Refitting the Western Cape chick survival model excluding the 8% of chicks not monitored from hatching does not change the inference about the effect of the island closures

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Background:

An analysis of the impact of the island closures experiment on chick survival at Robben and Dassen Island was presented to the 2019 IWS panel in Sherley et al. 2019 (hereafter MARAM/IWS/2019/PENG/P4). This was updated in Sherley 2020a (hereafter FISHERIES/2020/JUL/SWG-PEL/53REV) following the panel recommendations (Die et al. 2019) using model selection to examine the impact of different hierarchical frailty terms on the modelled results. Both the results in MARAM/IWS/2019/PENG/P4 and the best fitting model in the analysis in FISHERIES/2020/JUL/SWG-PEL/53REV found a >10% increase in chick survival during closed years relative to open years at both islands (Table 1, model number M1).

However, beside the use of model selection, one additional difference in the models was introduced between MARAM/IWS/2019/PENG/P4 and the update in FISHERIES/2020/JUL/SWG-PEL/53REV. That was to use a lognormal hazard function rather than an exponential hazards function (as has been used for these analyses in the past, e.g. Sherley et al. 2018). This was based on a model selection analysis of four different, commonly used frailty distributions which indicated that lognormal provided the best fit to the data (see Appendix 2, top of page 15 in FISHERIES/2020/JUL/SWG-PEL/53REV). Results were also presented in Appendix 2 (see Figure A2.1, page 16 of FISHERIES/2020/JUL/SWG-PEL/53REV) to show that the new estimates of chick survival (based on lognormal hazards) were not credibly different from those presented in the past (based on exponential hazards). A model validation plot was also presented that compared the lognormal modelled survival rates (and 95% credible intervals) to non-parametric Kaplan-Meier (KM) estimates (and their 95% confidence intervals). This model validation plot (Figure A4.13 on page 27 of FISHERIES/2020/JUL/SWG-PEL/53REV) prompted discussion in a subsequent SWG-PEL meeting and the following written response from Butterworth 2020 (see page 32 of FISHERIES/2020/AUG/SWG-PEL/82):

"The use of an exponential model for survival rather than the "log-normal" model would be simpler and more readily interpreted, and seems attractive given indications (if I am understanding correctly from Sherley's comments during the 30 July meeting) that the differences in results of interest are not large. The particular reason for this is that then the non-equivalence of exposure time and chick age (because of variable commencement of the age at which different chicks are first recorded) does not potentially confound results. But then the marked (and apparently relatively precisely estimated) change in the estimated survival rate at for Robben (but not Dassen) from the KM estimates after some 50 days exposure becomes a concern. To what extent then might these estimates of cumulative survival

be confounded by different distributions of the chick age at which this monitoring commences? Some restrictions on the data used for these analyses, for example through elimination of data for chick for which monitoring is known to have started only at a fairly late stage, might be desirable. However, the matter should first be discussed to check whether some prior further diagnostic investigations might provide insight, before perhaps embarking on further onerous data extractions".

As well as the following written response from Bergh (2020a): *"The Kaplan Meier results suggests that at Robben Island chick survivorship is dependent on time, or chick age (see Figure A4.13 of FISHERIES/2020/JUL/SWG-PEL/53REV). The potential that this has biased the closure effect estimate because of the selection of chicks at different ages/times for estimating chick survivorship needs to be fully explored. This has not been done in FISHERIES/2020/JUL/SWG-PEL/53REV.*

In reply, Sherley (2020b) stated: "*Results comparing the log-normal and exponential hazard functions were given already in an appendix of FISHERIES/2020/JUL/SWG-PEL/53REV. It makes no appreciable difference to the inference whether a log-normal or exponential hazard function is used. The log-normal model gives a more parsimonious fit to the data based on model selection (see FISHERIES/2020/JUL/SWG-PEL/53REV) because the log-normal hazard function can be monotonically decreasing based on the mean and standard deviation of survival time on the log scale*".

And used an additional residual analysis (see pages 18–19 in FISHERIES/2020/SEP/SWG-PEL/85) to predict that if the small lack of fit between the data and the lognormal hazard model was affecting the estimates of chick survival in open and closed years at Robben Island, it appeared to be doing so in such a way as to underestimate the magnitude of the closure effect at that colony, not enhance it (see R18 of FISHERIES/2020/SEP/SWG-PEL/85):

"*the mean error between the KM model and the [log-normal] LN model is less than 1.5% (Figure R1), meaning that on average, the estimates from the LN are within 1.5% of the KM. And, at Robben Island, where the LN fits the least well of the two islands … the LN over-estimates survival more on average and at 74 days for the Open years than for the Closed years at Robben Island. This means that the meaningful closure effect detected at Robben Island is in spite of, not caused by, any bias that might exist in the dataset from the different chick ages at which this monitoring commences*".

