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Report of the Technical Working Group on

CCSBT collaborative risk assessment for seabird bycatch with surface longlines in the Southern Hemisphere

New Zealand version prepared for consideration at ERSWG15 (Revised on 31 May 2024)

1. BACKGROUND and INTRODUCTION

The issue of substantial interactions between SBT fisheries and seabirds was well recognized even at the time of establishment of the CCSBT in 1994. An initial draft of recommendations on reducing the incidental bycatch of seabirds was developed in 2006 at the 6th meeting of the CCSBT Ecologically Related Species Working Group (ERSWG), which ignited the debate whether the CCSBT can make binding measures for ERS related issues. Subsequently, the 7th meeting of ERSWG could not reach agreement on draft recommendations. The debate around the CCSBT's legal capacity to establish mandatory measures on ERS related matters continued until 2018 when the CCSBT agreed on the Resolution to Align CCSBT's Ecologically Related Species measures with those of other tuna RFMOs at the 25th Annual Meeting, which was updated at the 28th Annual Meeting in 2021.

A Performance Review was conducted in 2008 that criticized the ERSWG and pointed to, at the very least, a need to assess the risks and impacts of SBT fisheries on ERS species and adopt an appropriate mitigation strategy to address those risks and impacts. In response, the 15th Annual Commission meeting in 2008 agreed to develop a non-binding recommendation for the CCSBT covering bycatch mitigation for seabirds, sea turtles and sharks. Additionally, it agreed to develop a Strategic Plan and established Strategy and Fisheries Management Working Group. The Plan was adopted at a Special Meeting held in 2011, which included three items and seven action items under the ERSWG.

In 2014, the Strategy and Fisheries Management Working Group was re-established to discuss revisions of the action plan. At the same time, following the ERSWG recommendation, a small technical group, Effectiveness of Seabird Mitigation Measures Technical Group (SMMTG), was established to provide advice to the ERSWG on feasible, practical, timely, and effective technical approaches for measuring and monitoring the effectiveness of seabird mitigation measures in SBT longline fisheries. Both groups tabled their reports in 2015. The ERSWG took the SMMTG recommendations to progress in two directions: 1) undertaking a global assessment of seabird bycatch collaboratively among all tuna RFMOs through the support of the ABNJ Tuna Project Seabirds component that was concluded in 2019 (Abraham et al 2019)), and 2) developing an ERSWG work plan. The latter led to the development of the CCSBT Multi-year Seabird Strategy, which was adopted at the 26th Annual Meeting of CCSBT.

A range of actions to be undertaken under each specific objective of the Multi-year Seabird Strategy was developed at the 14th meeting of ERSWG in 2021 and adopted by the 29th Annual meeting of CCSBT, which included an action to "update SEFRA seabird risk assessment" (1E) with New Zealand and Japan volunteering to take a leading role intersessionally. This would also allow work to "assess the cumulative impacts of fishing for SBT on seabirds, particularly threatened albatross and petrel species, across tuna RFMOs including developing methods for extrapolating seabird bycatch levels and seabird bycatch rates to identify total mortalities and total mortality rates" (3D) to be undertaken.

New Zealand and Japan held initial discussions in Wellington, New Zealand in June 2022 and agreed on a tentative work plan that included two technical workshops, one online and the other hybrid, and one face-to-face data preparatory meeting (Appendix 1). It was also agreed that the CCSBT collaborative assessment would begin after the completion of a seabird risk assessment of fisheries within New Zealand and would be developed based on the model developed for the New Zealand domestic risk assessment.

Following the decision at the 29th meeting of the Commission to hold one technical workshop before ERSWG-15, the original work plan was modified to hold one combined meeting to review the SEFRA procedure developed by New Zealand and to agree on basic data requirements in 2023, and one assessment meeting online, but with voluntary participation face-to-face without asking the Secretariat for assistance in conducting the meeting.

The first technical workshop (hybrid) was held in Wellington, New Zealand, from 21 to 22 June

2023 with the participation of Australia, Japan, New Zealand and Taiwan. Agreed outcomes from the meeting can be found in Appendix 2. The meeting agreed the first collaborative assessment would be based on the best available science and knowledge and provide a basis for future regular assessments with continuous improvements. The technical workshop agreed a range of basic assumptions, the time-period subject to the analysis, a range of species to be covered, and the temporal and spatial resolutions. The workshop established two expert teams: 1) for reviewing seabird biological parameters and distribution data, and 2) for incorporating modifications agreed at the workshop and evaluating them, together with the draft work schedule.

A review of biological parameters was shared among the group in January 2024. The New Zealand domestic seabird risk analysis was concluded in October 2023 and the program package including seabird observed catch and effort preparation package was provided in late 2023. Thereafter, the individual 'Contracting Party and Cooperating non-contracting parties' (CPCs) processed the observed seabird catch and effort data and ran the model for catchability estimation independently, using each CPCs domestic information.

The second technical workshop (hybrid) was held in Wellington, New Zealand, from 27 to 29 February 2024 with participation from Australia, Japan, New Zealand and Taiwan. The workshop reviewed the model outputs step-by-step and evaluated the reliability/ feasibility of estimated parameters. The workshop noted problems in estimating species-specific catch, mainly due to potential errors in observed seabird identification, and a mismatch in overlap caused by partial coverage of bird density distribution information with tracking data.

Consequently, the workshop agreed to further modify the model by incorporating new aggregation as a species complex for those species difficult to identify at species level. Observed capture and observed overlaps were summed across species within the species complex during the model fitting. Therefore, the model would ignore the species identification confusion within a species complex but would make a prediction of total mortality at species level relying on the overlap information (discussed further in section 4.2). The revised procedure was reviewed at an online discussion held on 4 April 2024 that confirmed general consistencies between the predicted and observed catches with the agreed aggregations.

The technical group examined the outputs of the modified model including the estimates of total bycatch mortalities and corresponding risks at an online discussion held on 23 April, 2024. The technical group noted that at least two of the biological parameters (the number of breeding pairs, and the probability of breeding for some species) show a large shift away from the priors when the model was run (discussed further in the Section 4.3). This would impact on the assessment of catchability estimates and evaluation of relative risks in particular for small albatrosses (mollymawks) and medium petrels, so the model output for those species groups should be interpreted carefully.

This document describes the process and results of the CCSBT collaborative seabird risk assessment for the surface longline fishery using the Spatially Explicit Fisheries Risk Assessment (SEFRA) framework. The document includes the methodology used, assumptions, input data and their preparation, initial review results and subsequent model modifications, and the final outputs. The document is focused on the description of facts and observations and does not include interpretations, particularly on potential implications for CCSBT seabird management.

While the outputs of the SEFRA update are expected to provide a basis for addressing other actions in the CCSBT Multi-year Seabird Strategy, including "to agree on a SBT seabird bycatch target for reducing the level of impact of SBT fishing operations on seabird populations" (1A), to "agree on the list of priority species and corresponding management targets, taking into account the status of seabird population, distributional overlaps with SBT fisheries, and significance of SBT fisheries in their mortality" (1D), and "establish a robust definition of high risk areas that takes into account the precautionary approach" (1F), such considerations are left to the individual CPCs and subsequent discussions at the ERS.

2. METHODS

2.1 General concept of SEFRA

A Spatially Explicit Fisheries Risk Assessment (SEFRA) framework used in this risk assessment was developed and has been utilised in New Zealand as standard procedure to estimate the risk to seabirds and other protected species caused by commercial fishing (Edwards et al. 2023a, Abraham et al. 2017a, b, Sharp 2019) and subsequently applied to the capture of Diomedea albatrosses in southern hemisphere longline fisheries (Ochi et al 2018, Abraham et al. 2019).

The approach is designed to accommodate multiple species and fisheries simultaneously, constructing risk profiles as a function of spatial and temporal overlap. Application has been primarily within the New Zealand Exclusive Economic Zone (EEZ; e.g., Richard & Abraham 2015, Richard et al. 2017, 2020), but, since seabirds migrate widely across the southern hemisphere, a comprehensive assessment of the fisheries risk needs to account for all the fishing effort that may be encountered as they move through international waters. This, as well as the need to inform management outside of the New Zealand EEZ, has motivated application of the method in this wider context.

The SEFRA approach is a quasi-spatial model where temporal and spatial overlap of the seabird distribution and fishing effort are used to predict a catch. Parameterisation of the capture rate per unit of overlap occurs via a fit to fisheries observer capture data, and total captures are calculated by multiplication of the total overlap (including the unobserved component) with this estimated rate (referred to as the *catchability*). Deaths are calculated from the predicted captures using a mortality multiplier that accounts for the probability of dead capture and cryptic mortality. Following estimation of the total deaths, the SEFRA approach attempts to quantify the risk using a limit reference point referred to as the Population Sustainability Threshold (PST; Sharp 2019). For the current project, instead of risk we report the relative mortality per species *s* as:

$$Relative\ Mortality_s = \frac{Total\ deaths_s}{Maximum\ population\ growth_s}$$

which is equal to the proportion of the theoretical maximum growth rate removed by fisheries bycatch per year. The relative mortality approach still provides the same relative ranking as that achieved using the PST reference point:

$$PST_s = \frac{1}{2} \cdot \varphi \cdot r_s \cdot N_s$$

However, this assessment only considers a subset of total fishing effort and therefore cannot estimate overall risk to the population from fishing. Since the PST reference point is designed to allow a measurement of risk, and includes management related tuning parameters, it was determined that use of this reference point may be misleading.

The maximum population growth is a function of both the population size and productivity:

$$Maximum\ population\ growth_s = r_s \cdot N_s$$

where r_s is the maximum intrinsic population growth rate (i.e., under optimal conditions and in the absence of density dependent constraints), and N_s is the total population size, which we assume in the current setting to be the total number of adults.

To estimate total deaths, first the capture rate per unit of overlap must be paramterised per fishery fleet and species group. To do this the catchability coefficient $\boldsymbol{q}$ is estimated using observed capture and effort data, and then is applied to the total effort to obtain the predicted total seabird catch.

Individual members of the CCSBT are each treated as one fishery fleet, except the joint-venture (JV) operation under New Zealand flag that was handled as a separate fleet based on its characteristics in Japanese operational style under strict management and surveillance under the joint venture arrangement. For those Members with no observed capture data available, the q was obtained from the fleet with the similar operational characteristics, such as operating area and operation procedures, and fishing efforts reported to the CCSBT. The approximation utilised in the current assessment is shown in Table 2.

The assessment was targeted to cover the 27 ACAP priority species. Those species were grouped into six species groups: wandering albatross, royal albatross, small albatross, sooty albatross, large petrel, and medium petrel, according to their feeding behaviour and aggression, and willingness to travel large distances to a fishing vessel. The catchability was shared across species within a species group, assuming that their vulnerability to fishing is a determined by these shared behavioural characteristics. The list of species assessed, along with their species group, is given in Table 1. The fishery coverage of the assessment was defined as surface longline fisheries operated by the CCSBT members in the southern hemisphere, regardless of target species, in the period from 2012 to 2019 inclusive. A first model run assumed constant catchability over the whole time period. For a second model run, the temporal range was divided into two periods, 2012-2016 and 2017-2019, with a separate catchability estimated for each. Because of changes to both the model structure (e.g. monthly biological distributions) and the input data (e.g. updated biological parameters) direct comparisons between these results and those from the previous southern hemisphere risk assessment (Abraham et al., 2019) should not be made. Additionally, changes between the early and late period could be used to quantify any changes in seabird bycatch that may have occurred since 2016, though it would not be possible to assess if these were being driven by changes in fishing practices or seabird abundance. The assessment is able to distinguish between live and dead captures, and estimates deaths assuming mortality of live captures post release. To ensure consistency with the previous assessment, which assumed that all captures led to death of the bird, we applied a 99% mortality rate to live captures (effectively treating all captures as dead). This gives a more precautionary estimate of bycatch impacts. Also, inadequacy of biological and distributional information of immature birds as well as ambiguity in capture data caused difficulty in distinguishing maturity stage and all captured birds were treated as adults.

2.2 Seabirds available to the CCSBT fishery

The seabird population is usually indicated as number of breeding pairs in colonies. Therefore, the information on the total breeding pairs, N_{bp} in the world was translated into the total adult population, N_{adult}, using the probability of breeding $P\_{breeding}$.

$$N_{adult} = \frac{2 * N_{bp}}{P_{breeding}}$$

Then, the number of adults available to the CCSBT surface longline is determined by multiplying with the probability of being in the southern hemisphere (P_{SH}) first and adjusted with the probability of being breeding and nesting, since seabirds are likely not available for fishery whilst they are attending the nest. Outside the breeding season, the probability of nesting becomes zero (i.e. P_{nest} = 0), and all adults are considered to be available to surface longline fishing. This adjustment is made for each month:

$$N = N_{adult} * P_{SH} * \left[1 - P_{breeding} * P_{nest}\right]$$

The SEFRA requires the number of seabirds available in a certain time (month) and location (grid cell) and therefore need to allocate above mentioned N into each grid cell.

2.3 Estimation of the catchability

The first stage in the estimation of fleet specific catchability and bird specific vulnerability requires estimating overlap between observed fishing events and seabird distributions. This is done by overlaying the relative density of seabirds estimated from available seabird tracking data with observed fishing effort and seabird bycatch information.

The relative density of seabirds can be described using the term, $d_{s,m,x}$, which is derived from the number of individuals of species *s* in grid cell *x* in month *m* (see Section 0). It was treated as a fixed data input to the model. When y_{smx} is the estimated number of individuals in grid cell $\boldsymbol{x}$, and $\boldsymbol{A_x}$ as size of grid cell $\boldsymbol{x}$ in square kilometers, then $d_{s,m,x}$ in grid cell $\boldsymbol{x}$ is:

$$d_{s,m,x} = \frac{y_{s,m,x}}{A_x \cdot \sum_x y_{s,m,x}}$$

The value $y_{s,m,x}/\sum_x y_{s,m,x}$ is treated as the multinomial sampling probability of an individual from species s being in grid cell *x* during month m. The absolute density, in number of birds per grid cell, is therefore:

$$\mathbb{D}_{s,m,x} = d_{s,m,x} \cdot N_s$$

If fishing effort is allocated to grid cell $\boldsymbol{x}$, and assuming a random distribution of birds and fishing effort within that grid, then the overlap is a measure of the possibility for interaction per grid cell:

$$overlap_{f,s,m,x} = effort_{f,m,x} \cdot d_{s,m,x}$$

The SEFRA process then takes this overlap and sums it by grid cell and month such that the density overlap is:

$$desnity\ overlap_{s,f} = \sum_{x,m} (effort_{f,m,x} \cdot \mathbb{D}_{s,m,x})$$

The observable interactions are referred to as captures and are a function of the catchability ($q_{z,f}$), defined at the level of the fishery fleet f and species group z. Model predicted captures are therefore expected to be:

$$predicted\ captures_{z,f} = q_{z|s,f} \cdot \sum desntiy\ overlap_{s,f}$$

The model is fit to the observed captures with the likelihood is abbreviated as:

$$observed\ captures_{z,f} \sim Poisson(predicted\ captures_{z,f})$$

A problem with this likelihood is that captures may be recorded at a taxonomic level that is lower than the species. Likelihoods are required that fit the model to these low-resolution captures. This also means that the captures recorded for any given species will likely underestimate the total observed captures for that species, because some of those observed captures will have been recorded at, for example, the genus or family level.

To construct a likelihood that is able to accommodate low resolution captures we first defined the cumulative captures. For example the cumulative captures that include genus level identification would be:

$$\text{cumulative captures}_{f,z} = \sum C_{f,genus} + \sum C_{f,species\ complex} + \sum C_{f,s}$$

Using this definition we can then include probability terms that measure the probability that a capture is recorded at a series of lower taxonomic resolutions. In the current model, a capture for species s may be recorded at the species, species complex, genus, family level or phyla. Similarly, the inclusive predicted captures would be the summation of all model-predicted captures for members of that genus. In this case, we require a probability π_G, which refers to the probability of a capture being recorded at the genus level or higher. And we would therefore write, for genus-level captures:

$$\text{inclusive observed captures} \sim Poisson(\text{inclusive predicted captures} \cdot \pi_G)$$

Intuitively, the π_G term accounts for the fact that a proportion 1 - π_G of the captures of any given genus may have been recorded at a taxonomic resolution that is lower than the genus level. For the complete model, a set of ordered probability terms is required: $\pi_S < \pi_C < \pi_G < \pi_F$, referring to the probabilities of being recorded at the species level, at the species complex level or higher, the genus level or higher, or the family level or higher. These probabilities were assumed to be conditional on the fishery fleet and estimated as part of the model fit. As for the genus-level capture likelihood above, likelihood functions were constructed for the other taxonomic resolutions and the model was fitted to the revised likelihoods using the inclusive captures.

The catchability itself is a function of fishery group f and species group z covariates. The fishery group coefficient β_f is centred on the intercept term, with deviations around this intercept constrained to sum to zero. Species group coefficients $\beta_{z|f}$ were specific to the fishery group and were similarly constrained to sum to zero. This allowed the catchability per species group to deviate from the fishery group effect in a fishery group-specific manner.

$$log_{10}(q_{f,z}) = \beta_0 + \beta_f + \beta_{z|f}$$

2.4 Prediction of deaths

Captures are a subset of all the interactions between fishing effort and birds. These captures can lead to death but not all deaths will have resulted from observable captures because they can be cryptic (unobservable even were an observer present). To predict the number of deaths based on the number captures we use a mortality multiplier. This multiplier specifically relates the number of predicted observable captures to the number of deaths. It includes observable dead captures, the rate of cryptic capture per observable capture, and the probability that these cryptic captures lead to death (cryptic mortality). It also includes the death of live captures post-release. For this assessment it was assumed that almost all seabirds that were caught subsequently died (post release survival was set to 0.01). The multiplier was used to scale up the predicted captures to the predicted deaths. During the second technical workshop New Zealand suggested using the surface longline mortality multiplier from the Edwards et al (2023a) assessment.

$$total\ deaths_{s,f,m,x} = q_{z,f} \cdot overlap_{s,f,m,x} \cdot N_s \cdot K$$

For this assessment all captures are considered dead, so there is only consideration of the probability that a capture was observable.

2.5 Maximum population growth rate

The estimated total seabird mortality taken by the CCSBT longline fleets and measured as the number of deaths was then compared with the maximum population growth rate, for the optimal intrinsic population growth rate, r_s, is required. This will allow the deaths to be compared per species in a manner that accounts for their relative productivity levels. First this requires an accompanying distribution for $r_s = \ln(\lambda_s)$. This was achieved using allometric theory as follows. Mean generation time is first approximated as:

$$\bar{T} = A + \frac{S}{\lambda - S}$$

Allometric theory defines the optimal generation time such that:

$$T_{[opt]} \cdot \ln(\lambda) = k$$

Where $k \approx 1$ is a constant. Therefore, under constant fecundity and assumed optimal conditions we can write:

$$\frac{k}{\ln(\lambda)} = A + \frac{S^{opt}}{\lambda - S^{opt}}$$

$$\lambda = \exp\left(k \cdot \left(\mathrm{A} + \frac{S^{opt}}{\lambda - S^{opt}}\right)^{-1}\right)$$

which must be solved numerically. This provides the so-called demographic-invariant solution for λ (Niel & Lebreton 2005) that has been used in the applications of the SEFRA methodology to date (e.g., Abraham et al. 2017) including this exercise.

A major assumption of this approach is that we have information on the optimum survivorship (S_s^{opt}) and the current age at first breeding (A_s^{curr}) as indicative of the current environmental conditions. These are estimated parameters within the model, each with strongly informed priors.

2.6 Parameter estimation

All estimation was performed within a Bayesian framework using rstan (Stan Development Team 2020). Two chains were run for 2000 iterations each, with the first half discarded. Posterior samples from estimated parameters were inspected visually to ensure convergence of the model. All biological parameters were treated as estimable: N_s^{BP}, P_s^{B}, S_s^{opt}, A_c^{curr} with strongly informed priors.

Predictor coefficients for the catchability coefficients (β_f and $\beta_{z|f}$) were given standard normal priors. The intercept term β_0 was given improper uninformative priors.

3. DATA

3.1 Seabird biological input parameters

The model required accurate and up-to-date estimates for the biological parameters with associated uncertainties for each species to be analyzed, including population size, breeding probability, proportion of adults on nest, age at first breeding (under current and optimal conditions) and adult survival (under current and optimal condition). Biological inputs to the risk assessment consist of demographic parameters, generally represented with statistical distributions (referred to as priors) and spatial distribution as point estimates without uncertainty. The demographic parameters with distributions can be updated during the model fit, which was of strong concern in the group. The biological information was collated, reviewed and evaluated by many experts, and was more reliable than the bycatch occurrence information fragmentarily collected through observer programs. Additionally, free modification of biological parameters could result in shifting of judgement basis for risk caused by bycatch. Due to the difficulty of completely decoupling updates of the biological parameters, the group accepted placing strong constraints into the modification of biological parameters as a compromise.

