CCSBT-ERS/2406/13
(ERSWG Agenda Item5.1.3)

Report of the Technical Working Group on

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

1. BACKGROUNDS 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 recommendation on reducing the incidental bycatch of seabirds was developed in 2006 at the 6th meeting of the CCSBT Ecologically Related Species Working Group (ERSWG) in 2006, which ignited the debate whether the CCSBT can make binding measures for ERS related issues. As a result, the 7th meeting of ERSWG could not reach agreement on draft recommendation. The debate on the CCSBT's legal capacity of establishing the mandatory measures on ERS related matter 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, that was updated at the 28th Annual Meeting in 2021.

A Performance Review was conducted in 2008 that criticized non-functioning of the ERSWG and pointed, at the very least, 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 to be performing effectively. In response, the 15th Annual meeting in 2008 agreed to develop a non-binding recommendation for the CCSBT covering By-catch mitigation for seabirds, sea turtles and sharks. Also, it agreed to develop a Strategic Plan and established Strategy and Fisheries Management Working Group. The Plan was adopted at the Special Meeting held in 2011, which included three items and seven action plans under the ERSWG.

In 2014, the Strategy and Fisheries Management Working Group was re-established to discuss the revision of 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 into 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 (Edwards et al (2023)), 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 was developed at the 14th meeting of ERSWG in 2021 and adopted by the 29th Annual meeting of CCSBT, which included 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 ongoing seabird risk assessment of fisheries within New Zealand and would be developed upon the model developed for the New Zealand domestic risk assessment.

Following the decision by the 29th session 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. The note of agreement is in Appendix 2. The meeting agreed this first collaborative assessment would be based on the best available science and knowledge and provide a basis for future regular assessment 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 evaluate 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 the late 2023. Thereafter, the individual 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 the participation of 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.

In consequence, 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 sumed across species within the species complex during the model fitting. In that way, 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 (details in section 4.2). The revised procedure was reviewed at an online discussion held on 4th 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 23rd April, 2024. The technical group noted that at least two of biological parameters: 1) the number of breeding pairs, and 2) the probability of breeding for some species, show a large shift away from the priors when the model was run (details in the Section 4.3). Although this would cause impacts on the assessment of catchability estimates and evaluation of relative risks in particular for small albatrosses (mollymawks) and medium petrels. The model output of those species groups should be interpreted carefully.

This document described the process and outputs of the CCSBT collaborative seabird risk assessment of its 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 model modification afterwards, and the final outputs. All details of biological reviews and seabird distribution information with tracking data are in Appendix XX. The document is focused on the description of facts and observations and does not include interpretations, particularly on potential implications for the CCSBT seabird management.

While the outputs of 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 utilized in New Zealand as standard procedure to estimate the risk to seabirds and other protected species caused by commercial fishing (add ref. Sharp 2016, 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, XXX).

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 the birds move through international waters. This has motivated application of the method in a wider context.

Catch per unit effort is considered in a linear relation with density/ population of target organisms with catchability as multiplier. Therefore, catch can be expressed as multiple of catchability, population density of target organisms, and fishing effort. The SEFRA approach is a quasi-spatial model where temporal and spatial overlap of the seabird distribution that is equivalent as expected bird occurrence and fishing effort are used to predict a catch.

Details on the estimation procedure are in the Section 2.2-2.5, while details on observed catch and effort information is in the Section 3.3.

Individual CPCs of the CCSBT are each treated as one fleet, except the joint-venture operation under New Zealand's flag, which 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 CPCs with no available observed capture data, the $\boldsymbol{q}$ obtained from the fleet with the similar operational characteristics is used, such as operating area and operation procedures, and fishing efforts reported to the CCSBT. The approximation utilized in the current assessment is shown in Table 2.

The assessment was targeted to cover the 27 ACAP-listed albatross and petrel species that occur in the southern hemisphere. These species were grouped into six species groups, wandering albatross, royal albatross, small albatross, sooty albatross, large petrel, and medium petrel, according to their behaviour and phylogeny. The bird-specific vulnerability was estimated within the species groups, assuming that their vulnerability to fishing may be a function of feeding behaviour and aggression, and willingness to travel large distances to a fishing vessel. 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 operated by the CCSBT CPCs in the southern hemisphere, regardless their targeting, in the period from 2012 to 2019. The temporal range was also divided into two periods, 2012-2016 and 2017-2019, the former to compare with the previous assessment (Abraham et al. 2019) and the aim of the latter was to assess the progress made since the previous assessment in the capability of fleets of avoiding seabird bycatch. However, biological input parameters were treated as constant due to the lack of data at sufficiently high temporal resolutions. [vulnerability vs susceptibility – check whole document]

The assessment treated all captures as dead, in other words, assuming no survival of birds live-released, which would give more conservative assessment of bycatch impacts. Also, limitation of biological and distributional information, currently available, of immature birds, as well as ambiguity in capture data, caused difficulty in distinguishing maturity stage and all captured birds were treated as adults, which will again give more conservative assessment of bycatch risks. However, differences in distribution and behavior of immature birds from adults may introduce additional uncertainty.

The on-board observers would not be able to count all bycatch events. Also, the possibility of additional mortality caused by bird interaction with fishing operations, so-called cryptic mortality, was noted, but there was only one estimates whose credibility is still controversial. The mortality 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). Therefore a mortality multiplier was included to account for the probability of un-observed bycatch during observed operation and cryptic deaths that may not be observable even with an observer present. These multipliers are used to scale up the predicted captures to the predicted deaths Final estimate of total bycatch mortality is shown both with and without this multiplier.

The estimated total seabird catch is compared with the intrinsic maximum population growth rate of individual seabird species, calculated from the number of breeding pairs, the probability of breeding, and theoretical maximum growth rate. In this assessment the risk is referred to as a proportion of estimated mortality, i.e. catch, caused by the CCSBT surface longline fisheries in the intrinsic maximum population growth.

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*** globally 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 while 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. This transformation 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 needs to allocate above mentioned ***N*** into each grid cell.

Spatial models were fitted to available seabird tracking data and used to estimate the relative density, $\boldsymbol{d_x}$, in grid cell $\boldsymbol{x}$ (see Section 3.2), which was treated as a fixed data input to the model, with the multinomial sampling probability. When $\boldsymbol{y_x}$ is the estimated proportion of individuals accumulated occurrences of seabirds tracking in grid cell $\boldsymbol{x}$, and $\boldsymbol{A_x}$ as size of grid cell $\boldsymbol{x}$ in square kilometers, then $\boldsymbol{d_x}$ in grid cell $\boldsymbol{x}$ is:

$$d_x = \frac{y_x}{A_x * \sum y_x}$$

While this relative occurrence $\boldsymbol{d_x}$, was defined for individual species, many of seabird catch was reported in a form of aggregated species due to difficulty in accurate identifications. To allow full utilization of existing observed seabird catch information, the assessment here introduced the concept of the species group that assumed similar behavior against the fishing gears.

Correspondingly, the definition of relative occurrence $\boldsymbol{d}_x$ was expanded to apply to indicate relative occurrences of belonging to a certain species group $\boldsymbol{z}$ with the same formula.

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

The same procedure was used when it was decided to introduce a capture species complex for those species difficult to distinguish each other after reviewing the initial results. In either case, the proportion of tracking birds is consistent among species, this should not cause any biases. Even using the relative occurrence $\boldsymbol{d}_x$ for aggregated species, the species-specific occurrence is still maintained in the model for parameter estimate. Only observed captures for species with a positive observed overlap were retained when preparing the data for analysis, since only these data can be used to parameterize the model.

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

$$\mathbb{D}_{z,\, z} = d_{z,x} * N_{z,}$$

2.3 Estimation of fleet-specific catchability and bird-specific vulnerability

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

$$\text{Overlap}_{z,x,} = \text{effort}_{x,}\, d_{z,x}$$

And the density overlap is:

$$\text{Density overlap}_{zf} = \Sigma_{,x}\text{effort}_{,\,x}\, \mathbb{D}_{z,\,x}$$

With the vulnerability υ_z , the total number of interactions per species group z and fleet f is expected to be:

$$\text{Interactions}_{z,\,f} = \upsilon_{z,\,f}\, \text{Density overlap}_{z,\,f}$$

The observable interactions are referred to as captures and are a function of the catchability (q_z) and are therefore expected to be:

$$\text{Captures}_{z,\,f} = q_{z,\,f}\, \text{Density overlap}_{z,\,f}$$

Therefore, catch taken by certain fleet $\boldsymbol{f}$ in grid cell $\boldsymbol{x}$ and month $\boldsymbol{m}$ is described as:

$$\boldsymbol{C}_{x,m} = \boldsymbol{q} * \boldsymbol{D}_{x,m} * \boldsymbol{E}_{x,m}$$

The model is fitted to the observed capture $\boldsymbol{C'}$(f,x,m) and observed fishing efforts $\boldsymbol{E'}$(f,x,m)to obtain catchability estimate q for individual fleet $\boldsymbol{f}$:

$$\boldsymbol{C'}_{f,x,m} = \boldsymbol{q} * \boldsymbol{D}_{x,m} * \boldsymbol{E'}_{f,x,m}$$

where the catchability itself is a function of fishery group $\boldsymbol{f}$ and species group $\boldsymbol{z}$ covariates and the fishery group coefficient $\boldsymbol{\beta(f)}$ is centred on the intercept term, with deviations around this intercept constrained to sum to zero. Species group coefficients $\boldsymbol{\beta(z|f)}$ 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.

$$\boldsymbol{C'}_{f,s} \sim Poisson(\boldsymbol{\mu}_{f,s})$$

$$\boldsymbol{Log\ (q(f,z)) = \beta(0) + \beta(f) + \beta(z|f)}$$

The total capture of fleet $\boldsymbol{f}$ for a given species in species group z is then calculated with obtained estimate of catchability $\boldsymbol{q}$ and total fishing efforts $\boldsymbol{E}$(f,x,m).

Seabirds taken from the fleet where no observed information is available is estimated by applying the catchability of the fleet of similar operational nature. Table 2 indicates the actual catchability utilized in this analysis.

2.4 Optimal intrinsic population growth and risk caused by the CCSBT fleets

The estimated total seabird mortality taken by the CCSBT longline fleets is then compared with the theoretical optimal intrinsic population growth per species. This will give a proportion of supplementary population growth component removed by exploitation with the CCSBT longline fleets and is used as an indicator of relative risk caused by the CCSBT fisheries.

$$Relative\ Mortality_{\square} = \frac{Total\ bycatch\ by\ the\ CCSBT\ longline_{\square}}{Maximum\ growth_s}$$

, where maximum growth is a function of the population size $\boldsymbol{N_s}$ and maximum intrinsic population growth rate, $\boldsymbol{r_s}$, the growth rate attainable under optimal conditions without density dependent constraints, for species $\boldsymbol{s}$:

$$Maximum\ growth_s = \boldsymbol{r_s} \cdot \boldsymbol{N_s}$$

In this document, N_s is assumed to be the same as the total number of adults.

