Nightingale island rock lobster assessment updated for 2020

Susan Johnston and Doug Butterworth

MARAM

Department of Mathematics and Applied Mathematics

University of Cape Town

Rondebosch, 7701

Summary

This paper provides an updated assessment of the rock lobster resource at Nightingale island. This assessment includes updated data from both the commercial fishery and the biomass surveys. The recent (2013+) high GLM standardised CPUE values (and biomass survey index values) at the island, which were not anticipated earlier, suggest that the possible negative impact of the OLIVA incident on adults may have been overestimated previously and that the associated additional mortality was much less than originally assumed. The 2020 Reference Case (RC) assessment assumes zero adult mortality in 2011 due to the OLIVA incident, but continues to assume an associated additional 80% juvenile mortality. Results indicate that juvenile mortality following the OLIVA incident is likely to have been much less than this RC assumption. The current spawning biomass is estimated to be at a healthy 75%-87% of its pristine level. It is proposed that the RC be revised to assume an OLIVA-associated additional juvenile mortality reduced to 20%.

Introduction

The age-structured population model used for this assessment is described fully in Johnston and Butterworth (2013). The last assessment of the Nightingale resource was presented in 2017 (Johnston and Butterworth 2017). This previous 2017 assessment took GLM standardised CPUE data into account to 2016 only. A small but important change to the assessment model has been made in 2020. This is to increase the flexibility allowed in the fishing selectivity functions when fitting to the data. This was achieved by increasing the σ_{μ} value from 0.02 to 0.2 (see equations 1-5). This results in much improved fits, to especially the female commercial catch-at-age data.

The updated 2020 assessment model is fit to the following data.

1) Standardised longline CPUE data for 1997-2018[1] (previous assessment only to 2016). (2011 and 2012 CPUE not included due to closure/test fishing).
2) Biomass survey CPUE data for 2006-2019 (previous assessment only to 2015), with 2008 data absent.
3) Catch-at-length data from the onboard observers (males and females separate) for 1997-2018 (previous assessment only to 2015), with 2000 missing.

[1] The split season is referenced by the first year, i.e. 2010 refers to the 2010/2011 season.

4) Catch-at-length data from the biomass survey (males and females separate) for 2006-2019 (previous assessment only to 2015), with 2008 data absent.
5) Discard % for 1997-2018 (previous assessment only to 2015), with 2011 missing.

Impact of the OLIVA incident on Nightingale lobsters

Reference Case model assumptions

The impact that the OLIVA had on the resource at Nightingale is initially assumed unchanged from the 2015 assessment and assumes the following:

i) an 80% once off additional mortality of juvenile lobsters aged 1, 2 and 3 years during the 2011 season, and
ii) a 0% once off additional mortality on adults (ages 4+) during the 2011 season (as assumed for the 2017 assessments, whereas a value of 50% was used for the 2014 and 2015 RC models).

The 80% juvenile/50% adult mortality assumptions were initially considered reasonable for the 2014 and 2015 assessments[2], but more recent CPUE data (since 2013) indicate that it is very unlikely that there was much if any impact on the adults as a result of the OLIVA incident – hence the modification to assume a 0% once off additional mortality on adults.

Results of the updated 2020 assessments suggest that the 80% once off additional juvenile mortality is now unlikely to be the most probable scenario. This is discussed further the Results and Discussion section below.

The commercial fishery at Nightingale was closed for the 2011 season. A precautionary TAC of 40 MT was set for 2012, of 65 MT for 2013, and of 70 initially but increasing in midseason to 75 MT for the 2014-2016 seasons, this last increase was due to good catch rates and in accordance with the pre-specified management recommendations. An OMP was developed for setting TACs at Nightingale in 2017. This resulted in a TAC for of 75 MT for 2017, 83 MT for 2018 and 85 MT for 2019. A new OMP is to be developed and implemented in 2020.

The selectivity functions

The model estimation procedure allows for the commercial selectivity functions to vary over time. Random variation in the values of the μ parameter values is modelled as follows:

[2] Cape Town Workshop held 16-18 November 2011.

$$S_{y,l}^{m,comm} = \frac{e^{-(\mu^m + \varepsilon_y^m)l}}{1 + e^{-\delta^m (l - l_*^m)}} \tag{1}$$

$$S_{y,l}^{f,comm} = P\frac{e^{-(\mu^f + \varepsilon_y^f)l}}{1 + e^{-\delta^f (l - l_*^f)}} \tag{2}$$

where

$$\varepsilon_y^m \sim N(\,0, \left(\sigma_\mu^2\right)\;) \tag{3}$$

$$\varepsilon_y^f \sim N(\,0, \left(\sigma_\mu^2\right)\;) \tag{4}$$

Consequently, a penalty term is added to the negative log likelihood:

$$-lnL \rightarrow -lnL + \frac{1}{2\sigma_\mu^2}\sum_{1997}^{2018}[(\varepsilon_y^m)^2 + \left(\varepsilon_y^f\right)^2] \tag{5}$$

with σ_μ fixed at 0.2.

The female scaling parameter "P" also varies over time to improve fits of the model to the commercial CAL data. Thus, equation (2) is modified further to:

$$S_{y,l}^{f,comm} = (P + \varepsilon_y^P)\frac{e^{-(\mu_y^f + \varepsilon_y^f)l}}{1 + e^{-\delta^f (l - l_*^f)}} \tag{6}$$

where

$$\varepsilon_y^P \sim N(\,0, (\sigma_P^2)\;) \tag{7}$$

Consequently, a further penalty term is added to the negative log likelihood:

$$-lnL = -lnL + \frac{1}{2\sigma_p^2}\sum_{1997}^{2018}\;(\varepsilon_y^P)^2 \tag{8}$$

with σ_P fixed at 0.2.

Additions made in 2017 to the assessment model to improve model fits to CAL data

In past assessments, there was a fairly consistent overestimation of lobsters present in the largest size classes. In order to rectify this problem, the normal distribution associated with the length-at-age of lobsters was modified to be truncated at the upper level by 1.5 SD and the lower level by 3.0 SD (this latter as previously). This prevents the model from assuming the presence of unrealistically large lobsters, and secures an improved fit to these data.

It was also evident that the model produced a poor fit to the female CAL data (averaged over years) from the biomass surveys. To improve this fit, a further component was added to the –lnL function:

$$-lnL \rightarrow -lnL + w\sum_{l=65}^{l=85}\left[CAL_{ave,l}^{obs} - CAL_{ave,l}^{mod}\right]^2 \qquad (9)$$

Improved fits were found when the weight *w* was set at 1000.

Note that as these surveys have been conducted in a consistent manner over time, both the associated male and female selectivity functions are assumed to be time invariant.

Sensitivity tests

The following sensitivity tests are run; they assume a lesser impact on mortality in 2011 on the **juvenile** lobsters due to the OLIVA incident:

SEN1: a 20% (instead of 80%) once off additional mortality on juveniles (ages 1-3) during the 2011 season (retaining the assumption of 0% additional adult mortality), and

SEN2: a 0% (instead of 80%) once off additional mortality on juveniles (ages 1-3) during the 2011 season (retaining the assumption of 0% additional adult mortality).

Further sensitivity tests will be considered for OMP testing, e.g. different F_{2009} values.

Projections

Although a new OMP is to be developed and implemented in 2020 for the Nightingale resource, deterministic projections in the range of 80 MT to 120 MT are reported here to provide an initial indication of potential resource productivity.

Results and Discussion

The recent (2013+) high GLM standardized CPUE and biomass survey indices reported at Nightingale (Johnston and Butterworth 2019 and Johnston 2020) were not anticipated at the time of the OLIVA incident. They suggest that the impact of the OLIVA incident on the resource was overestimated then. For this reason, the RC assumptions to take into account the possible effects of the OLIVA on adult mortality have remain modified from the initial additional 50% (once off 2011 adult mortality) to zero. The OLIVA impact on juveniles for the RC remains at 80% (again a once off additional mortality in 2011 due to the OLIVA incident) in order to be cautious, as a possible delayed impact of such enhanced juvenile mortality could be yet to be observed – although given the continued high CPUE values this possibility has become increasingly less likely over time.

Table 1 compares the 2020 updated RC Nightingale assessment with results of the two sensitivity tests (which assume lower OLIVA related additional juvenile mortality in 2011). The 2017 RC results are also reported in the first column for comparison. Figure 1 contains plots of the 2020 RC assessment fits to both the longline CPUE and biomass survey Leg1 CPUE data, as well as further model estimated trends. A comparison to the 2016 RC estimated values for exploitable biomass is also provided in these plots. Note that the recent high catch rates, and hence abundances, are ascribed to particularly strong recruitment over the 2005-2011 period.

The plot of the RC selectivity μ residuals in Figure 2a relates to how fast the right hand limb of the selectivity function decreases. Figure 2b plots the female multiplicative scalar residuals, which indicate how the relative selectivity for females has changed over time, e.g. for the period 2002-2004 there was a reduced female selectivity (compared to the norm). Figure 2c shows the actual estimated selectivity functions for males and females for both the commercial and the biomass surveys.

Figures 3 and 4 respectively show fits to the commercial and to the biomass survey CAL data averaged over all years, as well as the residual plots and annual fits to the 2014-2018 observed values.

Results in Table 1 show that the RC model has a much poorer fit when compared with the two sensitivity tests which assume less juvenile mortality in 2011.

The three 2020 models reported estimate the current (2020) spawning biomass as a fraction of the unexploited equilibrium level to be between 0.75 (RC) and 0.87 (SEN2).

Figure 1 indicates that the RC model fits the longline CPUE data reasonably well, but remains unable to fully reflect the very high CPUE values observed for 2017 and 2018. Fits to the discard proportion data are reasonably good, except for the first six year period in the late 1990s.

The RC fits to the commercial longline catch-at-length (CAL) data are good (Figure 3) when averaged over the full time period for which data are available. Figure 4 reports the RC model fit to the biomass survey CAL data. Again, the fits are in the main reasonably good. The refinement of adding further weight to the associated likelihood function (see equation 9) to improve the overall fits to the female biomass survey CAL data remains successful. Figure 4c for the survey CAL data by year does however show some poor fits to recent data, though note that the data for females in recent years is very erratic (and unlike for the commercial data, no annual variation in the female scalar parameter is admitted).

Figure 5 shows a good fit between the observed and estimated percentage females in the commercial catch.

Figure 6a compares the estimated exploitable biomass trends, in units of CPUE, for the RC, SEN1 and SEN2. Figure 6b males similar comparisons but for the biomass survey CPUE. Figure 6b compares the RC, SEN1 and SEN2 model fits to the 2015-2018 commercial CAL data.

It is especially interesting to note that better model fits to the overall data are achieved for the SEN1 (20% additional juvenile mortality in 2011) and SEN2 (0% additional juvenile mortality in 2011) tests when compared with the RC, as evidenced in the various –lnL values reported in Table 1. The effects of any substantial impact on the juveniles could still however become evident in the future; this is due to the lag effect arising for the juveniles affected by the OLIVA incident needing time to grow to the legally catchable sized component of the population. Figure 8 shows that we can expect about 6 year and 7 year lags for males and females respectively between the time of the OLIVA incident in 2011 to the time these juveniles would first appear in the commercial catch (i.e. 2017 for males and 2018 for females). The biomass survey, however, samples lobsters below minimum size. Males are sampled from sizes 55mm CL, which corresponds (see Figure 8) to age four, meaning that the effects of the OLIVA on juveniles (if any) should have been evident since around 2015 in the biomass survey data. There does not appear to be any evidence for this (Figure 4c).