A literature review was conducted to update and improve upon demographic parameters summarized in a previous assessment (Edwards et al., 2023) while spatial distributions were based on Devine et al (In Press). Subsequently, the draft input parameters were hosted online by ACAP and a supplementary review was organized with 73 seabird experts invited to review these input parameters and provide input on estimates, uncertainty, and adequate prior distributions. These experts were selected based on their publication record and known involvement with particular species of interest. To facilitate the review, population size, breeding probability, and adult survival were disaggregated per colony (and subsequently reaggregated for use in the model). Further engagement with all experts resulted in a response rate of ~38% and a successful review of all parameters for all target species.

It was cautioned that the bird population dynamic data is incomplete. ACAP reports that gaps in population data remain for globally significant breeding populations at sites that are logistically difficult to access and for species that are particularly difficult to census (ACAP 2024). Nine albatross or petrel species on nine islands groups, estimated to hold >10% of the species' global population, have not had a population estimate in >10 years. Similarly, four species at seven island groups, which account for >5% of the species' total global breeding population, have not been censused since 2012. As an example, New Zealand is assumed to hold 33% of the world population of light-mantled sooty albatross (*Phoebetria palpebrata*), but as this species is notoriously difficult to survey, population estimates rely on incomplete data from the 1970s and 1990s, depending on the island group. Other population parameters, such as breeding probability, are even more limited for these poorly surveyed populations.

The technical group agreed to utilise the updated demographic parameters and their statistical distributions, but use the spatial distribution data synthesized by Devine et al. (in press) and subsequently used in Edwards et al (2023). However, the ongoing need for improved spatial data was flagged for future work.

Part of the review included an investigation into the time periods covered by the data underlying the parameters to assess whether temporal variation in demographic parameters could be included in the model. This investigation revealed that data on demographic parameters for many species are not recorded at temporal intervals on a scale fine enough to allow for the inclusion of temporally varying demographic parameters in the model.

3.2 Seabird distribution information

For the previous iteration of the Southern Hemisphere risk assessment, Devine et al. (2023) used spatiotemporal 3-dimension GAMs to create monthly maps for 28 seabird taxa in the southern hemisphere using tracking data. Distribution maps were only for adults and the adult only model was continued for this risk assessment, as Lonergan et al, (2017) states there is difficulty in distinguishing older immatures/pre-breeders (which may also have well-developed gonads) from adults, even with necropsy. This approach was also considered to be more conservative as all captures would be measured against the adult proportion of the population when evaluating the risk. Tracking data were the preferred data to produce species distributions maps, because of the fine spatiotemporal resolution of the data, and the reasonably good seasonal/spatial coverage of information for most species (i.e., throughout most phases of their respective breeding cycles). Tracking data for most species were requested from individual data owners via BirdLife International. Some tracking data were also retrieved from the Department of Conservation website[1] for Gibson's albatross (*Diomedea antipodensis gibsoni*), northern royal albatross (*Diomedea sanfordi*), Salvin's albatross (*Thalassarche salvini*), and from Dragonfly Data Science for Antipodean albatross (*Diomedea antipodensis antipodensis*).

The 3-dimensional spatiotemporal GAM approach worked well, even when data was relatively sparse. For species for which tracking data was limited (not all major colonies had data), distribution maps were augmented with mapping layers from Carneiro et al. (2020). Only four species had distributions that lacked substantial data from the main colonies.

Expected densities were predicted into a 1-degree cell resolution for each month. Often extremely small but positive values were predicted at the margins of the distribution. This caused, for example, densities predicted across continental boundaries where species were known not to occur, such as across the southern tip of South America. A manual soap film boundary was constructed, where values less than the 40th percentile ($<10^{-5}$) were set to 0. Data were then aggregated at a 5-degree cell resolution, and then the same rule applied, i.e. density values below the 40th percentile ($<10^{-5}$) were set to 0, to remove data where only a few 1-degree cells contributed to the 5-degree cell. This resolved the issues in predicting distribution at the margins such that predictions did not cross continents.

A review of biological inputs to the seabird risk assessment of Edwards et al. (2023) was undertaken as

[1] https://docnewzealand.shinyapps.io/albatrosstracker/

part of the collaborative update to the assessment. This review was coordinated by the Department of Conservation (New Zealand) and sought feedback from international experts on the species-specific distribution maps. Notable issues with the distributions and recommendations for future work can be found in Table A.6 of Edwards et al (2024).

3.3 Seabird bycatch and effort from surface longlines

The assessment utilised the observed monthly catch and effort data provided by the participating CPCs in the calendar years for 2012 to 2019. The spatial resolution used was decided by each CPC, though ultimately 5x5 degree cells were used. Individual CPCs compiled their own data using the package provided by the modeling team that allowed direct inputs into the model, as well as compilation into one combined file. The time periods selected (2012-2016 and 2017-2019) were chosen to allow a comparison between the previous assessment (2012 – 2016) and evaluation of change afterward (2017 – 2019). Onboard observer programs were drastically reduced and/or ceased for high-sea operating fleets due to movement constraints during the COVID-19 pandemic from 2020 to 2022, which meant that these data could not be incorporated into the analysis. Japan, New Zealand and Taiwan provided the observed catch and effort data. New Zealand joint venture information was added only for reference purposes with the previous assessment and did not include any information for the later period.

Australia encountered problems with domestic data confidentiality rules, as well as allocating species identification since the chosen time period corresponded to a shift towards using Electronic Monitoring. The provision of Australian longline fishery seabird bycatch and fishing effort data to the project was not possible due to timing. Under the Australian Government's information disclosure policy, agreements are established to protect confidential information. An agreement has been prepared for the project that will allow the inclusion of Australia's data in future, as this assessment is updated. For this round of assessment, Australia agreed to apply the catchability coefficient estimated for New Zealand as an initial approximation, based on the same coastal nature of its fishing operation.

South Africa indicated its intention to provide the observed catch and effort data at a late stage of the assessment process. Time constraints prevented this occurring and South Africa expressed its continued commitment to participate in the process in future. Additionally, South Africa expressed keen interest and enthusiasm to actively engage in future seabird risk assessment opportunities and projects. South Africa's pelagic longline fleet has on average 21 local flagged vessels active each year, and only one Joint Venture Japanese vessel with no Joint Venture operations having taken place in 2022 and 2023. Observer coverage in recent years across the fleet has typically been around 20% of hooks set for operations covering the entire coastline, i.e. CCSBT areas 9, 14 and 15. Scientific observers report on all seabird interactions during fishing operations to the species level where possible and provide a description of the fate of each seabird. South Africa's dedicated Offshore Resource Observer Programme (OROP) ran from 2002 to 2011. Since then, vessels have been deploying RFMO recognized and accredited observers at their cost. Therefore, historical observer data are available from 2002 to the current year. Additionally, vessels have been reporting on their interactions with seabirds in their skipper logbooks since 2015, indicating to species level when possible and the fate of seabird as dead or alive. South Africa will continue to collect these data and is willing to process these data into the required format for future risk assessment projects.

Neither Korea nor Indonesia participated in the process described in this report.

The seabird bycatch and effort data from Taiwanese longline vessels spanning 2012 to 2019 were sourced from two datasets: 1) observer records for seabird bycatch and observed effort, and, 2) logbooks and e-logbooks documenting fishing effort. All Taiwanese tuna longline vessels, regardless of size or target species, were considered the same fleet (TW). While the observer data aimed to identify seabird bycatch to the species level, Gibson's albatross was not differentiated from other species, likely resulting in being recorded as Antipodean albatross or similar species. Observers were restricted to a maximum of eight working hours during hauling, resulting in incomplete hook observations. Hence, the observed number of hooks were provided. Fishing effort data consisted of logbook-recorded number of hooks set from 2012-2016, while e-logbook data provided effort information for 2017-2019, as e-logbook implementation began in 2017. In Taiwan's data, the Gibson's and Antipodean albatross were reported as Antipodean, since there is no code assigned to Gibson's in Taiwanese observer reporting forms. Therefore, a 'Gibson's and Antipodean albatross' group was created for this analysis.

While it is ideal for all seabird catch to be identified to a species level, both Japanese and Taiwanese data contained a substantial amount of data with species aggregation as shown in Table 3. About 80% of seabird catch reported was within one species group, though reporting in family level crossed multiple species groups; Diomedeidae for four and Procellariidae for two. Over 96% of reported seabird catch was considered to belong either to Diomedeidae or Procellariidae which covers the 27 ACAP species in this assessment, even when assuming that all catch reported as generic "birds" falls outside these two categories.

Regarding total effort under CCSBT, the technical group agreed to utilise the effort information maintained by the CCSBT Secretariat unless the CPC provides updated information on longline effort in the southern hemisphere for all targets. Japan and Taiwan provided the corresponding data for their respective southern hemisphere longline effort. The RFMO data contained surface longline effort from Australia, Indonesia, Korea, New Zealand and South Africa. The total effort of Japan and Taiwan was updated to be included in the model.

4. RESULTS

4.1 Review of initial catchability coefficient estimates (q) and their reliabilities

Initial models were fitted to each CPC's observer dataset in isolation, as well as to a combined dataset including observer data from all participating CPCs. First, the behavior of direct model output, i.e. the catchability coefficients estimate, was examined against the source data used. The results obtained with the combined dataset were compared with those obtained when only one CPC's input data was used, to evaluate the impacts of partial spatial data coverage. The results indicated that the model could predict the catchability coefficients relatively well even with data of spatially limited coverage, e.g. NZ (Table 5 and Figure 1). The technical group considered it preferable to utilise the combined dataset expecting complementary effects of fulfilling missing components, and that this would also give an assurance for a model capacity to combine model outputs after running a model independently when and where data sharing would be restricted. It was agreed to utilise the combined data set for all the analyses afterwards.

Figure 2 shows species group-specific and fleet-specific catchability coefficients obtained with combined data. The Figure indicated unrealistically high catchability for the Japanese fleet on the large petrel group, and to a lesser extent on the sooty albatross group. Those two groups also indicated large uncertainty in estimates for New Zealand's domestic fleet. This was considered potentially to be driven by a mismatch between seabird capture data and distributional information obtained from tracking, namely that the tracking data used for southern giant petrel only accounted for less than 30% of the world population and northern giant petrel was missing tracking from the Pacific Ocean representing >20% of the world population. For the Japanese fleet the model estimated unrealistically high values for q to explain catch occurring in areas with low estimated population density and limited observations in the cells with density overlap. For the New Zealand fleet there were no observed captures of either species of giant petrel for the model period.

Figure 3 shows a comparison of species group-specific catchability standardised with fleet-specific catchability that should indicate a general pattern in vulnerability among species groups. However, the Figure did not show any consistent pattern other than a similarity between small albatross and medium petrel groups. The New Zealand joint venture fleet was in fact an operation by the Japanese vessels within New Zealand waters and operated in the same way as the Japanese fleet, and therefore both are expected to show a similar pattern in catchability coefficients among species groups. However, the pattern did not show any particular consistency, which raised a concern on plausibility of assumptions on the similarity of catchability according to the operational characteristics' similarity, the basis of utilizing *q* obtained from alternative fleet when no observed catch and effort data is available. This emphasized the importance of all CPCs participating in the collaborative analysis with their own data being incorporated.

4.2 General examination of initial model outputs – comparison between predicted and observed values for observed catch by species

The technical group examined the prediction of an observed capture against the observed seabird capture used as an input. The model predicted the observed seabird capture based on estimated catchability coefficient of certain fleet and species group-specific, together with species specific overlap density given as an input and observed effort information. Through species-specific density overlap, the species group level estimation would translate into a catch estimate at species level. Since the process relies heavily on the credibility of density overlap mainly derived from tracking data, the discussion here was conducted in conjunction with consideration on reliability of species identification and distribution data derived from tracking data.

The model prediction on observed seabird capture by species is shown in Table 6, against all data provided. According to the methodology description, the model fitted by species group, if so, the prediction at species group level should be also available. The results were examined together with general consideration of species identification difficulty and reliability of temporal-spatial seabird distribution maps (Table 7).

The empirical data used in the model reflects the best available evidence but are nevertheless incomplete. Species distributions were derived from tracking data requested from individual data owners via BirdLife International. Some tracking data was also retrieved from the Department of Conservation's website. Seabird tracking activities have only occurred at a subset of known seabird breeding sites, while tracking efforts globally are ever increasing (Bernard et al. 2021). Some tagging studies are focused on adult birds and as such there is limited data available for juveniles, immatures, and pre-breeders, which can comprise up to 55% of seabird populations (Carneiro et al. 2020). The assessment in this report compensates this by using a conservative approach of assuming that every bycaught bird is an adult. However, this does not negate the potential impacts of species where tracking of other life stages is not available, and for these species the current model may be omitting important areas for these other life stages.

The seabird distributions derived from tracking studies used in this report may under-represent the actual distributions of seabirds, at least for some species. For example, the distribution of Campbell black-browed albatross (*Thalassarche impavida*) is based on limited short-term tracking efforts (Sztukowski et al. 2017). The distribution of grey-headed albatross (*T. chrysostoma*) and light-mantled sooty albatross are biased towards the tracking efforts conducted in the Atlantic Ocean, while substantial populations persist in the Pacific Ocean, which remain poorly tracked to date (Cleeland et al. 2019, Goetz et al. 2022). Similarly, both Giant Petrel species are under-represented due to the limitations of the available tracking data, particularly the lack of tracking of northern giant petrels (*Macronectis halli*) in the Pacific. Giant petrel data were largely under-represented and therefore removed from the final model.

Tracking coverage for the Antipodean albatross (which contains extensive tracking for all life and breading stages), Tristan albatross (*D. dabbenena*), Indian yellow-nosed albatross (*T* *carteri*), New Zealand white-capped albatross (*T. steadi*), Salvin's albatross, Chatham albatross (*T. eremita*), black petrel (*Procellaria parkensoni*), and white-chinned petrel (*P. aequinoctialis*) were considered adequate from the review of the data. For a number of species including Gibson's albatross, wandering albatross (*D. exulans*), southern royal albatross (*D. epomophora*), shy albatross (*T. cauta*), southern Buller's albatross (*T. bulleri bulleri*), light-mantled sooty albatross, grey petrel (*P. cinerea*) and Westland petrel (*P. westlandica*) additional tracking data have become available since the publication of Devine et al. (In Press). The review undertaken by the experts provided clear guidance on the priorities for future revisions of the distribution maps.

Bird specialists considered that there is a false sophistication in the identification of species bycaught in SBT fisheries. At-sea identification of dead seabirds is problematic. Species differentiation between juveniles of similar species (e.g. among giant albatross, mollymawk and petrel species) is difficult. Additionally, the condition of the retrieved birds can hinder their identification, for example, if a bird is damaged or waterlogged.

It was noted the extremely low occurrence of certain species from the areas of well-known overlap was likely caused by reporting practices of those species which are difficult to distinguish from each other. The technical group considered that a false sophistication in species identification could distort the whole picture and it would be preferrable to reflect the existing difficulty into the model. The group also considered that a large divergence between predicted and observed values and catchability coefficient estimations of giant petrels was mainly caused by lack of density overlap information in the time and area where the majority of captures occurred.

Ultimately, the technical group agreed to introduce a concept of species-complex for those species difficult to distinguish and to disregard the species identification label attached to the capture records. Accordingly, the group agreed to treat all members of the wandering albatross group as one species complex and that the species allocation of predicted catch would be made based on the density overlap per species since the reliability of distribution maps of this group is quite high. Similarly, two yellow-nosed albatrosses, shy albatross and New Zealand white-capped albatross, Southern and Northern Buller's albatrosses (*T. b. platei*), and three medium petrels (black, Westland and white-chinned) would be treated as a species-complex, respectively. The agreed species-complex covers a large portion of data reported under the aggregated species by Japan and Taiwan.

It was also agreed to drop the giant petrel group from this round of assessment, considering their relatively healthy stock conditions with less concerns together with a large gap in tracking data, and mismatches with bycatch occurrence time and areas.

While fitting the model to predicted observable captures it was noted that for several species, such as the wandering albatross, high numbers of captures were occurring in areas of low species density. For the New Zealand domestic risk assessment, where certainty around identification is high, predicted observable captures at the species level were calculated using the term π which portioned out the predicted captures based on the proportion of observed species identification. Due to uncertainty in species level identification for some observed captures this term was not used as a diagnostic for the model fit. This was however found to be useful for assessing limitations around species identification in observed captures.

4.3 Modifications introduced and corresponding results

The outputs of the modified model were presented at an online meeting held on 4 April 2024 for estimation of catchability coefficients and examination of predicted and observed capture data, and an online meeting on 18 April 2024 for estimation of total seabird bycatch mortality and its risk.

The model was run with two conditions: 1) with a constant catchability over the whole time period (i.e. 2012-2019), and 2) with two catchability estimates for an early (2012-2016) and late (2017-2019) period. The former corresponded roughly to the years that were utilised in the 2019 assessment. The results section is split into two parts. In the first part we provide model fit diagnostics and estimates of the catchabilities. In the second part we provide model outputs, including estimates of the total number of deaths and risk.

Convergence of the model with a single time period was good (Figure 4), and the model was able to reproduce the number of observed captures per code (Tables 9, 10 and Figure 5). Figure 10 showed fits to the observed data for both runs with the one time period and two time periods models. Both models were able to fit the data. No obvious issues in the model fit arose for the two-period model, despite the reduced size of data available for each period. This indicates the possibility to assess the temporary change in catchability when at least three years of data is available.

The group noted that the biological parameters, in terms of number of breeding pairs and the probability of breeding, showed large shifts through the model fitting process (Figures 8a and 8b). The number of breeding pairs of black-browed albatross (DIM) and white-chinned petrel (PRO) dropped substantially, while New Zealand white-capped albatross (TWD) and grey petrel (PCI) showed visible increases in posteriors. Alternatively, the probability of breeding of Campbell black-browned albatross (TQW), grey-headed albatross (DIC) and southern Buller's albatross (DSB) dropped to almost zero and that for Indian yellow-nosed albatross (TQH), New Zealand white-capped albatross (TWD), and light-mantled sooty albatross (PHE) was reduced by two-thirds to a half. The probability of breeding of grey petrel (PCI) and Westland petrel (PCW) also showed visible declines. The level of change indicates that the model is forcing the priors to update unrealistically to ensure that q is constant throughout the species group. It was noted that substantial updates frequently occurred in small albatrosses and medium petrels. The same diagnosis existed from the initial model, indicating that the issues identified here would apply to all analyses included in this document. Due to the structure of the model, the strong updates to biological prior distributions for the effected species had a limited effect on other species within the same catchability group, for which adequate fits to observations were achieved without implausible updates to the prior distributions.

Both parameters influence the estimates of number of vulnerable birds available for capture by the fishery and are therefore co-estimated with the catchability parameters. The posteriors typically matched the input prior values. When the prior is updated, it indicates that the number of vulnerable birds needs to be adjusted to fit the observed data. Species may share catchability, but the overlap per species is fixed on input. If the overlap is a poor predictor of the catchability, then the number of vulnerable individuals may need to be adjusted by updating the biological priors. The prior updates therefore provide an indication of where the overlap data are inconsistent with the captures.

The discussion indicated many drawbacks and limitation of spatiotemporal distribution solely derived from spatially or temporally biased tracking data. The model treated density overlap with the species distributions derived from tracking data as no associated error and forced all the other parameters to fit it, which caused this situation. It is also possible that bycatch of juveniles, immatures and pre-breeders, which make up a significant portion of the population, is requiring the model to increase the adult portion of the population to compensate. It should be noted that some previous assessments utilised seabird distribution based on combined information obtained from tracking data, general distribution range and hypothetical bird distribution around breeding areas which had a much broader range. An alternative way of improving model-fit other than updating biological parameters should be taken into consideration as an option for future improvement of the model.

The review of the species distributions has identified a clear need to update the distributions using both existing tracking data, and the collection of further tracking data from colonies that currently lack tracking, which would require substantial time and resourcing. Those biological parameters were used not only to predict the number of vulnerable birds to longline fishery bycatch, but also as a basis for assessing the risk of bycatch.

Specifically, prior information on the biological values was used to estimate population growth yet these may be conservative in scenarios where high proportions of juveniles, immatures and pre-breeders have different distributions as adults, as may be the case in the Tasman Sea. As the species distributions do not fully capture these life cycle stages and may be spatially or temporally biased for some selected species, caution should be used when interpreting results.

Posterior plots of the catchabilities per species group and fishery group are shown in Figure 9 and in Table 8. The width of the boxplots indicates both the quantity and consistency of the data (large amounts of data that are consistent with the model structure will usually generate less uncertainty in the posterior). The NZ (JV) fleet has the lowest catchabilities, and the JPN fleet has the highest. The NZL (DOM) and TWN fleets have intermediate catchabilities. The relative catchability per species group differs per fleet, but typically medium petrels and mollymawks have lower catchabilities, whereas the wandering albatross, royal albatross and sooty albatross have higher catchabilities.

Comparative catchabilities for each of the early and late time periods, per species group and fishery group, is shown in Figure 7.

The predicted total number of annual deaths with cryptic deaths per species is listed in Table 11, together with cryptic deaths, productivity index based on both priors and posteriors of biological parameters and corresponding relative mortality. The productivity index is calculated as the maximum intrinsic growth rate multiplied by the number of adults per species. The global spatial distributions of deaths per catchability estimate (i.e., per estimated fishery group and species group) are illustrated in Figure 9.

