2020 sole dynamic Schaefer production model results

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Summary

The sole resource is modelled by a dynamic Schaefer production model which allows for a drop in the value of the intrinsic growth rate parameter from 2000 onwards. The model is fit to the available CPUE and survey abundance indices. These data are not sufficiently informative to be able to distinguish amongst fairly wide ranges of pre- and post-2000 intrinsic growth rate parameters. Nevertheless, all suggest that the sole resource has never been substantially depleted (being well above its MSY level), and furthermore that the current replacement yield and MSY are reasonably robustly estimated in the ranges of 275-350 and 490-720 mt respectively. Given that this update 2020 assessment indicates slightly lower values for resource productivity than in 2019, consideration should be given to some reduction in the current TAC of 502 mt.

Introduction

In recent years two hypotheses to explain low CPUEs for the sole resource over the 2012-2016 period have been considered, namely a decrease in abundance and a decrease in catchability. However, by 2018 CPUEs had returned to levels similar to those pre-2013, rendering the first of these hypotheses now scarcely viable – abundance could not have near doubled in such a short period of only some two years.

For the 2019 assessment of the sole resource a simple dynamic production model was fit to the available data under the assumption of a catchability reduction over 2012-2016. A number of analyses were undertaken related to r (the intrinsic growth rate) and μ (the parameter that quantifies the extent of catchability reduction over the period 2012-2016, which was assumed to explain the lower CPUE values better over that period). Furthermore, r was considered to be period-specific where $r1$ (ranging from 0.2-0.5) refers to the intrinsic growth rate for the period 1920-1999 and $r2$ (ranging from 0.05-0.2) to that rate for the period 2000-2018. μ was either estimated or fixed.

For 2020, this assessment approach has again been applied to updated sole data (with CPUE and catches extended to include 2019 data) to assist in TAC deliberations.

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Methodology

The observation error assessment model applied is as follows

The dynamic Schaefer model 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*,
r is the intrinsic rate of population growth (note that as explained further below, the value of *r* is allowed to change after a specified year),
K is pristine biomass (which is assumed to reflect the biomass at the start of the catch time series in 1920), and
C_y is the annual catch over the period 1920-2019.

The likelihood is calculated assuming that the abundance indices are log-normally distributed about their expected values:

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

where I_y^i is the value for abundance index *i* for year *y*, $q_i B_y$ is the corresponding model estimate (q_i being the estimated catchability coefficient for each index of abundance), and ε_y^i is the observation error for each index, $\sim N(0, \sigma_i^2)$, for year *y*.

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

$$-\ell n L_i = n_i \ell n(\hat{\sigma}_i) + \frac{n_i}{2} \qquad (3)$$

where n_i is the number of annual data values for index *I*, and the standard deviation for each index is given by:

$$\hat{\sigma}_i = \sqrt{\frac{1}{n_i}(\sum_y \ell n\, I_y - \ell n(\hat{q}_i) - \ell n \hat{B}_y\ )^2} \qquad (4)$$

where

$$ln\hat{q}_i = \frac{1}{n_i}\sum\nolimits_y ln\left(\frac{I_y}{\hat{B}_y}\right)$$

The following data have been included in the analyses:

- sole catches (1920-2019),

- nominal CPUE index (1986-2019)
- autumn survey index (utilizing “old” gear),
- autumn survey index (utilizing “new” gear),
- spring survey index (utilizing “old” gear), and
- spring survey index (utilizing “new” gear).

Note that the nominal rather than the standardised CPUE index was used because the former is available for a much longer period, and also because over the period for which both are available, they do not differ greatly.

Results

A number of analyses have been undertaken related to *r* (intrinsic growth rate) and μ (an estimable parameter that quantifies the extent of catchability reduction over the period 2012-2016, which is assumed to better explain the lower CPUE values over that period). Furthermore, *r* is considered to be period-specific where *r*1 (ranging from 0.2-0.5) refers to intrinsic growth for the period 1920-1999 and *r*2 (ranging from 0.05-0.2) refers to intrinsic growth for the period 2000-2019.