Figure 7 plots the estimated CPUE values along with the stock recruit residuals. The bottom plot shows again about a 7-year lag between recruitment and the legally catchable portion of the resource.

Figure 8 shows plots of Bsp, Bsp/K and Bexp for projections of future (2020+) TAC values ranging from 75 MT to 90 MT.

Figure 9a shows RC deterministic projections for Bsp, Bsp/K and Bexp for a range (80 MT – 120 MT) of future constant catches. In all the cases examined, the biomass is predicted to increase over the next 13 years. Figure 9b shows similar projections, but for SEN1. Figure 9c compares projections at 80 MT for the RC, SEN1 and SEN2 models. Figure 9d provides a comparative plot of the RC, SEN1 and SEN2 estimated stock recruit residuals – note that SEN1 and SEN2 (which fit the data better) have much lower recruitments for the 2007-2011 period; these feed into the projection period producing rather different projections between the RC and the SEN1 and SEN2 models.

Conclusions

It is proposed that to change the RC to SEN1 i.e. the additional mortality on juveniles due to the OLIVA incident in 2011 is reduced from 80% to 20%, given the very clear improved fit to the data that results.

References

Johnston, S.J., Brandao, A. and Butterworth, D.S. 2019. Updated 2017 GLMM-standardised lobster CPUE from the Tristan da Cunha outer group of islands. MARAM/Tristan/2019/FEB/01.

Johnston, S.J. and Butterworth, D.S. 2013. The age structured population modeling approach for the assessment of the rock lobster resources at the Tristan da Cunha group of islands. MARAM/Tristan/2013/Mar/07. 15pp.

Johnston, S.J. and Butterworth, D.S. 2017. Updated 2017 Nightingale island rock lobster assessment. MARAM/Tristan/2017/MAY/07.

Johnston, S.J. 2020. Tristan group biomass survey (Leg1) results including data from the 2019 season. MARAM/Tristan/2020/JAN/01.

Table 1: Updated Nightingale 2020 assessment results. The 2017 RC assessment results are reported in the shaded second column to allow for ready comparisons. The values in *italics* are fixed on input. Values in parentheses are estimated σ values. (Note that the –lnL values are not comparable between the 2017 and 2020 assessments because the latter take further data as well as a larger σ_μ into account). Results for 2020 are reported for the RC, and the SEN1 and SEN2 sensitivity tests.

	2017 assessment RC [σ_μ=0.02] **(2011 adult mortality due to OLIVA = 0% and juvenile mortality=80%)**	**2020 assessment RC** [σ_μ=0.2] **(2011 adult mortality due to OLIVA = 0% and juvenile mortality=80%)**	**2020 assessment SEN1** [σ_μ=0.2] **(2011 adult mortality due to OLIVA = 0% and juvenile mortality=20%)**	**2020 assessment SEN2** [σ_μ=0.2] **(2011 adult mortality due to OLIVA = 0% and juvenile mortality=0%)**
# parameters estimated	101	110	110	110
σ_R	*0.4*	*0.4*	*0.4*	*0.4*
K	607	936	670	635
h	0.73	0.59	0.74	0.78
F_{2009} fixed at	*0.3*	*0.3*	*0.3*	*0.3*
θ	0.239	0.174	0.248	0.266
-lnL total	-2.31	-10.73	-19.42	-20.01
-lnL CPUE T	-18.26	-26.93	-28.05	-28.23
-lnL CPUE longline	-12.79 (0.261)	-17.38 (0.174)	-17.81 (0.160)	-17.89 (0.158)
-lnL CPUE Survey Leg1	-5.48 (0.462)	-9.54 (0.409)	-10.24 (0.398)	-10.35 (0.340)
-lnL CAL T	-77.46	-120.69	-161.11	-161.26
-lnL CAL onboard observer	-63.91 (0.070)	-94.74 (0.067)	-122.25 (0.063)	-122.62 (0.063)
-lnL CAL Survey Leg 1	-13.55 (0.095)	-25.95 (0.013)	-38.85 (0.12)	-38.64 (0.12)
SR1 pen	8.15	9.31	7.32	7.13
-lnL discard	3.66	2.29	2.35	2.36
Bsp(1990)/Ksp	0.22	0.16	0.23	0.25
Bsp(2017)/Ksp	0.62	0.75	0.96	1.01
Bsp(2019)/Ksp	-	0.71	0.88	0.91
Bsp(2020)/Ksp	-	0.75	0.85	0.87
Bsp(2017)/Bsp(1990)	2.29	4.62	4.16	4.08
Bsp(2019)/Bsp(1990)	-	4.39	3.79	3.66
Bsp(2020)/Bsp(1990)	-	4.62	3.70	3.52
Bexp(2016)	306	489	519	531
Bexp(2019)	-	453	383	374
Bexp(2020)	-	489	366	349
Bexp(2016)/Bexp(1990)	2.78	4.50	4.71	4.74
Bexp(2019)/Bexp(1990)	-	4.17	3.48	3.34
Bexp(2020)/Bexp(1990)	-	4.47	3.32	3.12
Programs	NRC.tpl	N1.tpl	Sen1.tpl	Sen2.tpl

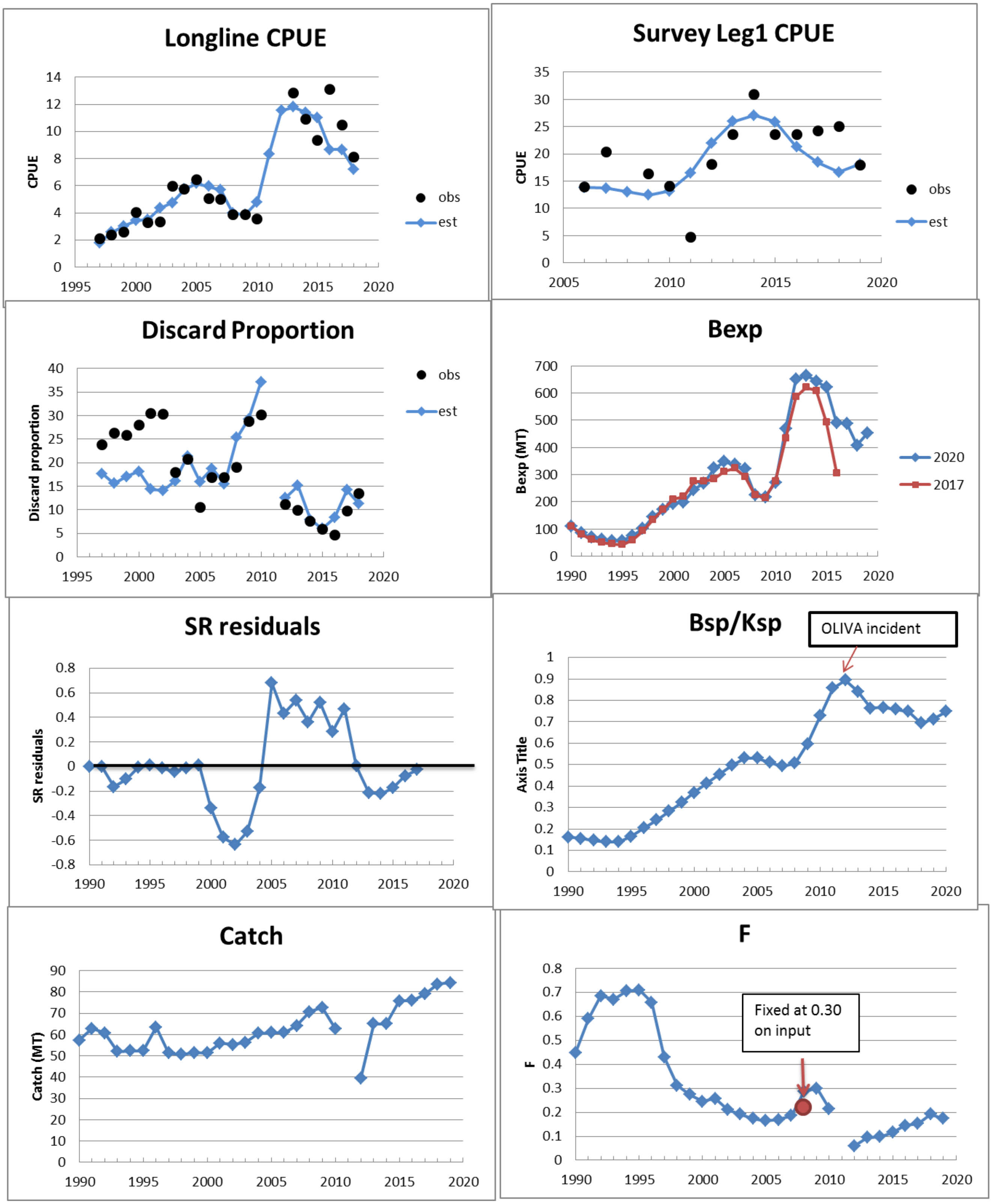


Figure 1: Nightingale 2020 **RC** assessment results. The exploitable biomass trend from the 2017 RC assessment are also plotted for comparative purposes.

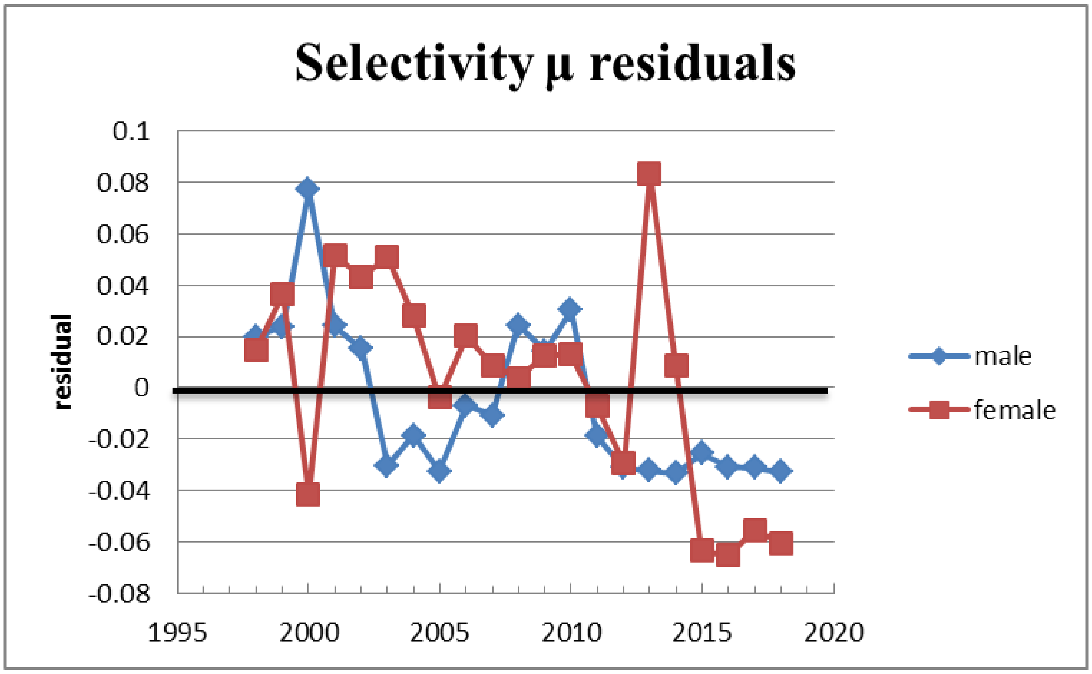


Figure 2a: Nightingale **RC** estimated μ residuals (used to allow commercial selectivity function variation from year to year).

