Updated assessment of the squid resource, *Loligo reynaudii*

J.P. Glazer

Summary

An assessment of the squid resource was last undertaken in 2016 and at that time included data to 2015. An additional 2 years of data are now available and these have been included in an updated assessment. A Bayesian analysis has been conducted and projections 10 years into the future suggest that effort in this fishery could be increased to 295 000 person-days.

Introduction

The squid stock assessment model is based upon Baranov catch equations. An assessment was last undertaken in 2016 and provided slightly more optimistic results than those obtained from the 2013 assessment, suggesting that the then current TAE of 250 000 person-days could be increased to 270 000 person-days without undue risk to the resource (Glazer and Butterworth, 2016). It was cautioned that given a crew complement of 2451 fishers, the average number of days fished should not exceed 110 days in order to ensure that the target effort level of 270 000 person-days not be exceeded. A recommendation of this nature was subsequently submitted to DAFF Management by the Squid Scientific Working Group.

Additional and/or revised data have become available since the assessment that was conducted in 2016. These data have thus been included in an updated assessment of the resource, the results of which are reported here. Results from a sensitivity test are also reported where the current jig CPUE index (restricted to 19 core vessels and records where 3≤crew≤20) is replaced by one in which the data are restricted to 14 core vessels and records where 3≤crew≤26 (Glazer 2019).

Data included in the analyses

The following sets of data are included in the assessment of the squid resource:

- Jig catches for the period 1985-2017 (provided by SABS/NRCS),
- Trawl catches for the period 1971-2017 (Glazer 2016, DAFF Demersal Company Table Reports),
- Nominal jig CPUE indices for the period 1995-2017 for (i) the current core set of 19 vessels constrained to records where 3≤crew≤20 and (ii) a revised core set of 14 vessels constrained to records where 3≤crew≤26 (Glazer, 2019),
- Standardized trawl CPUE indices for the period 1978-1999 (Roel, 1998),
- Autumn survey abundance indices for the period 1988-2010, and spring survey abundance indices for the period 1986-2006 (Tracey Fairweather, DAFF, *pers. commn*).

The data inputs are reported in Tables 1-4 respectively.

Currently the assessment model includes abundance indices obtained from surveys conducted on the South Coast by *RV Africana* utilizing “old” gear. It should be noted that surveys have also been conducted by RV Africana using “new” gear as well as by *FV Andromeda* and *FV Compass Challenger*, but it is unlikely that the catchabilities across the two gear types and the different vessels will be the same. Since no calibration exercises have yet been undertaken, the abundance indices used in the squid assessment model have been restricted to those obtained from *RV Africana* “old” gear surveys (the series of which ends in 2010). Six autumn surveys and five spring surveys have since been conducted by the *RV Africana* utilizing “new” gear and consideration should be given to including those indices in future assessments (either as separate indices or calibrated to *RV Africana* “old” gear indices).

The 2016 assessment included survey abundance estimates reported in Fairweather (2016) where depth was allocated on a grid basis (as a result of improved bathymetric data) as opposed to being allocated according to depth fished as was applied in the past. In November 2018 an error was detected in the abundance estimates of Fairweather (2016) and these have subsequently been corrected. It is the corrected abundance estimates (Table 4) that are included in the updated assessment.

Roel (2008) reported that the population model is split into two periods, January-March and April-December, to better reflect the dynamics of the resource and the two fisheries that exploit it (jig and trawl). This relates mostly to the fact that very little recruitment takes place during the January-March period and that jig and trawl catches are disproportionately divided between the two periods. The January-March jig CPUE index is not included in the model fit since it is over this period that major changes in fishing patterns took place, including an increase in fishing operations offshore of the spawning grounds (Roel and Butterworth, 2000). This then renders the reliability of the January-March CPUE as an index of abundance questionable given concerns about comparability over time (Glazer and Butterworth, 2006).

The monthly catches for 2016 and 2017 were provided by the National Regulator for Compulsory Specifications (NRCS). The additional closed season for those years occurred over months April-June respectively. However, one vessel in the 2016 NRCS data had zero catch recorded against March and 2.7 tons (0.03% of the annual catch) recoded against April. Similarly, four vessels in the 2017 data had zero catch recoded against March and a total of 5.8 tons (0.05% of the annual catch) recorded against April. It has therefore been assumed that catches were erroneously recorded against April and they were re-allocated to March for assessment purposes.

The assessment model

The resource is modelled by applying Baranov catch equations and these are provided in Appendix A together with the likelihood equations and prior distributions assumed for the estimable parameters.

Joint posterior mode estimates

Table 6 compares model estimates at the joint posterior mode for:

i) the assessment conducted in 2016 (denoted "2016") – which includes the current default jig CPUE index (derived from 19 core vessels and records where 3≤crew≤20),

ii) the assessment conducted in 2019 (denoted "2019") – which includes the current default jig CPUE index, and

iii) the assessment conducted in 2019, but fitting to an alternative jig CPUE index (denoted "2019*") which is derived from 14 core vessels and records where 3≤crew≤26.

Table 1 compares $\frac{B_y^*}{K}$ (begin-year biomass relative to pristine biomass) across each of the assessments for the most recent few years. The $\frac{B_{2016}^*}{K}$ ratios for the 2016, 2019 and 2019* assessments were calculated to be 0.36, 0.4 and 0.43. A comparison is also made between the 2019 and 2019* assessments, where the $\frac{B_{2018}^*}{K}$ ratios were calculated to be 0.6 and 0.68 respectively. These results suggest that the 2019* assessment yields a more positive outlook on resource status. This is likely a result of the April-December jig CPUE index which shows a marked increase in CPUE since 2015. It is also noted that the recent increase in CPUE is sharper for the CPUE index derived from 14 core vessels and restricted to 3≤crew≤26 when compared to the CPUE index derived from 19 core vessels and restricted to 3≤crew≤20 (Table 2).

