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Estimates of unreported SBT catch by CCSBT non-cooperating non-member states between 2007 and 2023

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EXECUTIVE SUMMARY

Edwards, C.T.T.; Hoyle, S.D. (2026). Estimates of unreported SBT catch by CCSBT non-cooperating non-member states between 2007 and 2023.

Submission to the 16th CCSBT OMMP Technical Meeting, 22 – 26 June 2026, Seattle, United States of America

Stock assessment and management of southern bluefin tuna (SBT) requires knowledge of the total catch. Non-cooperating non-members of the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) do not report SBT catches to the Commission, and estimates of this unreported catch are required. This has been achieved (CCSBT-ESC/1609/BGD02/Rev.1; CCSBT-ESC/1909/33; CCSBT-OMMP/2006/04; CCSBT-OMMP/2306/07) by fitting a two-part statistical model to the CCSBT catch rate data, and using the fitted model to predict the catch from non-member effort data collected by the other relevant tuna RFMOs (the Indian Ocean Tuna Commission, the International Commission for the Conservation of Atlantic Tunas and the Western Central Pacific Fisheries Commission). For the current iteration of the work, the same model used for CCSBT-OMMP/2306/07, without any further development, was applied to updated data from the period 2007 – 2023.

Non-member catches were estimated under assumed catch rates equal to those of either the Japanese (JP) or Taiwanese (TW) fleets, adjusted for spatial and temporal covariates, representing target and non-target SBT fisheries respectively. Catch estimates under each of these assumptions were taken to represent a range of possible values. Using the updated data, non-member catch was estimated to have fluctuated around 1000 tonnes since 2018, which is consistent with previous estimates.

Improvements to the approach have been suggested; in particular, the development of a model better able to account for spatio-temporal patterns in the data. We have also noted that the JP and TW fleets have very different spatial distributions, and that fleet-specific catchability effects estimated by the model may not be fully separated from the underlying SBT biomass distribution. If this is the case, then the application of a fleet-specific catchability term to spatio-temporal strata where the fleet would not typically fish, is questionable, and could be revisited in future work.

1. INTRODUCTION

The level of unaccounted mortality (UAM) by non-cooperating non-members (NCNMs) of the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) is a key input to assessments of stock status for southern bluefin tuna (SBT) and execution of the Management Procedure (MP) that is used to recommend catches. However, there is no reliable information available on SBT catch by NCNMs and these catches therefore need to be estimated from NCNM effort data.

Effort data reported to other regional tuna fisheries management organisations (tRFMOs), particularly the IOTC (Indian Ocean Tuna Commission), ICCAT (International Commission for the Conservation of Atlantic Tunas) and WCPFC (Western and Central Pacific Fisheries Commission), shows a large degree of overlap with SBT fishing grounds (e.g. Larcombe 2014, Francis & Hoyle 2019). However, SBT catch may not be reported, and even for members of the CCSBT effort may not be reported when SBT is not being targeted.

Following work by the Extended Scientific Committee in 2014 (ESC19), two separate papers were presented to ESC20 that provided estimates of non-member catches of SBT from fleets reporting to the IOTC and WCPFC (Chambers & Hoyle 2015, Hoyle & Chambers 2015). Edwards et al. (2016) presented updates (including ICCAT effort data) to ESC21 (CCSBT 2016), and Edwards et al. (2019) included revisions to the data that increased the estimated non-member catches for the Indian and Atlantic Oceans (ESC24; CCSBT 2019). Further work was conducted by Edwards et al. (2020) and presented to the 11th Operating Model and Management Procedure (OMMP) Technical Meeting. In 2021, the ESC recommended that the non-member effort timeseries be updated to support execution of the MP in 2022 (CCSBT 2021), and this was reported to the 12th OMMP Technical Meeting (Edwards & Hoyle 2022). The CCSBT SBT stock assessment was then updated in 2023, for which UAM updates were produced by Edwards & Hoyle (2023). The current work is a re-iteration of the model implemented by Edwards & Hoyle (2023), applied to updated data to generate UAM estimates for the 2007–2023 period, required for the 16th OMMP Technical Meeting.