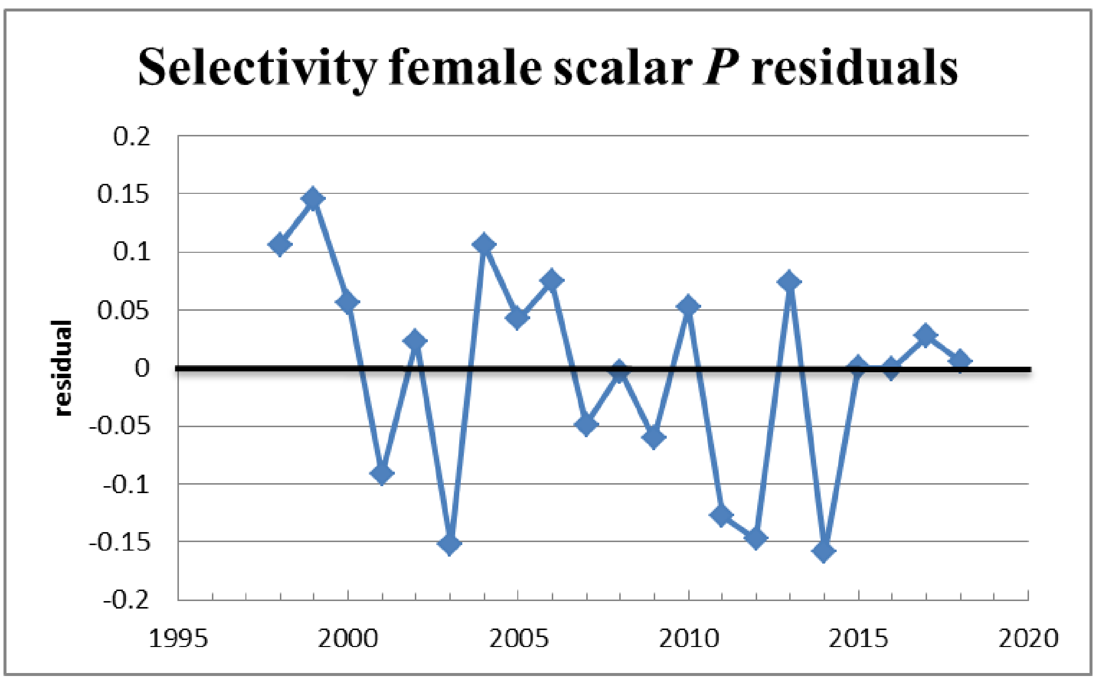


Figure 2b: Nightingale **RC** estimated female selectivity scalar (the *P* parameter) residuals (used for commercial selectivity function variation from year to year).

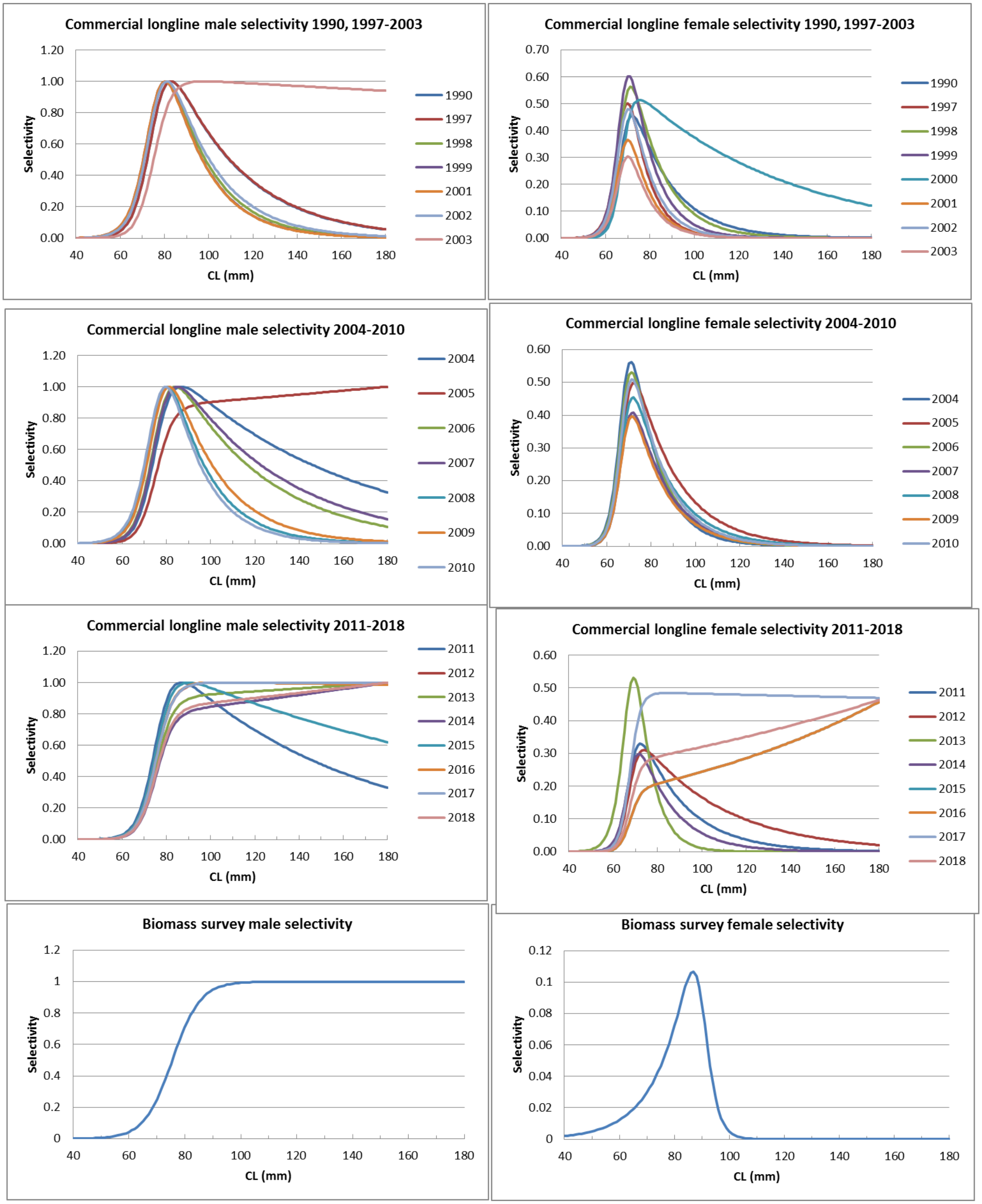


Figure 2c: Male (left) and female (right) estimated selectivity functions for both the commercial and the biomass survey.

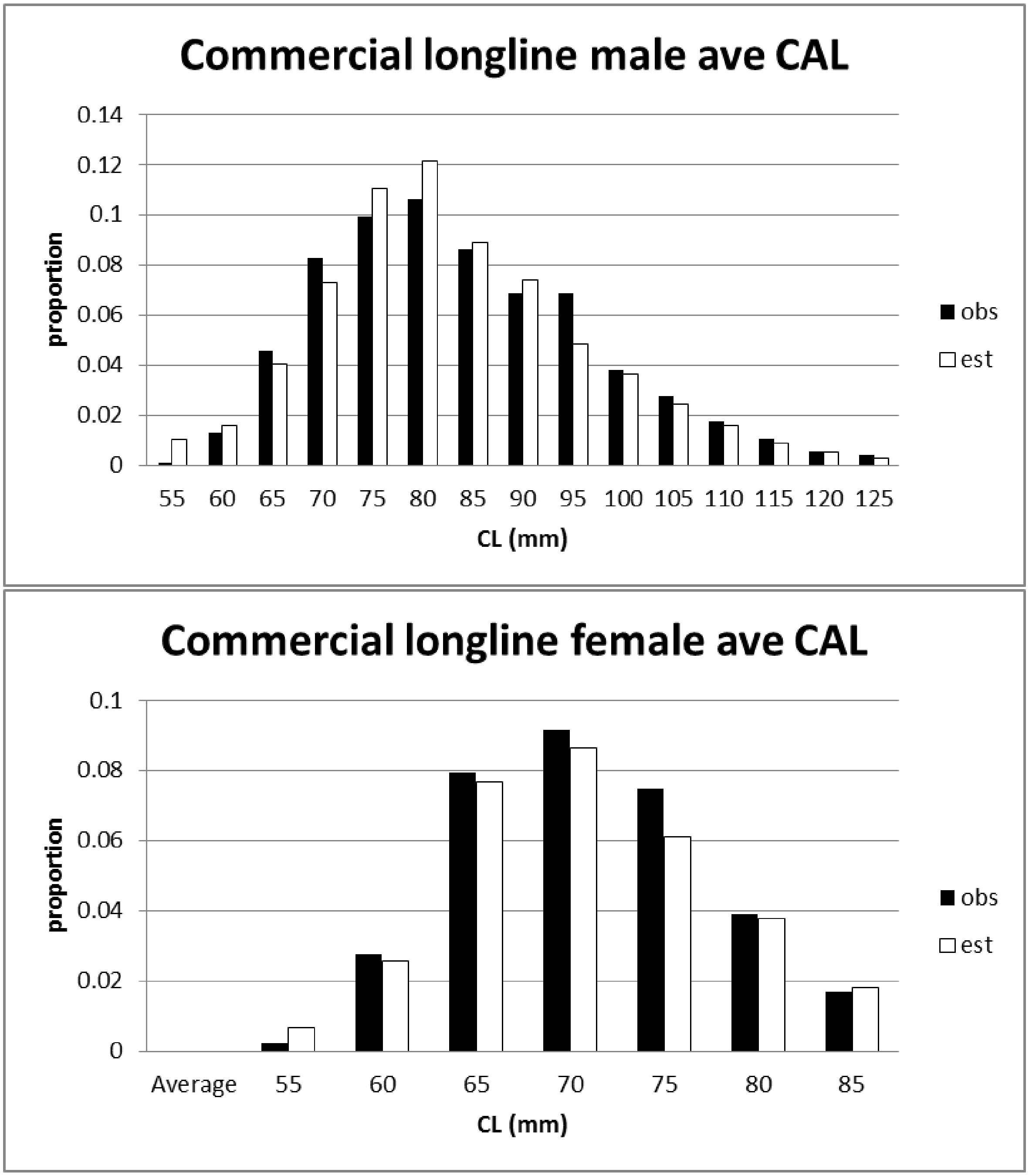


Figure 3a: Nightingale commercial longline **RC** CAL fits averaged over years for males (upper panel) and females (lower panel).

