Supplementary Material

Seabird assemblages are linked to the major western boundary current off eastern Australia

Daudt, N.W.; Woehler, E.J.; Schofield, M.R.; Smith, R.O.; Bugoni, L.; Rayment, W.J.

2024-03-06

This document is a supplementary file for Daudt et al. (2024). Briefly, here you will find:

- **List of packages** (and version) used for data wrangling, visualisation and analyses, and their full references;
- **Table 1**: Summary of sampling effort by voyage;
- **Fig. 1**: Number of occurrences, frequency of occurrence (FO), and numeric frequency (NF) for each recorded species by season;
- **Figs. 2, 3**: Plots for choosing best RCP group number (`multifit`);
- **Figs. 4, 5**: Residual plots from the best fitted models;
- **Figs. 6, 7**: Partial plots for covariates;
- **Figs. 8, 9**: Probability maps from seasonal predictions;
- **Figs. 10, 11**: Species profiles for each season;
- **Fig. 12**: Species-richness and sample-coverage curves.

List of packages

We used the following packages 'plyr' 1.8.8 (Wickham, 2011), 'dplyr' 1.1.2 (Wickham et al., 2023a), 'tidyr' 1.3.0 (Wickham et al., 2023c), 'readr' 2.1.4 (Wickham et al., 2023b), 'tibble' 3.2.1 (Müller and Wickham, 2023), 'lubridate' 1.9.2 (Grolemund and Wickham, 2011), 'stringr' 1.5.0 (Wickham, 2022), 'purrr' 1.0.1 (Wickham and Henry, 2023), 'ggplot2' 3.4.2 (Wickham, 2016), 'ggspatial' 1.1.7 (Dunnington, 2022), 'patchwork' 1.1.2 (Pedersen, 2022), 'RColorBrewer' 1.1-3 (Neuwirth, 2022), 'rnaturalearth' 0.3.2 (Massicotte and South, 2023), 'sp' 1.6-0 (Bivand et al., 2013; Pebesma and Bivand, 2005), 'sf' 1.0-8 (Pebesma, 2018), 'mapview' 2.11.0 (Appelhans et al., 2022), 'raster' 3.5-21 (Hijmans, 2022a), 'terra' 1.6-7 (Hijmans, 2022b), 'rerddap' 1.0.2 (Chamberlain, 2023), 'rerddapXtracto' 1.1.4 (Mendelssohn, 2022), 'hadsstR' (Byrnes and Dunic, 2017), 'corrplot' 0.92 (Wei and Simko, 2021), and the ones referenced in the main text.

The code is archived in an Open Science Framework repository in (Daudt et al., 2023), where you can find a detailed walk-through.

References

Appelhans, T., Detsch, F., Reudenbach, C., Woellauer, S., 2022. mapview: Interactive viewing of spatial data in R, R package version 2.11.0, https://CRAN.r-project.org/package=mapview.

Bivand, R.S., Pebesma, E., Gomez-Rubio, V., 2013. Applied spatial data analysis with R, second edition. Springer, NY.

Byrnes, J., Dunic, J., 2017. hadsstR: R library for working with HadSST data, R package version 1.0.0, https://github.com/jebyrnes/hadsstR.

Chamberlain, S., 2023. rerddap: General purpose client for 'ERDDAP' servers, R package version 1.0.2, https://CRAN.r-project.org/package=rerddap.

Daudt, N.W., Woehler, E.J., Schofield, M.R., Smith, R.O., Bugoni, L., Rayment, W.J., 2024. Seabird assemblages are linked to the major western boundary current off eastern Australia. Progress in Oceanography. https://doi.org/10.1016/j.pocean.2024.103215

Daudt, N.W., Woehler, E.J., Schofield, M.R., Smith, R.O., Bugoni, L., Rayment, W.J., 2023. Data and code: Seabird assemblages off eastern australia. https://doi.org/10.17605/OSF.IO/N582D

Dunnington, D., 2022. ggspatial: Spatial data framework for ggplot2, R package version 1.1.7, https://CRAN.r-project.org/package=ggspatial.

Grolemund, G., Wickham, H., 2011. Dates and times made easy with lubridate. Journal of Statistical Software 40, 1–25.

Hijmans, R.J., 2022a. raster: Geographic data analysis and modeling, R package version 3.5-21, https://CRAN.r-project.org/package=raster.

Hijmans, R.J., 2022b. terra: Spatial data analysis, R package version 1.6-7, https://CRAN.r-project.org/package=terra.

Massicotte, P., South, A., 2023. rnaturalearth: World map data from natural earth, R package version 0.3.2, https://CRAN.r-project.org/package=rnaturalearth.

Mendelssohn, R., 2022. rerddapXtracto: Extracts environmental data from 'ERDDAP' web services, R package version 1.1.4, https://CRAN.r-project.org/package=rerddapXtracto.

Müller, K., Wickham, H., 2023. tibble: Simple data frames, R package version 3.2.1, https://CRAN.r-project.org/package=tibble.

Neuwirth, E., 2022. RColorBrewer: ColorBrewer palettes, R package version 1.1-3, https://CRAN.r-project.org/package=RColorBrewer.

Pebesma, E., 2018. Simple features for R: standardized support for spatial vector data. The R Journal 10, 439–446. https://doi.org/10.32614/RJ-2018-009

Pebesma, E.J., Bivand, R.S., 2005. Classes and methods for spatial data in R. R News 5, 9–13.

Pedersen, T.L., 2022. patchwork: The composer of plots, R package version 1.1.2, https://CRAN.r-project.org/package=patchwork.

Wei, T., Simko, V., 2021. R package 'corrplot': Visualization of a correlation matrix, R package version 0.92, https://github.com/taiyun/corrplot.

Wickham, H., 2022. stringr: Simple, consistent wrappers for common string operations, R package version 1.5.0, https://CRAN.r-project.org/package=stringr.

Wickham, H., 2016. ggplot2: Elegant graphics for data analysis. Springer-Verlag New York.

Wickham, H., 2011. The split-apply-combine strategy for data analysis. Journal of Statistical Software 40, 1–29.

Wickham, H., François, R., Henry, L., Müller, K., Vaughan, D., 2023a. dplyr: A grammar of data manipulation, R package version 1.1.2, https://CRAN.r-project.org/package=dplyr.

Wickham, H., Henry, L., 2023. purrr: Functional programming tools, R package version 1.0.1, https://CRAN.r-project.org/package=purrr.

Wickham, H., Hester, J., Bryan, J., 2023b. readr: Read rectangular text data, R package version 2.1.4, https://CRAN.r-project.org/package=readr.

Wickham, H., Vaughan, D., Girlich, M., 2023c. tidyr: Tidy messy data, R package version 1.3.0, https://CRAN.r-project.org/package=tidyr.