2. DATA AND METHODS

2.1. Methodology

The data preparation and analyses follows that described by Edwards et al. (2019, 2020) and Edwards & Hoyle (2022, 2023) and can be summarized in the following steps:

1. Obtain catch, effort and size data from member and cooperating non-member states reporting to CCSBT by $5^\circ \times 5^\circ$ grid cell, year and month, for the Pacific, Indian and Atlantic Oceans.
2. Model length data in order to estimate catch weight in tonnes for CCSBT member fleets that report catches in numbers only (i.e., the Japanese fleet).
3. Obtain longline fishing effort reported to the WCPFC, IOTC and ICCAT and allocate to $5^\circ \times 5^\circ$ grid cell, by year and month.
4. Create adjusted CCSBT effort data for Japan (JP), Korea (KR) and Taiwan (TW) that includes unreported, zero-catch effort recorded in the WCPFC, IOTC and ICCAT data bases by these CCSBT members.
5. Fit statistical models to catch and adjusted effort data for all CCSBT fleets and estimate spatial and temporal covariates contributing to the catch per unit effort.
6. Use the model results to predict the non-member SBT catch per unit effort for spatio-temporal strata, and based on two alternate assumptions: all non-member effort has the

same catchability as estimated for JP, and all non-member effort has the same catchability as estimated for TW. These fleets represent fisheries in which SBT is largely a target (JP) or a bycatch species (TW).

7. Extract longline fishing effort reported to the WCPFC, IOTC and ICCAT by non-member, non-cooperating states, and estimate the SBT catch by multiplying NCNM effort by the predicted SBT catch per unit effort.
8. Sum the predicted NCNM catch across strata and report the range of values obtained assuming either JP or TW catchability for the NCNM fleets.

2.2. CCSBT catch and effort data

Longline catch and effort data, targeting all species, for parties reporting to the CCSBT were obtained directly from the secretariat, up to and including 2023. Data at latitudes lower than 20°S were excluded, and the remainder aggregated by flag, calendar year, month and $5^\circ \times 5^\circ$ grid cell (allocated to the statistical areas in Figure 1) for 2007 onwards, acknowledging that catches prior to 2007 are known to be unreliable (Polacheck 2012). Raw catch and effort data were groomed and checked for consistency with extracts used for the previous analysis (Edwards & Hoyle 2023, e.g., Figures 2 and 3).

When preparing the CCSBT data for estimation of the catch rate, two preliminary steps were required: first, JP catches were converted from numbers to kilograms using the average weight per fish (Hoyle & Chambers 2015); second, estimates of the "adjusted" member effort were created (Edwards et al. 2019). This latter procedure attempts to partially account for known underreporting of effort by CCSBT members, and in particular the non-reporting of zero-catch effort by JP, KR and TW when SBT is not being targetted. Calculation of an adjusted effort was conducted by substituting effort collected from the other tuna RFMOs (otRFMOs; see below), in cases where this effort was higher than the effort reported to the CCSBT. Using the adjusted effort is considered the preferred approach (CCSBT 2016), since an upward bias in the CCSBT catch rates would otherwise translate into an upward bias in the estimated non-member catches. Differences in the Adjusted and Unadjusted effort and catch rates per flag are illustrated in Figure 4, and per statistical area in Figure 5. The spatial distribution of Adjusted CCSBT catch rates by flag and year are mapped per grid cell in Figures 6 and 7 respectively.

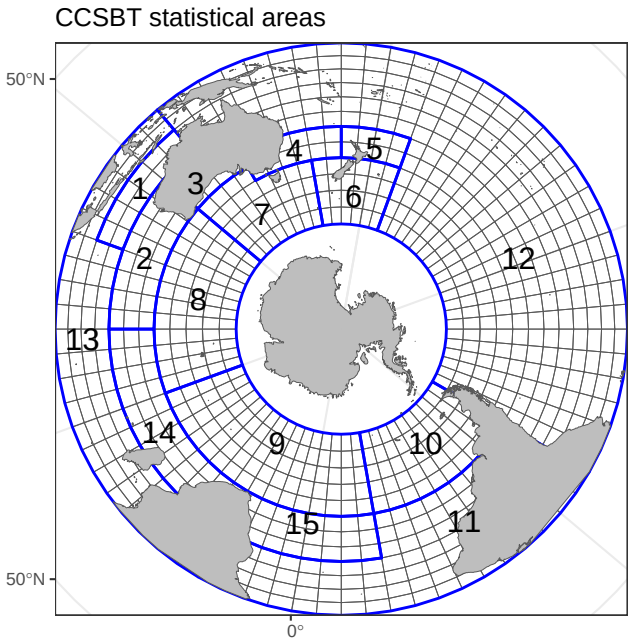


Figure 1: Spatial boundaries for the CCSBT statistical areas. Grid cells of $5^\circ \times 5^\circ$ are shown, between 0° and 60°S, which are the CCSBT latitudinal limits. The current analysis is restricted to latitudes higher than 20°S on the assumption that unreported SBT catches at lower latitudes are negligible.