Tables1a and 1b report the parameter values obtained from the 2019 and 2020 assessments respectively. Table 2 shows comparisons of the values of selected parameters from each of the two assessments, with the results for the three models that fit the data best being highlighted (note that the r1/r2 combination of 0.3/0.1 contributes to one of the three models that best fit the data in both the 2019 and 2020 assessments).

Figures 1-7 show the past catch and biomass trajectories, as well as the fits to the respective indices of abundance.

Discussion

Figure 1 shows that catches have been markedly less over the 2004+ period compared to beforehand (this was, at least in part, a consequence of a reduction in the fishing effort applied). However, there is no indication of an associated increase in biomass from the abundance index data available. This results in models with an unchanged value over time of the *r* intrinsic growth rate parameter being unable to fit the data (without estimating biomass to be at unrealistically high levels).

Consequently, the earlier value of *r* (*r*1) is assumed to drop to a lower value (*r*2) from 2000 onwards. Table 1 shows the results of fits for various input combinations of *r*1 (from 0.2 to 0.5) and *r*2 (from 0.05 to 0.2). Some combinations with *r*2 only slightly less than *r*1 are omitted; this is because they result in notably worse fits to the data (this is because they suggest recent marked increases in abundance).

The results for the three best fitting models for both the 2019 and 2020 assessments are highlighted in both Table 1 and Table 2. However, there is little to choose between these three and the other combinations for which results are reported. The reasons are clear from the comparisons between abundance data and model predictions in Figures 3 to 7: these data are not really able to discriminate amongst these different *r*1/*r*2 combinations.

A notable feature of the results in Tables 1 and 2, which is also evident from the biomass trajectory plots in Figure 2, is the indication that the resource has never been greatly depleted. For the 2020 assessment, the most pessimistic current depletion (B(2020)/K) in these Tables is 73%, with the best fits yielding values in the vicinity of 80%.

As regards advice on a TAC, the three best fitting models for the 2020 assessment suggest a current Replacement Yield (RY) in the 310-340 mt range; this estimate seems fairly robust, as estimates for other $r1/r2$ combinations are not that dissimilar (and estimates for the lowest $r2$ value shown can probably be discounted as an intrinsic growth rate for sole as low as 0.05 seems implausible). Overall then RY is likely in the range of 275-350 mt.

As last year, a case can be made for a TAC that is higher than RY, given that the current depletion (about 80%) is estimated to be well above the MSY level of 50%. Some consideration might be given to (a highish proportion of) the MSY estimates, which for $r2 \geq 0.1$ range from about 490-720 mt.

At present, the sole TAC is set at 502 mt with an associated TAE of 26352 fishing hours. This TAC was set based on MSY estimates. Given that this update 2020 assessment indicates slightly lower values for resource productivity than last year, consideration should be given to some reduction in this TAC.

Tables 1a: 2019 Assessment parameter estimates and TACs under possible harvest control rules from a suite of dynamic Schaefer production model assessments fitted to the nominal CPUE values over 1986 to 2018, and conducted for various fixed input values of *r* (*r*1 refers to intrinsic growth for the period 1920-1999 and *r*2 refers to intrinsic growth for the period 2000-2018). μ is an estimable parameter that quantifies the extent of catchability reduction over the period 2012-2016; such an assumption explains the lower CPUE values over that period than a biomass decline. Biomass and catch units are mt. The three models which best fit the data as indicated by –lnL are highlighted.

r1	r2	μ	-lnL	K	B(2019)	B(2019)/K	MSY 0.25*r1*K	Replacement Yield r1*B(2019)*(1-B(2019)/K)	F_{msy} Catch 0.5*r1*B(2019)	MSY 0.25*r2*K	Replacement Yield r2*B(2019)*(1-B(2019)/K)	F_{msy} Catch 0.5*r2*B(2019)
0.2	0.05	0.558	-51.114	31552	23659	0.750	1578	1184	2366	394	296	591
0.3	0.05	0.560	-51.070	33092	26328	0.796	2482	1615	3949	414	269	658
0.4	0.05	0.561	-51.029	34329	28040	0.817	3433	2055	5608	429	257	701
0.5	0.05	0.561	-51.007	35091	29063	0.828	4386	2496	7266	439	250	727
0.2	0.1	0.532	-51.157	20078	14436	0.719	1004	811	1444	502	406	722
0.3	0.1	0.550	-51.446	20558	16109	0.784	1542	1046	2416	514	349	805
0.4	0.1	0.553	-51.383	22204	18203	0.820	2220	1312	3641	555	328	910
0.5	0.1	0.554	-51.344	23355	19564	0.838	2919	1588	4891	584	318	978
0.3	0.15	0.522	-51.239	14799	11640	0.787	1110	745	1746	555	373	873
0.4	0.15	0.537	-51.464	15826	13119	0.829	1583	897	2624	593	337	984
0.5	0.15	0.541	-51.467	17005	14501	0.853	2126	1068	3625	638	320	1088
0.4	0.2	0.509	-51.022	12499	10625	0.850	1250	637	2125	625	319	1063
0.5	0.2	0.522	-51.297	13329	11619	0.872	1666	745	2905	666	298	1162