And in response again, Bergh (2020b) wrote that this argument: *"suggests that the chick survival estimates may be biased. This is a reason to carry out further work to correct for this bias, by, for example and as suggested in FISHERIES/2020/SEP/SWG-PEL/87, excluding from analyses chicks that were not monitored from their hatching date".*

And Butterworth (2020b FISHERIES/2020/SEP/SWG-PEL/96rev) wrote: *"the marked (and apparently relatively precisely estimated) change in the estimated survival rate at Robben (but not Dassen) island from the KM estimates of these rates after some 50 days exposure is a concern".*

Accordingly, the below presents results for chick survival at Dassen Island and Robben Island excluding chicks that were not monitored prior to hatching.

Results:

Of the 3,219 African penguin chicks monitored for survival at Robben Island between 2008 and 2018, 357 (~11%) were not monitored from hatching. And of the 1,673 penguin chicks

monitored for survival at Dassen Island over those same years, 31 (~2%) were not monitored from hatching. To ensure that these 388 chicks (~8% of the total) were not confounding the results of the Western Cape chick survival model used to estimate the impact of the island closures experiment, the model was refit using only the 92% of chicks (n = 4,504) that were monitored from the egg stage. For this model (M1.I.H in Table 1), I retained the lognormal hazard function and model structure described in Appendix 2 (eqn. A2.1) of FISHERIES/2020/JUL/SWG-PEL/53REV, except that island-specific closure effects were retained (i.e. the Island × Closure interaction) as requested in FISHERIES/2020/AUG/SWG-PEL/82 and FISHERIES/2020/AUG/SWG-PEL/84.

Refitting the Western Cape chick survival model to exclude the ~11% of chicks that were not monitored from hatching resulted in a small increase in the strength of the positive closure effect at Robben Island (Table 1, Figure 1). The closure effect increased from a 9.8% improvement in chick survival during Closed years relative to Open years, to an 11.2% improvement at Robben Island (Table 1). The Dassen Island results remain unchanged with an 11.4% improvement in chick survival during Closed years relative to Open years (Table 1).

Based on this model (M1.I.H) the probability that the closures to purse-seine fishing around Robben and Dassen Island improved penguin chick survival exceeded 99.5% at both islands. Moreover, the percentage effect size exceeded the 10% pre-agreed threshold for what constitutes a biologically meaningful effect at both islands (Table 1) and the inference about the effect of the island closures experiment on chick survival remains unchanged.

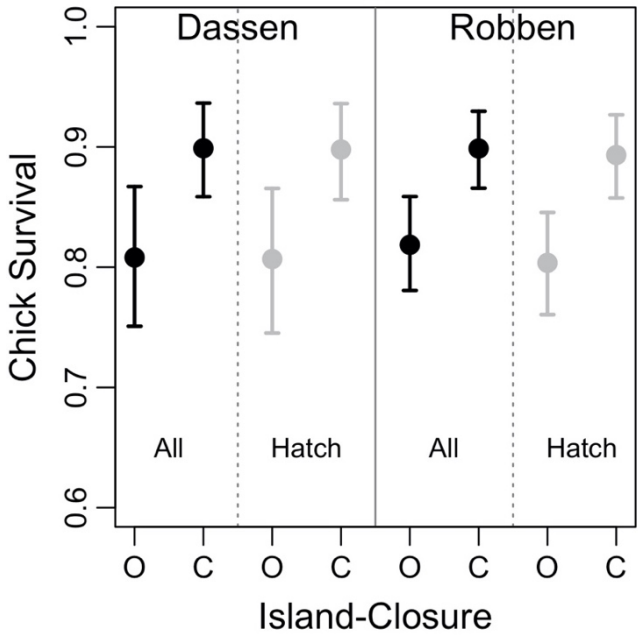

Figure 1: Model estimated mean (± 95% highest posterior density intervals, HPDI) chick survival between 2008 and 2018 at Dassen Island and Robben Island in years when a 20 km radius around each island was open (O) to or closed (C) to purse-seine fishing using either all (n = 4,892) African penguin chicks monitored in that time frame (All, black points and whiskers) or only the 92% of chicks (n = 4,504) monitored from hatching (Hatch, grey points and whiskers).

