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Critical re-evaluation of 2023 New Zealand Seabird Risk Assessment estimates of fisheries deaths and risk in key deepwater trawl fisheries, with reference to Southern Buller's albatross, Salvin's albatross, and white-capped albatross

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SUMMARY

The 2023 New Zealand seabird risk assessment (SRA) described in Edwards et al. (2023) suggests that commercial fisheries impacts may be at unsustainable levels for Southern Buller's albatross (and to a lesser extent Salvin's and white-capped albatross), and that deepwater trawl fisheries may be largely responsible for these impacts. Taken at face value, these estimates may raise concerns about Marine Stewardship Council certification of New Zealand deepwater fisheries (e.g. hoki) under environmental standard 3.0 (Marine Stewardship Council 2022); however the published outputs of the 2023 SRA are not sufficient to address these questions. Furthermore the published 2023 SRA estimates of fisheries deaths utilize outdated estimates of 'cryptic mortality' (i.e. unobservable deaths) that have not been subject to critical scrutiny.

In this analysis we utilize the statistical model informing the 2023 SRA to estimate seabird captures summarized by target fisheries more appropriate to the MSC 'units of assessment', with a focus on deepwater trawl fisheries that capture Southern Buller's albatross (i.e. hoki-hake-ling, squid, scampi, and barracuda target fisheries). Next we access never-before-utilized fisheries observer data to revisit the estimation of cryptic mortality and live release survival to produce new estimates of seabird captures, deaths, and population level risk from these trawl fisheries, separately for Southern Buller's albatross, Salvin's albatross, and white-capped albatross.

Our analysis demonstrates that the 2023 SRA (like all previous NZ SRA's) dramatically over-estimates seabird deaths and population level risk in deepwater trawl fisheries, by roughly a factor of 5, arising primarily from a coarse and outdated treatment of cryptic mortality. Applying a sensitivity to illustrate a pessimistic (impact-maximizing) scenario, we estimate that the 2023 SRA still over-estimates cryptic mortality (hence deaths and risk) in deepwater trawl fisheries by roughly a factor of 3.5 for these species.

We identify the following reasons for the magnitude of this error:

i) the authors of the 2023 SRA were not responsible for re-estimating cryptic mortality; instead, the relevant 'cryptic mortality multipliers' have been uncritically carried forward from previous SRA's dating back nearly 15 years, often incorrectly and with inadequate government oversight;

ii) some of the cryptic mortality multipliers utilised in the 2023 SRA derive from studies that are 15-20 years out of date, from fisheries that are not an appropriate proxy for understanding NZ deepwater trawl fisheries in 2024; others derive from subjective decisions that have never been subject to critical scrutiny;

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iii) the 2023 SRA pools data from the full period 2006-2020 to estimate seabird catchability, effectively erasing the effects of substantial changes to fishery operations, including a major focus on developing and implementing seabird capture mitigation, in the period 2006-2015;

iv) the 2023 SRA pools data across all trawl fisheries and does not utilize improved higher-resolution data collected by fisheries observers since 2019; in contrast our analysis is fishery-specific and uses only current, higher-resolution data (2019-2024).

The results of our analysis indicate that (in the period 2019-2024):

- Collectively, the hoki-hake-ling, squid, scampi, barracuda, and southern blue whiting fisheries are responsible for an estimated…
    - …95 Southern Buller's albatross deaths annually, relative to a Population Sustainability Threshold (PST) of 613;
    - …221 Salvin's albatross deaths annually, relative to a PST of 2551;
    - …286 white-capped albatross deaths annually, relative to a PST of 5367;

- Fisheries impacts from NZ deepwater trawl fisheries are not having unsustainable effects on the population status of these three seabird species. We estimate that the cumulative impact of these five deepwater trawl fisheries will reduce the equilibrium population status…
    - … of Southern Buller's albatross by 7.7% relative to unimpacted status;
    - … of Salvin's albatross by 4.3% relative to unimpacted status;
    - … of white-capped albatross by 2.6% relative to unimpacted status;

- Deepwater fisheries are not the highest source of fisheries impact for any of these three seabird species:
    - The greatest impact to Southern Buller's albatross comes from surface longline fisheries, followed by inshore trawl fisheries (noting however that inshore trawl impacts are likely to be substantially overestimated in the 2023 SRA[1]);
    - The greatest impact to Salvin's albatross, by a very wide margin, comes from inshore trawl fisheries (noting the caveat above);
    - The greatest impact to white-capped albatross comes from inshore trawl fisheries (noting the caveat above) followed by surface longline fisheries.

- Even accepting the remainder of the 2023 SRA impact estimates at face value, cumulative impacts across all New Zealand fisheries are unlikely to be unsustainable for any of these three seabird species.

[1] The analysis described in this paper focuses on the identified deepwater trawl fisheries, and does not include inshore trawl fisheries. But until a similar analysis is completed for inshore trawl fisheries, the only fishery-specific estimates that are available are those from the published 2023 SRA results. It is highly likely that the same mechanisms that causes the 2023 SRA to over-estimate cryptic mortality multipliers for deepwater trawl fisheries are also affecting the estimation of total deaths and risk in inshore trawl fisheries. We anticipate that when cryptic mortality is re-estimated for inshore trawl fisheries using the methods we describe in this analysis, the proportion of total fisheries deaths and risk attributable to inshore trawl fisheries will decrease.

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We estimate that, even assuming 2023 SRA estimates for other species are accurate, the cumulative effect of all NZ fisheries impacts will be to reduce the equilibrium population status…

- … of Southern Buller's albatross by 30.4% relative to unimpacted status
- … of Salvin's albatross by 18.2% relative to unimpacted status
- … of white-capped albatross by 14.2% relative to unimpacted status

INTRODUCTION

Since the origins of the Spatially Explicit Fisheries Risk Assessment (SEFRA) method in around 2011, there have been numerous derivations and partial implementations of this statistical method applied to estimate incidental captures and deaths of seabirds. These models and/or the publications summarizing them have been iteratively referred to as 'the' New Zealand Seabird Risk Assessment (SRA) (although there have been a number of different models produced, and the method itself has evolved considerably since its origins; i.e. from Sharp et al. 2011 to Sharp 2019). From around 2014 the NZ SRA has been used to estimate the cumulative population-level impact of incidental fisheries deaths on New Zealand seabirds across all New Zealand commercial fisheries, and also to evaluate the performance of particular New Zealand fisheries against environmental performance targets for seabird bycatch, both internally (e.g. the New Zealand NPOA-Seabirds) and for external assessors (e.g. the Marine Stewardship Council). But the published outputs of SRA models, including the most recent 2023 described in Edwards et al. (2023), are not well suited for the latter purpose, because these publications assess fisheries risk at the scale of the species, or broken down by fishing methods or vessel types, but MSC assessors require credible estimates of seabird deaths corresponding to particular 'units of assessment' (i.e. particular assessed fisheries).

2023 New Zealand SRA estimates of deepwater trawl fishery impacts on Southern Buller's Albatross, Salvin's albatross, white-capped albatross, to inform Marine Stewardship Council certification

The 2023 SRA summarized by Edwards et al. (2023) and supporting documents (Peatman et al. 2023, Edwards et al. 2023b) estimate that cumulative New Zealand fisheries impacts may exceed a 'sustainable' threshold for a single species, Southern Buller's Albatross. In this publication, the Population Sustainability Threshold (PST) is defined such that 'Risk > 1' corresponds to a level of anthropogenic mortality sufficient to reduce the equilibrium population status to less than half of its unimpacted state. The mean risk score for Southern Buller's Albatross in the 2023 SRA is 1.19 (95% CI 0.71 – 2.65). Taken at face value, these published outputs suggest that fisheries impacts on Southern Buller's Albatross may exceed sustainable levels.

Estimated impacts on two additional species, Salvin's albatross and white-capped albatross, are also of concern: estimated risk scores are lower than 1, but the upper bound of the 95% confidence intervals exceed 1: estimated risk for Salvin's albatross = 0.69 (0.35 - 1.69); estimated risk for white-capped albatross = 0.50 (0.29 – 1.07).

In the 2023 SRA, an estimated 71%, 96%, and 90% of total fisheries risk to Southern Buller's Albatross, Salvin's albatross, and white-capped albatross, respectively, is estimated to originate from trawl fisheries. If the estimates are accurate, and if deepwater trawl fisheries are a large proportion of those totals, then

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it is possible that, at least for Southern Buller's albatross, these impacts may be sufficiently high to violate protected species impact thresholds under the MSC standard v3 (Marine Stewardship Council 2023). But the SRA publications do not disaggregate trawl fishery risk by categories that correspond to the MSC units of assessment, so MSC assessors cannot extract the numbers they need from these publications alone.

Disaggregating SEFRA outputs using Risk Atlas

The SEFRA method (Sharp 2019) estimates fishery-seabird interactions, captures, and deaths as a function of the time- and location-specific density of seabirds present at each individual fishing event, summed across all fishing events.

In the first instance, SEFRA model outputs are typically reported at the species or population scale, in order to identify what species are most at risk and what is likely to be the combined population-level effect of all commercial fisheries interactions occurring within the spatial domain of the model (i.e. in this instance the New Zealand EEZ). In the 2023 New Zealand seabird risk assessment (2023 SRA) described in Edwards et al. (2023), estimated captures and population-level risk are also disaggregated and summarized within categories corresponding to different fishing methods (Edwards et al. 2023 tables 17-18), or matching the 'fishery group' categories used by the model to partition the observer data in the estimation of species catchability q_z (Edwards et al. 2023 Table 19). Summaries at the fishery group level are useful to identify what vessel types and gear configurations are more likely to catch birds; for example the outputs in Edwards et al. (2023) indicate that trawl vessels equipped with meal plants catch fewer seabirds than vessels without meal plants.

But the fishery group categories used to define the SEFRA model structure do not correspond to any recognized fishery management or administrative boundaries. Fishery managers, and independent parties evaluating the performance of particular fisheries (e.g. the MSC), require estimates of seabird captures and risk that correspond with the MSC 'units of assessment' or within defined target fisheries, or within particular fisheries management areas (FMAs) defined by Fisheries New Zealand.

Using the Risk Atlas platform (Webber unpublished), we can query SEFRA models and generate customized estimates of seabird captures, deaths, or risk within user-defined subsets of the assessment domain, e.g. to meet the assessment needs of the MSC or of managers focused on the effects of particular fisheries, or in specific locations. SEFRA outputs can be summed or disaggregated at any user-defined scale down to the level of individual fishing events, using any variable that appears in routine event-level fisheries or observer databases.

Note that with Risk Atlas the SEFRA model itself is not re-run: there are no new MCMC's; species catchability is not re-estimated. Instead, Risk Atlas uses the posteriors of the catchability estimates already generated by the SEFRA model (in this case as described in Edwards et al. 2023) and re-applies these to individual fishing events summed within the new user-defined categories. For this reason, the actual model predictions are unchanged (at the scale of the fishing event); but we can query and sum the event-level estimates within differently-defined categories corresponding to spatial or administrative boundaries, for example to meet the needs of the MSC assessors.

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In this analysis we generate estimates of seabird captures summed by fishing method, by FMA, and by target species, to meet the needs of MSC assessors charged with assessing the environmental performance of the defined New Zealand deepwater trawl fisheries. We also update the estimation of seabird cryptic mortality (i.e. unobservable fisheries deaths) in these key deepwater trawl fisheries to generate improved fishery-specific estimates of seabird deaths and population-level risk, using new fisheries observer data not utilized by the 2023 SRA.

Updated protected species interaction (PSI) data collected by FNZ fisheries observers

In 2017-2018, the Fisheries New Zealand Research and Data Management team (RDM) undertook a process to improve the Observer Protected Species Interaction (PSI) Form concurrent with the rollout of electronic data capture tablets for fisheries observers. The new PSI form was designed in consultation with FNZ scientists with responsibility for the protected species research program (including the author of this report), and included new data collection specifically designed to inform improved estimates of seabird cryptic mortality. Relevant extracts of the Observer PSI form are included in Annex D.

The new PSI form was rolled out fully by the beginning of the 2019-2020 fishing year, meaning that we now have available nearly 5 years of fisheries observer data collected for purposes of better characterizing seabird interactions, including cryptic mortality. But to date these data have not been used by Fisheries New Zealand or to update the parameterization of the 2023 SRA described by Edwards et al. (2023). Especially in well-observed fisheries (i.e. deepwater trawl fisheries) there are now sufficient numbers of observed captures to characterize these interactions on a fishery-specific basis, and using only recent data, e.g. to understand the location and nature of the interaction/ capture event and the injury status of the bird. There is no need to pool data across dissimilar fisheries or across the full history of the protected species captures database extending back to 2006 (as was done in the 2023 SRA described in Edwards et al. 2023).

Cryptic mortality

Cryptic mortality refers to seabirds that die as a consequence of their direct interaction with the fishing gear, but are not brought on board the vessel (alive or dead) and do not come into direct contact with the observers or crew; hence these interactions are unobservable: they will not be counted among 'observed captures' even on fully observed fishing events (see Sharp 2019). Cryptic mortality occurs when seabird carcasses are not retained by the fishing gear, or when birds are injured by the gear *without being captured*, and subsequently die of their injuries[2].

[2] Note that this definition of cryptic mortality does NOT include seabirds that are captured and released alive but that subsequently die of their injuries ('post-release deaths'). This narrow definition is consistent with the original SEFRA method publication (Sharp 2019) but diverges from broader definitions used elsewhere (e.g. Gilman et al. 2013). Because the mathematical definition of 'cryptic mortality multipliers' (including values inherited from previous implementations of the SRA and then utilized in the 2023 SRA) require that *cryptic deaths are distinct from and in addition to observed captures*, it is important that the original (narrower) SEFRA definition is retained,

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The single greatest source of uncertainty (and identifiable error) in the SRA described in Edwards et al (2023) arises from untested (and in some instances indefensible) assumptions giving rise to the estimation of cryptic mortality. This is not a criticism of the statistical model or its authors, because *the SEFRA model described by Edwards et al. (2023) does not estimate cryptic mortality at all*. Instead, for the first time (in the sequence of New Zealand seabird risk assessments since 2011) the new SRA model of Edwards et al. (2023) does an effective job of separating cryptic mortality from the statistical model; i.e. the model estimates total observable seabird captures (by fitting to observed captures, as recorded by fisheries observers), and the estimation of seabird deaths (some of which are unobservable, i.e. cryptic) occurs subsequently, outside the model. This is a more defensible modelling approach than fitting to estimated deaths (including cryptic deaths), because it means that the model fit will not be affected by subjective and/or untestable input priors about cryptic mortality, which are highly uncertain.

Because the process of scaling up from observable captures to total deaths now occurs outside the statistical model, this means that the estimation of cryptic mortality can occur separately on an appropriate taxon- and fishery-specific basis, unconstrained by model structure choices applied inside the SRA. However, that was not done as part of the 2023 SRA: estimating fishery-specific and up-to-date cryptic multipliers was not part of the contract to deliver the new SRA described in Edwards et al. (2023); instead, the various structural assumptions and rate estimates that had been applied to estimate cryptic mortality in previous SRA models were 'carried forward' and re-applied to the outputs of the model described in Edwards et al. (2023), without critical scrutiny.

In February 2024 FNZ held a half-day workshop to discuss the estimation of seabird cryptic mortality. FNZ acknowledged that new work to update the estimation of cryptic mortality -- including at improved taxon- and fishery-specific resolution wherever possible -- is a priority, and recommended improved data collection. In the analyses below we deliver on that identified priority, and in doing so we demonstrate that considerable improvements are possible now (including for species and/or fisheries other than those presented here) using currently available data and existing analytical tools.

A recently published FNZ project by Meyer (2023), 'Desktop update of estimation of seabird cryptic mortality in trawls, via warp and net captures in the New Zealand domestic fleet using standard mitigation' (AEBAR #322) had intended to address the acknowledged problems with the way cryptic mortality multipliers are derived and applied in trawl fisheries, but the outputs of that project were not available in time for adoption into the 2023 SRA model by Edwards et al. (2023), and the potential for that study was only partially realized. The modelling approach -- whereby the fate of individual birds interacting with fishing gear is tracked via a transition matrix and each transition probability is estimated either empirically (fitting to observed captures data for all bird fates that are observable) or subjectively (from input priors) – is ideal, having been devised for precisely this purpose. But the structure of the transition matrix in Meyer (2023), and the choice of input priors (for subjectively estimated probabilities) or the use of data (for empirically estimated transitions) should ideally be informed by expert input from people with operational knowledge of gear configuration and mitigation use in the different fisheries, and of how birds

to prevent post-release deaths from being double-counted. We note further that it is unclear from the published outputs describing the 2023 SRA which definition was implemented by Edwards et al. (2023). In the outputs from this analysis we are careful to distinguish between cryptic deaths and post-release deaths, to avoid further confusion.

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interact with the gear. Statisticians working in isolation cannot be expected to understand the differences between how every bird species interacts with every fishery; this kind of knowledge is best elicited in a scientific working group or workshop setting, as was done successfully to estimate sea lion cryptic mortality in trawls employing SLEDS (Meyer 2019).

Below we apply the transition matrix modelling approach of Meyer (2023) to estimate the fate of seabird interactions with trawl gear, using an updated transition matrix consistent with improved fisheries observer data collected since 2019. We perform this analysis separately for each of the following deepwater trawl fisheries:

- The hoki-hake-ling target fishery (HHL)
- The arrow squid target fishery (SQU)
- The scampi target fishery (SCI)
- The barracuda target fishery (BAR)

Collectively, these target fisheries are responsible for the large majority of Southern Buller's albatross captures in trawl fisheries, as estimated in the 2023 SRA. We subsequently expand the analysis to also include two additional species for which the 2023 SRA estimates high or medium fisheries risk with a substantial portion of that risk attributed to deepwater trawl species, i.e. Salvin's albatross and white-capped albatross.

The main body of this report refers primarily to Southern Buller's albatross. Results for Salvin's albatross and white-capped albatross were obtained using identical methods, and are presented in appendices, following the same sequence and format as the Southern Buller's albatross outputs described in the main report body.

METHODS AND RESULTS

Below we examine the breakdown of estimated commercial fisheries captures for Southern Buller's albatross among different summary categories. These figures were obtained using the Risk Atlas interface to query the outputs of the 2023 SRA model described in Edwards et al. (2023). Note that for purposes of the analysis described in this paper below we utilize only the estimated *total observable captures* from the 2023 SRA; the subsequent breakdown of *live vs dead captures*, and the conversion of *observable captures* to *total deaths* (including cryptic deaths) are re-estimated in the course of this analysis, using more appropriate data, as described below. Deaths estimates as extracted from the 2023 SRA and included in Tables 1-3 (grey shaded columns) are provided for comparison only, noting that our subsequent analysis demonstrates that these 2023 SRA deaths estimates are not credible.

Southern Buller's albatross estimated annual captures

Estimated annual captures by fishing method.

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At the coarsest level, it is apparent that an estimated 63% of all New Zealand commercial fishery captures of Southern Buller's Albatross occur in surface longline fisheries. (152 of 242 estimated captures annually). Trawl fisheries collectively account for an estimated 33% of commercial fishery captures (79 of 242 estimated captures annually).

Table 1: Southern Buller's albatross estimated annual captures, by fishing method, extracted from the model described in the 2023 New Zealand Seabird Risk Assessment (Edwards et al. 2023)

fishing method	Captures	live captures*	dead captures*	2023 SRA deaths*
surface longline	152.5	19.1	133.4	198.4
trawl	78.8	24.6	54.2	516.9
bottom longline	10.6	2.1	8.5	13.2
setnet	0.4	0.1	0.2	0.3
Grand Total	**242.3**	**46.0**	**196.4**	**728.8**

* the breakdown of live vs. dead captures, and total deaths, are re-estimated below

Note also that 242 estimated annual captures across all fisheries is much lower than the mean estimated Population Sustainability Threshold (PST) for Southern Buller's albatross, which is 613 (Table 15 of Edwards et al. 2023). The much higher risk score in the 2023 SRA of Edwards et al. (2023), and the much higher proportion of that risk attributed to trawl fisheries rather than surface longline fisheries, reflect the influence of very high cryptic mortality multipliers applied to trawl fishery captures. But these cryptic mortality multipliers are demonstrably inaccurate, having been derived from overseas proxy studies, sparse datasets, and uninformed assumptions in a process that is now nearly 15 years out of date (see below).