Relative mortalities per time period for the two-period model are illustrated in Figures 11 and 12, where the prior demographic information is used as basis of population growth. Total mortality prediction is in Table 12. Relative mortality rates were broadly consistent for the two periods, though with differences observed for some species, for example increases in relative mortalities for sooty albatrosses in the later period. The time period-specific relative mortality rates are influenced by a number of variables, including the relative levels of total effort by the different fleets, the spatial distribution of their effort relative to the distribution of the seabird populations, as well as the estimated catchabilities. Additionally, the biological inputs to the risk assessment model were time invariant. This complicates interpretation of model runs with time-period specific catchabilities, as catchabilities are confounded with the size of the population available for capture in fisheries.

Table 13 shows a comparison of the assessment of total mortality obtained from this analysis and that of 2019 (Abraham et al. 2019). It should be noted that there are a number of differences in the methodology applied in this analysis compared to that from 2019. While the 2024 analysis utilised updated biological inputs, the 2019 assessment fixed biological parameters. Additionally, the observed catch and effort used was different between the two analyses. While the 2019 analysis applied Japan's estimated catchabilities (which is the highest among Japan, Taiwan, and New Zealand) to all fleets that did not contribute observer data (i.e. Korea, Indonesia, and Taiwan), the catchability obtained from Japan was only applied to Korea in 2024. On the other hand, the 2019 assessment utilised the observed catch and effort data from Australia and South Africa which showed substantially lower estimated catchability than New Zealand. These two CPCs were approximated using the catchability estimated for the New Zealand domestic fleet in the 2024 assessment.

Despite technical differences in input data and model structures, the results of this collaborative assessment are broadly consistent, particularly in 1) high risk to species from the Wandering albatross species group, 2) importance of the Tasman area as an area with an elevated risk profile, and 3) the same four of the five species identified as most at risk. It should be noted that Abraham et al (2019) indicated general consistency with other previous assessments (e.g. Peatman et al. (2019), Richards et al (2024)). The group also noted that the more substantial differences in total mortality estimates were observed for those species with substantial updates in biological parameters observed.

4.4 Code errors detected after the conclusion of Group discussion

Code errors in compiling observed catch and effort data for medium petrel species group and Procellariidae were detected and updated outputs were shared. Number of observations used in the updated outputs was shown in Table 14 and comparison of catchability estimates in Table 15. A comparison between the model fit is provided in Figure 13 and a comparison between the estimated of total deaths are provided in Figure 14.~~,~~

These outputs indicated; ~~1)~~ compilation errors for “Medium petrel species group” and “Procellaridae” were~~as~~ fixed~~ but some minor discrepancies remained (Campbell black-browed albatross, Diomedeidae, and Birds), 2) the model exclude giant petrels from Procellaridae catch and effort information, while keeping them in the Birds~~. For the 3-MAY-2024 run, there are slight misfits for PRZ, PTZ and PRX (Figure 13). A coding error caused in some of the PRZ captures to be not-assigned to the PTZ and PRX capture groups. This resulted in the observed captures for PTZ and PRX being too low, which causes the model to underestimate captures of PRZ and overestimate captures of PTZ and PRX. These are resolved in the updated 15-MAY-2024 run.

Because PRZ captures were being lost, this caused a drop in the catchability. With the corrected model, the catchability for the medium petrel species group has increased. This leads to an increase in the predicted petrel deaths. The deaths for the other species are largely unchanged. There is a small non-significant decrease in the deaths for the other species, but only for the petrels are the intervals non-overlapping. The cause of this is that there is some correlation between species groups because the model is fitting to capture groups to accommodate species identification at a lower resolution than the species groups used to estimate the catchability. For example, the model must fit to a capture group called "seabirds" to ensure that the 223 observed captures in the Japanese and 8 captures Taiwanese data can incorporated into the model. As a result this will introduce some unavoidable correlation between the catchability estimates per species group. By increasing the catchability of PRZ the model will reduce it slightly elsewhere so that the total number of seabird captures remains the same.

~~Table 15 shows a substantial update the estimated catchability for the medium petrel group, other updates to catchability are due to the stochastic nature of the Bayesian model.~~ Because the medium petrel species group was not being considered due to issues with the biological parameters updating and the other adjustments in catchability were minor there wa~~i~~s no ~~substantial~~ significant difference in the resulting estimates of deaths for the species groups considered to be reliable~~s~~.

5. CONCLUSIONS, REMAINING ISSUES AND NEXT STEPS

This process was useful in developing mutual collaboration and understanding among colleagues with different expertise. An increased number of participants expressed their intention to contribute data to the next iteration. Many participants deepened their understanding of the nature of the SEFRA and its potential and limitations, as well as the limitation of currently available information to support the model. All participants agreed that it would be beneficial to maintain the current momentum at least to ensure delivery of the first collaborative risk assessment result.

While there are unresolved issues, there remain three things which require urgent attention: 1) archiving codes and input data in an accessible and workable way, 2) modification of the model to resolve the issues in relating to updating biological parameters and, and 3) preparing observed seabird catch and effort data for those CPCs that have not yet done so. To make this possible, it is important to formalize the process as a CCSBT activity with clear Terms of Reference and responsibilities, though recognizing that the current assessment process was supported with informal and voluntary contribution of all the participating CPCs and institutions.

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Table 1: Species and catchability groups used in the southern hemisphere risk assessment model. Note that the final model applied species-complex and excluded the Southern and Northern giant petrels catch data from the model (see Section 4.2 for details).

Species code	Common name	Scientific name	Species group	Species-complex
DIW	Gibson's albatross	*Diomedea antipodensis gibsoni*	Wandering albatross	Wandering albatross complex
DQS	Antipodean albatross	*Diomedea antipodensis antipodensis*	Wandering albatross	Wandering albatross complex
DIX	Wandering albatross	*Diomedea exulans*	Wandering albatross	Wandering albatross complex
DBN	Tristan albatross	*Diomedea dabbenena*	Wandering albatross	Wandering albatross complex
DAM	Amsterdam albatross	*Diomedea amsterdamensis*	Wandering albatross	Wandering albatross complex
DIP	Southern royal albatross	*Diomedea epomophora*	Royal albatross	Royal albatrosses
DIQ	Northern royal albatross	*Diomedea sanfordi*	Royal albatross	Royal albatrosses
DCR	Atlantic yellow-nosed albatross	*Thalassarche chlororhynchos*	Small albatross	Yellow-nosed albatrosses
TQH	Indian yellow-nosed albatross	*Thalassarche carteri*	Small albatross	Yellow-nosed albatrosses
DIM	Black-browed albatross	*Thalassarche melanophris*	Small albatross	Black-browed albatrosses
TQW	Campbell black-browed albatross	*Thalassarche impavida*	Small albatross	Black-browed albatrosses
DCU	Shy albatross	*Thalassarche cauta*	Small albatross	Shy-type albatross
TWD	New Zealand white-capped albatross	*Thalassarche cauta steadi*	Small albatross	Shy-type albatross
DKS	Salvin's albatross	*Thalassarche salvini*	Small albatross	
DER	Chatham Island albatross	*Thalassarche eremita*	Small albatross	
DIC	Grey-headed albatross	*Thalassarche chrysostoma*	Small albatross	
DIB	Southern Buller's albatross	*Thalassarche bulleri bulleri*	Small albatross	Buller's albatross
DNB	Northern Buller's albatross	*Thalassarche bulleri platei*	Small albatross	Buller's albatross
PHU	Sooty albatross	*Phoebetria fusca*	Sooty albatross	
PHE	Light-mantled sooty albatross	*Phoebetria palpebrata*	Sooty albatross	
MAI	Southern giant petrel	*Macronectes giganteus*	Giant petrels	
MAH	Northern giant petrel	*Macronectes halli*	Giant petrels	
PCI	Grey petrel	*Procellaria cinerea*	Medium petrel	
PRK	Black petrel	*Procellaria parkinsoni*	Medium petrel	Petrel complex
PCW	Westland petrel	*Procellaria westlandica*	Medium petrel	Petrel complex
PRO	White-chinned petrel	*Procellaria aequinoctialis*	Medium petrel	Petrel complex
PCN	Spectacled petrel	*Procellaria conspicillata*	Medium petrel	Petrel complex

Table 2: Fleet-specific catchability and proxy values

Fleet	Catchability utilised
Australia	New Zealand domestic
Indonesia	New Zealand domestic
Japan	Japan
Korea	Japan
New Zealand domestic	New Zealand domestic
New Zealand joint venture	New Zealand joint venture
South Africa	New Zealand domestic
Taiwan	Taiwan

[New Zealand Version (Rev.1)]

Table 3. Observed seabird catch data of Japan and Taiwan with their reported identification.

Species code	Common name	Scientific name	Sp Grp	JPN all	JPN early	JPN late	TWN all	TWN early	TWN late
DIW	Gibson's albatross	*Diomedea antipodensis gibsoni*	1	32	24	8	na	na	na
DQS	Antipodean albatross	*Diomedea antipodensis antipodensis*	1	3	3		na	na	na
	Gibson's and Antipodean albatross						6	4	2
DIX	Wandering albatross	*Diomedea exulans*	1	162	91	71	48	26	22
DBN	Tristan albatross	*Diomedea dabbanena*	1	14	8	6	0	0	0
DAM	Amsterdam albatross	*Diomedea amsterdamensis*	1	0	0	0	0	0	0
	Wandering albatross complex		1	131	107	24			
		SPECIES GROUP 1 TOTAL		**342**	**233**	**109**	**54**	**30**	**24**
DIP	Southern royal albatross	*Diomedea epomophora*	2	12	11	1	1	0	1
DIQ	Northern royal albatross	*Diomedea sanfordi*	2	2	2		3	2	1
	Royal albatrosses		2	7	5	2			
		SPECIES GROUP 2 TOTAL		**21**	**18**	**3**	**4**	**2**	**2**
	Diomedea spp		1,2	26	25	1			
		***Diomedea* spp TOTAL**		**389**	**276**	**113**	**58**	**32**	**26**
CDR	Atlantic yellow-nosed albatross	*Thalassarche chlorothynchos*	3	8	7	1	85	72	13
TQH	Indian yellow-nosed albatross	*Thalassarche carteri*	3	138	108	30	63	42	21
	Yellow-nosed albatrosses		3	59	11	48			
DIM	Black-browed albatross	*Thalassarche melanophris*	3	301	180	121	101	92	9
TQW	Campbell black-browed albatross	*Thalassarche impavida*	3	170	111	59	12	9	3
	Black-browed albatrosses		3	312	160	152			
DCU	Shy albatross	*Thalassarche cauta*	3	0	0	0	4	4	0
	Shy-type albatross		3	796	429	367			
TWD	New Zealand's white-capped albatross	*Thalassarche cauta steadi*	3	0	0	0	34	22	12
DKS	Salvin's albatross	*Thalassarche salvini*	3	0	0	0	8	0	8

[New Zealand Version (Rev.1)]

Table 3. [Continued] Observed seabird catch data of Japan and Taiwan with their reported identification.

Species code	Common name	Scientific name	Sp Grp	JPN all	TWN early				Sp Grp
DER	Chatham Island albatross	*Thalassarche eremita*	3	3	1	2	0	0	0
DIC	Grey-headed albatross	*Thalassarche chrysostoma*	3	840	656	184	17	15	2
DSB	Southern Buller's albatross	*Thalassarche bulleri bulleri*	3	0	0	0	0	0	0
DNB	Northern Buller's albtatross	*Thalassarche buller platei*	3	9	8	1	0	0	0
	Buller's albatross		3	780	398	382	4	1	3
	Thalassarche spp.		3	267	257	10			
		SPECIES GROUP 3 TOTAL		**3683**	**2326**	**1357**	**328**	**257**	**71**
PHU	Sooty albatross	*Phoebetria fusca*	4	134	52	82	61	43	18
PHE	Light-mantled sooty albatross	*Phoebetria palpebrata*	4	95	56	39	6	4	2
	Phoebetria spp		4	4	3	1			
		SPECIES GROUP 4 TOTAL		**233**	**111**	**122**	**67**	**47**	**20**
	Diomedeidae		1,2,3,4	822	456	366	170	169	1
		***Diomedeidae* TOTAL**		**5101**	**3144**	**1957**	**623**	**505**	**118**
MAI	Southern giant petrel	*Macronectes giganteus*	5	94	60	34	7	4	3
MAH	Northern giant petrel	*Macronectes halii*	5	88	51	37	3	3	0
	Macronectes spp.		5				1	1	0
		SPECIES GROUP 5 TOTAL		**182**	**111**	**71**	**11**	**8**	**3**
PCI	Grey petrel	Procellaria cinerea	6	152	89	63	3	2	1
PRK	Black petrel	*Procellaria parkinsoni*	6	5	3	2	0	0	0
PCW	Westland petrel	*Procellaria westlandica*	6	4	4	0	1	1	0
PRO	White-chinned petrel	*Procellaria aequinoctialis*	6	407	186	221	190	132	58
PCN	Spectacled petrel	*Procellaria conspicillata*	6	44	24	20	53	53	0
	Precellaria spp		6				25	24	1
		SPECIES GROUP 6 TOTAL		**612**	**306**	**306**	**272**	**212**	**60**
	Procellariidae		5,6	165	110	55	14	2	12
		Procellariidae TOTAL		959	527	432	297	222	75
	Birds		?	223	209	14	8	8	0

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Table 4: Total effort by fleet in 1000 hooks

Year	AUS	JPN	KOR	NZL	TWN	ZAF	IDN
2012	7 051.7	132 955.1	52 674.2	2 932.3	225 852.7	4 298.3	-
2013	6 897.8	116 537.5	61 177.6	2 235.7	250 937.6	4 838.2	-
2014	6 805.2	103 089.9	54 717.3	2 782.0	247 603.6	3 030.9	-
2015	8 359.8	92 143.4	53 627.5	2 845.2	217 063.7	3 053.1	-
2016	7 849.1	90 765.9	59 769.2	1 386.6	249 709.3	2 228.0	-
2017	8 927.6	90 093.6	43 957.8	1 277.2	309 153.1	2 662.5	-
2018	7 785.2	87 406.1	43 973.9	1 402.7	287 858.5	2 904.4	1 276.5
2019	8 215.0	69 702.5	51 692.8	1 053.8	319 264.7	2 539.4	1 702.4

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Table 5: Catchability coefficients estimated from the combined dataset as well as those from individual CPCs seabird catch and effort data for the initial model run

Dataset	Species Group	JPN		TWN		NZL (DOM)		NZL (JV)	
Combined	Wandering albatross	8.45	(7.12-10)	0.62	(0.47-0.78)	5.04	(3.99-6.27)	0.04	(0.01-0.11)
Combined	Royal albatross	7.63	(4.21-12.09)	2.17	(0.92-4.29)	3.53	(2.1-5.59)	0.07	(0.01-0.22)
Combined	Mollymawk	4.26	(3.86-4.68)	0.74	(0.65-0.83)	2.42	(2.13-2.77)	0.21	(0.17-0.26)
Combined	Sooty albatross	21.9	(17.54-27.13)	4.6	(3.51-5.88)	5.94	(0.28-26.56)	0.35	(0.01-1.52)
Combined	Large petrel	52.48	(41.98-64.44)	0.8	(0.48-1.24)	5.73	(0.29-25.92)	0.34	(0.01-1.66)
Combined	Medium petrel	4	(3.38-4.68)	0.71	(0.58-0.84)	5.48	(4.48-6.58)	0.18	(0.07-0.34)
Combined	Fleet specific q	10.31	(9.24-11.38)	1.15	(0.96-1.36)	3.71	(1. 92-6.44)	0.11	(0.04-0.24)
JPN	Wandering albatross	8.1	(6.79-9.53)						
JPN	Royal albatross	7.59	(4.28-12.17)						
JPN	Mollymawk	3.12	(2.82-3.45)						
JPN	Sooty albatross	20.45	(16.62-25.58)						
JPN	Large petrel	51.54	(42.01-62.6)						
JPN	Medium petrel	2.95	(2.43-3.54)						
JPN	Fleet specific q	9.1	(8.13-10.08)						
TWN	Wandering albatross			2.13	(1.66-2.68)				
TWN	Royal albatross			2.53	(0.95-4.92)				
TWN	Mollymawk			1.77	(1.59-1.95)				
TWN	Sooty albatross			5.33	(4.18-6.69)				
TWN	Large petrel			0.82	(0.51-1.21)				
TWN	Medium petrel			0.54	(0.44-0.66)				
TWN	Fleet specific q			1.65	(1.39-1.94)				
NZL	Wandering albatross					4.96	(3.82-6.28)	0.03	(0-0.1)
NZL	Royal albatross					3.37	(1.91-5.38)	0.05	(0.01-0.17)
NZL	Mollymawk					3.29	(2.69-4.03)	0.31	(0.24-0.39)
NZL	Sooty albatross					6.04	(0.31-27.03)	0.25	(0.01-1.28)
NZL	Large petrel					6.55	(0.26-35.06)	0.22	(0.01-1.11)
NZL	Medium petrel					4.5	(3.58-5.55)	0.14	(0.05-0.28)
NZL	Fleet specific q					3.77	(1.87-6.9)	0.09	(0.03-0.21)

Table 6: Comparison of predicted vs observed values for seabird observed capture. Initial model with combined dataset for 2012-2019.

Code	Common name	Sp Grp	JPN Obs	JPN Pred	TWN Obs	TWN Pred	NZL Obs	NZL Pred	NZL (JV) Obs	NZL (JV) Pred
DIW	Gibson's albatross	1	32	45 (34.2-56.7)	0	2.1 (0-4.8)	11	9.1 (4-14.4)	0	0 (0-0.3)
DQS	Antipodean albatross	1	3	4.3 (1.7-7.3)	0	0.7 (0-2.8)	12	5.5 (1.9-9.9)	0	0 (0-0.2)
	Gibson's and Antipodean albatross		0		6		0		0	
DIX	Wandering albatross	1	162	111.4 (93.4-131.2)	48	41.4 (28.9-55.2)	3	6.8 (2.9-11.6)	0	0 (0-0.3)
DBN	Tristan albatross	1	14	17.3 (10-25.1)	0	1.5 (0-4.2)	0	0 (0-0)	0	0 (0-0)
DAM	Amsterdam albatross	1	0	0.1 (0-2.1)	0	0.1 (0-1.8)	0	0 (0-0)	0	0 (0-0)
	Wandering albatross complex	1	131		0		0		0	
0	**SPECIES GROUP 1 TOTAL**		**342**		**54**		**26**		**0**	
DIP	Southern royal albatross	2	12	12.2 (6.9-18.8)	1	2.8 (0-6.8)	10	5.4 (1.7-10.3)	0	0.1 (0-0.5)
DIQ	Northern royal albatross	2	2	0.7 (0-2.1)	3	0.7 (0-2.8)	1	3.1 (0.6-6.9)	0	0 (0-0.1)
	Royal albatrosses	2	7		0		0		0	
	SPECIES GROUP 2 TOTAL		**21**		**4**		**11**		**0**	
	Diomedea spp	1,2	26		0		2		0	
	***Diomedea* spp TOTAL**		**389**		**58**		**39**		**0**	
CDR	Atlantic yellow-nosed albatross	3	8	14.5 (9.1-20.1)	85	18.1 (10.1-26.6)	0	0 (0-0)	0	0 (0-0)
TQH	Indian yellow-nosed albatross	3	138	113.1 (96.2-131.3)	63	60.6 (46.1-76.4)	0	0 (0-0)	0	0 (0-0)
	Yellow-nosed albatrosses	3	59		0		0		0	
DIM	Black-browed albatross	3	301	425.6 (390-462.8)	101	37 (26.5-48.1)	3	11 (5.7-16.9)	0	0.8 (0.1-1.9)
TQW	Campbell black-browed albatross	3	170	65.7 (52.2-79.5)	12	0.7 (0-2.3)	11	32.9 (23-44.5)	1	3.8 (1.7-6.6)
	Black-browed albatrosses	3	312		0		0		0	
DCU	Shy albatross	3	0	47.6 (34.9-61.1)	4	0 (0-0.7)	0	0 (0-0)	0	0 (0-0)
	Shy-type albatross	3	796		0		0		0	
TWD	New Zealand's white-capped albatross	3	0	272.3 (244.4-302.7)	34	34.2 (23.7-45.7)	151	65.9 (50.5-83.6)	11	5 (2.5-8.7)
DKS	Salvin's albatross	3	0	8 (4.4-12.1)	8	1.6 (0-4.1_	1	12.1 (6.4-18.7)	0	0.3 (0-1.9)
DER	Chatham Island albatross	3	3	1.3 (0-3)	0	0.2 (0-0.8)	0	0.5 (0-1.9)	0	0 (0-0)
DIC	Grey-headed albatross	3	840	682.3 (623.7-737.5)	17	178.2 (152.9-207.6)	1	0.1 (0-0.7)	0	0 (0-0)

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Table 6 [Continued]: Comparison of predicted vs observed values for seabird observed capture. Initial model with combined dataset for 2012-2019.