Table 1. Summary of seabird sampling effort by voyage, off eastern Australia, during Australasian Seabird Group's ship-based surveys between 2016–2021. Start and finish dates and geographic ranges of each voyage, including the number of seabird records and the number of individuals and species recorded

Voyage	**Date start**	**Date end**	**Latitudinal range**	**Longitudinal range**	**No. of records**	**No. of birds**	**No. of species**
in2016_t02	2016-08-25	2016-08-28	-43 – -34	147 – 152	344	475	25
in2016_v06	2016-10-29	2016-11-12	-27 – -27	153 – 155	284	2892	14
in2017_v02	2017-03-16	2017-03-27	-47 – -43	142 – 147	911	7122	30
in2017_t01	2017-09-24	2017-10-01	-33 – -9	143 – 154	370	4540	17
in2017_t02	2017-11-24	2017-11-25	-44 – -42	141 – 147	113	11010	17
in2018_t02	2018-05-14	2018-05-20	-43 – -27	148 – 154	214	6168	31
in2018_c01	2018-05-28	2018-06-07	-41 – -39	146 – 149	644	2846	25
in2018_v04	2018-09-11	2018-10-07	-47 – -34	141 – 155	1136	10434	36
in2018_v06	2018-11-22	2018-12-18	-44 – -41	146 – 149	1957	59628	43
in2019_v07	2019-04-10	2019-04-22	-43 – -38	147 – 150	412	1472	26
in2019_t01	2019-04-29	2019-05-02	-44 – -39	141 – 148	140	177	18
in2019_v04	2019-08-07	2019-09-01	-24 – -10	146 – 160	1321	13383	26
in2019_t02	2019-10-03	2019-10-10	-27 – -9	142 – 154	245	1895	28
fk201228	2020-12-27	2021-01-25	-27 – -23	153 – 157	1063	17298	20
fk210206	2021-02-06	2021-03-05	-27 – -19	153 – 157	1107	3306	14

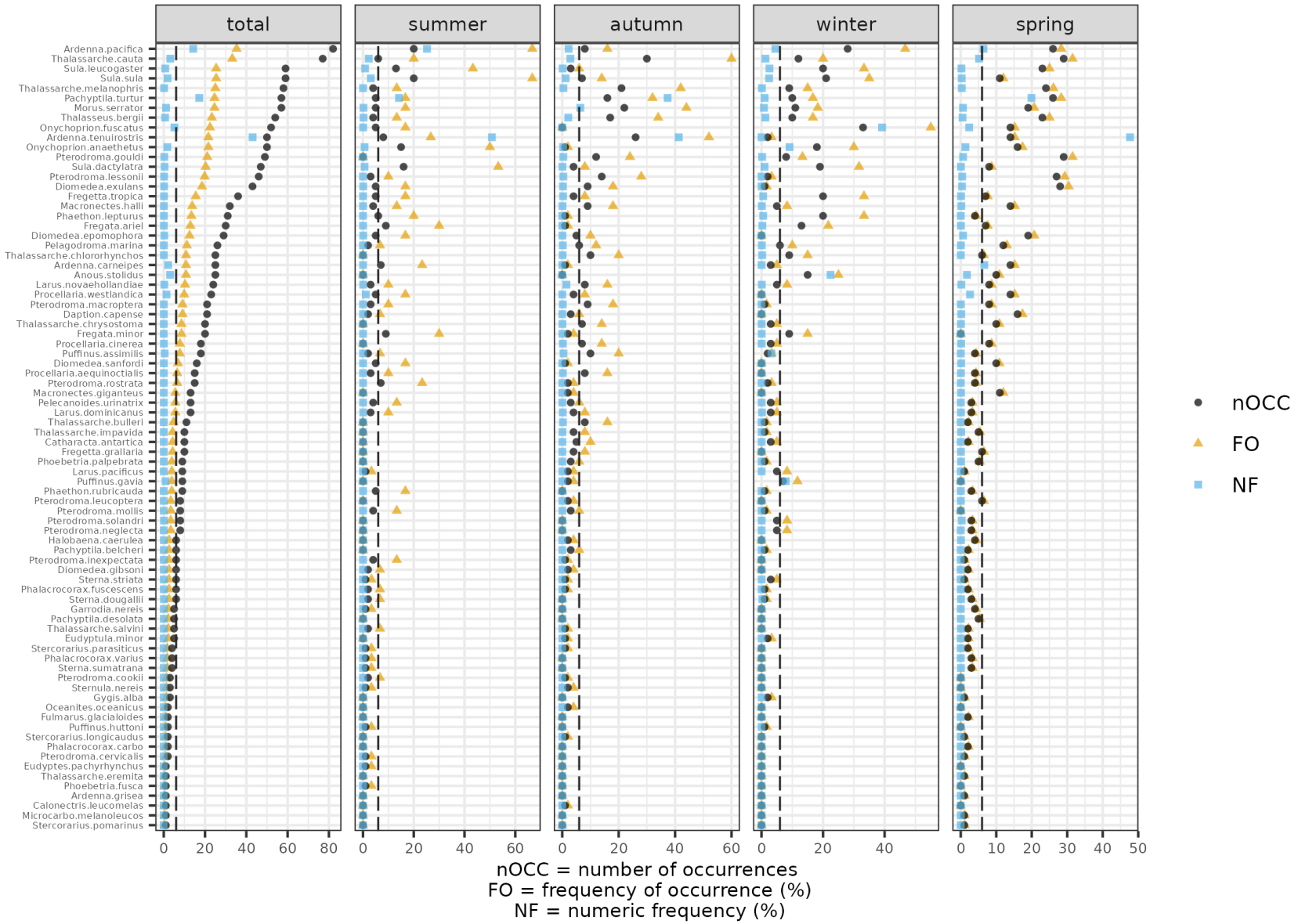


Figure 1: Number of occurrences (nOCC), frequency of occurrence (FO) and numeric frequency (NF) of seabirds recorded off eastern Australia during Australasian Seabird Group's ship-based surveys between 2016–2021. The dashed line represents the number of occurrence thresholds (n = 6) each taxon had to match for its inclusion in the seasonal models (see *Methods* in the main text). Species are ordered from the largest to the lowest total number of occurrences.