For this analysis we begin by querying the outputs of the Edwards et al. (2023) model to estimate *annual observable captures* of Southern Buller's albatross within categories that are useful to the MSC assessment process, i.e. by target fishery. *Estimated annual captures* are the actual outputs of the Edwards et al. (2023) statistical model; estimated *deaths* in 2023 SRA publication are a product of the observable captures multiplied by *cryptic mortality multipliers*, which were in large part not re-estimated as part of that project. The translation of estimated captures into deaths occurs outside the Edwards et al. (2023) statistical model and does not affect model fit.

Estimated annual trawl captures, by target species

When summarized by fishery target species, most Southern Buller's albatross trawl fishery captures are estimated to occur in hoki target fisheries (33%), followed by squid (30%), scampi (13%), and barracuda (8.5%) target fisheries (Table 2). Captures in these fisheries are well estimated (i.e. with relatively low uncertainty) based on quality data, reflecting high observer coverage. A relatively minor proportion of estimated captures occur in ling and hake target trawl fisheries, but these targets are included in Table 2 because the HOK-HAK-LIN target fisheries typically involve the same fleet fishing in the same areas, and are in some contexts assessed as a single unit. Southern blue whiting fisheries account for a negligible portion of captures, but are summarized separately here to meet the needs of the MSC assessment

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process for deepwater fisheries. All other deepwater and midwater target trawl fisheries, and inshore target trawl fisheries, collectively account for only 10 estimated captures per year, and are not summarized separately.

Table 2: Southern Buller's albatross estimated annual trawl fishery captures, by target fishery, extracted from the 20203 SRA model of Edwards et al. (2023)

Fishery target	Captures	live captures*	dead captures*	2023 SRA deaths*
HOK	26.0	7.5	18.5	169.5
SQU	23.6	8.5	15.1	154.9
SCI	10.2	2.2	8.0	67.7
BAR	6.7	2.1	4.6	43.6
LIN	1.9	0.6	1.3	12.7
HAK	0.4	0.1	0.3	2.3
SBW	0.1	0.0	0.0	0.4
All other trawl	10.1	3.6	6.4	65.7
Grand Total	**78.8**	**24.6**	**54.2**	**516.9**

* the breakdown of live vs. dead captures, and total deaths, are re-estimated below

Estimated annual captures in the hoki-hake-ling fishery, by management area

Spatially, the highest proportion of estimated Southern Buller's albatross captures in the HHL fisheries occur in FMA7 (west coast South Island) followed by FMA3 (east coast South Island) and FMA4 (Subantarctic Islands/ Campbell Plateau) (Table 3).

Table 3: Southern Buller's albatross estimated annual captures in HOK-HAK-LIN target fisheries, by FMA, extracted from the model of Edwards et al. (2023)

Fishery Management Area	Captures	live captures	dead captures	2023 SRA deaths*
FMA1	0.0	0.0	0.0	0.0
FMA2	0.2	0.1	0.1	1.1
FMA3	6.5	1.9	4.6	42.7
FMA4	0.1	0.0	0.1	1.0
FMA5	6.4	1.8	4.5	41.6
FMA6	3.8	1.1	2.7	25.2
FMA7	11.2	3.2	8.0	73.1
FMA9	0.0	0.0	0.0	0.0
Total	**28.2**	**8.2**	**20.1**	**184.6**

* the breakdown of live vs. dead captures, and total deaths, are re-estimated below

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Detailed characterization of large seabird interaction fates, using current fisheries observer data

In the analyses that follow, we characterize Protected Species Interactions using data from the updated PSI form including seasons 2019/20 – 2023/24 (i.e. 5 years; MPI data extract received May 2024).

To increase the number of available captures, and reflecting the assumption that seabirds of similar size and physiology will be affected similarly by contrasts in fishing practices and/or mitigation between different target fisheries, the breakdown of captures data between different capture types/locations are pooled for all 'large seabirds' (albatrosses and mollymawks, plus giant petrels). This is the same convention applied in the 2023 SRA described in Edwards et al. (2023, see that reference Table 1).

To reflect fishery-specific contrasts in fishing practices and mitigation uptake affecting seabird interactions, we summarise observed captures separately for each of the following target fisheries which account for the major portion of trawl risk to southern Buller's albatrosses:

- HOK-HAK-LIN (HHL)
- SQU
- SCI
- BAR

To reflect known changes in trawl fishing practice, gear configuration, and mitigation uptake (including offal discard practices) in the decade of roughly 2006-2015, and to take advantage of the improved resolution of the available data since the update of the Observer PSI form in 2019, we pool captures data across fishing years from 2019/20 to 2023/24, and take this 5-year time period to be representative of 'current' fishing practice affecting seabird captures and cryptic deaths.

In Table 4 we summarize observed captures by location of capture (on the gear) and seabird injury status, as recorded by fisheries observers on the updated (in 2019) Protected Species Interaction form. A copy of the relevant data categories and observer instructions is appended in Annex D.

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Table 4: Location of capture and end life status for observed large seabird captures, 2019/20-2023/24, by target fishery, from updated fisheries observer PSI forms

Fishery target	HOK-HAK-LIN	SQU	SCI	BAR
warp captures	**28**	**47**	**10**	**3**
proportion on warp	0.155	0.167	0.323	0.069
± 95% CI	± 0.044	± 0.037	± 0.138	± 0.006
internal net captures	**54**	**61**	**9**	**2**
- released alive uninjured	2	6	0	0
- released injured or status unknown	1	2	1	0
- dead	51	53	8	2
external net captures	**75**	**138**	**0**	**27**
- released alive uninjured	26	56	0	5
- released injured or status unknown	6	8	0	3
- dead	43	74	0	10
other captures	**24**	**35**	**10**	**8**
- released alive uninjured	13	22	4	2
- released injured or status unknown	0	3	2	1
- dead	11	10	4	5
total	**181**	**281**	**29**	**40**

Updated transition matrix for large seabird interactions with deepwater trawl fisheries

Following the methods of Meyer (2023) and applying the same software, we modified the transition matrix for seabird interactions with trawl fisheries to reflect the categories of observed interactions and seabird outcomes (termed 'fates') that are reflected in the updated Fisheries Observer PSI data collection categories and summarized in Table 4. The updated transition matrix is shown below in Figure 1.

Boxes represent interim or terminal states (occupied by integer numbers of seabirds); arrows represent transitions, where all possible transition probabilities away from a given state sum to 1. The final status of seabirds having passed through the transition matrix (i.e. terminal boxes at the right) are termed 'fates'.

Fates or interim states that correspond to classes of observable capture, which can therefore be estimated directly from the fisheries observer data, are colored yellow. Other terminal fates rely on transitions subsequent to the observable state (i.e. post-capture transition processes) so the estimated probabilities

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and numbers of birds occupying those terminal fates will reflect Bayesian priors assigned on the basis of logic or expert knowledge.

Live released and surviving birds are colored green; live released birds that die subsequently of their injuries are colored orange; cryptic deaths are colored red[3]. Fate boxes in blue denote surviving birds that are never classed as captures (i.e. non-fatal warp contacts).

Two major changes are immediately apparent relative to the transition matrix used by Meyer (2023).

First, the updated matrix includes captures data for three categories of interaction rather than two, i.e. 'net interactions', 'warp interactions', and 'other interactions'. The new 'other' category includes birds that become entangled in mitigation gear (e.g. bird bafflers, tori lines) or other parts of the fishing gear besides the net or warp (e.g. lazy line or paravane, or other unspecified location). But most significantly this category also includes seabirds recorded as 'brought on board' (code B in the PSI form extracts reproduced in Annex D). The description of this category for observers reads "*use this code for when an animal is brought on board the vessel and released by the crew but was not tangled in commercial fishing gear, e.g. animals 'riding' the cod end).*" As can be expected, the vast majority of birds coded 'B' are also coded 'released alive and uninjured' and these birds can be expected to have a very high survival rate, not having been physically entangled in any part of the gear.

Second, the updated matrix includes separate transitions for birds classed as having different levels of injury, allowing us to estimate survival rates that reflect the actual injury status of birds as recorded by the observers in each particular fishery. Previous treatments of cryptic mortality in every New Zealand SRA have applied the same estimate of post-release survival to all live-released birds across all fisheries, without reference to capture location, injury status, or fishery-specific observer data.

Input parameterisation of subjectively estimated transition probabilities

For those transitions that are subsequent to observable states and therefore reflect only imposed priors (purple arrows in Figure 1), the choice of priors is shown in Table 6 below. Input parameterization of these priors is justified as follows:

Live release survival as a function of recorded 'end status'

Observers assign live released seabirds to one of three 'end status' categories to reflect their subjectively judged likelihood of survival:

- 'Returned alive and uninjured', (**q8, q11, r4**)
- 'Returned alive and injured', **(q9, q12, r5**)
- 'Returned alive but unlikely to survive', (N/A)

[3] Note that seabirds that die post-release are NOT classed as cryptic deaths because they have already been counted among observed captures; captures and cryptic deaths are mutually exclusive categories. There was terminological confusion on this point between Edwards et al. (2023) and the original SEFRA method description (Sharp 2019). See discussion, below.

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Logically, any bird judged to have a likelihood of survival lower than 50% should be assigned to the latter 'unlikely to survive' category; this implies that the mean survival in the 'alive and injured' state should be 50% or greater. On that basis we assigned the mean survival probability for the 'alive and injured' state as 0.50 (the most pessimistic assumption) but with a very high uncertainty (0.2 – 0.8) reflecting that some observers may be unwilling to guess, therefore this category could include birds across a wide range of actual injury severity.

The 'alive and uninjured' status was assigned mean survival 80% with higher certainty (0.65-0.95) noting that there are detailed observer codes for reporting even minor injuries, and this category includes birds not literally captured in the gear but merely 'brought on board' (Code B) e.g. birds that are 'riding the codend' and assisted by crew off of the vessel. (Note the technical definition of 'capture' includes any bird that makes physical contact with a crew member in the course of being released).

For symmetry then the 'unlikely to survive' category was assigned a very pessimistic likelihood of survival (mean 0.20, range 0.05-0.35); but as there were very few birds assigned to this end status, in the run stage, in order to simplify the model structure, these birds were considered already dead (a pessimistic assumption but one that had minimal impact on the results).

Carcass non-retention leading to cryptic death

The likelihood that seabird carcass may be lost before they can be counted by observers is by necessity estimated subjectively, from first principles.

Net interactions:

- For seabirds that die inside the net, the likelihood that the carcass may be lost before it can be observed is judged to be very low (mean carcass retention rate 0.90, **q10**): under normal net operations hydraulic forces keep objects inside the net, and seabird carcasses are too large pass through the meshes.
- For seabirds that die on the outside of the net, the likelihood that the carcass may be lost is judged to be higher than for internal interactions, but still lower than the likelihood of the carcass being retained (mean retention rate 0.75, **q13**). This reflects the observation that under normal operations the net meshes, once tightened, do not loosen again until the net is on the deck, so a bird entrapped by closing meshes is unlikely to fall out once it is dead. Observers and crew do not commonly report finding bird feet in the meshes unattached to bodies. Unlike longline fisheries, trawl fisheries do not typically catch birds on the setting of the gear, only on the haul, so there is minimal opportunity for an entangled carcass to be lost during the course of an extended fishing event.

Other interactions:

- Because this category includes a wide range of possible interaction types, including those for which the capture location is unspecified, we apply a relatively low and highly uncertain carcass retention rate (0.5, range 0.2-0.8, **r6**). This implies that at the lower bound of retention only 1 in 5 deaths results in an observable dead capture.

Warp interactions:

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Following terminology and assumptions laid out in the original formulation of the SEFRA method for seabirds (Sharp et al 2011, Sharp 2019) a 'surface warp strike' is when a seabird resting or hovering on the water, often with its wings spread, is contacted by a moving warp. In contrast, an 'aerial warp strike' is when seabird flying above the water hits the warp with its own forward momentum (noting that the warp may also be moving or pitching simultaneously). Surface warp strikes may entangle birds in the warp and drag then underwater where they drown; observable captures occur if the carcass is impaled on a sprag or sufficiently entangled in the warp or trawl block to be retrieved upon hauling. In contrast, aerial strikes may be fatal if they are of sufficient force to break a bird's wing, but they do not typically result in observable captures (i.e. all aerial warp strike deaths are cryptic).

Deaths arising from warp interactions are certainly the most difficult to estimate empirically, and are the greatest source of uncertainty in the estimation of trawl fishery cryptic mortality rates. The most recent rigorous treatment of cryptic mortality potentially arising from trawl warp interactions in New Zealand fisheries is as published in Meyer (2023). It was originally intended that the outputs of this project would inform the input parameterization of the cryptic multipliers applied to outputs of the 2023 SRA model, but this did not occur due to lack of time before the publication of the Edwards et al. (2023) project was finalized.

To estimate warp interaction probabilities, we apply the base case assumptions of Meyer (2023), who in turn relied upon New Zealand observer data and data published in Parker (2013).

- **s1** -- proportion of warp interactions that are surface strikes (as opposed to aerial strikes): here Meyer (2023) apply New Zealand observer data dedicated to observing warp strikes. The author notes that these data were sparse but the estimate (0.79) closely matches the conclusions of Parker (2013), that most warp interactions are surface strikes.
- **s2** -- proportion of aerial strikes that are fatal: following Meyer (2023) we apply low estimate of aerial strike fatality rate (mean .007), originally from Graham Parker (pers comm)
- **s3** – we apply a relatively pessimistic sensitivity from Meyer (2023) who in turn cites data from Parker (2013) to estimate the proportion of surface strikes that are ultimately fatal (mean .056)

We acknowledge that the source data giving rise to these estimates (Parker (2013) is itself an imperfect (and dated) proxy for New Zealand deepwater fisheries; however it is valuable to note that in the particular case of large seabird interactions with New Zealand deepwater fisheries, a*ctual estimates of captures, deaths, and risk are highly insensitive to these three transition parameters.* Studying Figure 1 reveals the reason: because trawl warp captures are anchored to actual data, (*C_warp_dead)*, the assumption of what *proportion* of surface warp strikes are lethal (rate **s3**) is somewhat immaterial: changing this rate mostly only changes the assumed number of birds that interact with the warp but survive. The only leverage that rate **s3** wields to affect estimated deaths is that it affects the number of assumed aerial strikes (which are calculated as a proportion of the total warp interactions, i.e. **1-s1**); but because the number of aerial strike deaths is extremely low (base case estimate for Southern Buller's albatross = 1 death; see below), even major changes in the relevant rates **s1, s2** and **s3** will have only a minor influence on the outcome in terms of total numbers of deaths.

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It follows that the rate that truly matters in the estimation of warp strike deaths is **s4,** the proportion of fatal surface warp strikes that are retained and observable to be counted as captures; as this 'carcass retention rate' drops, it has an inverse multiplier effect on the estimated number of cryptic deaths.

To illustrate this dependency, and to explore the range of plausible values for the **s4** parameter, we produced a base case estimate and two different sensitivities, applying a higher or lower prior to the surface warp strike carcass retention probability. The base case and both sensitivities utilise the same observations published in Parker (2013), shown here in Table 5, but interpreted differently (i.e. applying more or less pessimistic assumptions about which observations should be counted as a seabird death).

Table 5 Observations of warp interactions and seabird fate republished from Parker (2013) and utilized by Meyer (2023) and in this analysis in the estimation of warp interaction transition probabilities

	Day (n=7)	Station number (n=13)	Dead	Broken wing	Suspected Death	Possible Death	Unknown outcome
Patrol vessel	2	2	1	–	2	1	–
	5	9	1	–	–	–	–
	7	13	–	1	–	–	–
Trawl vessel	2	2	6 (in corpse catcher)	–	–	–	8
	5	9	1	–	–	–	4
	7	13	3	–	–	–	19
	Total		6 (12)	1	2	1	31

The s4 sensitivities are described as follows:

- **S4base** – Reflecting the advice of the relevant Fisheries New Zealand scientific working group (pers comm). Meyer (2023) adopted a relatively pessimistic interpretation of Parker (2013) data, whereby seabirds classed by the following patrol vessel as 'dead', 'broken wing', 'suspected death' and 'possible death' are all considered to have died, i.e. these are all cryptic deaths. Observed captures on board the trawl capture using the corpse catcher device were not included among observable captures, because this device is not used on New Zealand trawl fishing vessels.

  This sensitivity essentially assumes that 4 of 10 seabird deaths were observable (noting however that Meyer (2023) fitted each observation day as a separate event, rather than fitting to all days

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simultaneously). Under these assumptions Meyer (2023) estimated that 35.8% (14.1 – 61.3%) of fatal surface strike deaths result in an observable capture. We apply this as our base case estimate.

- **S4strict**—We also applied a strict (and more optimistic) interpretation of the Parker (2013) data, under which only birds classed as 'dead' and 'broken wing' were considered to be cryptic deaths, such that 4 out of 7 deaths were observable. Under these assumptions we estimated that 57.5% (36.8 – 77.6%) of fatal surface strike deaths result in an observable capture.

- **S4pessimistic–** In addition, we applied a sensitivity under which all six corpse catcher deaths are counted among cryptic deaths, as if without the corpse catcher all six birds would nonetheless have died, but none of the six carcasses would have been retained and observable. We do this to illustrate the extent to which total trawl fishery deaths and risk is sensitive to this single **s4** parameter, and to bound the most extreme (highest impact) scenario that would be possible for the number of seabird deaths observed or inferred by the Parker (2013) study (i.e. 4 observed deaths out of 16 total deaths). We note however that there is no basis to assume that 0 of 6 carcasses in the same day would have been retained in the absence of the corpse catcher; the scenario is provided for illustrative purposes only, and may exceed the plausible upper bound in the estimation of cryptic mortality arising from trawl interactions.

The **s4** priors were estimated in JAGS by fitting a binomial model to the number of observable deaths and total deaths, separately for each observation in the dataset (i.e, day and station combined) as described in Meyer (2023). (Note that the six corpse catcher deaths in the **s4pessimistic** sensitivity were not assigned a unique time step).

The cryptic mortality transition matrix software described in Meyer (2023) was then run twelve times: once for each of four deepwater target fisheries, for the s4 base case and both the strict and the pessimistic s4 sensitivities. The updated transition matrix (Fig.1) was used, parameterized using priors as shown in Table 6, and fitted to captures data corresponding to different observable interaction fates as shown in Table 4.

Estimated transition probabilities and cryptic mortality multipliers

Results are summarized in Tables 7 and 8, for the base case and pessimistic s4 sensitivity, respectively.

Noting that MSC assessors are likely to be more interested in the best guess and in the pessimistic upper bound estimate of seabird deaths and risk than in the most optimistic estimate, full results for the **s4strict** sensitivity are not shown. In summary, the **s4strict** sensitivity yielded the following cryptic mortality multipliers (deaths/captures):

- HHL: cryptic multiplier = 0.921;
- SQU: cryptic multiplier = 0.802;
- SCI: cryptic multiplier = 0.941
- BAR: cryptic multiplier = 0.768

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That the cryptic multipliers are estimated to be less than 1 indicates that if the warp carcass retention rate **s4** is this high, then total deaths are lower than total captures, due to live release survival.

