An updated assessment of the Agulhas sole resource, *Austroglossus pectoralis*

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Summary

Butterworth and Glazer (2014) reported results from the application of a simple form of the dynamic Schaefer model to account for a large drop in sole CPUE over the period 2009-2013. The two hypotheses considered were (i) the drop in CPUE was a consequence of decreasing catchability and (ii) the drop in CPUE was a consequence of decreasing productivity. The model was applied again in 2016 (Butterworth et al., 2016) and 2017 (Glazer et al., 2017). Results from the assessment conducted in 2017 yielded more positive future projections for the most pessimistic scenario (a decrease in productivity, where effort remains at its current reduced level into the future). Recent biomasses were estimated to be higher and projected to decrease more slowly if the 2013 effort level was maintained. Given that data are now available for 2017, the assessment model has once again been updated, with results reported here. These point to yet a more positive resource situation.

Introduction

In 2014 concern was expressed regarding the steady decline in sole CPUE since 2009. An initial assessment of the resource was thus undertaken by applying a simple form of the dynamic Schaefer model (Butterworth and Glazer, 2014). Data inputs to the assessment comprise annual catches and a standardized CPUE index, both of which are available since 2000. Results from the most recent assessment which includes data to 2017 are reported below.

The data

The annual catch series and CPUE index used in the assessment model are reported in Table 1 and cover the period 2000-2017. The catches relate to the total sole catch made per annum, while the standardized CPUE index relates to that of Model Cb in Fairweather and Glazer (2018). This reflects a CPUE index derived from data for seven sole specialist vessels in six of the nine grid blocks that comprise the sole grounds, where these data are further restricted to sole targeted fishing only. Of note is the substantial increase in CPUE in 2017. It should also be noted that no inshore trawl fishing took place as a result of a moratorium placed on the fishery over the period mid-December 2016 to June 2017.

The assessment model

The dynamic Schaefer model (chosen for use here because of its simplicity) is of the form:

$$B_{y+1} = B_y + rB_y[1 - \frac{B_y}{K}] - C_y \qquad (1)$$

where

B_y is the biomass estimated in year *y*, with the starting biomass B_{2000} assumed to be at the MSY level *K*/2, *r* is an estimable parameter (the intrinsic rate of population growth), which for realism was constrained to lie in the range [0.4; 0.7] in past analyses.

K is pristine biomass set at 800/(*r*/4), i.e. the MSY is assumed to be 800 tons (an amount landed regularly in the past), and
C_y is the annual catch.

The likelihood is calculated assuming that the abundance index (CPUE) is log-normally distributed about its expected values:

$$I_y = q_y B_y e^{\varepsilon_y} \qquad (2)$$

where I_y is the abundance index for year *y*, $q_y B_y$ is the corresponding model estimate (q_y being the estimated year-dependent catchability coefficients), and ε_y is the observation error, $\sim N(0, \sigma_{cpue}^2)$, in year *y*.

The contribution of the abundance index to the negative log-likelihood function (after the removal of constants) is given by:

$$-\ell nL = n\ell n\left(\hat{\sigma}_{cpue}\right) + \frac{n}{2} \qquad (3)$$

In assessing the status of the sole resource two hypotheses have been considered in an attempt explain the decline in CPUE experienced over the period 2009-2013. These are as follows:

- **Hypothesis 1**: assumes that catchability decreased over the period 2009-2013. For the assessment conducted in 2017 the following assumptions were made for the year-dependent q_y parameters:

  q_y is defined as qZ_y, where:

  - Z_y=1 for y≤2010,
  - $Z_{2011} = 1 - \mu$,
  - $Z_{2012} = 1 - 2\mu$,
  - $Z_{2013} = 1 - 4\mu$,
  - $Z_{2014} = 1 - 3\mu$,
  - $Z_{2015} = 1 - 2.5\mu$, and
  - $Z_{2016+} = 1 - 3.5\mu$

Given additional data, Z_{2016} was maintained at $1 - 3.5\mu$ and Z_{2017+} was set at $1 - 1.5\mu$. μ is assumed to be 0.2.