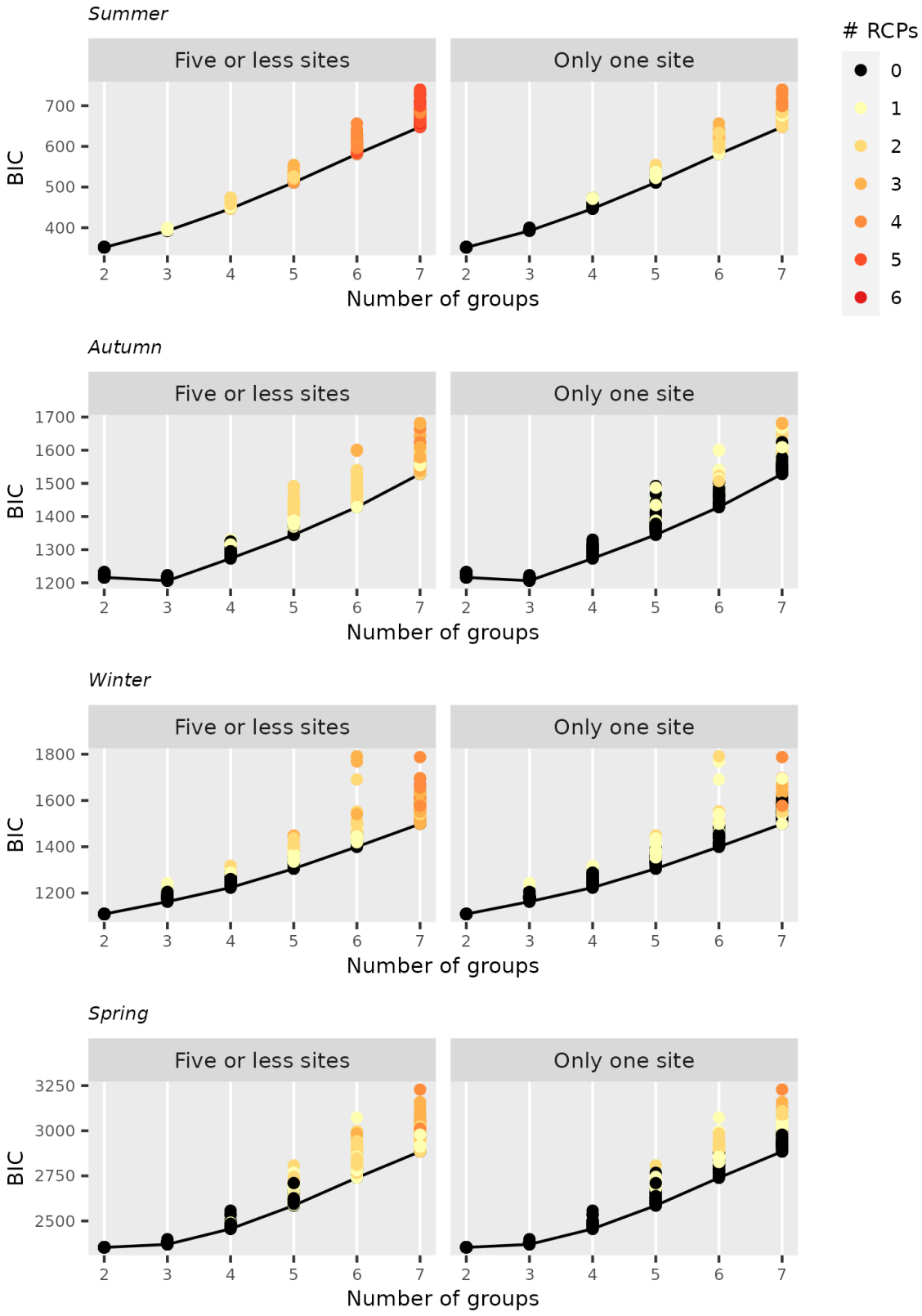


Figure 2: Multifit plot for Region of Common Profiles (RCP) for each seasonal presence-absence model, applied to seabirds off eastern Australia. The number of groups with the lowest BIC value indicates the best number of groups (assemblages) that describes the data. For each number of groups, we ran 100 models with random starting values to avoid getting stuck in an incorrect 'optima' (see *Methods* in the main text). The resulting plot also shows how many groups were 'empty' (colour scale) with 'five or less' or 'only one' sites assigned to an RCP, i.e. the model was fit with, say, 5 groups, but 3 of them had 'five or less' or 'only one' sites (grids) allocated to an RCP.

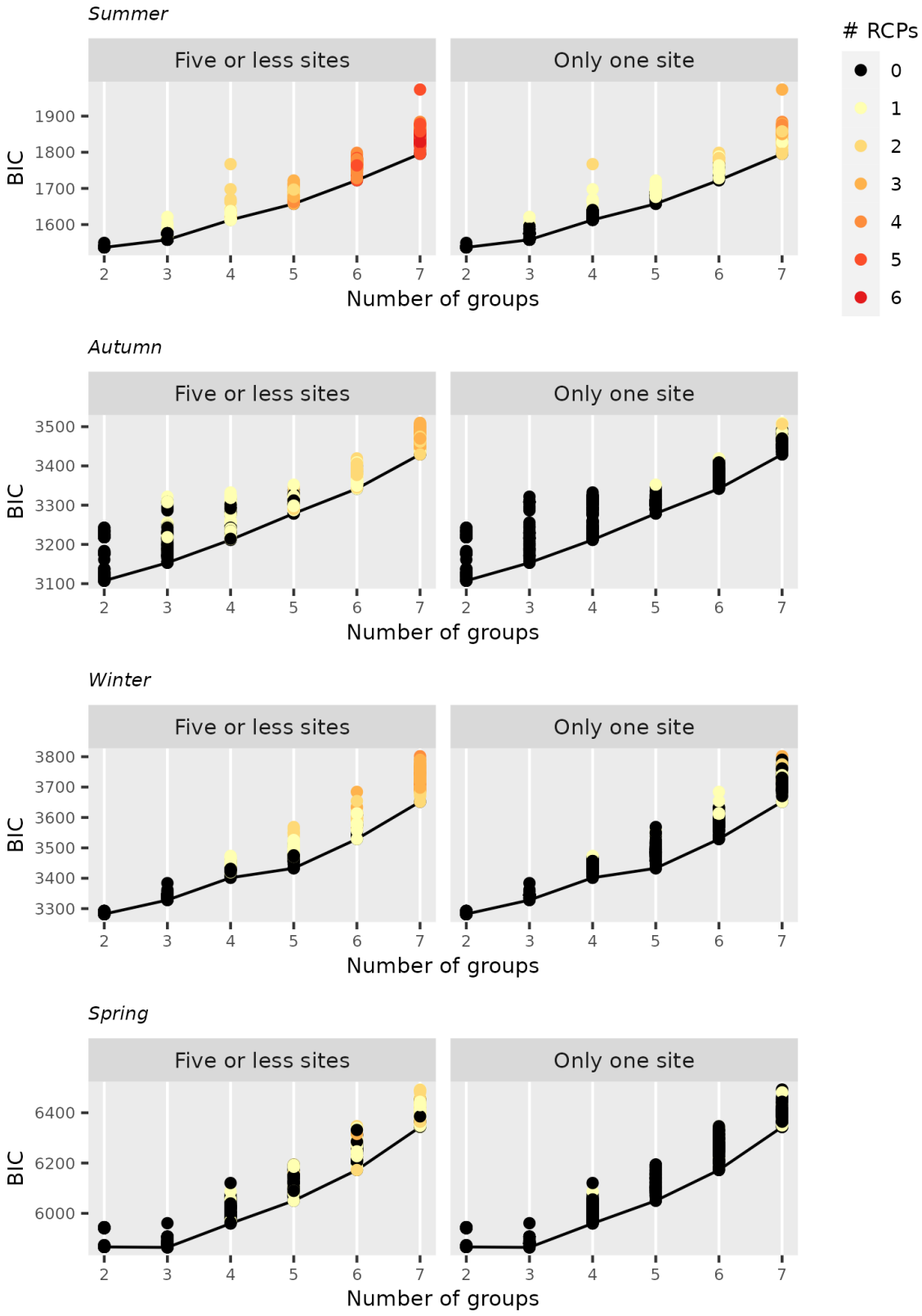
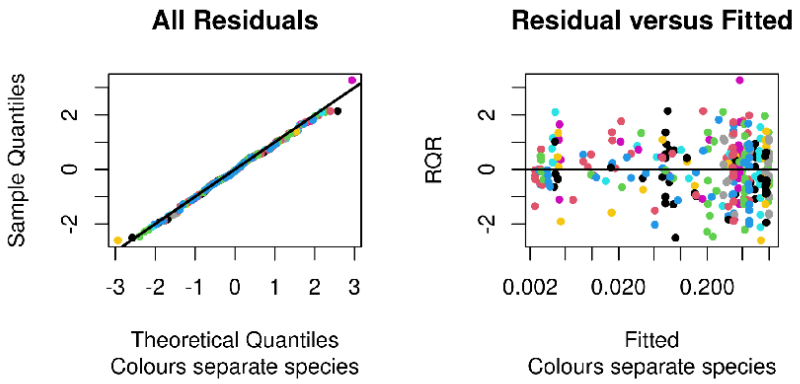
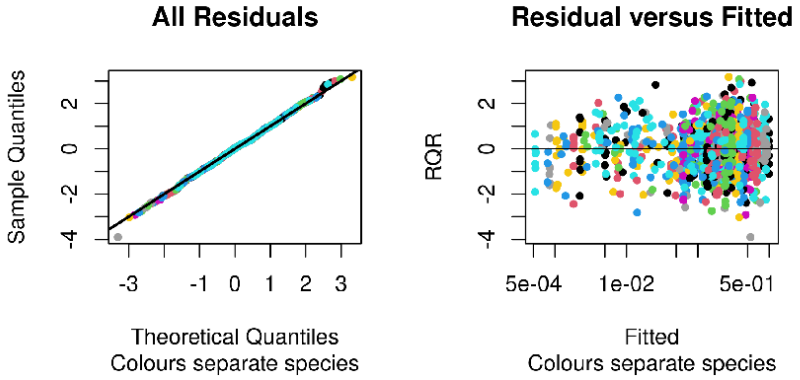