Figures 1-8 compare the estimated recruitment series, the recruitment residuals, begin-year biomass series and fits to the indices of abundance. Of note is the increase in recruitment, begin-year biomass and the April-December jig CPUE indices for the two most recent years.

Bayesian analyses

A Bayesian analysis was undertaken for assessment 2019* (the model which includes jig CPUE indices derived from 14 core vessels and restricted to records where 3≤crew≤26). A chain of 800 million samples was run, saving every 2000 which resulted in 400 000 samples available for analysis purposes. Since the MCMC failed to satisfy certain convergence tests, further analyses were undertaken to determine whether such lack of convergence would substantially affect estimation of the statistic of interest, namely the biomass at the end of the 10 year projection period relative to pristine biomass, i.e. $\frac{B_{2027}^*}{K}$.

This was tested by discarding the first 10% of the chain as burn-in and then splitting the remaining 360 000 samples into ten consecutive pieces, each piece containing 36 000 samples. The model was then projected forward under various constant effort scenarios (see Appendix B for assumptions related to effort when projecting into the future) using each of the ten sets of samples separately, as well as the full chain of 360 000 samples. The resulting $\frac{B_{2027}^*}{K}$ statistics and associated probability intervals are plotted in Figure 9 for a suite of fixed effort levels (spanning the range of TAEs that have applied in this fishery in the past).

For each of the 10 sub-samples a regression was performed to estimate the effort level at which the lower 5th percentile of $\frac{B^*_{2027}}{K}$ is equal to 0.2, i.e. E(0.2). The standard deviation (SD= σ) for E(0.2) across the samples was also determined as was the standard error for the overall estimate (SE=$\frac{\sigma}{\sqrt{n}}$). These are reported in the table below.

	E(0.2) '000 person-days
chain 1	301.5
chain 2	291.5
chain 3	292.7
chain 4	281.9
chain 5	301.4
chain 6	290.7
chain 7	292.8
chain 8	294.6
chain 9	302.3
chain 10	304.8
average	295.4
SD	7.0
SE	2.2

E(0.2) for the 360 000 samples was estimated to be 294.9 with a 95% confidence interval of (290.6, 299.3). The relative consistency of the results above for the different sub-samples, plus the reasonably precise eventual estimate of E(0.2), suggests that the lack of convergence does not adversely impact the reliability and precision of the estimate or compromise its use for the basis of management advice.

Performance Statistics

Since the ten parts of the chain yield similar results all 360 000 samples were used to perform stochastic projections 10 years into the future under various constant effort scenarios and the following performance statistics are reported:

- average annual catches by the jig fishery
- average annual variation (AAV) in catch by the jig fishery from one year to the next, where:

$$AAV = \frac{1}{10}\sum_{y=2018}^{y=2027} \left|C_y - C_{y-1}\right|/C_{y-1}$$

- $\frac{B^*_{2027}}{K}$
- $\frac{B^*_{lowest}}{K}$

These results are presented in Figure 10 and indicate that any effort exceeding around 295 000 person-days will result in a probability exceeding 5% of the biomass falling below 20% of pristine in any future year.

The average projected jig CPUE for fixed effort levels is shown in Figure 11 together with the average CPUE as reported by the jig fishery for the period 2013-2017. The projected CPUE falls below the recent historic average (2013-2017) for effort levels exceeding 200 000 person-days. It should be noted that the recent historic average differs markedly from that of the 2016 assessment (see table below) and the reason for this is most likely the substantial increase in CPUE experienced in the jig fishery in 2016 and 2017 (see Figure 4).

Assessment	Years averaged over	p95	mean	p05
2016	2011-2015	30.06	22.02	12.18
2019	2013-2017	46.53	30.68	12.63

Acknowledgement

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Table 1: Trawl[1] and jig[2] squid catches (tons) split by period.

Trawl Catches (t)

Year	Jan-Mar	Apr-Dec
1971	96.31	183.69
1972	176.12	335.88
1973	322.31	614.69
1974	1245.89	2376.11
1975	1255.18	2393.82
1976	724.76	1382.24
1977	1128.94	2153.06
1978	1085.99	3903.01
1979	2128.42	2987.58
1980	971.16	2082.84
1981	1373.42	2382.58
1982	1450.72	2153.28
1983	2292.13	1822.87
1984	574.08	1540.92
1985	769.71	917.29
1986	211.91	633.09
1987	240.40	411.60
1988	159.40	661.60
1989	391.01	771.99
1990	249.78	495.22
1991	161.00	335.00
1992	92.05	194.95
1993	50.66	227.34
1994	224.71	275.29
1995	123.10	215.90
1996	167.69	216.31
1997	72.81	164.40
1998	122.49	195.40
1999	93.13	194.32
2000	81.66	272.46
2001	119.41	124.83
2002	62.74	142.43
2003	76.14	264.19
2004	123.47	267.91
2005	94.60	278.73
2006	134.22	223.98
2007	126.77	369.32
2008	169.35	359.06
2009	395.80	363.63
2010	228.91	344.71
2011	256.86	202.91
2012	71.55	155.78
2013	15.67	45.08
2014	77.40	135.29
2015	85.60	247.48
2016	292.03	350.43
2017	165.35	380.75

Jig Catches (t)

Year	Jan-Mar	Apr-Dec
1985	117	2487
1986	248	3151
1987	170	2627
1988	213	4614
1989	2044	7534
1990	459	1728
1991	149	4330
1992	218	1752
1993	309	6402
1994	2493	4356
1995	1735	5578
1996	1828	4996
1997	945	2829
1998	1644	4919
1999	1662	4973
2000	1217	4844
2001	719	2228
2002	1819	7795
2003	2166	9654
2004	5028	8233
2005	2758	6389
2006	3583	5708
2007	2044	7394
2008	3034	5987
2009	3242	7099
2010	3665	7112
2011	3154	4642
2012	2018	4374
2013	521	2143
2014	1192	5715
2015	2734	3745
2016	2974	6978
2017	3807	8112

[1] Source: Glazer (2016) for 1971-1996 catches; Annual Demersal Company Table Reports for catches post 1996
[2] Source: Reports from SABS/NRCS

Table 2: Jig CPUE indices (kg/person-day) split by period. The indices in the left panel are derived from 19 core vessels and records where 3≤ crew ≤20. The indices in the right panel relate to 14 of the 19 core vessels (those that have been active in the fishery over the entire period) and records where 3≤ crew ≤26. Note that the model fits to the April-December index only.