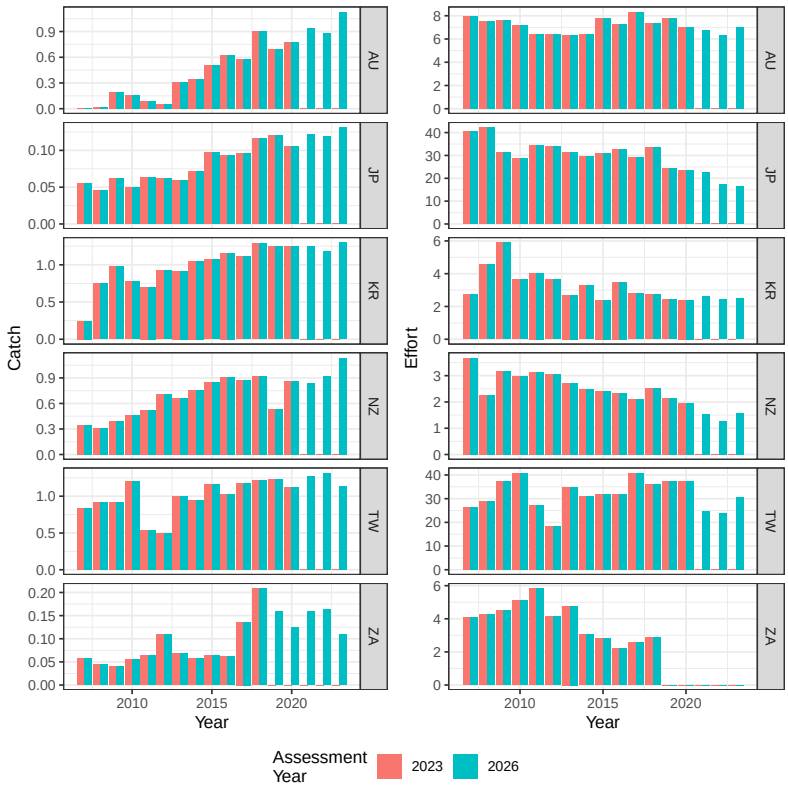


Figure 2: Raw catch and effort data reported to the CCSBT per member fleet. Catch is plotted in units of a thousand tonnes except for JP, for which catch is plotted in units of a million individuals. Effort is in units of a million hooks. Effort data from ZA is known to be incomplete from 2019 onwards, and was therefore excluded.