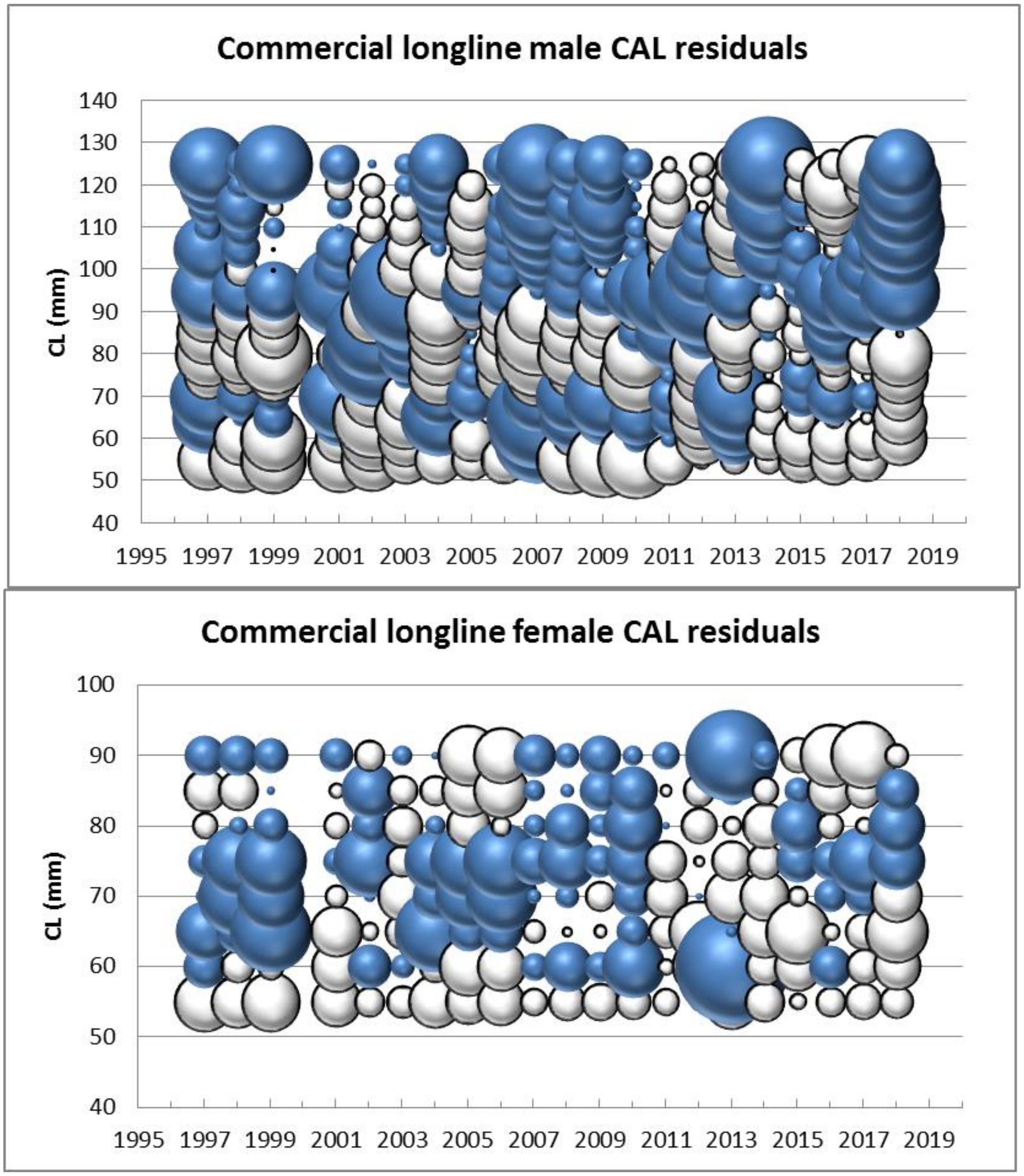


Figure 3b: Nightingale standardized commercial longline CAL residuals for the **RC** model for males (upper panel) and females (lower panel). The dark bubbles reflect positive and the light bubbles reflect negative residuals, with the bubble radii proportional to the magnitudes of the residuals.

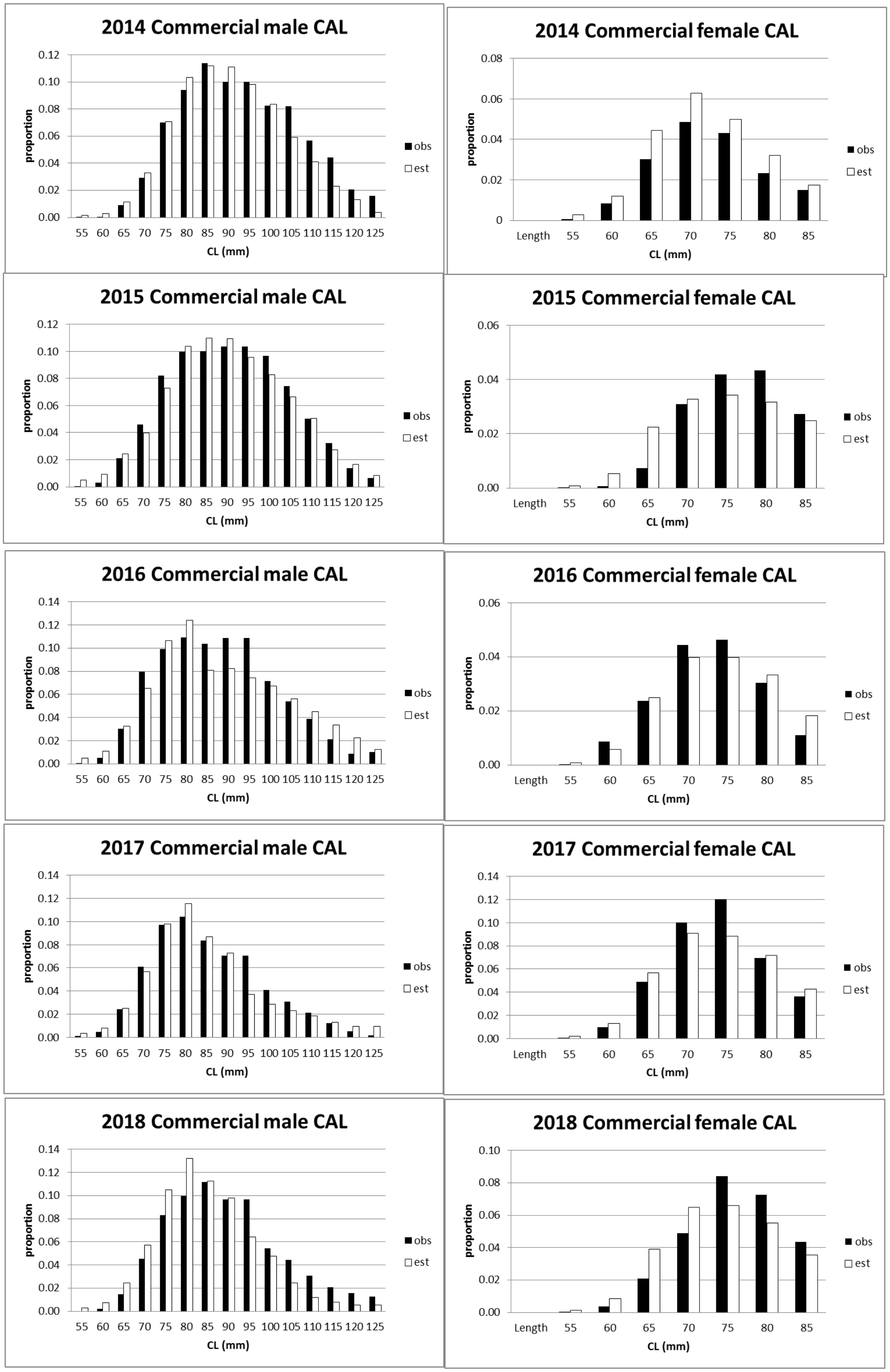


Figure 3c: Nightingale commercial longline **RC** CAL fits for each of the years from 2014 to 2018 for males (left panels) and females (right panels).

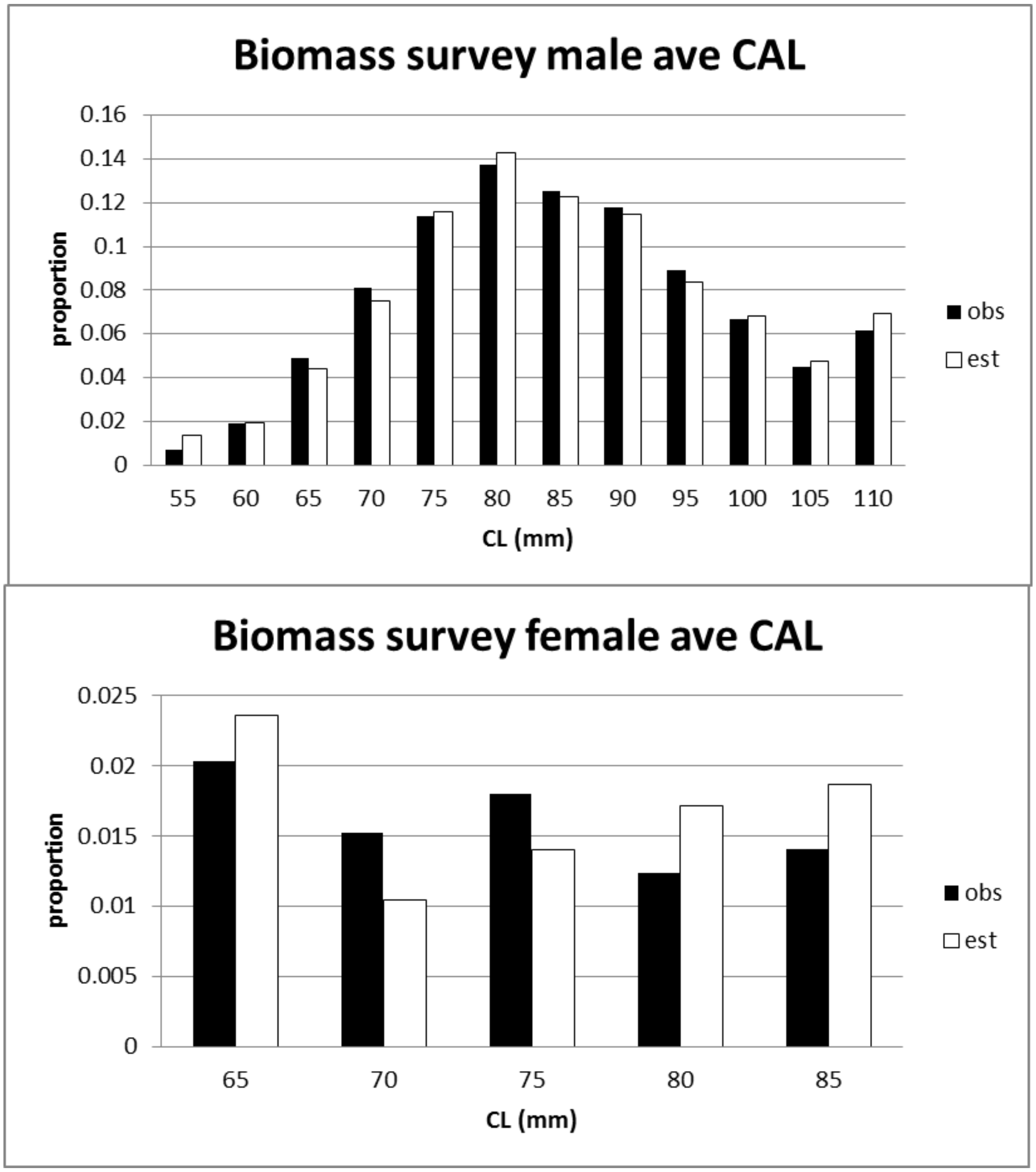


Figure 4a: Nightingale biomass survey Leg1 **RC** CAL fits averaged over years for males (upper panel) and females (lower panel).