Table 1b: 2020 Assessment parameter estimates and TACs under possible harvest control rules from a suite of dynamic Schaefer production model assessments fitted to the nominal CPUE values over 1986 to 2018, and conducted for various fixed input values of *r* (*r*1 refers to intrinsic growth for the period 1920-1999 and *r*2 refers to intrinsic growth for the period 2000-2018). µ is an estimable parameter that quantifies the extent of catchability reduction over the period 2012-2016; such an assumption explains the lower CPUE values over that period than a biomass decline. Biomass and catch units are mt. The three models which best fit the data as indicated by –lnL are highlighted.

							MSY	Replacement Yield	F_{msy} Catch	MSY	Replacement Yield	F_{msy} Catch
r1	r2	µ	-lnL	K	B(2020)	B(2020)/K	0.25*r1*K	r1*B(2020)*(1-B(2019)/K)	0.5*r1*B(2020)	0.25*r2*K	r2*B(2020)*(1-B(2020)/K)	0.5*r2*B(2020)
0.2	0.05	0.567	-52.582	29667	21735	0.733	1483	1162	2174	371	291	543
0.3	0.05	0.569	-52.588	30880	24109	0.781	2316	1586	3616	386	264	603
0.4	0.05	0.569	-52.562	31928	25639	0.803	3193	2020	5128	399	253	641
0.5	0.05	0.569	-52.548	32580	26555	0.815	4073	2456	6639	407	246	664
0.2	0.1	0.538	-51.849	19715	14188	0.720	986	796	1419	493	398	709
0.3	0.1	0.559	-52.609	19644	15258	0.777	1473	1022	2289	491	341	763
0.4	0.1	0.561	-52.661	21053	17119	0.813	2105	1280	3424	526	320	856
0.5	0.1	0.562	-52.670	22063	18340	0.831	2758	1547	4585	552	309	917
0.3	0.15	0.525	-51.556	15330	12449	0.812	1150	702	1867	575	351	934
0.4	0.15	0.542	-52.259	15671	13097	0.836	1567	861	2619	588	323	982
0.5	0.15	0.547	-52.439	16631	14234	0.856	2079	1026	3558	624	308	1068
0.4	0.2	0.510	-51.157	14458	12872	0.890	1446	565	2574	723	282	1287
0.5	0.2	0.525	-51.804	14026	12466	0.889	1753	693	3117	701	277	1247

Table 2: Comparisons of select statistics related to the *r*1 and *r*2 combinations as derived from the 2019 and 2020 assessments respectively, the latter excluding r2=0.05. The three models which best fit the data as indicated by –lnL are highlighted.

2019 Assessment

	-lnL			
	r2			
r1	**0.05**	**0.1**	**0.15**	**0.2**
0.2	-51.114	-51.157		
0.3	-51.070	-51.446	-51.239	
0.4	-51.029	-51.383	-51.464	-51.022
0.5	-51.007	-51.344	-51.467	-51.297

2020 Assessment

	-lnL			
	r2			
r1	**0.05**	**0.1**	**0.15**	**0.2**
0.2	-52.582	-51.849		
0.3	-52.588	-52.609	-51.556	
0.4	-52.562	-52.661	-52.259	-51.157
0.5	-52.548	-52.670	-52.439	-51.804

	B(2019)/K			
	r2			
r1	**0.05**	**0.1**	**0.15**	**0.2**
0.2	0.750	0.719		
0.3	0.796	0.784	0.787	
0.4	0.817	0.820	0.829	0.850
0.5	0.828	0.838	0.853	0.872

