Projections of the Robben Island African penguin population

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1 Introduction

The Robben Island penguin population model was described in the working group document FISHERIES/2012/JUL/SWG–PEL/35. This paper shows projected penguin numbers under various scenarios concerning the future abundance and distribution of sardine.

2 Results

Figure 1 compares projections under various conditions without fishing (including 80% probability intervals) and also includes median projections under the OMP-13 candidate management procedure (the Base MP of de Moor and Butterworth 2012). For the right-hand column, $\tilde{\sigma} = 0.088$ which is the maximum likelihood estimate for the parameter. For the left column, an alternative value for $\tilde{\sigma}$ is used, namely $\tilde{\sigma} = 0.062$. This is two standard errors below the maximum likelihood estimate, being chosen to reflect the lowest "plausible" value consistent with the data. The three rows correspond to different future sardine abundance distributions in the absence of fishing: 50% more than the total predicted sardine biomass distribution (top), the biomass distribution west of Cape Agulhas assuming proportions similar to those observed over 1984–1999 (middle), and the biomass distributions west of Cape Agulhas assuming proportions similar to those observed over 2000–2011.

Table 1 provides values for the median increase in penguin abundance at Robben Island from 2012 to 2022, both without and with fishing, together with the ratio of those two increases.

Figure 2 shows the model-fitted trajectory of adult female moulters (dark curve). The dashed line below is a trajectory corresponding to the same demographic parameter estimates (birth rates and death rates) but with immigrating birds removed. This graph shows that virtually all

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increases in the size of the Robben Island colony during the 1990s are attributable to immigrants. The large peak in sardine abundance over the years 1998–2003 (see Figure 3) had relatively little effect. This suggests that without these immigrants the colony would have been barely self-sustaining over this period.

Figure 4 shows the distribution of the total sardine observed 1+ biomass over the years 2012–2022 as projected by the sardine assessment model assuming that no fishing takes place. The index of 1 corresponds to the maximum sardine 1+ biomass previously observed west of Cape Agulhas (1 343 thousand tons in 2003). The dashed and dotted curves show the distribution of sardine biomass under two alternative hypotheses for the future spatial distribution of the resource. The proportion of the biomass assumed to lie to the west of Cape Agulhas in the future is determined by sampling at random from historically observed proportions from one of two periods: 1984–1999 (dashed curve) and 2000–2011 (dotted curve).

3 Discussion

Figure 1 indicates that in all cases, the impact of fishing on penguin numbers through the reduction of total sardine biomass by the fishery is rather small, especially when compared to other factors influencing the dynamics. Best predictions should be based on the best estimate of $\tilde{\sigma}$ of 0.088. For that value, apparently surprisingly, the median projection for penguins even in the absence of fishing is virtually flat (Figure 1 and Table 1). Why is this the case when the penguin population grew in the early to mid-90s (before the sardine boom) at sardine biomass levels similar to those now projected? The answer is provided by Figure 2: the reason for growth in the Robben Island population over that period in the 1990s was immigration, not any substantial excess of the reproduction over the death rate.

This also explains why fishing has little impact on penguin trajectories in most instances when $\tilde{\sigma} = 0.088$ (Figure 1 and Table 1). Figure 5 shows that penguin mortality increases only once the sardine biomass drops below about 0.25 (in terms of the index used). The sardine biomass distributions in Figure 4 show that for the assumptions that all the sardine biomass is west of Cape Agulhas, or that this proportion is given by the 1984–1999 distribution, only 2% or 6% respectively of these distributions fall below the critical 0.25 index value. Hence for most of the

time, the sardine biomass, with or without fishing, is at a level where the average penguin adult survival rate is as high as possible. However, for a 2000–2011 distribution of sardine west of Cape Agulhas, some 40% of the sardine distribution in Figure 4 is below the 0.25 index level where survival rate drops, so that frequently the natural death rate exceeds the reproduction rate, and consequently the penguin abundance declines.

If $\tilde{\sigma}$ is smaller, the variation about the relationship shown in Figure 5 is less, resulting in fewer instances when adult annual mortality reaches high values. Consequently there is a greater likelihood of penguin population increase (Figure 1 and Table 1), although even in that situation, continuation of the 2000–2011 sardine distribution would not see sufficient sardine west of Cape Agulhas to prevent further population decline.

Reference

de Moor, C.L. and Butterworth, D.S. 2012. Further results towards the selection of "Draft OMP-13". Document FISHERIES/2012/NOV/SWG-PEL/61. 17pp.