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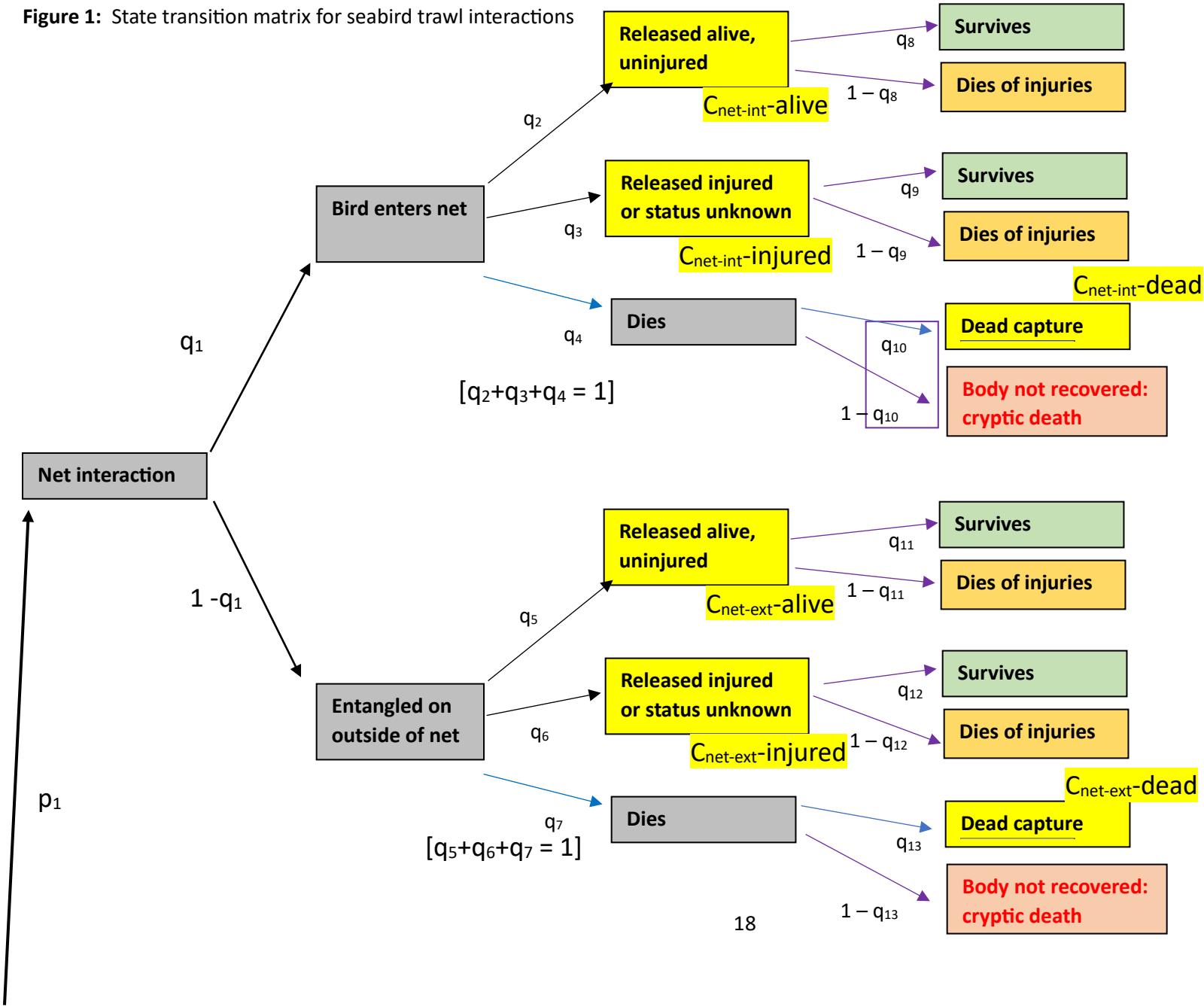
Figure 1: State transition matrix for seabird trawl interactions



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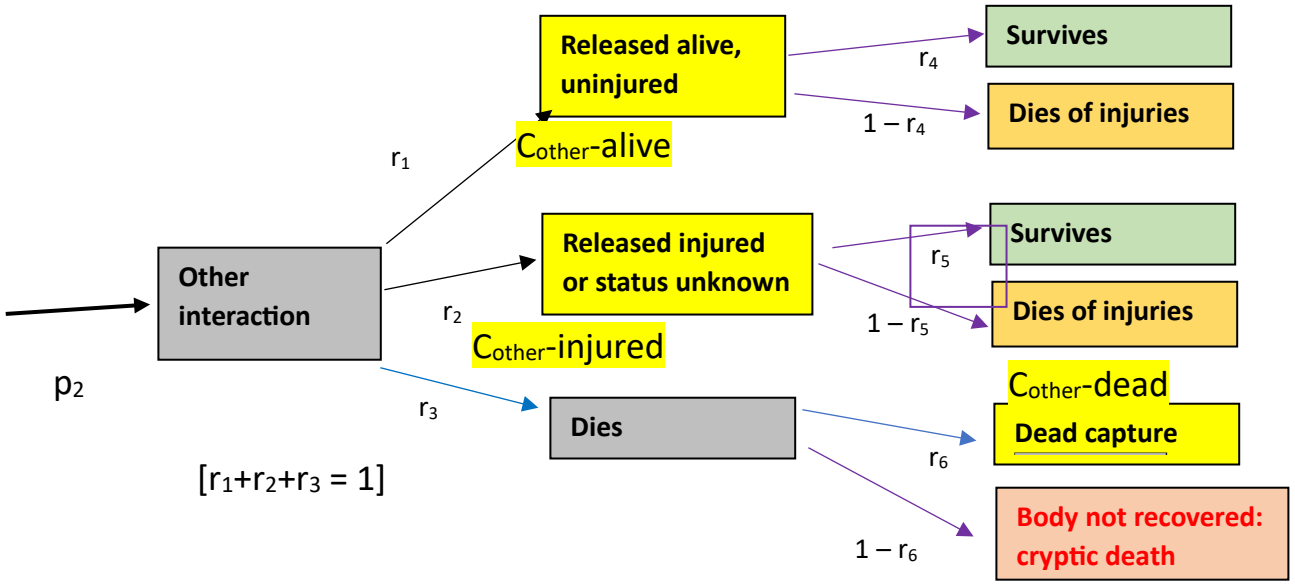

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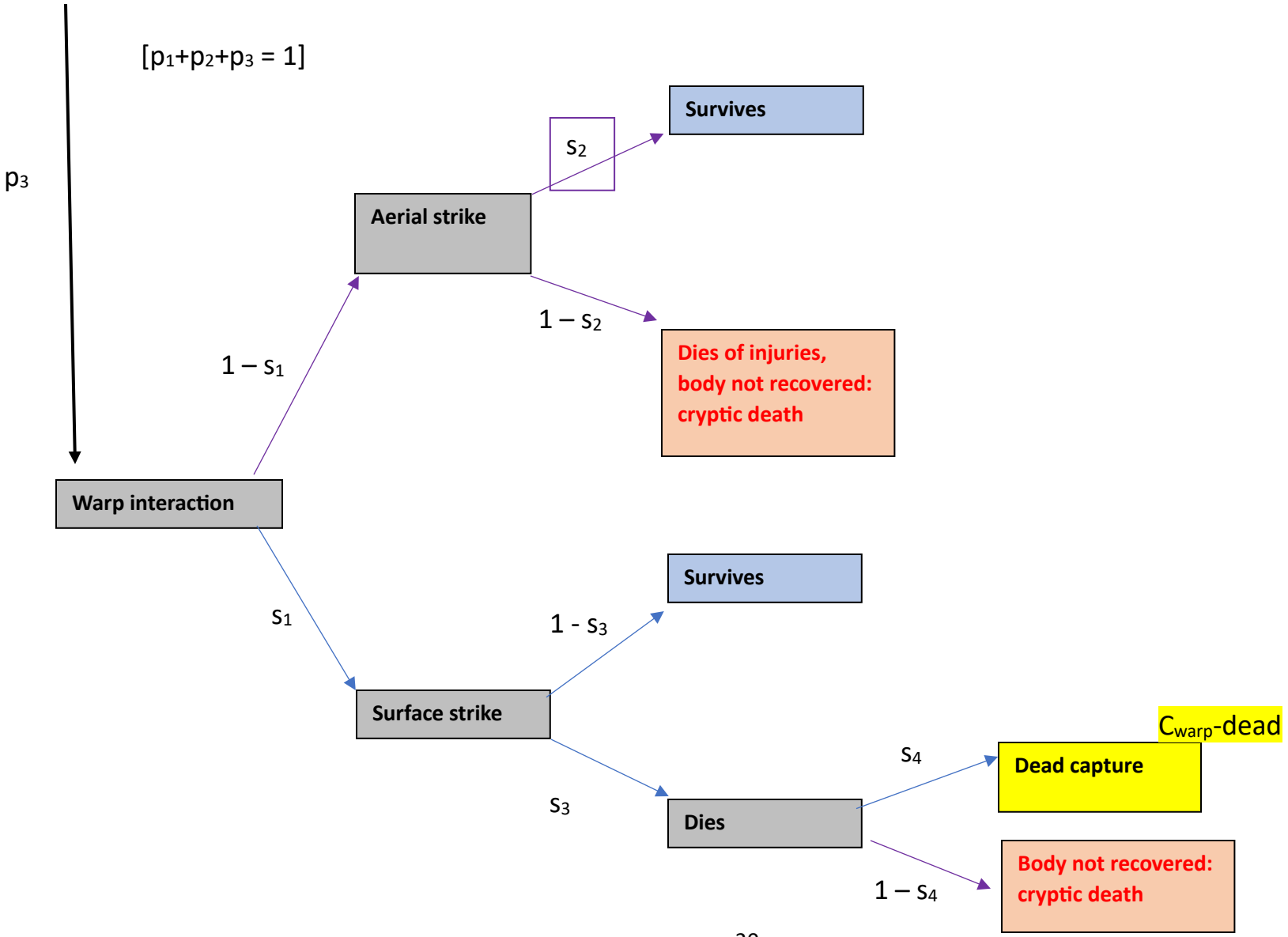

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Table 6. Cryptic mortality transition matrix probability terms, including input priors and sources

		prior mean	shape and range (or 95% CI for lognormal)	source of prior or estimate
All interactions				
p1	prop. net interactions	-		estimated from captures data
p2	prop. other interactions	-		estimated from captures data
p3	prop. warp interactions	-		estimated from captures data
Net interactions		-		
q1	prop. net interactions internal to net	-		estimated from captures data
q2	internal: captured alive, released uninjured	-		estimated from captures data
q3	internal: captured alive, released injured	-		estimated from captures data
q4	internal: dead in net	-		estimated from captures data
q5	external: captured alive, released uninjured	-		estimated from captures data
q6	external: captured alive, released injured	-		estimated from captures data
q7	external: dead on net	-		estimated from captures data
q8	internal: uninjured release survives	0.8	0.65-0.95 uniform	[this paper]
q9	internal: injured release survives	0.5	0.2-0.8 uniform	[this paper]
q10	internal: dead carcass retained	0.9	0.8-1.0 uniform	[this paper]
q11	external: uninjured release survives	0.8	0.65-0.95 uniform	[this paper]
q12	external: injured release survives	0.5	0.2-0.8 uniform	[this paper]
q13	external: dead carcass retained	0.75	0.55-0.95 uniform	[this paper]
other interactions				
r1	other interaction: alive, released uninjured	-		estimated from captures data
r2	other interaction: alive, released injured	-		estimated from captures data
r3	other interaction: dead	-		estimated from captures data
r4	other interaction: uninjured release survives	0.8	0.65-0.95 uniform	[this paper]
r5	other interaction: injured release survives	0.5	0.2-0.8 uniform	[this paper]
r6	other interaction: dead carcass retained	0.5	0.25-0.75 uniform	[this paper]

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warp interactions

s1	warp interaction: prop. surface strike	0.787	normal on logit scale (0.623-0.915)	Meyer 2023, from Mitigation Assessment Warp-Strike Form
s2	aerial strike: dies	0.007	lognormal (0.005-0.01)	Meyer 2023 citing Parker pers. comm.
s3	surface strike: dies	0.056	normal on logit scale (0.033-0.084)	Meyer 2023 citing Parker 2013
s4_base	fatal surface strike: carcass retained	0.358	normal on logit scale (0.141-0.613)	Meyer 2023 citing Parker 2013
s4_strict	fatal surface strike: carcass retained	0.570	normal on logit scale (0.386-0.778)	this paper, citing Parker 2013
s4_pessimistic	fatal surface strike: carcass retained	0.277	normal on logit scale (0.102-0.495)	this paper, citing Parker 2013

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Table 7. Large seabird interaction transition matrix probability estimates under base case s4 scenario

		prior mean	mean estimate			
all interactions			HHL	SQU	SCI	BAR
p1	prop. net interactions	-	0.112	0.160	0.014	0.026
p2	prop. other interactions	-	0.033	0.046	0.013	0.012
p3	prop. warp interactions	-	0.854	0.794	0.973	0.962
net interactions		-				
q1	prop. net interactions internal to net	-	0.525	0.417	0.939	0.127
q2	internal: captured alive, released uninjured	-	0.077	0.121	0.157	0.275
q3	internal: captured alive, released injured	-	0.064	0.069	0.218	0.280
q4	internal: dead in net	-	0.859	0.810	0.625	0.445
q5	external: captured alive, released uninjured	-	0.515	0.616	0.337	0.304
q6	external: captured alive, released injured	-	0.137	0.100	0.336	0.212
q7	external: dead on net	-	0.347	0.284	0.328	0.484
q8	internal: uninjured release survives	0.8	0.800	0.800	0.799	0.800
q9	internal: injured release survives	0.5	0.500	0.500	0.501	0.501
q10	internal: dead carcass retained	0.9	0.917	0.914	0.903	0.903
q11	external: uninjured release survives	0.8	0.800	0.801	0.800	0.800
q12	external: injured release survives	0.5	0.500	0.501	0.501	0.501
q13	external: dead carcass retained	0.75	0.785	0.787	0.739	0.779
other interactions						
r1	other interaction: alive, released uninjured	-	0.424	0.500	0.341	0.262
r2	other interaction: alive, released injured	-	0.068	0.101	0.220	0.196
r3	other interaction: dead	-	0.508	0.400	0.439	0.542
r4	other interaction: uninjured release survives	0.8	0.800	0.801	0.800	0.800
r5	other interaction: injured release survives	0.5	0.498	0.498	0.500	0.501
r6	other interaction: dead carcass retained	0.5	0.571	0.532	0.545	0.562
warp interactions						
s1	warp interaction: prop. surface strike	0.787	0.758	0.769	0.728	0.703
s2	aerial strike: dies	0.007	0.007	0.007	0.007	0.007
s3	surface strike: dies	0.056	0.161	0.255	0.079	0.035
s4_base	fatal surface strike: carcass retained	0.358	0.432	0.448	0.374	0.327
cryptic mortality multiplier (D/C)			**1.283**	**1.182**	**2.119**	**1.350**

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Table 8. Seabird interaction transition matrix probability estimates under pessimistic s4 sensitivity

		prior mean	mean estimate			
all interactions			HHL	SQU	SCI	BAR
p1	prop. net interactions	-	0.112	0.160	0.014	0.026
p2	prop. other interactions	-	0.033	0.046	0.013	0.012
p3	prop. warp interactions	-	0.854	0.794	0.973	0.962
net interactions		-				
q1	prop. net interactions internal to net	-	0.525	0.415	0.938	0.127
q2	internal: captured alive, released uninjured	-	0.078	0.121	0.157	0.280
q3	internal: captured alive, released injured	-	0.063	0.069	0.221	0.276
q4	internal: dead in net	-	0.859	0.809	0.622	0.445
q5	external: captured alive, released uninjured	-	0.516	0.613	0.336	0.302
q6	external: captured alive, released injured	-	0.138	0.099	0.336	0.212
q7	external: dead on net	-	0.346	0.288	0.328	0.485
q8	internal: uninjured release survives	0.8	0.800	0.801	0.801	0.800
q9	internal: injured release survives	0.5	0.500	0.499	0.499	0.501
q10	internal: dead carcass retained	0.9	0.917	0.916	0.903	0.902
q11	external: uninjured release survives	0.8	0.800	0.800	0.800	0.800
q12	external: injured release survives	0.5	0.499	0.501	0.500	0.499
q13	external: dead carcass retained	0.75	0.786	0.785	0.740	0.779
other interactions						
r1	other interaction: alive, released uninjured	-	0.424	0.500	0.341	0.262
r2	other interaction: alive, released injured	-	0.069	0.102	0.219	0.197
r3	other interaction: dead	-	0.507	0.399	0.440	0.541
r4	other interaction: uninjured release survives	0.8	0.800	0.800	0.800	0.800
r5	other interaction: injured release survives	0.5	0.499	0.500	0.501	0.502
r6	other interaction: dead carcass retained	0.5	0.572	0.535	0.544	0.563
warp interactions						
s1	warp interaction: prop. surface strike	0.787	0.777	0.800	0.744	0.722
s2	aerial strike: dies	0.007	0.007	0.007	0.007	0.007
s3	surface strike: dies	0.056	0.310	0.421	0.160	0.070
s4_pessimistic	fatal surface strike: carcass retained	0.277	0.210	0.240	0.169	0.143
cryptic mortality multiplier (D/C)			**1.935**	**1.687**	**3.857**	**1.983**

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Numbers of birds experiencing each designated terminal fate in Figure 1

For ease of interpretation, in Tables 9-10 we apply the transition probabilities in Tables 7-8 to estimate the fate of 1000 large bird interactions under each scenario. (Note that because a majority of interactions are non-lethal warp contacts, which do not result in captures or deaths, the totals do not sum to 1000; detailed fates of the full 1000 interactions, including confidence intervals, are reproduced in Annex C Tables C1 and C2.)

Table 9 Fate of 1000 large bird interactions, under base case s4 sensitivity (mean and 95% CI)

fate of 1000 large bird interactions: base case	**HHL**	**SQU**	**SCI**	**BAR**
bird enters net, live release, survives	5.5	8.7	3.0	1.2
bird enters net, live release, dies	2.8	3.9	1.8	0.6
bird enters net, dead capture	46.3	49.0	7.3	1.3
bird enters net, cryptic death	4.4	4.8	0.8	0.1
external net entanglement, live release, survives	25.2	49.9	0.4	7.7
external net entanglement, live release, dies	9.0	15.9	0.2	3.7
external net entanglement, dead capture	14.6	20.8	0.2	8.7
external net entanglement, cryptic death	4.7	6.8	0.1	2.8
other interaction, live release, survives	12.1	20.2	4.9	3.6
other interaction, live release, dies	3.9	6.8	2.3	1.7
other interaction, dead capture	9.4	9.3	3.0	3.6
other interaction, cryptic death	7.9	9.4	2.8	3.0
aerial warp strike, cryptic death	1.4	1.3	1.9	2.0
surface warp strike, dead capture	27.8	46.7	10.1	3.3
surface warp strike, cryptic death	68.7	98.7	39.4	16.8
all captures C	**156.6** (133.5-181.2)	**231.2** (201.6-262.5)	**33.1** (22.7-44.6)	**35.4** (24.7-46.5)
live captures	**58.5** (30.3-90.2)	**105.4** (66.9-147.7)	**12.5** (2.3-26.1)	**18.5** (4.5-35.7)
dead captures	**98.1** (77.4-119.4)	**125.8** (100.2-152.5)	**20.6** (12.6-29.1)	**16.9** (8.6-26.1)
cryptic + post-release deaths	**102.7** (22.5-276.8)	**147.6** (33.9-367.5)	**49.2** (5.9-157.8)	**30.8** (7.3-77.1)
all deaths D	**200.8** (107.0-380.8)	**273.4** (143.7-497.1)	**69.8** (19.2-179.1)	**47.7** (18.0-96.6)
proportion released alive	**0.373**	**0.456**	**0.377**	**0.523**
Cryptic mortality multiplier (D/C)	**1.283** (0.750-2.411)	**1.182** (0.674-2.143)	**2.119** (0.743-5.387)	**1.350** (0.617-2.677)

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Table 10 Fate of 1000 large bird interactions under pessimistic s4 sensitivity (mean and 95% CI)

fate of 1000 large bird interactions: base case	**HHL**	**SQU**	**SCI**	**BAR**
bird enters net, live release, survives	5.5	8.7	3.0	1.2
bird enters net, live release, dies	2.8	3.9	1.8	0.6
bird enters net, dead capture	46.3	48.9	7.3	1.3
bird enters net, cryptic death	4.4	4.7	0.8	0.1
external net entanglement, live release, survives	25.2	49.8	0.3	7.6
external net entanglement, live release, dies	9.0	15.9	0.2	3.7
external net entanglement, dead capture	14.6	21.2	0.2	8.7
external net entanglement, cryptic death	4.7	7.1	0.1	2.8
other interaction, live release, survives	12.1	20.2	4.9	3.6
other interaction, live release, dies	3.9	6.8	2.3	1.7
other interaction, dead capture	9.3	9.4	3.0	3.5
other interaction, cryptic death	7.9	9.3	2.8	3.0
aerial warp strike, cryptic death	1.3	1.1	1.7	1.9
surface warp strike, dead capture	27.5	46.2	9.9	3.1
surface warp strike, cryptic death	170.1	214.5	96.0	39.0
all captures C	**156.2** (131.7-180.0)	**230.9** (200.4-261.0)	**32.9** (22.4-44.2)	**35.4** (24.8-46.7)
live captures	**58.5** (30.1-89.9)	**105.3** (65.6-146.8)	**12.5** (2.3-26.0)	**18.5** (4.7-35.9)
proportion alive	**0.375**	**0.456**	**0.381**	**0.525**
dead captures	**98.7** (76.8-119.3)	**125.7** (99.7-152.5)	**20.6** (12.6-28.8)	**16.9** (8.6-25.5)
Cryptic + post-release deaths	**204.0** (33.9-481.8)	**263.1** (57.5-558.3)	**105.7** (9.2-305.1)	**52.9** (9.9-143.0)
all deaths D	**301.7** (127.4-587.9)	**388.8** (176.4-688.3)	**126.0** (24.3-327.5)	**69.6** (20.3-161.5)
Cryptic mortality multiplier (D/C)	**1.935** (0.83-3.74)	**1.687** (0.78-2.97)	**3.857** (0.89-10.00)	**1.98** (0.68-4.51)

These results reveal that cryptic mortality in trawl fisheries has been dramatically over-estimated in every New Zealand seabird risk assessment model, including the 2023 SRA described by Edwards et al. (2023). Substantial differences are apparent between the target fisheries, reflecting that different gear and/or mitigation configurations affect where on the gear seabirds are likely to be captured, and what is their injury status, with direct implications for differential cryptic mortality in different fisheries. For example in scampi fisheries seabirds are caught more often on the warp, generating a higher number of cryptic deaths and a higher cryptic multiplier; in barracuda target fisheries a higher proportion of seabird captures are released alive.