Year	Jan-Mar	Apr-Dec
1995	30.48	31.24
1996	29.49	25.36
1997	15.88	16.24
1998	18.21	26.11
1999	29.66	25.83
2000	19.68	28.16
2001	21.36	19.42
2002	22.40	30.58
2003	28.44	37.03
2004	45.00	26.74
2005	22.85	21.97
2006	30.48	22.49
2007	21.66	26.77
2008	29.21	37.29
2009	37.98	32.84
2010	31.24	25.89
2011	25.57	17.86
2012	16.26	21.31
2013	8.86	12.25
2014	23.53	34.11
2015	31.51	23.16
2016	26.40	34.50
2017	32.36	48.19

Year	Jan-Mar	Apr-Dec
1995	24.90	28.93
1996	29.92	25.17
1997	16.84	17.37
1998	19.23	23.27
1999	30.48	26.00
2000	18.93	28.55
2001	22.81	17.67
2002	22.82	32.65
2003	28.21	37.36
2004	45.32	26.44
2005	22.93	21.37
2006	31.72	22.57
2007	23.53	26.83
2008	27.83	35.78
2009	35.24	34.28
2010	33.35	27.12
2011	26.64	19.06
2012	17.20	24.26
2013	10.05	12.49
2014	21.09	33.26
2015	33.54	24.63
2016	29.42	37.13
2017	35.09	55.22

Table 3: Trawl CPUE indices (kg/minute) (Roel, 1998).

	CPUE	
Year	**Jan-Mar**	**Apr-Dec**
1978	13.77	7.46
1979	19.97	7.92
1980	14.52	4.31
1981	17.78	8.12
1982	16.50	4.94
1983	24.10	3.22
1984	8.90	4.02
1985	12.69	3.17
1986	6.20	2.80
1987	5.79	2.11
1988	5.60	3.15
1989	8.81	3.43
1990	6.25	2.07
1991	5.28	2.34
1992	3.84	1.72
1993	3.53	2.09
1994	6.58	2.14
1995	5.20	2.08
1996	5.25	2.10
1997	4.34	1.79
1998	4.83	2.21
1999	5.17	1.84

Table 4 – 0-200m Abundance estimates obtained from research surveys conducted by *RV Africana* between 1986 and 2010 (Fairweather, *pers. commn*). These are updates of the indices included in the 2016 assessment for reasons explained in the text.

	South Coast Autumn Index		South Coast Spring Index	
Year	Abundance (t)	SE (t)	Abundance (t)	SE (t)
1986			8664	2096
1987			11211	1648
1988	8159	1179		
1989	17485	3869		
1990	8491	1716	12354	1729
1991	13574	3314	22168	3829
1992	11322	1250	9294	1373
1993	20410	3507	13161	2303
1994	20441	4664	14194	2219
1995	21812	2848	12466	1434
1996	24618	2445		
1997	8854	899		
1998				
1999	17190	2071		
2000				
2001			9626	1437
2002				
2003	20855	2623		
2004				
2005				
2006	19885	2061	11748	1196
2007				
2008				
2009				
2010	15809	2156		

Table 5: Comparison of parameter estimates at the joint posterior mode obtained from the 2016 and 2019 assessments respectively.

	2016 Assessment	2019 Assessment	2019* Assessment
Model parameters	19 vessels, 3<=crew<=20	19 vessels, 3<=crew<=20	14 vessels, 3<=crew<=26
Parameter estimates			
X	11.074	11.138	11.325
R0 (initial recruitment)	64473	68760.9	82857.6
Y	0.337	0.265	0.252
η	2.083	2.070	2.472
g	1.278	1.284	1.287
h	0.348	0.346	0.335
B*1971	89385.3	95106.6	114477
B*2015	34722.2	38824	47916
B*2016	32371.6	38134.4	48794.4
B*2017	n/a	49086.4	64500.4
B*2018	n/a	57235.9	78235.5
B*2015/B*1971	0.388	0.408	0.419
B*2016/B*1971	0.362	0.401	0.426
B*2017/B*1971	n/a	0.516	0.563
B*2018/B*1971	n/a	0.602	0.683
Stock-recruit residuals			
σ_R(input)	0.3	0.3	0.3
σ_R(estimated)	0.21	0.21	0.21
CPUE jig Apr-Dec			
q	0.000452089	0.00042231	0.000348582
σ*	0.2	0.2	0.2
CPUE Trawl Jan-Mar			
q	0.000184048	0.000176813	0.000147615
σ*	0.2	0.2	0.2
CPUE Trawl Apr-Dec			
q	3.73E-05	3.58E-05	3.00E-05
σ*	0.2	0.2	0.2
" old"Autumn index			
q	0.173045	3.58E-05	0.138588
σ*	0.353658	0.353452	0.354219
"old" Spring index			
q	0.244128	0.22478	0.188889
σ*	0.26245	0.249231	0.248248
-ℓnL values			
jig A-D	-10.03	-10.70	-10.55
trawl J-M	-6.91	-6.91	-6.91
trawl A-D	-9.96	-10.02	-10.00
"old" autumn	5.31	5.31	5.34
"old" spring	0.81	0.30	0.26
S/R residuals	-2.13	-1.80	-1.59
$F_{jig\ J\text{-}M}$	-92.79	-98.77	-98.77
$F_{jig\ A\text{-}D}$	-92.78	-98.77	-98.77
$F_{trawl\ J\text{-}M}$	-134.69	-140.68	-140.68
$F_{trawl\ A\text{-}D}$	-134.69	-140.68	-140.68
penalties (g)	-1.08	-1.03	-1.01
Total	-478.93	-503.76	-503.36