Table 1: Ratios of penguin numbers in 2022 to those in 2012 under various future sardine biomass scenarios, with and without fishing. The columns labelled "ratio" give the value with fishing divided by the corresponding value without fishing in each case, using the medians of the distributions in question. B is the total projected sardine biomass distribution under the most recent agreed sardine operating model and fishing under the Base MP of de Moor and Butterworth (2012).

	$\tilde{\sigma} = 0.062$			$\tilde{\sigma} = 0.088$		
	No fishing	With fishing	ratio	No fishing	With fishing	ratio
$B \times 1.5$	2.04	1.91	0.93	1.15	1.10	0.96
B	1.92	1.79	0.93	1.14	1.05	0.92
1984–1999	1.74	1.42	0.82	1.04	0.90	0.86
2000–2011	0.61	0.42	0.68	0.46	0.32	0.69

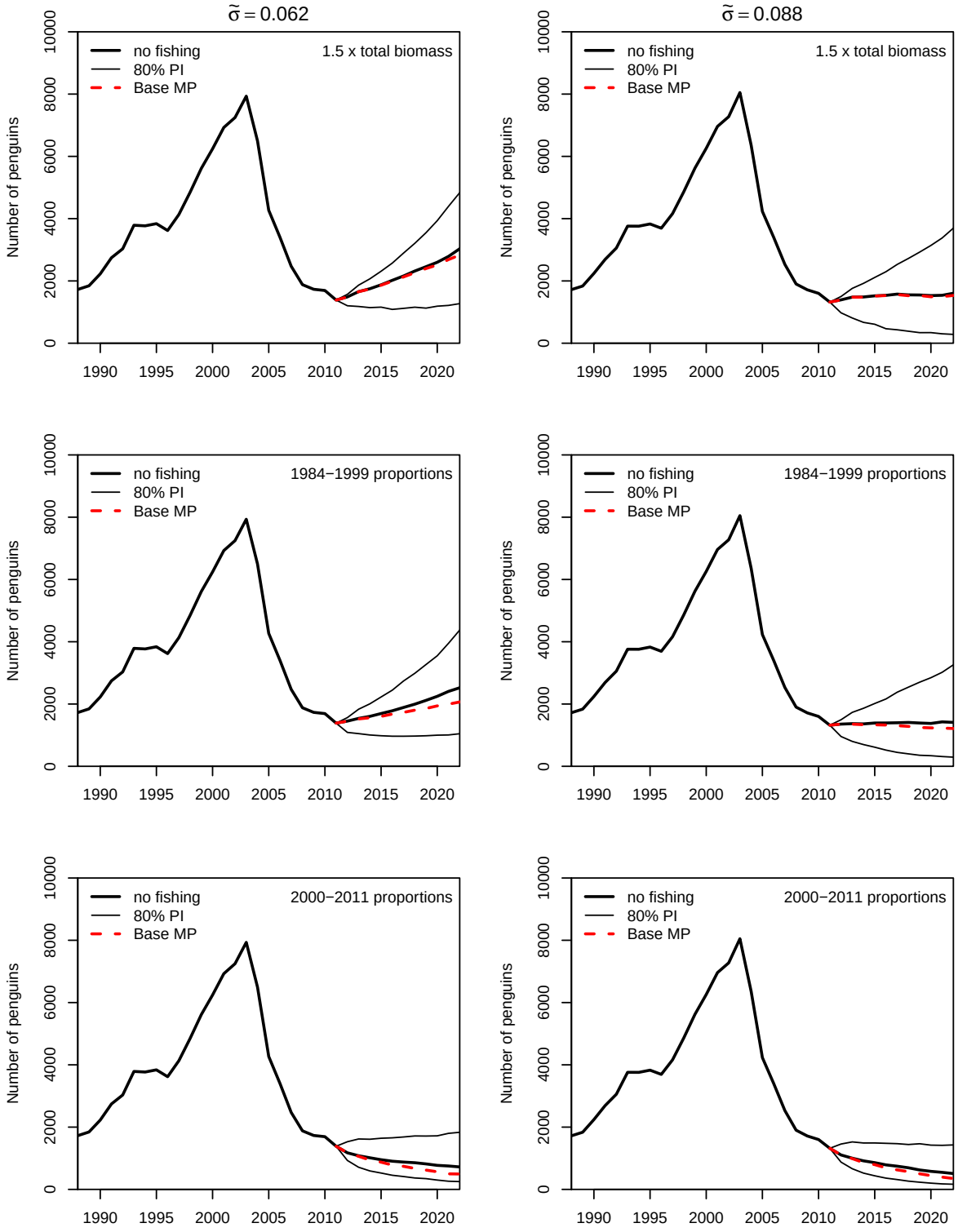

Figure 1: Comparison of projected penguin numbers with and without fishing under various future sardine biomass scenarios.