But the results are consistent that *across all deepwater trawl fisheries, for all large seabirds (albatrosses and mollymawks) the estimated cryptic multipliers are substantially lower than has been assumed to date; as a consequence, seabird deaths*

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and population-level risk will have been over-estimated for all large birds (albatrosses and mollymawks) in all deepwater trawl fisheries, by a factor of roughly 3-6. We discuss the likely reasons for this dramatic over-estimation below.

Southern Buller's albatross captures, deaths, and risk by deepwater target fishery

To estimate captures and risk specifically for Southern Buller's albatross, we used fishery-specific estimated annual captures outputs from the 2023 SRA described in Edwards et al. (2023), disaggregated to target fishery using Risk Atlas (Table 4) and we assigned those captures to individual seabird fate categories as in Figure 1, using the fishery-specific proportional breakdown of birds to different interaction fates as shown in Tables 9-10. Results are shown in Tables 11 and 12

Table 101. Estimated annual captures and deaths of Southern Buller's albatross, assigned to different capture locations and seabird interaction fates, by target fishery (base case scenario)

fate of bird interaction	**HHL**	**SQU**	**SCI**	**BAR**
bird enters net, live release, survives	1.0	0.9	0.9	0.2
bird enters net, live release, dies	0.5	0.4	0.6	0.1
bird enters net, dead capture	8.4	5.0	2.3	0.3
bird enters net, dies, not recovered (cryptic death)	0.8	0.5	0.3	0.0
external net entanglement, live release, survives	4.6	5.1	0.1	1.5
external net entanglement, live release, dies	1.6	1.6	0.1	0.7
external net entanglement, dead capture	2.6	2.1	0.1	1.6
external net entanglement, cryptic death	0.8	0.7	0.0	0.5
other interaction, live release, survives	2.2	2.1	1.5	0.7
other interaction, live release, dies	0.7	0.7	0.7	0.3
other interaction, dead capture	1.7	1.0	0.9	0.7
other interaction, cryptic death	1.4	1.0	0.9	0.6
aerial warps strike, cryptic death	0.3	0.1	0.6	0.4
surface warp strike, dead capture	5.0	4.8	3.1	0.6
surface warp strike, cryptic death	12.4	10.1	12.1	3.2
all captures C	**28.3** (24.1-32.7)	**23.6** (20.6-26.8)	**10.2** (7.0-13.7)	**6.7** (4.7-8.8)
live captures	**10.6** (5.5-16.3)	**10.8** (6.8-15.1)	**3.8** (0.7-8.0)	**3.5** (0.9-6.8)
proportion alive	**.373**	**.456**	**.377**	**.523**
dead captures	**17.7** (14.0-21.6)	**12.8** (10.2-15.6)	**6.4** (3.9-8.9)	**3.2** (1.6-5.0)
cryptic + post-release deaths	**18.6** (4.1-50.0)	**15.1** (3.5-37.5)	**15.1** (1.8-48.6)	**5.8** (3.4-18.3)
all deaths D	**36.3** (19.3-68.8)	**27.9** (14.7-50.7)	**21.5** (5.9-55.1)	**9.0** (3.4-18.3)
fishery-specific risk (D/ PST)	**0.059**	**0.046**	**0.035**	**0.015**

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Table 12 Estimated annual captures and deaths of Southern Buller's albatross, assigned to different capture locations and seabird interaction fates, by target fishery (pessimistic s4 sensitivity)

fate of bird interaction	**HHL**	**SQU**	**SCI**	**BAR**
bird enters net, live release, survives	1.0	0.9	0.9	0.2
bird enters net, live release, dies	0.5	0.4	0.6	0.1
bird enters net, dead capture	8.4	5.0	2.2	0.3
bird enters net, cryptic death	0.8	0.5	0.2	0.0
external net entanglement, live release, survives	4.6	5.1	0.1	1.5
external net entanglement, live release, dies	1.6	1.6	0.1	0.7
external net entanglement, dead capture	2.6	2.2	0.1	1.7
external net entanglement, cryptic death	0.9	0.7	0.0	0.5
other interaction, live release, survives	2.2	2.1	1.5	0.7
other interaction, live release, dies	0.7	0.7	0.7	0.3
other interaction, dead capture	1.7	1.0	0.9	0.7
other interaction, cryptic death	1.4	0.9	0.9	0.6
aerial warps strike, cryptic death	0.2	0.1	0.5	0.4
surface warp strike, dead capture	5.0	4.7	3.1	0.6
surface warp strike, cryptic death	30.8	21.9	29.7	7.4
all captures C	**28.3** (23.9-32.6)	**23.6** (20.5-26.7)	**10.2** (7.0-13.7)	**6.7** (4.7-8.9)
live captures	**10.6** (5.5-16.3)	**10.8** (6.7-15.0)	**3.9** (0.7-8.1)	**3.5** (0.9-6.8)
proportion released alive	**.375**	**.456**	**.381**	**.525**
dead captures	**17.7** (13.9-21.6)	**12.8** (10.2-15.6)	**6.3** (3.9-8.9)	**3.2** (1.6-4.9)
cryptic + post-release deaths	**37.0** (6.1-87.3)	**26.9** (5.9-57.1)	**32.8** (2.9-94.6)	**10.1** (1.9-27.3)
all deaths D	**54.7** (23.1-106.5)	**39.7** (18.0-70.3)	**39.1** (7.5-101.5)	**13.3** (3.9-30.8)
fishery-specific risk (D/ PST)	**0.089**	**0.065**	**0.064**	**0.022**

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Collectively, the main deepwater target fisheries analyzed here are estimated to kill 95 Southern Bullers albatrosses per year (or 147 under the pessimistic s4 scenario). For comparison, the 2023 SRA estimated 517 deaths per year assigned to these same deepwater target fisheries, i.e. the 2023 SRA over-estimates deaths and risk from these fisheries by 544% (or 352%), arising from its coarse and outdated treatment of cryptic mortality.

The PST for Salvin's albatross is 613 birds (Edwards et al. 2023 Table 15). Collectively, the contribution of the deepwater trawl fisheries analyzed here the species-level risk score for Salvin's albatross is 95/613, i.e. 0.155 (or 147/613, i.e. 0.240.). Put another way, we estimate that the effect of these fisheries on the population status of Salvin's albatross is to reduce equilibrium population size by 7.8% (or 12.0%) relative to its unimpacted state.

Species-level risk for Southern Buller's albatross

In Table 13 below we combine elements of Tables 1, 2, 11, and 12 to estimate captures, deaths, and risk for Southern Buller's albatross across all New Zealand commercial fisheries.

Table 13 Estimated annual captures, deaths, and risk to Southern Buller's albatross from all New Zealand commercial fisheries

Fishery target	live captures	dead captures	Total captures	Total deaths (base case)	Total risk (base case)	Total deaths (pessimistic s4)	Total risk (pessimistic s4)
HOK-HAK-LIN	10.6	17.7	28.3	36.3	0.059	54.7	0.089
SQU	10.8	12.8	23.6	27.9	0.046	39.7	0.065
SCI	3.8	6.4	10.2	21.5	0.035	39.1	0.064
BAR	3.6	3.2	6.7	9	0.015	13.3	0.022
SBW	0	0	0.1	0	0.000	0	0.000
All other trawl	3.6	6.4	10.1	65.7*	0.107*	65.7*	0.107*
Bottom longline	2.1	8.5	10.6	13.2*	0.022*	13.2*	0.022*
surface longline	19.1	133.4	152.5	198.4*	0.324*	198.4*	0.324*
setnet	0.1	0.2	0.4	0.3*	0.000*	0.3*	0.000*
Total	**53.7**	**188.6**	**242.5**	**372.3***	**0.607***	**424.4***	**0.692***

*include estimates reproduced from Edwards et al. (2023)

These results suggest that across all New Zealand fisheries, there are 372 (or 424) annual deaths of Southern Buller's albatross, such that the cumulative species-level risk = 0.607 (or 0.692). These estimates would suggest that the equilibrium population size will be reduced by 30.3% (or 34.6%) as a consequence of all New Zealand commercial fisheries. Note however the largest share of species-level risk (0.342) is attributed to 'all other trawl', i.e. primarily inshore trawl fisheries. It is almost certain that the same mechanisms that caused the 2023 SRA to cryptic mortality in deepwater trawl fisheries is also affecting

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the 2023 SRA estimates for inshore trawl fisheries, i.e. this estimate is likely to biased high. Improved understanding of fisheries risk to Salvin's albatross would benefit from a focused analysis on cryptic mortality in inshore fisheries, similar to this analysis for deepwater trawl fisheries.

Note that estimates of deaths and risk from 'all other trawl' and from bottom longline, surface longline, and set net fisheries depend on estimates of cryptic mortality that were not a part of this analysis, and so are reproduced here from the 2023 SRA estimates of Edwards et al. (2023). It is highly likely that the same mechanisms that caused the 2023 SRA to over-estimate cryptic mortality in major deepwater trawl fisheries will also affect inshore trawl fisheries, to an unknown extent. It is also likely that the estimation of cryptic mortality in longline fisheries may suffer from similar structural and/or parameterization problems, but because cryptic mortality is assumed to be much lower in longline fisheries relative to trawl fisheries, the actual effect on total deaths and risk (for Southern Buller's albatross) is likely to be less. In this table we reproduce the 2023 SRA estimates for those fisheries that we did not re-estimate, to allow estimation of cumulative deaths and risk across all New Zealand commercial fisheries, noting that these estimates would benefit from a similar deeper investigation of cryptic mortality applied to all fisheries and fishing methods that make a substantial contribution to species level risk.

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DISCUSSION

How can we be confident that these estimates are superior to the estimates in the New Zealand SRA?

It is foreseeable that any critical reader will want to know how this analysis can utilize the actual model outputs described in Edwards et al. (2023) to estimate fishery-specific captures, and still reach such dramatically different conclusions regarding deaths and risk. Without full access to the input parameterization and internal structure of the Edwards et al. (2023) model, it is not possible for us to fully explain these differences. The implementation of cryptic mortality (i.e. the process for translating estimated observable captures to estimated total deaths) is not fully explained in the 2023 SRA publications (Edwards et al. 2023), and some of the statements regarding cryptic mortality in that and the two accompanying AEBR publications (Edwards et al. 2023b, Peatman et al. 2023) are internally contradictory. The only way to conclusively identify what combination of factors is most responsible for the over-estimation would be for Fisheries New Zealand to commission the authors of Edwards et al. (2023) to fully document relevant equations and input parameters and to re-run the application of cryptic mortality using substituted parameters. That analysis is beyond the ability of this report to deliver.

Nonetheless it is possible to identify a number of structural factors and suboptimal parameterization choices that will have caused the cryptic mortality multipliers in the 2023 SRA to be dramatically over-estimated; we identify these factors in the detailed discussion that follows.

However without even engaging how the 2023 SRA derived its estimates of cryptic mortality, we can be confident that our analysis (in this report) produces superior estimates, for the following reasons:

1) We use a superior method: we apply the transition matrix approach of Meyer et al. (2023), which was specifically designed for this purpose. This approach incorporates all subjective knowledge as priors, and estimates every transition probability simultaneously by fitting to captures data for each of the observable seabird interaction fates. In contrast every previous New Zealand SRA has estimated each transition separately, often cobbling together estimates based on data culled from disparate and incompatible studies, and without fitting to observations.
2) We use the best available data: since 2019, the New Zealand fisheries observers have collected improved high-resolution Protected Species Interaction data specifically designed to inform the estimation of cryptic mortality and live release survival. Our analysis is the first time these data have been used for this purpose. The 2023 SRA relies on parameter estimates carried forward from a period before these data were being collected.
3) We use current data: Our analysis uses data from 2019-2024, collected by New Zealand fisheries observers. The 2023 SRA used observer data pooled from New Zealand fisheries across the full period 2006-2020 (for estimated parameters) or borrowed from publications pertaining to overseas fisheries that are themselves referring to data that are up to 20 years out of date (e.g. Watkins 2008, Abraham and Thompson 2009).
4) We use fishery-specific data: our analysis uses data specific to each of the major New Zealand deepwater fisheries analyzed here (targeting HHL, SQU, SCI, BAR), each of which has distinct characteristics that will affect the way seabirds interact with the fishing gear. The 2023 SRA used data pooled for all New Zealand trawl fisheries back to 2006, including inshore fisheries employing very different gears and practices.

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On this basis we can be confident that this analysis provides the best available estimate of cryptic mortality in New Zealand trawl fisheries. In the section that follows we dig deeper into the sequence of events that allowed the estimation of cryptic mortality in the New Zealand SRA to remain so skewed for so long.

How did the New Zealand seabird risk assessment get cryptic mortality so wrong?

We identify the following factors, all of which will have contributed in varying degrees to the over-estimation of cryptic mortality in trawl fisheries, in the 2023 SRA and in previous versions of the New Zealand seabird risk assessment.

1. *No single official or research provider has been responsible for overseeing the effective design or implementation of a complete New Zealand seabird risk assessment, through multiple iterations.*

The origins and history of the New Zealand seabird risk assessment (SRA) are described in Sharp (2019). The method was originally devised arising from a New Zealand government workshop in 2009 to inform the development of the New Zealand NPOA-seabirds (Sharp et al. 2011) and subsequently updated and refined through numerous iterations (Waugh et al. (2009), Richard et al. (2011), Richard and Abraham Richard & Abraham (2013b), Richard &Abraham (2015), Richard et al. (2017), Richard et al. (2020), Webber (2020), Edwards et al. (2023). With every update, research providers would be tasked with using newly collected captures data and with making specified changes to the model structure or method, but there was never a version of the seabird risk assessment where either the government or the externally contracted research provider took responsibility for updating and harmonizing all of the method, the data, the structural assumptions, and the various parameter inputs simultaneously. As a consequence, different parameters or structural assumptions got 'carried forward' from previous SRAs on the basis that, e.g. "*this is what was used before and we don't have a reason to change it*" until the structure of the model had changed enough to render the original inputs inappropriate, but nobody remembered their origins. We recognize that this is a primarily a structural criticism of the way in which Fisheries New Zealand has managed it seabird science program for the past 15 years, rather than a method criticism of any particular New Zealand SRA, but the magnitude of the accumulated errors in the estimation of cryptic mortality in the 2023 SRA cannot be understood outside of this context.

In 2018 a method paper was formally produced (Sharp 2019) to ensure consistency between different SEFRA models, in part to create a clearer understanding of the method (and prevent errors in its implementation) and in part to force consistency between different SEFRA models, to enable the development of analytical tools (i.e. Risk Atlas, Webber unpublished) that utilize the outputs of models produced by different research providers. Following Sharp (2019), Webber (2020) was commissioned to re-code the (at that time) most recent SRA model consistent with the method description in Sharp (2019), but that project was strictly a statistical / model-building exercise that took no responsibility for examining or modifying input parameters or biological assumptions. Subsequently Edwards et al.

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(2023) was commissioned to build a new SRA model consistent with Sharp (2019) and utilizing the model template provided by Webber (2020), while also revisiting structural assumptions and biological inputs.

The 2023 SRA model produced by Edwards et al. (2023) was the first New Zealand SRA model that was fully consistent with the SEFRA method as described in Sharp (2019). In the opinion of this reviewer (see separate review by Sharp 2023) the Edwards et al. (2023) model successfully resolved a number of long-standing structural problems. Foremost among these was removing the estimation of cryptic mortality from the model itself; this allows the model to optimize the estimation of observable captures fitted to fisheries observer data, unaffected by assumptions about cryptic mortality. (Previous SRA models had incorporated cryptic mortality inside the model before the fitting stage, effectively fitting to deaths rather than captures, thereby allowing untested assumptions about cryptic deaths to influence model fit, potentially skewing captures estimation across different species and fisheries.) This structural change was a major improvement, but it also meant that the authors of Edwards et al. (2023) were not responsible for validating or updating the estimation of cryptic mortality in the SRA. Instead, their model estimated observable captures, and cryptic mortality multipliers were to be applied to the model outputs. The original intent was that these multipliers were to be supplied by a different research provider (Meyer 2023) and/or recommended by the FNZ Aquatic Environment Working Group.

If Meyer (2023) had been delivered in time to allow incorporation of updated cryptic multipliers into the 2023 SRA of Edwards et al. (2023), a better outcome would have been likely, but without oversight by FNZ to combine the outputs of these projects, Edwards et al. (2023) delivered their outputs at a time when Meyer (2023) was still in progress; in this context the 2023 SRA was forced instead to once again 'carry forward' the cryptic mortality multipliers inherited from previous SRA model implementations. Most of the assumptions underlying these cryptic multipliers are demonstrably out of date and/or inappropriate (see below) but to our knowledge no New Zealand science working group has ever been tasked with reviewing them.

2. *Pooling all fisheries data since 2006 effectively erases any changes in the rate or nature of seabird interactions over time, over a period in which very significant changes occurred to the operation of New Zealand trawl fisheries to mitigate impacts on seabirds, shifting the majority of seabird interactions from the warp to the net.*

The bounds within which fisheries observer data are pooled in the estimation of catchability under the SEFRA method should be made with care (Sharp 2019, section 3.3.7): the structural assumption is that all fishing events assigned to the same fishery group have an equal probability of capturing a seabird (per seabird encounter). Pooling data from dissimilar gear types, or across time periods with dissimilar fishing or mitigation practices, effectively erases any contrast in seabird catchability within the pool: the model can only estimate a single (average) catchability within the group.

Seabird mitigation was first mandated on New Zealand deepwater fisheries in 2006; this year marks the beginning of a roughly decade-long process of developing and adapting seabird mitigation and

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improved offal discard practices to reduce the risk to seabirds. By pooling data from 2006-2020 in the estimation of seabird catchability, the SRA of Edwards et al. (2023) will not reflect any changes that occurred in seabird captures during that period, and estimated capture rates will be anchored by a large body of early data, rather than responsive to changes that may have occurred more recently. In the FNZ working group the authors of Edwards et al. (2023) said that testing the use of shorter time blocks showed no significant change in capture rate over that period, thereby justifying the use of the full time period. *But the 2023 SRA of Edwards et al. (2023), in the captures estimation stage, does not differentiate between warp captures and net captures.* In trawl fisheries, a constant total capture rate can conceal a substantial change in capture composition, from primarily warp captures (before mitigation uptake) to primarily net captures (after mitigation uptake). By all accounts, this is what actually occurred in New Zealand deepwater trawl fisheries as a consequence of seabird mitigation adoption in the decade 2006-2015 (e.g. see MPI 2024, Lokkeborg 2011, Phillips et al. 2024).