Code	Common name	Sp Grp	JPN Obs	JPN Pred	TWN Obs	TWN Pred	NZL Obs	NZL Pred	NZL (JV) Obs	NZL (JV) Pred
DSB	Southern Buller's albatross	3	0	226.7 (199.6-254.4)	0	18.9 (11.8-27.9)	0	64.7 (50.4-80.7)	0	4 (1.8-7.4)
DNB	Northern Buller's albtatross	3	9	17.3 (11-24.8)	0	1.3 (0-3.7)	0	8.9 (4.1-14.8)	0	0.4 (0-1.1)
	Buller's albatross	3	780		4		125		62	
	Thalassarche spp.	3	267		0		0		0	
	SPECIES GROUP 3 TOTAL		**3683**		**328**		**292**		**74**	
PHU	Sooty albatross	4	134	106 (88.5-125.3)	61	47.4 (33.4-62.3)	0	0 (0-0)	0	0 (0-0)
PHE	Light-mantled sooty albatross	4	95	53.3 (40.76-67)	6	14.2 (7.2-22)	0	0 (0-0)	0	0 (0-0)
	Phoebetria spp	4	4		0		0		0	
	SPECIES GROUP 4 TOTAL		**233**		**67**		**0**		**0**	
	Diomedeidae	1,2,3,4	822		170		0		0	
	***Diomedeidae* TOTAL**		**5127**		**623**		**331**		**74**	
MAI	Southern giant petrel	5	94	71.2 (57-85.8)	7	5.3 (1.4-10)	0	0 (0-0)	0	0 (0-0)
MAH	Northern giant petrel	5	88	40.7 (30.5-52.3)	3	4.3 (0.8-9.1)	0	0 (0-0)	0	0 (0-0)
	Macronectes spp.	5	0		1		0		0	
	SPECIES GROUP 5 TOTAL		**182**		**11**		**0**		**0**	
PCI	Grey petrel	6	152	67.5 (53.8-82.5)	3	16.5 (9.1-24)	4	16.5 (9.9-24.1)	0	0.1 (0-0.5)
PRK	Black petrel	6	5	3.9 (1.3-7.1)	0	1.1 (0-3)	32	3.6 (0.7-7.2)	0	0 (0-0.2)
PCW	Westland petrel	6	4	10.1 (5.2-16)	1	1.6 (0-4)	37	21.9 (13.4-31)	1	0.4 (0-1.1)
PRO	White-chinned petrel	6	407	280.9 (254-311.9)	190	172.6 (144.1-199.9)	12	22.2 (14.7-31.2)	1	0 (0-0)
PCN	Spectacled petrel	6	44	15.9 (10.4-22.5)	53	38 (26.5-52.3)	0	0 (0-0)	0	0 (0-0)
	Precellaria spp	6	0		25	0			0	
	SPECIES GROUP 6 TOTAL		**612**		**272**		**85**		**2**	
	Procellariidae	5,6	165		14		0		0	
	***Procellariidae* TOTAL**		**959**		**297**		**85**		**2**	
	Birds	?	223		8		0		0	

Table 7: Results of general consideration on reliability and decisions taken for further model modifications. Columns "ID" and "Maps" indicating general evaluation of reliability of species level identification and seabird spatiotemporal distribution maps derived from tracking data.

Code	Common name	Sp Grp	Obs	Predicted		ID	Maps	Decision taken
DIW	Gibson's albatross	1	43	56.2	(4.1-19.5)	L	H	
DQS	Antipodean albatross	1	15	10.5	(1.9-12.9)	L	H	
	Gibson's and Antipodean albatross		6					Removing species info in capture, reassign total prediction according to density overlap
DIX	Wandering albatross	1	213	159.6	(125.2-198.3)	L	H	
DBN	Tristan albatross	1	14	18.8	(10-29.3)	L	H	
DAM	Amsterdam albatross	1	0	0.2	(0-1.2)	L	H	
	Wandering albatross complex	1	131					
	SPECIES GROUP 1 TOTAL		**422**					
DIP	Southern royal albatross	2	23	20.5	(8.6-45.4)	M	M	No change
DIQ	Northern royal albatross	2	6	4.5	(0.6-11.9)	M	H	
	Royal albatrosses	2	7					
	SPECIES GROUP 2 TOTAL		**36**					
	Diomedea spp	1,2	28					
	Diomedea spp TOTAL		486					
CDR	Atlantic yellow-nosed albatross	3	93	32.6	(19.2-46.7)	M	H	Removing species info in capture, reassign total prediction according to density overlap
TQH	Indian yellow-nosed albatross	3	201	173.7	(142.3-207.7)	M	H	
	Yellow-nosed albatrosses	3	59					
DIM	Black-browed albatross	3	405	474.4	(422.3-529.7)	Var	M	No change
TQW	Campbell black-browed albatross	3	194	103.1	(76.9-132.9)	M	L	
	Black-browed albatrosses	3	312					
DCU	Shy albatross	3	4	47.6	(34.9-61.8)	L	L	Removing species info in capture, reassign total prediction according to density overlap
TWD	New Zealand's white-capped albatross	3	196	377.4	(321.1-440.7)	L	H	
	Shy-type albatross	3	796					
DKS	Salvin's albatross	3	9	22	(10.8-35.8)	M	H	No change

Table 7 [Continued]: Results of general consideration on reliability and decisions taken for further model modifications. Columns "ID" and "Maps" indicating general evaluation of reliability of species level identification and seabird spatiotemporal distribution maps derived from tracking data.

DER	Chatham Island albatross	3	3	2	(0-5.7)	H	H	
DIC	Grey-headed albatross	3	858	860.6	(776.6-945.8)	M	M	
DSB	Southern Buller's albatross	3	0	314.3	(183.6-370.4)	L	H	Removing species info in capture, reassign total prediction according to density overlap
DNB	Northern Buller's albtatross	3	9	27.9	(15.1-44.4)	L	H	
	Buller's albatross	3	909					
	Thalassarche spp.	3	267					
	SPECIES GROUP 3 TOTAL		**4315**					
PHU	Sooty albatross	4	195	153.4	(121.9-187.6)	M	M	No change
PHE	Light-mantled sooty albatross	4	101	67.5	(47.9-89)	M	M	
	Phoebetria spp	4	4					
	SPECIES GROUP 4 TOTAL		**300**					
	Diomedeidae	1,2,3,4	992					
	Diomedeidae TOTAL		6065					
MAI	Southern giant petrel	5	101	76.5	(59.1-95.8)	M	M	Removing from analysis
MAH	Northern giant petrel	5	91	45	(31.3-61.4)	M	M	
	Macronectes spp.	5	1					
	SPECIES GROUP 5 TOTAL		**193**					
PCI	Grey petrel	6	159	100.6	(72.8-131.1)	H	L	No change
PRK	Black petrel	6	37	8.6	(2-17.3)	L	M	Removing species info in capture, reassign total prediction according to density overlap
PCW	Westland petrel	6	43	34	(18.7-52.1)	L	M	
PRO	White-chinned petrel	6	610	475.7	(412.8-543)	L	M	
PCN	Spectacled petrel	6	97	53.9	(36.9-74.8)	L	M	No change
	Precellaria spp	6	25					
	SPECIES GROUP 6 TOTAL		**971**					
	Procellariidae	5,6	179					
	Procellariidae TOTAL		1343					
	Birds	?	231					

Table 8: Catchability coefficients estimates obtained with the initial model as well as the model after modification incorporated.

Model	Species group	JPN	TWN	NZL (DOM)	NZL (JV)
Initial					
	Wandering albatross	8.45 (7.2-10)	0.62 (0.47-0.78)	5.04 (3.99-6.27)	0.04 (0.01-0.11)
	Royal albatross	7.63 (4.21-12.09)	2.17 (0.92-4.29)	3.53 (2.1-5.59)	0.07 (0.01-0.22)
	Mollymawk	4.26 (3.86-4.68)	0.74 (0.65-0.83)	2.42 (2.13-2.77)	0.21 (0.17-0.26)
	Sooty albatross	21.9 (17.54-27.13)	4.6 (3.51-5.88)	5.94 (0.28-26.56)	0.35 (0.01-1.52)
	Large petrel	52.48 (41.98-64.44)	0.8 (0.48-1.24)	5.73 (0.29-25.92)	0.34 (0.01-1.66)
	Medium petrel	4 (3.38-4.68)	0.71 (0.58-0.84)	5.48 (4.48-6.58)	0.18 (0.07-0.34)
	Fleet specific q	10.31 (9.24-11.38)	1.15 (0.96-1.36)	3.71 (1.92-6.44)	0.11 (0.04-0.24)
After modification (2012-2019)					
	Wandering albatross	15.27 (12.71-18.1)	2.63 (2.04-3.35)	4.22 (2.92-5.78)	0.16 (0.01-0.56)
	Royal albatross	6.24 (3.6-10.19)	2.32 (0.97-4.41)	4.38 (2.39-7.05)	0.23 (0.02-0.97)
	Mollymawk	3.63 (3.25-4.04)	0.68 (0.6-0.78)	1.47 (1.27-1.68)	0.13 (0.1-0.15)
	Sooty albatross	18.83 (15.24-23.15)	5.05 (3.88-6.42)	5.94 (0.23-29.94)	0.52 (0.02-3.09)
	Large petrel	-			
	Medium petrel	3.04 (2.5-3.64)	0.59 (0.48-0.71)	4.17 (3.3-5.11)	0.12 (0.05-0.23)
	Fleet specific q	7.17 (6.28-8.12)	1.63 (1.35-1.91)	3.22 (1.86-5.05)	0.15 (0.06-0.34)
After modification (2012-2016)					
	Wandering albatross	16.91 (13.92-20.31)	2.78 (2.01-3.68)	6.24 (4.1-8.78)	0.17 (0.02-0.57)
	Royal albatross	8.2 (4.59-13.33)	2.49 (0.78-5.54)	3.27 (1.48-6.05)	0.26 (0.02-1.06)
	Mollymawk	3.56 (3.17-3.99)	0.96 (0.83-1.09)	1.76 (1.5-2.06)	0.13 (0.11-0.15)
	Sooty albatross	12.01 (9.43-14.85)	6.53 (4.94-8.52)	5.8 (0.23-27.23)	0.57 (0.02-3.53)
	Large petrel	-			
	Medium petrel	2.2 (1.78-2.65)	0.67 (0.53-0.82)	3.43 (2.52-4.48)	0.12 (0.05-0.23)
	Fleet specific q	6.6 (5.76-7.48)	1.91 (1.54-2.34)	3.25 (1.8-5.35)	0.16 (0.05-0.33)
After modification (2017-2019)					
	Wandering albatross	12.55 (10.4-15.05)	2.25 (1.55-3.11)	2.4 (1.25-3.93)	
	Royal albatross	2.43 (0.71-5.29)	3.94 (0.94-8.95)	5.58 (2.97-9.13)	
	Mollymawk	3.9 (3.46-4.4)	0.31 (0.26-0.37)	1.31 (1.12-1.54)	
	Sooty albatross	34.75 (27.72-43.62)	2.91 (1.97-4.1)	6.01 (0.21-28.27)	
	Large petrel	-			
	Medium petrel	5.13 (4.15-6.18)	0.45 (0.35-0.56)	4.88 (3.64-6.3)	
	Fleet specific q	7.18 (5.71-8.67)	1.25 (0.93-1.56)	3.04 (1.68-5.04)	

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Table 9. Observed and predicted captures per capture code.

Code	Common name	JPN Observed	JPN Estimated	TWN Observed	TWN Estimated	NZL Observed	NZL Estimated	NZL (JV) Observed	NZL (JV) Estimated
DIP	Southern royal albatross	12	15.7 (7.9-24.5)	1	2.7 (0-6.3)	10	3.1 (1.1-6.1)	0	0 (0-0)
DIQ	Northern royal albatross	2	0.8 (0-2.6)	3	0.7 (0-2.5)	1	1.8 (0.3-4)	0	0 (0-0)
DIM	Black-browed albatross	301	559.1 (504.9-612.5)	101	30.5 (21.7-40.5)	3	3 (1.2-5.3)	0	0 (0-0)
TQW	Campbell albatross	170	116.1 (92.7-140.8)	12	0.8 (0-2.6)	11	12.1 (7.1-18.8)	1	2 (0.2-5.9)
DKS	Salvin's albatross	0	0 (0-0)	8	1.7 (0-4.5)	1	4.2 (1.9-7.4)	0	0 (0-0)
DER	Chatham Islands albatross	3	1.7 (0-4.1)	0	0 (0-0)	0	0 (0-0)	0	0 (0-0)
DIC	Grey-headed albatross	840	723.3 (657.6-792.1)	17	118 (95.8-143.8)	1	0 (0-0.3)	0	0 (0-0)
PHU	Sooty albatross	134	135.6 (110.8-161.4)	61	44.7 (32.1-59.9)	0	0 (0-0)	0	0 (0-0)
PHE	Light-mantled sooty albatross	95	68.4 (50.9-87.4)	6	13.4 (7.6-20.7)	0	0 (0-0)	0	0 (0-0)
PCI	Grey petrel	152	110 (87-135.3)	3	16.9 (10.4-24.7)	4	7.9 (4.3-13)	0	0 (0-0)
PCN	Spectacled petrel	44	24.5 (15.1-34.5)	53	37.5 (25.6-51.2)	0	0 (0-0)	0	0 (0-0)
DRA	Royal albatrosses	21	19.4 (10.7-29.8)	4	4.4 (0.8-10.1)	11	15.6 (7.3-25.9)	0	0 (0-0)
DYN	Yellow-nosed albatrosses	205	218.2 (183.2-255)	148	87.8 (68.9-108.8)	0	0 (0-0)	0	0 (0-0)
DST	Shy-type albatrosses	796	777.1 (709.1-849.2)	38	60.2 (44.8-77.2)	151	95.4 (75.3-116.4)	11	23 (14.1-33.6)
DBB	Black-browed albatrosses	783	793.5 (722.4-858.9)	113	41.2 (29.5-52.9)	14	48.3 (34.9-62.8)	1	16.8 (9.3-25.6)
DIB	Buller's albatross	789	749.8 (685.6-817.1)	4	43.5 (31-56.3)	125	125.6 (101.4-151)	62	24.1 (14.7-34.8)
DWC	Wandering albatrosses	342	345.7 (303.1-384.5)	54	54 (37.7-71.5)	27	24.1 (13.4-37.2)	0	0 (0-0)
PRZ	Petrels	416	447.3 (400.4-493.9)	191	188.7 (160.4-219.9)	81	61.8 (44.9-78.8)	2	1.7 (0-4.8)
DIZ	*Diomedia* spp	389	388 (345.7-435.5)	58	59.2 (43.2-77.6)	40	40.5 (26.3-56.1)	0	0 (0-0)
THZ	*Thalassarche* spp	3683	3628 (3486.8-3784.7)	328	396.7 (353.3-439.6)	292	289.1 (253.5-326.3)	74	70.1 (52.9-88.3)
PHZ	Sooty albatrosses	233	256.4 (217-294.1)	67	78 (58.7-99.6)	0	0 (0-0)	0	0 (0-0)
PTZ	Medium petrels	612	644.2 (591.7-697)	272	264.6 (227.8-299.5)	85	88.5 (68.7-110.4)	2	2.2 (0-5.8)
ALZ	Diomedeidae	5127	5123.8 (4936.2-5301.2)	623	598.2 (540-658.3)	332	336.9 (299-376.7)	74	78 (57.9-100)
PRX	Procellariidae	777	774.1 (710-841.8)	286	296.3 (259.5-338)	85	90.7 (68.7-113.4)	2	2.4 (0-6.8)
BLZ	Birds	6127	6124.8 (5918-6343)	917	930.8 (851.9-1011)	417	441.7 (392-493)	76	87.5 (65-111)

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Table 10. Comparison between observed vs predicted catch at species and species-complex.

			Initial model			After modification		
Code	**Common name**	**Sp Grp**	**Obs**	**Predicted**		**Obs**	**Predicted**	
DIW	Gibson's albatross	1	43	56.2	(4.1-19.5)			
DQS	Antipodean albatross	1	15	10.5	(1.9-12.9)			
	Gibson's and Antipodean albatross		6					
DIX	Wandering albatross	1	213	159.6	(125.2-198.3)			
DBN	Tristan albatross	1	14	18.8	(10-29.3)			
DAM	Amsterdam albatross	1	0	0.2	(0-1.2)			
	Wandering albatross complex	1	131					
	SPECIES GROUP 1 TOTAL		**422**			**423**	**423.8**	**(354.2-493.2)**
DIP	Southern royal albatross	2	23	20.5	(8.6-45.4)	23	21.5	(9-36.9)
DIQ	Northern royal albatross	2	6	4.5	(0.6-11.9)	6	3.3	(0.3-9.1)
	Royal albatrosses	2	7			7		
	SPECIES GROUP 2 TOTAL		**36**			**36**	**39.4**	**(18.8-65.8)**
	Diomedea spp	1,2	28					
	Diomedea spp TOTAL		486			487	487.7	(415.2-569.2)
CDR	Atlantic yellow-nosed albatross	3	93	32.6	(19.2-46.7)			
TQH	Indian yellow-nosed albatross	3	201	173.7	(142.3-207.7)			
	Yellow-nosed albatrosses	3	59					
	Yellow-nosed albatrosses TOTAL					353	306	(252.1-363.8)
DIM	Black-browed albatross	3	405	474.4	(422.3-529.7)	405	592.6	(527.8-658.3)
TQW	Campbell black-browed albatross	3	194	103.1	(76.9-132.9)	194	131	(100-168.1)
	Black-browed albatrosses	3	312					
DCU	Shy albatross	3	4	47.6	(34.9-61.8)			
TWD	New Zealand's white-capped albatross	3	196	377.4	(321.1-440.7)			
	Shy-type albatross	3	796					
	Shy-type albatross TOTAL					996	955.7	(843.3-1076.4)
DKS	Salvin's albatross	3	9	22	(10.8-35.8)	9	5.9	(1.9-11.9)

Table 10 [Continued]. Comparison between observed vs predicted catch at species and species-complex.

DER	Chatham Island albatross	3	3	2	(0-5.7)	3	1.7	(0-4.1)
DIC	Grey-headed albatross	3	858	860.6	(776.6-945.8)	858	841.3	(753.4-936.2)
DSB	Southern Buller's albatross	3	0	314.3	(183.6-370.4)			
DNB	Northern Buller's albtatross	3	9	27.9	(15.1-44.4)			
	Buller's albatross	3	909					
	Buller's albatross TOTAL					980	943	(832.7-1059.2)
	Thalassarche spp.	3	267					
	SPECIES GROUP 3 TOTAL		**4315**			**4377**	**4383.9**	**(4146.5-4638.9)**
PHU	Sooty albatross	4	195	153.4	(121.9-187.6)	300	334.4	(275.7-393.7)
PHE	Light-mantled sooty albatross	4	101	67.5	(47.9-89)	101	81.8	(58.5-108.1)
	Phoebetria spp	4	4					
	SPECIES GROUP 4 TOTAL		**300**			**300**	**334.4**	**(275.7-393.7)**
	Diomedeidae	1,2,3,4	992					
	Diomedeidae TOTAL		6065			6156	6136.9	(5833.1-6436.2)
MAI	Southern giant petrel	5	101	76.5	(59.1-95.8)			
MAH	Northern giant petrel	5	91	45	(31.3-61.4)			
	Macronectes spp.	5	1					
	SPECIES GROUP 5 TOTAL		**193**					
PCI	Grey petrel	6	159	100.6	(72.8-131.1)	159	134.8	(101.7-173)
PRK	Black petrel	6	37	8.6	(2-17.3)			
PCW	Westland petrel	6	43	34	(18.7-52.1)			
PRO	White-chinned petrel	6	610	475.7	(412.8-543)			
	Petrels TOTAL (PRK, PCW, PRO)					690	699.5	(605.7-797.4)
PCN	Spectacled petrel	6	97	53.9	(36.9-74.8)	97	62	(40.7-85.7)
	Procellaria spp	6	25					
	SPECIES GROUP 6 TOTAL		**971**			**971**	**999.5**	**(888.2-1112.7)**
	Procellariidae	5,6	179					
	Procellariidae TOTAL		1150			1150	1163.5	(1038.2-1300)
	Birds		7537			7537	7584.8	(7226.9-7958)

Table 11. Final model outputs of the predicted bycatch mortality and cryptic deaths, together with the productivities and relative mortalities corresponding to priors and posteriors of biological parameters. Relative mortalities are measured relative to a productivity index, which is the maximum intrinsic growth multiplied by the total number of adults.