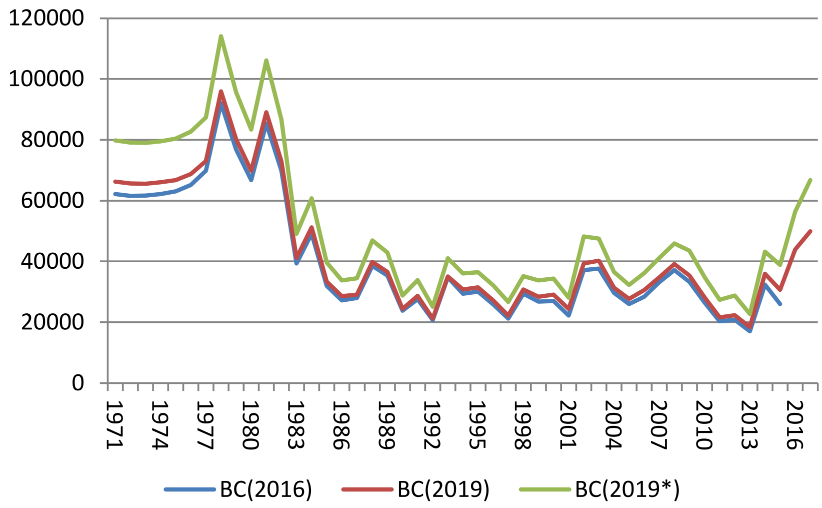

Figure 1: Recruitment (tons).

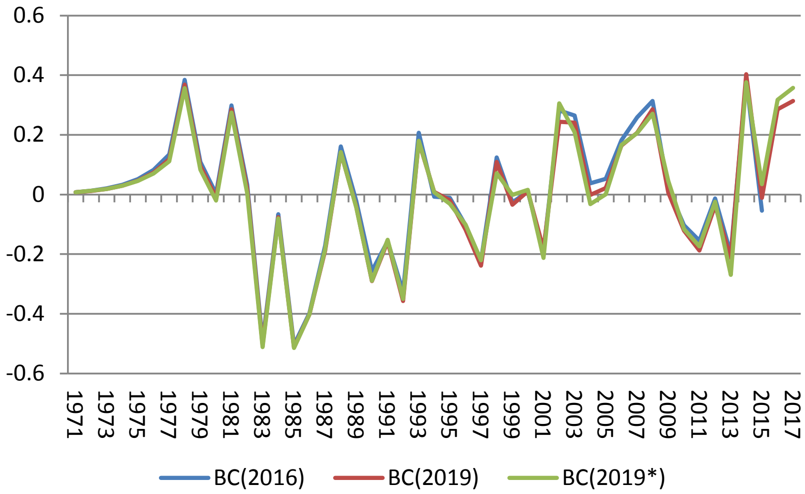

Figure 2: Recruitment residuals.

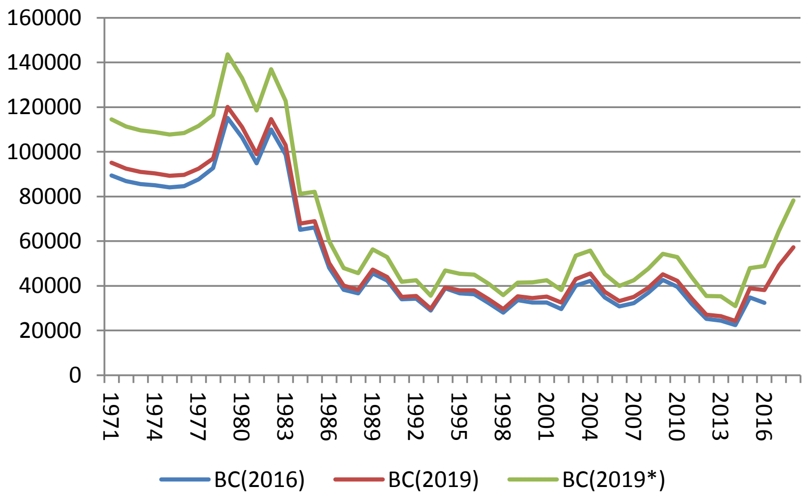

Figure 3: Begin-year biomass (tons).

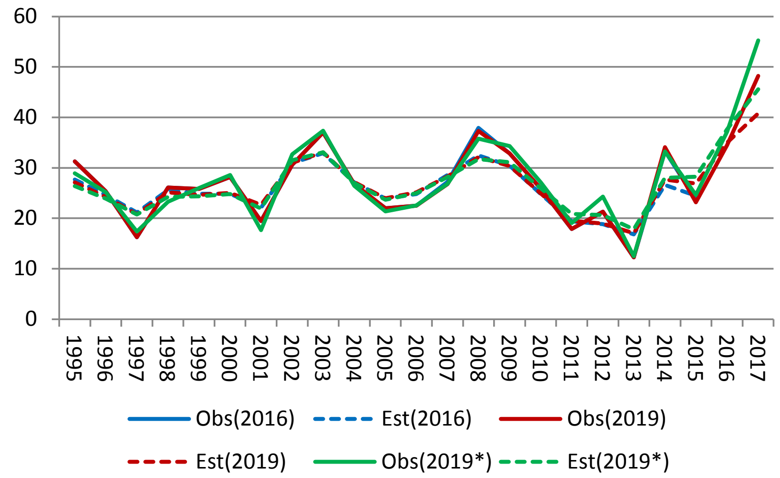

Figure 4: Fits to the April-December jig CPUE indices (kg/person-day).