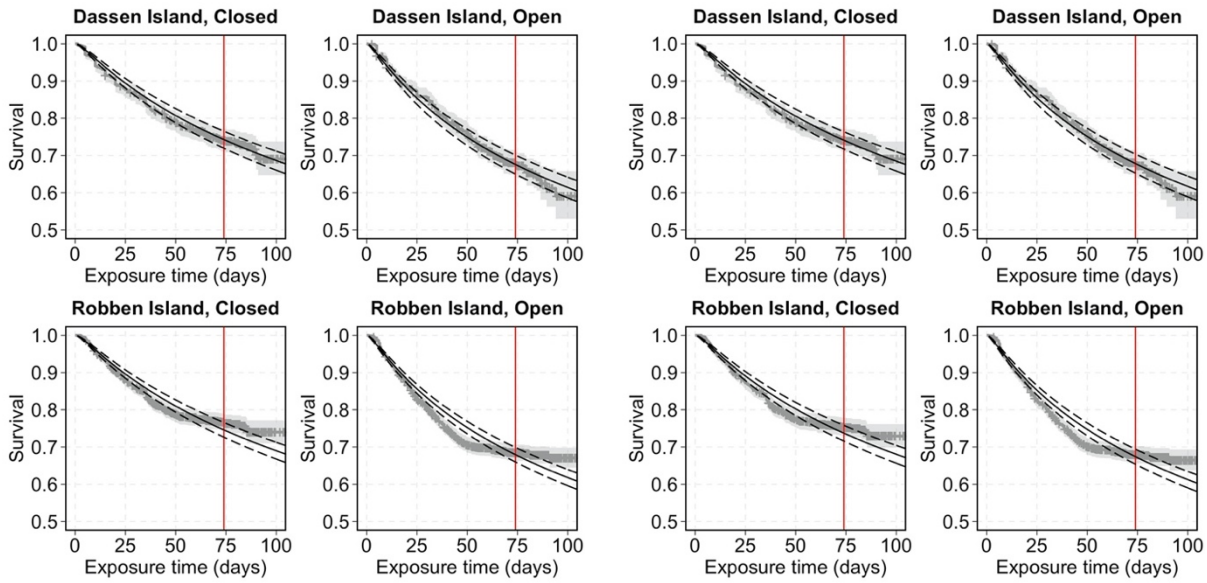

Figure 2: Model validation plots for Chick Survival at Dassen Island (top) and Robben Island (bottom) during years that were and Open to fishing. On the left is the original plot from FISHERIES/2020/JUL/SWG-PEL/53REV (using all 4,892 chicks monitored) on the right is the updated plot using only the 92% of chicks (n = 4,504) that were monitored from the egg stage. Panels show the comparison of the non-parametric Kaplan-Meier (KM) estimate of survival (grey points, +) and its 95% confidence intervals (grey polygons) and the predicted survival rates (solid black curves) and 95% credible intervals (black dashed curves) based on a model with a lognormal hazard function and no shared frailty term. The vertical red line marks time = 74 days, the age at which the predicted chick survival is compared between islands and closure statuses in the results section of this document and elsewhere (Sherley et al. 2013, 2015, 2018, 2019). Crucially, the predictions from the log-normal model and the KM estimate (which is derived only from the observations) are not credibly different at 74 days in either model, which indicates adequate model fit to predict chick survival at time = 74 days.

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Table 1: Results from models tested to assess the impact of the fishing closures on African penguin chick survival at Robben and Dassen Islands. M1 presents the results from the best fitting model from the model selection presented in FISHERIES/2020/JUL/SWG-PEL/53REV. M1.I presents the results from an update of M1 to include island-specific closure effects as requested by two participants at the SWG-PEL, and first presented in Sherley (2020c; FISHERIES/2020/SEP/SWG-PEL/87). M1.I.H presents an update of M1.I using only the 92% of chicks (n = 4,504) that were monitored from the egg stage.

Model Number	Random effects structure	Island and Closure fixed effects structure	Robben Closure effect mean (95% HPDI)	Percentage difference (95% HPDI)	Probability of effect	Dassen Closure effect mean (95% HPDI)	Percentage difference (95% HPDI)	Probability of effect
M1	Island/Year/BirdID	Island + Closure	0.38 (0.21–0.55)	10.3% (5.4–15.2%)	100%	0.38 (0.21–0.55)	10.6% (5.2–16.2%)	100%
M1.I	Island/Year/BirdID	Island × Closure	0.37 (0.16–0.57)	9.8% (4.1–15.7%)	99.9%	0.41 (0.11–0.70)	11.4% (2.4–20.4%)	99.7%
M1.I.H	Island/Year/BirdID	Island × Closure	0.39 (0.18–0.62)	11.2% (4.6–18.0%)	100%	0.41 (0.10–0.69)	11.4% (2.2–20.9%)	99.6%

Notes: HPDI = highest posterior density intervals. Probability of effect = the percentage of the closure effect posterior estimates > 0. Model M1 used an additive Island and Closure fixed effects structure, so only one overall closure effect for the two islands is estimated. In this table, the same effect size is given for both islands, but only one estimate is made in the model (the percentage difference for each island individually can be extracted from the model posteriors as a derived parameter).