0.018	0.040	0.066	0.084	0.092	0.097	0.102	0.105	0.096	0.080	0.061	0.046	0.032	0.022	0.015	0.011	0.008	0.006	0.004	0.003	0.002	0.002	0.001	0.001	0.000	0.001
1984	0.000	0.000	0.000	0.000	0.001	0.003	0.017	0.050	0.086	0.114	0.132	0.139	0.121	0.083	0.058	0.043	0.035	0.028	0.022	0.018	0.016	0.012	0.009	0.006	0.004	0.002	0.001	0.001	0.001	0.000	0.000	0.001
1985	0.000	0.000	0.000	0.000	0.000	0.002	0.006	0.016	0.036	0.055	0.068	0.083	0.100	0.116	0.106	0.097	0.087	0.063	0.045	0.032	0.025	0.020	0.014	0.010	0.006	0.004	0.003	0.002	0.001	0.001	0.000	0.001
1986	0.000	0.000	0.000	0.000	0.001	0.005	0.019	0.048	0.081	0.102	0.096	0.090	0.072	0.067	0.059	0.054	0.055	0.052	0.047	0.042	0.036	0.025	0.017	0.011	0.007	0.004	0.003	0.002	0.001	0.001	0.001	0.001
1987	0.000	0.000	0.000	0.000	0.000	0.003	0.010	0.029	0.061	0.099	0.110	0.136	0.113	0.086	0.065	0.055	0.046	0.040	0.031	0.026	0.025	0.023	0.014	0.010	0.006	0.004	0.003	0.002	0.001	0.001	0.001	0.001
1988	0.000	0.000	0.000	0.001	0.006	0.021	0.051	0.093	0.097	0.093	0.085	0.082	0.081	0.069	0.062	0.052	0.047	0.036	0.031	0.024	0.021	0.019	0.010	0.007	0.005	0.003	0.002	0.001	0.001	0.001	0.000	0.001
1989	0.000	0.000	0.000	0.002	0.008	0.024	0.051	0.082	0.097	0.102	0.102	0.099	0.080	0.065	0.055	0.052	0.040	0.032	0.024	0.023	0.018	0.016	0.009	0.006	0.004	0.003	0.002	0.001	0.001	0.000	0.000	0.000
1990	0.000	0.000	0.000	0.001	0.003	0.010	0.024	0.048	0.064	0.075	0.095	0.106	0.111	0.089	0.078	0.068	0.053	0.040	0.032	0.029	0.022	0.016	0.012	0.008	0.005	0.004	0.002	0.002	0.001	0.001	0.000	0.001
1991	0.000	0.000	0.000	0.001	0.003	0.010	0.023	0.043	0.065	0.075	0.075	0.077	0.080	0.085	0.083	0.077	0.067	0.059	0.044	0.039	0.028	0.021	0.015	0.011	0.007	0.005	0.003	0.002	0.001	0.001	0.001	0.001
1992	0.000	0.000	0.002	0.006	0.015	0.035	0.058	0.077	0.082	0.083	0.082	0.074	0.073	0.066	0.063	0.055	0.051	0.043	0.033	0.030	0.023	0.017	0.011	0.007	0.005	0.003	0.002	0.002	0.001	0.001	0.001	0.001
1993	0.000	0.000	0.000	0.002	0.005	0.014	0.031	0.066	0.070	0.079	0.092	0.111	0.122	0.094	0.070	0.060	0.049	0.034	0.023	0.022	0.019	0.013	0.008	0.005	0.004	0.003	0.002	0.001	0.001	0.000	0.000	0.000
1994	0.000	0.000	0.001	0.003	0.010	0.032	0.046	0.073	0.084	0.084	0.077	0.073	0.069	0.061	0.058	0.066	0.052	0.039	0.036	0.035	0.031	0.025	0.017	0.010	0.006	0.004	0.002	0.002	0.001	0.000	0.000	0.000
1995	0.000	0.000	0.000	0.001	0.005	0.015	0.036	0.048	0.079	0.091	0.091	0.093	0.090	0.084	0.072	0.065	0.053	0.040	0.028	0.024	0.020	0.018	0.014	0.011	0.009	0.006	0.004	0.002	0.002	0.001	0.000	0.000
1996	0.000	0.000	0.001	0.002	0.008	0.021	0.062	0.078	0.095	0.130	0.117	0.089	0.092	0.065	0.051	0.048	0.035	0.024	0.019	0.016	0.013	0.012	0.009	0.006	0.004	0.003	0.002	0.001	0.000	0.000	0.000	0.000
1998	0.000	0.000	0.000	0.001	0.004	0.022	0.056	0.082	0.146	0.132	0.105	0.076	0.064	0.063	0.049	0.045	0.037	0.027	0.022	0.015	0.012	0.011	0.007	0.008	0.006	0.004	0.003	0.002	0.001	0.000	0.000	0.000
1999	0.000	0.000	0.000	0.001	0.005	0.014	0.037	0.066	0.078	0.118	0.124	0.098	0.092	0.080	0.066	0.052	0.035	0.034	0.020	0.021	0.012	0.011	0.008	0.008	0.007	0.006	0.005	0.003	0.001	0.000	0.000	0.001
2000	0.000	0.000	0.000	0.000	0.004	0.009	0.029	0.064	0.085	0.108	0.117	0.106	0.096	0.079	0.075	0.059	0.046	0.034	0.022	0.018	0.010	0.010	0.008	0.006	0.005	0.004	0.004	0.002	0.001	0.000	0.000	0.000
2001	0.000	0.000	0.000	0.001	0.004	0.015	0.049	0.095	0.137	0.131	0.109	0.080	0.064	0.046	0.032	0.028	0.028	0.024	0.025	0.028	0.025	0.021	0.019	0.011	0.009	0.007	0.005	0.005	0.001	0.001	0.000	0.000
2006	0.000	0.000	0.000	0.001	0.002	0.016	0.052	0.118	0.183	0.132	0.122	0.063	0.055	0.043	0.031	0.030	0.024	0.020	0.019	0.020	0.020	0.014	0.013	0.006	0.004	0.003	0.003	0.001	0.000	0.001	0.000	0.001
2007	0.000	0.001	0.003	0.010	0.026	0.063	0.091	0.118	0.114	0.103	0.091	0.070	0.049	0.037	0.034	0.030	0.031	0.024	0.021	0.019	0.018	0.014	0.011	0.005	0.004	0.003	0.005	0.003	0.001	0.001	0.000	0.000
2008	0.000	0.002	0.002	0.007	0.025	0.067	0.093	0.091	0.100	0.090	0.083	0.070	0.058	0.046	0.041	0.039	0.034	0.032	0.025	0.025	0.020	0.016	0.013	0.007	0.005	0.004	0.003	0.001	0.001	0.001	0.000	0.001
2009	0.000	0.000	0.002	0.012	0.033	0.071	0.093	0.086	0.083	0.097	0.086	0.072	0.053	0.049	0.045	0.038	0.035	0.031	0.025	0.026	0.020	0.016	0.011	0.006	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000
2010	0.000	0.001	0.004	0.014	0.037	0.070	0.099	0.107	0.081	0.086	0.079	0.063	0.052	0.044	0.039	0.035	0.033	0.036	0.026	0.028	0.020	0.015	0.012	0.007	0.004	0.003	0.002	0.001	0.001	0.000	0.000	0.000
2011	0.000	0.001	0.004	0.013	0.031	0.073	0.093	0.099	0.089	0.095	0.098	0.077	0.056	0.045	0.038	0.033	0.032	0.027	0.022	0.022	0.016	0.013	0.008	0.005	0.004	0.003	0.002	0.001	0.000	0.000	0.000	0.000
2012	0.001	0.002	0.005	0.017	0.038	0.070	0.097	0.108	0.095	0.083	0.081	0.069	0.055	0.048	0.044	0.035	0.027	0.027	0.021	0.021	0.016	0.013	0.010	0.005	0.004	0.003	0.002	0.001	0.001	0.001	0.000	0.001
2013	0.000	0.000	0.000	0.002	0.011	0.029	0.067	0.112	0.111	0.107	0.103	0.085	0.065	0.059	0.049	0.035	0.031	0.023	0.021	0.019	0.016	0.014	0.009	0.008	0.006	0.005	0.003	0.002	0.002	0.001	0.001	0.001
2014	0.000	0.000	0.000	0.002	0.009	0.019	0.056	0.092	0.125	0.092	0.100	0.101	0.085	0.062	0.047	0.043	0.039	0.032	0.019	0.015	0.013	0.008	0.008	0.008	0.006	0.003	0.004	0.003	0.002	0.002	0.001	0.003
2015	0.000	0.001	0.005	0.015	0.036	0.084	0.117	0.115	0.108	0.089	0.079	0.071	0.049	0.043	0.036	0.032	0.024	0.023	0.022	0.016	0.014	0.008	0.005	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000

Table App.A.5d: West coast longline, species combined, sex-aggregated, catch-at-length data.