- **Hypothesis 2**: assumes that productivity decreased over the period 2007-2013. For the assessment conducted in 2017the following assumptions were made for the year-dependent r_y and K_y parameters:

  r_y and K_y are defined as rU_y and KU_y, where:
  - U_y=1 for y≤2007,

- $U_{2008+} = e^{-\delta}$,
- $U_{2009} = e^{-2\delta}$,
- $U_{2010} = e^{-3\delta}$,
- $U_{2011} = e^{-4\delta}$
- $U_{2012} = e^{-5\delta}$,
- $U_{2013} = e^{-6\delta}$,
- $U_{2014} = e^{-5\delta}$
- $U_{2015} = e^{-4\delta}$, and
- $U_{2016+} = e^{-3\delta}$

δ is assumed to be 0.3.

Given the substantial CPUE increase in 2017, the U_y values assumed previously (shown above) required re-evaluation since they no longer provided an adequate fit to the CPUE data. The turn-around point of U_y is now set at 2011 instead of 2013 as per the 2017 assessment. Additionally, U_{2017} is set at $e^{-W\delta}$, where *W* and δ were initially included as estimable parameters with a linear relationship assumed between U_{2011} and U_{2017}. Attempts to estimate both *W* and δ (for a fixed *r* =0.4) proved unsuccessful. Model fits were thus evaluated for a combination of fixed *W* and δ values (and *r*=0.4). The resulting $-lnL$ values indicated that a *W* of zero was preferred by the data. *r* and *W* were thus fixed at 0.4 and 0 respectively and δ was estimated across the range [0.01, 1] in units of 0.01. The best fit was achieved for δ=0.36. The model was thus re-run, fixing *W* and δ and estimating *r*, with *r*=0.39 providing the best fit to the data.

The model fits to the CPUE index and the resultant biomass indices for the two hypotheses are shown in Figure 1.

Forward Projections

Hypothesis 1 was projected deterministically 20 years into the future for the following two scenarios:
Scenario A: project forward from the same levels as for Z_y as estimated for 2017; and
Scenario B: project forward, allowing Z_y to increase back to 1 by 2019.
The above two scenarios are depicted graphically in Figure 2.

Hypothesis 2 was also projected deterministically 20 years into the future for a scenario where U_y increases back to 1 by 2017. This is depicted graphically in Figure 3.

The following future effort levels (E_y) were applied in the projections:

$E_{2018} = E_{2013}$, and
$E_{2019+} = (1 - a)E_{2013}$

Values of a for which results have been reported in the past are 0 (i.e. no phase down from the 2013 level), 0.2 and 0.3. For this updated assessment one further a value has been considered; namely α=-0.1 (i.e. $E_{2019+}$is 10% higher than E_{2013}). This was added because of the improved resource situation indicated by the updated data.

Results and Discussion

Results from the analyses for projection scenarios A and B for Hypothesis 1 (related to a change in catchability) are shown in Figure 4 while the projection scenario for Hypothesis 2 (related to a change in productivity) is shown in Figure 5 for the each of the future effort level options specified. A comparison across Hypothesis/Scenario combinations for the each of the α values considered is shown in Figure 6.

Figure 4 indicates that if the data reflect a catchability effect, and whether future levels of catchability remain low or increase, this would not be a cause for concern given that the projected biomass remains at high levels irrespective of the level of future effort (amongst the options considered) that is applied. It is further notable that allowing an increase in effort for the 2019+ period (i.e. α=-0.1) would result in greater catches with only a slight reduction in biomass levels when compared against the α=0 scenario.

Figure 5 indicates that if the data reflect a productivity effect, then biomass, catches and CPUE increase over the projection period for each of value of α tested. Allowing an increase in effort for the 2019+ period (i.e. α=-0.1) would result in greater catches but lower biomass levels when compared against the α=0 scenario.

Comparisons of the Hypothesis/Scenario combinations for each of the future effort levels tested are shown in Figure 6. Across the α options, α=0.3 would be best to ensure biomass recovery if biomass is indeed low, but this is at the expense of future catches. If slower recovery can be accepted for the reduced productivity hypothesis, then and effort increase of up to 10% (i.e. α=-0.1) might be considered.