This approach differs from previous assessments where a Population Sustainability Threshold (PST; Sharp 2019) was used to identify estimate risk. For this assessment the values used to relate the theoretical maximum growth to a management objective have been removed. The relative mortality approach still provides the same ranking as PST, but with this assessment only using a subset of total fishing effort it was determined that any relation of the outputs to a population recovery target would be meaningless.

The so-called demographic-invariant solution for λ (i.e. exp (r_s)) (Niel & Lebreton 2005) has been used in the applications of the SEFRA methodology to date (e.g., Abraham et al. 2017) and followed in this exercise.

Allometric theory indicates that the optimal generation time can be shown as:

$$T[opt] = k / r_s$$

Where k ≈ 1 is a constant. The mean generation time (T) can be approximated using the first age of breeding (A) and survivorship (S) as:

$$T = A + (S / (\exp(r_s) - S))$$

Under the optimal condition:

$$T_{opt} = k / r_s = A + (S_{opt} / (\exp(r_s) - S_{opt}))$$

The equation is solved numerically, using the optimum survivorship (S_{opt}) and uses the current age at first breeding (A_{curr}) as indicative of the current environmental conditions. These are estimated parameters within the model, each with strongly informed priors.

2.5 Parameter estimation

All estimation was performed within a Bayesian framework using rstan (Stan Development Team 2020). Two chains were run for 2,000 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^{BP}, PB, S_{opt}, A_{curr}; with strongly informed priors.

Predictor coefficients for the catchability (β_f and $\beta_{z|f}$) were given standard normal priors. The intercept terms 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. Those parameters with distribution can be updated during the model fit, which was of strong concern with 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, due to bird visibility. Also, free modification of biological parameters could result in shifting of judgement basis for risk caused by bycatch. Corresponding to the claim of difficulty of completely disconnecting the subroutine conducting biological parameter updates, the group accepted placing strong constraints into the modification of biological parameters, as a compromise.

Literature review was conducted to update and improve upon demographic parameters summarized used in the previous assessments (Abraham et al., 2019) while spatial distributions were based on Devine et al (In Press). Subsequently, a 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 target species. 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 dynamics data are 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 2022). 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, 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 utilize 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), but 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.

Priors are listed in Appendix A and those per species in Appendix B.

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 spatio-temporal 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 Bird Life International. Some tracking data were also retrieved from the Department of Conservation website (https://docnewzealand.shinyapps.io/albatrosstracker/) for *Diomedea antipodensis gibsoni* (Gibson's albatross), *Diomedea sanfordi* (Northern Royal albatross), *Thalassarche salvini* (Salvin's albatross), and from Dragonfly Data Science (DDS) for *Diomedea antipodensis antipodensis* (Antipodean albatross).

The 3-dimensional spatiotemporal GAM approach worked well, even when data were relatively few. 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 a large amount of 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. (2023b) was undertaken as 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 Edwards et al (2024).

3.3 Seabird bycatch and effort of surface longlines

The assessment utilized 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 left to the decision by each CPC, though it ended up in 5x5 degree cells. 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 period was selected to allow a comparison to the previous assessment conducted in 2019 (2012 – 2016) and evaluation of change afterward (2017 – 2019). Onboard observer programs were drastically reduced and/or totally 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 relating to domestic data confidentiality rules, as well as allocating species identification, since the required period corresponded to a shift towards using Electronic Monitoring of fishing operations and related species identification issues. 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 the process in future. South Africa expressed its keen interest and enthusiasm to actively engage, be involved in and participate 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 in recent years 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 to the process.

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) logbook and e-logbook 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 bycatch seabird species to the species level, Gibson's albatross was not differentiated from other species, likely resulting in recording as Antipodean albatross or similar species. Observers were restricted to a maximum of 8 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 no code assigned to Gibson's in Taiwanese observers reporting form. So, Gibson's and Antipodean albatross group was created for this analysis.

While it is ideal for all the seabird catch to be identified into a species level, both Japan and Taiwan data contained 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 crossed multiple species groups; Diomedeidae for four and Procellariidae for two. Over 96% of reported seabird catch was considered to belong either Diomedeidae or Procellariidae that are covered with the selected 27 ACAP species in this assessment, even assuming all catch reported under "Birds" category being neither of them.

Regarding the total efforts under the CCSBT, the technical group agreed to utilize the effort information maintained at the CCSBT Secretariat unless the CPC would provide updated information of longline effort in the southern hemisphere regardless the target. Japan and Taiwan provided the corresponding data for their respective southern hemisphere longline efforts The RFMO data containing surface longline effort data from Australia, Indonesia, Korea, New Zealand and South Africa. The total effort of Japan and the Taiwan was updated to be included in the mode.

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, and 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 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 the data of a spatially limited coverage, e.g. NZ (Table 5 and Figure 1). The technical group considered it preferable to utilize 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 utilize the combined data set for all the analyses afterwards.

Figure 2 showed species group-specific and fleet-specific catchability coefficients obtained with combined data. The Figure indicated unrealistically high catchability for the Japan 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 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. The issue was further discussed at later stage.

Figure 3 showed a comparison of species group-specific catchability standardized with fleet-specific catchability that should indicate general pattern in vulnerability among species group. However, the Figure did not show any consistent pattern other than similarity between small albatross and medium petrel groups. The New Zealand joint venture fleet was in fact the operation by the Japanese vessels within the 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 coefficient among species groups. However, the pattern did not show any particular consistency, which raised a concern on plausibility of assumption 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 available. This emphasized the importance of all CPCs participating to the collaborative analysis with its own data to be incorporate in the analysis.

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 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 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 was shown in Table 6, against the whole data provided. The results were examined together with general consideration on species identification difficulty and reliability of temporal-spatial seabird distribution map (Table 7).

The empirical data used in the model reflects the best available evidence but are nevertheless incomplete. Species distributions derive from tracking data requested from individual data owners via Bird Life International. Some tracking data were 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. 2023). 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 to up to 55% of seabird populations (Carneiro et al. 2019). The modelling approach here uses the conservative approach used in the New Zealand domestic seabird risk assessment (Edwards et al, 2023) to compensate for this by assuming every bycaught bird as 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 study under-represent the actual distributions of seabirds, at least for some species. For example, the distribution of Campbell Albatross is based on limited short-term tracking efforts (Sztukowski et al. 2017). The distribution of Grey-headed Albatross and Light-mantled Albatross are biased towards the tracking efforts conducted in 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 in the Pacific. Giant petrels 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, Indian yellow-nosed albatross, white-capped albatross, Salvin's albatross, Chatham albatross, black petrel, and white-chinned petrel were considered adequate from the review of the data. For a number of species including Gibson's albatross, wandering albatross, southern royal albatross, shy albatross, southern Buller's albatross, light-mantled sooty albatross, grey petrel and Westland petrel additional tracking data have become available since the publication of Divine 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 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. The condition of the retrieved birds can hinder their identification.

It was noted the extremely low occurrence of certain species from the areas of well-known overlap was caused by reporting practice of those species difficult to distinguish 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 divergency between predicted and observed values and catchability coefficient estimation of giant petrels were mainly caused by lack of density overlap information in the time and area where the majority of capture occurred.

In the end, the technical group agreed to introduce species-complex for those species difficult to distinguish and to ignore the species identification label attached with the capture records. Accordingly, the group agreed to treat all wandering albatross group as one species complex and that species allocation of predicted catch would be made based on the density overlap per species since the reliability of distribution map of this group is quite high. In the similar way, two yellow-nosed albatrosses, shy albatross and New Zealand white-capped albatross, Southern and Northern Buller's albatrosses, and three medium petrels (Black, Westland and White-chinned) would be treated as species-complex, respectively. The species-complex agreed covers the 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 big gap in tracking data, and mismatch 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 ID 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 whole period (i.e. 2012-2019), and 2) with two catchability estimates for an early (2012-2016) and late (2017-2019) periods. The former corresponded roughly to the years that were utilized 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 period 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 3 years data becomes available.

The group noted that the biological parameters, in terms of number of breeding pairs and the probability of breeding, showed large shifts through 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. On the other hand, 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 sooth albatross (PHE) 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 whole 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. Whereas 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 into 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 of previous assessments utilized seabird distribution based on combined information obtained from tracking data, general distribution range and hypothetical bird distribution around breeding areas which had much broader range. Alternative way of improving model-fit other than updating biological parameters should be taken into the consideration as an option for future improvement of the model.

The review of the species distributions has identified a clear need to update the species distributions using both existing tracking data, and the collection of further tracking data from colonies that currently lack and tracking, this 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 of 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 and 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 (see also 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 a 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 death and 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 Table 11 and Figures 11 and 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 late period. The time period-specific relatively 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 showed the 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 a number of differences in the methodology applied in this analysis compared to that from 2019. While the 2024 analysis utilized updated biological inputs, the 2019 assessment fixed biological parameters. Additionally, the observed catch and effort used was different between two analyses. While the 2019 analysis applied Japan's estimated catchabilities, that is the highest among Japan, Taiwan, and New Zealand, for all fleets that did not contribute observer data (i.e. Korea, Indonesia, and Taiwan), the catchability obtained from Japan was only applied to Korea. On the other hand, the 2019 assessment utilized the observed catch and effort data from Australia and South Africa, which showed substantially lower estimated catchability than New Zealand, those two CPCs were approximated using the catchability estimated for New Zealand domestics in 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.

5. CONCLUSIONS, REMAINING ISSUES AND NEXT STEPS

The 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 next iteration. Many participants deepened their understanding of the nature of the SEFRA and its potential and limitation, 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 require urgent attention: 1) archiving codes and inputs data in an accessible and workable way, 2) modification of the model to resolve the issues in relating to updating biological parameters, these area address errors and 3) preparing observed seabird catch and effort data for those CPCs that have not yet done so. To make this possible, it would be important to make the formalize the whole 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.

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	n.a.
PHE	Light-mantled sooty albatross	*Phoebetria palpebrata*	Sooty albatross	n.a.
MAI	Southern giant petrel	*Macronectes giganteus*	Giant petrels	-
MAH	Northern giant petrel	*Macronectes halli*	Giant petrels	-
PCI	Grey petrel	*Procellaria cinerea*	Medium petrel	n.a.
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	n.a.

