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Sensitivity of the seabird risk assessment to three years without captures

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Richard, Y.; Abraham, E.R. (2017). Sensitivity of the seabird risk assessment to three years without captures. ***New Zealand Aquatic Environment and Biodiversity Report No. 182.*** **8 p.**

The "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (NPOA) sets out a five-year plan for reducing seabird mortalities in commercial fisheries, to be achieved by 30 June 2018. Over this period, the NPOA requires that "species currently categorised as at 'very high risk' or 'high risk' from fishing move to a lower category of risk". The risk ranking of seabird taxa within New Zealand's Exclusive Economic Zone was estimated in a recent assessment of the risk of commercial fisheries to seabirds. Here, we used simulated data to test the sensitivity of the risk assessment to a reduction in captures. In particular, we simulated an additional three years of fishing effort and observer data, identical to the most recent three years of fishing, but with no observed seabird captures in any fishery.

We successfully fitted a model to these data, allowing for a step change in vulnerability. The estimated risk ranking over the three simulated years was predicted to be "negligible risk" for most species. Nevertheless, the risk category of four species was still estimated to be non-negligible, including black petrel, Salvin's albatross, flesh-footed shearwater, and southern Buller's albatross. Black petrel was still estimated to be at "very high risk", despite the lack of captures. This outcome was caused by a lack of observer coverage in small-vessel bottom-longline and inshore trawl fisheries. The model indicated that a large number of seabird fatalities was still statistically possible, given the overlap between these fisheries and the four species, even though no captures were reported.

This result demonstrates that with current levels of observer coverage, it will not be possible to meet the goals of the NPOA, and reduce the risk category of the seabird species estimated to be most at risk. Even if there are no captures over three years, a reduction in the estimated risk will not be achieved without increasing observer coverage. We recommend that a more detailed simulation study is carried out to demonstrate the observer coverage required to satisfy the NPOA goals, for a range of reductions in capture rates.

1. INTRODUCTION

The "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (NPOA) sets out a five-year plan for reducing seabird mortalities, to be achieved by 30 June 2018 (Ministry for Primary Industries 2013). Before this date, the NPOA requires that "species currently categorised as at 'very high risk' or 'high risk' from fishing move to a lower category of risk". The risk ranking was estimated in the recent risk assessment for 70 seabird taxa within New Zealand's Exclusive Economic Zone, based on the ratio of the annual potential fatalities in commercial fisheries to the Potential Biological Removal (PBR) (Richard & Abraham 2015). The PBR is an index of population productivity, defined as the maximum level of human-caused mortalities a population can incur while remaining above half its carrying capacity with a 95% probability (Wade 1998, Richard & Abraham 2013a, 2013b, 2013c).

Estimation of the risk to seabirds is derived from records of seabird captures reported by government observers on-board fishing vessels. Observer coverage is variable between fisheries (Abraham et al. 2016). For fisheries with low observer coverage, there is limited understanding of their impact on seabirds. Furthermore, low observer coverage also makes it difficult to assess any reductions in capture rates, thus limiting the ability of fisheries managers to demonstrate progress towards meeting the goals of the NPOA.

In this study, we used simulated data to investigate a scenario of no seabird captures over a three-year period. Specifically, the investigation focused on what the reduction in the estimated risk rankings would be if there were no seabird captures over three years at the current level of observer coverage.

2. METHODS

In the recent seabird risk assessment (Richard & Abraham 2015), the number of observed captures was related to the overlap between species and fisheries:

$$C_{gs} \sim \text{Poisson}(\mu_{gs}), \tag{1}$$
$$\mu_{gs} = v_0 v_g v_s O_{gs} \epsilon_{gs}, \tag{2}$$

where C_{gs} is the number of annual observable captures of the species group s in the fishery group g, μ_{gs} is the mean number of observable captures of species group s in the fishery group g, v_g is the overall vulnerability of seabirds in the fishery group g (reflecting that some fisheries tend to attract more birds than others), v_s is the vulnerability of the species group, s (reflecting that some birds have a tendency to interact more strongly with fishing than others), and v_0 is the intercept. The overlap O_{gs} between the species group s and the fishery group g, is the product of fishing effort and bird density at each fishing event, summed over all fishing events, and ϵ_{gs} is the error associated with the combination of species group, s, and the fishing group, g, defined as a random effect. The species and fishery groups are defined and presented in the recent seabird risk assessment (Richard & Abraham 2015).