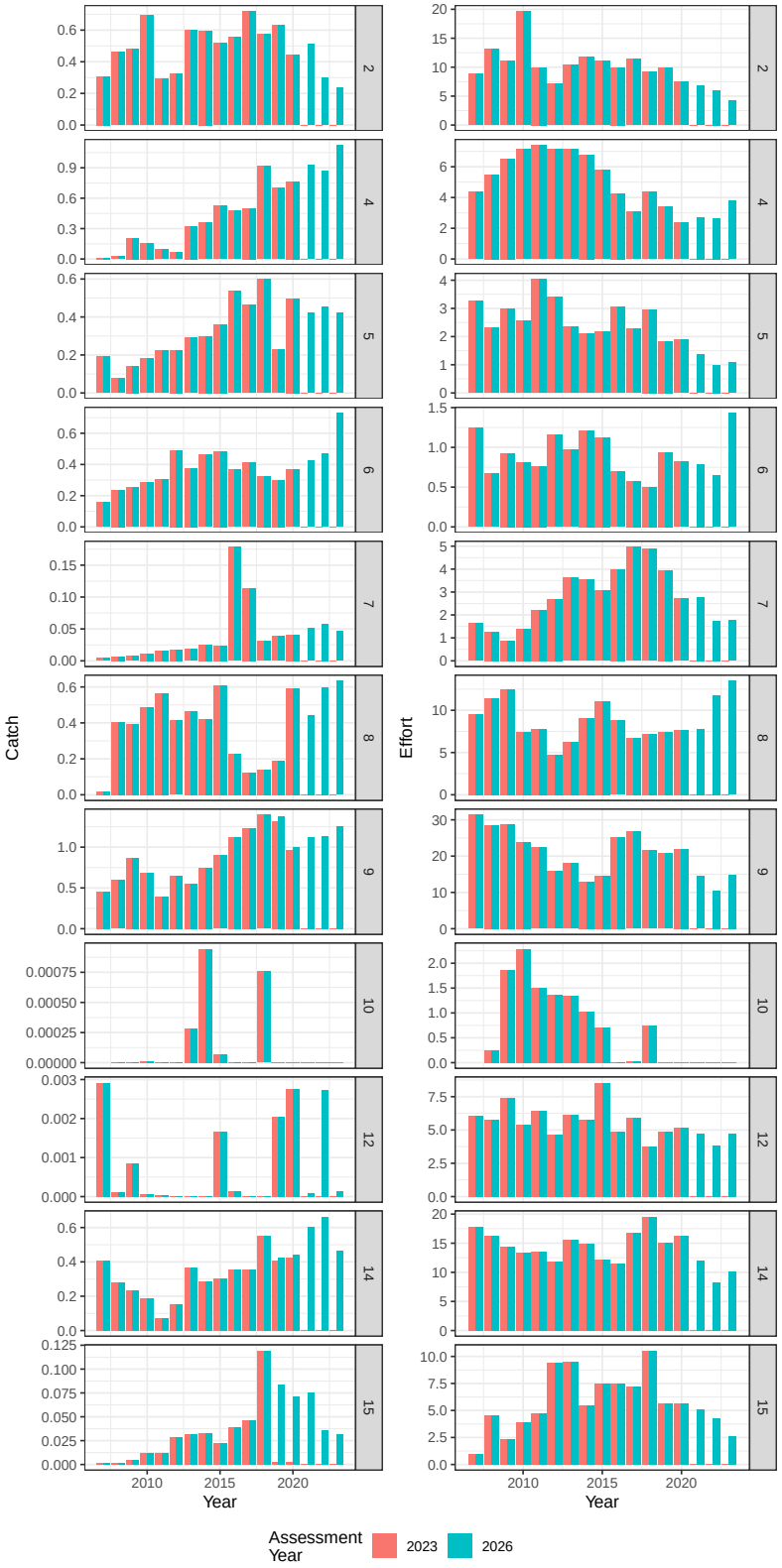


Figure 3: Raw catch and effort data reported to the CCSBT per statistical area. Catch is plotted in units of a thousand tonnes except for JP, for which catch is plotted in units of a million individuals. Effort is in units of a million hooks. Effort data from ZA is known to be incomplete from 2019 onwards, and was therefore excluded.