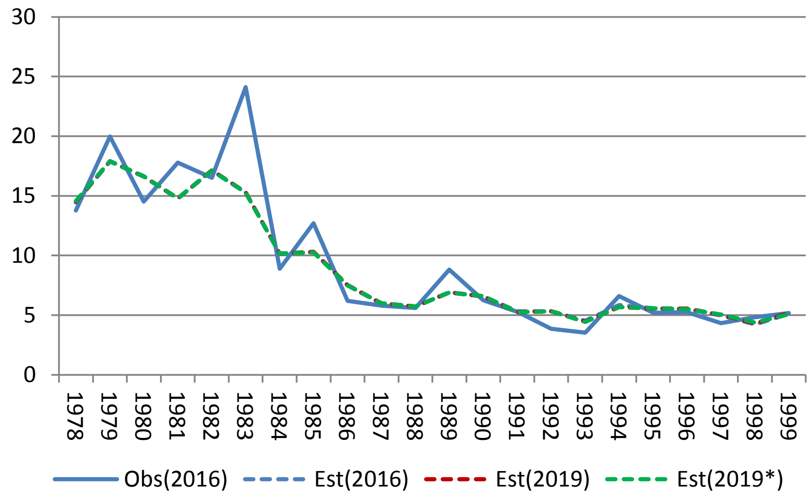

Figure 5: Fits to the January-March trawl CPUE index (kg/minute).

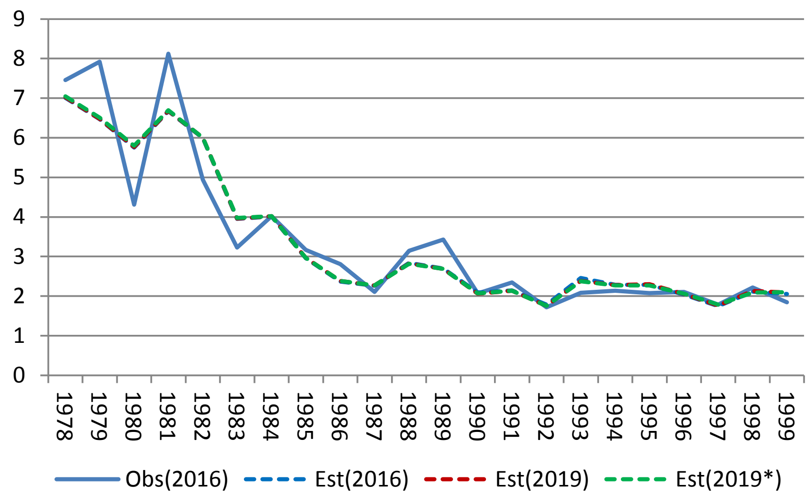

Figure 6: Fits to the April-December trawl CPUE index (kg/minute).

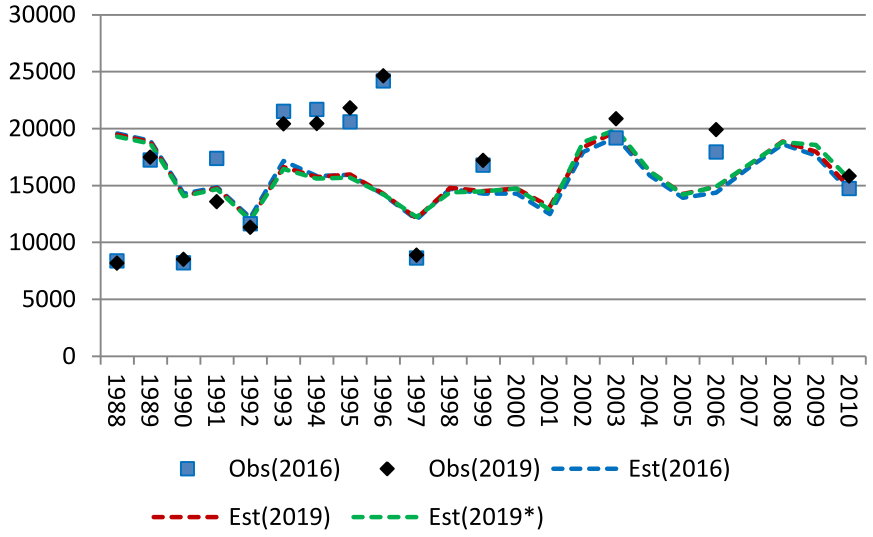

Figure 7: Fits to the autumn survey biomass indices (tons).

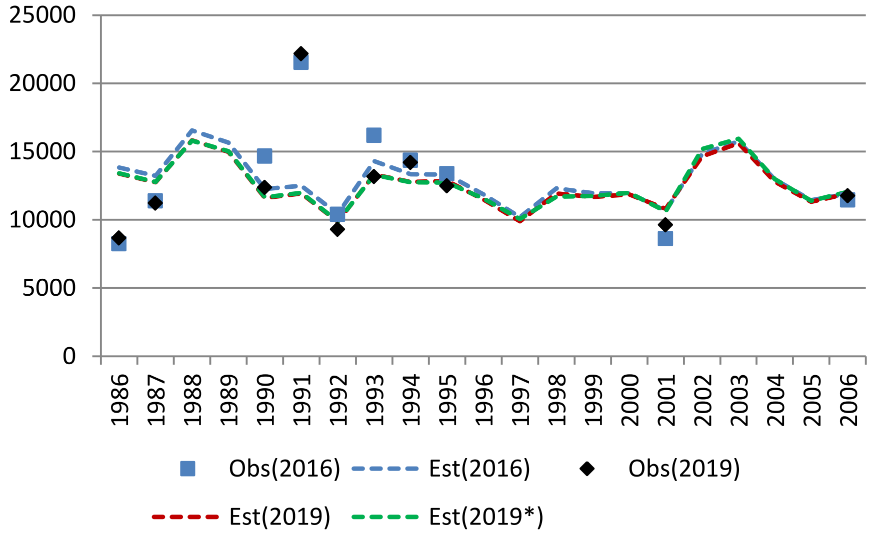

Figure 8: Fits to the spring survey biomass indices (tons).