Figure 3: Multifit plot for Region of Common Profiles (RCP) for each seasonal abundance (count) model, applied to seabirds off eastern Australia. The number of groups with the lowest BIC value indicates the best number of groups (assemblages) that describes the data. For each number of groups, we ran 100 models with random starting values to avoid getting stuck in an incorrect 'optima' (see *Methods* in the main text). The resulting plot also shows how many groups were 'empty' (colour scale) with 'five or less' or 'only one' sites assigned to an RCP, i.e. the model was fit with, say, 5 groups, but 3 of them had 'five or less' or 'only one' sites (grids) allocated to an RCP.

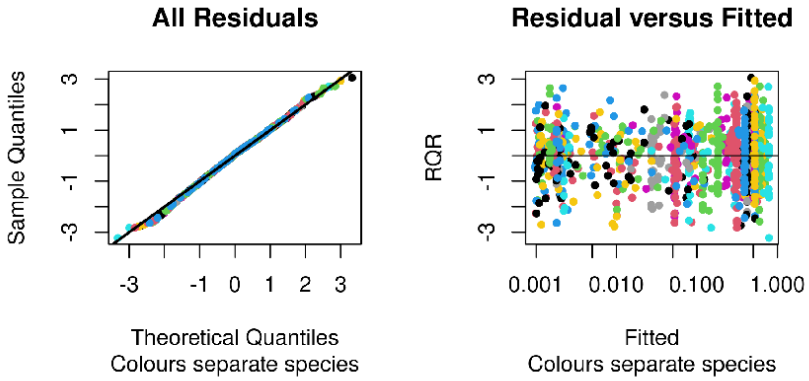
Summer



Autumn



Winter



Spring

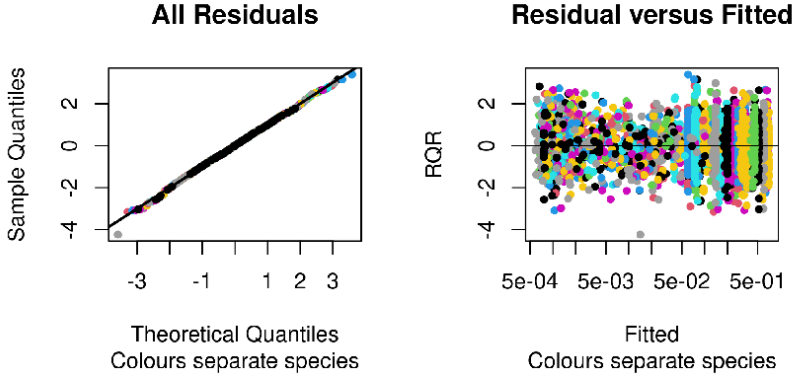
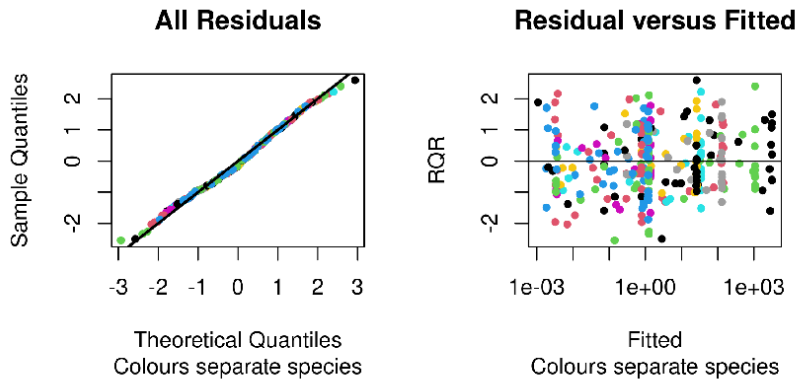
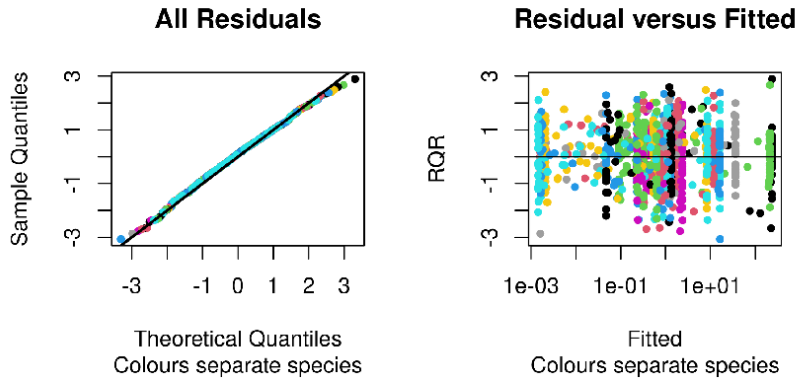


Figure 4: Best model residuals for each seasonal presence-absence Region of Common Profile model, applied to seabirds off eastern Australia.