West coast longline, species combined																																
Length	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	79
1994	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.004	0.006	0.007	0.008	0.010	0.014	0.019	0.027	0.035	0.040	0.044	0.049	0.055	0.068	0.078	0.080	0.084	0.080	0.071	0.061	0.157
1995	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.002	0.002	0.005	0.009	0.018	0.022	0.044	0.042	0.053	0.064	0.057	0.075	0.071	0.076	0.083	0.062	0.069	0.060	0.185
1996	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.003	0.005	0.008	0.014	0.021	0.032	0.046	0.058	0.065	0.088	0.083	0.086	0.075	0.071	0.061	0.052	0.144	
1997	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.003	0.007	0.011	0.015	0.027	0.028	0.046	0.047	0.046	0.060	0.068	0.076	0.072	0.078	0.079	0.070	0.067	0.051	0.145

Table App.A.5e: South coast longline, species combined, sex-aggregated, catch-at-length data.

Length	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65
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Table App.A.5f: West coast longline, *M. paradoxus*, sex-disaggregated, catch-at-length data (Somhlaba and Leslie, 2014) (males in blue, females in pink).

Length	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81+
2000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.004	0.006	0.006	0.013	0.018	0.034	0.034	0.045	0.072	0.080	0.095	0.104	0.095	0.097	0.085	0.068	0.059	0.042	0.030
2000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.002	0.003	0.007	0.016	0.020	0.033	0.049	0.074	0.093	0.114	0.110	0.104	0.097	0.089	0.062	0.056	0.040	0.024
2001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.003	0.003	0.008	0.013	0.023	0.048	0.075	0.084	0.076	0.080	0.068	0.065	0.056	0.074	0.082	0.064	0.057	0.032	0.031	0.034	0.008	0.016
2001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.005	0.006	0.011	0.019	0.029	0.043	0.057	0.069	0.077	0.095	0.106	0.107	0.098	0.084	0.069	0.054	0.040	0.027
2002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.003	0.004	0.008	0.014	0.027	0.028	0.041	0.059	0.070	0.074	0.074	0.071	0.072	0.068	0.088	0.076	0.066	0.061	0.052	0.040
2002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.003	0.008	0.012	0.022	0.030	0.044	0.067	0.103	0.086	0.093	0.092	0.088	0.089	0.082	0.071	0.058	0.046	0.027
2003	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.002	0.004	0.007	0.010	0.016	0.032	0.044	0.055	0.062	0.072	0.082	0.084	0.092	0.093	0.073	0.069	0.065	0.049	0.034	0.025	0.021
2003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.003	0.005	0.010	0.020	0.033	0.052	0.071	0.090	0.098	0.102	0.094	0.095	0.079	0.069	0.058	0.048	0.037	0.030
2004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.001	0.002	0.012	0.015	0.020	0.026	0.036	0.051	0.065	0.077	0.097	0.108	0.114	0.101	0.081	0.062	0.043	0.030	0.025	0.014	0.010	0.006
2004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.007	0.012	0.018	0.029	0.037	0.050	0.061	0.081	0.097	0.106	0.103	0.097	0.083	0.067	0.052	0.038	0.027	0.019	0.012
2005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.007	0.014	0.019	0.030	0.040	0.054	0.079	0.084	0.107	0.099	0.091	0.086	0.081	0.063	0.045	0.035	0.025	0.013	0.011	0.008	0.005
2005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.004	0.006	0.013	0.024	0.037	0.056	0.074	0.091	0.097	0.103	0.101	0.091	0.077	0.064	0.052	0.039	0.030	0.021	0.018
2006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.004	0.005	0.005	0.014	0.018	0.024	0.031	0.049	0.067	0.098	0.121	0.120	0.119	0.103	0.075	0.052	0.036	0.027	0.014	0.006	0.005	0.002	0.000
2006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.006	0.012	0.009	0.030	0.041	0.058	0.073	0.088	0.100	0.109	0.107	0.093	0.078	0.058	0.043	0.031	0.023	0.016	0.011
2007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.005	0.005	0.013	0.021	0.026	0.056	0.074	0.094	0.086	0.097	0.101	0.046	0.054	0.073	0.035	0.038	0.041	0.051	0.025	0.035	0.010	0.008
2007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.002	0.005	0.009	0.019	0.036	0.060	0.089	0.105	0.113	0.112	0.117	0.093	0.074	0.058	0.042	0.027	0.017	0.012	0.008
2008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.003	0.014	0.020	0.033	0.044	0.050	0.066	0.073	0.081	0.093	0.096	0.076	0.063	0.052	0.051	0.057	0.023	0.021	0.032	0.028	0.016	0.007
2008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.005	0.012	0.016	0.032	0.038	0.062	0.079	0.096	0.111	0.112	0.092	0.078	0.062	0.050	0.037	0.034	0.026	0.024	0.017	0.012
2009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.015	0.009	0.010	0.018	0.039	0.051	0.050	0.061	0.086	0.114	0.101	0.080	0.069	0.062	0.053	0.038	0.034	0.033	0.021	0.016	0.015	0.012	0.008
2009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.006	0.009	0.020	0.032	0.048	0.073	0.090	0.112	0.109	0.115	0.105	0.079	0.065	0.038	0.031	0.022	0.018	0.013	0.006	0.004
2010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.003	0.003	0.008	0.013	0.023	0.048	0.075	0.084	0.076	0.080	0.068	0.065	0.056	0.074	0.082	0.064	0.057	0.032	0.031	0.034	0.008	0.016
2010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.005	0.006	0.011	0.019	0.029	0.043	0.057	0.069	0.077	0.095	0.106	0.107	0.098	0.084	0.069	0.054	0.040	0.027

Table App.A.5g: West coast longline, *M. capensis*, sex-disaggregated, catch-at-length data (Somhlaba and Leslie, 2014) (males in blue, females in pink).