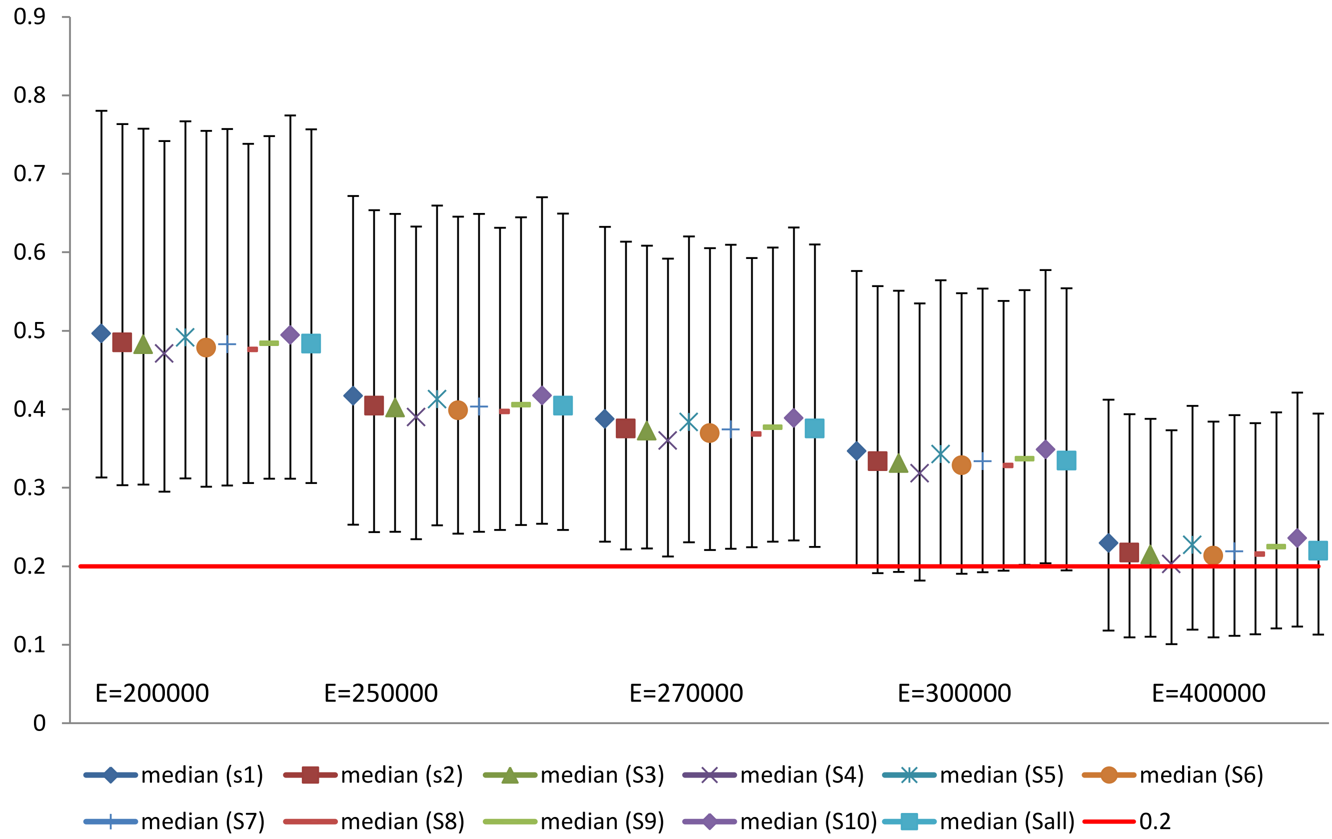

Figure 9: Median B_{2027}/K for various effort levels obtained from projecting forward from ten parts of the chain where each part contains 36 000 samples, as well as for the full chain comprising 360 000 samples. The 5^{th} and 95^{th} percentiles are shown. The red horizontal line represents 0.2K.