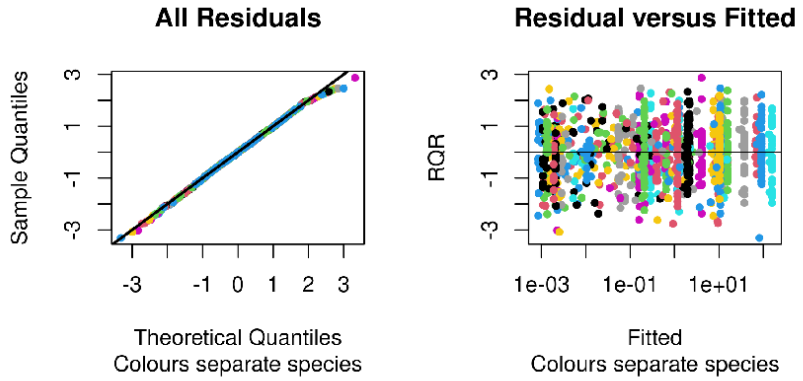
Summer



Autumn



Winter



Spring

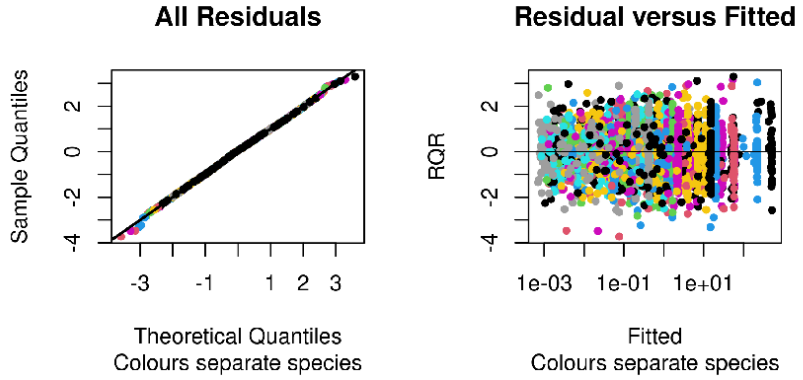


Figure 5: Best model residuals for each seasonal abundance (count) Region of Common Profile model, applied to seabirds off eastern Australia.

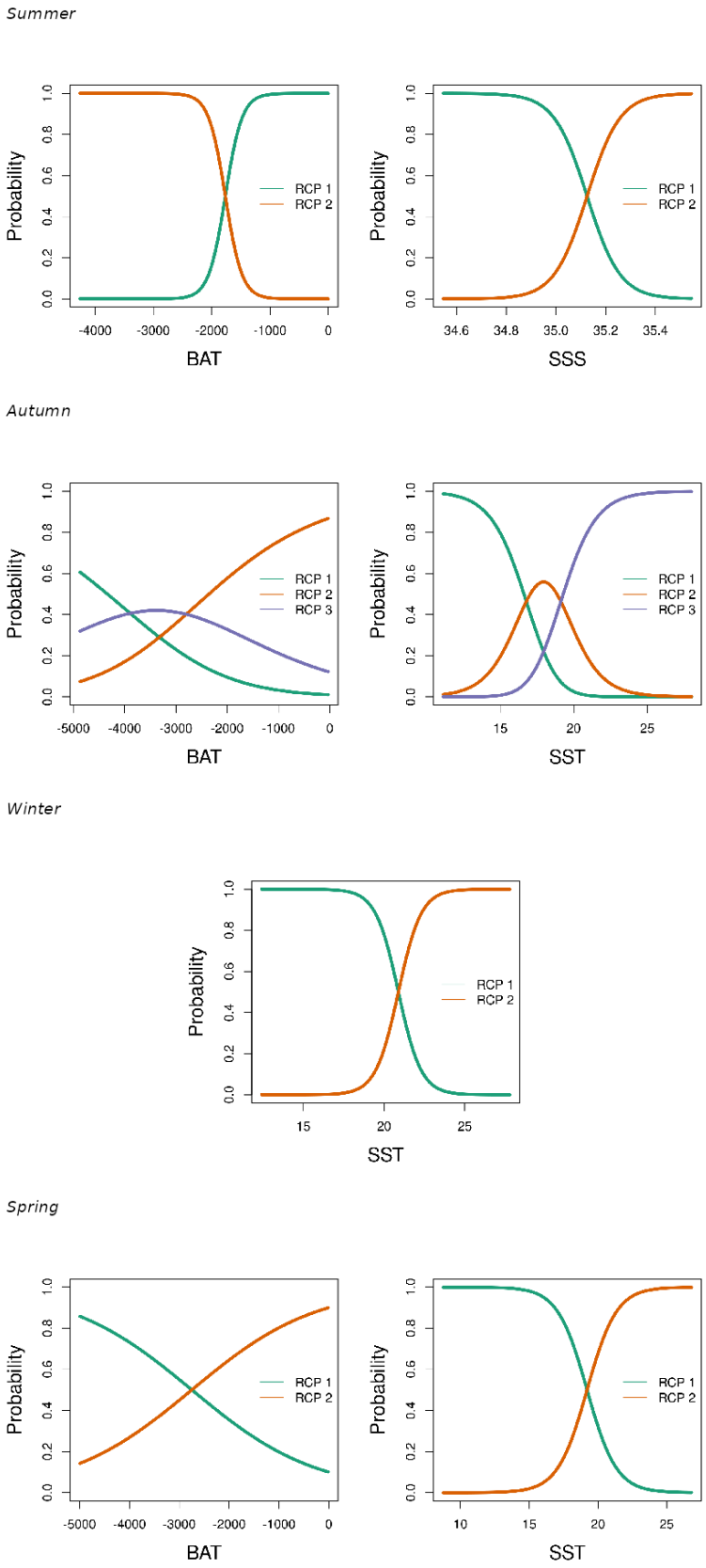


Figure 6: Partial plots for the retained covariates in the best seasonal models based on presence-absence data. The plot shows the probability of belonging to a Region of Common Profiles (RCP) against the environmental value. Refer to Table 1 in the main text for the environmental data acronyms.