The whole process of mandated and voluntary seabird mitigation and improved offal discard practices adopted by the New Zealand fishing industry since 2006 has been designed to keep seabirds away from the trawl warps, where the vast majority of interactions used to occur. A corresponding rise in seabird interactions on the net may reflect that the birds are persistent and not easily deterred further back from the vessel, but a shift from warp captures to net captures has enormous implications for cryptic mortality. To illustrate, the 2023 SRA assumes that for every warp capture, an additional **20** large seabirds are killed but not recovered, with no live releases; in contrast every net capture implies an additional **0.3** cryptic deaths, and some of the captures are released alive.

By averaging across all trawl fisheries and the full time period from 2006-2020, Edwards et al. (2023) estimate that 28% of large seabird captures occur on the warp. Using fishery-specific and current data, the actual figures are 15% and 17% for hoki-hake-ling and squid fisheries, respectively (Table 5), i.e. confirming that the temporal trend has been a reduced warp:net capture ratio. This trend, and the corresponding increase in the potential for net-captured seabirds to be released alive, likely accounts for a large portion of the overestimation of trawl fishery cryptic mortality in every New Zealand SRA to date. There can be no justification not to use fishery-specific and current data to improve these estimates, as we have done here.

3. *The origins of the mathematical assumptions underlying the estimation of cryptic mortality in the New Zealand SRA's are not well documented and in some instances impossible to determine. When the history of each parameter input is unpacked with reference to each of the transition probabilities in our Figure 1, it becomes clear that many of these parameter inputs have been misunderstood, misapplied, or uncritically carried forward through multiple iterations of the SRA without reference to available data.*

In this section we examine the origins and justification for the transition probability estimates that underlie the estimation of cryptic mortality in the New Zealand SRA. For ease of comparison we refer to the labeling convention in Figure 1 and Table 5, noting however that our transition matrix is more complete than has been applied in the past, so some of these transition probabilities have no

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counterpart in Edwards et al. (2023) or previous SRA publications. Furthermore, without a corresponding diagram or a full published set of equations and input parameters, it is not entirely clear how the cryptic mortality multipliers that are referred to in the 2023 SRA documents (Edwards et al. 2023 and 2023b; Peatman et al. 2023) have been applied mathematically, noting that some of the estimates have been carried forward through multiple versions of the SRA from a time when different transition matrices had been assumed. In particular it is unclear how live release survival has been applied, whether cryptic multipliers are applied to live released birds, and whether the published cryptic mortality multipliers are meant to reflect also the probability of survival for live released birds (see below).

Location of interaction (i.e. net vs. warp vs. 'other')

Edwards et al (2023) pooled all observer data from all trawl fisheries (2006-2020) to estimate that 72% of large bird captures are on the net (**p1**), and 28% on the warp (**p3**) (Edwards et al. 2023, Table 4). But because cryptic mortality can now be estimated independently from model estimates of captures, there is no need to rely on such coarse approximations; in this study we produce estimates specific to each target fishery, using current data.

It is unclear how the 2023 SRA deals with seabirds reported as captured on mitigation gear or recorded 'brought on board' (i.e. there is no equivalent to rate **p2**), noting that the full observer reporting categories reflecting these types of interactions were only added to the observer Protected Species Interaction form in 2019, but these types of interactions would have become more common as seabird mitigation changed from 2006 onward.

Warp interactions: aerial vs. surface warp strikes

To estimate cryptic deaths arising from warp interactions, Edwards et al (2023b; AEBAR #313) use assumptions inherited from previous seabird risk assessments since 2011. In that report the method description for how these multipliers were originally derived is reproduced in full from Richard et al. (2020), who report that all of the relevant transition probabilities for warp interactions (**s1 – s4**) were estimated by combining data from two unrelated studies: Watkins et al. (2008) and Abraham (2010), as follows:

> Cryptic multipliers for warp captures were constructed using dedicated monitoring of warps in New Zealand trawl fisheries (Abraham 2010) and the South African deepwater hake fishery (Watkins et al. 2008). Abraham (2010) report estimates of the total number of warp strikes per observable capture, i.e., S_{warp}/C_{warp}. Watkins et al. (2008) report information that was used to calculate the probability of a strike being a surface warp strike, $p(S_{surf}|S_{warp})$, and an aerial warp strike,

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$p(S_{air}|S_{warp})$. In combination, the observations of Watkins et al. (2008) and Abraham (2010) allow estimation of the number of surface warp strikes per observable capture, S_{surf}/C_{warp}, and the number of aerial warp strikes per observable capture S_{air}/C_{warp}:

$$S_{surf}/C_{warp} = p(S_{surf}|S_{warp}) \cdot (S_{warp}/C_{warp})$$
$$S_{air}/C_{warp} = p(S_{air}|S_{warp}) \cdot (S_{warp}/C_{warp})$$
$$= (1 - p(S_{surf}|S_{warp})) \cdot (S_{warp}/C_{warp})$$

Watkins et al. (2008) also report the total number of mortalities resulting from the observed surface warp strikes, with seabirds considered as drowned if they did not resurface within *ca.* 30 seconds of a surface strike. As such, the mortalities include both "observable" mortalities, i.e., seabird carcasses that remain on the gear, as well as "unobservable" mortalities. This allows estimation of the probability that a surface strike results in a mortality, $p(D_{surf}|S_{surf})$. The total deaths resulting from surface warp strikes per observable capture, k_{surf}, is then:

$$k_{surf} = D_{surf}/C_{warp} = p(D_{surf}|S_{surf}) \cdot (S_{surf}/C_{warp})$$
$$= p(D_{surf}|S_{surf}) \cdot p(S_{surf}|S_{warp}) \cdot (S_{warp}/C_{warp})$$

On this basis the 2023 SRA assumes that 37% of large bird warp strikes are surface warp strikes, and 63% are aerial strikes.

Notwithstanding the convoluted nature of that explanation (and the apparent circularity of using observed captures to estimate warp strike rates and also observed warp strikes to estimate fatal capture rates) what has apparently been lost in the complexity of the initial mathematics are the following considerations:

i) Watkins et al. (2008) report observations from a single study in a South African hake fishery in 2004, employing no seabird mitigation and continuously discharging offal. The rate and nature of seabird interactions with warp cables is strongly determined by the practice of discharging offal (see Lokkeborg 2011).

Abraham (2010) summarizes warp strike observations from the years 2004/05 -2008/09, a period that includes years both before and after seabird mitigation was first mandated in New Zealand, noting that the process of mitigation refinement, especially offal discard practices, continued well beyond this period.

Clearly these data cannot be considered representative of New Zealand trawl fisheries in 2024. The following text from Abraham and Thompson (2009) shows the speed and extent to which the introduction of seabird mitigation changed the nature of seabird interactions with New Zealand fishing gear in this period:

The average warp strike rate has decreased since 2004–05, when warp strike observations were first made in New Zealand fisheries. For small birds (all birds other than albatrosses and giant petrels), the average warp strike rate has decreased from 3.03 to 0.55 strikes

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per hour. For large birds (albatrosses and giant petrels), the average warp strike rate has decreased from 2.35 to 0.39 strikes per hour. The decrease is associated with an increase in the use of mitigation devices, which were made mandatory in January 2006 for all trawlers over 28 m in length fishing in New Zealand waters. In 2004–05 mitigation was not compulsory and was used during 48% of the observations. In 2006–07, mitigation was used during 92% of observations.

ii) In Watkins et al. (2008), data to estimate the rate at which surface warp strikes result in cryptic deaths (**s4**) were estimated by observers on board the fishing vessel, on the assumption that seabirds not seen to re-surface after a strike were assumed drowned. But fisheries observers on board the moving fishing vessel are not well positioned to observe what happens in the wake of the vessel after it passes, especially in the context of the very high seabird interaction rates and aggressive conspecific interactions by giant petrels described in that paper.

It appears then that that cryptic multipliers in the NZ SRA have been estimated based on warp strike observations that are badly out of date, and were probably a poor proxy for New Zealand trawl fisheries even by the time they were published. The observations giving rise to these estimates reflect warp strike conditions that occurred nearly 20 years ago, before the widespread adoption of seabird mitigation. At the time that the SEFRA method was first being formulated (2009-2011) reference to estimates arising from these studies reflected a genuine absence of other available information and was intended to inform an iterative process of research prioritization, to focus scrutiny on poorly estimated inputs until they could be improved. That the same cryptic mortality multipliers have instead been carried forward through multiple versions of the seabird risk assessment without being critically examined reflects a failure of government oversight, and should be corrected.

Recognizing these limitations, Meyer (2023) sought and utilized more recent studies from what are likely to be more appropriate proxy fisheries representative of New Zealand deepwater trawl fisheries. Warp strike observations to estimate **s1** are from New Zealand fisheries observers, albeit from a wider suite of fisheries than are the focus of this analysis, but at least from a time period after the introduction of seabird mitigation. To estimate **s2, s3,** and **s4**, Meyer utilized the study by Parker (2013) which used a dedicated following vessel to investigate the fate of warp struck birds (i.e. providing a superior observation platform to that provided by the fishing vessel).

We consider that the data utilized by Meyer (2023) are both more recent and from fisheries that better approximate New Zealand deepwater trawl fisheries than those utilized by previous New Zealand SRAs and (and carried forward for use in Edwards et al. 2023). We note also that parameter **s4,** the carcass retention rate of fatal warp strikes, is the parameter that most affects the estimation of cryptic deaths, and on that basis we produced additional **s4** sensitivities including a 'pessimistic' sensitivity representing a 'worst case' interpretation of the data.

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Net captures, live release survival

The 2023 SRA of Edwards et al (2023) and previous New Zealand SRAs make no distinction between internal vs. external net interactions (**q1)**. The likelihood of death and of carcass non-retention will almost certainly be different for internal vs. externally captured birds.

For live release survival of net captured birds, Edwards et al. (2023) applied a uniform distribution range 0-1 (mean 0.5) without reference to seabird injury status. It is implausible that post release survival estimates could be this low e.g. for birds whose feet get trapped in tightening trawl meshes on the outside of nets (noting for example that Edwards et al. (2023) assumed live release survival of 0.4 for birds hooked through the mouth by surface longlines, a much more serious injury).

Meyer (2023) assumed mean live release survival 0.75 (0.5-1, uniform distribution) but also without reference to seabird injury status.

Our analysis refines these estimates with reference to improved data from the updated observer PSI form, reflecting actual seabird injury status (i.e. **q8, q9, q11, q12**).

Net captures, carcass non-retention

For both internal and external net captures, Edwards et al (2023) assumed a likelihood of carcass retention of 0.77 (range 0.41-0.9; not uniform). The prior for this estimate was carried forward through numerous previous versions of the SRA. Its origin is that this is the inverse of a cryptic mortality multiplier (mean 1.3, range 1.1-1.7) that was imposed subjectively by the original architect of the SEFRA method (Sharp) first as a simple point estimate and later, when cryptic mortality was integrated into a Bayesian SRA model, applying an input distribution with a mean and range. Richard et al. (2020) describe the origins of this parameter as follows:

> *In preparation of a previous risk assessment (Richard et al. 2011), it was agreed that the number of cryptic net deaths, U_{net}, is likely to be lower than the number of observable captures, C_{net}. A ratio of cryptic to observable captures of U_{net}/C_{net} = 0.3 was used in the earlier assessment by Richard et al. (2011). To consider uncertainty around this ratio, we assumed that U_{net}/C_{net} followed a log-normal distribution with a 95% confidence interval of 0.1 to 0.7, and mean of 0.3. This range was not based on data.*
> *The total number of deaths due to net interactions is the sum of observed and unobserved deaths, therefore*
>
> $M_{net} = D_{net}/C_{net} = 1 + U_{net}/C_{net}$. (A-7)

We note that the net capture carcass retention parameter was misinterpreted by Meyer (2023), which accounts for that author's estimate of a cryptic multiplier for net captures considerably higher than had been estimated by others. The inherited 'default' parameter that was cited was for a cryptic multiplier of 1.3 (1.1-1.7) but what was actually applied was a probability of carcass

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retention of 0.3 (0.1-0.7), which implies a cryptic multiplier that is the inverse, i.e. 3.33 (1.4 – 10). The mistake was not discovered prior to publication of the final research report, and when it was discussed in a government cryptic mortality workshop hosted by Fisheries New Zealand in February 2024, neither the FNZ officials nor the research providers delivering the SRA knew the origins of this parameter.

In this analysis, for external captures we assumed a similar rate of carcass retention as was used previously (i.e. we use **q13** =0.75 vs. 077) and a higher rate of retention for internal captures (**q10** = 0.9). But the confusion illustrates the dangers of expecting external research providers to deliver models using input parameters inherited from previous studies of which they have no knowledge and for which they have no responsibility, without adequate oversight from the contracting government scientist.

4. *Ambiguous terminology and confusion around the definition of what constitutes a 'cryptic' death appears to have resulted in cryptic multipliers being applied inappropriately to seabirds released alive or to other seabird interaction fates not giving rise to cryptic deaths.*

To inform (and following on from) a cryptic mortality workshop hosted by FNZ in February 2024, and recognizing that the authors of Edwards et al. (2023) were charged with implementing rather than revisiting the assumptions of previous SRAs regarding cryptic mortality, Seafood New Zealand requested of the New Zealand government a complete documentation of input parameters utilized in the SRA of Edwards et al. (2023); however FNZ officials were unable to provide this. In the absence of clear documentation, confused or contradictory statements contained in the three AEBAR publications describing the 2023 SRA (Edwards et al. 2023 and 2023b; Peatman et al. 2023) suggest that the mathematical estimation of cryptic deaths may have been corrupted, irrespective of inappropriate parameterization.

As originally conceived, a cryptic mortality multiplier (denoted k) was meant to convert observable captures to total deaths: k = D/C. The multiplier is the emergent property of the various state transitions in the seabird interaction transition matrix (e.g. as in our Figure 1); as the transition probabilities change, the multiplier also changes. But different research providers delivering different versions of the SRA have interpreted and applied the same terms differently, but nonetheless borrowed parameter estimates from each other. And at times they have applied cryptic mortality multipliers (an emergent property of a series of transition probabilities) as if they are instead estimates of the transition probabilities themselves, or vice versa. The whole process is now hopelessly confused. *Until the full mathematical formulation for converting captures to deaths is clearly documented for different seabird fates, and a full list of input parameters is provided, it is not possible to ascertain how cryptic mortality has been estimated in the 2023 SRA.*

Confused language in the documentation of the 2023 SRA provide some clues. For example, Edwards et al. (2023b) coin the term 'cryptic capture' and write (p 13) *"It is important to note that cryptic mortalities can result from observable captures, e.g., post-release mortalities, as well as unobservable captures."* But as formally defined for fishers and fisheries observers, there is no such thing as an

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'unobservable capture'; a capture is only a capture if it is observable. And in the SEFRA method described in Sharp (2019) 'cryptic capture' is an oxymoron: a death is only cryptic if it is unobservable. Post-release deaths, while uncertain, have nonetheless already been counted among observed captures; including those deaths in the estimation of cryptic multipliers and then applying those multipliers would mean those deaths are double-counted.

We note also that live release survival was not considered or incorporated into any New Zealand SRA until 2017 (Sharp 2019); it is inappropriate then that cryptic multipliers from before this period are carried forward and applied within the current SRA, including for birds released alive. Edwards et al. (2023b) write (p. 16) with reference to net captures: "*We note that all cryptic net captures were previously considered to result in fatalities. However, in the current risk assessment, the cryptic multiplier is applied to both alive and dead observable captures".* This is clearly a mistake: for example the net capture multiplier of 1.3 was chosen arbitrarily in 2011 to represent the assumption that for every 10 birds that die in or on the net, an additional 3 carcasses may be lost without being observable. There is no mechanism justifying the application of this same multiplier to birds recorded as captured and released alive.

It is unclear to what extent similar formulation problems may affect the estimation of warp captures and deaths, for which live releases are not a consideration, but it is possible that some similar mechanism or confusion may also be affecting these estimates.

Alternately it may be that the estimation of cryptic warp deaths in the 2023 SRA described in Edwards et al. (2023) is mathematically correct (i.e. consistent with their own parameterization) but references to cryptic multipliers in the text are distorted by their inclusion of captured and live-released birds. Without a method- or fishery-specific breakdown of estimated captures (as we provide in Tables 1-4, using Risk Atlas) it is difficult from the published documents alone to evaluate how the cryptic multipliers are being implemented in Edwards et al. (2023); but in any event, carrying forward parameter inputs from a time when the terms themselves were interpreted differently (section 3 above) is inappropriate.

How is cryptic mortality treated elsewhere?

Seabird cryptic mortality is recognized as a potentially important issue but is only rarely addressed empirically. In a recent (August 2024) extensive review of seabird bycatch estimation practices across 25 selected fisheries, Phillips et al. (2024) write that "*The only two fisheries in which bycatch totals and rates were based on a cryptic mortality multiplier were in the Falklands*". The Falklands Islands study referred to made reference to the same study by Parker (2013) that we have relied upon here (Falkland Islands Government 2023). With reference to New Zealand, that review was referring to the 'protected species captures' estimation (MPI 2024), which does not address cryptic mortality and did not cite the 2023 SRA of Edwards et al. (2023).

Regarding standardized data collection, Phillips et al. (2024) recommends "M*onitoring should distinguish injury or mortality associated with collisions with warp cables, monitoring cables and paravanes, and net*

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captures during shooting, towing and hauling." – this is the data that is now available via the updated Protected Species Interaction form, which we utilize here for the first time.

That review acknowledged the efforts of previous NZ SRAs (e.g. Richard et al 2017) to apply cryptic mortality multipliers at the coarse scale of all trawl fisheries, and recommends: *"Ideally, fisheries-specific and, better still, species-specific scalars would be used that account for unobserved events to generate more realistic bycatch totals for trawl fisheries, but this is likely to remain a challenging and contentious area"*. Using Risk Atlas (Webber unpublished) and the transition matrix estimation method of Meyer (2023) applied to outputs of the SEFRA model of Edwards et al. (2023), that is precisely what we have delivered with this analysis.

The review by Phillips et al. (2024) does not state what level of cryptic mortality is actually assumed to occur in the fisheries it reviewed. A NOAA technical memorandum for Alaskan groundfish fisheries (Tide and Eich 2022) acknowledges the potential for cryptic mortality due to carcass non-retention in trawl fishery interactions, and states that "*The AFSC is evaluating these additional sources of mortality on trawl vessels, which can be three times the bycatch recorded in standard sampling*" based on as yet unpublished analyses. Their proposed cryptic multiplier of x3 matches closely with that applied by the Falkland Islands and with our own base case treatment of the Parker et al. (2013) dataset in this analysis, noting that this analysis goes further by also giving rigorous treatment to the estimation of different seabird fates, including live release survival, using fishery-specific data.

CONCLUSIONS

It has been known since the publication of Webber (2020) that cryptic mortality is the single greatest source of uncertainty in the New Zealand SRA, and is likely to have been grossly over-estimated through a number of SRA updates. Concurrent delivery of a new SRA by Edwards et al. (2023) and the seabird cryptic mortality project described in Meyer (2023) was intended to resolve this confusion, but Meyer (2023) was only partly successful, and its outputs were not adopted for use in the 2023 SRA described in Edwards et al. (2023).

In this analysis we have endeavored to complete the promise of that project, for large seabirds in selected New Zealand trawl fisheries. We have shown that for all large seabirds (mollymawks and albatrosses) the treatment of cryptic mortality in the 2023 New Zealand SRA over-estimates seabird deaths and risk by a factor of 3-6 in the major target fisheries capturing Southern Buller's albatross, (i.e. the hoki-hake-ling fishery, the squid target fishery, the scampi target fishery, and the barracuda target fishery). For the hoki-hake-ling fishery specifically, the 2023 SRA over-estimates seabird deaths and risk by a factor of 5.3.