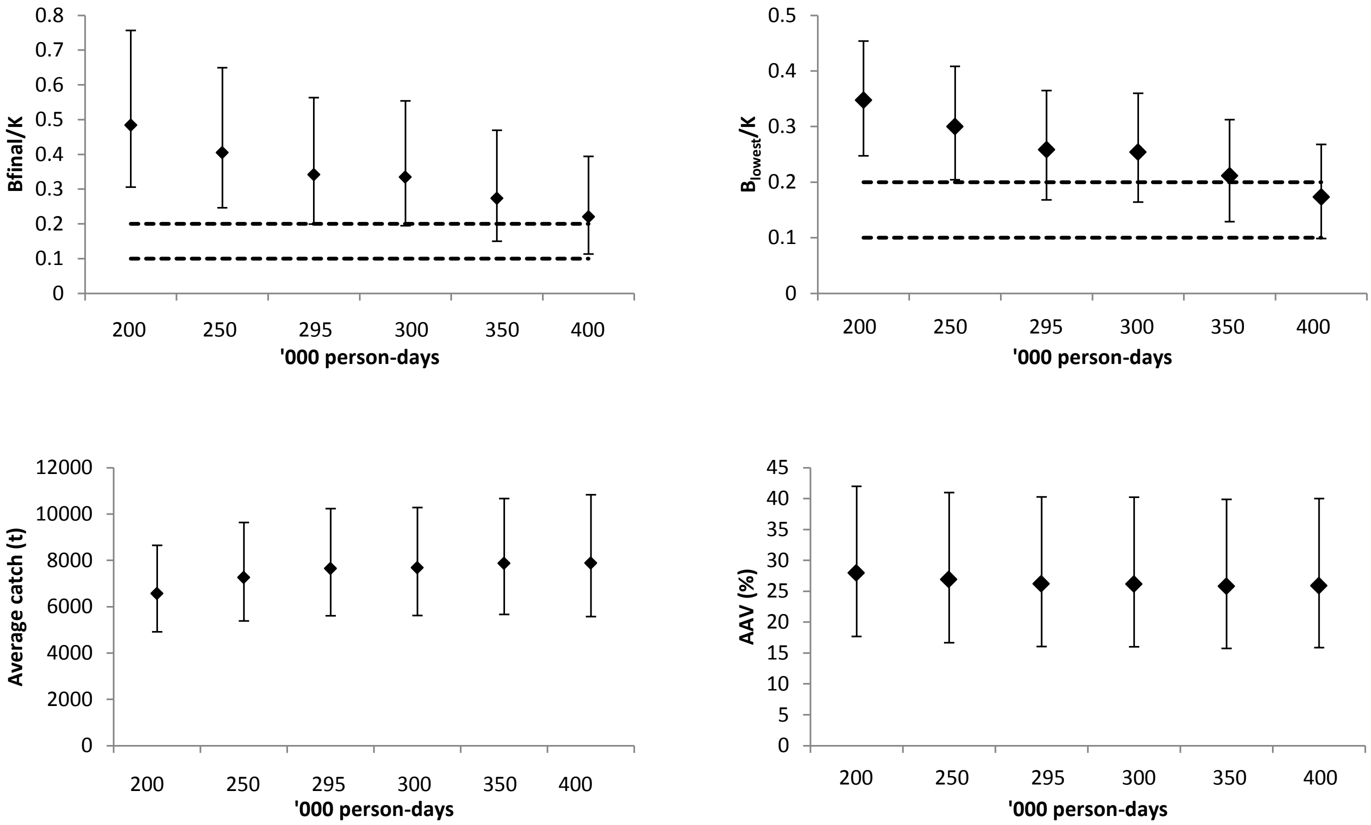

Figure 10: Performance statistics obtained from projecting the resource forward utilizing 360 000 samples. Catches refer to those made by the jig fishery. To aid interpretation, dashed horizontal lines at depletions of 0.1 and 0.2 are included in the top two plots.

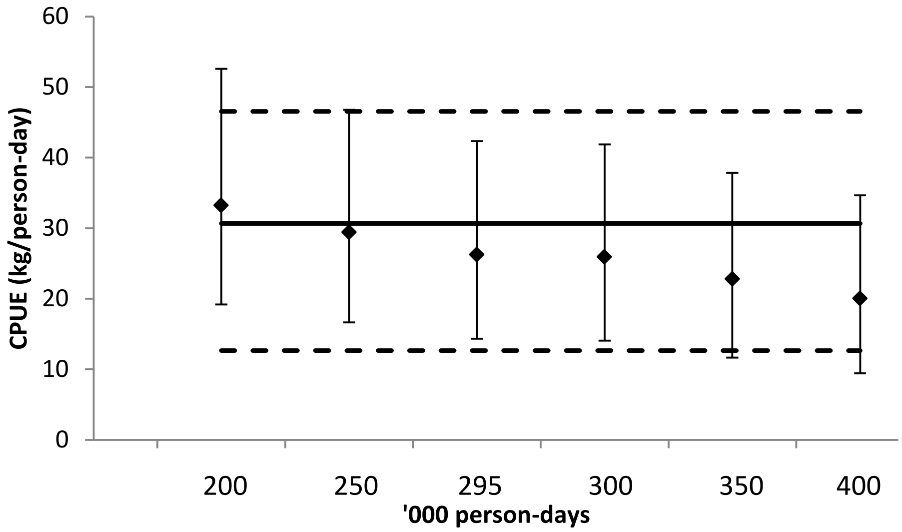

Figure 11: Average jig CPUE over the projection period for various fixed levels of effort. The 5th and 95th percentiles are also shown. The horizontal lines represent the average annual nominal jig CPUE as taken by the fishery over the period 2013 – 2017 (for all vessels and restricted to records where 3≤crew≤26) together with the 5th and 95th percentiles.

Appendix A

Table A.1: Baranov model formulations.

Description	**Baranov equations**
2nd period biomass	$B_y = B_y^* e^{-0.25(g+F_y^{jig,J-M}+F_y^{trawl,J-M})}$
begin-year biomass	$B_{y+1}^* = (B_y + e^{0.75g} R_y) e^{-0.75(g+F_y^{jig\ A-D}+F_y^{trawl\ A-D})}$
Recruitment	$R_y = \dfrac{\alpha B_y^* e^{-\eta F_{y-1}^{jig\ A-D}}}{\beta + B_y^*} e^{(\xi_y - \frac{\sigma_R^2}{2})}$
Average biomass: Jan-Mar trawl/jig CPUE	$\overline{B}_y = B_y^* e^{-\frac{1.5}{12}(g+F_y^{jig,J-M}+F_y^{trawl,J-M})}$
Average biomass Apr-Dec trawl/jig CPUE	$\bar{B}_y = (B_y + e^{0.75g} R_y) e^{-\frac{4.5}{12}(g+F_y^{jig,A-D}+F_y^{trawl,A-D})}$
Average biomass: spring index	$\bar{B}_y = (B_y + e^{0.75g} R_y) e^{-\frac{5.5}{12}(g+F_y^{jig,A-D}+F_y^{trawl,A-D})}$
Average biomass: autumn index	$\bar{B}_y = (B_y + e^{0.75g} R_y) e^{-\frac{1}{12}(g+F_y^{jig,A-D}+F_y^{trawl,A-D})}$
Fits to catches (to determine Fs)	
jig Jan-Mar	$\hat{C}_y^{jig,J-M} = 0.25 F_y^{jig,J-M} B_y^* (1 - e^{-0.25\left(g+F_y^{jig,J-M}+F_y^{trawl,J-M}\right)}) / [0.25(g + F_y^{jig,J-M} + F_y^{trawl,J-M})]$
jig Apr-Dec	$\hat{C}_y^{jig,A-D} = 0.75 F_y^{jig,A-D} (B_y + e^{0.75g} R_y)(1 - e^{-0.75\left(g+F_y^{jig,A-D}+F_y^{trawl,A-D}\right)}) / [0.75(g + F_y^{jig,A-D} + F_y^{trawl,A-D})]$
Trawl Jan-Mar	$\hat{C}_y^{tr,J-M} = 0.25 F_y^{trawl,J-M} B_y^* (1 - e^{-0.25\left(g+F_y^{jig,J-M}+F_y^{trawl,J-M}\right)}) / [0.25(g + F_y^{jig,J-M} + F_y^{trawl,J-M})]$
trawl Apr-Dec	$\hat{C}_y^{tr,A-D} = 0.75 F_y^{trawl,A-D} (B_y + e^{0.75g} R_y)(1 - e^{-0.75\left(g+F_y^{jig,A-D}+F_y^{trawl,A-D}\right)}) / [0.75(g + F_y^{jig,A-D} + F_y^{trawl,A-D})]$