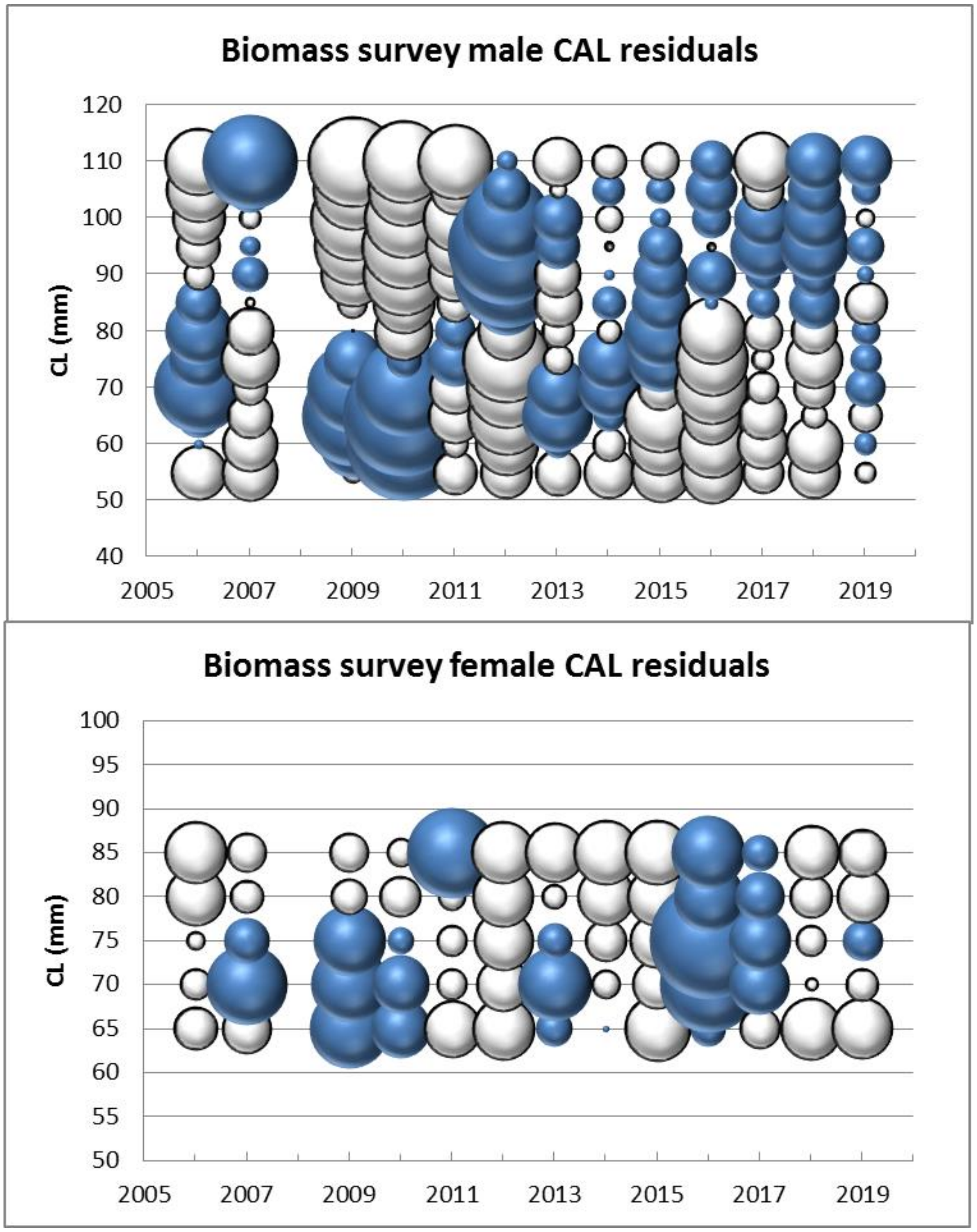


Figure 4b: Nightingale standardized biomass survey Leg 1 CAL residuals for the **RC** model for males (upper panel) and females (lower panel). The dark bubbles reflect positive and the light bubbles reflect negative residuals, with the bubble radii proportional to the magnitudes of the residuals.

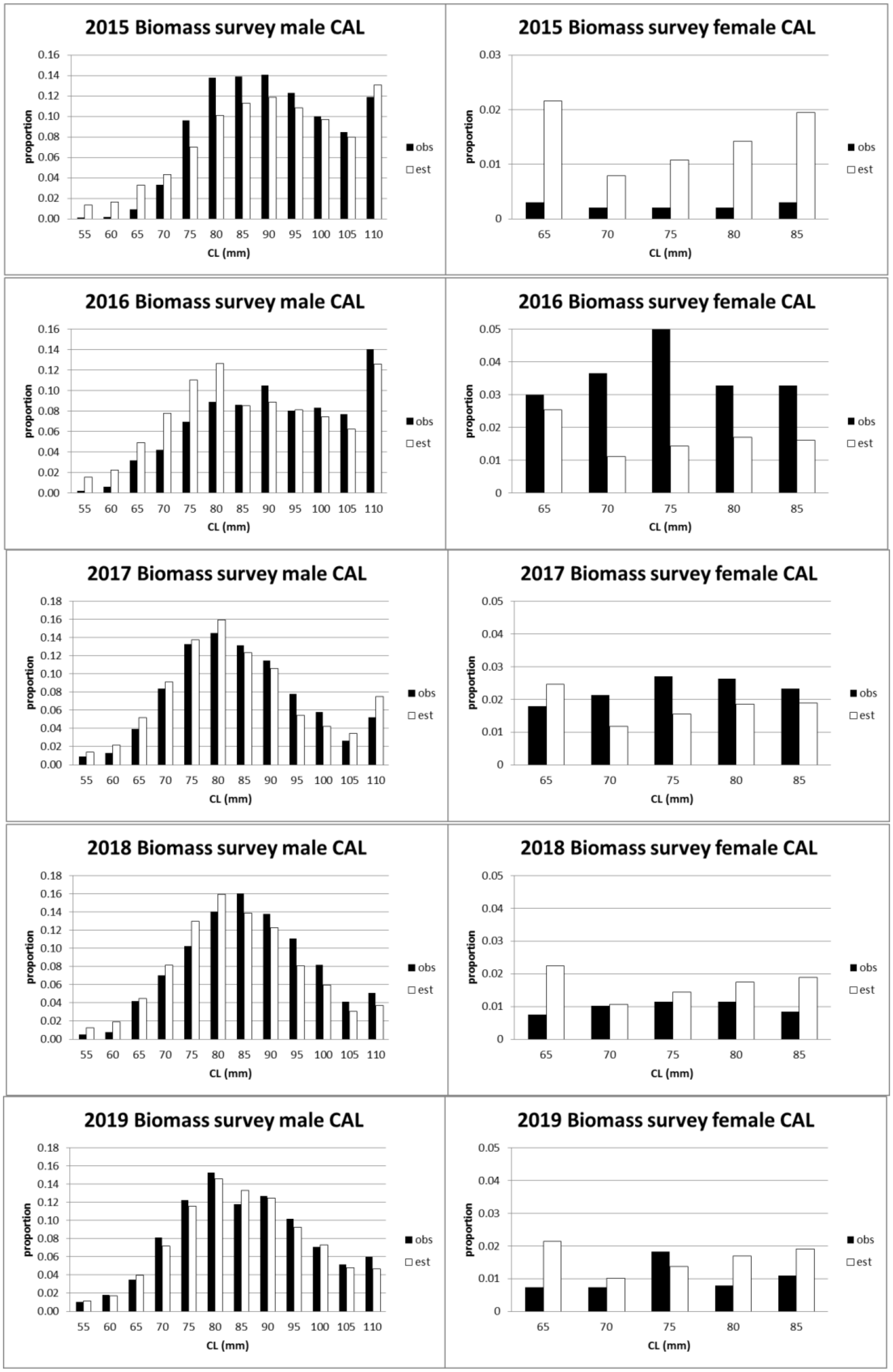


Figure 4c: Nightingale biomass survey **RC** CAL fits for each of the years from 2015 to 2019 for males (left panels) and females (right panels).

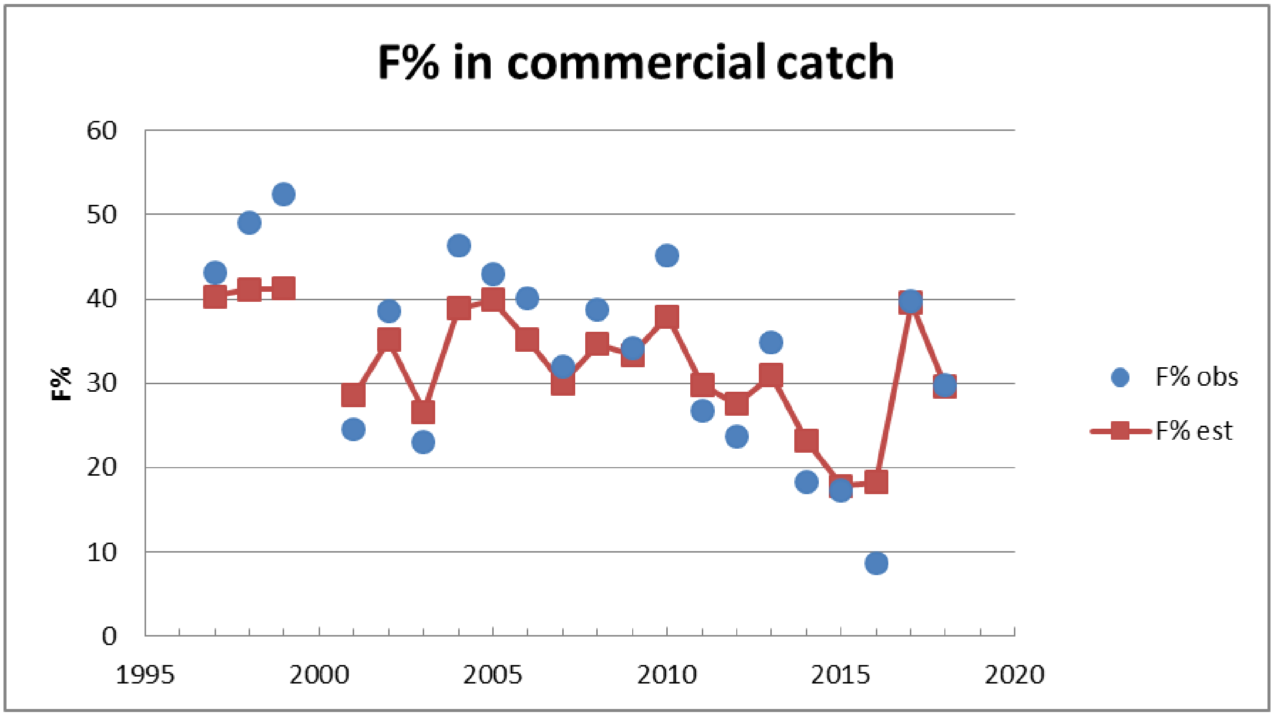


Figure 5: Comparison between the observed and estimated percentage females in the commercial catch.