West coast longline, <i>M. capensis</i>																																	
Length	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81+	
2000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.006	0.008	0.023	0.028	0.042	0.055	0.072	0.092	0.092	0.123	0.120	0.095	0.071	0.063	0.043	0.029	0.010	0.010	0.012	0.002	
2000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.005	0.011	0.016	0.020	0.028	0.035	0.047	0.067	0.075	0.077	0.087	0.093	0.090	0.086	0.082	0.071	0.048	0.035	0.021	
2001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.011	0.008	0.017	0.017	0.039	0.047	0.075	0.116	0.110	0.134	0.087	0.076	0.064	0.071	0.036	0.034	0.022	0.014	0.007	0.007	0.004	
2001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.004	0.005	0.011	0.019	0.037	0.060	0.088	0.105	0.091	0.077	0.072	0.073	0.066	0.069	0.052	0.052	0.040	0.043	0.030	
2002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.003	0.014	0.029	0.045	0.075	0.124	0.137	0.135	0.124	0.097	0.063	0.057	0.028	0.025	0.010	0.014	0.011	
2002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.005	0.009	0.016	0.031	0.057	0.082	0.111	0.133	0.135	0.120	0.097	0.069	0.050	0.035	0.027	0.020	
2003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.001	0.003	0.004	0.007	0.018	0.029	0.041	0.059	0.094	0.113	0.121	0.117	0.105	0.085	0.071	0.046	0.035	0.028	0.019	
2003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.004	0.008	0.013	0.021	0.038	0.059	0.078	0.100	0.115	0.119	0.117	0.104	0.082	0.063	0.043	0.031	
2004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.005	0.009	0.014	0.015	0.019	0.023	0.035	0.050	0.065	0.093	0.122	0.119	0.107	0.107	0.079	0.046	0.034	0.025	0.012	0.008	0.006	0.004	
2004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.004	0.010	0.017	0.029	0.042	0.054	0.068	0.075	0.086	0.095	0.100	0.100	0.095	0.079	0.065	0.046	0.031	
2005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.004	0.009	0.023	0.038	0.052	0.078	0.103	0.116	0.125	0.116	0.094	0.067	0.053	0.043	0.029	0.017	0.012	0.009	0.007	
2005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.004	0.009	0.019	0.029	0.041	0.060	0.082	0.101	0.112	0.110	0.102	0.086	0.070	0.053	0.041	0.034	0.025	0.020	
2006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.026	0.028	0.035	0.006	0.017	0.019	0.021	0.036	0.041	0.042	0.066	0.073	0.095	0.105	0.116	0.105	0.063	0.040	0.022	0.013	0.010	0.005	0.004	0.002	
2006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.005	0.005	0.004	0.007	0.012	0.019	0.027	0.029	0.037	0.044	0.057	0.067	0.083	0.102	0.107	0.104	0.094	0.071	0.052	0.031	0.023	0.017	
2007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.003	0.017	0.024	0.031	0.044	0.061	0.056	0.072	0.090	0.071	0.065	0.065	0.055	0.048	0.053	0.055	0.036	0.032	0.041	0.039	0.027	0.009	
2007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.012	0.018	0.029	0.051	0.062	0.040	0.046	0.057	0.062	0.065	0.053	0.047	0.060	0.057	0.076	0.053	0.046	0.055	0.058	0.035	0.017	
2008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.006	0.008	0.012	0.018	0.037	0.053	0.066	0.098	0.104	0.087	0.094	0.065	0.047	0.038	0.047	0.051	0.044	0.029	0.024	0.033	0.034	
2008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.005	0.007	0.008	0.018	0.028	0.053	0.048	0.064	0.070	0.103	0.081	0.083	0.065	0.081	0.074	0.050	0.052	0.038	0.038	0.033	
2009	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.004	0.004	0.007	0.011	0.020	0.024	0.036	0.037	0.048	0.052	0.066	0.074	0.094	0.093	0.093	0.082	0.063	0.048	0.039	0.035	0.026	0.020	0.011	0.010	
2009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.003	0.006	0.008	0.014	0.019	0.030	0.031	0.043	0.054	0.064	0.075	0.097	0.097	0.101	0.092	0.078	0.064	0.044	0.035	0.022	0.010	0.008	
2010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.011	0.008	0.017	0.017	0.039	0.047	0.075	0.116	0.110	0.134	0.087	0.076	0.064	0.071	0.036	0.034	0.022	0.014	0.007	0.007	0.004	
2010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.004	0.005	0.011	0.019	0.037	0.060	0.088	0.105	0.091	0.077	0.072	0.073	0.066	0.069	0.052	0.052	0.040	0.043	0.030	

Table App.A.5h: South coast longline, *M. paradoxus*, sex-disaggregated, catch-at-length data (Somhlaba and Leslie, 2014) (males in blue, females in pink).

Length	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81+
2001	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.005	0.005	0.000	0.005	0.005	0.000	0.015	0.031	0.015	0.051	0.071	0.071	0.097	0.051	0.097	0.102	0.026	0.061	0.077	0.051	0.036	0.051	0.026	0.036	0.010
2002	0.000	0.000	0.000	0.000	0.000	0.007	0.007	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.007	0.007	0.014	0.058	0.051	0.058	0.159	0.065	0.065	0.138	0.080	0.080	0.051	0.051	0.036	0.029	0.007
2006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.053	0.053	0.105	0.105	0.158	0.053	0.105	0.158	0.105	0.053	0.053	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.057	0.114	0.143	0.029	0.086	0.143	0.086	0.000	0.029	0.029	0.029	0.000	0.086	0.057	0.000	0.000	0.029	0.057	0.000	0.000	0.000
2008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.007	0.014	0.018	0.034	0.043	0.073	0.082	0.089	0.101	0.106	0.101	0.092	0.076	0.071	0.038	0.027	0.012	0.009	0.005	0.000	0.000
2008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.005	0.015	0.019	0.029	0.036	0.056	0.067	0.082	0.089	0.108	0.097	0.108	0.097	0.078	0.046	0.032	0.019	0.011	0.002	0.000	0.000
2009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.017	0.017	0.017	0.032	0.046	0.070	0.087	0.133	0.168	0.130	0.078	0.046	0.035	0.029	0.017	0.029	0.017	0.014	0.009	0.000	0.000	0.000
2009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.015	0.024	0.020	0.059	0.078	0.098	0.093	0.117	0.117	0.141	0.083	0.044	0.020	0.024	0.039	0.020	0.005	0.000	0.000	0.000	0.005	0.000
2010	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.005	0.005	0.000	0.005	0.005	0.000	0.015	0.031	0.015	0.051	0.071	0.071	0.097	0.051	0.097	0.102	0.026	0.061	0.077	0.051	0.036	0.051	0.026	0.036	0.010
2010	0.000	0.000	0.000	0.000	0.000	0.007	0.007	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.007	0.007	0.014	0.058	0.051	0.058	0.159	0.065	0.065	0.138	0.080	0.080	0.051	0.051	0.036	0.029	0.007

Table App.A.5i: South coast longline, *M. capensis*, sex-disaggregated, catch-at-length data (Somhlaba and Leslie, 2014) (males in blue, females in pink).

Length	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81+
2001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.004	0.004	0.007	0.011	0.020	0.024	0.036	0.037	0.048	0.052	0.066	0.074	0.094	0.093	0.093	0.082	0.063	0.048	0.039	0.035	0.026	0.020	0.011	0.004
2002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.011	0.008	0.017	0.017	0.039	0.047	0.075	0.116	0.110	0.134	0.087	0.076	0.064	0.071	0.036	0.034	0.022	0.014	0.007	0.007	0.004
2002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.011	0.008	0.017	0.017	0.039	0.047	0.075	0.116	0.110	0.134	0.087	0.076	0.064	0.071	0.036	0.034	0.022	0.014	0.007	0.007	0.004
2003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.003	0.014	0.029	0.045	0.075	0.124	0.137	0.135	0.124	0.097	0.063	0.057	0.028	0.025	0.010	0.014	0.011
2003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.005	0.011	0.016	0.020	0.028	0.035	0.047	0.067	0.075	0.077	0.087	0.093	0.090	0.086	0.082	0.071	0.048	0.035	0.021
2004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.001	0.003	0.004	0.007	0.018	0.029	0.041	0.059	0.094	0.113	0.121	0.117	0.105	0.085	0.071	0.046	0.035	0.028	0.019
2004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.004	0.005	0.011	0.019	0.037	0.060	0.088	0.105	0.091	0.077	0.072	0.073	0.066	0.069	0.052	0.052	0.040	0.043	0.030
2005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.005	0.009	0.014	0.015	0.019	0.023	0.035	0.050	0.065	0.093	0.122	0.119	0.107	0.107	0.079	0.046	0.034	0.025	0.012	0.008	0.006	0.004
2005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.005	0.009	0.016	0.031	0.057	0.082	0.111	0.133	0.135	0.120	0.097	0.069	0.050	0.035	0.027	0.020
2006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.004	0.009	0.023	0.038	0.052	0.078	0.103	0.116	0.125	0.116	0.094	0.067	0.053	0.043	0.029	0.017	0.012	0.009	0.007
2006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.004	0.008	0.013	0.021	0.038	0.059	0.078	0.100	0.115	0.119	0.117	0.104	0.082	0.063	0.043	0.031
2008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.026	0.028	0.035	0.006	0.017	0.019	0.021	0.036	0.041	0.042	0.066	0.073	0.095	0.105	0.116	0.105	0.063	0.040	0.022	0.013	0.010	0.005	0.004	0.002
2008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.004	0.010	0.017	0.029	0.042	0.054	0.068	0.075	0.086	0.095	0.100	0.100	0.095	0.079	0.065	0.046	0.031
2009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.003	0.017	0.024	0.031	0.044	0.061	0.056	0.072	0.090	0.071	0.065	0.065	0.055	0.048	0.053	0.055	0.036	0.032	0.041	0.039	0.027	0.009
2009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.004	0.009	0.019	0.029	0.041	0.060	0.082	0.101	0.112	0.110	0.102	0.086	0.070	0.053	0.041	0.034	0.025	0.020
2010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.006	0.008	0.012	0.018	0.037	0.053	0.066	0.098	0.104	0.087	0.094	0.065	0.047	0.038	0.047	0.051	0.044	0.029	0.024	0.033	0.034
2010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.005	0.005	0.004	0.007	0.012	0.019	0.027	0.029	0.037	0.044	0.057	0.067	0.083	0.102	0.107	0.104	0.094	0.071	0.052	0.031	0.023	0.017

[illegible][illegible]

Table App.A.6c: *M. paradoxus*, sex-disaggregated, west coast summer survey catch-at-length data (Fairweather and Ross-Gillespie, pers. commn).