References

Butterworth, DS and Glazer, JP. 2014. A preliminary assessment of the South African east coast sole resource, *Austroglossus pectoralis*. Unpublished DAFF working Group document: Fisheries/2018/OCT/SWG-DEM/63. 12pp.

Butterworth, DS, Glazer, JP, Fairweather, TP and Durholtz, MD. 2016. An updated assessment of the Agulhas sole resource, *Austroglossus pectoralis*. Unpublished DAFF Working Group document: Fisheries/2016/SEP/SWG-DEM/53. 12pp.

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Table 1: Catch and standardized CPUE input to the dynamic Schaefer assessment model.

Year	Catch (t)	CPUE (kg/min)
2000	1060	0.31
2001	850	0.32
2002	702	0.22
2003	754	0.22
2004	612	0.23
2005	485	0.20
2006	428	0.22
2007	331	0.20
2008	448	0.20
2009	568	0.30
2010	570	0.25
2011	436	0.24
2012	338	0.17
2013	127	0.09
2014	208	0.13
2015	258	0.15
2016	125	0.105
2017	113	0.269

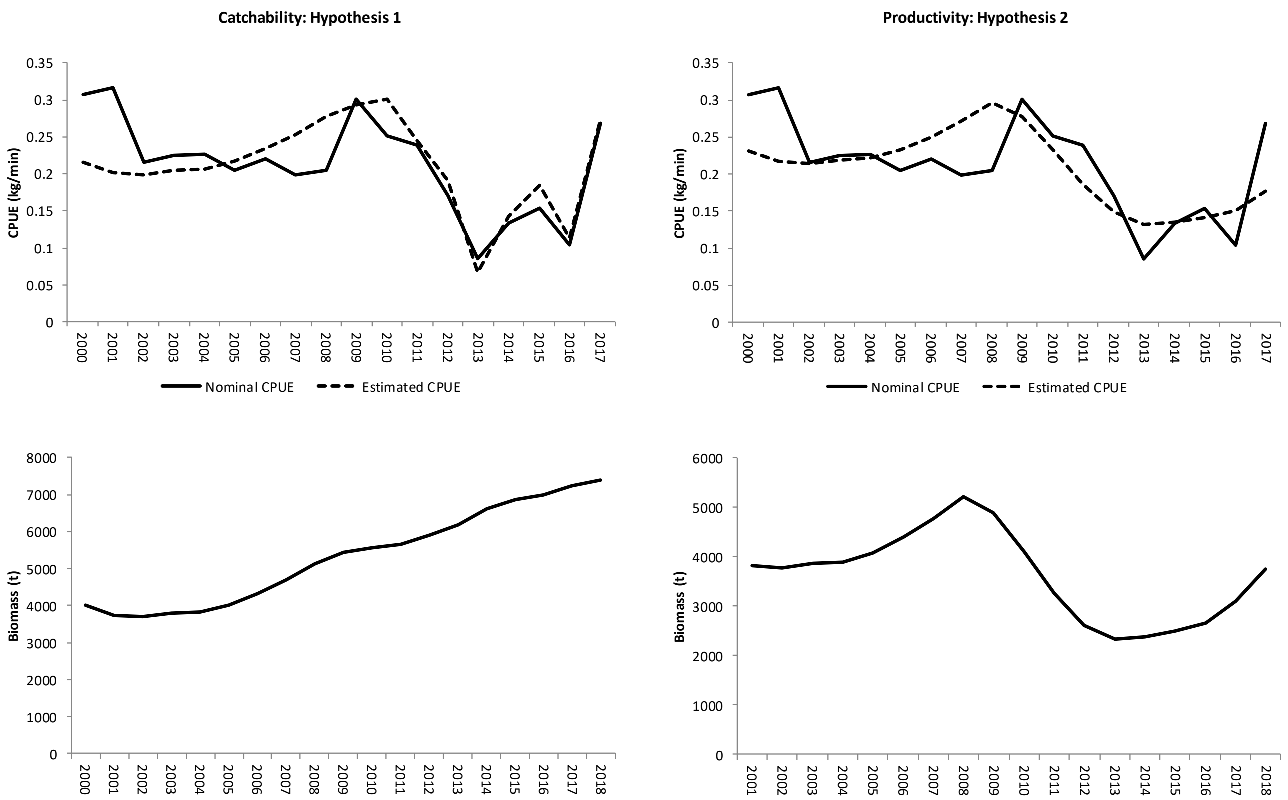

Figure 1: Fits to the CPUE data (top panel) and the biomass trends (lower panel) for Hypothesis 1 (a reduction in catchability) and Hypothesis 2 (a reduction in productivity) respectively.

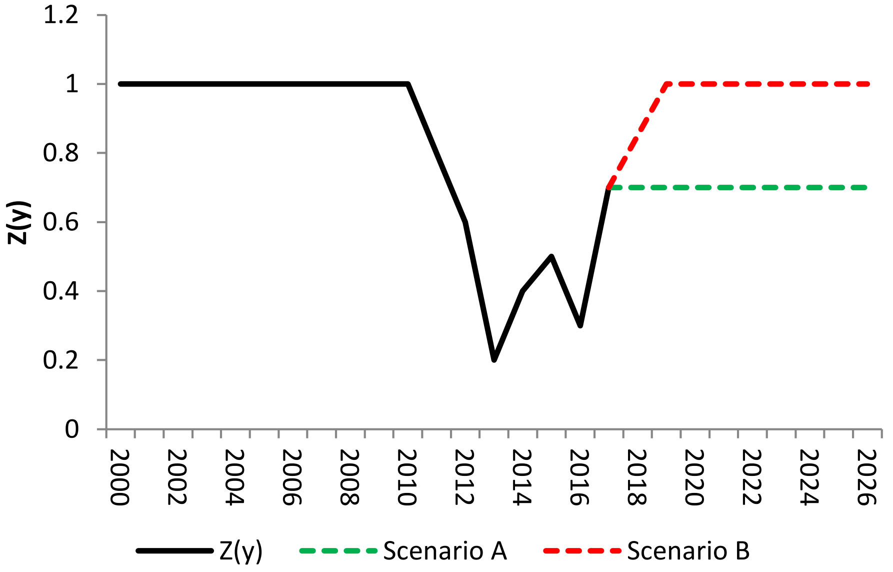

Figure 2: Projection Scenarios A and B related to Hypothesis 1: catchability has decreased by 80% over 2010-2013, it fluctuates until 2017, and then remains at the same level as for 2017 or increases back to a relative Z_y of 1 by 2019.

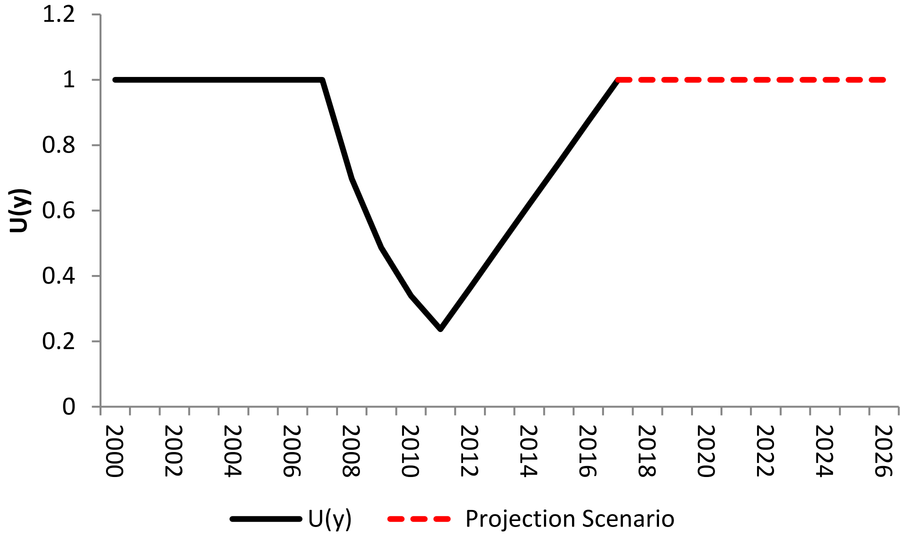

Figure 3: Projection Scenario related to Hypothesis 2: productivity has dropped by 76% over 2007-2011 and then increases back to a relative U_y of 1 by 2017. Linear interpolation was applied to obtain the U_y values between U_{2011} and U_{2017}.