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

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

			Sp Grp	JPN			TWN		
				all	early	late	all	early	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 dabbenena*	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**
DCR	Atlantic yellow-nosed albatross	*Thalassarche chlororhynchos*	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 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
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 albatross	*Thalassarche bulleri 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 halli*	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
	Procellaria 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

Table 4: Total effort by fleet in 1000 hooks

Year	AUS	JPN	KOR	NZL	TWN	ZAF	IDN
2012	7,052	132,955	52,674	2,932	225,853	4,298	-
2013	6,898	116,538	61,178	2,236	250,938	4,838	-
2014	6,805	103,090	54,717	2,782	247,604	3,031	-
2015	8,360	92,143	53,628	2,845	217,064	3,053	-
2016	7,849	90,766	59,769	1,387	249,709	2,228	-
2017	8,928	90,094	43,958	1,277	309,153	2,663	-
2018	7,785	87,406	43,974	1,403	287,859	2,904	1,277
2019	8,215	69,703	51,693	1,054	319,265	2,539	1,702

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

Data set	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.

		Species Grp	JPN		TWN		NZL		NZL (JV)	
			Obs	Pred	Obs	Pred	Obs	Pred	Obs	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				6					
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 (0-0.4)	0	0.1 (0-0.8)	0	0 (0-0)	0	0 (0-0)
	Wandering albatross complex	1	131							
	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							
	SPECIES GROUP 2 TOTAL		***21***		***4***		***11***		***0***	
	Diomedea spp	1,2	26				2			
	Diomedea spp TOTAL		**389**		**58**		**39**		**0**	
DCR	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							
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							
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							
TWD	New Zealand 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 (0-0.9)
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)
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 albatross	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			
	Thalassarche spp	3	267							
	SPECIES GROUP 3 TOTAL		***3683***		***328***		***292***		***12***	
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 (40.7-67)	6	14.2 (7.2-22)	0	0 (0-0)	0	0 (0-0)
	Phoebetria spp	4	4							
	SPECIES GROUP 4 TOTAL		***233***		***67***		***0***		***0***	
	Diomedeidae	1,2,3,4	822		170					
			5101		**623**		**329**		**12**	
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			1					
	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)
	Procellaria spp	6			25					
	SPECIES GROUP 6 TOTAL		***612***		***272***		***85***		***2***	
	Procellariidae	5,6	165		14					
	Procellariidae TOTAL		**959**		**297**		**85**		**2**	
	Birds	?	223		8					

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.

		Species Grp	Obs	Pred		ID	Maps	Decisions 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,
DIX	Wandering albatross	1	213	159.6	(125.2-198.3)	L	H	reassign total prediction according to
DBN	Tristan albatross	1	14	18.8	(10-29.3)	L	H	density overlap
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	L	No change
DIQ	Northern royal albatross	2	6	4.5	(0.6-11.9)	M	H	No change
	Royal albatrosses	2	7					
	SPECIES GROUP 2 TOTAL		***36***					
	Diomedea spp	1,2	28					
	Diomedea spp TOTAL		***486***					
DCR	Atlantic yellow-nosed albatross	3	93	32.6	(19.2-46.7)	M	H	Treating as one species complex in
TQH	Indian yellow-nosed albatross	3	201	173.7	(142.3-207.7)	M	H	capture, reassign total prediction
	Yellow-nosed albatrosses	3	59					according to density overlap
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	No change
	Black-browed albatrosses	3	312					
DCU	Shy albatross	3	4	47.6	(34.9-61.8)	L	L	Treating as one species complex in
	Shy-type albatross	3	796					capture, reassign total prediction
TWD	New Zealand white-capped albatross	3	196	377.4	(321.1-440.7)	L	H	according to density overlap
DKS	Salvin's albatross	3	9	22	(10.8-35.8)	M	H	No change
DER	Chatham Island albatross	3	3	2	(0-5.7)	H	H	No change
DIC	Grey-headed albatross	3	858	860.6	(776.6-945.8)	M	M	No change
DSB	Southern Buller's albatross	3	0	314.3	(183.6-370.4)	L	H	Treating as one species complex in
DNB	Northern Buller's albatross	3	9	27.9	(15.1-44.4	L	H	capture, reassign total prediction
	Buller's albatross	3	909					according to density overlap
	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	No change
	Phoebetria spp	4	4					
	SPECIES GROUP 4 TOTAL		***300***					
	Diomedeidae	1,2,3,4	992					
			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	Removing from analysis
	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	Treating as one species complex in
PCW	Westland petrel	6	43	34	(18.7-52.1)	L	M	capture, reassign total prediction
PRO	White-chinned petrel	6	610	475.7	(412.8-543)	L	M	according to density overlap
PCN	Spectacled petrel	6	97	53.9	(36.9-74.8)	L	M	No change
	Procellaria 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.

Datas 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)***
After modification (2012-2016):								
Wandering albatross	17.52	(14.37-20.75)	3.23	(2.37-4.34)	6.65	(4.29-9.45)	0.18	(0.02-0.55)
Royal albatross	8.33	(4.75-13.26)	2.72	(0.85-5.65)	3.31	(1.33-6.24)	0.24	(0.02-0.88)
Mollymawk	3.67	(3.27-4.1)	1.08	(0.95-1.23)	1.83	(1.55-2.14)	0.12	(0.1-0.15)
Sooty albatross	12.55	(10-15.75)	7.38	(5.55-9.5)	4.97	(0.21-25.05)	0.52	(0.02-2.7)
Large petrel	-	-	-	-	-	-	-	-
Medium petrel	1.53	(1.26-1.84)	0.46	(0.37-0.58)	1.46	(0.94-2.09)	0.14	(0.03-0.34)
Fleet specific q	***6.3***	***(5.53-7.17)***	***1.96***	***(1.56-2.39)***	***2.75***	***(1.54-4.41)***	***0.17***	***(0.05-0.32)***
After modification (2017-2019):								
Wandering albatross	13.33	(10.76=16.07)	2.63	(1.8-3.64)	2.71	(1.31-4.72)		
Royal albatross	2.5	(0.78-5.33)	4.39	(1.16-10.11)	6.01	(3.04-9.99)		
Mollymawk	4.12	(3.65-4.59)	0.36	(0.29-0.44)	1.45	(1.21-1.73)		
Sooty albatross	37.03	(29.09-45.67)	3.4	(2.34-4.68)	4.64	(0.24-21.74)		
Large petrel	-	-	-	-	-	-		
Medium petrel	3.16	(2.56-3.86)	0.22	(0.16-0.3)	1.93	(1.31-2.65)		
Fleet specific q	***6.79***	***(5.40-8.1)***	***1.22***	***(0.924-1.53)***	***2.6***	***(1.52-4.14)***		

Table 9. Observed and predicted captures per capture code.

		JPN			TWN			NZL			NZ_JV		
		obs	est.		obs	est.		obs	est.		obs	est.	
DIP	Southern royal albatross	12	15.9	(8.4-24.2)	1	0.7	(0-2.4)	10	3.7	(1-2.7)	0	0	(0-0)
DIQ	Northern royal albatross	2	0.8	(0-2.6)	3	0.9	(0-3.7)	1	2	(0.4-4.5)	0	0	(0-0)
DIM	Black-browed albatross	301	575	(520.9-631.9)	101	35.2	(23.6-48.4)	3	3.7	(1.6-6.6)	0	0	(0-0)
TQW	Campbell black-browed albatross	170	118.4	(95.1-143.2)	9	1.3	(0-3.4)	11	14.5	(9.1-21.8)	1	2	(0.2-5.8)
DKS	Salvin's albatross	0	0	(0-0)	8	0.2	(0-1)	1	5	(2.2-8.7)	0	0	(0-0)
DER	Chatham Island albatross	3	1.7	(0-4.1)	0	0	(0-0)	0	0	(0-0)	0	0	(0-0)
DIC	Grey-headed albatross	840	753.7	(687.8-821)	17	118.8	(92-149.1)	1	0	(0-0.4)	0	0	(0-0)
PHU	Sooty albatross	134	142.7	(117.4-169)	61	47.7	(31-67.1)	0	0	(0-0)	0	0	(0-0)
PHE	Light-mantled sooty albatross	95	71.8	(52.5-91.2)	6	13.5	(6.1-23)	0	0	(0-0)	0	0	(0-0)
PCI	Grey petrel	152	61.4	(46.8-76.4)	3	9.4	(3.8-16.6)	4	3	(1-5.7)	0	0	(0-0)
PCN	Spectacled petrel	44	13.7	(7.6-20.4)	53	23.7	(15.1-34)	0	0	(0-0)	0	0	(0-0)
DRA	Royal albatross Species Group	21	19.5	(10.5-30.2)	4	5.3	(0-14.3)	11	15.5	(7.3-25.8)	0	0	(0-0)
DYN	Yellow-nosed albatross complex	205	229.6	(193.3-269)	148	90.9	(68-114)	0	0	(0-0)	0	0	(0-0)
DST	Shy-type albatross complex	796	811	(744-878.9)	38	64.6	(46.5-84.6)	151	98.2	(79.9-120.3)	11	22.9	(13.9-33.3)
DBB	Black-brown albatross complex	783	805.3	(742.3-875)	113	41.6	(27.7-58.3)	14	48.1	(35.2-63.3)	1	16	(9.1-24.7)
DIB	Buller's albatross complex	789	785.2	(715.2-855)	4	49.6	(34.7-65.1)	125	129.1	(106.5-152.4)	62	24.2	(14.6-34.8)
DWC	Wandering albatross complex	342	356.2	(315.5-400)	54	53.3	(32.3-77.7)	27	25	(13.3-384)	0	0	(0-0)
PRZ	Petrels complex	416	280	(244.7-313.8)	191	99.1	(74.3-126.2)	81	24.3	(15.1-34.6)	2	2.3	(0-6.7)
DIZ	*Diamedia* spp	389	382	(339.8-423.7)	58	59.5	(38-85)	40	40.7	(27.3-55.8)	0	0	(0-0)
THZ	*Thalassarche* spp	3683	3563.5	(3432.1-3821.6)	328	394.8	(336.1-454.9)	292	292.6	(259-322)	74	70.1	(52.6-89.5)
PHZ	Sooth albatross Species Group	233	251.8	(216.8-288)	67	74.8	(51-103.3)	0	0	(0-0)	0	0	(0-0)
PTZ	Medium petrel species group	196	371.1	(333.8-412)	81	138	(106.8-171.5)	4	32.6	(21.4-45.2)	0	0	(0-0)
ALZ	Diomedeidae	5127	5045.8	(4869.7-5307.9)	623	590.1	(514.9-675.7)	332	341.2	(302.4-384.1)	74	78	(58.5-98.3)
PRX	Procellariidae	361	446.5	(400.9-494)	95	154	(119.3-192.2)	4	33.7	(21.9-46.8)	0	0	(0-0)
BLZ	Birds	6127	6122.7	(5908-6429)	917	915.5	(811-1030)	417	416.8	(364-476)	76	87.4	(67-110)