[illegible]

Table App.A.6d: *M. paradoxus*, sex-disaggregated, south coast survey catch-at-length data. (Fairweather and Ross-Gillespie, pers. commn).

[illegible]

Table App.A.6e: *M. capensis*, sex-disaggregated, west coast summer survey catch-at-length data (Fairweather and Ross-Gillespie, pers. commn).

Length	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71
1993	0.000	0.001	0.023	0.090	0.077	0.032	0.011	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
1993	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.007	0.016	0.049	0.055	0.052	0.041	0.039	0.029	0.010	0.008	0.007	0.005	0.004	0.007	0.005	0.006	0.002	0.005	0.002	0.002	0.001	0.001	0.000	0.009	
1993	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.015	0.030	0.053	0.045	0.050	0.043	0.029	0.019	0.009	0.005	0.006	0.010	0.007	0.009	0.007	0.008	0.005	0.005	0.005	0.003	0.003	0.002	0.003	0.000
1994	0.000	0.000	0.030	0.307	0.028	0.018	0.025	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	
1994	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.014	0.029	0.033	0.039	0.042	0.037	0.021	0.011	0.005	0.004	0.003	0.005	0.004	0.006	0.005	0.003	0.002	0.002	0.002	0.003	0.002	0.002	0.001	0.001	0.001	0.011
1994	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.014	0.027	0.027	0.029	0.030	0.027	0.017	0.012	0.007	0.004	0.004	0.005	0.007	0.008	0.007	0.006	0.005	0.004	0.004	0.006	0.006	0.005	0.004	0.000	
1995	0.000	0.000	0.000	0.001	0.008	0.019	0.044	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1995	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.146	0.153	0.088	0.016	0.005	0.003	0.003	0.004	0.002	0.002	0.003	0.002	0.003	0.002	0.002	0.001	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.002
1995	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.105	0.092	0.075	0.037	0.012	0.008	0.006	0.004	0.004	0.003	0.001	0.002	0.002	0.003	0.003	0.002	0.002	0.001	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000
1996	0.000	0.000	0.004	0.046	0.126	0.163	0.069	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1996	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.026	0.044	0.038	0.026	0.014	0.011	0.007	0.005	0.005	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.002	0.003	0.002	0.002	0.000	0.000	0.008
1996	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.051	0.014	0.007	0.036	0.045	0.037	0.026	0.017	0.016	0.018	0.013	0.006	0.005	0.005	0.004	0.002	0.003	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.002	0.000
1997	0.000	0.000	0.003	0.015	0.011	0.008	0.010	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
1997	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.041	0.000	0.054	0.103	0.118	0.081	0.024	0.012	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.003
1997	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.074	0.115	0.112	0.077	0.036	0.028	0.010	0.007	0.002	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.000	0.001	0.001	0.001	0.001	0.000
1999	0.000	0.035	0.372	0.202	0.142	0.107	0.033	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.006	0.008	0.006	0.006	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.001
1999	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.003	0.003	0.004	0.004	0.004	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.002	0.002	0.003	0.001	0.001	0.000	0.000	0.000
2006	0.001	0.011	0.169	0.116	0.051	0.041	0.121	0.189	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.045	0.025	0.011	0.005	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
2006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.064	0.027	0.045	0.025	0.010	0.006	0.005	0.004	0.003	0.002	0.002	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000
2007	0.000	0.001	0.005	0.011	0.016	0.011	0.019	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.024	0.059	0.095	0.084	0.049	0.030	0.017	0.011	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
2007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.070	0.136	0.108	0.071	0.047	0.024	0.010	0.005	0.004	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000
2008	0.000	0.014	0.099	0.064	0.080	0.077	0.110	0.135	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.021	0.013	0.012	0.015	0.016	0.015	0.010	0.006	0.005	0.005	0.007	0.007	0.010	0.007	0.007	0.005	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002
2008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.031	0.014	0.012	0.014	0.017	0.015	0.012	0.009	0.010	0.012	0.018	0.019	0.013	0.010	0.004	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000
2009	0.000	0.002	0.029	0.034	0.033	0.029	0.045	0.033	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.043	0.087	0.078	0.026	0.007	0.002	0.001	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
2009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.046	0.156	0.185	0.089	0.025	0.010	0.007	0.004	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000
2010	0.000	0.001	0.008	0.019	0.031	0.045	0.104	0.405	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.116	0.023	0.012	0.005	0.004	0.002	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.003
2010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.105	0.030	0.020	0.014	0.006	0.005	0.004	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.000
2011	0.000	0.010	0.101	0.456	0.235	0.028	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2011	0.000	0.000	0.000	0.00																														

Table App.A.6f: *M. capensis*, sex-disaggregated, south coast survey catch-at-length data (Fairweather and Ross-Gillespie, pers. commn).

[illegible]

Appendix B: Reference Case results

Table B1: Estimates of management quantities for the Reference Case.

	-lnL total	-3154.1
<i>M. paradoxus</i>	K^{sp}	318
	B^{sp}_{MSY}	55
	B^{sp}_{2016}	86
	B^{sp}_{2017}	93
	B^{sp}_{2016}/K^{sp}	0.27
	B^{sp}_{2017}/K^{sp}	0.29
	$B^{sp}_{2016}/B^{sp}_{MSY}$	1.56
	$B^{sp}_{2017}/B^{sp}_{MSY}$	1.67
	MSY	145
<i>M. capensis</i>	K^{sp}	290
	B^{sp}_{MSY}	86
	B^{sp}_{2016}	194
	B^{sp}_{2017}	198
	B^{sp}_{2016}/K^{sp}	0.67
	B^{sp}_{2017}/K^{sp}	0.68
	$B^{sp}_{2016}/B^{sp}_{MSY}$	2.25
	$B^{sp}_{2017}/B^{sp}_{MSY}$	2.30
	MSY	84