Common name	Total deaths	Cryptic deaths	Priors Maximum population growth	Relative mortality	Posterior Maximum population growth	Relative mortality
Gibson's albatross	606 (444-827)	159 (15-366)	940 (701-1 265)	0.65 (0.43-0.97)	943 (675-1 337)	0.64 (0.41-1.03)
Antipodean albatross	67 (48-96)	18 (3-39)	655 (499-861)	0.10 (0.07-0.15)	658 (465-906)	0.10 (0.07-0.17)
Wandering albatross	253 (179-354)	69 (13-144)	1 875 (1 403-2 594)	0.13 (0.09-0.19)	1 893 (1 336-2 665)	0.13 (0.08-0.22)
Tristan albatross	188 (113-312)	50 (5-126)	455 (274-771)	0.41 (0.28-0.62)	461 (264-792)	0.41 (0.20-0.85)
Amsterdam albatross	2 (2-4)	1 (0-2)	9 (7-13)	0.25 (0.17-0.38)	9 (6-14)	0.26 (0.15-0.47)
Southern royal albatross	74 (53-103)	16 (4-36)	1 146 (712-1 900)	0.06 (0.04-0.11)	1 165 (656-2 136)	0.06 (0.03-0.12)
Northern royal albatross	16 (9-26)	3 (1-8)	834 (567-1 367)	0.02 (0.01-0.03)	788 (508-1 348)	0.02 (0.01-0.04)
Atlantic yellow-nosed albatross	91 (63-133)	25 (4-56)	5 304 (3 965-7 124)	0.02 (0.01-0.02)	5 046 (3 580-7 070)	0.02 (0.01-0.03)
Indian yellow-nosed albatross*	943 (702-1 310)	264 (31-597)	13 901 (10 580-18 427)	0.07 (0.05-0.10)	6 469 (4 392-9 443)	0.15 (0.09-0.24)
Black-browed albatross*	1 268 (926-1 769)	354 (14-842)	56 203 (44 501-70 437)	0.02 (0.02-0.03)	84 043 (62 630-111 305)	0.02 (0.01-0.02)
Campbell black-browed albatross*	449 (332-626)	125 (15-283)	99 228 (71 446-138 500)	0.00 (0.00-0.01)	3 018 (2 166-4 397)	0.15 (0.09-0.24)
Shy albatross	128 (84-198)	35 (2-90)	2 377 (1 656-3 475)	0.05 (0.03-0.08)	2 267 (1 501-3 396)	0.06 (0.03-0.10)
New Zealand white-capped albatross*	2 158 (1 594-2 937)	601 (68-1 360)	28 743 (20 842-39 599)	0.07 (0.05-0.11)	11 429 (7 407-17 792)	0.19 (0.11-0.32)
Salvin's albatross	127 (84-194)	35 (4-84)	6 885 (4 841-9 760)	0.02 (0.01-0.03)	6 579 (4 502-9 731)	0.02 (0.01-0.03)
Chatham Island albatross	12 (8-18)	3 (-0-8)	703 (568-894)	0.02 (0.01-0.03)	693 (524-901)	0.02 (0.01-0.03)
Grey-headed albatross*	3 169 (2 409-4 250)	886 (129-1 934)	95 090 (76 764-118 084)	0.03 (0.02-0.05)	15 564 (9 205-32 810)	0.20 (0.09-0.39)
Southern Buller's albatross	2 110 (1 554-2 910)	587 (50-1 368)	23 601 (19 122-29 641)	0.09 (0.06-0.13)	1 625 (1 238-2 189)	1.29 (0.85-1.98)
Northern Buller's albatross	99 (70-142)	27 (3-64)	2 260 (1 814-2 902)	0.04 (0.03-0.06)	2 251 (1 704-2 954)	0.04 (0.03-0.07)
Sooty albatross	646 (475-857)	188 (34-391)	1 677 (1 193-2 315)	0.39 (0.25-0.58)	1 787 (1 250-2 534)	0.36 (0.22-0.59)
Light-mantled sooty albatross*	306 (220-426)	89 (16-189)	5 052 (3 505-7 424)	0.06 (0.04-0.09)	2 726 (1 800-4 646)	0.11 (0.06-0.19)

* species with updates to biological parameters

Table 11 [continued]. Final model outputs of the predicted bycatch mortality and cryptic deaths, together with the productivities and relative mortalities corresponding to priors and posteriors of biological parameters. Relative mortalities are measured relative to a productivity index, which is the maximum intrinsic growth multiplied by the total number of adults.

Common name	Total deaths	Cryptic deaths	Priors Maximum population growth	Relative mortality	Posterior Maximum population growth	Relative mortality
Grey petrel	458 (337-636)	128 (17-287)	35 025 (26 669-46 892)	0.01 (0.01-0.02)	17 542 (11 839-26 187)	0.03 (0.02-0.04)
Black petrel	38 (26-54)	11 (2-23)	1 267 (1 069-1 520)	0.03 (0.02-0.04)	1 264 (1 039-1 541)	0.03 (0.02-0.04)
Westland petrel*	117 (74-181)	32 (5-72)	1 929 (1 305-2 896)	0.06 (0.04-0.09)	1 810 (1 235-2 753)	0.06 (0.03-0.11)
White-chinned petrel*	3 167 (2 469-4 076)	894 (213-1 772)	148 436 (109 106-200 975)	0.02 (0.01-0.03)	272 104 (190 406-377 588)	0.01 (0.01-0.02)
Spectacled petrel	374 (263-531)	103 (17-227)	26 760 (18 315-39 850)	0.01 (0.01-0.02)	8 111 (5 858-11 660)	0.05 (0.03-0.07)

* species with updates to biological parameters

Table 12: Comparison of predicted seabird bycatch mortality, including cryptic mortality, according to the catchabilities estimated with observed catch and effort data in different time period

Species	2012-2019	2012-2016 (early)	2017-2019 (late)
Gibson's albatross	606 (444-827)	700 (522-980)	484 (342-684)
Antipodean albatross	67 (48-96)	81 (58-119)	50 (35-74)
Wandering albatross	253 (179-354)	205 (146-298)	303 (217-429)
Tristan albatross	188 (113-312)	179 (103-293)	186 (104-343)
Amsterdam albatross	2 (2-4)	2 (1-3)	3 (2-4)
Southern royal albatross	74 (53-103)	83 (57-120)	55 (34-85)
Northern royal albatross	16 (9-26)	16 (9-29)	19 (10-35)
Atlantic yellow-nosed albatross	91 (63-133)	116 (79-169)	62 (43-88)
Indian yellow-nosed albatross *	943 (702-1 310)	1 090 (802-1 492)	694 (508-953)
Black-browed albatross *	1 268 (926-1 769)	1 201 (872-1 660)	1 494 (1 066-2 087)
Campbell black-browed albatross *	449 (332-626)	415 (311-566)	548 (387-759)
Shy albatross	128 (84-198)	126 (81-189)	148 (98-235)
New Zealand white-capped albatross *	2 158 (1 594-2 937)	2 169 (1 659-2 948)	2 232 (1 633-3 067)
Salvin's albatross	127 (84-194)	140 (95-211)	127 (85-193)
Chatham Island albatross	12 (8-18)	12 (8-18)	13 (9-20)
Grey-headed albatross *	3 169 (2 409-4 250)	2 930 (2 243-3 857)	3 577 (2 631-4 929)
Southern Buller's albatross *	2 110 (1 554-2 910)	2 115 (1 594-2 878)	2 241 (1 614-3 102)
Northern Buller's albatross	99 (70-142)	106 (73-154)	101 (70-150)
Sooty albatross	646 (475-857)	468 (353-637)	1 210 (857-1 733)
Light-mantled sooty albatross *	306 (220-426)	217 (156-305)	540 (371-785)
Grey petrel *	458 (337-636)	378 (283-503)	735 (543-1 058)
Black petrel	38 (26-54)	33 (23-46)	44 (31-65)
Westland petrel *	117 (74-181)	101 (68-157)	142 (91-231)
White-chinned petrel *	3 167 (2 469-4 076)	2 491 (2 002-3 174)	4 577 (3 568-6 216)
Spectacled petrel	374 (263-531)	351 (246-508)	396 (280-572)

* species with updates to biological parameters

Table 13. Comparison with 2019 result on predicted seabird bycatch mortality. Estimates using the data 2012-2016 without including cryptic mortality was used for this comparison. Note, in the 2019 assessment the catchability for JPN was used as a proxy for fleets with no observer data in the analysed dataset. This difference and a number of updates to the methodology preclude direct comparison between the results of these two assessments.

Code	Common name	2019 assessment		2024 assessment	
DIW	Gibson's albatross	550	(466-640)	447	(429-461)
DQS	Antipodean albatross	147	(117-177)	49	(45-57)
DIX	Wandering albatross	696	(591-803)	184	(166-210)
DBN	Tristan albatross	377	(316-441)	138	(108-186)
DAM	Amsterdam albatross	6	(2-11)	1	(2-2)
DIP	Southern royal albatross	126	(76-187)	58	(49-67)
DIQ	Northern royal albatross	96	(57-143)	13	(8-18)
CDR	Atlantic yellow-nosed albatross	1080	(892-1290)	66	(59-77)
TQH	Indian yellow-nosed albatross	1860	(1540-2210)	679	(671-713)
DIM	Black-browed albatross	8350	(7580-9160)	914	(912-927)
TQW	Campbell black-browed albatross	812	(722-907)	324	(317-343)
DCU	Shy albatross	232	(196-269)	93	(82-108)
TWD	New Zealand's white-capped albatross	2060	(1870-2260)	1557	(1526-1577)
DKS	Salvin's albatross	10	(0-39)	92	(80-110)
DER	Chatham Island albatross	22	(0-86)	9	(8-10)
DIC	Grey-headed albatross	8440	(7800-9090)	2283	(2280-2316)
DSB	Southern Buller's albatross	2260	(2040-2480)	1523	(1504-1542)
DNB	Northern Buller's albatross			72	(67-78)
PHU	Sooty albatross	1350	(1100-1620)	458	(441-466)
PHE	Light-mantled sooty albatross	875	(708-1050)	217	(204-237)
MAI	Southern giant petrel	1460	(1210-1710)		
MAH	Northern giant petrel	493	(402-589)		
PCI	Grey petrel	1000	(807-1230)	330	(320-349)
PRK	Black petrel	191	(72-390)	27	(24-31)
PCW	Westland petrel	90	(45-155)	85	(69-109)
PRO	White-chinned petrel	7550	(6550-8630)	2273	(2256-2304)
PCN	Spectacled petrel	948	(576-1410)	271	(246-304)

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Table 14. Comparison of number of observations in input dataset and observed data in final outputs and updated outputs (after correction of errors in compiling petrel species aggregations) for fleets.

		JPN		TWN		NZL		NZL (JV)	
		Initial Model	Final Model	Initial Model	Final Model	Initial Model	Final Model	Initial Model	Final Model
DIW	Gibson's albatross	32		0		11		0	
DQS	Antipodean albatross	3		0		12		0	
	Gibson's and Antipodean albatross	0		6		0		0	
DIX	Wandering albatross	162		48		3		0	
DBN	Tristan albatross	14		0		0		0	
DAM	Amsterdam albatross	0		0		0		0	
	Wandering albatross complex	131	342	0	54	0	27	0	0
	SPECIES GROUP 1 TOTAL	**342**	**342**	**54**	**54**	**26**	**27**	**0**	**0**
DIP	Southern royal albatross	12	12	1	1	10	10	0	0
DIQ	Northern royal albatross	2	2	3	3	1	1	0	0
	Royal albatrosses	7	7	0	0	0	0	0	0
	SPECIES GROUP 2 TOTAL	**21**	**21**	**4**	**4**	**11**	**11**	**0**	**0**
	Diomedea spp	26	26	0	0	2	2	0	0
	Diomedea spp TOTAL	**389**	**389**	**58**	**58**	**39**	**40**	**0**	**0**
CDR	Atlantic yellow-nosed albatross	8		85		0		0	
TQH	Indian yellow-nosed albatross	138		63		0		0	
	Yellow-nosed albatrosses	59	205	0	148	0	0	0	0
DIM	Black-browed albatross	301		101		3		0	
TQW	Campbell black-browed albatross	170		12		11		1	
	Black-browed albatrosses	312	783	0	113	0	14	0	1
DCU	Shy albatross	0		4		0		0	
TWD	New Zealand's white-capped albatross	0		34		151		11	
	Shy-type albatross	796	796	0	38	0	151	0	11
DKS	Salvin's albatross	0	0	8	8	1	1	0	0
DER	Chatham Island albatross	3	3	0	0	0	0	0	0

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Table 14 [Continued]

DIC	Grey-headed albatross	840	840	17	17	1	1	0	0
DSB	Southern Buller's albatross	0		0		0		0	
DNB	Northern Buller's albtatross	9		0		0		0	
	Buller's albatross	780	789	4	4	125	125	62	62
	Thalassarche spp.	267	267	0	0	0	0	0	0
	SPECIES GROUP 3 TOTAL	**3683**	**3683**	**328**	**328**	**292**	**292**	**74**	**74**
PHU	Sooty albatross	134	134	61	61	0	0	0	0
PHE	Light-mantled sooty albatross	95	95	6	6	0	0	0	0
	Phoebetria spp	4	4	0	0	0	0	0	0
	SPECIES GROUP 4 TOTAL	**233**	**233**	**67**	**67**	**0**	**0**	**0**	**0**
	Diomedeidae	822	822	170	170	0	0	0	0
	Diomedeidae TOTAL	**5127**	**5127**	**623**	**623**	**331**	**332**	**74**	**74**
MAI	Southern giant petrel	94		7		0		0	
MAH	Northern giant petrel	88		3		0		0	
	Macronectes spp.			1					
	SPECIES GROUP 5 TOTAL	**182**		**11**		**0**		**0**	
PCI	Grey petrel	152	152	3	3	4	4	0	0
PRK	Black petrel	5		0		32		0	
PCW	Westland petrel	4		1		37		1	
PRO	White-chinned petrel	407		190		12		1	
PRZ	Petrel complex		416		191		81		2
PCN	Spectacled petrel	44	44	53	53	0	0	0	0
	Precellaria spp	0	0	25	25	0	0	0	0
	SPECIES GROUP 6 TOTAL	**612**	**612**	**272**	**272**	**85**	**85**	**2**	**2**
	Procellariidae	165	165	14	14	0	0	0	0
	Procellariidae TOTAL	**959**	**777**	**297**	**286**	**85**	**85**	**2**	**2**
	Birds	223	223	8	8	0	0	0	0
	Birds TOTAL	**6309**	**6127**	**928**	**917**	**416**	**417**	**76**	**76**

Table 15. Comparison of q estimates after correction of codes in compiling petrel species aggregations.

Data s species_group	JPN		TWN		NZL (DOM)		NZL (JV)	
Initial Model:								
Wandering albatross	8.45	(7.12-10)	0.62	(0.47-0.78)	5.04	(3.99-6.27)	0.04	(0.01-0.11)
Royal albatross	7.63	(4.21-12.09)	2.17	(0.92-4.29)	3.53	(2.1-5.59)	0.07	(0.01-0.22)
Mollymawk	4.26	(3.86-4.68)	0.74	(0.65-0.83)	2.42	(2.13-2.77)	0.21	(0.17-0.26)
Sooty albatross	21.9	(17.54-27.13)	4.6	(3.51-5.88)	5.94	(0.28-26.56)	0.35	(0.01-1.52)
Large petrel	52.48	(41.98-64.44)	0.8	(0.48-1.24)	5.73	(0.29-25.92)	0.34	(0.01-1.66)
Medium petrel	4	(3.38-4.68)	0.71	(0.58-0.84)	5.48	(4.48-6.58)	0.18	(0.07-0.34)
Fleet specific q	***10.31***	***(9.24-11.38)***	***1.15***	***(0.96-1.36)***	***3.71***	***(1.92-6.44)***	***0.11***	***(0.04-0.24)***
After modification (2012-2019):								
Wandering albatross	16.13	(13.51-18.78)	3.14	(2.43-3.93)	4.65	(3.14-6.33)	0.17	(0.02-0.58)
Royal albatross	6.39	(3.4-10.23)	2.63	(1.09-4.94)	4.58	(2.62-7.2)	0.21	(0.01-0.8)
Mollymawk	3.78	(3.42-4.2)	0.78	(0.68-0.9)	1.58	(1.35-1.83)	0.12	(0.1-0.15)
Sooty albatross	19.9	(16.03-25.06)	5.75	(4.45-7.43)	4.55	(0.25-21.5)	0.57	(0.02-3.64)
Large petrel	-	-	-	-	-	-	-	-
Medium petrel	1.97	(1.61-2.35)	0.38	(0.3-0.48)	1.66	(1.19-2.21	0.13	(0.03-0.32)
Fleet specific q	***6.54***	***(5.4-7.63)***	***1.59***	***(1.24-1.96)***	***2.67***	***(1.53-4.28)***	***0.17***	***(0.05-0.32)***
Update on 20240515 (2012-2019):								
Wandering albatross	15.27	(12.71-18.1)	2.63	(2.04-3.35)	4.22	(2.92-5.78)	0.16	(0.01-0.56)
Royal albatross	6.24	(3.6-10.19)	2.32	(0.97-4.41)	4.38	(2.39-7.05)	0.23	(0.02-0.97)
Mollymawk	3.63	(3.25-4.04)	0.68	(0.6-0.78)	1.47	(1.27-1.68)	0.13	(0.1-0.15)
Sooty albatross	18.83	(15.24-23.15)	5.05	(3.88-6.42)	5.94	(0.23-29.94)	0.52	(0.02-3.09)
Large petrel	-	-	-	-	-	-	-	-
Medium petrel	3.04	(2.5-3.64)	0.59	(0.48-0.71)	4.17	(3.3-5.11)	0.12	(0.05-0.23)
Fleet specific q	***7.17***	***(6.28-8.12)***	***1.63***	***(1.35-1.91)***	***3.22***	***(1.86-5.05)***	***0.15***	***(0.06-0.34)***

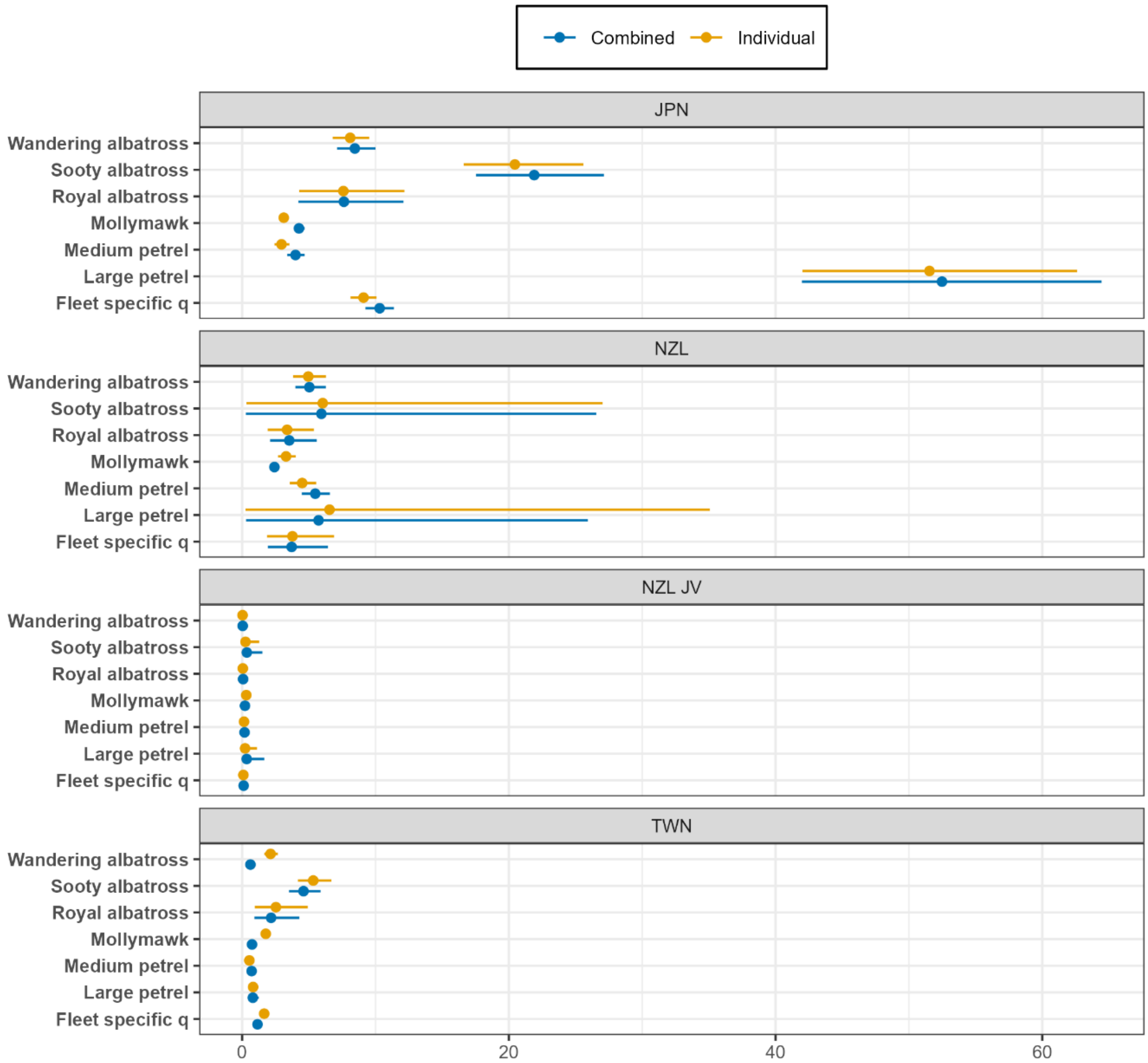

Figure 1. Comparison of catchability coefficient estimates according to data sources. Orange corresponds to the outputs using the combined data set and blue for individual CPC's data for the initial model run