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

		Species Grp		Initial model				After modification	
			Obs	Pred		Obs_org	Obs	Pred	
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						
DWC	***SPECIES GROUP 1 TOTAL***		***422***			***422***	***423***	***434.5***	***(361.1-851.7)***
DIP	Southern royal albatross	2	23	20.5	(8.6-45.4)	23	23	20.3	(9.4-29.3)
DIQ	Northern royal albatross	2	6	4.5	(0.6-11.9)	6	6	3.7	(0.4-10.8)
	Royal albatrosses	2	7						
DRA	***SPECIES GROUP 2 TOTAL***		***36***			***36***	***36***	***40.3***	***(17.8-70.3)***
	Diomedea spp	1,2	28						
DIZ	***Diomedea spp TOTAL***		***484***			***484***	***487***	***482.2***	***(405.1-564.5)***
DCR	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)	353	353	229.6	(193.3-269)
DYN	Yellow-nosed albatrosses	3	59						
DIM	Black-browed albatross	3	405	474.4	(422.3-529.7)	405	405	613.9	(546.1-686.9)
TQW	Campbell black-browed albatross	3	194	103.1	(76.9-132.9)	194	191	136.2	(104.4-174)
	Black-browed albatrosses	3	312						
DBB	*Black-browed albatrosses TOTAL*	3				911	911	911.3	(814.3-1022.8)
DCU	Shy albatross	3	4	47.6	(34.9-61.8)				
DST	Shy-type albatross	3	796			996	996	932.4	(838.4-1032.5)
TWD	New Zealand white-capped albatross	3	196	377.4	(321.1-440.7)				
DKS	Salvin's albatross	3	9	22	(10.8-35.8)	9	9	5.2	(2.2-9.7)
DER	Chatham Island albatross	3	3	2	(0-5.7)	3	3	1.7	(0-4.1)
DIC	Grey-headed albatross	3	858	860.6	(776.6-945.8)	858	858	872.5	(779.8-970.5)
DSB	Southern Buller's albatross	3	0	314.3	(183.6-370.4)				
DNB	Northern Buller's albatross	3	9	27.9	(15.1-44.4	918	980	938.6	(837.2-1042)
DIB	Buller's albatross	3	909						
	Thalassarche spp	3	267						
THZ	***SPECIES GROUP 3 TOTAL***		***4315***			***4315***	***4377***	***4320.9***	***(4080.7-4696.8)***
PHU	Sooty albatross	4	195	153.4	(121.9-187.6)	195	195	190.4	(148.4-236.1)
PHE	Light-mantled sooty albatross	4	101	67.5	(47.9-89)	101	101	85.3	(58.6-114.2)
	Phoebetria spp	4	4						
PHZ	***SPECIES GROUP 4 TOTAL***		***300***			***300***	***300***	***326.6***	***(267.8-391.3)***
	Diomedeidae	1,2,3,4	992						
ALZ			***6065***			***6065***	***6156***	***6055.4***	***(5745.9-6467.8)***
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	159	73.8	(51.6-98.7)
PRK	Black petrel	6	37	8.6	(2-17.3)				
PCW	Westland petrel	6	43	34	(18.7-52.1)	690	690	405.5	(334.1-481.2)
PRO	White-chinned petrel	6	610	475.7	(412.8-543)				
PCN	Spectacled petrel	6	97	53.9	(36.9-74.8)	97	97	37.4	(22.7-54.4)
	Procellaria spp	6	25						
PTZ	***SPECIES GROUP 6 TOTAL***		***971***			***971***	***281***	***541.7***	***(462-628.7)***
	Procellariidae	5,6	179						
PRX	***Procellariidae TOTAL***		***1343***			***1343***	***460***	***634.2***	***(542.1-733)***
	Birds	?	231						
BLZ	***Birds TOTAL***		***16237***			***16237***	***3794***	***7541.6***	***(7150-8044)***

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.

Species	Predicted total bycatch		Cryptic deaths		Priors		Posteriors	
					Productivity	Relative mortalities	Productivity	Relative mortalities
Gibson's albatross	647	(477-887)	170	(15-392)	946	0.69	936	0.69
Antipodean albatross	72	(52-103)	19	(3-42)	654	0.11	656	0.11
Wandering albatross	287	(204-394)	79	(18-165)	1,878	0.15	1,861	0.15
Tristan albatross	201	(115-348)	53	(5-135)	455	0.44	456	0.45
Amsterdam albatross	3	(2-4)	1	(0-2)	9	0.29	9	0.29
Southern royal albatross	77	(55-106)	17	(4-36)	1,145	0.07	1,165	0.07
Northern royal albatross	17	(10-28)	4	(1-9)	832	0.02	781	0.02
Atlantic yellow-nosed albatross	101	(71-149)	28	(4-65)	5,306	0.02	5,056	0.02
Indian yellow-nosed albatross *	1,037	(770-1 441)	286	(38-659)	14,440	0.07	6,430	0.16
Black-browed albatross *	1,331	(970-1 850)	363	(9-883)	56,332	0.02	84,450	0.02
Campbell black-browed albatross *	468	(346-642)	127	(14-296)	99,926	0	2,998	0.16
Shy albatross	133	(87-203)	36	(0-91)	2,363	0.06	2,234	0.06
NZ white-capped albatross *	2,314	(1 744-3 182)	637	(71-1 467)	29,528	0.08	11,428	0.2
Salvin's albatross	131	(90-195)	36	(3-86)	6,873	0.02	6,527	0.02
Chatham Island albatross	13	(9-19)	4	(-0-9)	703	0.02	691	0.02
Grey-headed albatross *	3,400	(2 597-4 597)	948	(154-2 105)	96,033	0.04	15,307	0.22
Southern Buller's albatross	2,252	(1 671-3 107)	613	(50-1 452)	24,321	0.09	1,623	1.39
Northern Buller's albatross	103	(74-149)	28	(3-66)	2,285	0.05	2,223	0.05
Sooty albatross	696	(524-928)	199	(44-412)	1,671	0.41	1,767	0.39
Light-mantled sooty albatross *	329	(241-457)	94	(19-202)	5,018	0.07	2,747	0.12
Southern giant petrel	-	-	-	-	-	-	-	-
Northern giant petrel	-	-	-	-	-	-	-	-
Grey petrel *	243	(176-339)	68	(7-153)	30,690	0.01	17,467	0.01
Black petrel	22	(16-32)	6	(1-14)	1,268	0.02	1,257	0.02
Westland petrel *	65	(40-100)	18	(4-40)	2,071	0.03	1,813	0.04
White-chinned petrel *	1,892	(1 461-2 448)	531	(113-1 077)	145,612	0.01	271,303	0.01
Spectacled petrel	206	(150-291)	56	(11-123)	23,588	0.01	8,102	0.03

* indicated those species with visible model updates in biological parameters observed in plot

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	652 (476-885)	740 (545-1 013)	524 (376-743)
Antipodean albatross	72 (51-104)	85 (62-121)	55 (38-79)
Wandering albatross	287 (203-397)	226 (158-329)	344 (233-486)
Tristan albatross	202 (122-352)	190 (117-318)	205 (111-362)
Amsterdam albatross	3 (2-4)	2 (1-4)	3 (2-5)
Southern royal albatross	77 (55-107)	86 (59-121)	56 (34-87)
Northern royal albatross	17 (10-28)	17 (10-30)	20 (10-36)
Atlantic yellow-nosed albatross	101 (71-147)	127 (89-192)	69 (48-98)
Indian yellow-nosed albatross *	1 036 (779-1 421)	1 160 (859-1 579)	758 (552-1 042)
Black-browed albatross *	1 324 (970-1 859)	1 226 (921-1 664)	1 581 (1 126-2 184)
Campbell black-browed albatross *	470 (338-643)	419 (315-566)	571 (404-812)
Shy albatross	132 (88-201)	127 (85-195)	157 (103-242)
New Zealand white-capped albatross *	2 325 (1 760-3 157)	2 301 (1 736-2 990)	2 420 (1 750-3 351)
Salvin's albatross	132 (90-200)	144 (100-214)	136 (90-209)
Chatham Island albatross	13 (9-19)	13 (9-18)	14 (10-20)
Grey-headed albatross *	3 401 (2 599-4 568)	3 076 (2 371-4 022)	3 853 (2 811-5 286)
Southern Buller's albatross *	2 266 (1 676-3 101)	2 225 (1 673-2 966)	2 413 (1 767-3 409)
Northern Buller's albatross	104 (74-151)	109 (77-154)	109 (74-157)
Sooty albatross	694 (527-932)	506 (369-682)	1 283 (928-1 833)
Light-mantled sooty albatross *	329 (235-462)	235 (169-325)	573 (406-840)
Grey petrel *	241 (178-337)	208 (155-283)	361 (251-523)
Black petrel	22 (15-32)	21 (14-30)	25 (17-37)
Westland petrel *	64 (41-101)	57 (37-87)	83 (54-136)
White-chinned petrel *	1 879 (1 458-2 435)	1 559 (1 224-1 994)	2 518 (1 884-3 395)
Spectacled petrel	208 (145-289)	212 (147-296)	189 (128-276)

* indicated those species with visible model updates in biological parameters observed in plot

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.

	2019 assessment	2024 assessment
Gibson's albatross	550 (466 - 640)	550 (513 - 580)
Antipodean albatross	147 (117 - 177)	63 (57 - 72)
Wandering albatross	696 (591 - 803)	165 (141 - 201)
Tristan albatross	377 (316 - 441)	141 (109 - 191)
Amsterdam albatross	6 (2 - 11)	1 (1 - 3)
Southern royal albatross	126 (76 - 187)	66 (55 - 77)
Northern royal albatross	96 (57 - 143)	13 (9 - 20)
Atlantic yellow-nosed albatross	1080 (892 - 1290)	93 (87 - 108)
Indian yellow-nosed albatross	1860 (1540 - 2210)	830 (810 - 867)*
Black-browed albatross	8350 (7580 - 9160)	883 (884 - 885)*
Campbell black-browed albatross	812 (722 - 907)	300 (291 - 320)*
Shy albatross	232 (196 - 269)	91 (81 - 111)
New Zealand white-capped albatross	2060 (1870 - 2260)	1648 (1599 - 1671)*
Salvin's albatross	10 (0 - 39)	103 (93 - 126)
Chatham Island albatross	22 (0 - 86)	9 (9 - 10)
Grey-headed albatross	8440 (7800 - 9090)	2216 (2210 - 2253)*
Southern Buller's albatross	2260 (2040 - 2480)	1593 (1567 - 1633)*
Northern Buller's albatross		79 (72 - 89)
Sooty albatross	1350 (1100 - 1620)	363 (334 - 385)
Light-mantled sooty albatross	875 (708 - 1050)	169 (154 - 186)*
Southern giant petrel	1460 (1210 - 1710)	(-)
Northern giant petrel	493 (402 - 589)	(-)
Grey petrel	1000 (807 - 1230)	151 (143 - 163)*
Black petrel	191 (72 - 390)	15 (13 - 18)
Westland petrel	90 (45 - 155)	42 (34 - 54)*
White-chinned petrel	7550 (6550 - 8630)	1131 (1113 - 1160)*
Spectacled petrel	948 (576 - 1410)	157 (141 - 172)