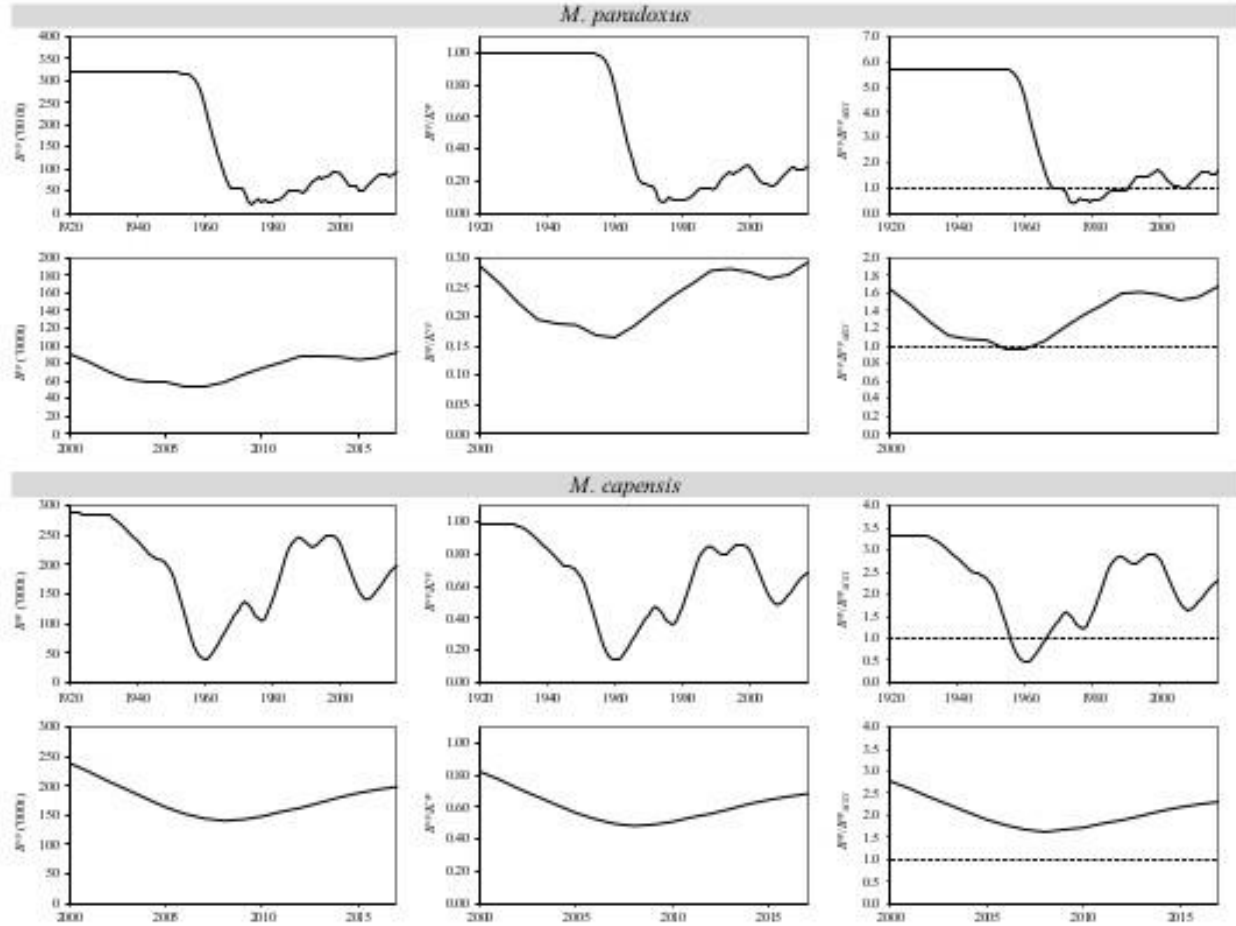


Figure B1: Spawning biomass trajectories (in absolute terms, and relative to pre-exploitation level and B_{MSY}) for the RC. The second and last rows repeat the first and third rows but with a different year range.

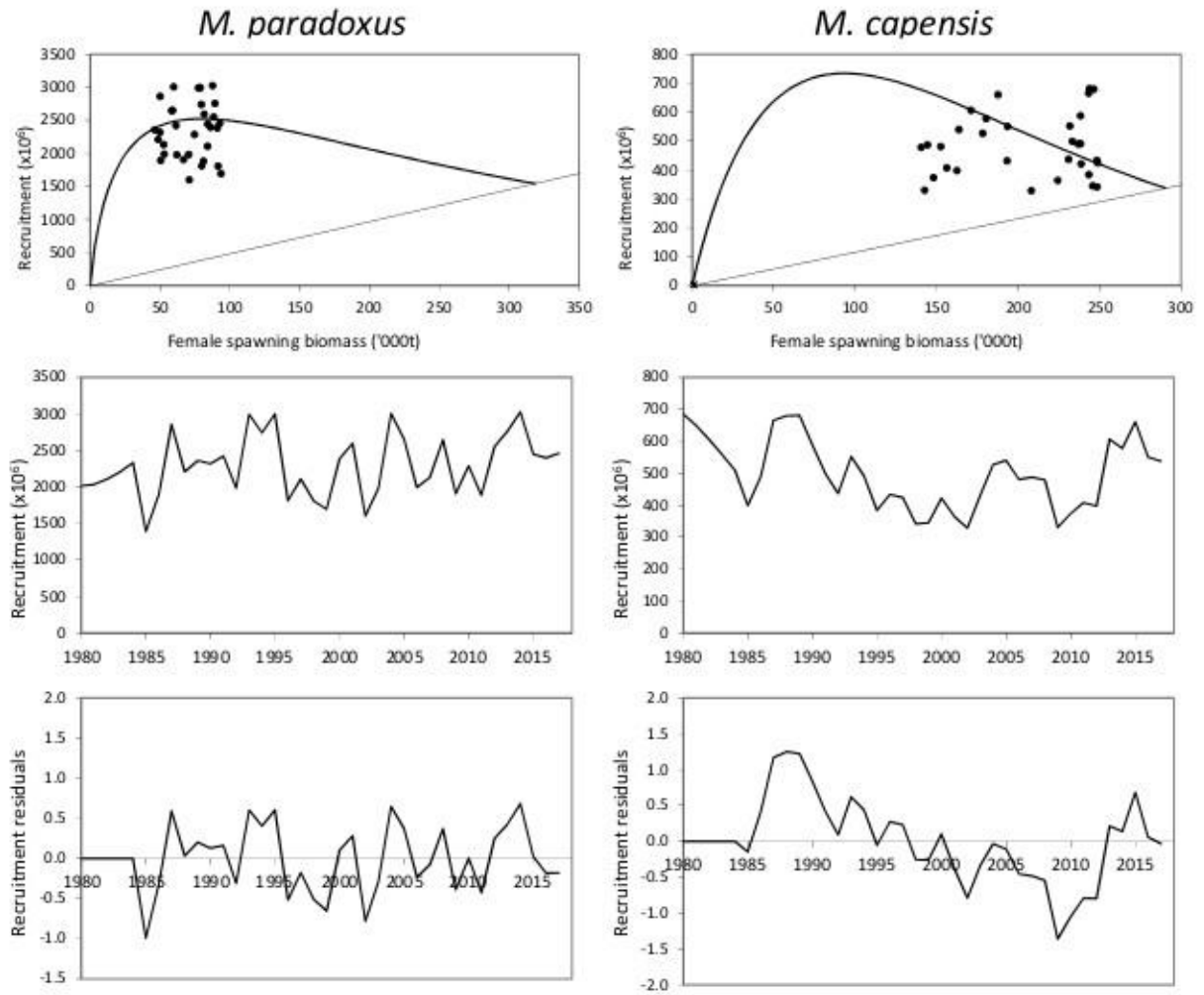


Figure B2: Stock-recruitment curves and recruitment trajectories for the Reference Case.