For set-net fisheries, a single fishery group was included, so that Equations 1 and 2 simplify to:

$$C_s \sim \text{Poisson}(\mu_s), \tag{3}$$
$$\mu_s = v_s O_s. \tag{4}$$

The models used in the risk assessment were amended to allow the fishery-related component of vulnerability to change over time. In particular, a change in fishing practice was represented by a step change in the fisheries vulnerability. The fishery-related vulnerability component v_g took the values $v_{g_{\text{pre}}}$ and $v_{g_{\text{post}}}$ for the years before and after the year when changes in fishing practice were introduced, respectively.

For set-net fisheries, the fisheries vulnerability component was added to Equation 4, taking the value 1 for the years before the changes in fishing practice, and v_g afterwards.

To facilitate model convergence, the prior distribution of ϵ_{gs} was changed from a log-normal distribution with a gamma-distributed hyperprior, to a gamma distribution with a uniform shrinkage hyperprior (Daniels 1999). For comparison with the time-varying formulation, the constant vulnerability model used in the recent risk assessment by Richard & Abraham (2015) was also tested (but with the gamma-distributed hyperprior).

A more complex model was tried, in which the fisheries vulnerability was represented as an annual random effect. This model could not be fitted due to the limited observer data. Therefore, only the model with a step change in vulnerability was considered.

To test the capacity of the risk assessment method to detect changes in capture rate, we added three years of data with no observed capture, under current levels of observer coverage. These three additional years of data, notionally representing the period 2013–14 to 2015–16, were obtained by replicating the data of fishing effort and observer coverage from the period between 2010–11 and 2012–13 used in the recent risk assessment by Richard & Abraham (2015), but with all observed seabird captures removed.

For the time-varying vulnerability model, the step change was set so that the fishing-related vulnerability could change between the period 2010–11 to 2012–13, and the simulated period 2013–14 to 2015–16 with no observed captures. In the time-invariant vulnerability model, the species vulnerability was constant over the entire period from 2010–11 to 2015–16.

Once fitted, the models were used to calculate the risk ratio for each species, following the same approach as the recent risk assessment, i.e., calculating the ratio of annual potential fatalities to the PBR (Richard & Abraham 2015). This approach involved estimation of the number of observable captures (the number of captures that would have been observed if all fishing vessels carried an observer), based on the estimated vulnerability, and the overlap between bird densities and the non-observed fishing effort, for the simulated period between 2013–14 and 2015–16. The number of observable captures was then multiplied by a factor depending on the species type to calculate the annual potential fatalities, taking into account that not all seabird captures are recovered on board (cryptic mortality). At the same time, the PBR was estimated for each species based on the annual survival rate, the age at first reproduction, and the population size. Finally, the estimated risk ratio for the simulated period was used to categorise the estimated risk for each species according to the NPOA classification:

- Very high risk: median risk ratio above 1 or an upper 95% credible limit above 2,
- High risk: median above 0.3 or an upper 95% credible limit above 1,
- Medium risk: median above 0.1 or an upper 95% credible limit above 0.3,
- Low risk: upper 95% credible limit above 0.1,
- Negligible risk: upper 95% credible limit less than 0.1.

3. RESULTS

Values for the risk ratio were estimated with the time-varying vulnerability model and with the time-invariant vulnerability model (Table 1). Under the time-invariant vulnerability model, the ranking of species, according to the median estimated risk ratio, followed that of the recent risk assessment (Richard & Abraham 2015), with black petrel, Salvin's albatross, flesh-footed shearwater, southern Buller's albatross, and Gibson's albatross estimated as the most at risk. The estimated risk ratios were, however, lower than in the risk assessment, due to the additional three years of data with no observed captures. Under this model, there were four species estimated to be at "very high risk", six species estimated at "high risk", six species at "medium risk", and eight species at "low" risk". There were 46 species with an estimated risk ranking of "negligible risk".