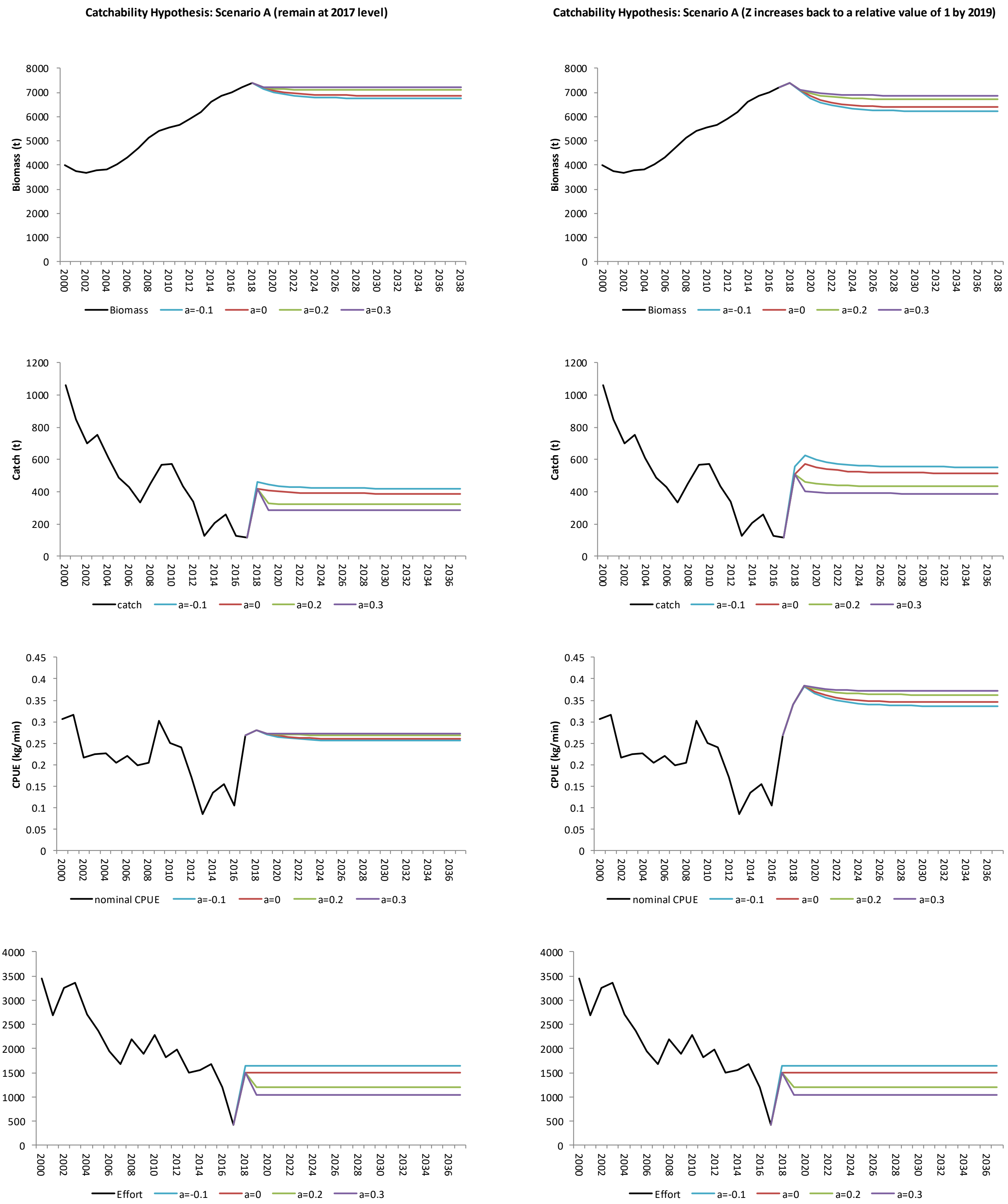

Figure 4: Projected biomass, catch and effort for Hypothesis 1: catchability has decreased by 80% over 2010-2013 for Scenario A (no change from 2017 value – left side plots) and Scenario B (back to normal by 2019 – right side plots) for different future effort levels.

