Assessment for Eastern Blue Mackerel

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Executive Summary

Stochastic Stock Reduction Analysis (SSRA) is used conduct an assessment for eastern blue mackerel to condition the management strategy evaluation that has been developed for this species group. The SSRA is based on an age-structured model and uses pre-specified values for biological parameters (natural mortality, growth, maturity, and stock-recruit steepness). The SSRA results in a value for depletion of 0.93 (SD 0.29) for the "best" values for stock-recruit steepness and σ_R (0.59 and 0.6) when autocorrelation in recruitment is ignored and 0.91 (0.49) when half of the variation in recruitment is due to autocorrelation. The best estimate of depletion, is, however, somewhat sensitive to assumptions regarding stock-recruit steepness σ_R, and the extent of autocorrelation in recruitment, with a range from 0.74 to 0.95, with lower values of steepness and a greater extent of variation and autocorrelation in recruitment leading to lower values for depletion, and vice versa.

Introduction

A management strategy evaluation (MSE) should ideally be conditioned to the data for the situation under consideration so that the results pertain to that situation most adequately, although appropriate alternative scenarios also need to be conducted to cover a reasonable range of uncertainties (Punt *et al*., 2016). Conditioning usually entails fitting the operating model (the model that represents the "reality" for the analyses) to the available data. However, this can be challenging for data-poor situations for which there may be insufficient data to conduct assessments. This is in large part the situation for Australia's Small Pelagic Fishery (SPF). Consequently, past MSE analyses for the SPF (e.g., Smith *et al*., 2015) have involved setting various parameters based on auxiliary information. These parameters include those such as current depletion, the steepness of the stock-recruit relationship and the extent of variation and autocorrelation about the stock-recruit relationship (ρ and σ_R), to which the results of projections under various alternative management strategies have been shown to be sensitive (A.D.M. Smith, Pers. Commn).

The only data available for eastern blue mackerel (*Scomber australasicus*) are a time-series of catches, an estimate of 2014 spawning stock biomass, and some estimates of biological parameters, making this a classic "data-poor" species. Consequently, this assessment is based on Stochastic Stock Reduction Analyses (SSRA), which uses only biological parameters, catches (from a single fleet) and an estimate of spawning stock biomass. The method involves setting the values for most of the population dynamics parameters (growth, maturity, selectivity, stock-recruit steepness, and the extent of variation and autocorrelation in recruitment about the stock-recruit relationship, ρ and σ_R), sampling values for the annual deviations in recruitment about the stock-recruit relationship from a normal distribution and a value for 2014 spawning stock biomass from its (log-normal) sampling distribution and solving for the value of unfished recruitment such that the projected spawning biomass equals the generated value. Repeating this process many (1,000 for the analyses of this report) times leads to a distribution for spawning stock biomass and depletion in each year of the modelled period. This approach is similar to Depletion-Based Stock Reduction Analysis (Dick and MacCall, 2011), except that it is conditioned on an estimate of absolute abundance.

1. Methods

The basic population dynamics reflect a single-sex age-structured model, with a plus-group:

$$N_{y,a} = \begin{cases} \dfrac{4hR_0\tilde{S}_y/\tilde{S}_0}{(1-h)+(5h-1)\tilde{S}_y/\tilde{S}_0} e^{\varepsilon_y - \sigma_R^2/2} & \text{if } a=0 \\ N_{y-1,a-1}e^{-Z_{y-1,a-1}} & \text{if } 1 \le a < x \\ N_{y-1,x-1}e^{-Z_{y-1,x-1}} + N_{y-1,x}e^{-Z_{y-1,x}} & \text{if } a = x \end{cases} \tag{1}$$

where $N_{y,a}$ is the number of fish of age *a* at the start of year *y*, $Z_{y,a}$ is the total mortality on animals of age *a* during year *y*:

$$Z_{y,a} = M + S_a F_y \tag{2}$$

M is the instantaneous rate of natural mortality, S_a is the selectivity of the fishery on animals of age *a*, F_y is the fully-selected fishing mortality rate during year *y*, $\tilde{S}_y$ is the spawning stock biomass at the start of the year:

$$\tilde{S}_y = \sum_a w_a f_a N_{y,a} \tag{3}$$

$\tilde{S}_0$ is the average unfished spawning stock biomass, w_a is the weight of an animal of age *a* at the start of the year, f_a is the proportion of animals of age *a* that are mature, *h* is the "steepness" of the stock-recruit relationship, ε_y is the recruitment deviation for year *y*:

$$\varepsilon_y = \rho\varepsilon_{y-1} + \sqrt{1-\rho^2}\eta_y \qquad \eta_y \sim N(0;\sigma_R^2) \tag{4}$$

σ_R is the standard deviation of the recruitment deviations in log-space, ρ is extent of autocorrelation in the deviations about the stock-recruit relationship, and *x* is the maximum age-class (assumed to be a plus-group).