*** indicated those species with visible model updates in biological parameters observed in plot**

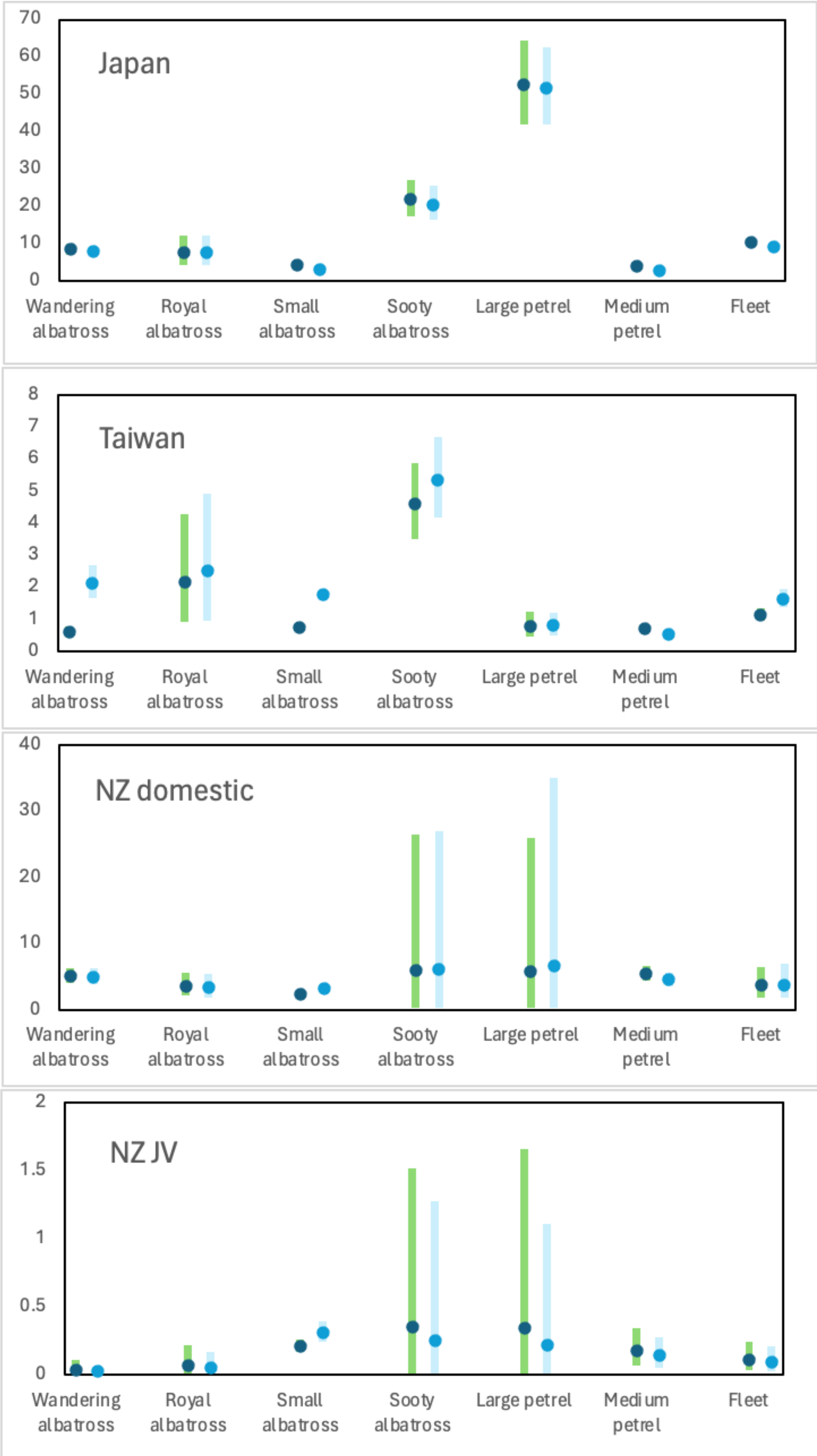

Figure 1 Comparison of catchability coefficient estimates according to data sources. Green corresponding to the outputs using the combined data set and blue for individual CPC's data

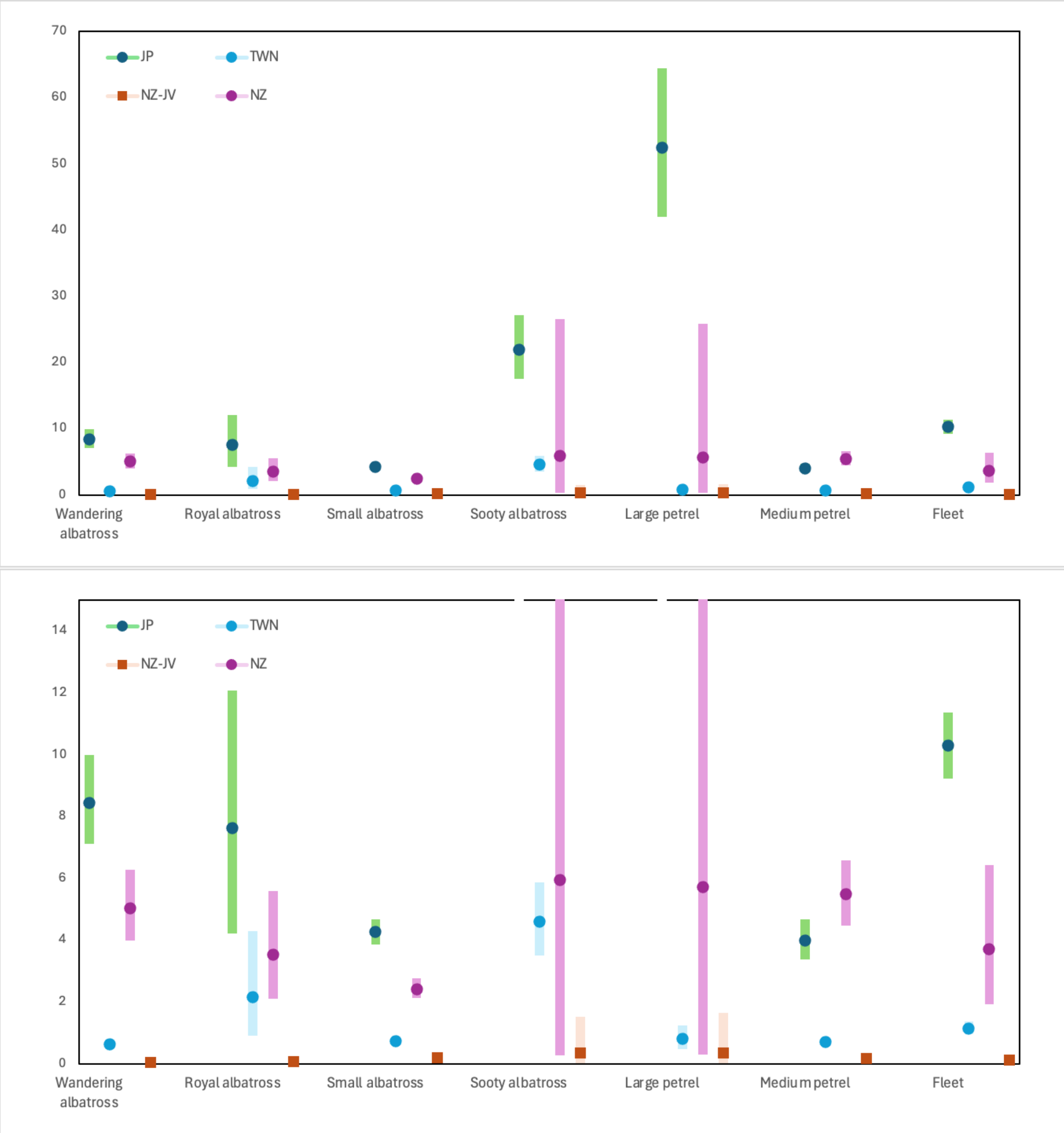

Figure 2. Catchability coefficient estimates obtained from the initial model. Lower figure with different Y-scale to focus differences among lower values.

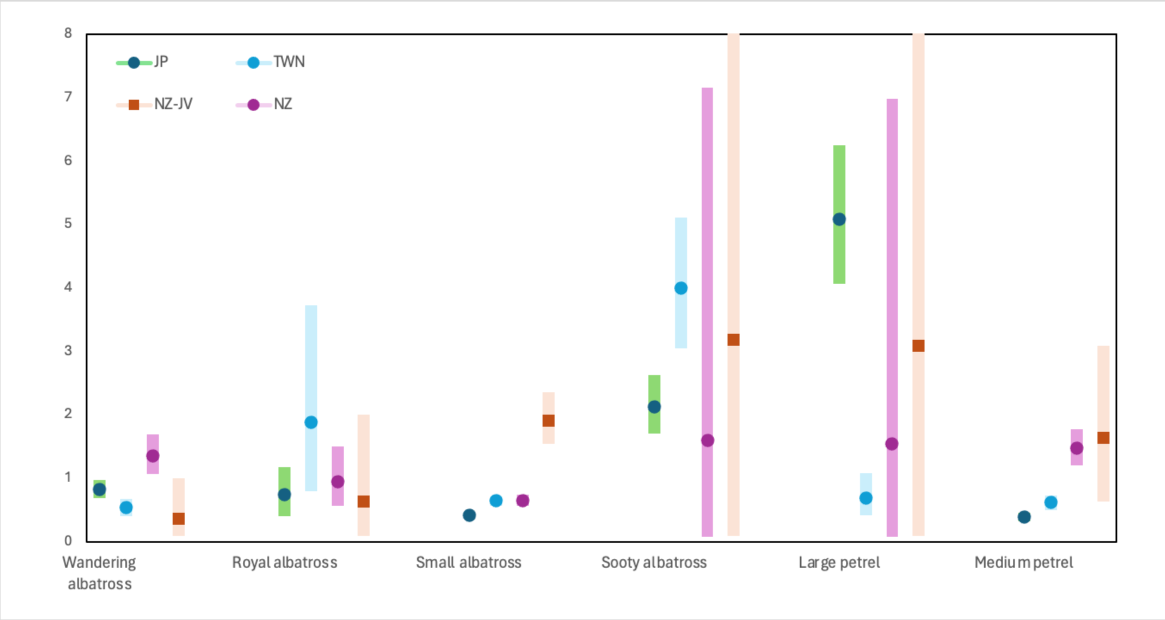

Figure 3 Catchability coefficients relative to fleet-specific catchability.