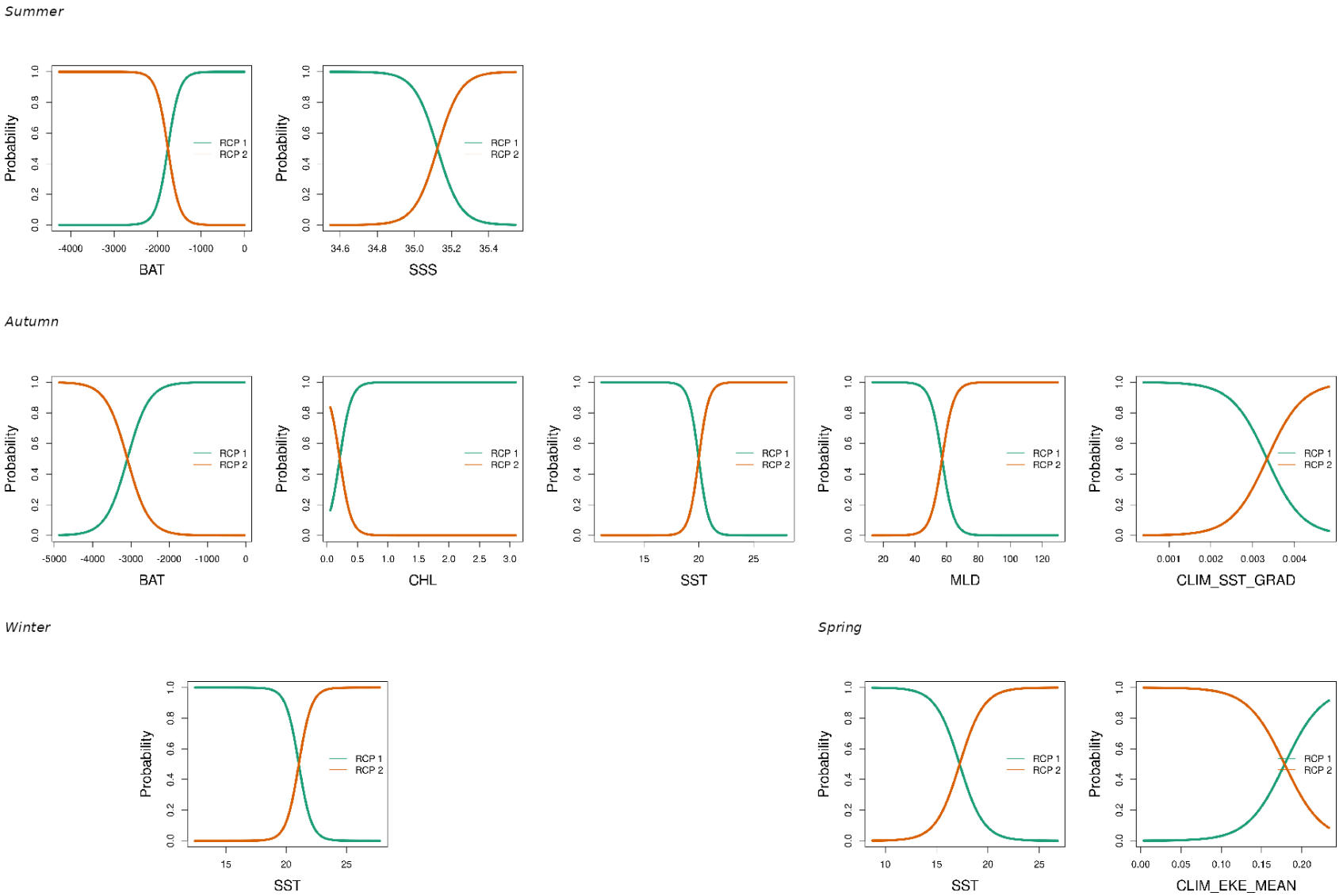


Figure 7: Partial plots for the retained covariates in the best seasonal models based on abundance data. The plot shows the probability of belonging to a Region of Common Profiles (RCP) against the environmental value. Refer to Table 1 in the main text for the environmental data acronyms.

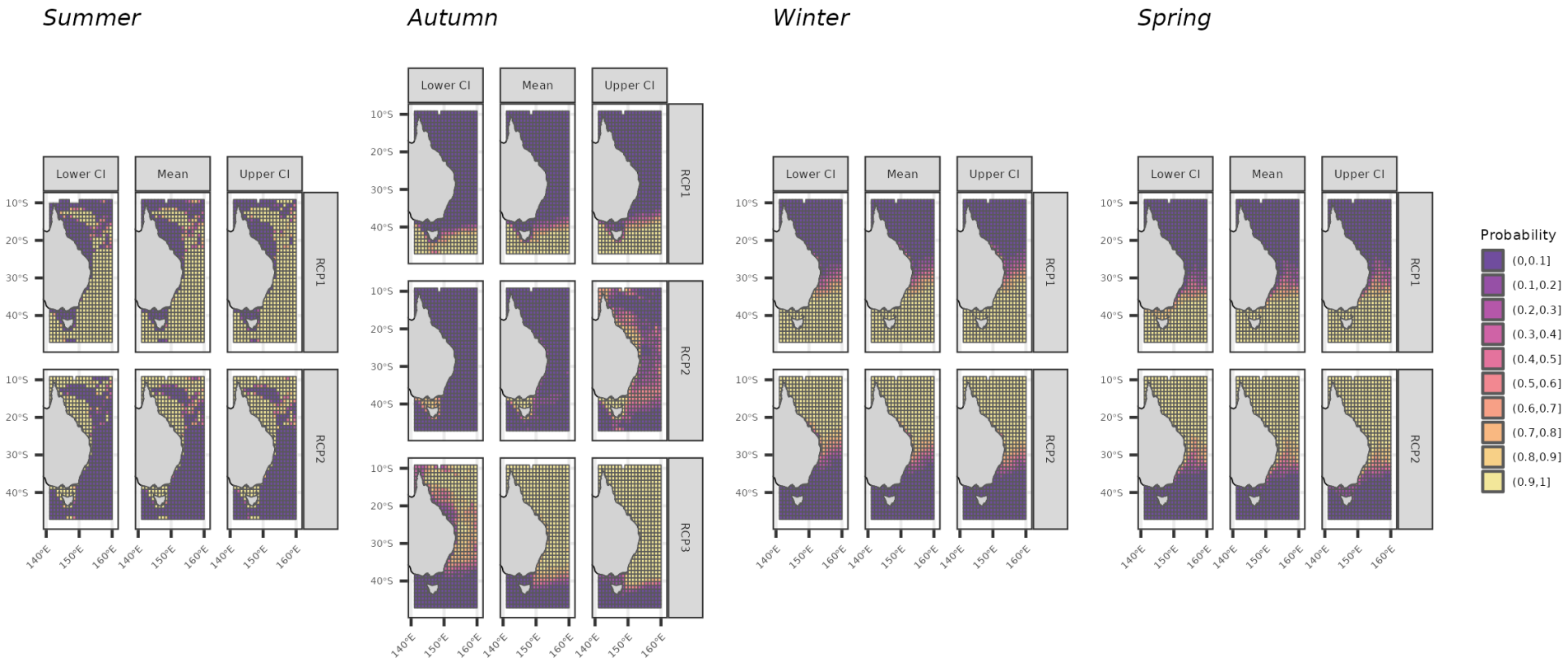


Figure 8: Predicted probability membership of for each seabird assemblage (Region of Common Profiles; RCP) and grid, off eastern Australia, from presence-absence models. The central column, 'mean', corresponds to the point prediction and Bayesian bootstraped, lower and upper confidence intervals (CI), on its sides.