In comparison, under the time-varying vulnerability model, only four of the total 70 species assessed had an estimated risk category higher than "negligible risk" (Table 1). Of these four species, black petrel had an estimated risk ranking of "very high risk", flesh-footed shearwater was estimated at "medium risk", and Salvin's albatross and Chatham Island albatross were estimated at "low risk".

The values for fisheries vulnerability in the time-invariant model were estimated to be between the estimates for each of the two periods (before and after the step change) of the time-varying model (Table 2). The estimates for the period after the step change were close to zero, with a lower 95% credible limit at 0 for all fishery groups.

In the time-varying vulnerability model, non-negligible risk ratios remained after the step change. These risk ratios were for fisheries that overlapped with some seabird species, but that had low observer coverage. For example, for black petrel and bottom-longline fisheries targeting snapper, observer coverage from 2010–11 to 2012–13 was only 0.09% (see summaries for the ten combinations of fisheries and species with the highest risk ratio in Table 3).

The highest estimated risk ratio was of black petrel in small-vessel bottom-longline fisheries targeting snapper, with a median of 0.17 (95% c.i.: 0–3.34) (Table 4). The estimated risk ratio in these fisheries resulted in the "very high risk" ranking of black petrel. There were an estimated mean 53 (95% c.i.: 0–321) annual potential fatalities of black petrel in small-vessel bottom-longline fisheries targeting snapper. Only 16 sets (0.09% of the total effort) were observed in three years in these fisheries, representing 0.09% of the total overlap between these fisheries and this seabird species. Black petrel also have overlap with other small-vessel bottom-longline and also inshore trawl fisheries, and their overall risk ratio had an estimated median of 0.54 (95% c.i.: 0.04–4.29).

The low observer coverage in small-vessel bottom-longline fisheries targeting snapper was also responsible for the risk ranking of flesh-footed shearwater. Low observer coverage in inshore trawl fisheries led

Table 1: Estimated risk ratios (median, 95% credible interval) for seabird species with a non-negligible risk ranking based on the addition of three years of simulated data with no observed seabird captures. Estimates were derived using a time-invariant vulnerability model and a time-varying vulnerability model (step change before the three simulated years without captures). Estimated median risk ratio values were coloured according to the associated risk category as defined in the "National Plan of Action – 2013 to reduce the incidental catch of seabirds in New Zealand fisheries" (Ministry for Primary Industries 2013): Red: very high risk; dark orange: high risk; light orange: medium risk; yellow: low risk.

	Time-invariant		Step change	
Species	Median	95% c.i.	Median	95% c.i.
Black petrel	**10.19**	6.24–18.06	**0.541**	0.04–4.29
Salvin's albatross	**2.686**	1.37–5.04	**0.031**	0.00–0.27
Flesh-footed shearwater	**1.29**	0.50–2.81	**0.059**	0.00–0.85
Southern Buller's albatross	**1.165**	0.61–2.42	0.009	0.00–0.04
Gibson's albatross	**0.86**	0.48–1.71	0.009	0.00–0.06
Chatham Island albatross	**0.844**	0.40–1.79	**0.015**	0.00–0.12
NZ white-capped albatross	**0.824**	0.43–1.50	0.007	0.00–0.08
Northern Buller's albatross	**0.746**	0.42–1.43	0.009	0.00–0.04
Antipodean albatross	**0.623**	0.38–1.01	0.007	0.00–0.04
Westland petrel	**0.338**	0.13–0.90	0.006	0.00–0.06
Campbell black-browed albatross	**0.225**	0.11–0.47	0.004	0.00–0.04
Stewart Island shag	**0.222**	0.14–0.35	0.002	0.00–0.04
White-chinned petrel	**0.165**	0.08–0.42	0.002	0.00–0.01
Northern giant petrel	**0.152**	0.03–0.70	0.001	0.00–0.02
Spotted shag	**0.137**	0.07–0.24	0.003	0.00–0.02
Northern royal albatross	**0.126**	0.04–0.40	0.002	0.00–0.02
Snares Cape petrel	**0.072**	0.03–0.20	0.002	0.00–0.02
Grey petrel	**0.059**	0.03–0.12	0.001	0.00–0.01
Southern royal albatross	**0.058**	0.03–0.14	0.001	0.00–0.01
Chatham petrel	**0.052**	0.00–0.27	0	0.00–0.06
Yellow-eyed penguin	**0.028**	0.01–0.11	0.001	0.00–0.01
Light-mantled sooty albatross	**0.021**	0.00–0.12	0	0.00–0.01
Fiordland crested penguin	**0.008**	0.00–0.16	0	0.00–0.01
NZ storm petrel	**0**	0.00–0.23	0	0.00–0.00