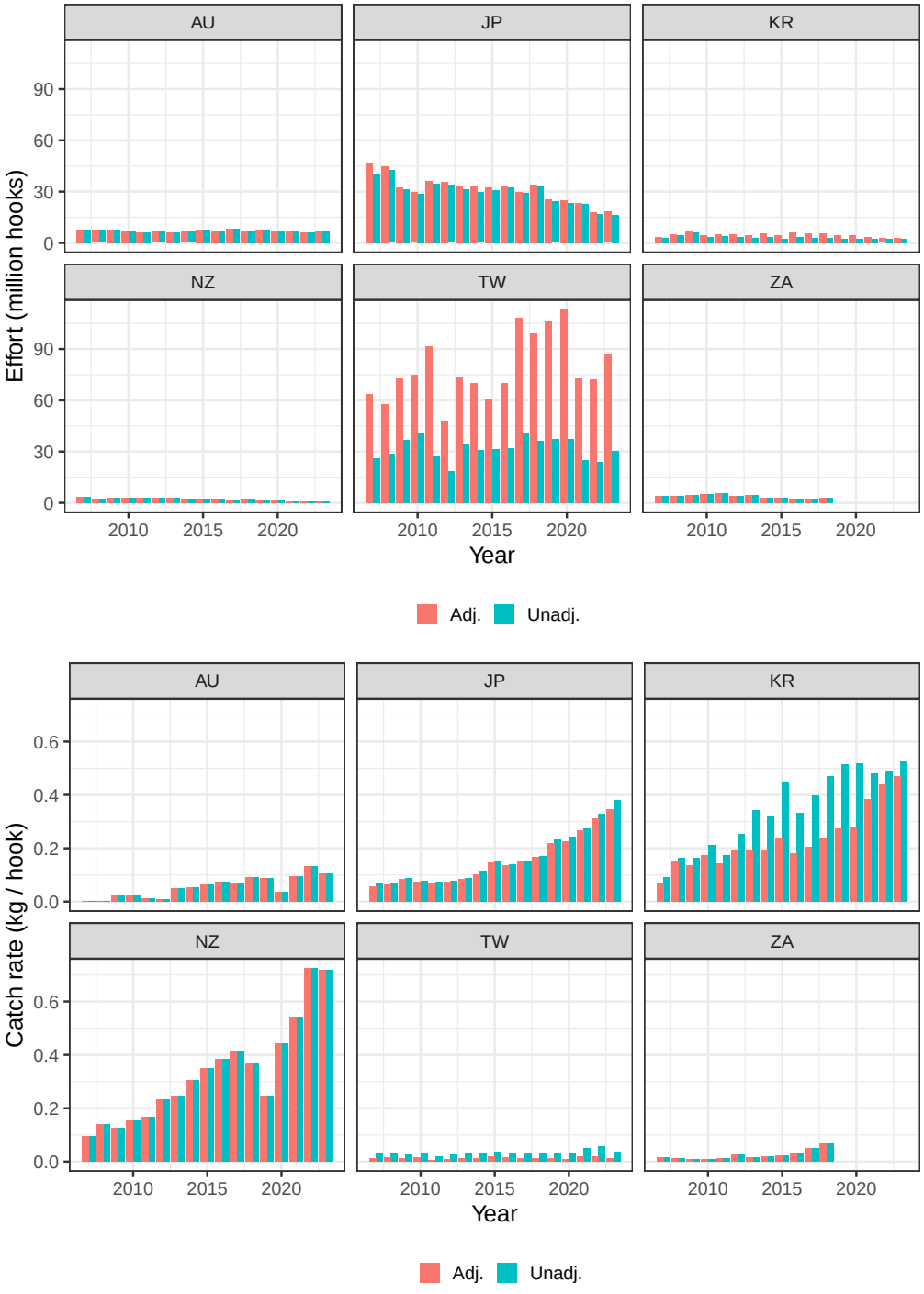


Figure 4: Unadjusted and Adjusted empirical CCSBT effort (top panel) and catch rates (bottom panel), per CCSBT member. Outliers (records with a catch rate of > 3 kg/hook) and incomplete data from ZA (2019 onwards) have been removed.

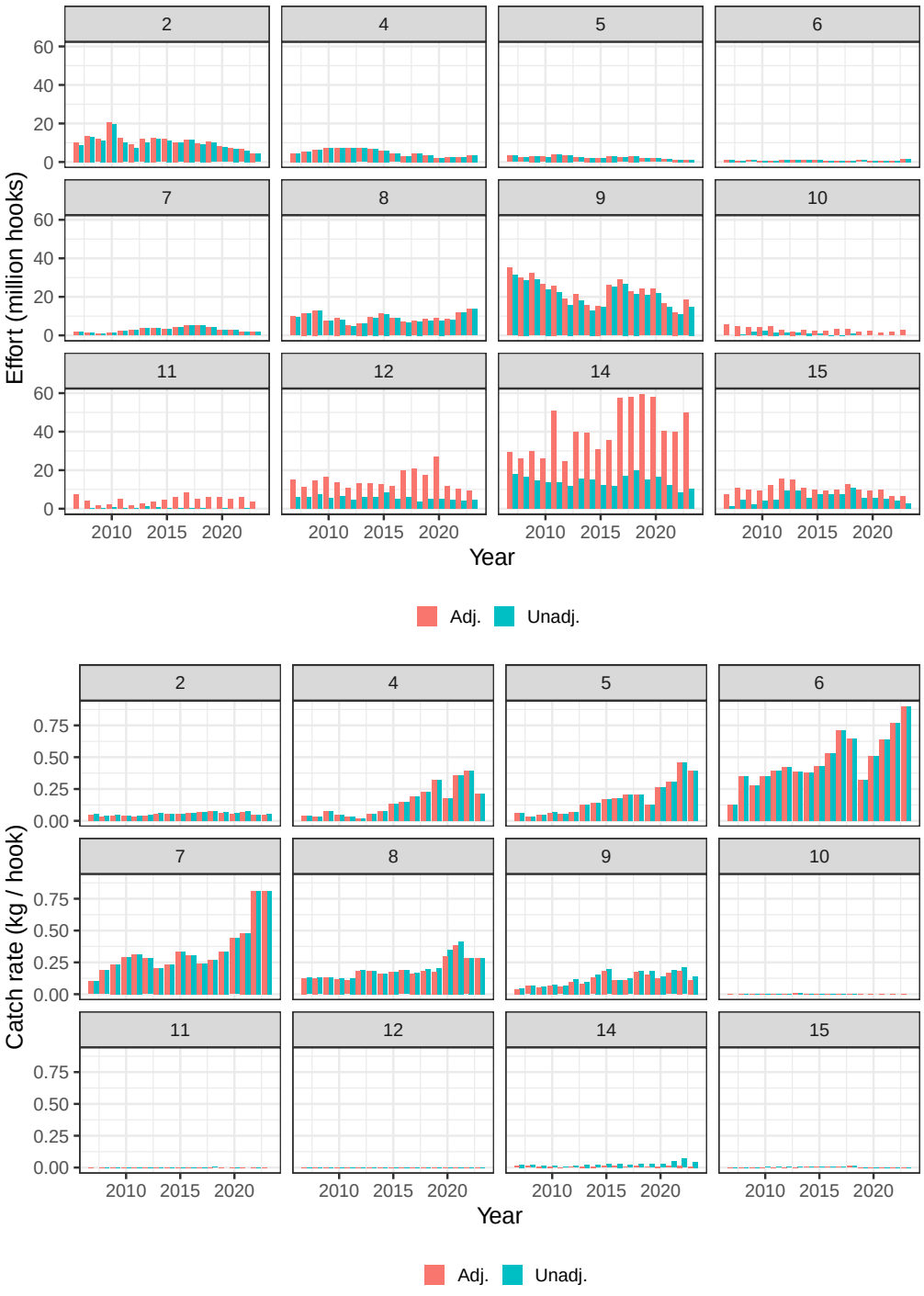


Figure 5: Unadjusted and Adjusted empirical CCSBT effort (top panel) and catch rates (bottom panel), per CCSBT statistical area. Outliers (records with a catch rate of > 3 kg/hook) and incomplete data from ZA (2019 onwards) have been removed.