The catches by age and year, $C_{y,a}$, are given by the Baranov equation:

$$C_{y,a} = \frac{S_a F_y}{Z_{y,a}} N_{y,a}(1-e^{-Z_{y,a}}) \tag{5}$$

and the catches in weight by:

$$\tilde{C}_y = \sum_a w_{a+1/2} C_{y,a} \tag{6}$$

The initial conditions correspond to a population at unfished equilibrium. There is a *x*-year burn-in with no catches but with recruitment variation so that the initial age-structure could differ from that in the unfished situation.

Most of the parameters of the model (e.g., weight-at-age, maturity-at-age, natural mortality, selectivity-at-age, steepness, σ_R) are set based on the values used for the MSE (Table 1). The values for *x* and *M* are set to 6 and 0.62yr^{-1} respectively following Smith *et al*. (2015). Thus, the free parameters of the model are unfished recruitment, R_0 (or equivalently $\tilde{S}_0$), the annual fully-selected fishing mortalities, and the annual deviations about the stock-recruitment relationship. The analysis estimates a distribution for R_0 and hence B_0 and the time-series for spawning stock biomass by generating a value for the 2014 spawning stock biomass from its log-normal sampling distribution and values for the η_y for all years from a normal distribution with mean 0 and standard deviation σ_R, and then solves for the value for R_0 and hence $\tilde{S}_0$ such that the model-predicted spawning biomass in 2014 equals the generated value. The values for fishing mortality by year are selected so that the model-predicted time-series of catches matches the observed time-series of catches exactly. The ratio of 2015 biomass to pre-fishery equilibrium biomass is then summarized to form a distribution for 2015 depletion.

The base values for stock-recruit steepness in Smith *et al*. (2015) was 0.59 for blue mackerel, with sensitivity examined to values of 0.47 and 0.71. The base value of σ_R was set to 0.6 in Smith *et al*. (2015). Given uncertainty regarding these two key parameters, results from the SSRA are presented for all combinations of steepness = 0.47, 0.59, and 0.71 and σ_R = 0.4, 0.6, 0.8, and 1.0[1] with the (0.59, 0.6) combination taken to be the base combination[2]. Results are also shown for two choices for the extent of autocorrelation (0 – no autocorrelation; 0.707 – half of the variation in recruitment is due to autocorrelation). Table 2 lists the annual catches. These catches were taken using a variety of gear types (primarily purse seine and midwater trawl), but this is ignored for the purposes of the SSRA. The estimate 2014 spawning stock biomass is 83,300t (Ward *et al*., 2016), with an assumed CV of 0.5.

3. Results

Figure 1 shows the distributions for 2015 depletion, along with the time-series of the distributions for spawning stock biomass and depletion for the base values of stock-recruit steepness and σ_R for the case in which ρ=0. The mean of the distribution for 2015 depletion is 0.93, with a standard deviation of 0.29. Table 3 shows the sensitivity of the values for the mean and standard deviation of the distribution for 2015 depletion to the assumed values for stock-recruit steepness, ρ and σ_R. The value for 2015 depletion ranges from 0.74 to 0.95, with lower values of steepness and a greater extent of variation and autocorrelation in recruitment leading to lower values for depletion, and vice versa. Increasing the values for σ_R and ρ both also lead to substantially greater uncertainty regarding current depletion.

4. Discussion

The results of this assessment could be used to provide several of the inputs to the management strategy evaluation for eastern blue mackerel. The SSRA suggests that the stock is likely to be fairly close to the average unfished level (but with uncertainty that depends on stock-recruit steepness, ρ and σ_R). The estimate of 2015 depletion based on the parameter values on which the MSE conducted by Smith *et al.* (2015) was based is 0.93, but the uncertainty about that estimate is high, particularly when account is taken of autocorrelation in recruitment.

The analyses are based on several assumptions that should be considered when interpreting the results of this work. In particular, the analyses assumed there were negligible catches prior to 1997/98, that the values assumed for growth and stock-recruit steepness are correct (with the results in Table 3 confirming that estimates of depletion will be sensitive to assumptions about the value of this parameter).

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[1] Smith *et al*. (2015) did not examine values for σ_R as high as 1, but the results of the state-space assessment method for jack mackerel suggest these to be plausible.

[2] Because this was the base-case for the analyses conducted by Smith *et al*. (2015)

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Table 1. Values for the biological parameters for eastern blue mackerel (source: Smith *et al*., 2015).

Age	Weight	Proportion mature	Selectivity
0	34.5	0.01*	0.01
1	142.6	0.17	0.17
2	278.2	0.69	0.69
3	402.6	0.91	0.91
4	501.3	0.97	0.97
5	573.7	0.98	0.98
6	643.9	0.99	0.99

* Set to zero given the form of the population dynamics model

Table 2. Catches (t) of eastern blue mackerel (Source: T. Ward, pers. Commn)

Year	Total		
1983/84	332	2000/01	899
1984/85	252	2001/02	641
1985/86	772	2002/03	836
1986/87	1322	2003/04	1036
1987/88	1443	2004/05	881
1988/89	462	1005/06	805
1989/90	102	2006/07	712
1990/91	173	2007/08	533
1991/92	232	2008/09	550
1992/93	401	2009/10	718
1993/94	506	2010/11	382
1994/95	314	2011/12	309
1995/96	338	2012/13	530
1996/97	324	2013/14	482
1997/98	512	2014/15	444
1998/99	748	2015/16	2366
1999/2000	851		

Table 3. Mean and standard deviation of 2015 depletion (expressed as percentages) for eastern blue mackerel as a function of stock-recruit steepness, ρ and σ_R based on SSRA.