to uncertain estimates of annual potential fatalities for Salvin's albatross and New Zealand white-capped albatross in this fishery group, with a mean of 39 (95% c.i.: 0–241) and 48 (95% c.i.: 0–304) annual potential fatalities, respectively. The estimate of annual fatalities contributed to the "low risk" category of Salvin's albatross.

4. DISCUSSION

This study used simulated data to assess the risk rankings derived in the the seabird risk assessment to a reduction in captures. Because complex models with year-to-year variations could not be fitted due to a lack of observations, the change over time was represented as a step change. With this step change, the fishery-related vulnerability took two values, for two successive periods. The timing of the step change could be decided on a per-fishery basis, to correspond with the establishment of "best fishing" practices, vessel management plans, or the use of mitigation devices.

The step change in the vulnerability was successfully modelled, allowing the estimated risk to change with time. We simulated an extreme case of a complete lack of seabird captures, with the same effort and observer coverage as during the fishing years 2010–11 to 2012–13. The risk calculated on the three years with no captures was estimated to be "negligible risk" for almost all of the 70 taxa considered.

Nevertheless, in spite of the absence of captures over the simulated three-year period, four seabird species were found to have high risk rankings, including black petrel, which was still estimated to be at "very high risk", with an upper 95% credible limit of the risk ratio over 2.

The risk ranking of these four species were determined by the large uncertainty in the number of annual potential fatalities. The uncertainty was caused by extremely low observer coverage in fisheries that had

Table 2: Estimates of the fishery-related vulnerability to capture (mean, 95% credible interval), obtained from a time-invariant (Time-invariant) and time-varying model (Step change), fitted to simulated data of fishing for an additional three years, during which no seabird captures are observed. Vulnerabilities for each fishing method were estimated independently and relative to the vulnerability in deepwater trawling, large-vessel bottom longlining, and small-vessel bottom longlining, respectively (set to 1 as the base case)(BLL, bottom longlining; SLL, surface longlining; SBW, southern blue whiting).

Fishery	Time-invariant		Step change			
			Pre change		Post change	
	Mean	95% c.i.	Mean	95% c.i.	Mean	95% c.i.
Small inshore trawl	1.98	0.47–5.44	3.45	0.90–9.07	0.06	0.00–0.42
Large processor trawl	4.59	1.26–11.26	10.10	3.14–24.54	0.02	0.00–0.11
Large meal trawl	4.06	1.12–10.46	8.76	2.52–22.76	0.02	0.00–0.11
Large fresher trawl	0.20	0.02–0.79	0.45	0.03–1.71	0.09	0.00–0.62
SBW trawl	10.24	1.94–32.07	22.07	4.58–68.99	0.20	0.00–1.30
Scampi trawl	6.78	1.82–18.63	13.69	4.07–34.42	0.05	0.00–0.31
Mackerel trawl	1.76	0.42–5.02	4.10	1.07–11.45	0.03	0.00–0.21
Squid trawl	5.52	1.50–14.83	11.90	3.45–30.50	0.01	0.00–0.04
Deepwater trawl	1.00	1.00–1.00	1.00	1.00–1.00	0.05	0.00–0.29
Flatfish trawl	1.21	0.21–4.09	2.56	0.46–8.07	0.05	0.00–0.32
Bluenose BLL	1.41	0.14–5.48	1.94	0.23–7.74	0.11	0.00–0.79
Small BLL	1.64	0.13–6.80	2.81	0.30–11.15	0.09	0.00–0.65
Snapper BLL	0.28	0.02–1.23	0.41	0.04–1.81	0.06	0.00–0.41
Large BLL	1.00	1.00–1.00	1.00	1.00–1.00	0.02	0.00–0.08
Small ling BLL	2.80	0.29–11.74	4.07	0.58–14.75	0.09	0.00–0.67
Large SLL	1.00	1.00–1.00	1.00	1.00–1.00	0.00	0.00–0.02
Small tuna SLL	1.83	0.70–4.07	2.07	0.81–4.65	0.01	0.00–0.06
Small swordfish SLL	3.22	0.99–7.91	4.03	1.35–10.00	0.04	0.00–0.28
Set net		–	1.00	1.00–1.00	0.06	0.00–0.28