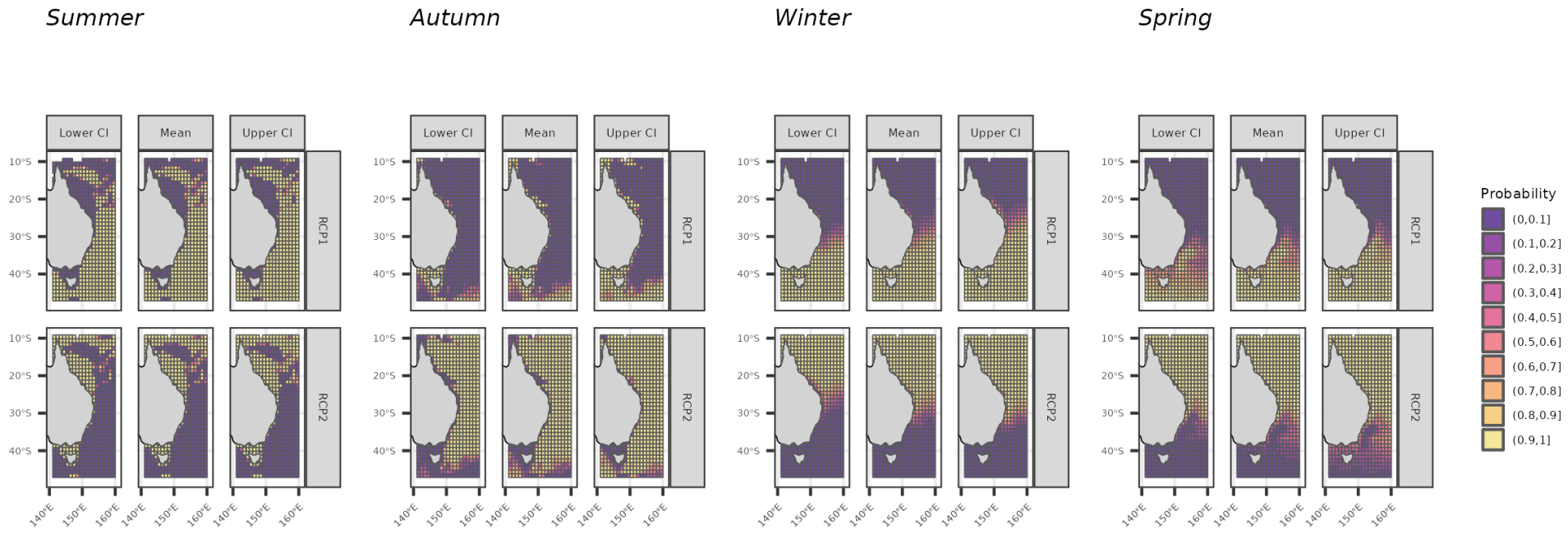


Figure 9: Predicted probability membership of for each seabird assemblage (Region of Common Profiles; RCP) and grid, off eastern Australia, from abundance (count) models. The central column, 'mean', corresponds to the point prediction and Bayesian bootstraped, lower and upper confidence intervals (CI), on its sides.

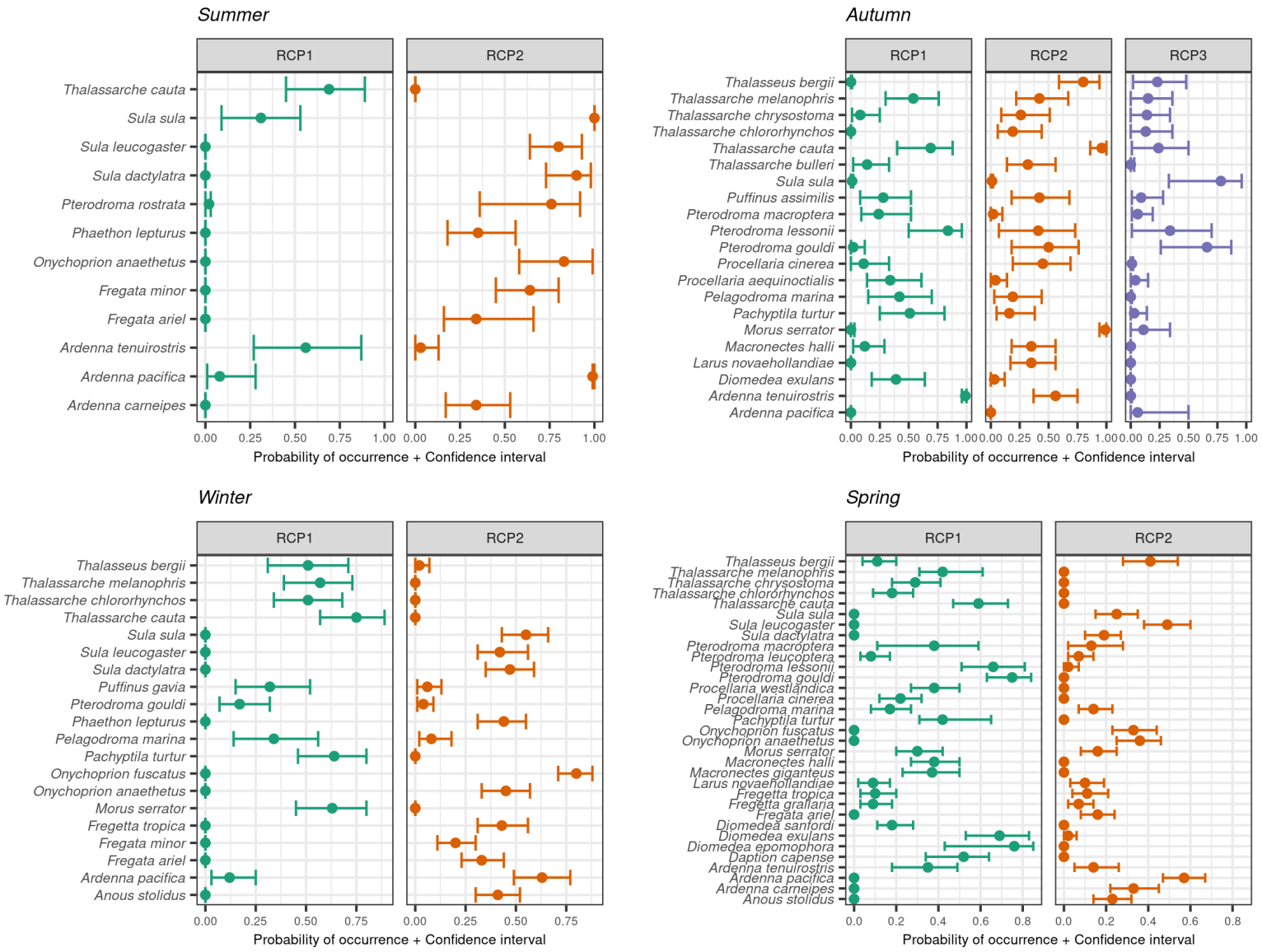


Figure 10: Species profiles for each assemblage (Region of Common Profiles; RCP) for each seasonal presence-absence model. Values are the average and confidence intervals of probability of occurrence for each species, based on 1000 Bayesian bootstraps. Note the species on the Y-axis are ordered alphabetically, from bottom up.