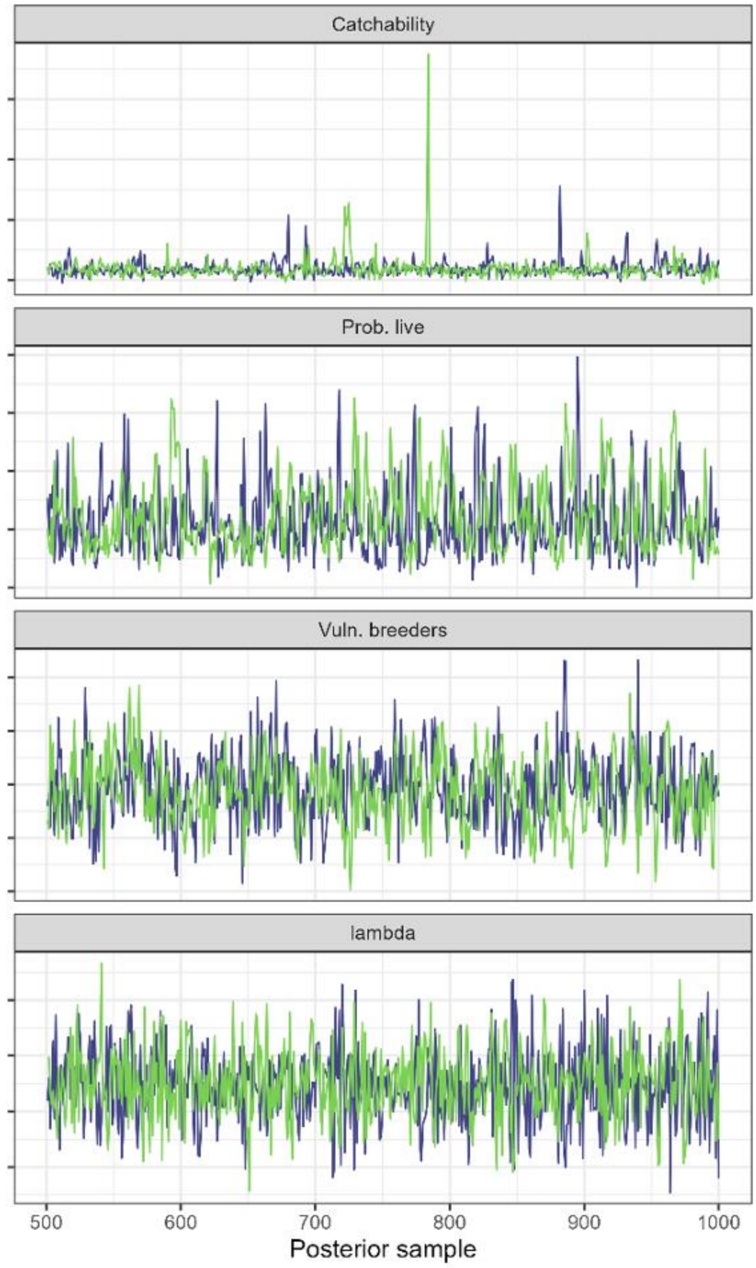

Figure 4. MCMC trace diagnostics for model fit. For each MCMC chain, the Euclidean norm is calculated for each parameter vector.

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.

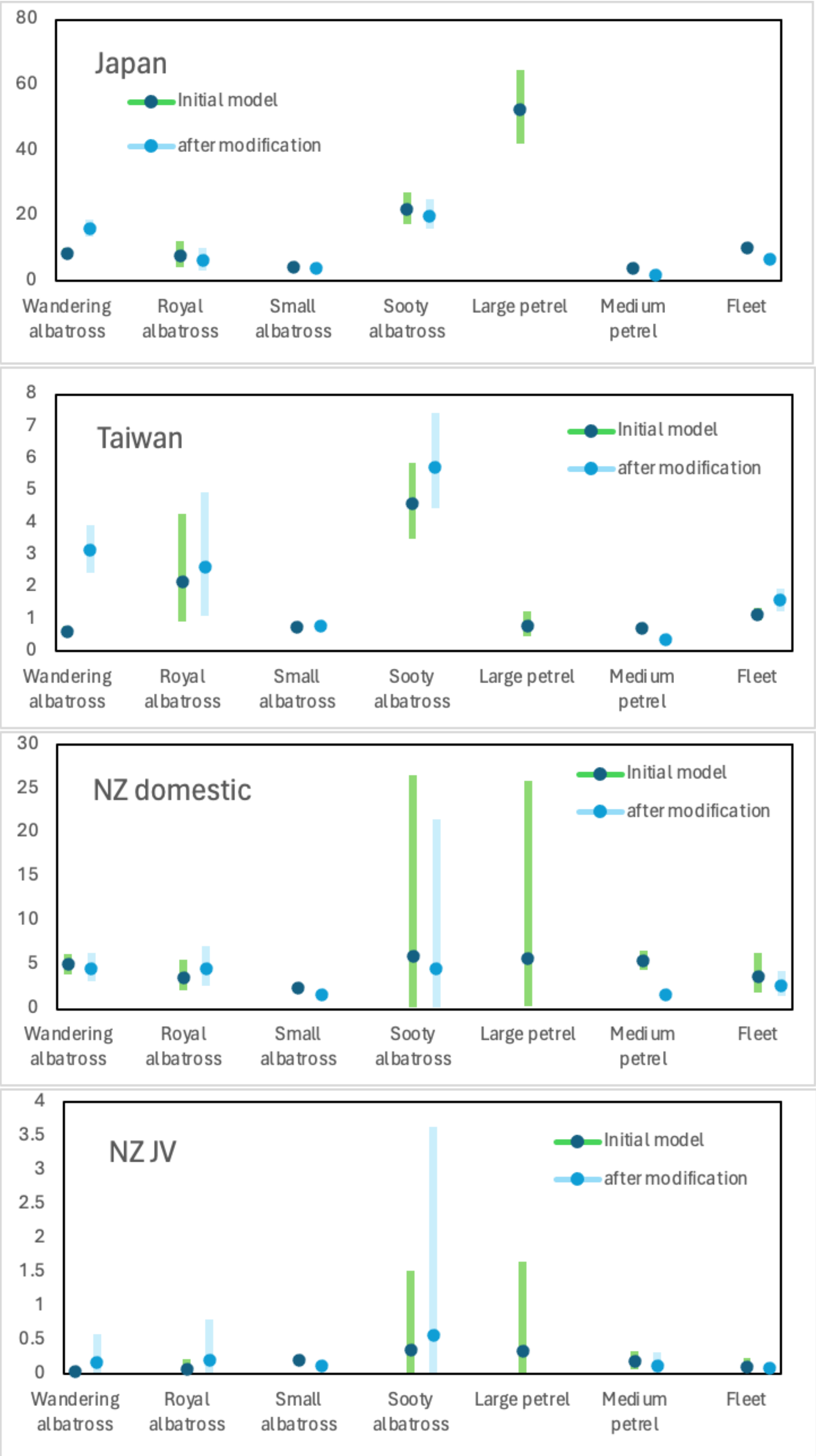

Figure 6. Comparison of catchability coefficient estimates between models before and after modification incorporated.

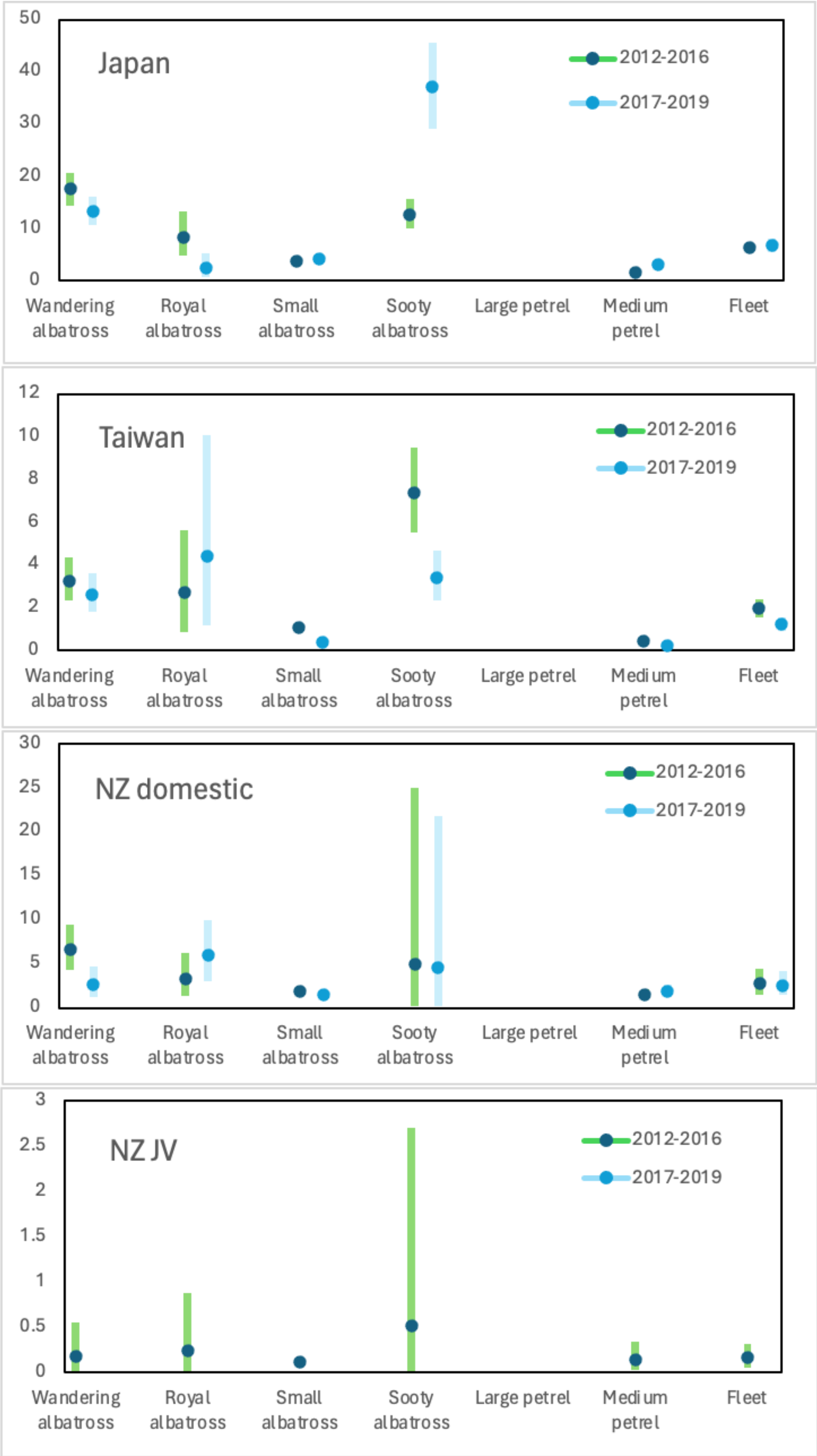

Figure 7. Change of catchability coefficients between two periods.