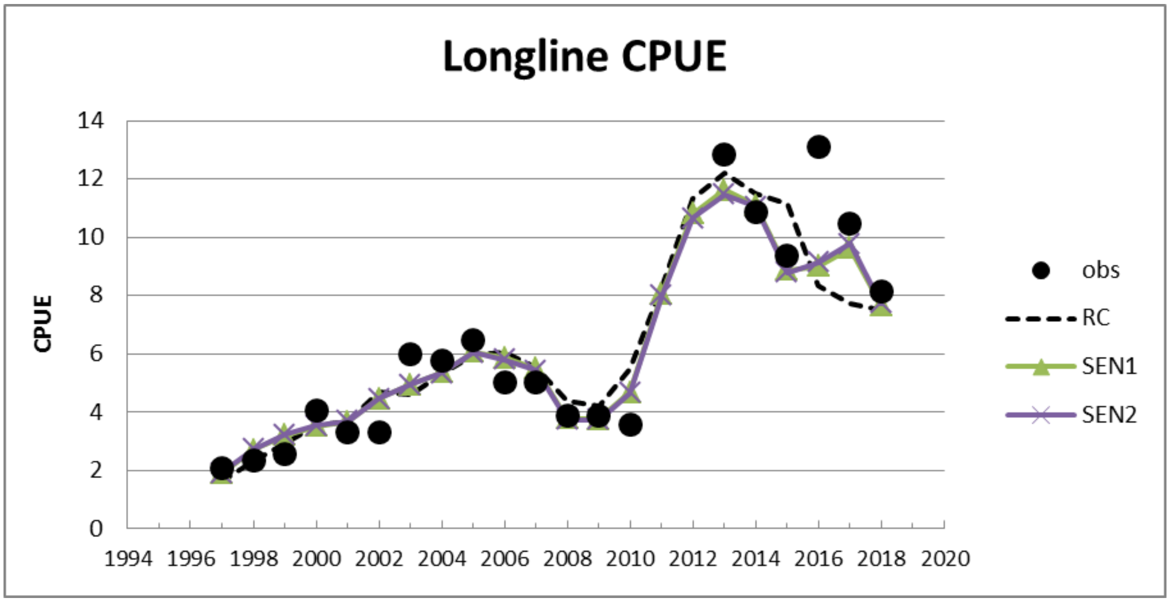


Figure 6a: Comparative plots of the estimated longline catch rates (CPUE) for the **RC** (80% juvenile and 0% adult mortality in 2011 due to OLIVA), **SEN1** (**20%** juvenile and 0% adult mortality in 2011 due to OLIVA), and **SEN2** (**0%** juvenile and 0% adult mortality in 2011 due to OLIVA). The GLM longline CPUE values derived from data are shown as black circles.

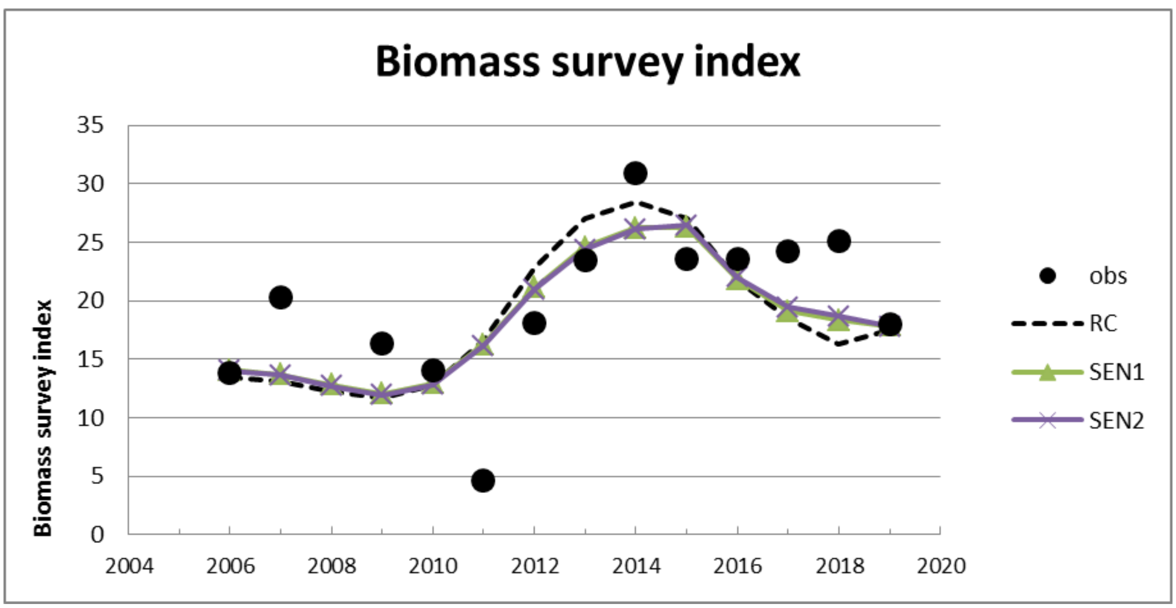


Figure 6b: Comparative plots of the estimated biomass survey indices for the **RC** (80% juvenile and 0% adult mortality in 2011 due to OLIVA), **SEN1** (**20%** juvenile and **0%** adult mortality in 2011 due to OLIVA), and **SEN2** (**0%** juvenile and **50%** adult mortality in 2011 due to OLIVA). The biomass survey indices derived from data are shown as black circles.

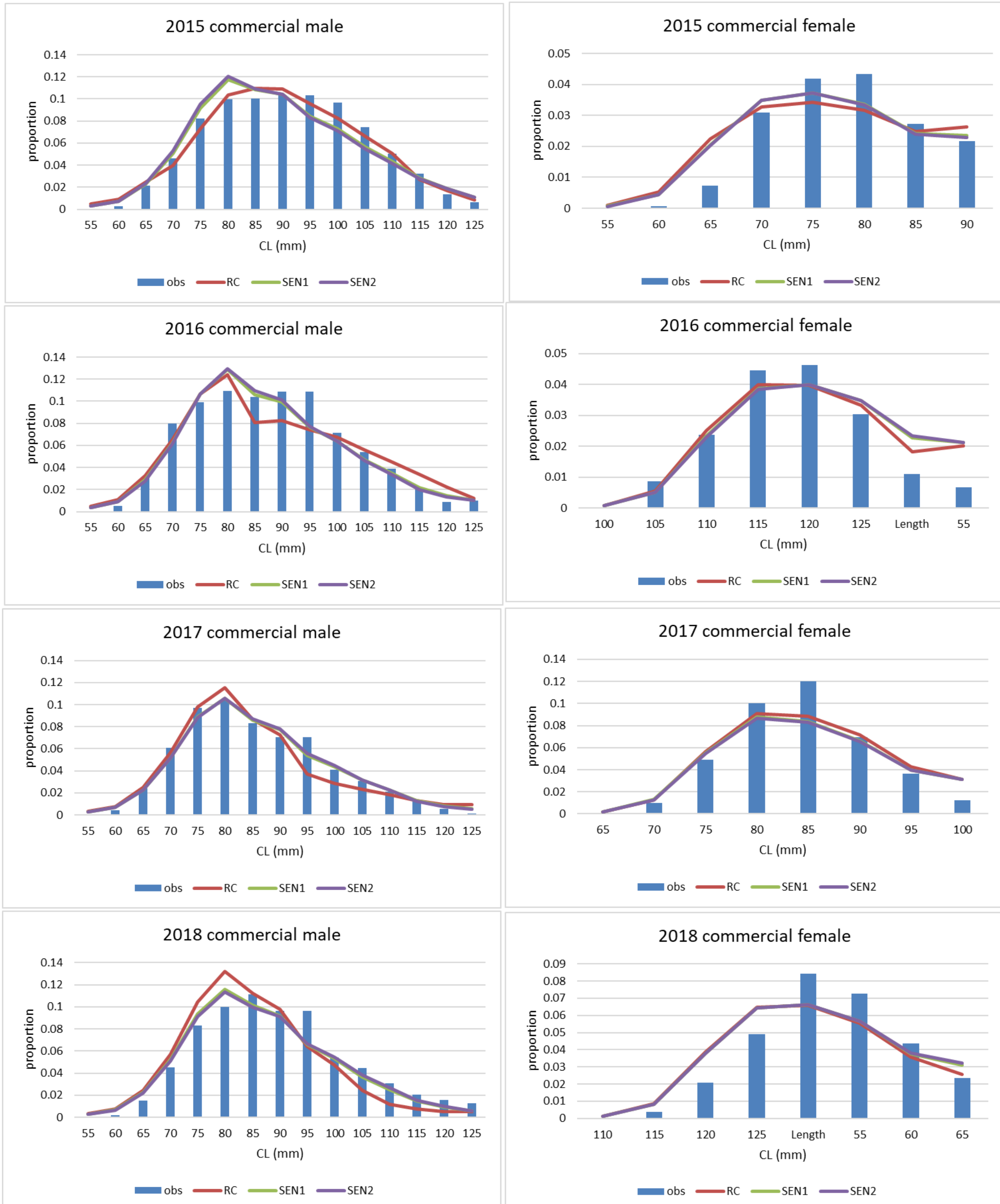
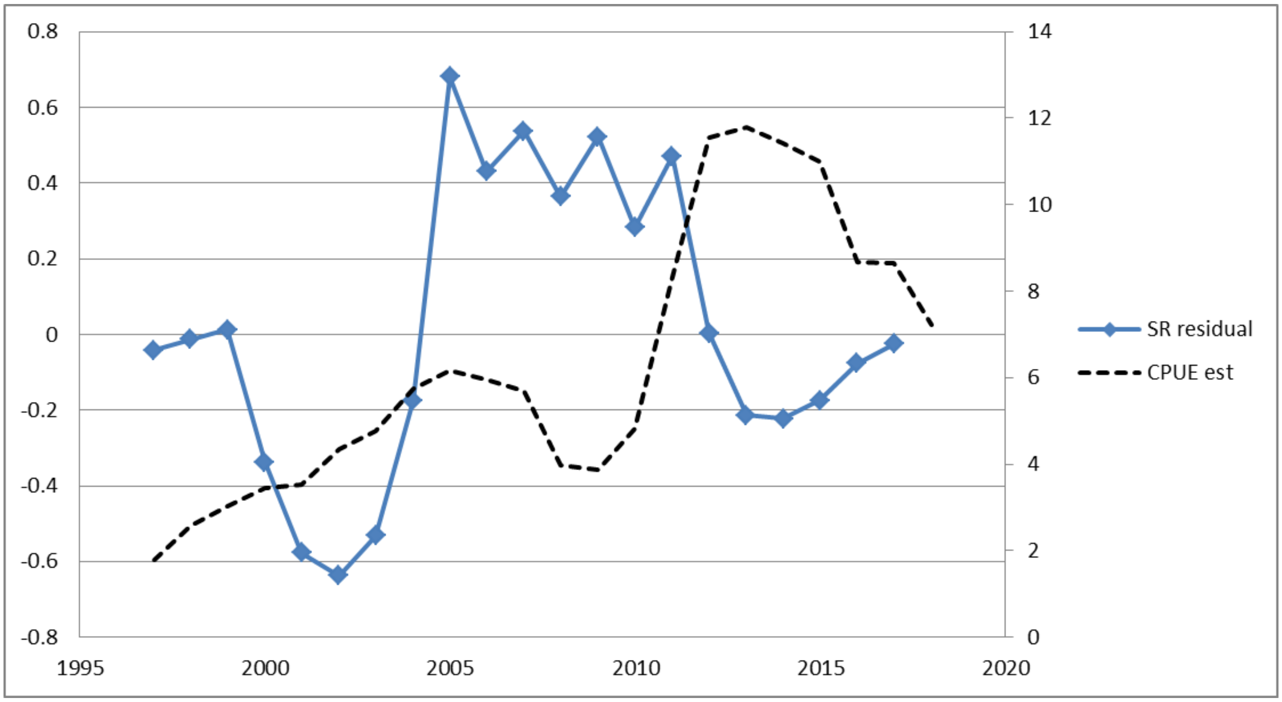


Figure 6c: Comparison between RC, SEN1 and SEN2 model fits to 2015-2018 commercial male (left panels) and female (right panels) CAL data.