Collectively, the major deepwater/middle depths trawl fisheries analyzed here are estimated to account for 94.7 Southern Buller's albatross deaths per year, compared with 277.6 deaths per year attributable to all other New Zealand target fisheries (i.e. all other trawl, bottom longline, surface longline, and setnet) as estimated by the SRA of Edwards et al. (2023). It is likely that the estimation of cryptic mortality in these other fisheries would benefit from closer investigation similar to what we have delivered in this analysis, but in any event it is clear that:

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i) the greatest source of deaths and risk to Southern Buller's albatross from New Zealand fisheries is from surface longline fisheries; and

ii) cumulative species-level risk to Southern Buller's albatross across all New Zealand fisheries is substantially less than 1 (i.e. risk = 0.61 under base case scenario, and 0.69 under the pessimistic surface warp strike retention scenario).

More generally, the re-estimation of cryptic mortality that we have delivered here are immediately applicable to all large birds (albatross and mollymawk species) in the HHL, SQU, SCI, and BAR target fisheries, with major implications for our understanding of fisheries risk to other at-risk seabird species, (i.e. Salvin's albatross, white-capped albatross; see annexes below).

Furthermore it is likely that similar issues are also negatively affecting the accuracy with which the current SRA estimates cryptic mortality in inshore trawl fisheries, and/or in all trawl fisheries with reference to medium-sized seabirds (petrels and shearwaters), and/or in surface and bottom longline fisheries, but understanding the extent to which that is affecting our understanding of seabird risk would require new analyses using alternate, appropriately focused data extracts.

CAVEAT

Throughout this analysis we have referred to mean estimates of seabird captures as predicted by the SRA of Edwards et al. (2023), without reference to the confidence intervals. Where subsequent estimates of deaths and risk include confidence intervals (Tables 9-12), the uncertainty reflects uncertainty arising from the estimation of cryptic mortality, not uncertainty of the original SRA captures estimates. This convention is necessary because while the SRA model query via Risk Atlas (Tables 1-3) provides us with summary statistics of the fishery-specific captures and deaths, including confidence intervals, it is not possible to combine those with the subsequent full posterior estimates of cryptic mortality without access to the full distribution of the original SRA posteriors. Mean estimates can be combined additively or multiplicatively as required, but a full treatment of uncertainty would require that our cryptic mortality posteriors, and posteriors derived from similar analyses focused on other fisheries and methods, are re-incorporated into the SRA itself. This should be done as a matter of priority.

In the meantime we can be confident that these considerations do not affect our conclusions, because:

i) cryptic mortality is the single greatest source of uncertainty in the estimation of deaths and risk in the SRA (i.e. compare the narrow ranges of estimated observable captures with the much wider ranges of the estimated total deaths; Edward et al. 2023, Table 16); and

ii) because the proportion of total deaths and risk attributable to deepwater and middle depths trawl fisheries in our Table 13 is such a minor proportion of the total across all fisheries, even applying the upper bound estimate of the pessimistic s4 sensitivity is not sufficient to generate a species risk score close to 1.

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FUTURE WORK

We have demonstrated that substantial improvements are possible in the estimation of seabird deaths and risk from New Zealand commercial fisheries, without the need to conduct new research and without waiting for new data collection (whether by cameras or by human observers), simply by making better use of data that are already available but have not been utilized until now.

The key to improving the seabird risk assessment estimates is to estimate the critical rates affecting cryptic mortality on a fishery-specific basis, using only recent observer data, and utilizing improved higher-resolution Protected Species Interaction data collected since 2019. We have delivered these results for three species in four key deepwater trawl fisheries; repeating this analysis for other at-risk species and other target fisheries, and other fishing methods, should be a high priority.

We note that the analysis we have delivered here has resulted in major changes to the estimation of seabird risk (i.e. reducing estimated deaths for the species and fisheries we analyzed by a factor of 3-6). We argue it is not defensible to continue investing in new data collection fed into routine updates of existing methods while it is likely that errors of a similar magnitude remain unaddressed for other species or fisheries not included in this analysis.

We note further that it is unlikely that cameras can replace human observers to collect the data necessary to refine these estimates, because no feasible camera array can reproduce the breadth of data collection contained in the fisheries observer Protected Species Interaction form.

Regarding the specific estimates produced in this analysis for three large seabird species and four deepwater trawl fisheries, we welcome greater scrutiny on these estimates. In particular it would be illustrative to run sensitivities substituting individual parameters in a stepwise fashion, to test the sensitivity of the outcome to different assumptions.

In the absence of the time and resource required to re-run the transition model for every combination of changed parameters, careful study of the numbers in Tables 11 and 12 was informative. allowing us to focus attention on those fates that are i) responsible for the largest number of seabird deaths; and ii) unobservable. It was on this basis that we chose to test an alternate parameterization for transition s4 (surface warp strike carcass retention rate), noting that the fate with the highest number of estimated deaths was surface warp strike cryptic deaths (highlighted yellow in Tables 11 and 12), and the fates responsible for the 2nd and 3rd highest numbers of birds are both of observable dead captures, hence already known from the data (highlighted gray).

If improving the estimation of cryptic mortality is a priority, then understanding sources of uncertainty is especially relevant to inform research planning. To more fully examine uncertainty in the estimation of cryptic mortality, in Annex C (Tables C1-C4) we reproduce the full outputs of the transition matrix analysis summarized in Tables 11 and 12, but this time retaining the estimated 95% confidence intervals around the estimation of each state transition and each terminal fate in Figure 1.

Critical consideration of the outputs of Annex C would suggest, and sensitivity analyses will likely confirm, that:

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i) aerial warp strikes are not a significant source of cryptic mortality regardless of how uncertain the rate estimations are; improving the estimation of aerial warp strike rates or fatality rates is not a high research priority;

ii) net captures often account for a majority of observable captures but are not a major source of uncertainty affecting cryptic mortality, because most net interactions are observable, and the majority of those are already dead (hence the outcome is neither cryptic nor uncertain);

iii) live release survival rates may be uncertain, but they are not a major source of uncertainty in the estimation of cryptic mortality, because they only apply a small and known number of observed live captures, and the rates themselves are bounded (0 to 1);

iv) the only transition rate that has a major effect on the estimation of cryptic mortality multipliers is the **s4** parameter, i.e. the fatal surface warp strike carcass retention rate;

v) increasing warp strike observation rates using conventional means, including human observers or cameras, will not generate meaningful improvements in the estimation of trawl fishery cryptic mortality because the uncertain phenomenon occurs under the water;

vi) The critical research question underlying uncertainty in cryptic mortality is whether seabirds dragged underwater by trawl warps:

   i. free themselves and re-surface alive, or
   ii. remain entangled in fishing gear where they are recovered as dead captures; or
   iii. drown but fall off of the fishing gear without being observed

… only research designed to better estimate the relative rate of these three outcomes will meaningfully improve the estimation of trawl fisheries cryptic mortality. Where water clarity is high it is possible that underwater cameras could help resolve these questions; alternately, repeating the methods of Parker (2013), i.e. using a separate small following vessel to observe birds re-surfacing after the trawl vessel has passed, may be useful.

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REFERENCES

Abraham, E.R. (2010). Warp strike in New Zealand trawl fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 60.

Abraham, E.R.; Thompson, F.N. (2009) Warp strike in New Zealand trawl fisheries, 2004–05 to 2006–07. New Zealand Aquatic Environment and Biodiversity Report No. 33. 21 p.

Edwards, C.T.T.; Peatman, T.; Goad, D.; Webber, D.N. (2023). Update to the risk assessment for New Zealand seabirds. New Zealand Aquatic Environment and Biodiversity Report No. 314. 66 p.

Edwards, C.; Peatman, T.; Goad, D.; Webber, D. (2023b). Fishery data inputs for the New Zealand Seabird Risk Assessment. New Zealand Aquatic Environment and Biodiversity Report No. 313. 117 p.

Falkland Islands Government, (2023). Fisheries Department Fisheries Statistics, Volume 27, 2022: 94pp Stanley, FIG Fisheries Department

Gilman, E.; Suuronen, P.; Halls, M.; Kennelly, S. (2013). Causes and methods to estimate cryptic sources of fishing mortality. Journal of Fish Biology, 83, 766-803.

Lokkeborg, Svein (2011). Best practices to mitigate seabird bycatch in longline, trawl and gillnet fisheries — efficiency and practical applicability. Marine Ecology Progress Series Vol. 435: 285–303, 2011. doi: 10.3354/meps09227

Marine Stewardship Council (2022). Marine Stewardship Council Standard v 3.0. Marine Stewardship Council, UK, 147 p.

Meyer (2023) Desktop update of estimation of seabird cryptic mortality in trawls, via warp and net captures in the New Zealand domestic fleet using standard mitigation. New Zealand Aquatic Environment and Biodiversity Report No. 322. 32 p.

Meyer, S. (2019). Desktop estimation of New Zealand sea lion cryptic mortality in trawls using SLEDs. New Zealand Aquatic Environment and Biodiversity Report No. 222. 25 p

Ministry for Primary Industries, 2024. Protected species bycatch in New Zealand fisheries. https://protectedspeciescaptures.nz/PSCv7/.

Parker, G.; Brickle, P.; Crofts, S.; Pompert, J.; Wolfaardt, A. (2013). Research into undetected seabird mortality in a demersal trawl fishery. Fifth Meeting of the Seabird Bycatch Working Group, SBWG5 Doc 07.

Parker, G., Crofts, S., Pompert, J., Wolfaardt, A., Brickle, P. (2013). In the wake of a factory trawler: research into undetected seabird mortality. Tech. Rep. FIG Fisheries Dept., Stanley, Falkland Islands. 25p

Peatman, T.; Edwards, C.; Goad, D.; Webber, D. (2023). Review of biological inputs for the New Zealand Seabird Risk Assessment. New Zealand Aquatic Environment and Biodiversity Report No. 312. 193 p.

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Phillips, R.A., Fox, E., Crawford, R., Price, S., and Yates, O. (2024) Incidental mortality of seabirds in trawl fisheries: A global review. Biological Conservation, 296, 110720, 11 pp.

Richard, Y.; Abraham, E.R. (2015). Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2012–13. New Zealand Aquatic Environment and Biodiversity Report No. 162. 89 p.

Richard, Y.; Abraham, E.R.; Berkenbusch, K. (2017). Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2014–15. New Zealand Aquatic Environment and Biodiversity Report No. 191. 104 p.

Richard, Y.; Abraham, E.R.; Berkenbusch, K. (2020). Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2016–17. New Zealand Aquatic Environment and Biodiversity Report No. 237. 57 p.

Sharp, B.R. (2019). Spatially Explicit Fisheries Risk Assessment (SEFRA): a framework for quantifying and managing incidental commercial fisheries impacts on non-target species, Chapter 3. Aquatic Environment and Biodiversity Annual Review 2018. 20 – 56

Sharp, B R; Waugh, S M; Walker, N A (2011) A risk assessment framework for incidental seabird mortality associated with New Zealand fishing in the New Zealand EEZ. (Unpublished report held by the Ministry for Primary Industries, Wellington.)

Tide, C. and Eich, A.M. 2022. Seabird Bycatch Estimates for Alaska Groundfish Fisheries: 2021. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-F/AKR-25, 46 p. 10.25923/01e2-3s52.

Watkins, B.; Petersen, S.; Ryan, P. (2008). Interactions between seabirds and deep-water hake trawl gear: an assessment of impacts in South African waters. Animal conservation 11 (4): 247–254.

Webber, D. (2020). A spatially explicit fisheries risk assessment (SEFRA) of New Zealand seabirds. Unpublished Final Research Report for Fisheries New Zealand project PRO2016-06, held by Fisheries New Zealand.

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ANNEXES

Annex A: Salvin's albatross

Salvin's albatross estimated annual captures

Annual estimated captures by fishing method.

Salvin's albatross are captured primarily in trawl fisheries (83% of observable captures) and to a much lesser extent in bottom longline and surface longline fisheries (Table 14). Because trawl fishery captures are assigned such a high cryptic mortality multiplier in the 2023 SRA, trawl fisheries are estimated to account for 96% of Salvin's albatross deaths; note however that this analysis demonstrates that deepwater trawl cryptic mortality is dramatically over-estimated in the 2023 SRA (below).

Table 14 Salvin's albatross estimated annual captures, by fishing method, extracted from the model described in the 2023 New Zealand Seabird Risk Assessment (Edwards et al. 2023)

fishing method	Captures	live captures*	dead captures*	2023 SRA deaths*
trawl	250.6	80.0	170.7	1641.3
bottom longline	42.3	3.6	38.8	56.3
surface longline	6.3	0.8	5.5	8.3
setnet	0.7	0.3	0.4	0.6
Grand Total	**300.0**	**84.6**	**215.4**	**1706.5**

* the breakdown of live vs. dead captures, and total deaths, are re-estimated below

Estimated annual trawl captures, by target species

When the 2023 SRA outputs are disaggregated by target fishery, it is apparent that among trawl fisheries, the largest proportion of estimated Salvin's albatross captures (39%) occur in the aggregate 'all other trawl' category (i.e. primarily small vessel inshore trawl fisheries) which are not the focus of this analysis. Of the deepwater target fisheries analyzed here, the hoki target fishery is responsible for the greatest share of total Salvin's albatross trawl fishery captures (37%) followed by the scampi and barracuda target fisheries (Table 15).

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Table 1511 Salvin's albatross estimated annual trawl fishery captures, by target fishery, extracted from the model described in Edwards et al. (2023)

Fishery target	Captures	live captures*	dead captures*	2023 SRA deaths*
HOK	94.1	27.5	66.6	615.4
SCI	27.3	5.9	21.3	178.3
BAR	24.2	8.7	15.5	159.3
SQU	5.0	1.8	3.2	32.9
LIN	1.5	0.5	1.0	9.7
SBW	0.3	0.1	0.2	2.0
HAK	0.1	0.0	0.0	0.5
All other trawl	98.2	35.4	62.7	643.3
Grand Total	**250.6**	**80.0**	**170.7**	**1641.3**

* the breakdown of live vs. dead captures, and total deaths, are re-estimated below

Estimated annual captures in the hoki-hake-ling fishery, by management area

Spatially, Salvin's albatross captures by the HHL fishery occur primarily in FMA3 (East Coast South Island) and FMA4 (Chatham Rise). See Table 16.

Table 16 Salvin's albatross estimated annual captures in HOK-HAK-LIN target fisheries, by FMA, extracted from the model described in Edwards et al. (2023)

Row Labels	Captures	Live captures*	Dead captures*	2023 SRA deaths*
FMA1	0.0	0.0	0.0	0.2
FMA2	10.9	3.4	7.4	71.1
FMA3	50.8	14.7	36.1	332.2
FMA4	29.5	8.4	21.0	192.6
FMA5	1.1	0.3	0.7	7.0
FMA6	0.4	0.1	0.3	2.9
FMA7	3.0	1.0	2.0	19.5
FMA9	0.0	0.0	0.0	0.0
Grand Total	**95.7**	**28.0***	**67.6***	**625.6***

* the breakdown of live vs. dead captures, and total deaths, are re-estimated below

Salvin's albatross captures, deaths, and risk by target fishery

Applying the improved estimation of cryptic mortality for large seabirds described in this report, we estimate that the HHL fishery kills 123 Salvin's albatrosses per year, followed by the SCI fishery (58 deaths), the barracuda fishery (33 deaths) and the squid fishery (6 deaths); Table 17.

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By far the greatest source of uncertainty in the estimation of trawl fishery deaths and risk is the s4 parameter, i.e. the proportion of birds killed by trawl warps for which the carcass is retained and observable. Under the pessimistic s4 sensitivity assuming very low carcass retention rates for fatal warp interactions, total estimated deaths are roughly 50% higher compared to the base case estimate (Table 18). However under both scenarios total deaths are still dramatically lower than estimated by the 2023 SRA, because the 2023 SRA consistently over-estimates the proportion of seabird interactions that occur on the warp vs. on the net or elsewhere, and underestimates the proportion of seabirds that are released alive with high probability of survival.

Table 1712 Estimated annual captures and deaths of Salvin's albatross, assigned to different capture locations and seabird interaction fates, by target fishery (base case scenario)

fate of bird interaction	**HHL**	**SQU**	**SCI**	**BAR**
bird enters net, live release, survives	3.4	0.2	2.5	0.8
bird enters net, live release, dies	1.7	0.1	1.5	0.4
bird enters net, dead capture	28.3	1.1	6.0	0.9
bird enters net, dies, not recovered (cryptic death)	2.7	0.1	0.7	0.1
external net entanglement, live release, survives	15.4	1.1	0.3	5.3
external net entanglement, live release, dies	5.5	0.3	0.2	2.5
external net entanglement, dead capture	8.9	0.5	0.2	5.9
external net entanglement, cryptic death	2.9	0.1	0.1	1.9
other interaction, live release, survives	7.4	0.4	4.0	2.4
other interaction, live release, dies	2.4	0.1	1.9	1.2
other interaction, dead capture	5.7	0.2	2.5	2.4
other interaction, cryptic death	4.8	0.2	2.3	2.1
aerial warps strike, cryptic death	0.9	0.0	1.5	1.4
surface warp strike, dead capture	17.0	1.0	8.3	2.3
surface warp strike, cryptic death	41.9	2.1	32.5	11.5
all captures C	**95.6** (81.5-110.6)	**5.0** (4.4-5.7)	**27.3** (18.7-36.7)	**24.2** (16.9-31.8)
live captures	**35.7** (18.5-55.1)	**2.3** (1.4-3.2)	**10.3** (19.-21.5)	**12.7** (3.1-24.4)
proportion alive	**0.373**	**0.456**	**0.377**	**0.523**
dead captures	**59.9** (47.2-72.9)	**2.7** 2.2-3.3)	**17.0** (10.4-23.9)	**11.5** (5.9-17.9)
cryptic + post-release deaths	**62.7** (13.7-169.0)	**3.2** 0.7-7.9)	**40.5** (4.9-130.0)	**21.1** (5.0-52.8)
all deaths D	**122.6** (65.3-232.5)	**5.9** (3.1-10.8)	**57.5** (15.8-147.6)	**32.6** (12.3-66.1)
fishery-specific risk (D/ PST)	**0.048**	**0.002**	**0.023**	**0.013**

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Table 1813 Estimated annual captures and deaths of Salvin's albatross, assigned to different capture locations and seabird interaction fates, by target fishery (pessimistic s4 scenario)

fate of bird interaction	HHL	SQU	SCI	BAR
bird enters net, live release, survives	3.4	0.2	2.5	0.8
bird enters net, live release, dies	1.7	0.1	1.5	0.4
bird enters net, dead capture	28.3	1.1	6.0	0.9
bird enters net,cryptic death	2.7	0.1	0.7	0.1
external net entanglement, live release, survives	15.4	1.1	0.3	5.3
external net entanglement, live release, dies	5.5	0.3	0.2	2.5
external net entanglement, dead capture	8.9	0.5	0.2	6.0
external net entanglement, cryptic death	2.9	0.2	0.1	1.9
other interaction, live release, survives	7.4	0.4	4.0	2.5
other interaction, live release, dies	2.4	0.1	1.9	1.2
other interaction, dead capture	5.7	0.2	2.5	2.4
other interaction, cryptic death	4.8	0.2	2.3	2.1
aerial warps strike, cryptic death	0.8	0.0	1.4	1.3
surface warp strike, dead capture	16.8	1.0	8.2	2.2
surface warp strike, cryptic death	104.1	4.6	79.6	26.8
all_captures	**95.6**	**5.0**	**27.3**	**24.2**
	(80.6-110.2)	(4.3-5.7)	(18.7-36.7)	(17.1-32.1)
live captures	**35.8B**	**2.3**	**10.4**	**12.7**
	(18.4-55.0)	(1.4-3.2)	(1.9-21.6)	(3.2-24.7)
dead captures	**59.8**	**2.7**	**16.9**	**11.5**
	(47.0-73.0)	(2.2-3.3)	(10.5-23.9)	(5.7-17.6)
cryptic + post-release_deaths	**124.8**	**5.7**	**87.7**	**36.4**
	(20.8-294.8)	(1.2-12.1)	(7.7-253.2)	(6.8-98.4)
all_deaths	**184.6**	**8.4**	**104.6**	**47.9**
	(78.0-359.7)	(3.8-14.9)	(20.2-271.7)	(14.0-111.2)
Fishery-specific risk (D/PST)	**0.072**	**0.003**	**0.041**	**0.019**

Collectively, the main deepwater target fisheries analyzed here are estimated to kill 219 Salvin's albatrosses per year (or 347 under the pessimistic s4 scenario). For comparison, the 2023 SRA estimated 998 deaths per year assigned to these same deepwater target fisheries, i.e. the 2023 SRA over-estimates deaths and risk from these fisheries by 456% (or 288%), arising from its coarse and outdated treatment of cryptic mortality.