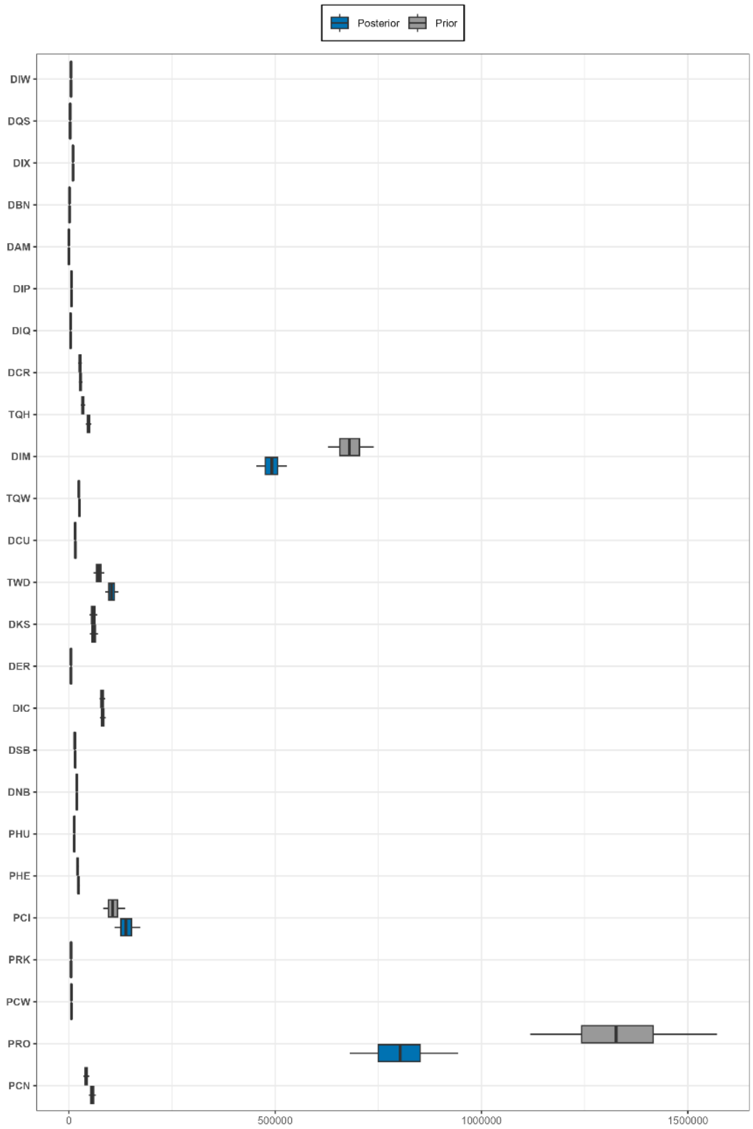

Figure 8a. Boxplots indicating the prior and posterior number of breeding pairs per species.

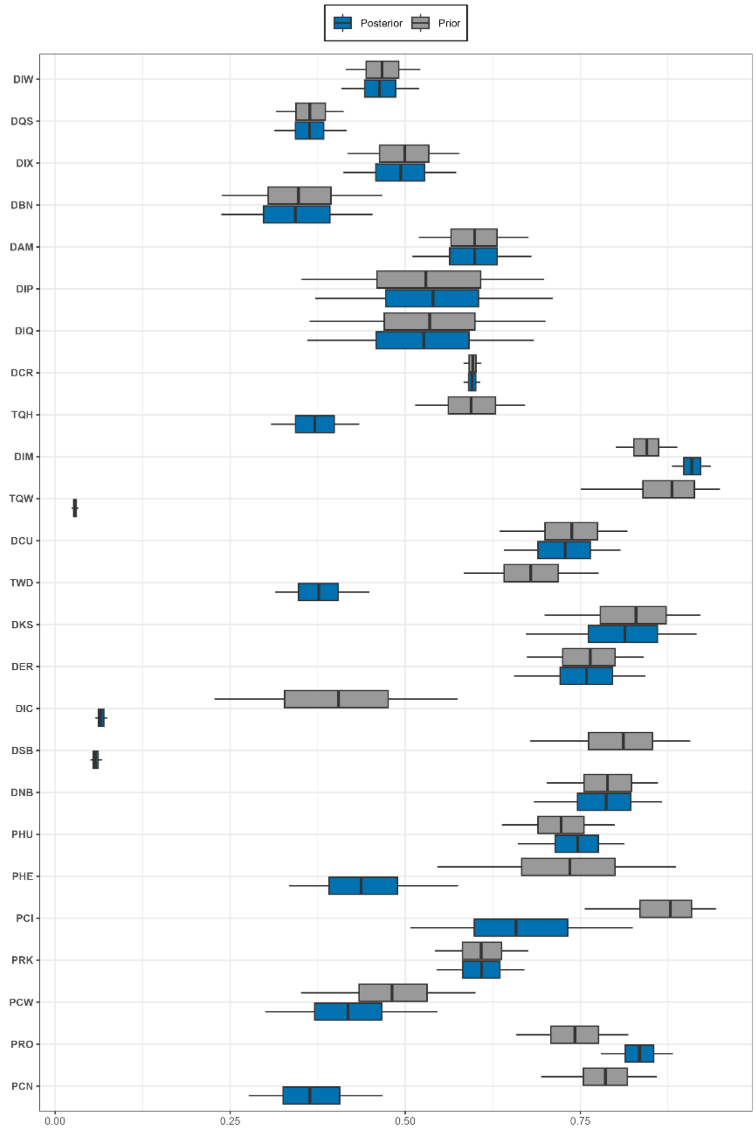

Figure 8b. Boxplots indicating the prior and posterior number of probability of breeding per species.

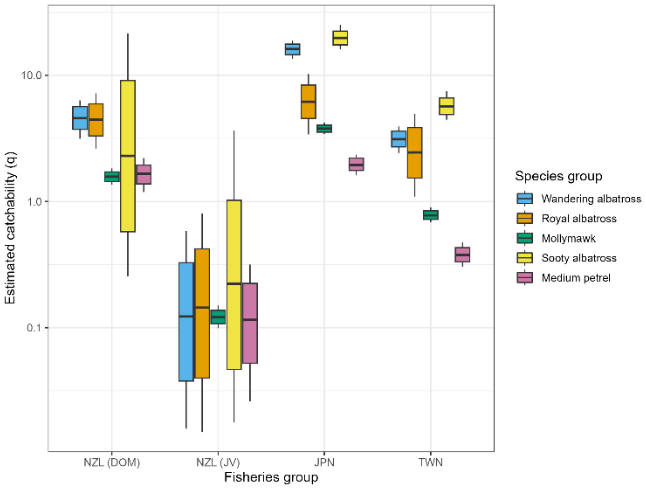

Figure 9. Boxplot showing posterior distribution of catchability values (on a log-10 scale) per species group and fishery group.

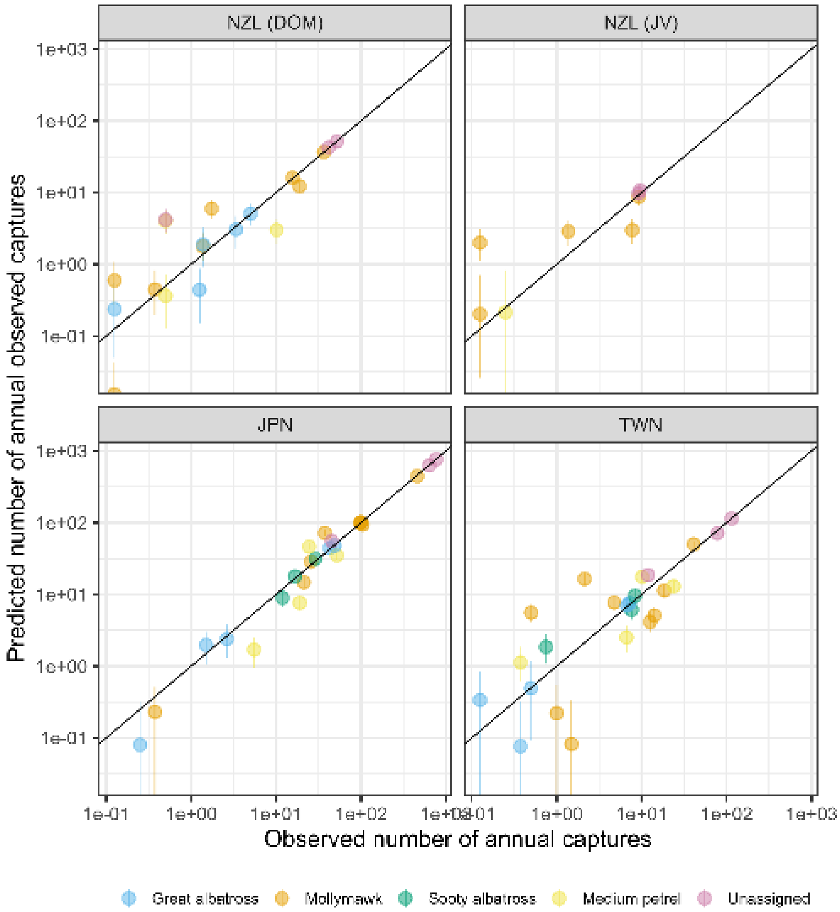

Figure 10a. Fit of the model to the average annual observed captures per capture code (on a log-10 scale) for the one time period model.