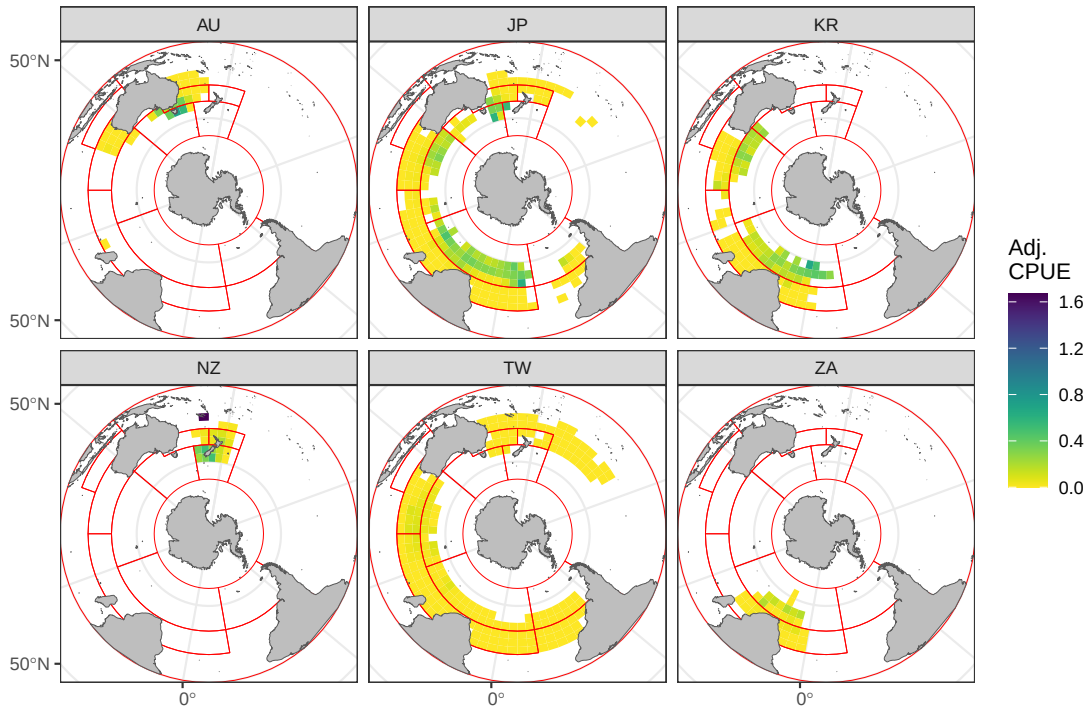


Figure 6: Empirical CCSBT catch rates, assuming an Adjusted catch rate in kg per hook, per CCSBT member flag. Arithmetic mean catch rate values across years are shown, with outliers (records with a catch rate of > 3 kg/hook) and incomplete data from ZA (2019 onwards) removed. Data from latitudes lower than 20°S are also excluded.