The PST for Salvin's albatross is 2551 birds (Edwards et al. 2023 Table 15). Collectively, the contribution of the deepwater trawl fisheries analyzed here the species-level risk score for Salvin's albatross is 219/2551, i.e. 0.089 (or 347/2551, i.e. 0.136). Put another way, we estimate that the effect of these fisheries on the population status of Salvin's albatross is to reduce equilibrium population size by 4.9% (or 6.8%) relative to its unimpacted state.

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Salvin's albatross captures, deaths, and risk across all New Zealand fisheries

Table 19 combines the results of this analysis for deepwater trawl fisheries with preexisting estimates for other New Zealand fisheries, from the 2023 SRA.

These results suggest that across all New Zealand fisheries, there are 929 (or 1056) annual deaths of Salvin's albatross, such that the cumulative species-level risk = 0.364 (or 0.414). These estimates would suggest that the equilibrium population size will be reduced by 18.2% in the base case (or 20.7% under the pessimistic s4 sensitivity) as a consequence of all New Zealand commercial fisheries. Note however the largest share of species-level risk (0.252) is attributed to 'all other trawl', i.e. primarily inshore trawl fisheries. It is almost certain that the same mechanisms that caused the 2023 SRA to cryptic mortality in deepwater trawl fisheries is also affecting the 2023 SRA estimates for inshore trawl fisheries, i.e. this estimate is likely to biased high. Improved understanding of fisheries risk to Salvin's albatross would benefit from a focused analysis on cryptic mortality in inshore fisheries, similar to this analysis for deepwater trawl fisheries.

Table 19 Estimated captures, deaths, and risk to Salvin's albatross from all New Zealand commercial fisheries

Fishery target	Captures	live captures	dead captures	all deaths (base case)	risk (base case)	all deaths (pessimistic s4)	risk (pessimistic s4)
HOK-HAK-LIN	95.6	35.7	59.9	122.6	0.048	184.6	0.072
SQU	5.0	2.3	2.7	5.9	0.002	8.4	0.003
SCI	27.3	10.3	17.0	57.5	0.023	104.6	0.041
BAR	24.2	12.7	11.5	32.6	0.013	47.9	0.019
SBW	0.3	0.1	0.2	2.0	0.001	2.0	0.001
all other trawl*	98.2	35.4	62.7	643.3	0.252	643.3	0.252
bottom longline*	42.3	3.6	38.8	56.3	0.022	56.3	0.022
surface longline*	6.3	0.8	5.5	8.3	0.003	8.3	0.003
setnet*	0.7	0.3	0.4	0.6	0.000	0.6	0.000
Total	**300.0**	**101.2**	**198.8**	**929.0**	**0.364**	**1055.9**	**0.414**

*includes estimates of deaths and risk reproduced from Edwards et al. (2023)

Annex B: White-capped albatross

White-capped albatross estimated annual captures

Estimated annual captures by fishing method.

White-capped albatrosses are captured primarily in trawl fisheries (63% of observable captures) followed by surface longline fisheries (31%) and to a much lesser extent in bottom longline fisheries (Table 20). Because trawl fishery captures are assigned such a high cryptic mortality multiplier in the 2023 SRA, trawl fisheries are estimated to account for 89% of Salvin's albatross deaths; note however that this analysis

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demonstrates that deepwater trawl cryptic mortality is dramatically over-estimated in the 2023 SRA (below).

Table 2014 White-capped albatross annual estimated captures, by fishing method, extracted from the model described in Edwards et al. (2023)

fishing method	Captures	live captures*	dead captures*	2023 SRA deaths*
trawl	361.9	127.3	234.6	2371.6
surface longline	178.9	22.6	156.3	232.2
bottom longline	29.4	6.7	22.7	35.6
setnet	1.1	0.4	0.7	0.9
Grand Total	**571.3**	**157.0**	**414.2**	**2640.2**

* the breakdown of live vs. dead captures, and total deaths, are re-estimated below

Estimated annual trawl captures, by target species

When the 2023 SRA outputs are disaggregated by target fishery, it is apparent that among trawl fisheries, the largest proportion of estimated white-capped albatross captures (41%) occur in the aggregate 'all other trawl' category (i.e. primarily small vessel inshore trawl fisheries) which are not the focus of this analysis. Of the deepwater target fisheries analyzed here, the squid target fishery is responsible for the greatest share of total white-capped albatross trawl fishery captures (26%) followed by the hoki (11%) and barracuda (10%) target fisheries (Table 21).

Table 21 White-capped albatross annual estimated annual trawl fishery captures, by target fishery, extracted from the model described in Edwards et al. (2023)

Fishery target	Captures	live captures*	dead captures*	2023 SRA deaths*
SQU	93.8	33.8	60.0	615.1
HOK	41.8	12.7	29.0	272.8
BAR	37.1	12.9	24.1	242.2
SCI	21.9	4.8	17.1	145.3
LIN	17.4	5.8	11.6	114.2
HAK	2.0	0.7	1.3	13.0
SBW	0.1	0.0	0.1	0.6
All other trawl	147.9	56.5	91.4	968.4
Grand Total	**361.9**	**127.3**	**234.6**	**2371.6**

* the breakdown of live vs. dead captures, and total deaths, are re-estimated below

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Annual estimated captures in the squid fishery, by management area

Spatially, white-capped albatross captures by the squid fishery occur primarily in FMA6 (Subantarctic Islands/ Campbell Plateau) and FMA5 (Southland). See Table 22.

Table 15 White-capped albatross estimated annual captures in SQU target fisheries, by FMA, extracted from the model of Edwards et al. (2023)

FMA	Captures	live captures*	dead captures*	2023 SRA deaths*
FMA1	0.0	0.0	0.0	0.0
FMA3	10.5	3.7	6.8	69.1
FMA4	0.1	0.0	0.1	0.7
FMA5	39.5	14.2	25.3	258.0
FMA6	43.6	15.9	27.7	286.9
FMA7	0.0	0.0	0.0	0.4
FMA9	0.0	0.0	0.0	0.0
Grand Total	**93.8**	**33.8**	**60.0**	**615.1**

* the breakdown of live vs. dead captures, and total deaths, are re-estimated below

White-capped albatross captures, deaths, and risk by target fishery

Applying the improved estimation of cryptic mortality for large seabirds described in this report, we estimate that the squid fishery kills 111 white-capped albatrosses per year, followed by the HHL fishery (78 deaths), the barracuda fishery (50 deaths) and the scampi fishery (46 deaths); Table 23.

As with other albatross species, the greatest source of uncertainty in the estimation of trawl fishery deaths and risk is the s4 parameter, i.e. the proportion of birds killed by trawl warps for which the carcass is retained and observable. As with other large seabird species above, under the pessimistic s4 sensitivity assuming very low carcass retention rates for fatal warp interactions, total estimated deaths are roughly 50% higher compared to the base case estimate (Table 24); under both scenarios total deaths are dramatically lower than estimated by the 2023 SRA.

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Table 2316 Estimated annual captures and deaths of white-capped albatross, assigned to different capture locations and seabird interaction fates, by target fishery (base case scenario)

fate of bird interaction	**HHL**	**SQU**	**SCI**	**BAR**
bird enters net, live release, survives	2.2	3.5	2.0	1.2
bird enters net, live release, dies	1.1	1.6	1.2	0.7
bird enters net, dead capture	18.1	19.9	4.8	1.4
bird enters net, dies, not recovered (cryptic death)	1.7	2.0	0.5	0.2
external net entanglement, live release, survives	9.8	20.2	0.2	8.1
external net entanglement, live release, dies	3.5	6.4	0.1	3.8
external net entanglement, dead capture	5.7	8.5	0.1	9.1
external net entanglement, cryptic death	1.8	2.7	0.1	2.9
other interaction, live release, survives	4.7	8.2	3.2	3.8
other interaction, live release, dies	1.5	2.7	1.5	1.8
other interaction, dead capture	3.7	3.8	2.0	3.7
other interaction, cryptic death	3.1	3.8	1.8	3.2
aerial warps strike, cryptic death	0.6	0.5	1.2	2.1
surface warp strike, dead capture	10.9	18.9	6.7	3.5
surface warp strike, cryptic death	26.8	40.1	26.0	17.7
all captures C	**61.2** (52.2-70.8)	**93.8** (81.8-106.5)	**21.9** (15.0-29.5)	**37.1** (25.9-48.8)
live captures	**22.9** (11.8-35.3)	**42.7** (27.1-59.9)	**8.3** (1.5-17.3)	**19.4** (4.7-37.4)
proportion alive	**0.373**	**0.456**	**0.377**	**0.523**
dead captures	**38.3** (30.2-46.7)	**51.1** 40.6-61.9)	**13.6** (8.4-19.2)	**17.7** (9.0-27.4)
cryptic + post-release deaths	**40.2** (8.8-108.2)	**59.9** (13.7-149.1)	**32.5** (3.9-104.3)	**32.3** (7.6-80.9)
all deaths D	**78.5** (41.8-148.9)	**110.9** (58.3-201.7)	**46.2** (12.7-118.4)	**50.0** (18.9-101.3)
fishery-specific risk (D/ PST)	**0.015**	**0.021**	**0.009**	**0.009**

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Table 24 Estimated annual captures and deaths of white capped albatross, assigned to different capture locations and seabird interaction fates, by target fishery (pessimistic s4 scenario)

fate of bird interaction				
bird enters net, live release, survives	2.2	3.5	2.0	1.2
bird enters net, live release, dies	1.1	1.6	1.2	0.7
bird enters net, dead capture	18.1	19.9	4.8	1.4
bird enters net,cryptic death	1.7	1.9	0.5	0.2
external net entanglement, live release, survives	9.9	20.2	0.2	8.1
external net entanglement, live release, dies	3.5	6.5	0.1	3.9
external net entanglement, dead capture	5.7	8.6	0.1	9.2
external net entanglement, cryptic death	1.8	2.9	0.1	3.0
other interaction, live release, survives	4.7	8.2	3.2	3.8
other interaction, live release, dies	1.5	2.7	1.5	1.8
other interaction, dead capture	3.7	3.8	2.0	3.7
other interaction, cryptic death	3.1	3.8	1.9	3.2
aerial warps strike, cryptic death	0.5	0.5	1.2	2.0
surface warp strike, dead capture	10.8	18.8	6.6	3.3
surface warp strike, cryptic death	66.6	87.1	63.9	41.1
all_captures	**61.2**	**93.8**	**21.9**	**37.1**
	(51.6-70.5)	(81.4-106.0)	(15.0-29.4)	(26.2-49.3)
live captures	**22.9**	**42.8**	**8.3**	**19.5**
	(11.8-35.2)	(26.6-59.6)	(1.5-17.3)	(5.0-37.9)
proportion alive	**0.375**	**0.456**	**0.381**	**0.525**
dead captures	**38.3**	**51.0**	**13.6**	**17.6**
	(30.1-46.7)	(40.5-61.9)	(8.4-19.2)	(8.7-27.0)
cryptic + post-release deaths	**79.9**	**106.9**	**70.3**	**55.8**
	(13.3-188.7)	(23.3-226.8)	(6.2-203.1)	(10.4-150.9)
all_deaths	**118.2**	**157.9**	**83.9**	**73.4**
	(49.4-230.3)	(71.7-279.6)	(16.2-218.0)	(21.5-170.4)
fishery-specific risk (D/PST)	**0.022**	**0.029**	**0.016**	**0.014**

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Collectively, the main deepwater target fisheries analyzed here are estimated to kill 286 white-capped albatrosses per year (or 433 under the pessimistic s4 scenario). For comparison, the 2023 SRA estimated 1407 deaths per year assigned to these same deepwater target fisheries, i.e. the 2023 SRA over-estimates deaths and risk from these fisheries by 491% (or 325%), arising from its coarse and outdated treatment of cryptic mortality.

The PST for white-capped albatross is 5367 birds (Edwards et al. 2023 Table 15). Collectively, the contribution of the deepwater trawl fisheries analyzed here the species-level risk score for white-capped albatross is 286/5367, i.e. 0.053 (or 433/5367, i.e. 0.081). Put another way, we estimate that the effect of deepwater trawl fisheries on the population status of white-capped albatross is to reduce equilibrium population size by 2.6% (or 4.0%) relative to its unimpacted state.

White-capped albatross captures, deaths, and risk across all New Zealand fisheries

Table 25 combines the results of this analysis for deepwater trawl fisheries with preexisting estimates for other New Zealand fisheries, from the 2023 SRA.

These results suggest that across all New Zealand fisheries, there are 1523 (or 1671) annual deaths of Salvin's albatross, such that cumulative species-level risk = 0.284 (or 0.311). These estimates would suggest that the equilibrium population size will be reduced by 14.2% in the base case (or 15.6% under the pessimistic s4 sensitivity) as a consequence of all New Zealand commercial fisheries. Note however that as with Salvin's albatross, the largest share of species-level risk for white-capped albatross (0.180) is attributed to 'all other trawl', i.e. primarily inshore trawl fisheries. It is almost certain that the same mechanisms that caused the 2023 SRA to cryptic mortality in deepwater trawl fisheries is also affecting the 2023 SRA estimates for inshore trawl fisheries, i.e. this estimate is likely to be biased high. Improved understanding of fisheries risk to white-capped albatross would benefit from a focused analysis on cryptic mortality in inshore fisheries, similar to this analysis for deepwater trawl fisheries.

Table 25 Estimated captures, deaths, and risk to white-capped albatross from all New Zealand commercial fisheries

Fishery target	Captures	live captures	dead captures	all deaths (base case)	risk (base case)	all deaths (pessimistic s4)	risk (pessimistic s4)
HOK-HAK-LIN	61.2	22.9	38.3	78.5	0.015	118.2	0.022
SQU	93.8	42.7	51.1	110.9	0.021	157.9	0.029
SCI	21.9	8.3	13.6	46.2	0.009	83.8	0.016
BAR	21.9	8.3	13.6	50.0	0.009	73.4	0.014
SBW	0.1	0.0	0.1	0.6	0.000	0.6	0.000
All other trawl*	147.9	56.5	91.4	968.4	0.180	968.4	0.180
bottom longline*	29.4	6.7	22.7	35.6	0.007	35.6	0.007
surface longline*	178.9	22.6	156.3	232.2	0.043	232.2	0.043
Setnet*	1.1	0.4	0.7	0.9	0.000	0.9	0.000
Total*	**556.2**	**168.5**	**387.7**	**1523.3**	**0.284**	**1670.9**	**0.311**

*includes estimates of deaths and risk reproduced from Edwards et al. (2023)

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Annex C: Full estimation of large seabird interaction fates, including confidence intervals

Table C1: Output transition probabilities under base case scenario, including 95% confidence interval

transition parameter		HHL	2.5th	97.5th	SQU	2.5th	97.5th	SCI	2.5th	97.5th	BAR	2.5th	97.5th
p1	net interaction	0.112	0.088	0.138	0.160	0.128	0.195	0.014	0.007	0.021	0.026	0.016	0.038
p2	other interaction	0.033	0.019	0.049	0.046	0.029	0.065	0.013	0.005	0.021	0.012	0.005	0.020
p3	warp interaction	0.854	0.824	0.883	0.794	0.754	0.832	0.973	0.962	0.984	0.962	0.947	0.975
q1	enters net	0.525	0.415	0.635	0.417	0.323	0.515	0.939	0.819	1.000	0.127	0.015	0.264
q2	inside net, released uninjured	0.077	0.023	0.141	0.121	0.052	0.196	0.157	0.019	0.323	0.275	0.026	0.582
q3	inside net, released injured	0.064	0.016	0.119	0.069	0.021	0.125	0.218	0.045	0.417	0.280	0.025	0.593
q4	inside net, dead	0.859	0.779	0.936	0.810	0.722	0.896	0.625	0.403	0.833	0.445	0.165	0.732
q5	external entangled, released uninjured	0.515	0.306	0.725	0.616	0.427	0.807	0.337	0.022	0.726	0.304	0.104	0.539
q6	external entangled, released injured	0.137	0.053	0.236	0.100	0.044	0.162	0.336	0.016	0.720	0.212	0.058	0.396
q7	extternal entangled, dead	0.347	0.118	0.570	0.284	0.091	0.486	0.328	0.070	0.626	0.484	0.210	0.749
q8	internal release uninjured, survives	0.800	0.665	0.949	0.800	0.650	0.935	0.799	0.650	0.935	0.800	0.654	0.939
q9	internal release injured, survives	0.500	0.220	0.789	0.500	0.213	0.782	0.501	0.210	0.779	0.501	0.224	0.794
q10	dead in net, retained	0.917	0.818	1.000	0.914	0.816	1.000	0.903	0.810	0.999	0.903	0.810	0.999
q11	external release uninjured, survives	0.800	0.655	0.939	0.801	0.662	0.947	0.800	0.658	0.942	0.800	0.652	0.937
q12	external release injured, survives	0.500	0.229	0.799	0.501	0.202	0.771	0.501	0.225	0.793	0.501	0.231	0.800
q13	external interaction, dead, retained	0.785	0.593	0.950	0.787	0.600	0.950	0.739	0.550	0.927	0.779	0.587	0.950
r1	other interaction released uninjured	0.424	0.236	0.624	0.500	0.314	0.675	0.341	0.126	0.576	0.262	0.065	0.483
r2	other interaction released injured	0.068	0.011	0.140	0.101	0.031	0.183	0.220	0.055	0.414	0.196	0.037	0.386
r3	other interaction, dead	0.508	0.314	0.704	0.400	0.223	0.590	0.439	0.209	0.675	0.542	0.305	0.778
r4	other interaction released uninjured, survives	0.800	0.654	0.939	0.801	0.665	0.949	0.800	0.656	0.940	0.800	0.651	0.935
r5	other interaction released injured, survives	0.498	0.203	0.772	0.498	0.200	0.769	0.500	0.201	0.770	0.501	0.221	0.790
r6	other entangelent, dead, retained	0.571	0.334	0.750	0.532	0.297	0.750	0.545	0.305	0.750	0.562	0.323	0.750
s1	surface warp strike	0.758	0.340	0.997	0.769	0.364	0.999	0.728	0.278	0.997	0.703	0.227	0.999
s2	aerial warp strike dies	0.007	0.005	0.009	0.007	0.005	0.009	0.007	0.005	0.009	0.007	0.005	0.009
s3	surface warp strke dies	0.161	0.025	0.463	0.255	0.053	0.659	0.079	0.006	0.264	0.035	0.001	0.121
s4	fatal surface warp strike, retained	0.432	0.057	0.841	0.448	0.090	0.858	0.374	0.023	0.814	0.327	0.011	0.774
	cryptic mortality multiplier	1.283	0.750	2.411	1.182	0.674	2.143	2.119	0.743	5.387	1.350	0.617	2.677