substantial overlap with these seabird species. The fisheries involved were predominantly small-vessel bottom-longline and inshore trawl fisheries, which have less than 1% of their effort observed. These fisheries have a high overlap with black petrel, flesh-footed shearwater, Salvin's albatross and Chatham Island albatross. Without sufficient observations, the model cannot reliably predict how many captures occurred, resulting in large uncertainties around the number of potential fatalities and, therefore, in the estimated risk ratio.

4.1 Implications for the seabird risk assessment

Black petrel was recently found to be the species the most at risk from commercial fisheries (Richard & Abraham 2015). Its estimated risk ratio had a median of 11.34 (95% c.i.: 6.85–19.81). The current study showed that part of this risk is associated with low observer coverage. The risk ranking for black petrel remained at "very high risk" even if no observed captures were recorded for three years (at current levels of observer coverage). This finding highlights that, at the recent average level of observer coverage in small-vessel bottom-longline and inshore-trawl fisheries, reductions of captures in these fisheries may not lead to a reduction in the risk ranking of this species. For this reason, the goal of the NPOA may not be achieved, regardless of any decrease in actual capture rates, because our ability to observe and detect any changes in capture rates is poor. The exact relationship between the reduction in capture rate, the reduction in risk ranking, and observer coverage is currently unknown. We recommend that a simulation study is undertaken to determine the level of observer coverage and the reduction in captures that are required to satisfy the NPOA goal that "species currently categorised as at 'very high risk' or 'high risk' from fishing move to a lower category of risk".

Table 3: Summary of total effort, effort observed, percentage of effort observed, total overlap, and percentage of overlap observed for the 10 combinations of species and fishery group with the highest estimated risk ratio (in the three years of simulated data). The units of effort are fishing events, and the effort and overlap data are for the three fishing years 2010–11 to 2012–13(BLL, bottom longlining).

Species	Fishery group	Effort			Overlap	
		Total	Observed	% obs.	Total	% obs.
Black petrel	Snapper BLL	18 403	16	0.09	97	0.08
Black petrel	Bluenose BLL	7 642	32	0.42	93	0.48
Flesh-footed shearwater	Snapper BLL	18 403	16	0.09	2 898	0.25
Black petrel	Small BLL	12 386	123	0.99	33	0.33
Salvin's albatross	Small inshore trawl	118 787	1 033	0.87	3 252	0.62
Chatham Island albatross	Small ling BLL	10 210	94	0.92	137	0.31
NZ white-capped albatross	Small inshore trawl	118 787	1 033	0.87	13 556	0.86
Salvin's albatross	Small ling BLL	10 210	94	0.92	299	1.23
Flesh-footed shearwater	Small BLL	12 386	123	0.99	291	0.92
Black petrel	Small inshore trawl	118 787	1 033	0.87	230	1.61

Table 4: Summary of estimates (and 95% credible interval, c.i.) of vulnerability, annual potential fatalities (APF), and risk ratio for the 10 combinations of species and fishery group with the highest estimated risk ratio, for the three years of simulated data (BLL, bottom longlining).