	B(2020)/K			
	r2			
r1	**0.05**	**0.1**	**0.15**	**0.2**
0.2	0.733	0.720		
0.3	0.781	0.777	0.812	
0.4	0.803	0.813	0.836	0.890
0.5	0.815	0.831	0.856	0.889

	MSY (based on r2)			
	r2			
r1	**0.05**	**0.1**	**0.15**	**0.2**
0.2	394	502		
0.3	414	514	555	
0.4	429	555	593	625
0.5	439	584	638	666

	MSY (based on r2)			
	r2			
r1	**0.05**	**0.1**	**0.15**	**0.2**
0.2	371	493		
0.3	386	491	575	
0.4	399	526	588	723
0.5	407	552	624	701

	RY based on r2			
	r2			
r1	**0.05**	**0.1**	**0.15**	**0.2**
0.2	296	406		
0.3	269	349	373	
0.4	257	328	337	319
0.5	250	318	320	298

	RY based on r2			
	r2			
r1	**0.05**	**0.1**	**0.15**	**0.2**
0.2	291	398		
0.3	264	341	351	
0.4	253	320	323	282
0.5	246	309	308	277

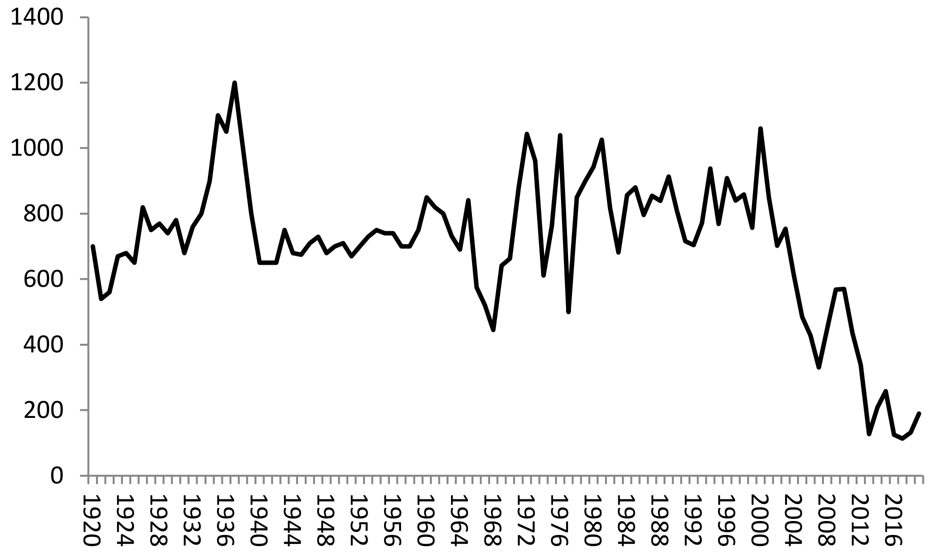

Figure 1: Annual sole catches (units: mt).