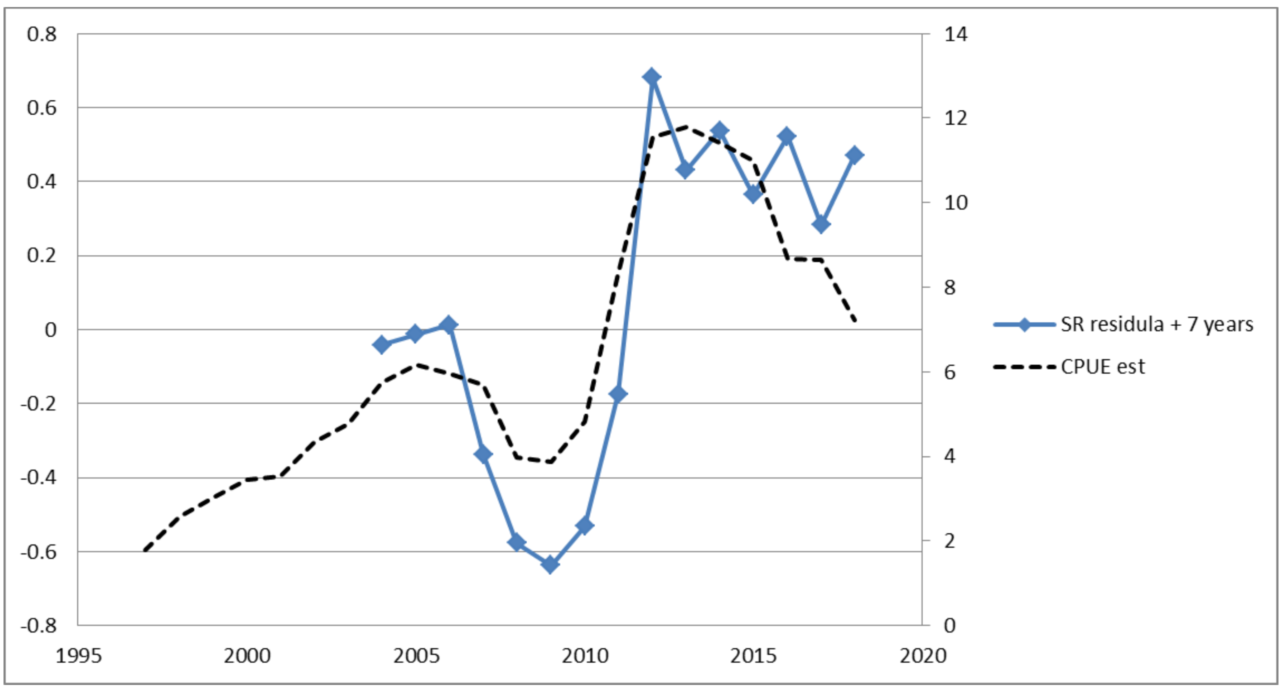


Figure 7: A plot of the estimated stock-recruit residuals and the estimated commercial CPUE, showing the time-lag between the two – top plot. The bottom plot shifts the S-R residuals by 7 years to show that there is roughly a 7-year time lag between recruitment and the exploitable biomass portion of the resource.

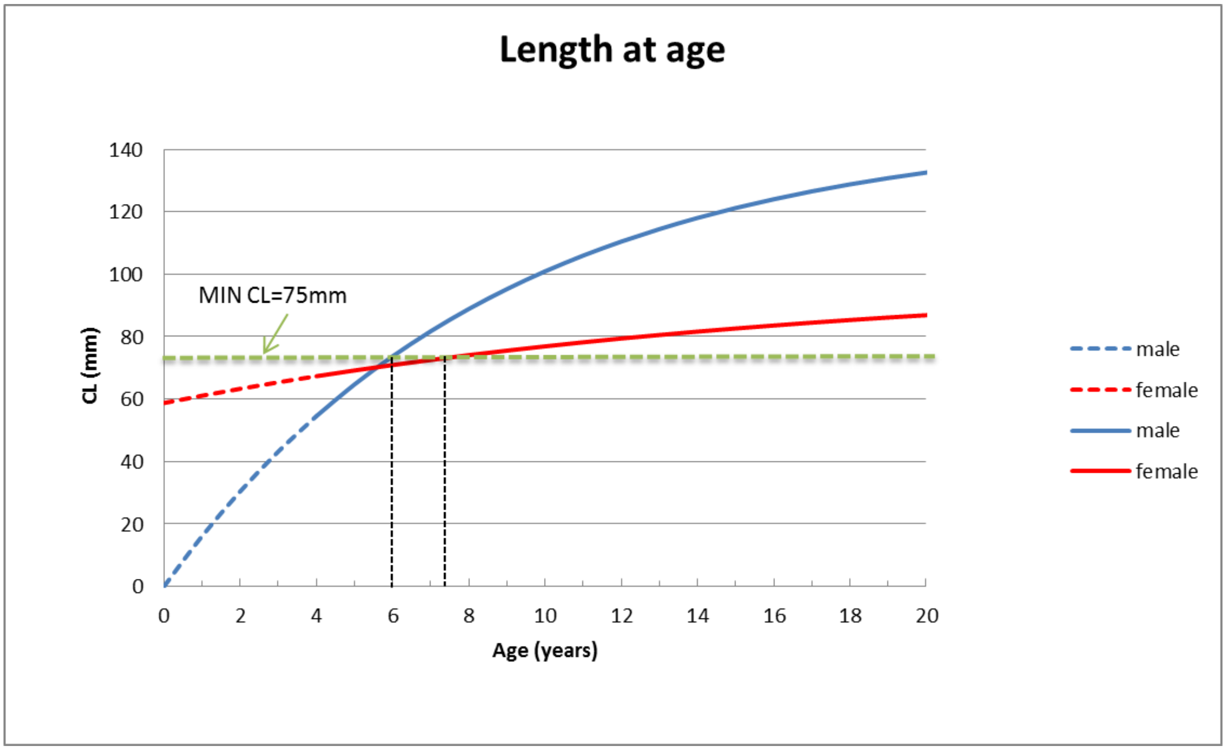


Figure 8: The Growth curves for male and female Nightingale lobsters. The green dashed horizontal line shows the current 75mm CL minimum length. [Note that the growth curves are shown as dotted for ages less than 4 years, because those parts of these curves play no role in the calculations of this paper. Clearly the female curve is unrealistic below that age; typically females initially grow almost as fast as males, but later in life their growth slows considerably relative to males, as they put more of their energy intake into egg production.]

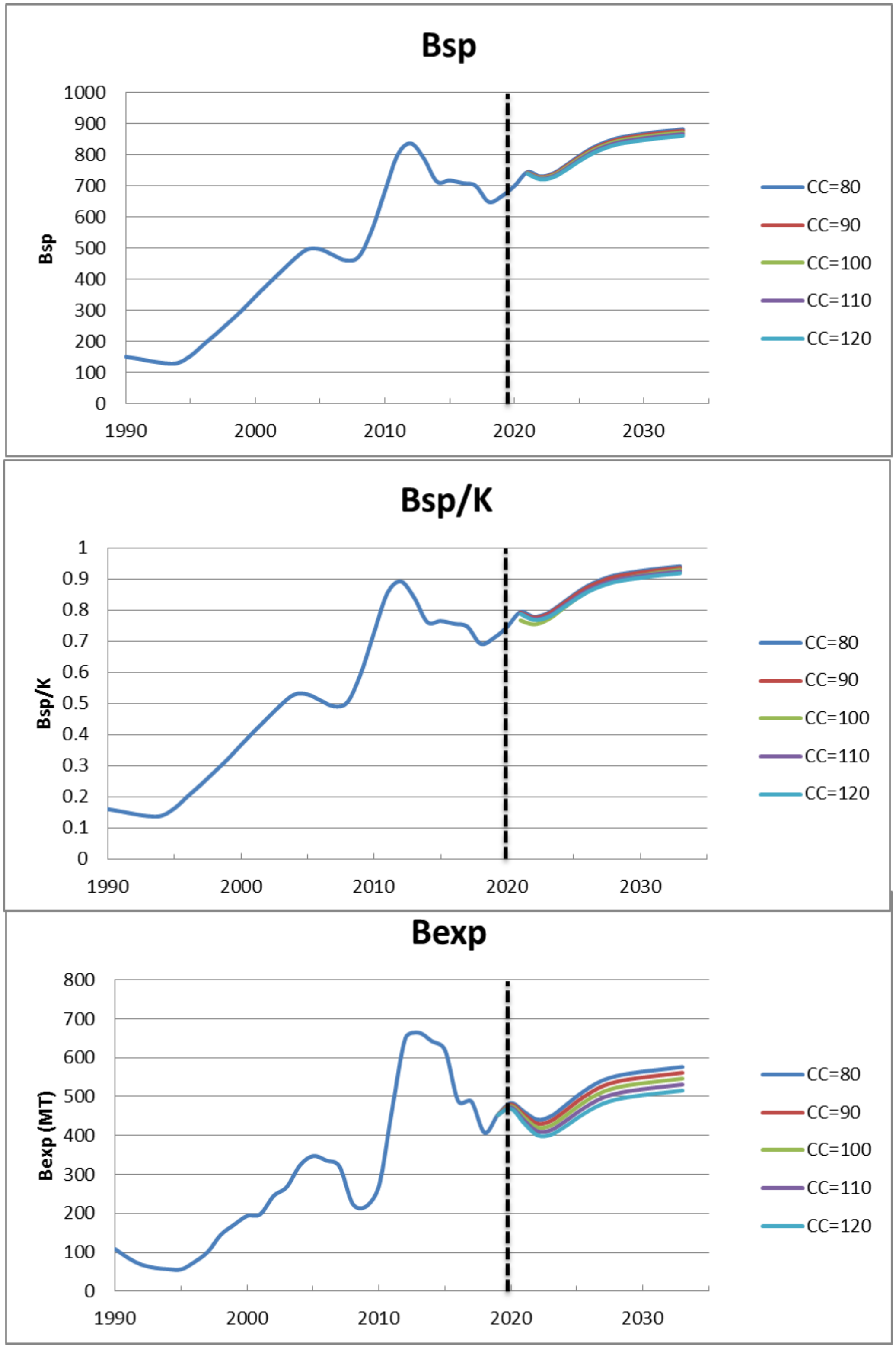


Figure 9a: RC deterministic projections of Bsp, Bsp/K and Bexp for a range (80 MT – 120 MT) of future annual constant catches.