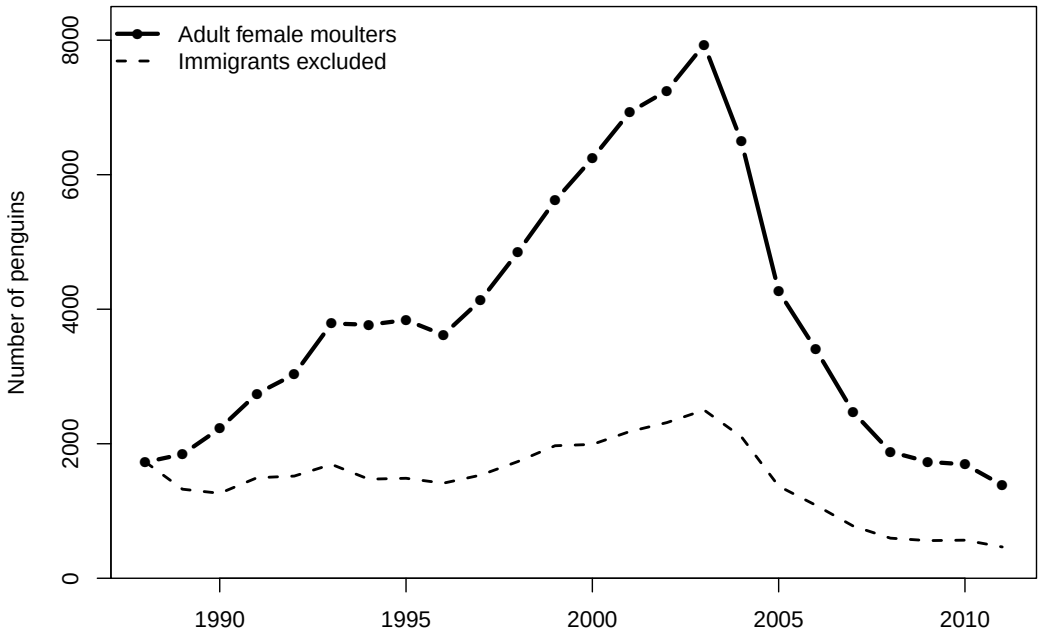

Figure 2: The fitted adult female penguin trajectory is compared to results for the same demographic parameter estimates but with no immigration.

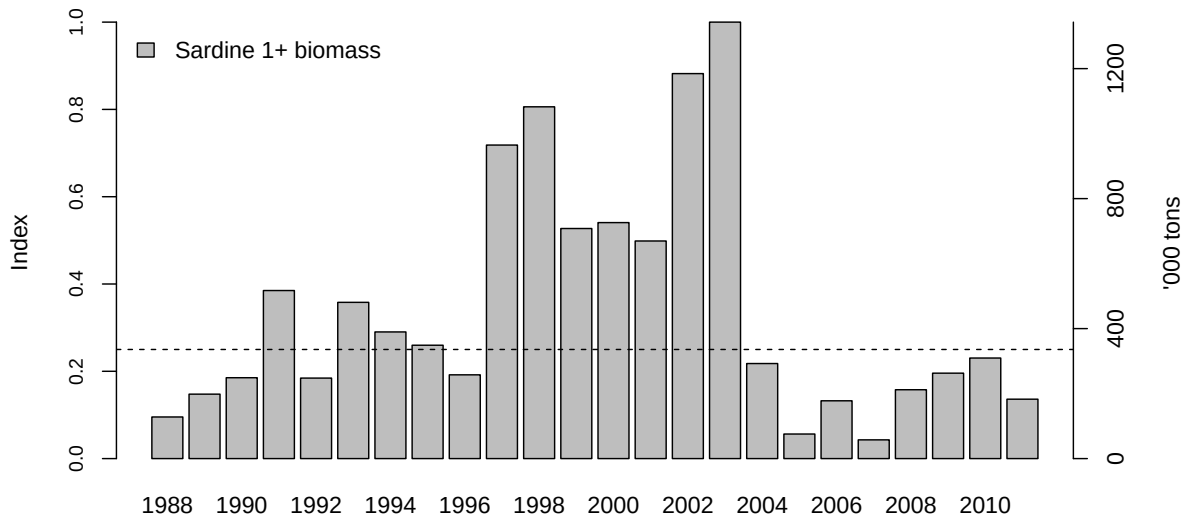

Figure 3: Sardine biomass observed west of Cape Agulhas in the annual hydroacoustic survey.