Species	Fishery group	Vulnerability		APF		Risk ratio	
		Mean	95% c.i.	Mean	95% c.i.	Median	95% c.i.
Black petrel	Snapper BLL	78 753.2	83.0–469 549.4	53	0–321	0.17	0.00–3.34
Black petrel	Bluenose BLL	41 449.0	31.2–264 167.0	27	0–172	0.08	0.00–1.82
Flesh-footed shearwater	Snapper BLL	3 013.0	3.1–17 765.2	61	0–351	0.04	0.00–0.84
Black petrel	Small BLL	43 378.8	31.2–267 411.6	10	0–62	0.03	0.00–0.65
Salvin's albatross	Small inshore trawl	436.6	0.4–2 577.5	39	0–241	0.01	0.00–0.26
Chatham Island albatross	Small ling BLL	2 023.2	1.7–12 784.0	2	0–13	0.00	0.00–0.09
NZ white-capped albatross	Small inshore trawl	128.7	0.1–817.5	48	0–304	0.00	0.00–0.08
Salvin's albatross	Small ling BLL	4 342.6	3.9–28 573.0	9	0–59	0.00	0.00–0.06
Flesh-footed shearwater	Small BLL	1 565.1	1.1–10 284.2	3	0–21	0.00	0.00–0.05
Black petrel	Small inshore trawl	251.3	0.2–1 787.7	1	0–5	0.00	0.00–0.05

5. ACKNOWLEDGMENTS

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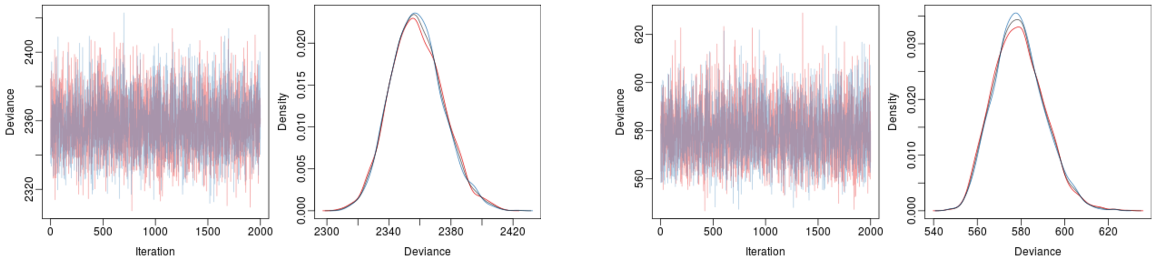
A APPENDIX A:

A.1 Diagnostics of the time-varying vulnerability model

(a) Trawl **(b) BLL**



(c) SLL **(d) SN**

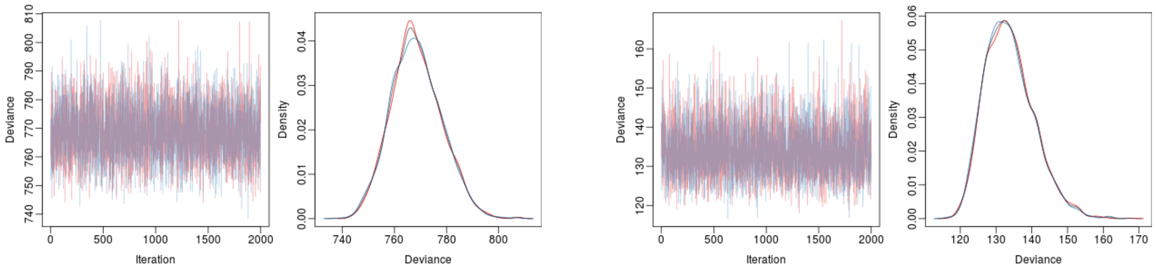


Figure A-1: Trace and posterior distribution of model deviance for each of the four Bayesian models (trawl, bottom-longline, surface-longline, and set-net fisheries) used to estimate the number of observable seabird captures in New Zealand fisheries.

Table A-1: Diagnostics of the four Bayesian models used to estimate the number of observable seabird captures in New Zealand fisheries, including trawl, bottom-longline (BLL), surface-longline (SLL), and set-net (SN) fisheries. Results shown are the Heidelberger & Welch (1983) test applied to each of the four models to assess that Monte Carlo Markov Chain (MCMC) convergence was sufficient. Test results are for each model, including the number of tests that passed or failed for both MCMC chains, or for any chain.

Model	No. parameters	Passed tests		Failed tests		Proportion failed (%)	
		Both chains	Any chain	Both chains	Any chain	Both chains	Any chain
Trawl	342	341	342	0	1	0.00	0.29
BLL	187	182	187	0	5	0.00	2.67
SLL	125	120	125	0	5	0.00	4.00
SN	20	20	20	0	0	0.00	0.00