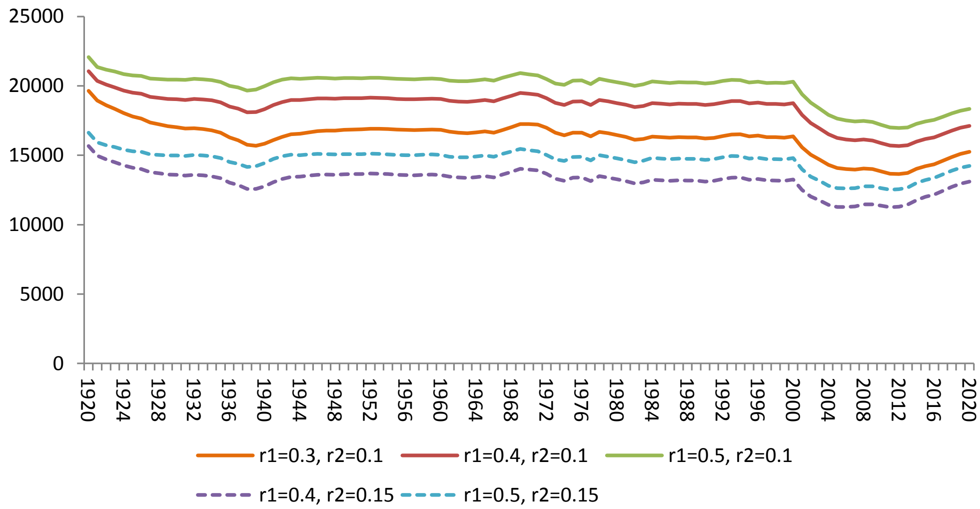

Figure 2: 2020 assessment biomass trajectories (units: tons) for the *r*1/*r*2 combinations that best fit the data in the 2019 and 2020 assessments respectively (as indicated in the legend). The dashed lines relate to the 2019 assessment best fit r1/r2 combinations and the solid lines relate to the 2020 assessment best fit r1/r2 combinations (note that there is only one trend for the r1=0.3 and r2=0.1 combination given that it was one of the best fits in both the 2019 and 2020 assessments).

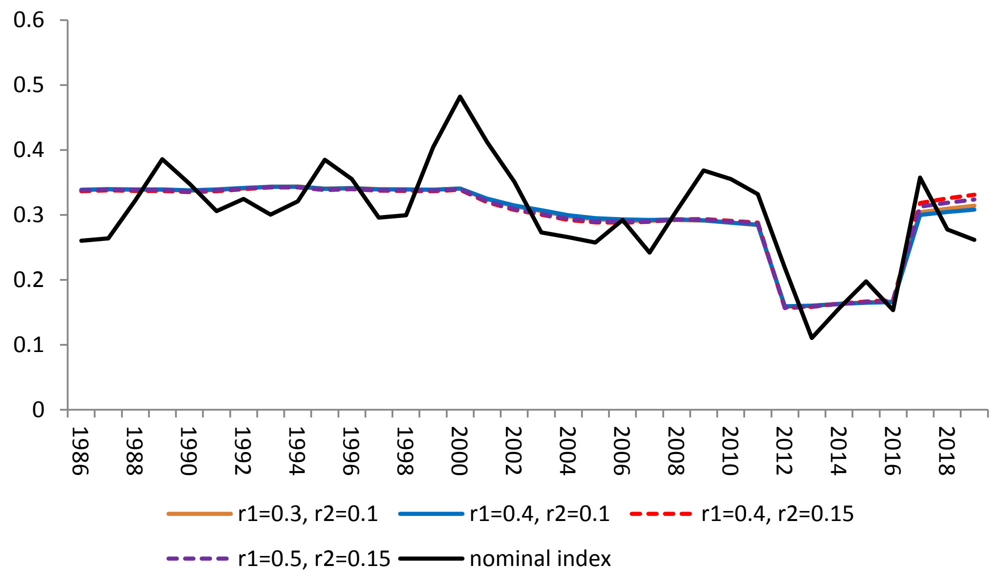

Figure 3: 2020 Assessment fits to the commercial CPUE index (units: kg/min) for the *r*1/*r*2 combinations that best fit the data in the 2019 and 2020 assessments respectively (as indicated in the legend). The dashed lines relate to the 2019 assessment best fit r1/r2 combinations and the solid lines relate to the 2020 assessment best fit r1/r2 combinations (note that there is only one trend for the r1=0.3 and r2=0.1 combination given that it was one of the best fits in both the 2019 and 2020 assessments).