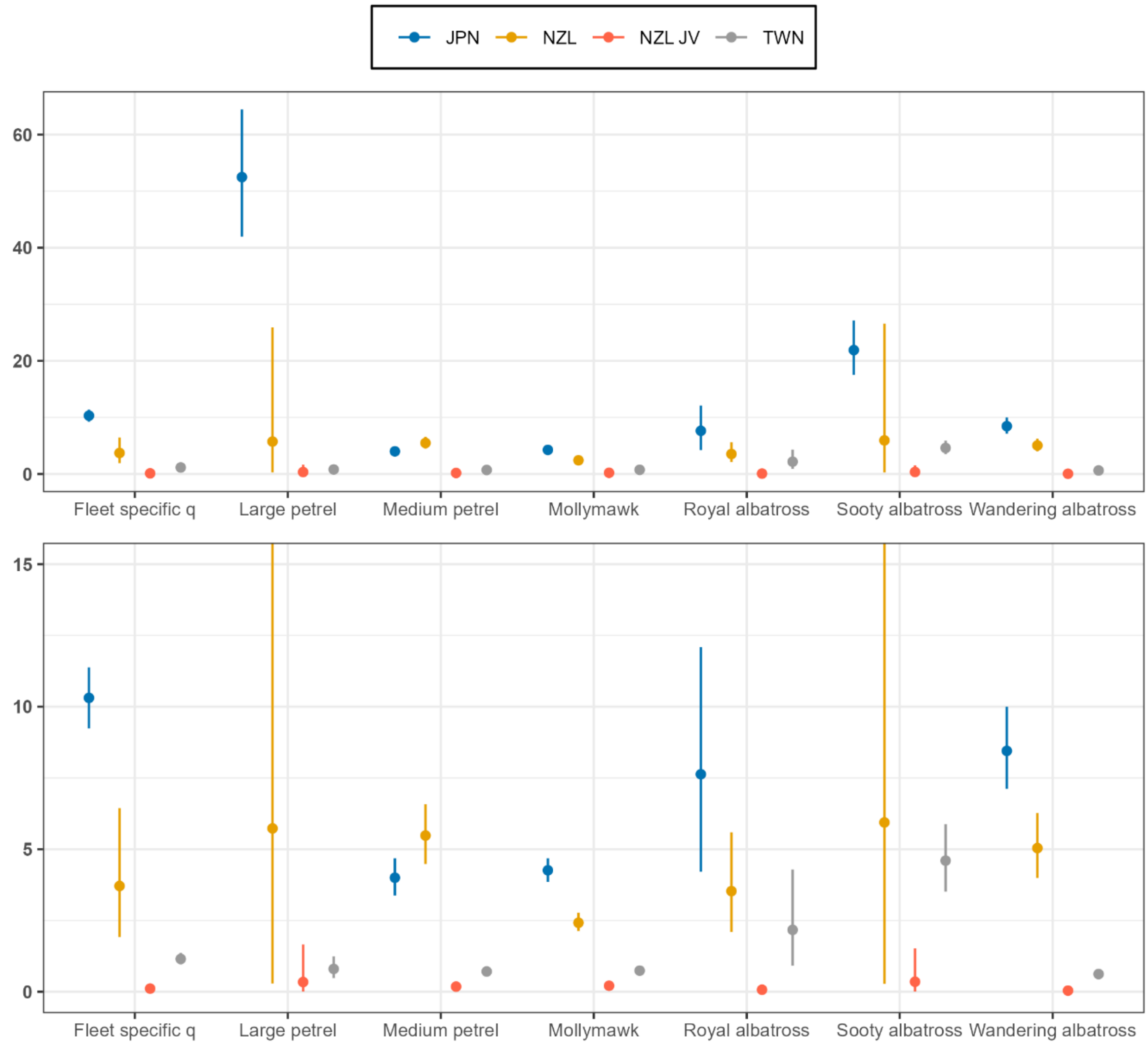

Figure 2. Catchability coefficient estimates obtained from the initial model. Lower figure with different Y-scale to focus differences among lower values.

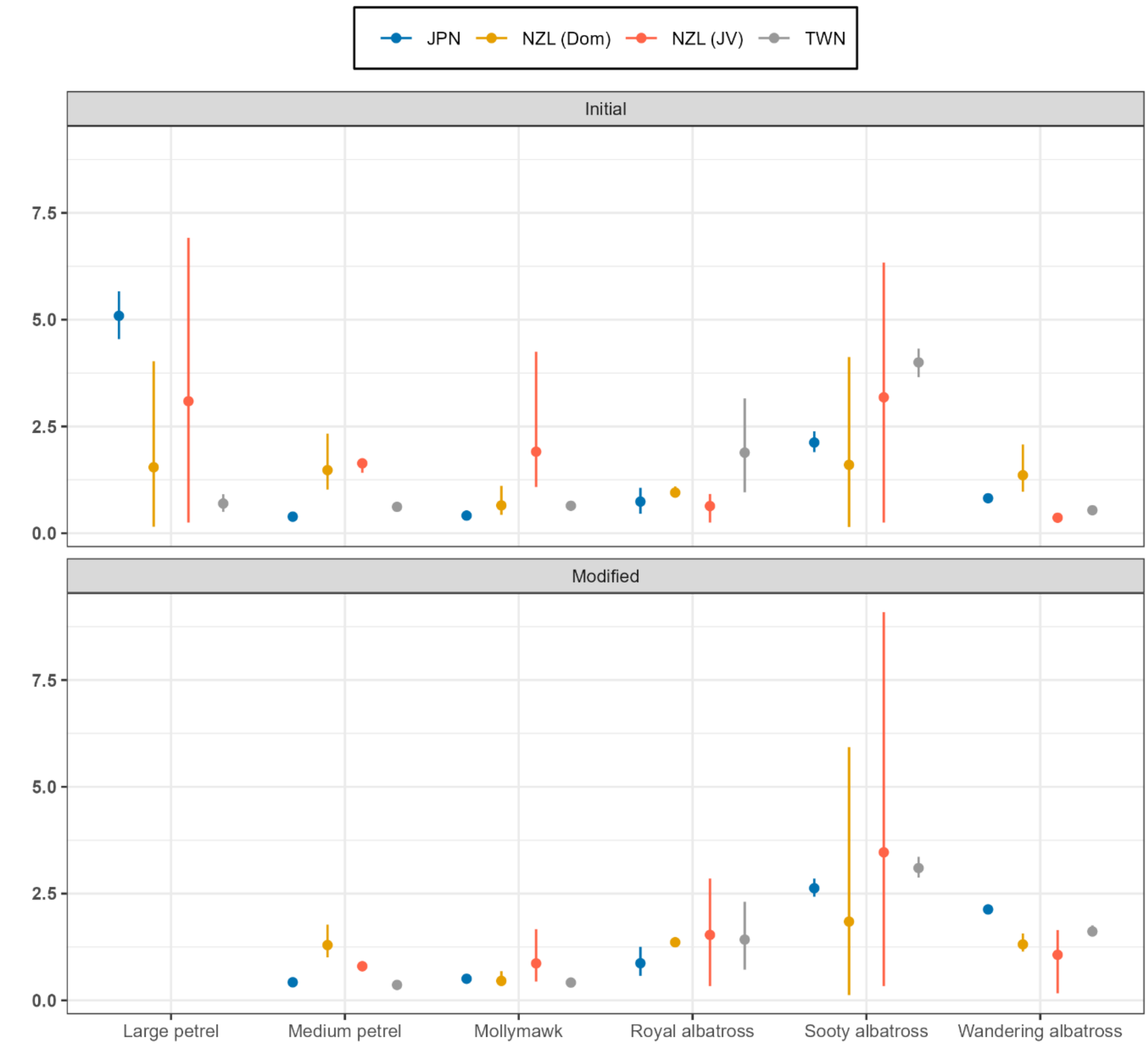

Figure 3. Catchability coefficients relative to fleet-specific catchability for the initial model .

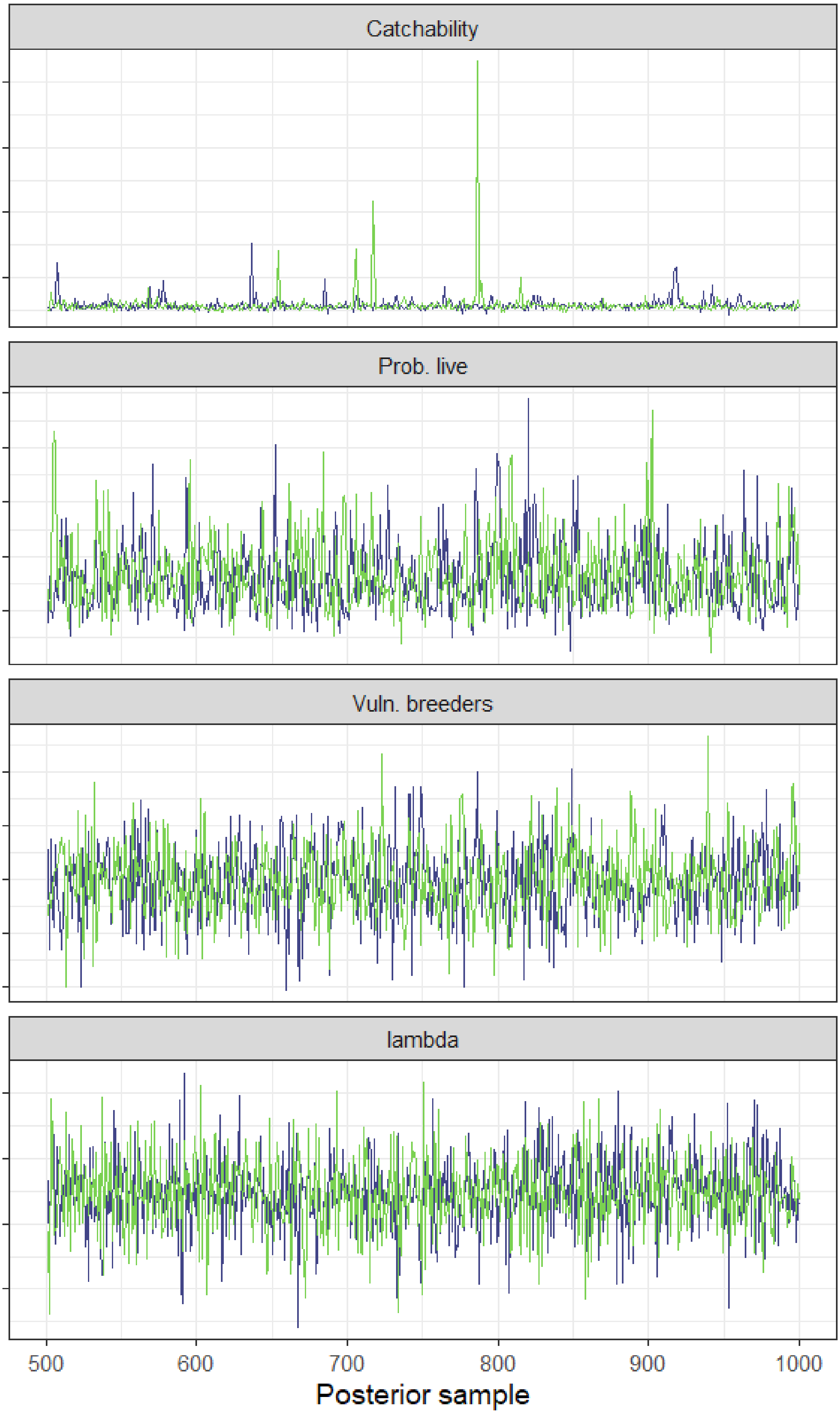

Figure 4. MCMC trace diagnostics for model fit. For each MCMC chain, the Euclidean norm is calculated for each parameter vector.

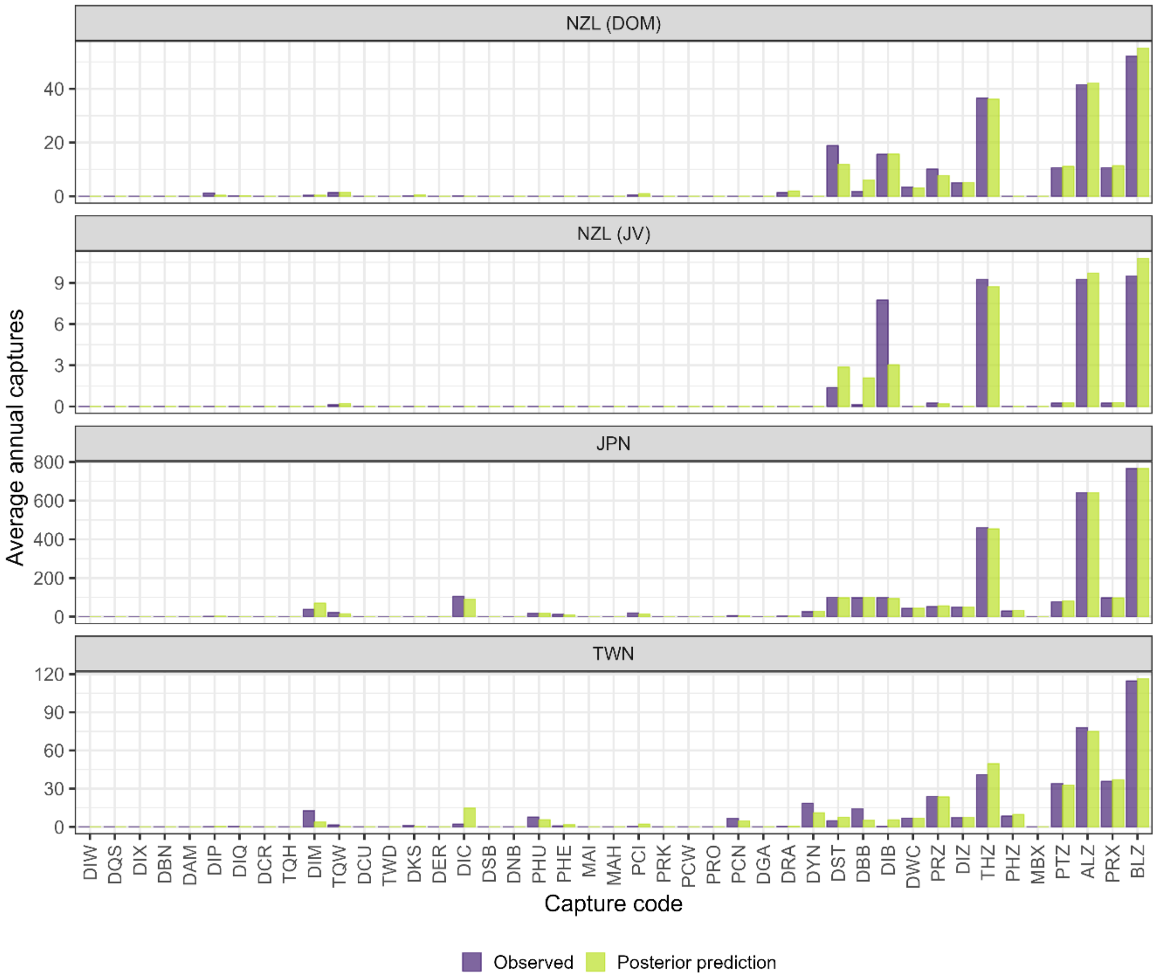

Figure 5. Model fit to the observed number of average annual captures per capture code. Empirical (observed) values are plotted next to the posterior predicted values.

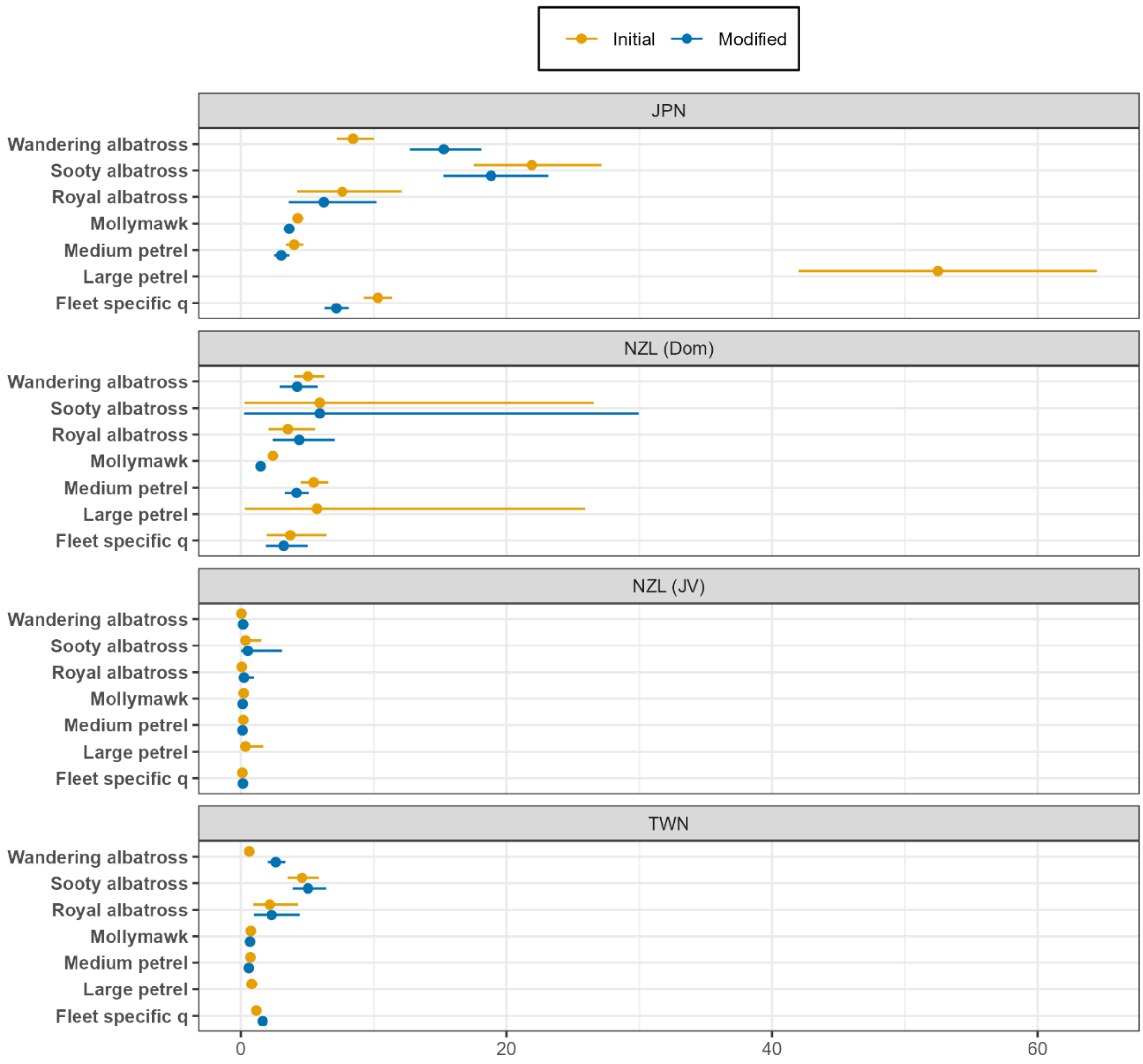

Figure 6. Comparison of catchability coefficient estimates between models before and after modification incorporated.

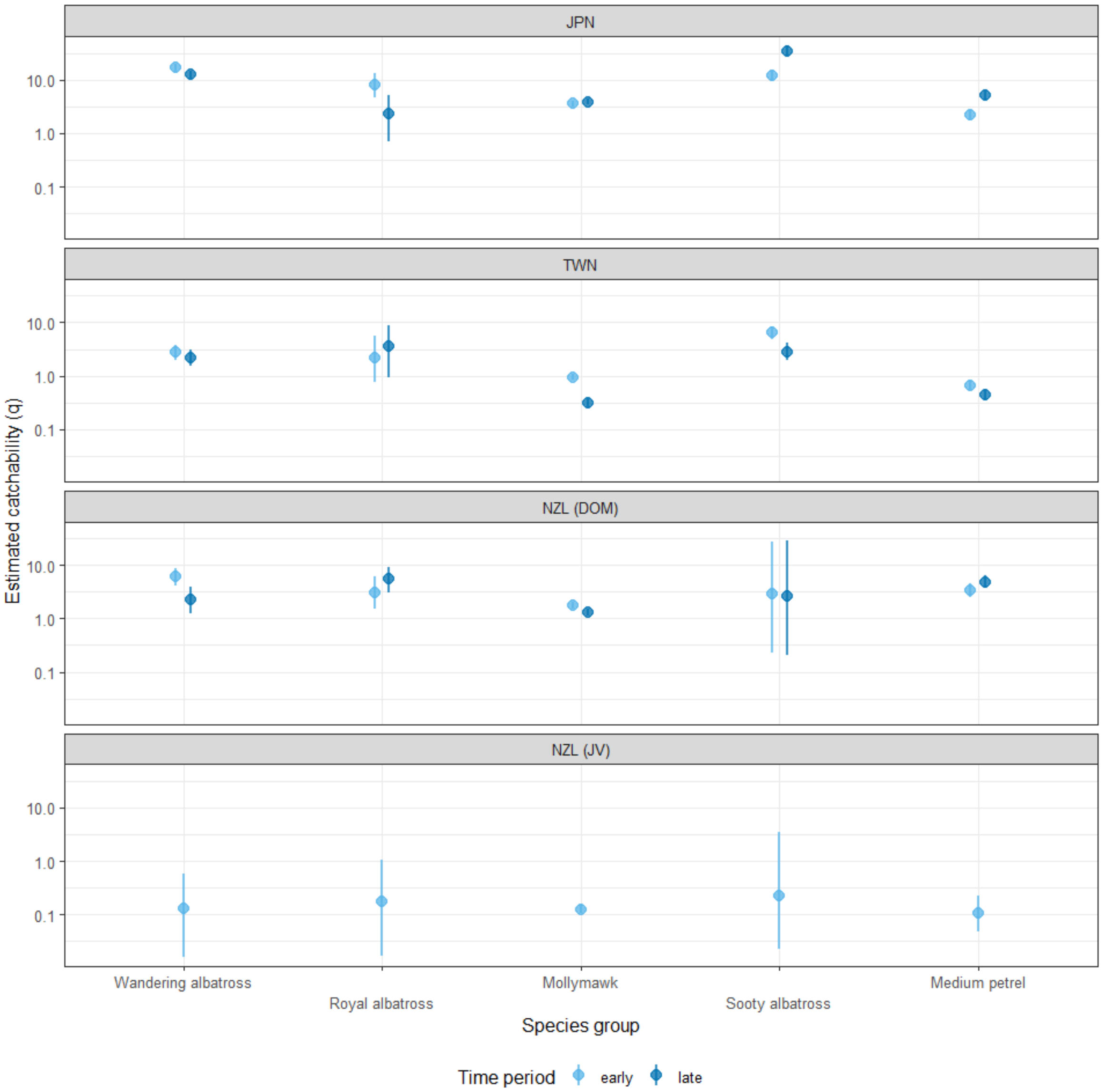

Figure 7. Change of catchability coefficients between two periods.