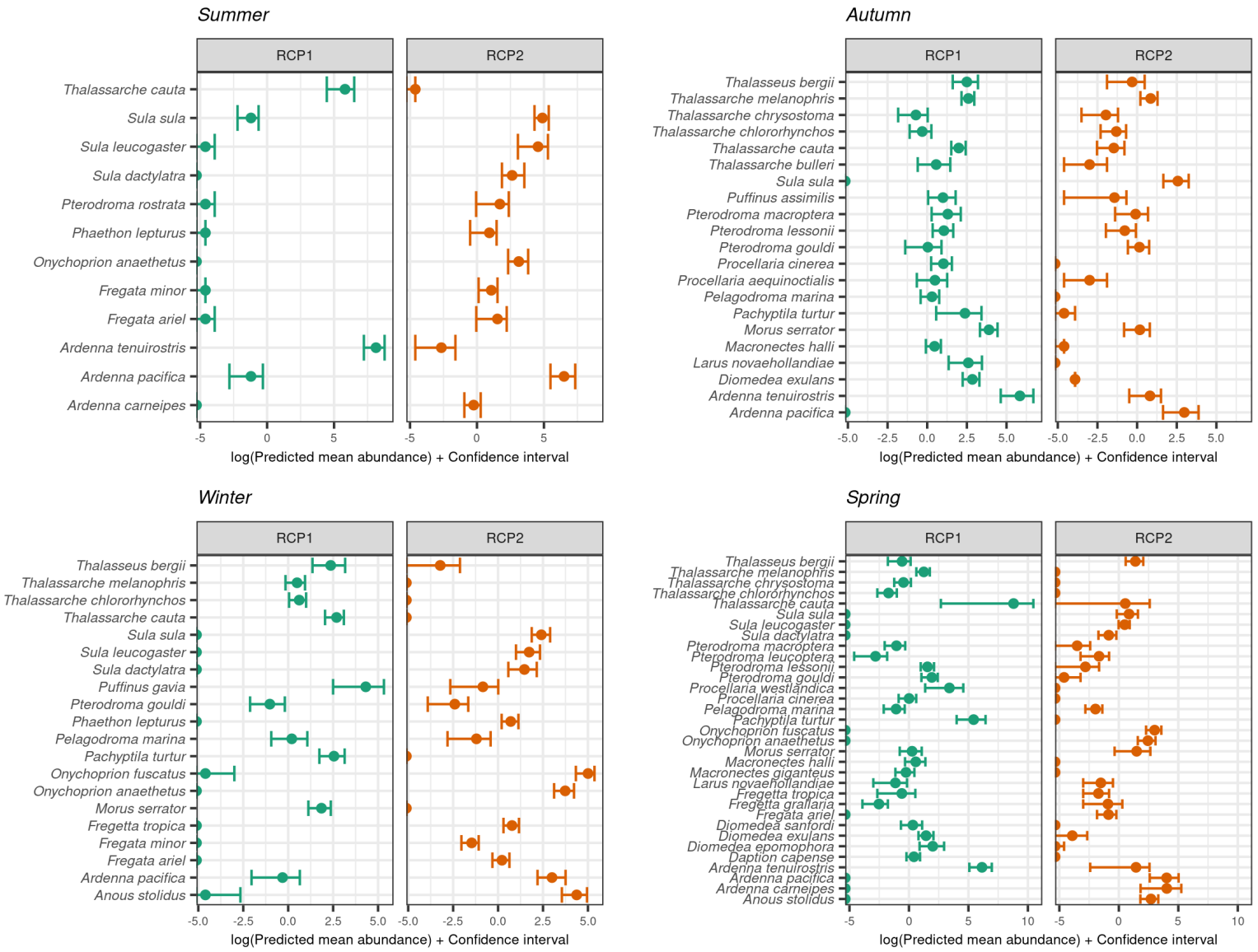


Figure 11: Species profiles for each assemblage (Region of Common Profiles; RCP) for each seasonal abundance (count) model. Values are the average and confidence intervals of predicted mean abundance for each species, based on 1000 Bayesian bootstraps. Values were log10-transformed to accommodate the high variation between species. Note the species on the Y-axis are ordered alphabetically, from bottom up.

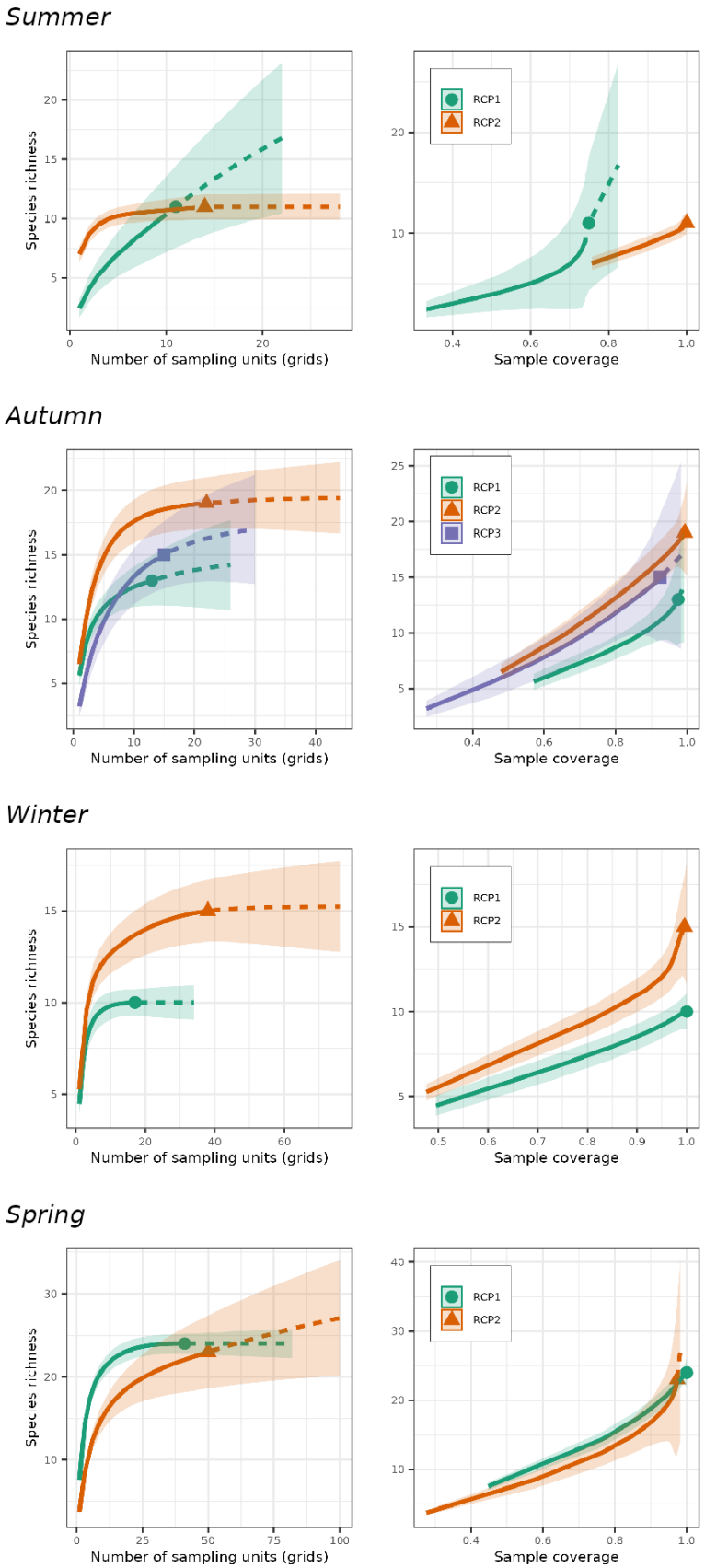


Figure 12: Diversity curve (alpha diversity) and sample coverage for each assemblage (Region of Common Profile; RCP) from each presence-absence seasonal model.