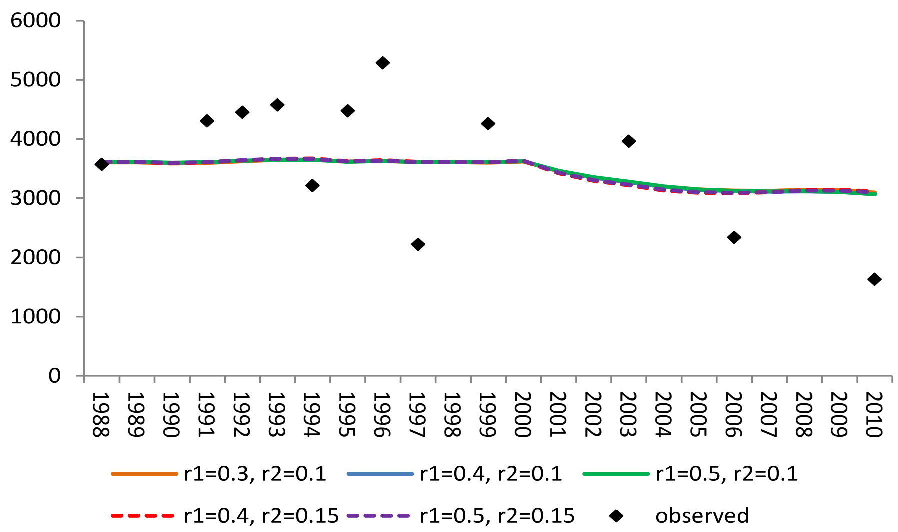

Figure 4: 2020 Assessment fits to the autumn old gear index (units: mt) for the *r*1/*r*2 combinations that best fit the data in the 2019 and 2020 assessments respectively (as indicated in the legend). The dashed lines relate to the 2019 assessment best fit r1/r2 combinations and the solid lines relate to the 2020 assessment best fit r1/r2 combinations (note that there is only one trend for the r1=0.3 and r2=0.1 combination given that it was one of the best fits in both the 2019 and 2020 assessments).

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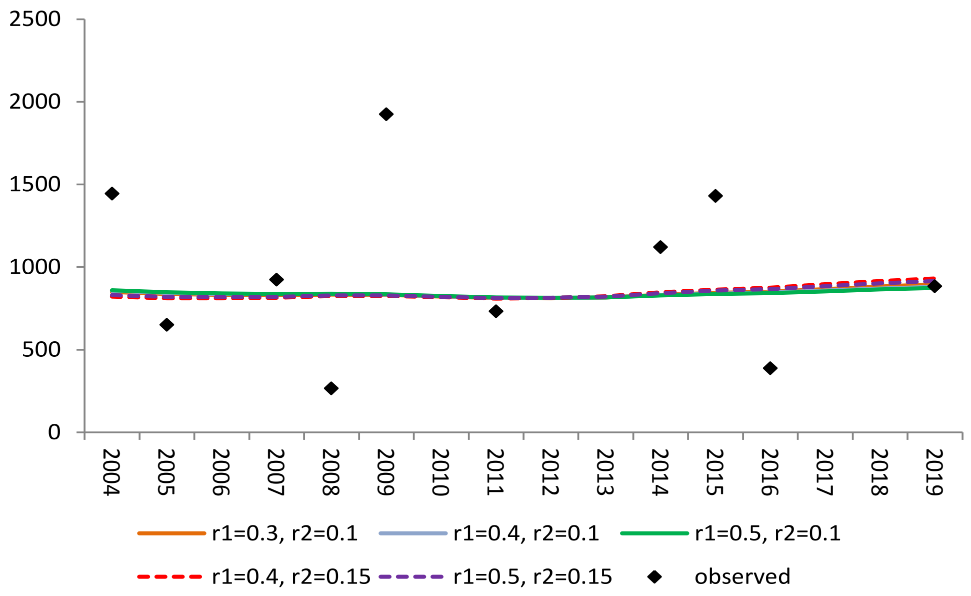

Figure 5: 2020 Assessment fits to the autumn new gear index (units: mt) for the *r*1/*r*2 combinations that best fit the data in the 2019 and 2020 assessments respectively (as indicated in the legend). The dashed lines relate to the 2019 assessment best fit r1/r2 combinations and the solid lines relate to the 2020 assessment best fit r1/r2 combinations (note that there is only one trend for the r1=0.3 and r2=0.1 combination given that it was one of the best fits in both the 2019 and 2020 assessments).