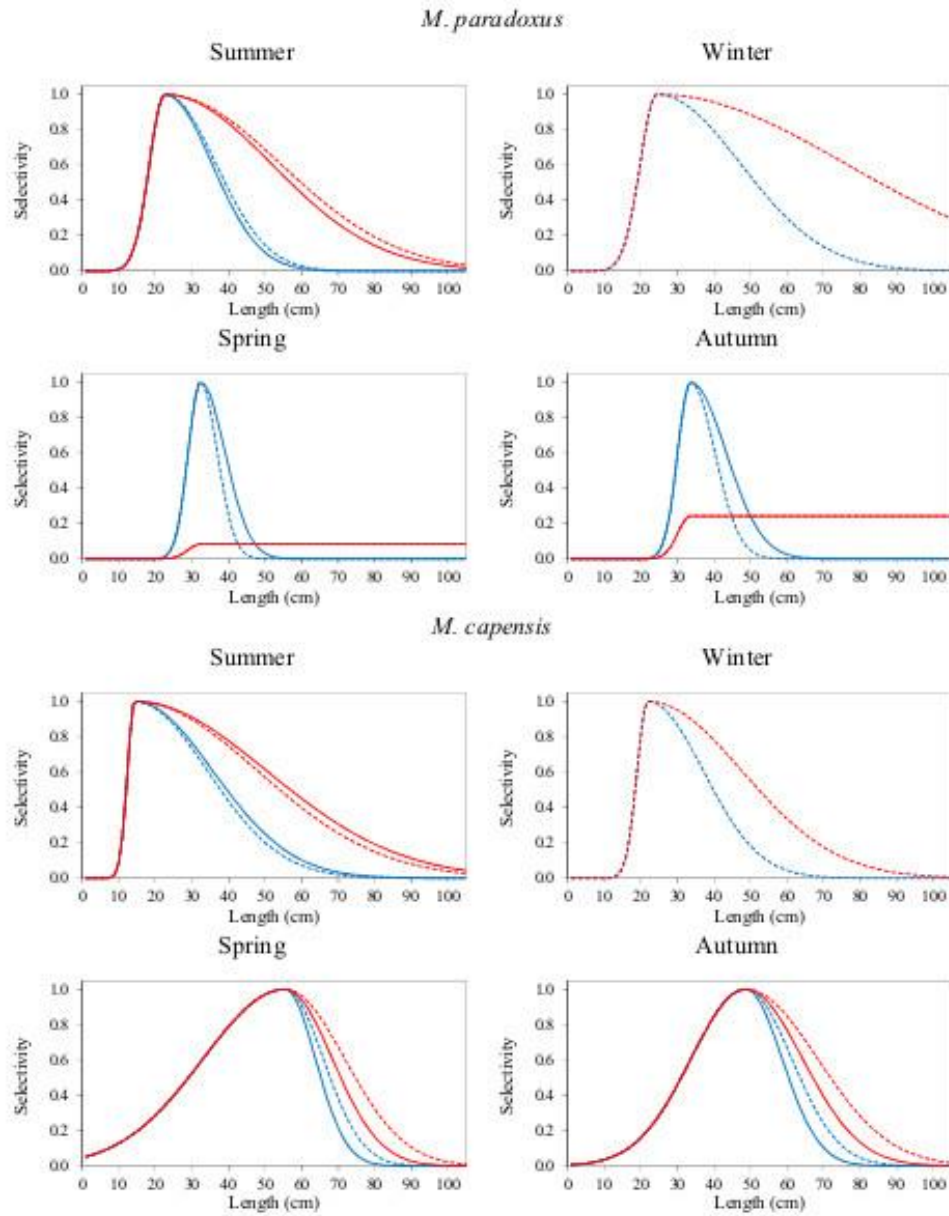


Figure B3: Survey selectivities-at-length for the Reference Case (blue curves for males, red curves for females, dashed curves for old gear and full curves for new gear).

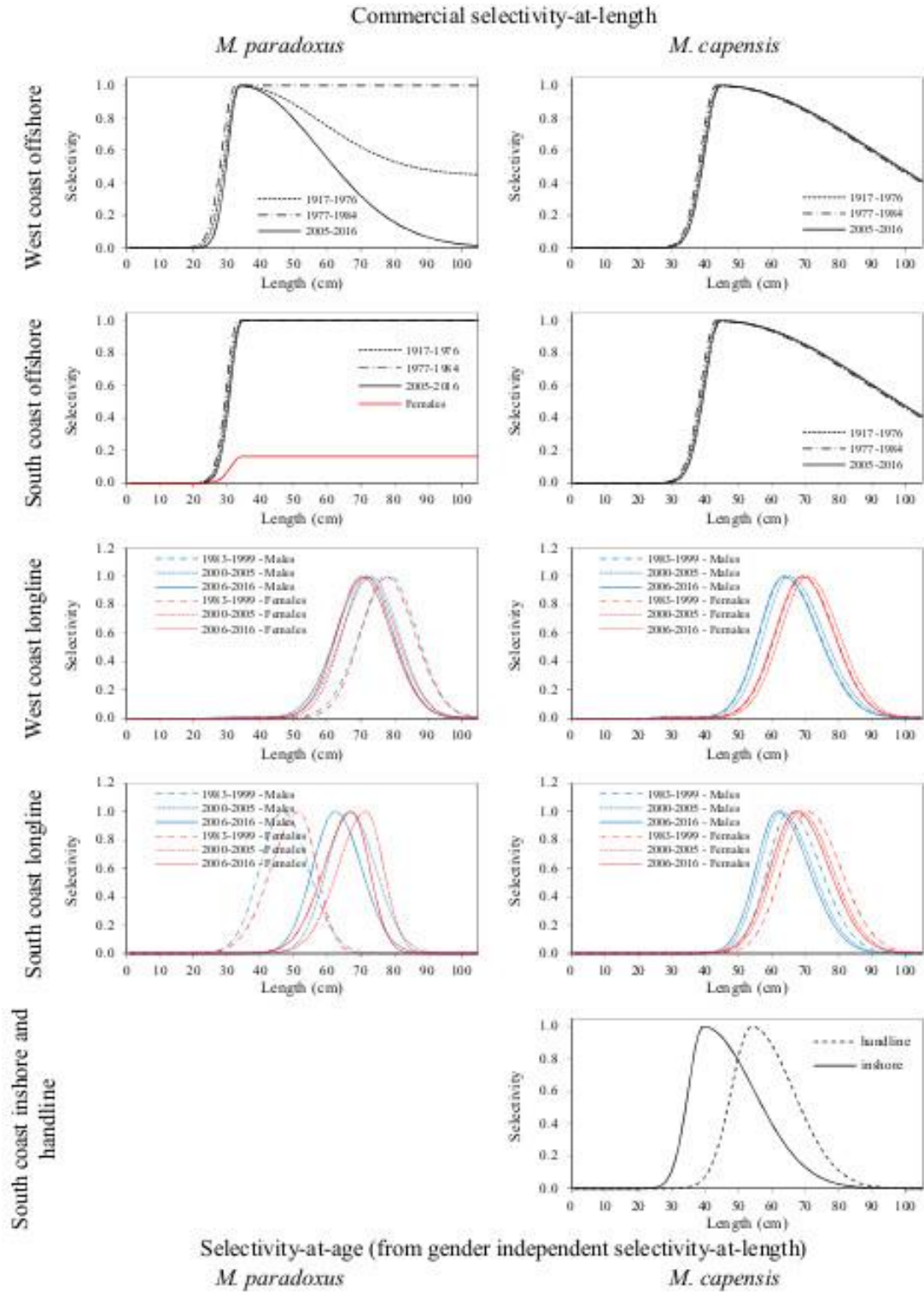


Figure B4: Commercial selectivities-at-length for the Reference Case (black curves for sex-aggregated, blue curves for males and red lines for females).

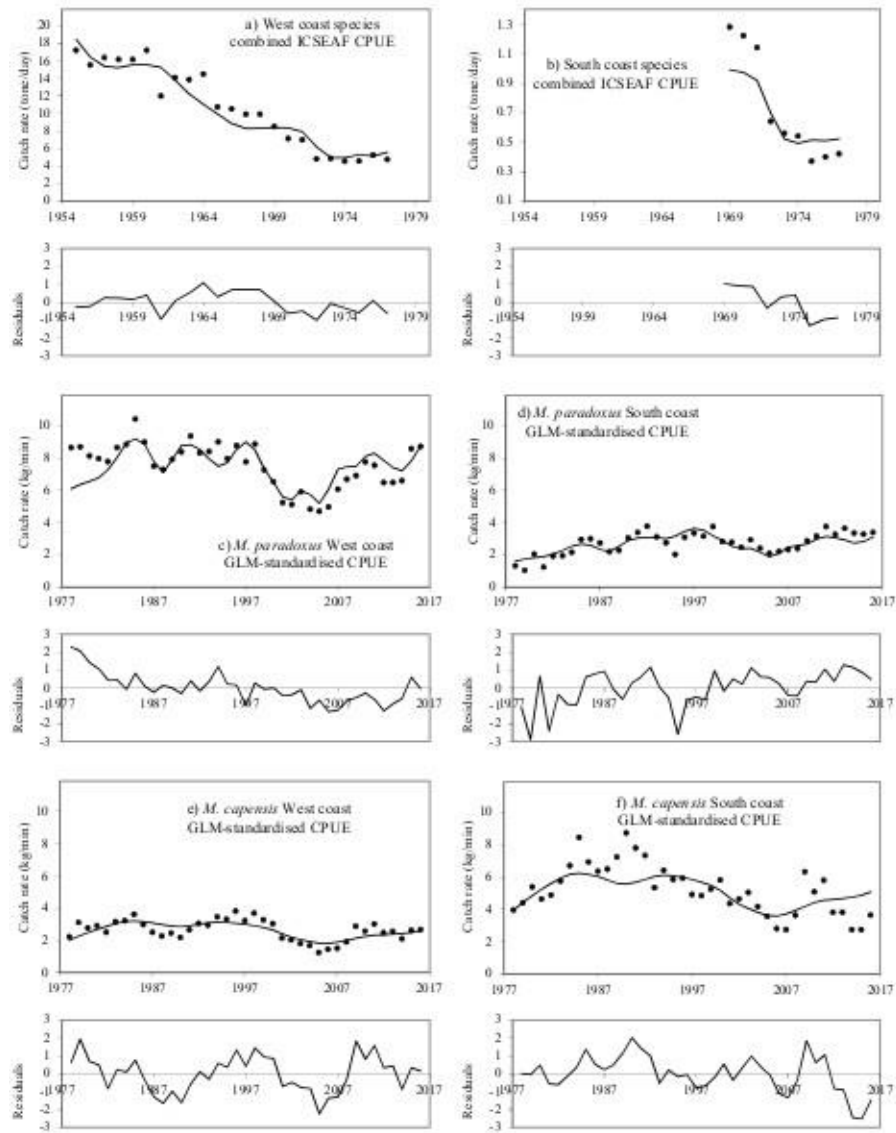


Figure B5: Fits to the CPUE series, with standardized residuals, for the Reference Case.