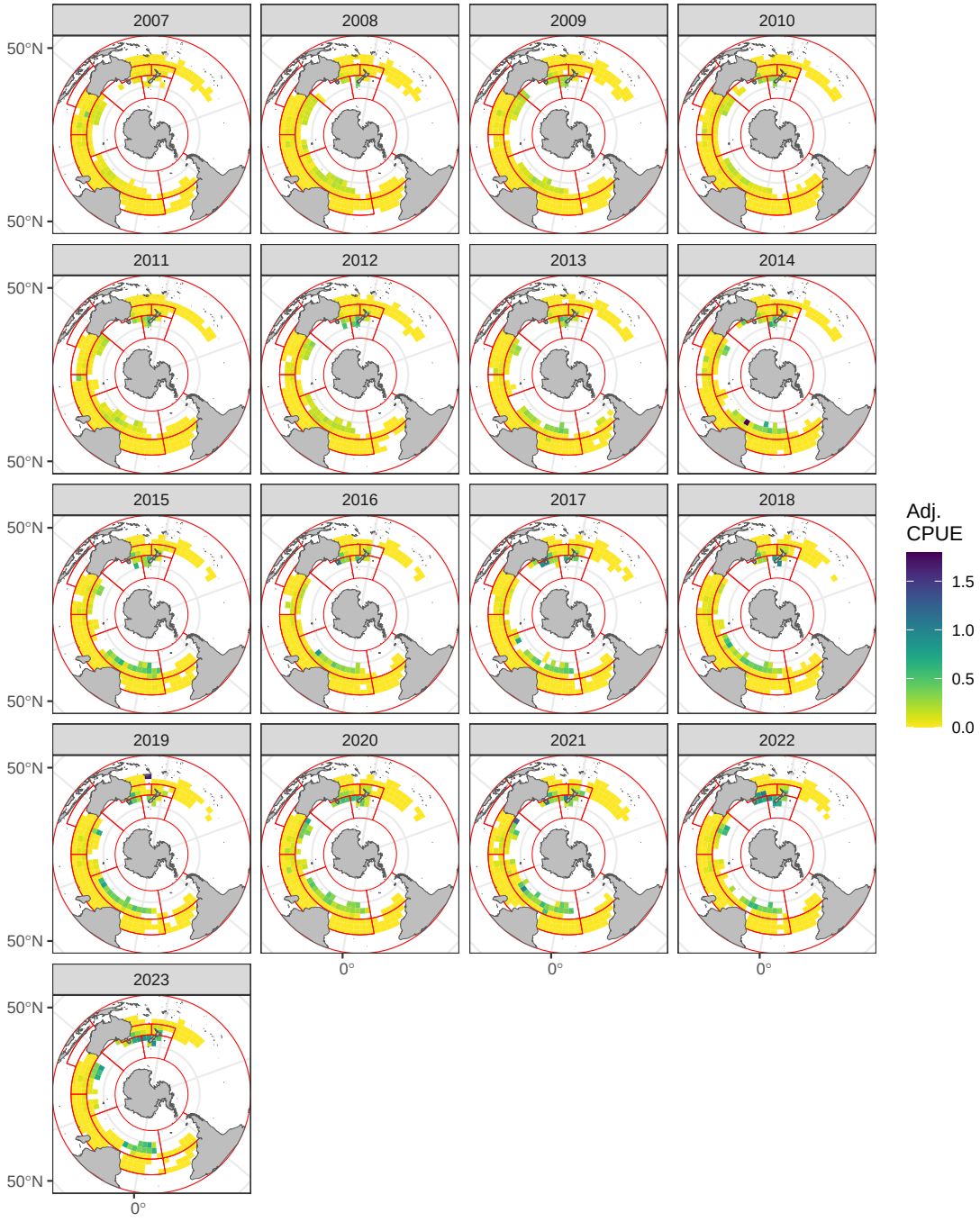


Figure 7: Empirical CCSBT catch rates, assuming an Adjusted catch rate in kg per hook, per year. Arithmetic mean catch rate values across flags are shown, with outliers (records with a catch rate of > 3 kg/hook) and incomplete data from ZA (2019 onwards) removed. Data from latitudes lower than $20°$S are also excluded.

2.3. Effort data from other tuna RFMOs

Longline effort data from 2007 onwards were collected from the other tRFMOs as detailed by Edwards & Hoyle (2022):

- **IOTC:** Publicly available longline effort data were obtained directly from www.iotc.org.
- **ICCAT:** Task II longline effort data were obtained directly from the databases available at www.iccat.int.
- **WCPFC:** Effort data from the WCPFC is submitted to the CCSBT, and was obtained from the secretariat.

Effort data from the Inter-American Tropical Tuna Commission (IATTC) were not included, due to likely low catches of SBT in that region. For the IOTC and WCPFC, all the effort data are represented in the database extracts. For ICCAT however, the effort data are incomplete, since only strata containing effort from three or more vessels is released publicly, and the amount of effort missing is unknown.

Effort was converted to hooks where necessary (a small amount of effort is reported in days fished) and aggregated by $5^\circ \times 5^\circ$ grid cell, by month, calendar year and flag. Effort data from the CCSBT were further used to identify strata likely to yield a positive SBT catch from non-member fleets: specifically, only other tRFMO effort within grid cells south of 20°S with corresponding CCSBT effort for that quarter (in any year), were retained.

Each new database extract was checked against extracts from Edwards & Hoyle (2023), with comparisons shown graphically in Figures A1, A2 and A3. Extracted data were not the same but were largely consistent, and there have been no noticeable changes in the effort reportedly recently, with the exceptions of a large increase in effort reported by Brazil to ICCAT in CCSBT Area 11 (this can be seen in Figure A2) and some unusually large effort values reported by China (CN) to the IOTC. This latter concern was addressed by trimming the upper 2.5% from the aggregated effort data prior to prediction of the catches.