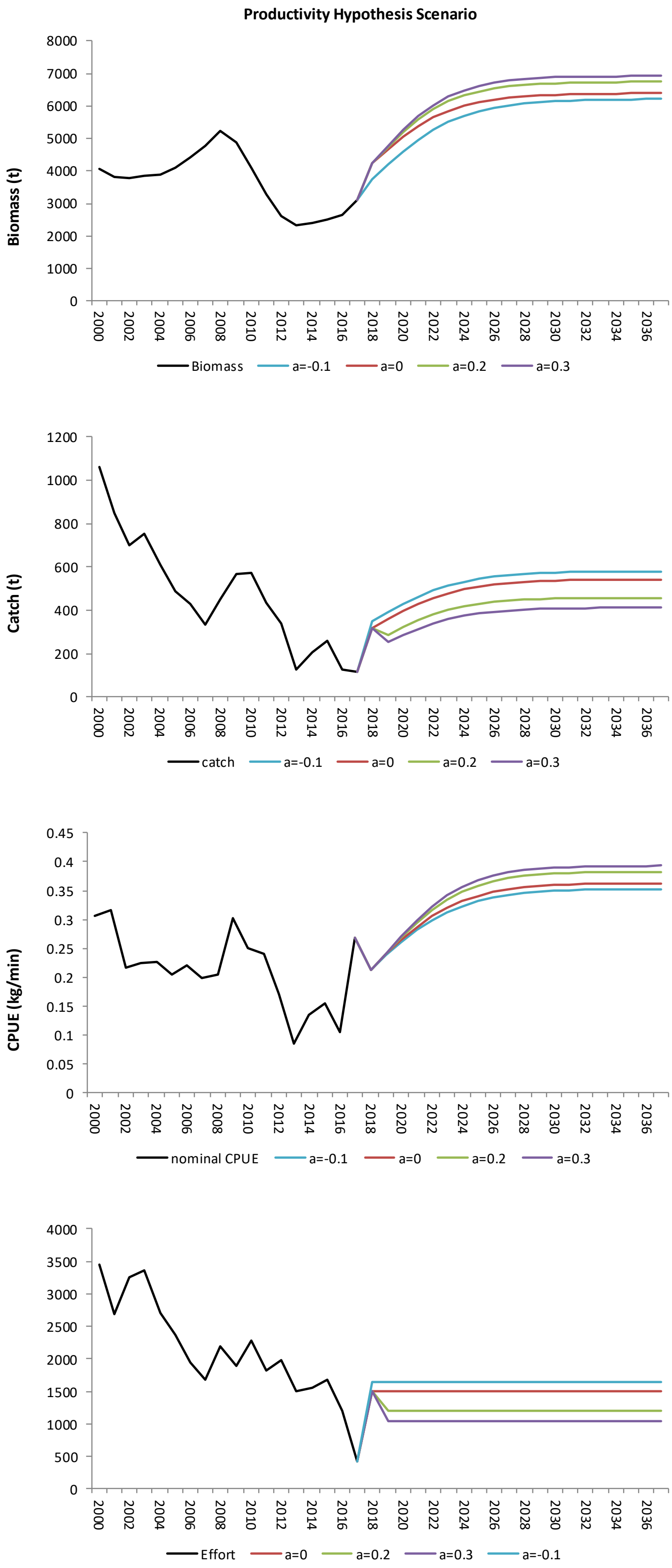

Figure 5: Projected biomass, catch and effort for Hypothesis 2: productivity has dropped by 76% over 2007-2011.