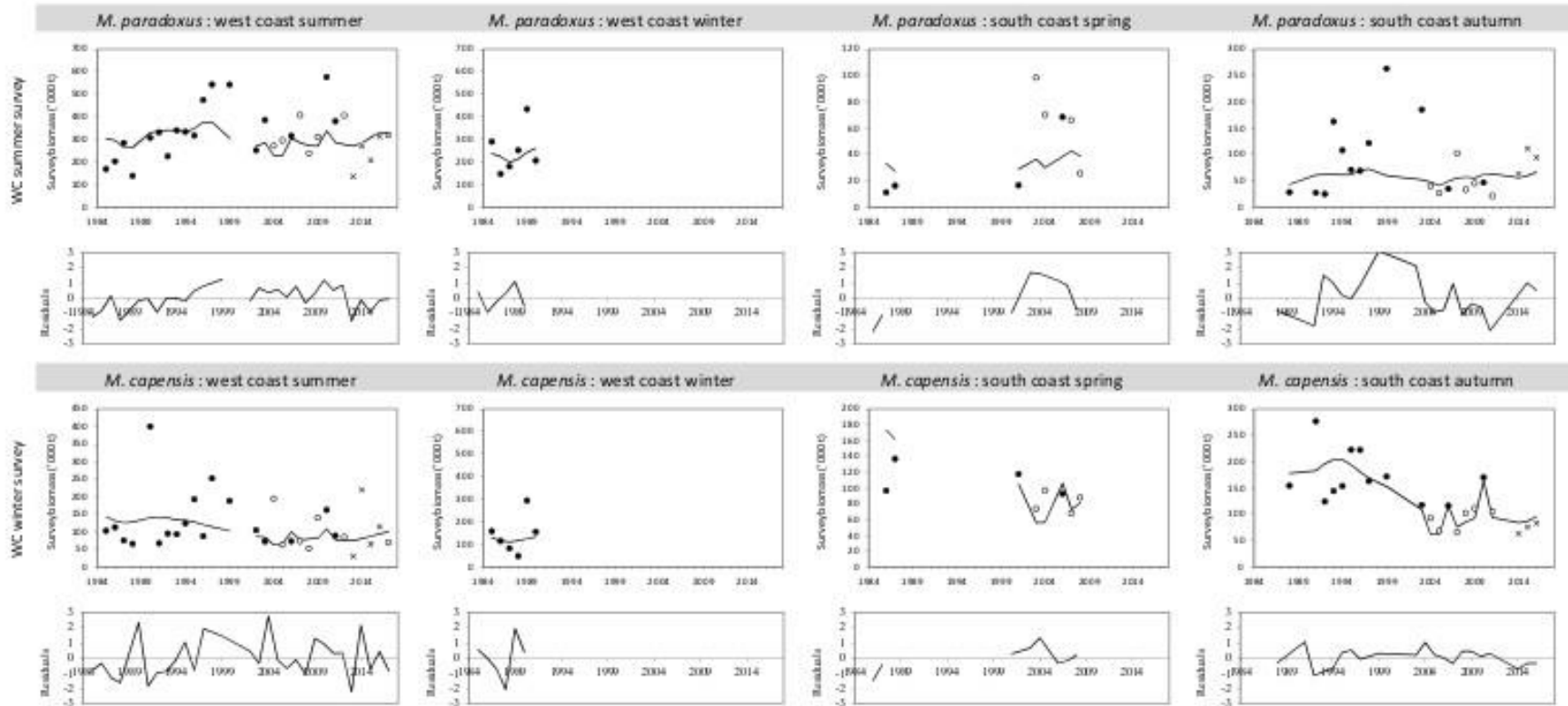


Figure B6: Fits to the survey series for the Reference Case. The full circles show the surveys conducted by the *Africana* old gear (adjusted by the Africana old/new gear calibration ratio), the open circles by the *Africana* new gear and crosses by industry vessels.

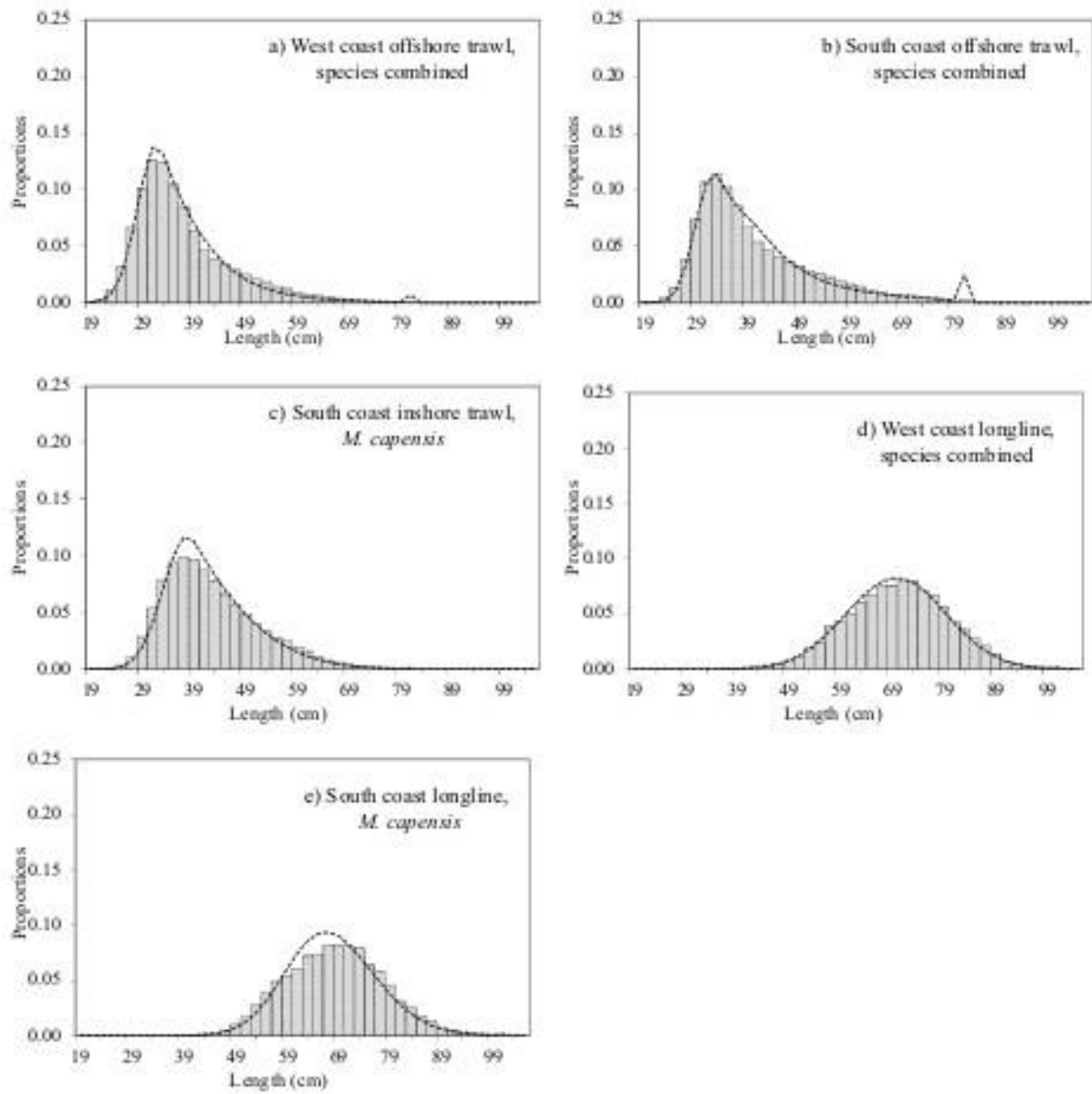


Figure B7: Fits to the commercial sex-aggregated catches-at-length averaged over years for the Reference Case.