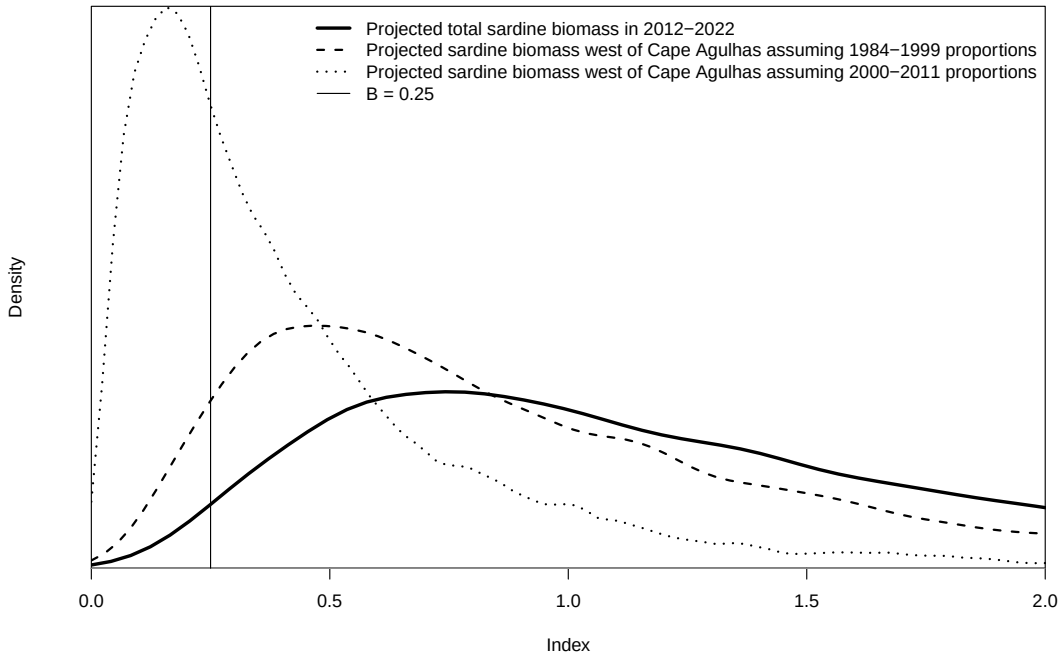

Figure 4: Distribution of future "observed" sardine 1+ biomass, and distributions of the biomass west of Cape Agulhas under two assumptions about future spatial distribution of the stock. All results refer to the situation in the absence of fishing.

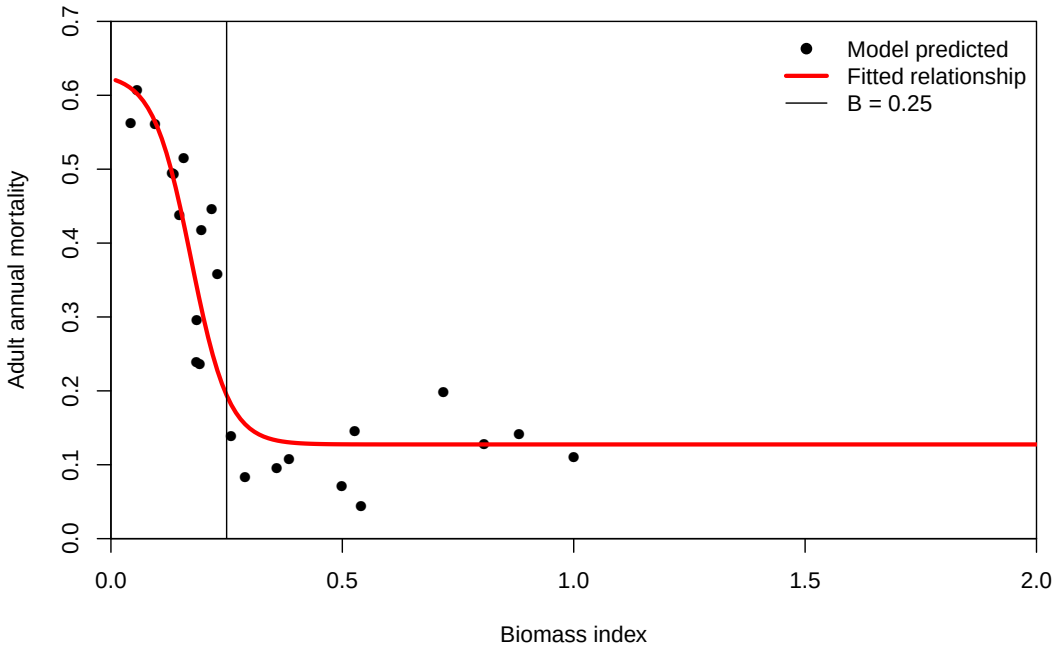

Figure 5: Fitted relationship between sardine biomass and adult annual mortality.