		ρ=0		**ρ=0.707**	
Steepness	σ_R	**Mean depletion**	**SD depletion**	**Mean depletion**	**SD depletion**
0.47	0.4	93.4	19.2	92.0	34.4
0.59	0.4	94.3	18.5	93.3	32.2
0.71	0.4	94.7	18.1	94.0	30.9
0.47	0.6	91.5	29.8	88.5	51.7
0.59	0.6	93.1	28.9	91.2	49.1
0.71	0.6	94.0	28.4	92.5	47.4
0.47	0.8	88.8	41.5	82.7	67.4
0.59	0.8	91.5	40.9	88.1	66.8
0.71	0.8	93.0	40.5	90.6	65.4
0.47	1.0	84.8	54.2	73.5	80.8
0.59	1.0	89.3	54.7	82.5	82.2
0.71	1.0	91.7	55.0	87.5	84.7

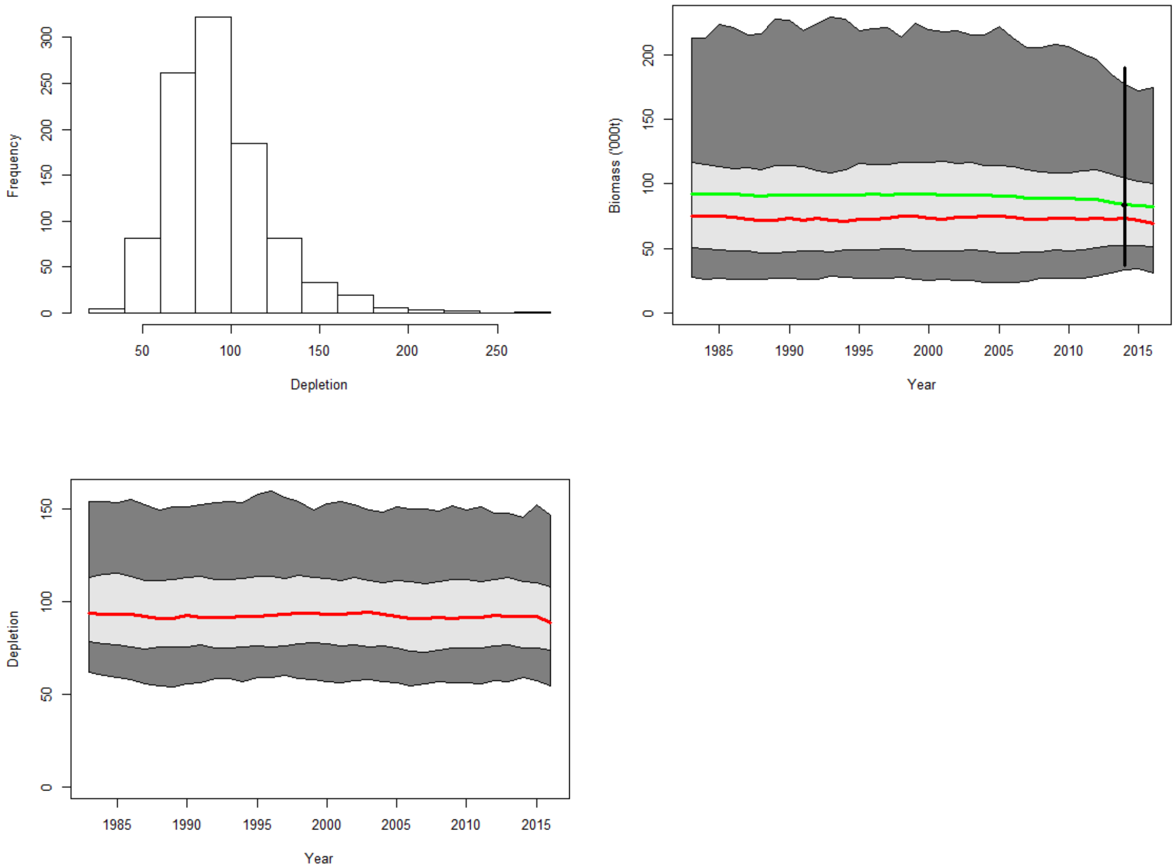

Figure 1. Distribution for 2015 depletion of eastern blue mackerel (expressed as a percentage) and the time-series for spawning stock biomass and depletion when steepness = 0.59, ρ=0 and σ_R = 0.6 based on SSRA. The red line is the distribution median, the green line is the distribution mean, the light gray area covers 50% of the distribution and the dark and light gray areas combine 90% of the distributions. The vertical line in the top-left panel is the DEPM estimate of abundance.