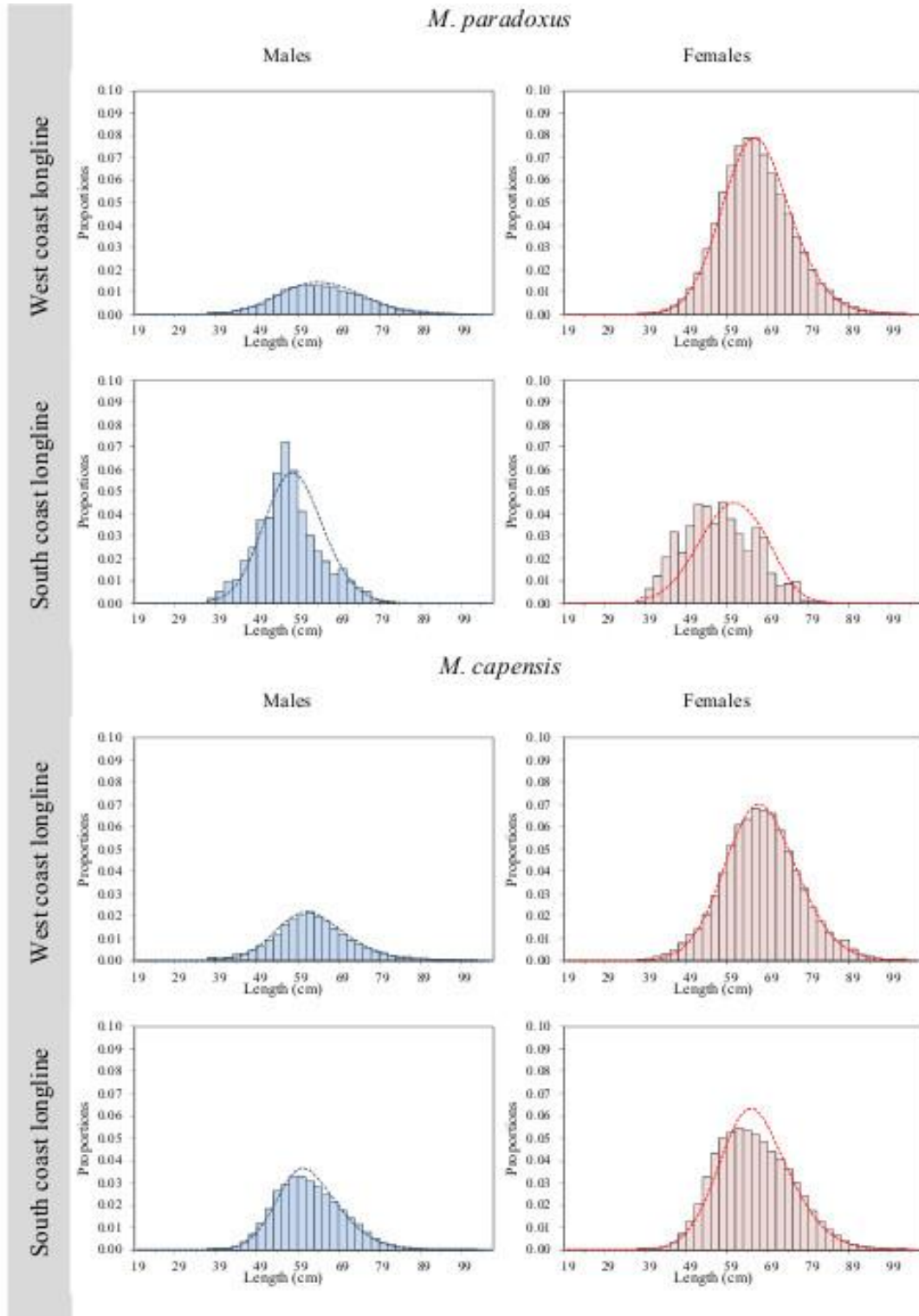


Figure B8: Fits to the commercial sex-disaggregated catches-at-length averaged over years for the Reference Case.

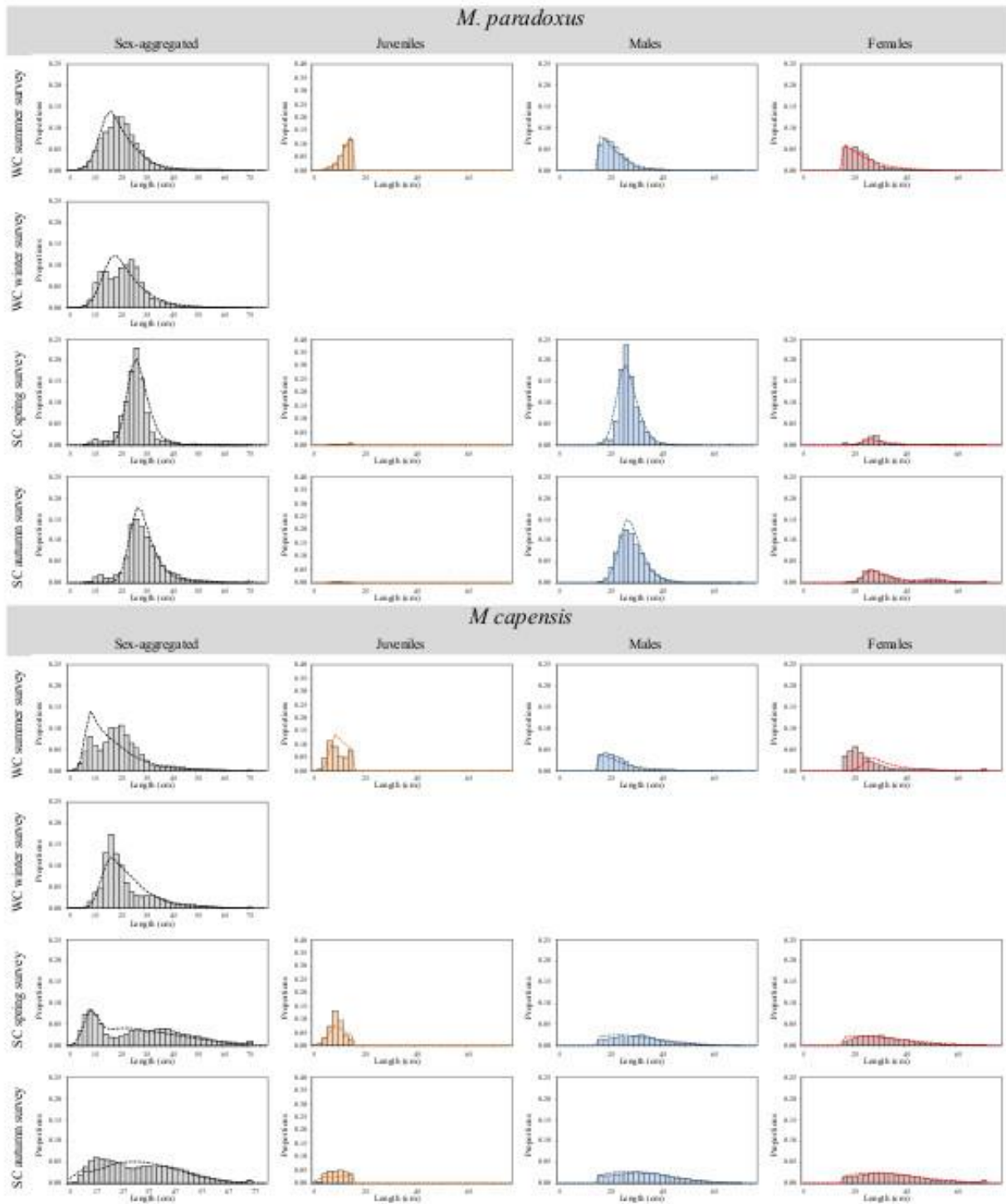


Figure B9: Fits to the survey sex-aggregated and sex-disaggregated catches-at-length averaged over years for the Reference Case