Table A.2: Fits to indices (- ℓnL)

Apr-Dec jig	$n\ell n\sqrt{2\pi}\sigma^*_{jAD} + \frac{1}{2\sigma^{*2}_{jAD}}\sum_{y=1}^{n}(\ell n(CPUE^{jAD}_y - \ell n(q_{jAD}) - \ell n(\bar{B}^{jAD}_y))^2$
Jan-Mar trawl	$n\ell n\sqrt{2\pi}\sigma^*_{tJM} + \frac{1}{2\sigma^{*2}_{tJM}}\sum_{y=1}^{n}(\ell n(CPUE^{tJM}_y - \ell n(q_{tJM}) - \ell n(\bar{B}^{tJM}_y))^2$
Apr-Dec trawl	$n\ell n\sqrt{2\pi}\sigma^*_{tAD} + \frac{1}{2\sigma^{*2}_{tAD}}\sum_{y=1}^{n}(\ell n(CPUE^{tAD}_y - \ell n(q_{tAD}) - \ell n(\bar{B}^{tAD}_y))^2$
Autumn index	$n\ell n\sqrt{2\pi}\sigma^*_{aut} + \frac{1}{2\sigma^{*2}_{aut}}\sum_{y=1}^{n}(\ell n(B^{aut}_y - \ell n(q_{aut}) - \ell n(\bar{B}^{aut}_y))^2$
Spring index	$n\ell n\sqrt{2\pi}\sigma^*_{spr} + \frac{1}{2\sigma^{*2}_{spr}}\sum_{y=1}^{n}(\ell n(B^{spr}_y - \ell n(q_{spr}) - \ell n(\bar{B}^{spr}_y))^2$
recruitment residuals	$\sum_{y=1}^{n}\ell n(\sqrt{2\pi}) + \ell n(\sigma_r) + \frac{1}{2\sigma^2_R}\xi^2_y)$
g penalty	$\ell n(\sqrt{2\pi}\sigma + \frac{1}{2\sigma^2}(g-1.2)^2$
Jan-Mar jig catches	$n\ell n\sqrt{2\pi CV^2} + \frac{1}{2CV^2}\sum_{y=1}^{n}(\ell nC^{jig,J-M}_y - \ell n\hat{C}^{jig,J-M}_y)^2$
Apr-Dec jig catches	$n\ell n\sqrt{2\pi CV^2} + \frac{1}{2CV^2}\sum_{y=1}^{n}(\ell nC^{jig,A-D}_y - \ell n\hat{C}^{jig,A-D}_y)^2$
Jan-Mar trawl catches	$n\ell n\sqrt{2\pi CV^2} + \frac{1}{2CV^2}\sum_{y=1}^{n}(\ell nC^{trawl,J-M}_y - \ell n\hat{C}^{trawl,J-M}_y)^2$
Apr-Dec trawl catches	$n\ell n\sqrt{2\pi CV^2} + \frac{1}{2CV^2}\sum_{y=1}^{n}(\ell nC^{trawl,A-D}_y - \ell n\hat{C}^{trawl,A-D}_y)^2$

Table A.3: Assumed priors for the estimable parameters

Parameter	**Prior Distribution**
X[1]	~U(-15,15)
Y[2]	~U(-1.5,1.5)
h	~U(0.25,1)
g	~N(1.2,0.1^2)
Stock recruitment residuals, ξ_y	~N(0,σ_R^2) where σ_R is assumed to be 0.3 on input
$F_y^{jig,Jan-Mar}$	~U(0,3.0)
$F_y^{jig,Apr-Dec}$	~U(0,3.0)
$F_y^{trawl,Jan-Mar}$	~U(0,3.0)
$F_y^{trawl,Apr-Dec}$	~U(0,3.0)

Appendix B

The assumptions made relating to effort in the projections are as follows:

- The proportion of annual jig effort expended in each period is equivalent to the average observed over the last 3 years for which data are available (2015-2017), and is 0.32:0.68 for Jan-Mar:Apr-Dec.

- Future trawl effort is constant and is equivalent to the average standardized effort in the trawl fishery over the last 5 years for which data are available (1995-1999).

- The proportion of annual trawl effort expended in each period is equivalent to the average observed over the last 5 years for which data are available (1995-1999), and is 0.19:0.81 for Jan-Mar:Apr-Dec.

[1] Initial Recruitment, $R_0 = e^X$
[2] The reduction in recruitment as a result of jigging disturbance, $\eta = e^{Y+1.0219X-10.92}$