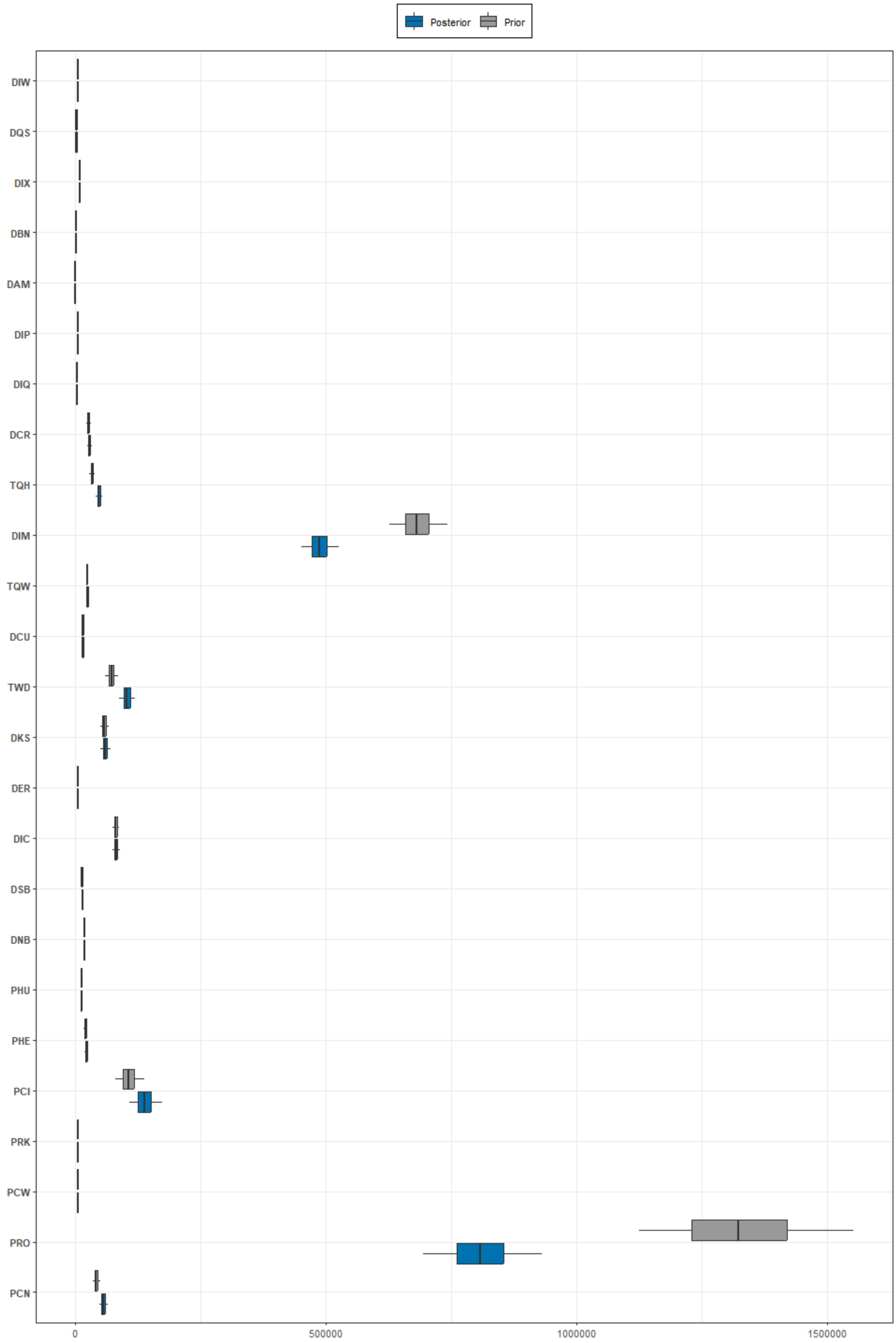

Figure 8a. Boxplots indicating the prior and posterior number of breeding pairs per species.

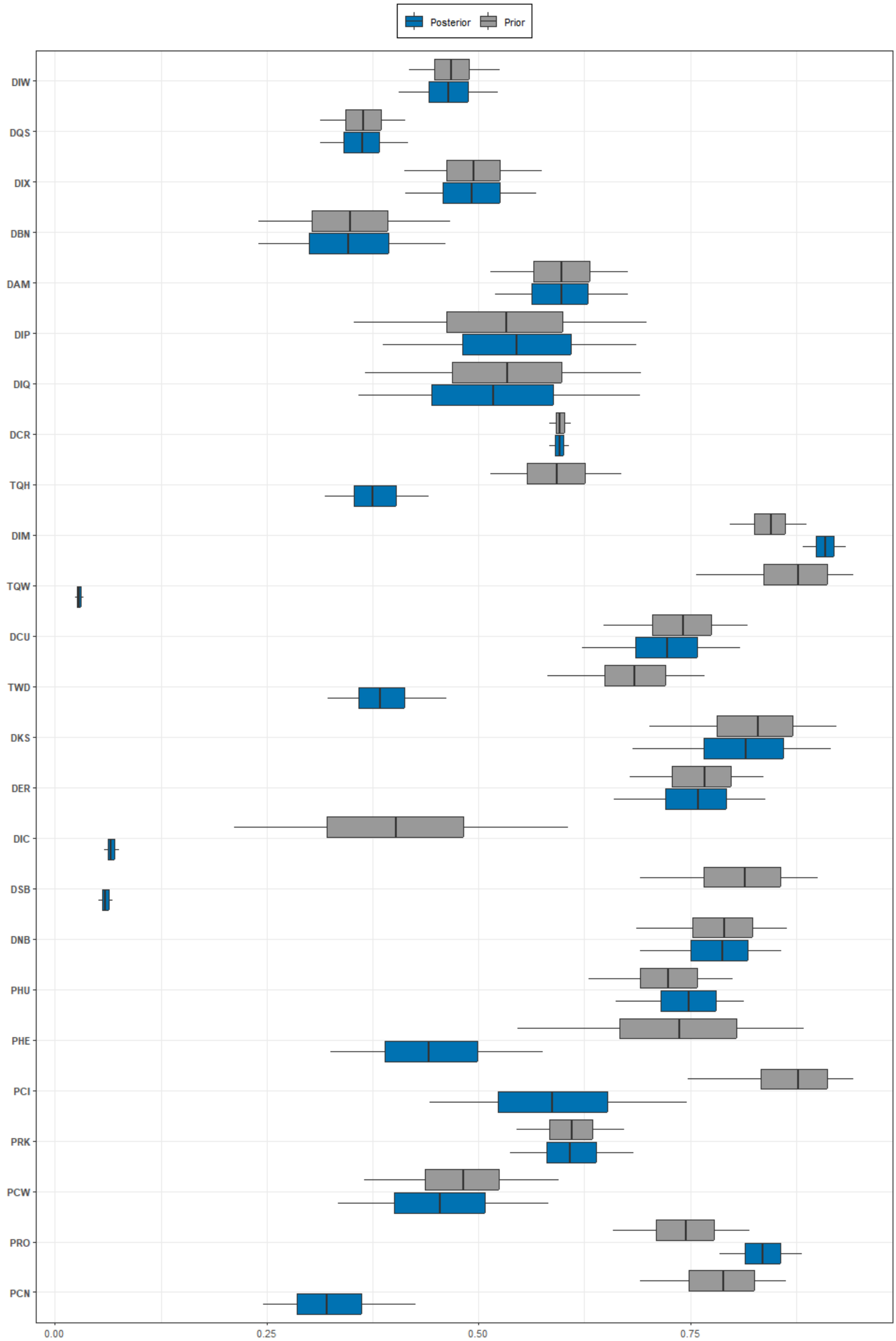

Figure 8b. Boxplots indicating the prior and posterior number of probability of breeding per species.

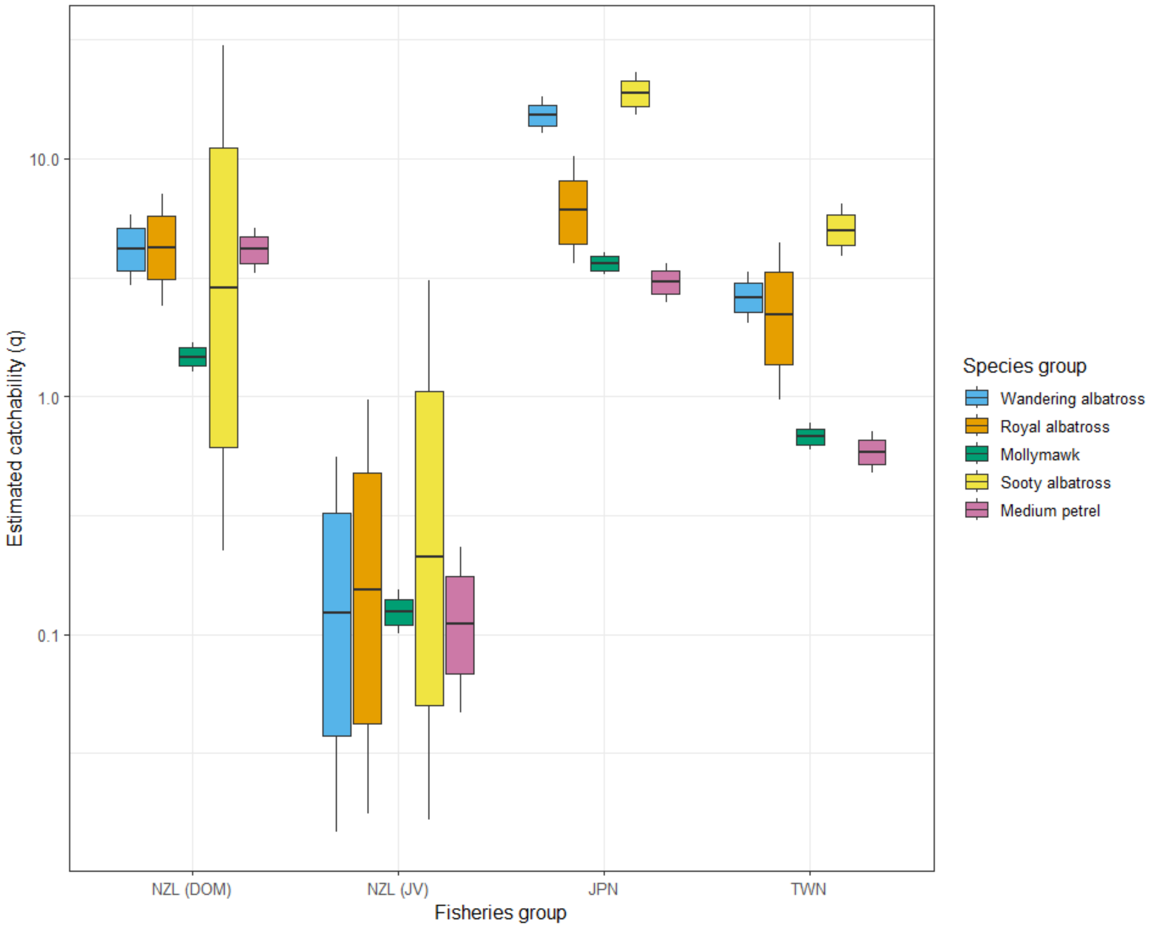

Figure 9. Boxplot showing posterior distribution of catchability values (on a log-10 scale) per species group and fishery group.

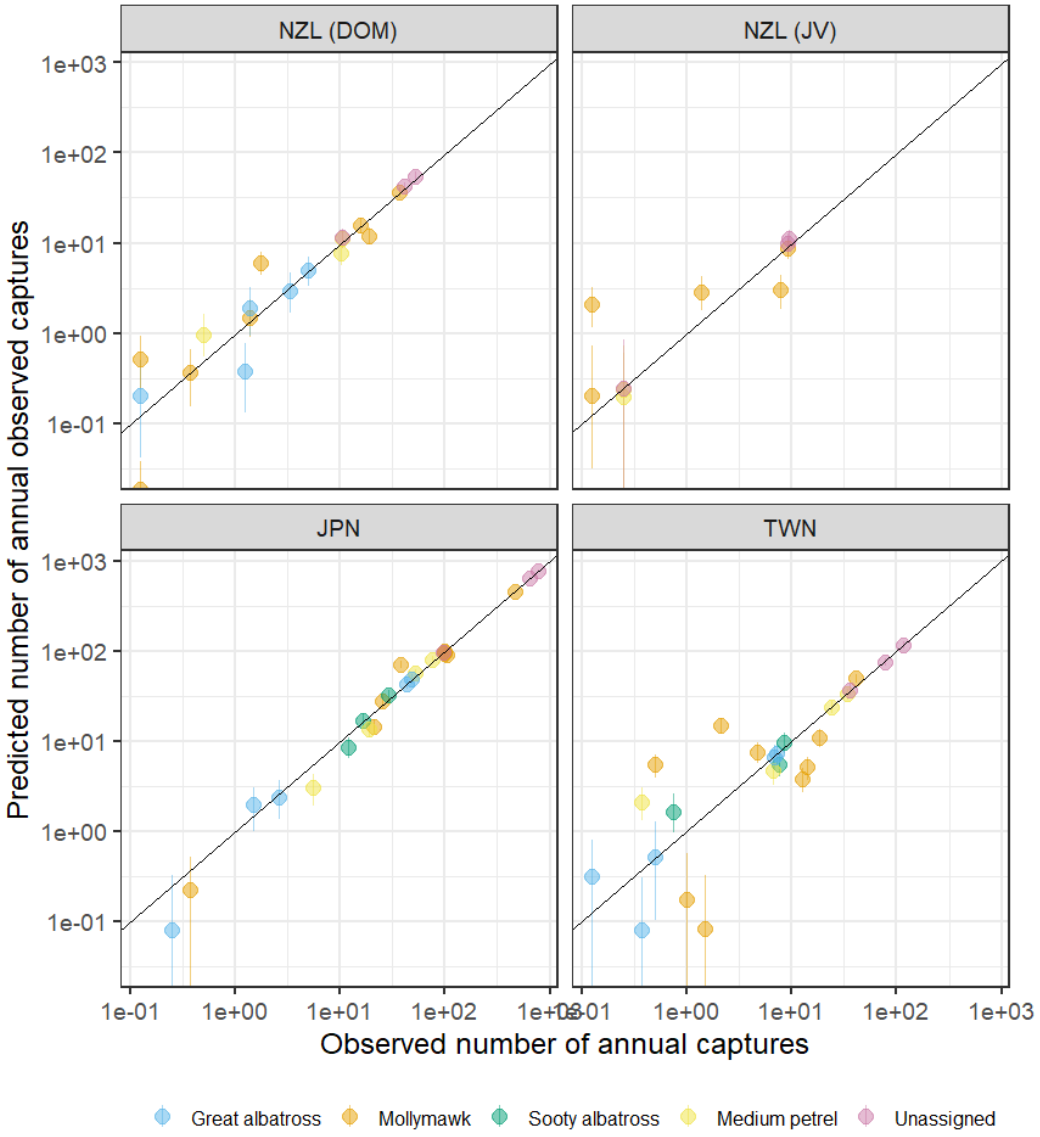

Figure 10a. Fit of the model to the average annual observed captures per capture code (on a log-10 scale) for the one time period model.

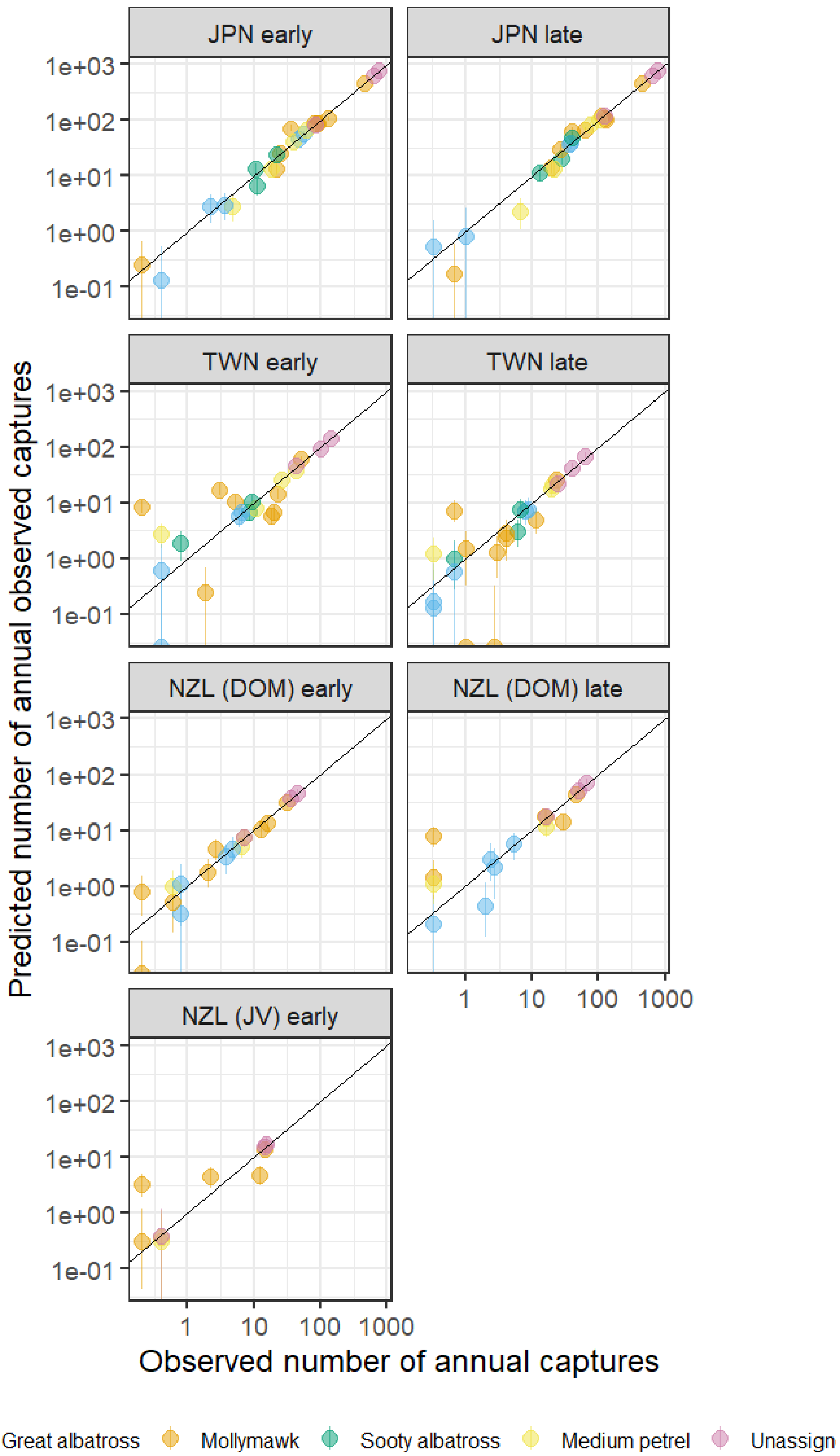

Figure 10b. Fit of the model to the average annual observed captures per capture code (on a log-10 scale) for the model.