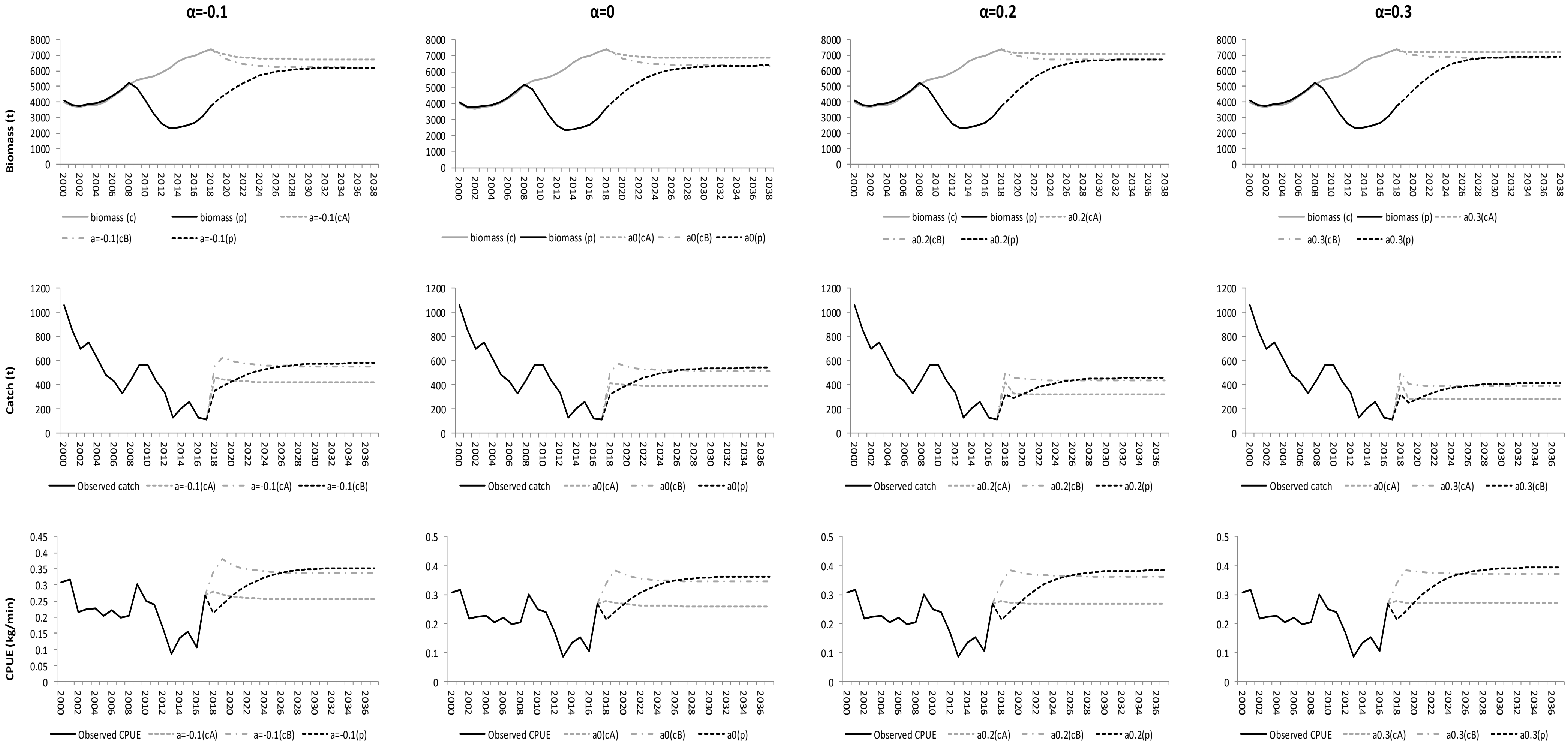

Figure 6: Comparisons across a=-0.1, a=0, a=0.2, and a=0.3 (different future effort levels) for the two hypotheses. "cA" and "cB" refer to the catchability hypothesis where for the future projections levels remain at those of 2017 (Ca) or increase to a relative value of 1 by 2019 (cB). "p" refers to the productivity hypothesis where U_y returns to a relative value of 1 by 2017.