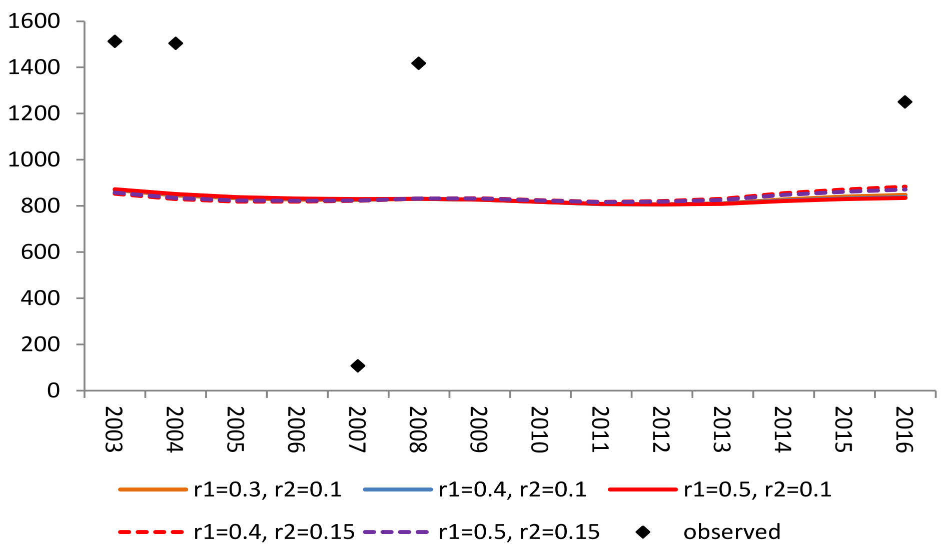

Figure 6: 2020 Assessment fits to the old gear spring index units=mt) for the *r*1/*r*2 combinations that best fit the data in the 2019 and 2020 assessments respectively (as indicated in the legend). The dashed lines relate to the 2019 assessment best fit r1/r2 combinations and the solid lines relate to the 2020 assessment best fit r1/r2 combinations (note that there is only one trend for the r1=0.3 and r2=0.1 combination given that it was one of the best fits in both the 2019 and 2020 assessments).

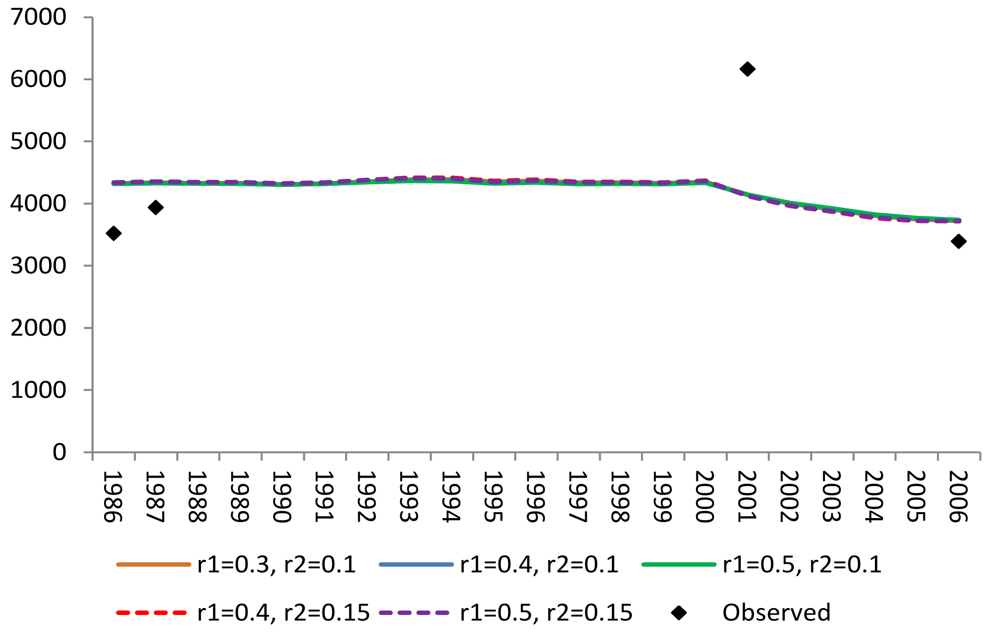

Figure 7: 2020 Assessment fits to the spring new gear index (units=mt) for the *r*1/*r*2 combinations that best fit the data in the 2019 and 2020 assessments respectively (as indicated in the legend). The dashed lines relate to the 2019 assessment best fit r1/r2 combinations and the solid lines relate to the 2020 assessment best fit r1/r2 combinations (note that there is only one trend for the r1=0.3 and r2=0.1 combination given that it was one of the best fits in both the 2019 and 2020 assessments).