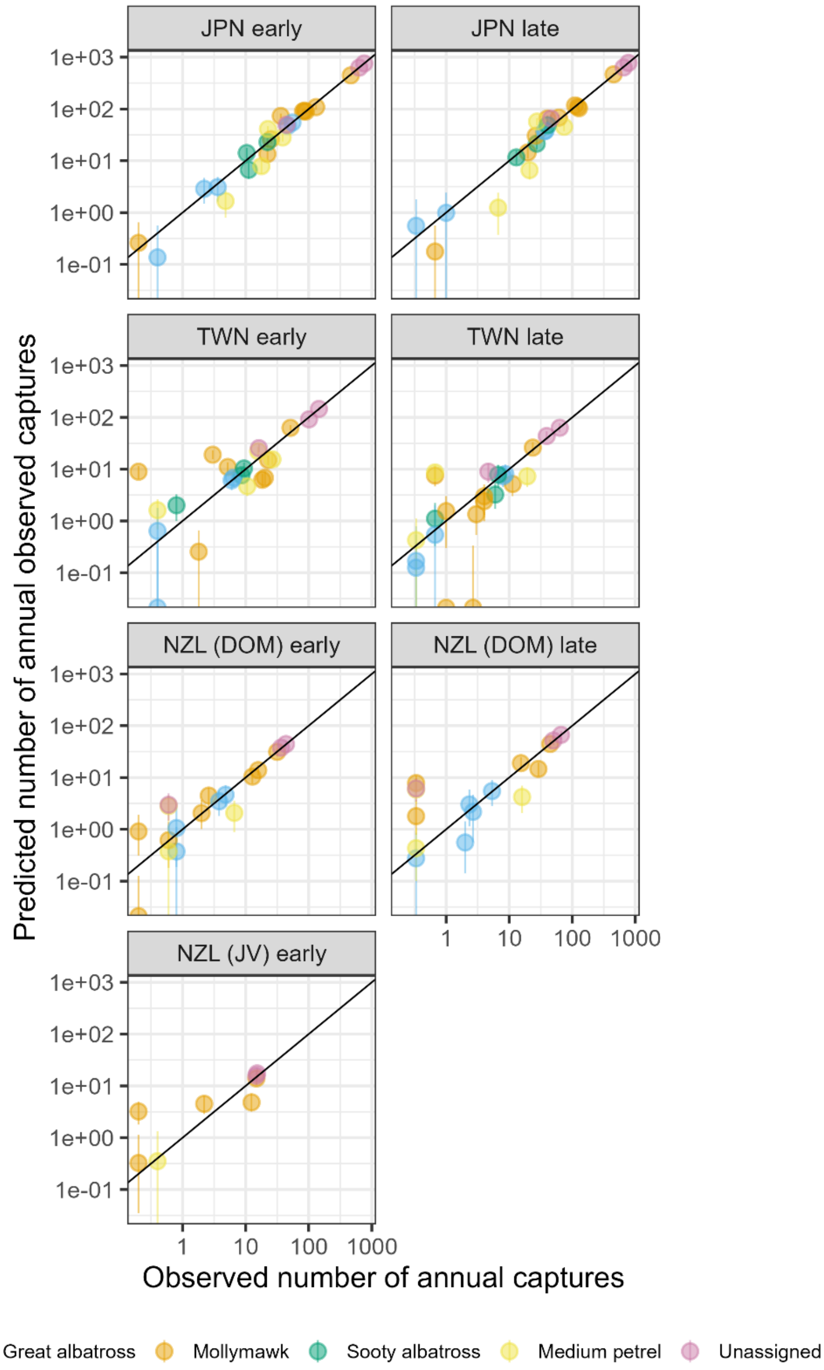

Figure 10b. Fit of the model to the average annual observed captures per capture code (on a log-10 scale) for the model.

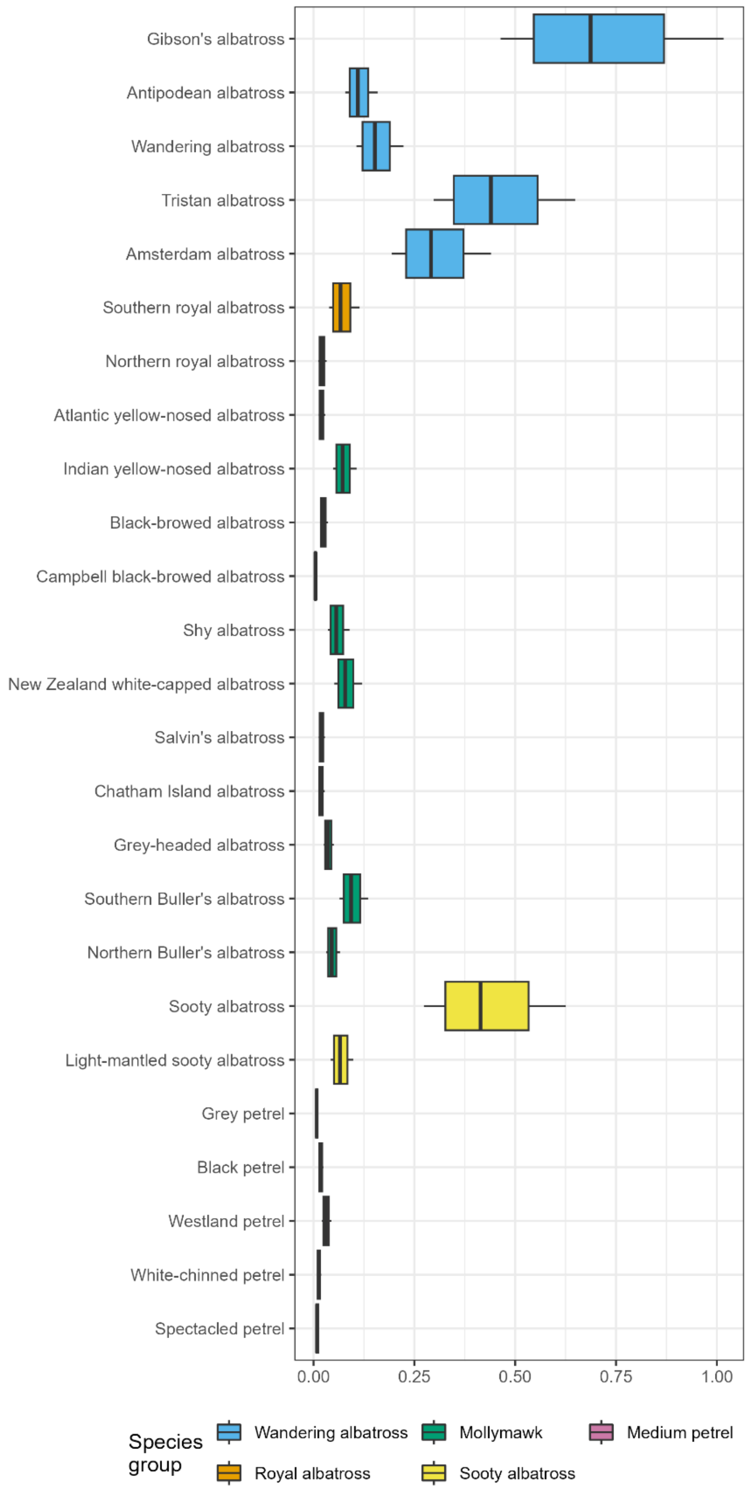

Figure 11 Relative mortalities per species with catchabilities shared across the full time period (2012 to 2019).

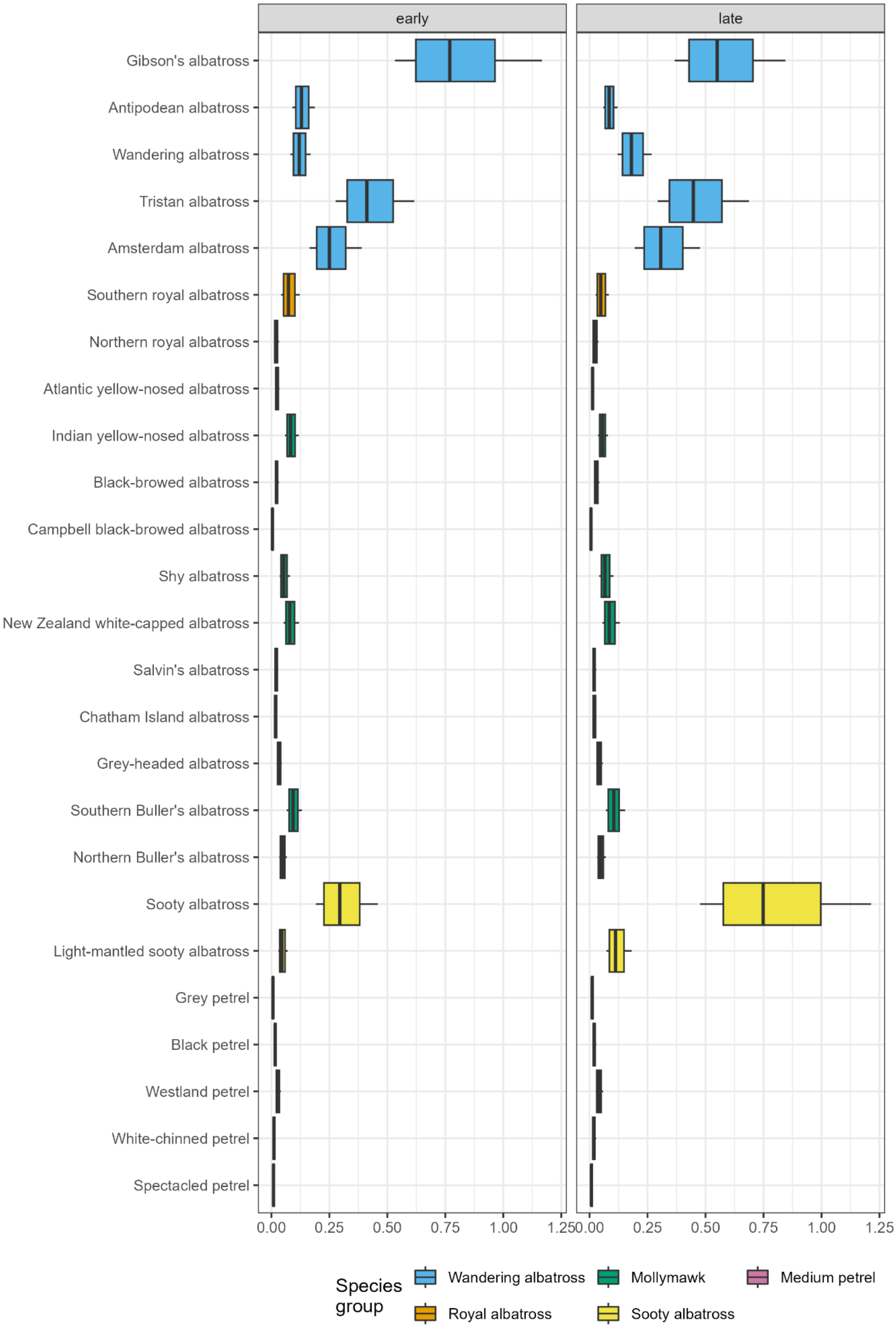

Figure 12 Relative mortalities per species with catchabilities specific to the early (2012-2016) and late (2017-2019) period.

Appendix XX: Initial work plan developed by New Zealand and Japan on XXX

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: Sachiko
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
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 summarising the technical session.

Appendix X: Note of agreement for the first Technica 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)[1]
        - 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[2]
    - 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[3]

[1] 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'
[2] Noting that ideally these parameters would align with the goals of the Multi-Year Seabird Strategy for ease of implementation of the strategy.
[3] 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[4]

- 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