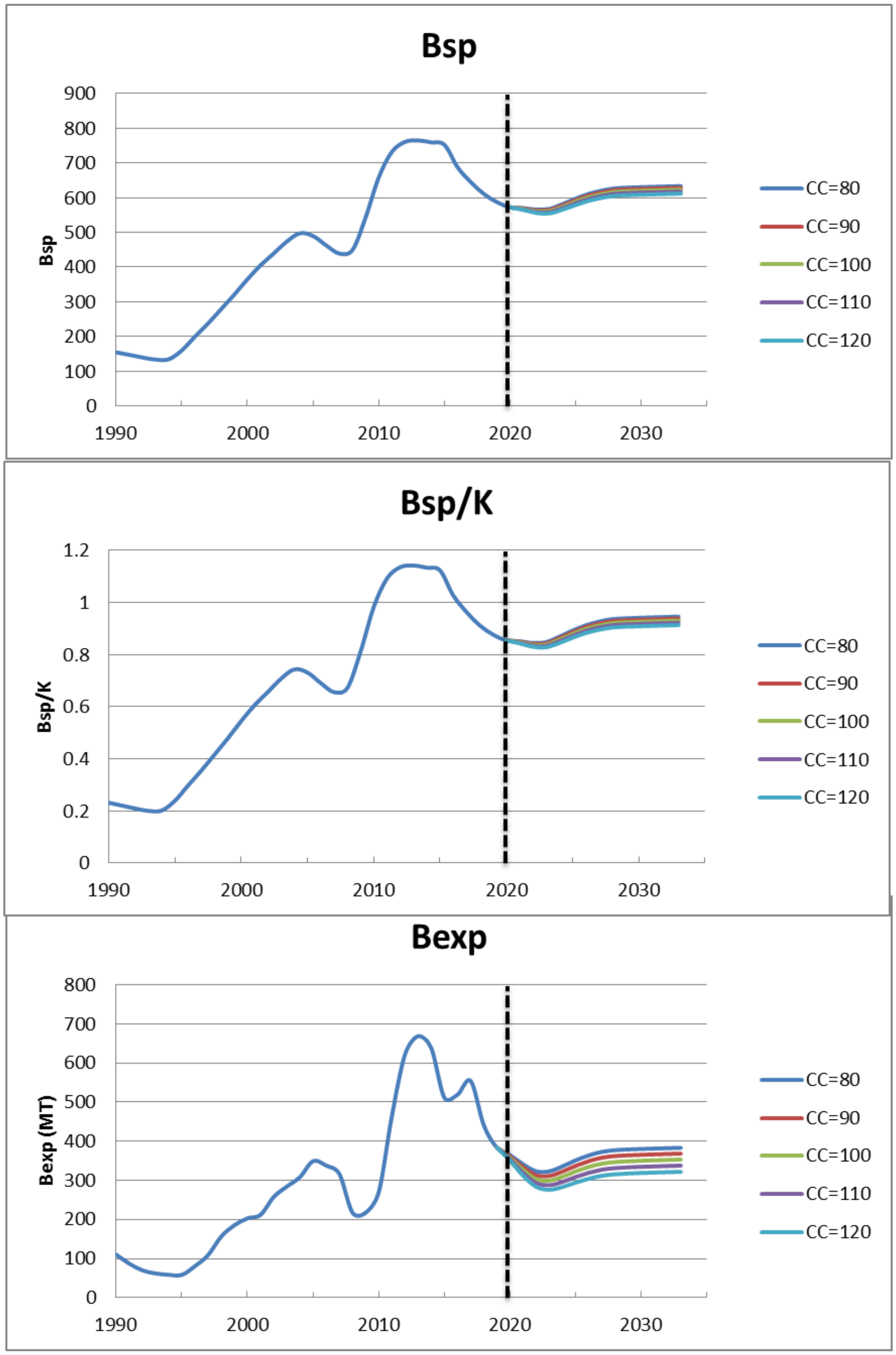


Figure 9b: SEN1 deterministic projections of Bsp, Bsp/K and Bexp for a range (80 MT – 120 MT) of future annual constant catches.

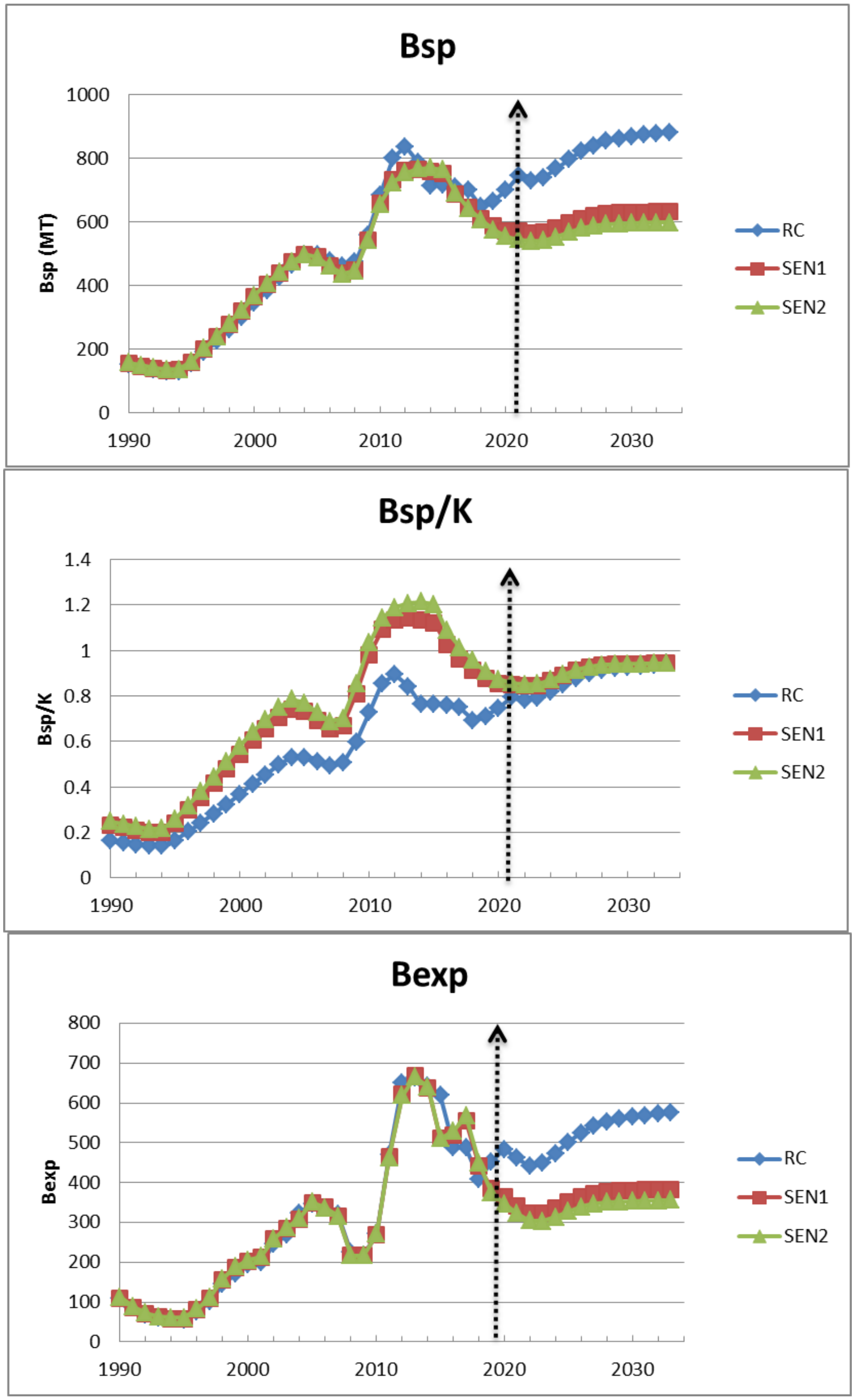


Figure 9c: BC, SEN1 and SEN2 deterministic projections of Bsp, Bsp/K and Bexp for a future constant annual catch of 80 MT.

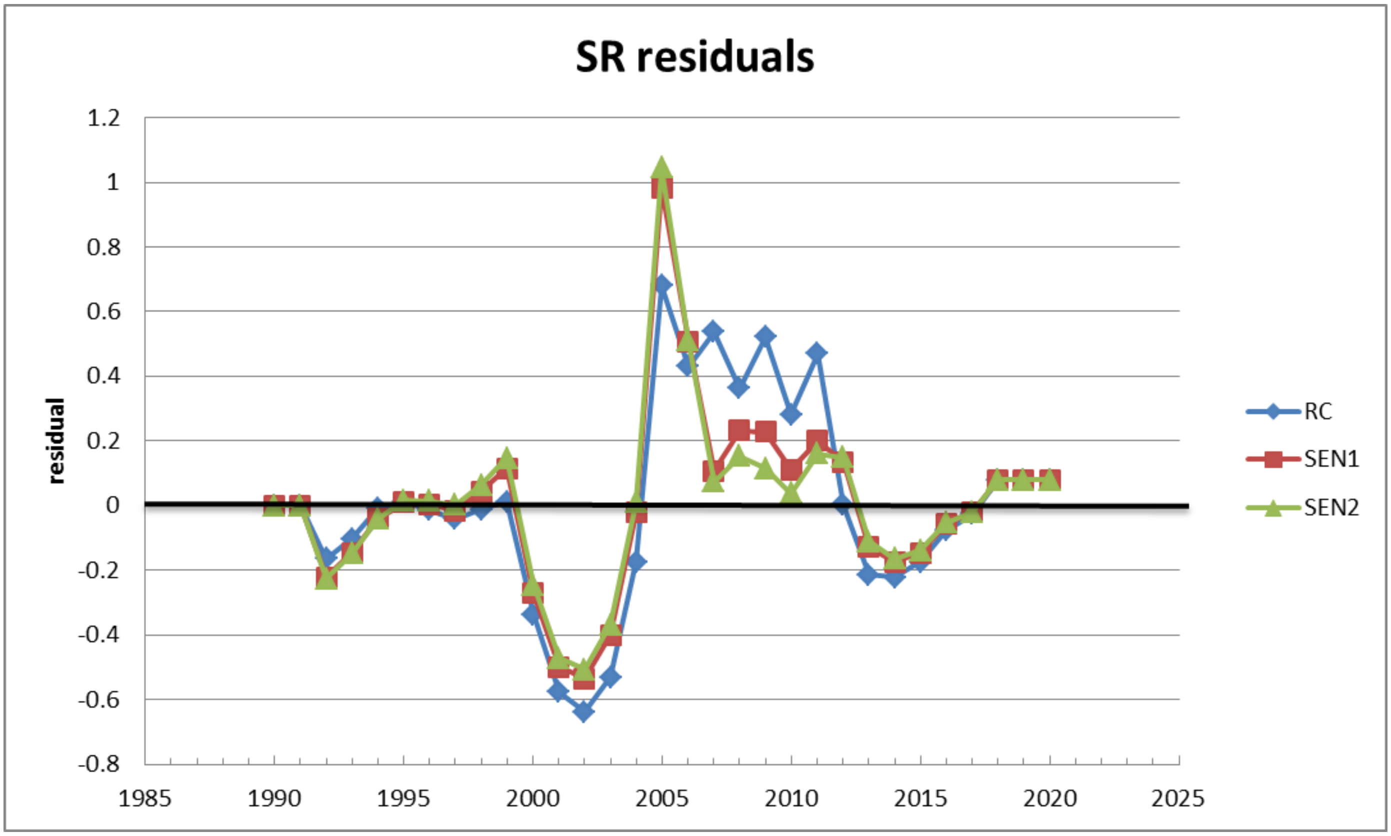


Figure 9d: A comparison of the RC, SEN1 and SEN2 stock recruit residuals