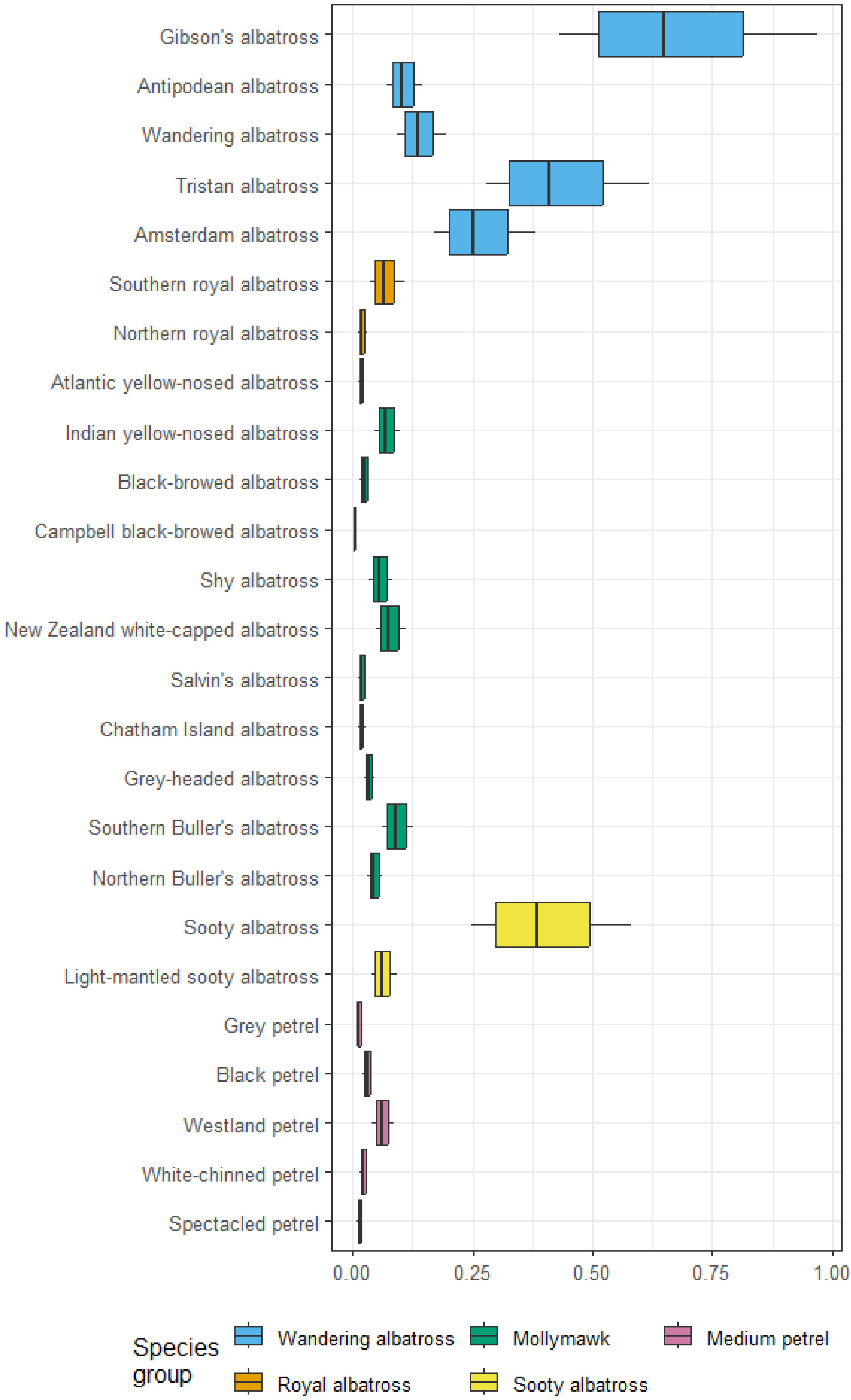

Figure 11. Relative mortalities per species with catchabilities shared across the full time period (2012 to 2019).

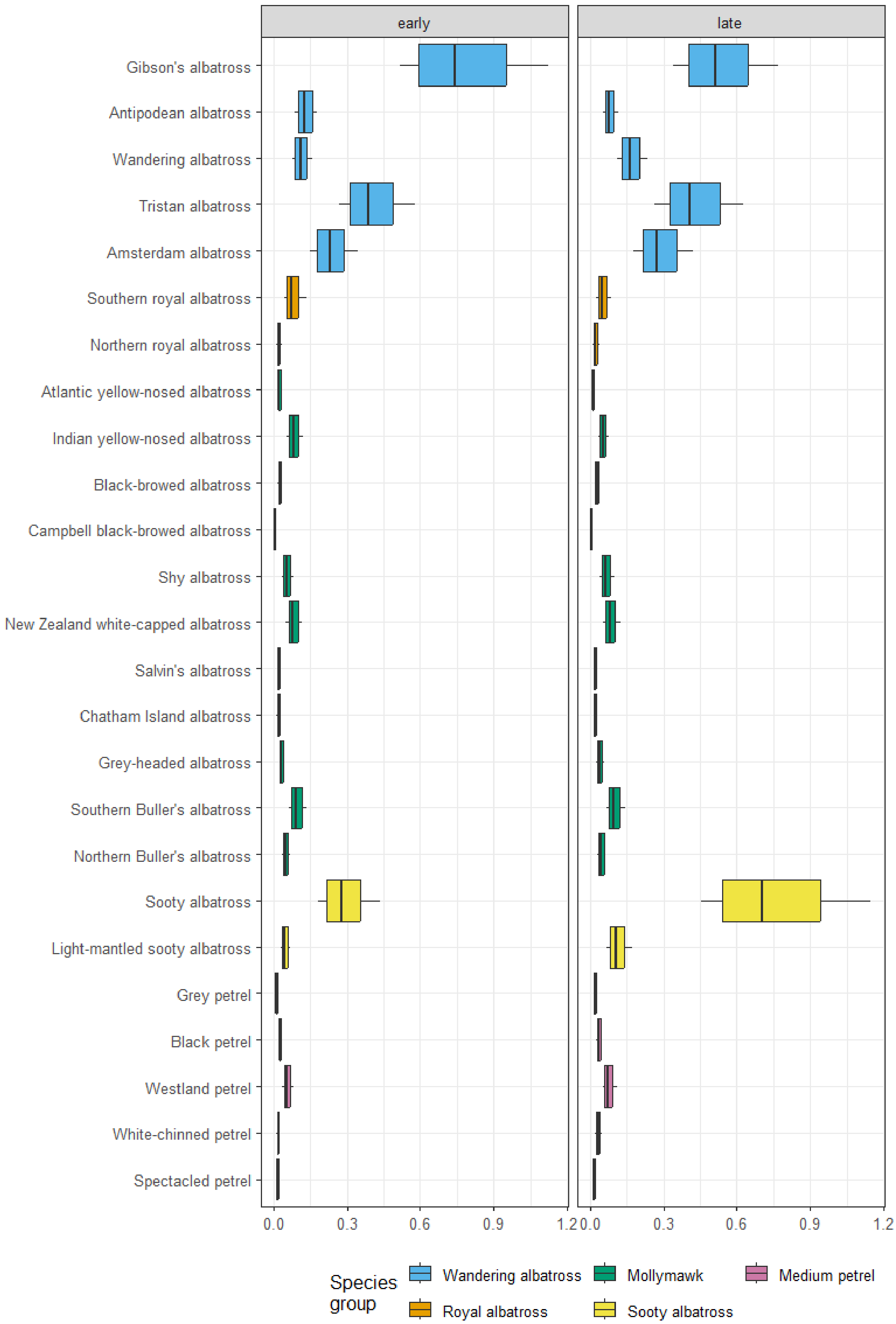

Figure 12. Relative mortalities per species with catchabilities specific to the early (2012-2016) and late (2017-2019) period.

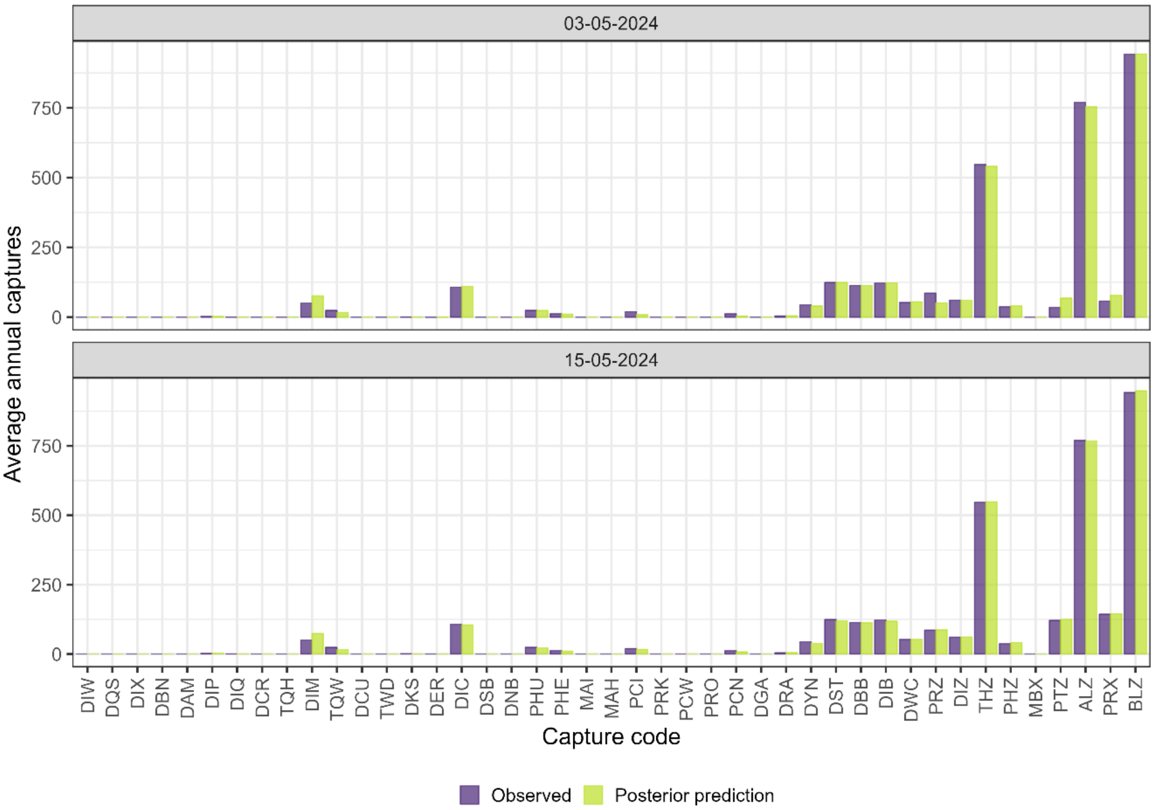

Figure 13. Model fit to the observed number of average annual captures per capture code for each model run. Empirical (observed) values are plotted next to the posterior predicted values.

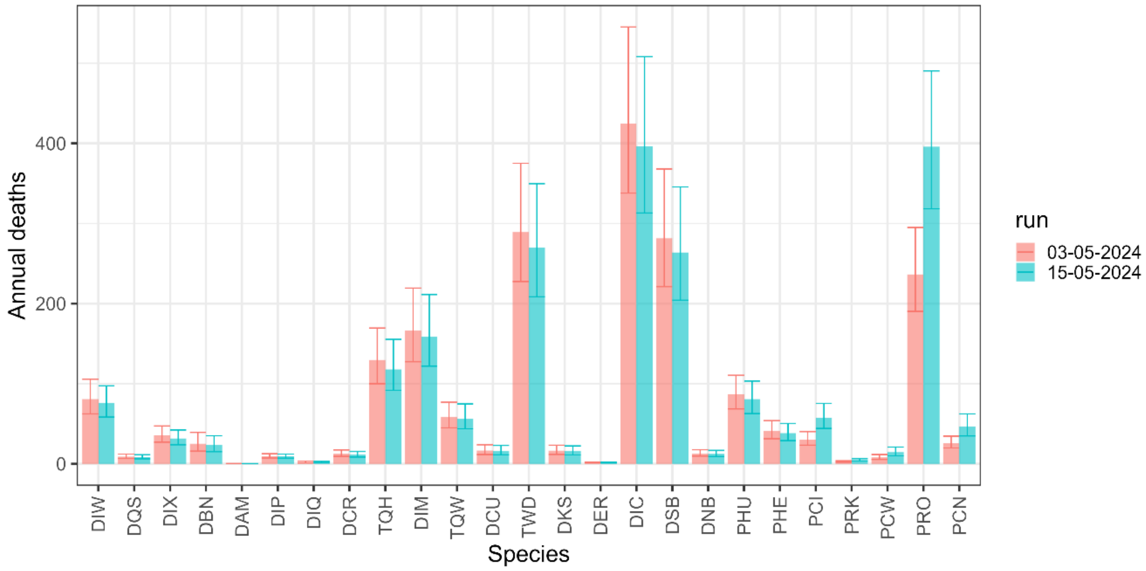

Figure 14. Estimated number of annual deaths per capture code for each model run.

Figure 13. Relative mortalities per species with catchabilities specific to the early (2012-2016) and late (2017-2019) period.

Appendix 1: Initial work plan developed by New Zealand and Japan in July 2022

Work plan for CCSBT-ERS – collaboration on Southern Hemisphere Risk Assessment

Japan and New Zealand would like to propose several Technical Workshops, and an intersessional work plan to establish a collaborative framework for a Southern Hemisphere Risk Assessment among the CCSBT Members. While collaboration within the CCSBT is the primary objective, it opens opportunity for wider acceptance by non-CCSBT Members whose surface longliners also overlap with seabirds in this study. This programme is therefore a first step towards a risk assessment of the entire southern hemisphere.
The work plan includes:

- Technical workshop I (virtual) in 1st Quarter 2023
- Data preparation meeting (face-to-face) in 3rd Quarter 2023
- Technical workshop II (face-to-face/virtual) in 1st Quarter 2024

All meetings will include options for virtual attendance if required.
Details of formats and objectives of the individual meetings are described below, together with inter-sessional preparatory work. Noting that the Data Preparatory Meeting and subsequent Technical Workshop II are contingent on New Zealand's internal research prioritisation process for 2023/24, and any potential funding contribution from other interested parties.

Technical Workshop I (Virtual)

Estimated dates: 1st quarter 2023 *Location: Online* *Duration: 1 – 2 days*

The aim of this workshop is for participating CCSBT-Member scientists to familiarise themselves with the SEFRA process, to understand and demonstrate the importance of collaborative participation, and summarise the data requirements needed to undertake this work. At least three presentations are planned:

i) The methodology and results from the current version of the Southern Hemisphere Risk Assessment conducted by New Zealand;
ii) The results from the quick analysis, comparing inclusion of Japanese data with initial model runs to evaluate increases in the precision of estimates;
iii) Summary of data requirements to conduct SEFRA; and
iv) Provisional work plan.

Coordinator: Sachik Tsuji

In preparation for this meeting, New Zealand and Japan will collaborate to establish the best way to share the inputs, codes and results sufficiently in advance to allow for the updated analyses with Japanese data.

The expected outputs include achieving general commitment by Members to participate in the collaborative risk assessment and receiving feedback and suggestions for further modification in methodology as well as potential constraints in input data provision.
It is expected that New Zealand will contract and fund the CCSBT-collaborative risk assessment.

After the completion of the first technical workshop, Japan and New Zealand will make efforts to encourage participation in the collaborative assessment with individual Members.
No support from ERS chair or Secretariat required.

Data Preparatory Meeting (In Person)

Estimated dates: 3rd quarter 2023 *Location: Wellington* *Duration: 5 days*

This workshop is to establish an integrated dataset for use in the CCSBT-collaborative risk assessment, including agreeing on fisheries and species grouping and the parameter inputs. Expected participants are scientists from member nations who agree to provide data into the collaborative assessment.

New Zealand and Japan would like to request the Secretariat to host this meeting. However, we recognize that this may not be possible in the first iteration of this process. Hosting by the CCSBT Secretariat is preferred due to the expectation that Members provide data towards establishing an integrated dataset under the CCSBT Secretariat to support a regular assessment.

Due to the highly technical nature of discussions, the meeting would ideally be face-to-face. Prior to the meeting, a GitHub repository for the code used in the analysis would be established and Members would have access.

At or promptly after the meeting, the integrated data set would be established, and the assessment would be conducted by an appropriate science provider funded by New Zealand. Items to be agreed upon at this workshop:

i) Fleet definition;
ii) Species grouping;
iii) Spatial and temporal resolution;
iv) Handling of data within the EEZ;
v) Handling of unidentified seabird captures;
vi) How information will be shared;
vii) What can and cannot be modified;
viii) Sensitivity runs including cryptic mortality

Coordinator: Sachiko Tsuji

Following this meeting the estimated input parameters would be shared among participating scientists. The New Zealand science provider would then develop a first draft of the assessment that would be reviewed before Technical Workshop II.

Ideally this meeting would take place in person, in Wellington New Zealand. This would ensure engagement with the contract researcher and IT infrastructure. There could be an option to attend virtually but strongly recommend an in-person presence.

Data manager: Support would be needed from the Secretariate for a data manger.

Output: Report drafted by the ERSWG Chair for members to report back to their respective governments summarizing the technical session.

[New Zealand Version (Rev.1)]

Appendix 2: Note of agreement for the first Technical workshop, 21-22 June 2023

**CCSBT ERSWG Collaboration on Southern Hemisphere Seabird Risk Assessment Workshop 1 -Technical workshop
21-22 June 2023
Online and in-person in Wellington New Zealand**

Meeting attendees

Neil Hughes, Jonathan Barrington, Heather Patterson (Australia), Shachiko Tsuji, Ochi Daisuke, Nishimoto Makoto (Japan), William Gibson, Heather Benko, Johannes Fisher, Robert Gear (New Zealand), Ting Chun (Taiwan), Martin Cryer (ERSWG Chair), Ross Wanless (CCSBT Seabird Project Manager), Charles Edwards (researcher), Yonat Swimmer (WCPFC Co-Chair Ecosystem and Bycatch Theme), Akira Soma, Dominic Vallieres (CCSBT Secretariat)

Purpose of meeting

For participating CCSBT-Member scientists to familiarise themselves with the spatially explicit fisheries risk assessment (SEFRA) process, to understand and demonstrate the importance of collaborative participation, and summarise the data requirements needed to undertake this work.

Agreed data requirements/parameters

- Spatial and temporal resolution and coverage
  - Temporal resolution: monthly
  - Temporal coverage:
    - Comparing two time periods (2012-2015 and 2017-2019) to compare q(f,z)[2]
    - Longest time period possible, determined by CCSBT reporting to assess period with adequate observer data (e.g. 2002-2019)
  - Spatial resolution: 5x5 or 1x1 where feasible
  - Spatial coverage: all southern hemisphere
- 'Fishery' definition and coverage[3]
  - All SLL effort from CCSBT Member nations regardless of declared target
  - Separated by fleet, each fleet considered an independent 'fishery'
  - Flag nation to decide on further disaggregation needs
- Seabird components
  - Coverage: ACAP priority species plus additional frequently bycaught species which occur in the southern hemisphere (e.g., wedge-tailed, flesh-footed, and sooty shearwaters) if feasible
  - Species/species groups: to be reviewed by species experts intersessionally[4]

[2] New Zealand has raised concerns around confounding between q(f,z) and N when fitting to C'. If two periods of stable seabird populations could be identified and population parameters entered into the model then q(f,z) may be able to be assessed. If N is fixed and q(f,z) allowed to vary then it will be impossible to assess whether a change in q(f,z) of the true value of N are effecting C'
[3] Noting that ideally these parameters would align with the goals of the Multi-Year Seabird Strategy for ease of implementation of the strategy.
[4] Utilizing the ACAP TOR to access/share seabird documents

  - Growth stage segmentation: juveniles and adults
  - Bird distribution file: to be reviewed by species experts intersessionally
  - P(nest): to be reviewed by species experts intersessionally
  - Biological parameters: to be reviewed by species experts intersessionally
  - Sustainability criteria: intrinsic growth, static or dynamic (conversation to continue intersessionally)

- Post-release and cryptic mortality
  - Post release mortality: assuming no survival – all caught birds assumed dead
  - Cryptic mortality: make visible in output by splitting out cryptic mortality from post release survival[5]

- Operational procedure
  - Establish combined data, then run the model – CCSBT Secretariat to act as data custodian
  - Meeting 2 to be held in first quarter 2024 – hybrid approach online and in Wellington New Zealand for collaborative model runs and sensitivity analysis
  - Closed GitHub to be used as code sharing platform
  - Intersessional communications among participating experts to be conducted via email

- Incorporating precautionary principle
  - Elements of the precautionary principle incorporated throughout (e.g., zero survivability, cryptic mortality)
  - Exploring sensitivities (vulnerability, psi, omega, P-obs) – to be considered intersessionally but also discussed at next workshop

Draft Work Plan:

Task	Lead	Deadline
Preparation of package to process input observer and effort data for SEFRA	NZ, JP	ASAP but before Nov 2023
Review and selection of bird distribution and biological data and creation of density maps (if feasible)*	NZ (DOC), AU, Dr Ross Wanless	First draft by Oct, final draft by end of 2023
Preparation of observer and effort data	Members	By meeting 2
Modification of model	NZ, JP	ASAP but before Nov 2023
Evaluation of model operability via GitHub	Members	By meeting 2
Meeting 2 (hybrid) - collaborative model run, interpretation of results, compilation of input data, sensitivity runs	Members	First quarter 2024 (Jan, Feb**)
Report preparation	Members	For delivery at ERSWG15***
Meeting 3 (if needed)	Members	In conjunction with ERSWG15 ***

* Species list will be based on what is currently available and Member's capacity to fill gaps, and input from species experts
**Avoiding lunar new year second week of February
*** ERSWG 15 scheduled for 4-7 June 2024, location TBD