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Table C2: Fate of 1000 large bird interactions under base case scenario, including 95% confidence interval

fate of 1000 seabird interactions	HHL	2.5th	97.5th	SQU	2.5th	97.5th	SCI	2.5th	97.5th	BAR	2.5th	97.5th
net_interaction	112.5	88.1	138.5	159.8	127.9	194.6	13.8	7.0	20.8	26.1	15.8	38.1
other_interaction	33.3	19.1	49.3	45.7	28.9	65.1	12.9	5.4	21.3	11.9	4.5	20.1
warp_interaction	854.3	824.2	882.9	794.5	754.3	831.7	973.3	961.9	984.0	962.0	946.9	975.3
bird_enters_net	59.0	42.7	75.5	66.4	49.2	84.9	13.0	6.2	19.9	3.3	0.3	7.0
inside_net_released_alive_uninjured	4.5	1.3	8.4	8.0	3.3	13.4	2.0	0.2	4.5	0.9	0.0	2.5
inside_net_released_alive_uninjured_survives	3.6	1.0	6.9	6.4	2.6	11.0	1.6	0.1	3.6	0.7	0.0	2.0
inside_net_released_alive_uninjured_dies	0.9	0.1	2.0	1.6	0.2	3.3	0.4	0.0	1.1	0.2	0.0	0.6
inside_net_released_alive_injured	3.7	0.9	7.1	4.6	1.3	8.5	2.8	0.5	5.9	0.9	0.0	2.5
inside_net_released_alive_injured_survives	1.9	0.2	4.1	2.3	0.4	4.9	1.4	0.1	3.3	0.5	0.0	1.3
inside_net_released_alive_injured_dies	1.9	0.3	4.1	2.3	0.4	4.9	1.4	0.1	3.3	0.5	0.0	1.3
inside_net__dies	50.7	36.2	66.6	53.8	38.3	70.7	8.1	3.3	13.7	1.5	0.1	3.5
inside_net__dies_capture	46.3	33.7	59.4	49.0	35.9	62.8	7.3	2.9	12.1	1.3	0.1	3.1
inside_net__dies_not_recovered	4.4	0.0	10.4	4.8	0.0	11.3	0.8	0.0	2.0	0.1	0.0	0.4
outside_net	53.5	36.6	73.8	93.4	68.6	123.7	0.8	0.0	2.5	22.8	12.7	33.9
outside_net_released_alive_uninjured	27.0	17.8	36.7	56.6	43.2	70.6	0.3	0.0	0.9	6.7	2.3	11.3
outside_net_released_alive_uninjured_survives	21.6	13.0	30.5	45.3	31.3	59.7	0.2	0.0	0.8	5.3	1.8	9.4
outside_net_released_alive_uninjured_dies	5.4	1.1	10.0	11.3	2.7	20.0	0.1	0.0	0.2	1.3	0.2	2.8
outside_net_released_alive_injured	7.2	2.8	12.2	9.2	4.0	14.8	0.3	0.0	0.9	4.7	1.3	8.5
outside_net_released_alive_injured_survives	3.6	0.8	7.2	4.6	1.2	9.0	0.1	0.0	0.5	2.3	0.4	5.0
outside_net_released_alive_injured_dies	3.6	0.8	7.2	4.6	1.1	9.0	0.1	0.0	0.5	2.3	0.4	5.0
outside_net__dies	19.3	4.0	38.5	27.6	5.5	55.7	0.3	0.0	1.0	11.5	2.3	22.2
outside_net__dies_capture	14.6	3.4	26.4	20.8	5.2	37.7	0.2	0.0	0.7	8.7	2.1	16.1
outside_net__dies_not_recovered	4.7	0.1	13.4	6.8	0.3	19.7	0.1	0.0	0.3	2.8	0.1	7.6
other_interaction_released_alive_uninjured	13.8	7.2	21.0	22.4	14.0	32.0	4.3	1.2	8.1	3.0	0.5	6.1
other_interaction_released_alive_uninjured_survives	11.0	5.3	17.1	18.0	10.4	26.5	3.5	0.9	6.6	2.4	0.4	5.0
other_interaction_released_alive_uninjured_dies	2.8	0.5	5.4	4.5	0.9	8.4	0.9	0.1	1.9	0.6	0.0	1.5
other_interaction_released_alive_injured	2.2	0.3	4.8	4.5	1.2	8.4	2.8	0.5	5.7	2.3	0.3	4.9
other_interaction_released_alive_injured_survives	1.1	0.1	2.6	2.3	0.3	4.9	1.4	0.1	3.2	1.1	0.1	2.7
other_interaction_released_alive_injured_dies	1.1	0.1	2.7	2.3	0.4	4.9	1.4	0.1	3.2	1.1	0.1	2.7
other_interaction__dies	17.3	6.5	30.8	18.8	6.8	34.2	5.8	1.2	11.5	6.6	1.6	12.9

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other_interaction__dies_capture	9.4	4.2	14.9	9.3	4.2	15.0	3.0	0.7	5.8	3.6	0.9	6.7
other_interaction__dies_not_recovered	7.9	1.7	18.7	9.4	1.9	22.2	2.8	0.4	6.8	3.0	0.4	7.3
warp_interactions_aerial	206.4	1.9	562.2	183.8	0.7	506.8	264.4	2.4	702.0	285.5	1.5	744.0
warp_interactions_aerial_survives	204.9	2.3	558.9	182.5	1.1	503.8	262.5	2.0	696.6	283.5	1.5	739.1
warp_interactions_aerial_dies_unrecovered	1.4	0.0	4.0	1.3	0.0	3.6	1.9	0.0	5.0	2.0	0.0	5.3
warp_interactions_surface	647.9	284.7	865.2	610.6	281.3	812.5	708.9	271.4	976.2	676.5	214.2	963.1
warp_interactions_surface_survives	551.4	173.8	814.5	465.2	118.6	732.9	659.4	215.3	951.2	656.3	197.8	954.3
warp_interactions_surface_dies	96.4	19.6	273.2	145.4	37.2	366.1	49.5	5.0	158.6	20.1	0.6	66.9
warp_interactions_surface_dies_dead_capture	27.8	18.1	38.2	46.7	33.3	59.9	10.1	4.4	16.3	3.3	0.5	6.8
warp_interactions_surface_dies_not_recovered	68.7	0.6	242.9	98.7	0.8	316.8	39.4	0.1	147.3	16.8	0.0	62.7

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Table C3: Output transition probabilities under pessimistic s4 sensitivity, including 95% confidence interval

transition parameter		HHL	2.5th	97.5th	SQU	2.5th	97.5th	SCI	2.5th	97.5th	BAR	2.5th	97.5th
p1	net interaction	0.112	0.088	0.138	0.160	0.128	0.196	0.014	0.007	0.021	0.026	0.016	0.038
p2	other interaction	0.033	0.019	0.049	0.046	0.029	0.065	0.013	0.005	0.021	0.012	0.005	0.020
p3	warp interaction	0.854	0.823	0.882	0.794	0.753	0.830	0.973	0.962	0.984	0.962	0.947	0.976
q1	enters net	0.525	0.411	0.635	0.415	0.314	0.508	0.938	0.816	1.000	0.127	0.014	0.261
q2	inside net, released uninjured	0.078	0.023	0.140	0.121	0.052	0.197	0.157	0.021	0.324	0.280	0.029	0.595
q3	inside net, released injured	0.063	0.016	0.119	0.069	0.021	0.125	0.221	0.050	0.425	0.276	0.031	0.591
q4	inside net, dead	0.859	0.778	0.933	0.809	0.718	0.894	0.622	0.404	0.834	0.445	0.173	0.733
q5	external entangled, released uninjured	0.516	0.311	0.733	0.613	0.414	0.802	0.336	0.016	0.718	0.302	0.096	0.527
q6	external entangled, released injured	0.138	0.054	0.236	0.099	0.041	0.161	0.336	0.023	0.725	0.212	0.055	0.392
q7	extternal entangled, dead	0.346	0.120	0.575	0.288	0.087	0.495	0.328	0.070	0.624	0.485	0.208	0.747
q8	internal release uninjured, survives	0.800	0.654	0.938	0.801	0.665	0.949	0.801	0.661	0.945	0.800	0.663	0.948
q9	internal release injured, survives	0.500	0.213	0.782	0.499	0.231	0.800	0.499	0.201	0.771	0.501	0.228	0.797
q10	dead in net, retained	0.917	0.818	1.000	0.916	0.816	1.000	0.903	0.811	1.000	0.902	0.809	0.998
q11	external release uninjured, survives	0.800	0.650	0.935	0.800	0.652	0.936	0.800	0.658	0.943	0.800	0.650	0.935
q12	external release injured, survives	0.499	0.225	0.794	0.501	0.229	0.798	0.500	0.222	0.791	0.499	0.218	0.787
q13	external interaction, dead, retained	0.786	0.592	0.950	0.785	0.595	0.950	0.740	0.550	0.926	0.779	0.585	0.950
r1	other interaction released uninjured	0.424	0.235	0.622	0.500	0.325	0.683	0.341	0.124	0.568	0.262	0.069	0.489
r2	other interaction released injured	0.069	0.010	0.142	0.102	0.031	0.183	0.219	0.052	0.409	0.197	0.036	0.388
r3	other interaction, dead	0.507	0.308	0.701	0.399	0.220	0.583	0.440	0.215	0.678	0.541	0.291	0.772
r4	other interaction released uninjured, survives	0.800	0.651	0.935	0.800	0.662	0.946	0.800	0.653	0.938	0.800	0.662	0.947
r5	other interaction released injured, survives	0.499	0.205	0.775	0.500	0.228	0.797	0.501	0.200	0.770	0.502	0.216	0.786
r6	other entangelent, dead, retained	0.572	0.332	0.750	0.535	0.299	0.750	0.544	0.302	0.750	0.563	0.318	0.750
s1	surface warp strike	0.777	0.397	0.999	0.800	0.452	0.998	0.744	0.310	0.998	0.722	0.261	0.999
s2	aerial warp strike dies	0.007	0.005	0.009	0.007	0.005	0.009	0.007	0.005	0.009	0.007	0.005	0.009
s3	surface warp strke dies	0.310	0.038	0.742	0.421	0.087	0.856	0.160	0.009	0.493	0.070	0.001	0.231
s4	fatal surface warp strike, retained	0.210	0.030	0.504	0.240	0.055	0.530	0.169	0.011	0.432	0.143	0.006	0.389
	Cryptic multiplier	**1.935**	**0.832**	**3.740**	**1.687**	**0.778**	**2.973**	**3.857**	**0.892**	**10.004**	**1.983**	**0.680**	**4.515**

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Table C4: Fate of 1000 large seabird interactions under pessimistic s4 sensitivity, including 95% confidence interval

fate of 1000 seabird interactions	HHL	2.5th	97.5th	SQU	2.5th	97.5th	SCI	2.5th	97.5th	BAR	2.5th	97.5th
net_interaction	112.4	88.4	138.5	160.1	128.2	195.7	13.8	7.1	20.7	26.1	15.7	37.9
other_interaction	33.2	18.6	49.1	45.6	28.7	64.8	13.0	5.3	21.3	11.9	4.5	20.2
warp_interaction	854.4	822.8	882.5	794.3	752.6	830.3	973.3	961.6	984.0	962.0	947.3	975.8
bird_enters_net	58.9	42.9	75.8	66.2	48.9	84.2	12.9	6.5	19.8	3.3	0.3	7.0
inside_net_released_alive_uninjured	4.6	1.3	8.4	8.0	3.3	13.4	2.0	0.2	4.5	0.9	0.0	2.4
inside_net_released_alive_uninjured_survives	3.6	1.0	6.9	6.4	2.4	10.9	1.6	0.2	3.6	0.7	0.0	2.0
inside_net_released_alive_uninjured_dies	0.9	0.1	2.0	1.6	0.2	3.3	0.4	0.0	1.0	0.2	0.0	0.6
inside_net_released_alive_injured	3.7	0.9	7.2	4.6	1.3	8.4	2.9	0.5	5.9	0.9	0.0	2.4
inside_net_released_alive_injured_survives	1.9	0.3	4.1	2.3	0.4	4.9	1.4	0.1	3.3	0.4	0.0	1.3
inside_net_released_alive_injured_dies	1.9	0.3	4.1	2.3	0.3	4.8	1.4	0.1	3.3	0.4	0.0	1.3
inside_net__dies	50.6	35.7	66.1	53.6	37.8	69.8	8.1	3.3	13.4	1.5	0.1	3.5
inside_net__dies_capture	46.3	33.7	59.4	48.9	36.1	62.6	7.3	2.9	12.0	1.3	0.1	3.1
inside_net__dies_not_recovered	4.4	0.0	10.5	4.7	0.0	11.2	0.8	0.0	1.9	0.1	0.0	0.4
outside_net	53.5	36.2	74.0	93.9	68.7	125.3	0.8	0.0	2.5	22.8	13.0	34.1
outside_net_released_alive_uninjured	27.0	17.6	36.2	56.5	42.6	70.3	0.3	0.0	0.9	6.6	2.5	11.5
outside_net_released_alive_uninjured_survives	21.6	13.2	30.6	45.2	31.3	60.2	0.2	0.0	0.7	5.3	1.8	9.3
outside_net_released_alive_uninjured_dies	5.4	1.2	10.0	11.3	2.6	19.9	0.1	0.0	0.2	1.3	0.2	2.8
outside_net_released_alive_injured	7.3	2.8	12.3	9.2	3.9	14.8	0.3	0.0	0.9	4.7	1.4	8.6
outside_net_released_alive_injured_survives	3.6	0.7	7.3	4.6	1.1	8.9	0.1	0.0	0.5	2.3	0.4	4.9
outside_net_released_alive_injured_dies	3.6	0.8	7.2	4.6	1.2	9.0	0.1	0.0	0.5	2.3	0.4	5.0
outside_net__dies	19.3	3.4	38.2	28.2	5.0	57.5	0.3	0.0	1.0	11.5	2.3	22.2
outside_net__dies_capture	14.6	3.8	27.1	21.2	5.5	39.1	0.2	0.0	0.7	8.7	1.8	15.8
outside_net__dies_not_recovered	4.7	0.2	13.6	7.1	0.2	20.8	0.1	0.0	0.3	2.8	0.1	7.7
other_interaction_released_alive_uninjured	13.7	7.1	20.9	22.4	13.2	31.3	4.3	1.1	8.1	3.0	0.5	6.0
other_interaction_released_alive_uninjured_survives	11.0	5.4	17.3	17.9	10.1	26.4	3.5	0.8	6.5	2.4	0.4	5.0
other_interaction_released_alive_uninjured_dies	2.8	0.5	5.4	4.5	0.9	8.4	0.9	0.1	1.9	0.6	0.0	1.4
other_interaction_released_alive_injured	2.2	0.3	4.8	4.6	1.3	8.5	2.8	0.5	5.7	2.3	0.3	4.9
other_interaction_released_alive_injured_survives	1.1	0.1	2.7	2.3	0.4	4.9	1.4	0.2	3.2	1.1	0.1	2.7

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other_interaction_released_alive_injured_dies	1.1	0.1	2.7	2.3	0.4	4.9	1.4	0.1	3.2	1.1	0.1	2.7
other_interaction__dies	17.2	6.2	30.5	18.6	6.8	33.8	5.8	1.3	11.6	6.6	1.5	13.0
other_interaction__dies_capture	9.3	4.1	15.0	9.4	4.3	15.2	3.0	0.8	5.9	3.5	0.9	6.7
other_interaction__dies_not_recovered	7.9	1.7	18.6	9.3	1.6	21.6	2.8	0.4	6.8	3.0	0.4	7.4
warp_interactions_aerial	190.2	1.1	514.3	159.1	1.7	435.3	249.2	1.8	671.1	267.0	1.6	711.3
warp_interactions_aerial_survives	188.9	1.1	510.9	158.0	1.6	432.1	247.5	1.8	666.2	265.1	0.9	705.5
warp_interactions_aerial_dies_unrecovered	1.3	0.0	3.6	1.1	0.0	3.1	1.7	0.0	4.8	1.9	0.0	5.0
warp_interactions_surface	664.2	335.4	868.7	635.2	352.6	812.8	724.1	298.4	973.0	695.0	249.3	966.2
warp_interactions_surface_survives	466.6	105.7	775.2	374.5	60.7	670.9	618.2	182.5	939.2	652.9	205.9	948.7
warp_interactions_surface_dies	197.6	28.5	476.0	260.7	54.1	555.5	105.8	7.7	306.6	42.1	1.1	132.6
warp_interactions_surface_dies_dead_capture	27.5	17.9	38.2	46.2	32.9	59.4	9.9	4.3	16.0	3.1	0.4	6.5
warp_interactions_surface_dies_not_recovered	170.1	3.9	446.4	214.5	11.1	506.9	96.0	1.9	295.8	39.0	0.3	128.0

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Annex D: relevant data fields of fisheries observer Protected Species Interaction form

Life status when first sighted
Use one of the codes below to indicate the life status of the animal when it was first observed.

1	Alive
2	Dead (showing no sign of life)
4	Decomposing

Interaction type
Use one of the codes below to indicate the interaction type. Note that for the purposes of interaction type, SLEDs can be considered a part of the net. Therefore any SLED captures should be coded under "F".

F	Caught in the fishing gear (this includes warps, paravanes or any other equipment directly involved in fishing).
M	Caught in seabird mitigation device (i.e. tori line or bird baffler)
L	Deck impact/deck landing (use this code for birds that impact against the superstructure of the vessel or land on the deck and are assisted off the vessel)
B	Brought on board (use this code for when an animal is brought on board the vessel and released by crew but was not tangled in commercial fishing gear (e.g. animals "riding" the cod-end)
R	Caught in recreational gear (for interations used on board this vessel)
O	Other (any other capture type that does not meet any definition above; describe in comments)
U	Unknown (you do not know how the interaction occurred, describe circumstances in comments)

Part of body
Use one of the codes below to indicate which part of the body was caught.

E	Entire body caught (i.e. net/warp capture, tangled in line or foul hooked)
W	Caught by wing (seabirds and protected rays)
F	Caught by flipper/feet
H	Caught by head (e.g. in net mesh)
M	Caught by mouth (i.e. hook in mouth)
U	Unknown (you do not know which part of the body was caught)

End status
Use one of the codes to indicate what happened to the animal at the end of the incident.

R	Whole body retained	U	Returned alive but injury status unknown
A	Returned alive and uninjured	D	Returned dead and unmarked
I	Returned alive and injured	M	Marked or tagged and then discarded dead
F	Returned alive but unlikely to survive	L	Not recovered
T	Tagged/banded and released alive uninjured	V	Tagged/banded and released alive injured
W	Tagged/banded and released unlikely to survive		

Code for samples taken
Use as many codes as applicable to indicate the samples taken from the animal.

B	Head	L	Feather
C	Leg	M	Tissue
E	Stomach	O	Other (detail in comments)
F	Teeth	V	Video
G	Skin sample	Y	More than 4 samples
J	Image (photograph)	Z	No samples collected
K	Ovary		

Location of capture
Use one of the codes below to indicate where the capture occurred (note that some codes are method specific). Complete this column if the interaction type is "F" or "M".

Trawl/danish seine vessels	
S	Caught on warp or door
NI	Internal net capture (the animal was caught inside the trawl net/codend/pounds)
NC	External net capture (the animal was caught/tangled in mesh of the cod-end)
NL	External net capture (the animal was caught/tangled in the mesh of the lengthener/taper)
NW	External net capture (the animal was caught in the mesh of the net wings/body)
SC	Animal was caught in the centre net of a triple-rig (SCI only)
SH	Animal was caught/tangled in the hood of the SLED
SG	Animal was caught on the grid of the SLED
L	Animal was caught/tangled in the net lazy line or paravane
OT	Other capture location on a trawl vessel (describe in comments)
Longline vessels	
TM	Tangled in mainline
TF	Tangled in float line
TS	Tangled in snood/branch line
TU	The line the animal was tangled in was unable to be determined
H	Caught on hook
TH	Animal was both caught on the hook and tangled in line
LL	Other type of gear capture on longline vessel (describe in comments)
Mitigation device – all vessels	
TO	Tangled in tori line
BB	Caught in bird baffler
WS	Caught in warp scarer
ML	Caught in longline hauling mitigation device
MO	Caught in other mitigation device (describe in comments)
Other	
NO	Net capture (purse seine or set net vessels only)
P	Caught in fishing pot
R	Caught in gear retrieval rope (i.e. potting/set netting)
O	Other location (only use this code if no others apply; describe in comments)
W	Caught on troll lure
X	Unknown

Injury/bodily status
Use as many of the codes as applicable to indicate the injury status of the animal.

A	Broken or drooping wing	P	Disorientated or unco-ordinated
B	Broken beak	Q	Froth or foam present in mouth/nostrils
C	Broken leg	R	Body in rigour
D	Broken flipper, fin or tail	S	Predated upon (e.g. by shark)
E	Broken shell	T	Liced
F	Open wound	V	Decaying
1	Killed by crew	W	Waterlogged
2	Injured by crew	X	Greased/oiled
K	Swallowed hook	O	Other describe in comments
L	Severed body part	U	Unknown (not able to assess)
M	Bleeding from orifices	Y	More than three visible injuries
N	Breathing but unconscious	Z	No visible injuries