The spatial limits of each other tRFMO and the distribution of non-member effort are illustrated in Figure 8. The total non-member effort over time is shown in Figure 9 and the total non-member effort per other tRFMO and per area are listed in Tables 1 and 2, respectively.

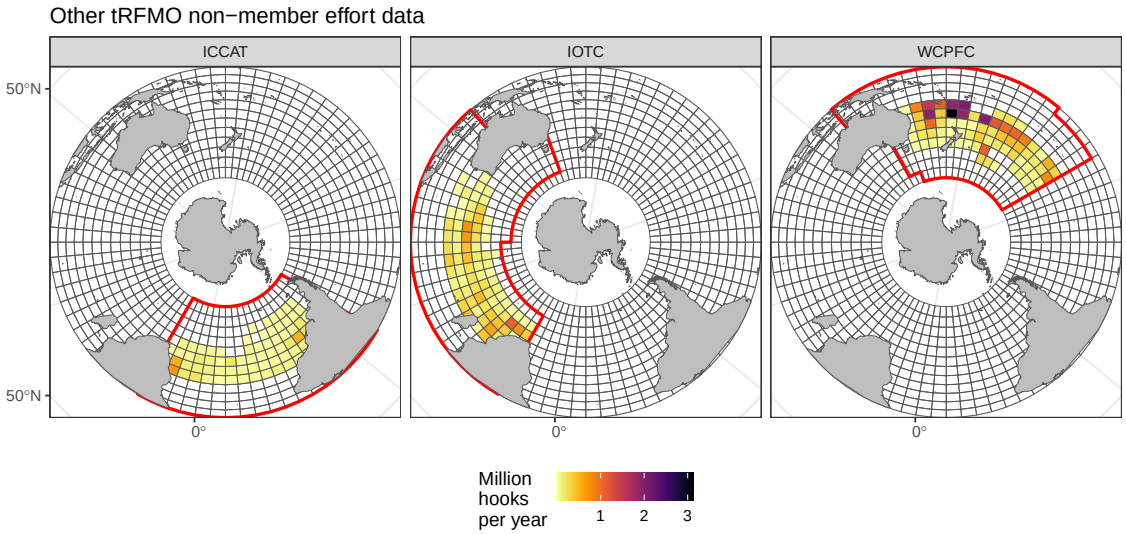


Figure 8: Spatial boundaries for each of the other tRFMOs (excluding IATTC) showing the distribution of non-member fishing effort (million hooks per year) south of 20°S.

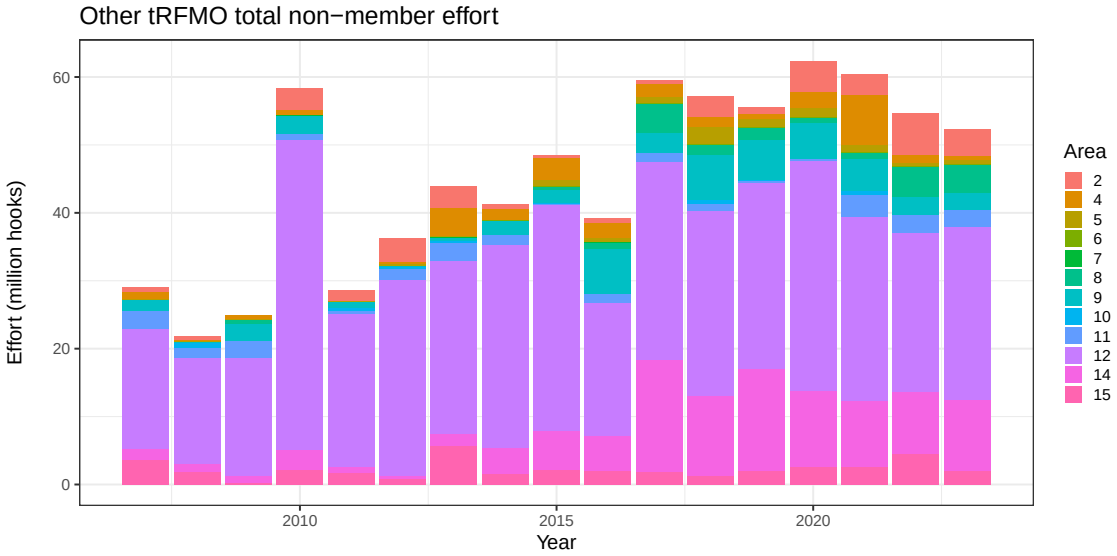


Figure 9: Total non-member effort (million hooks) per year per CCSBT statistical area.

Table 1: Sum of non-member effort (million hooks) per otRFMO. Effort outside of the spatio-temporal domain of the CCSBT effort data (defined per quarter and grid cell) were discarded under the assumption that SBT catch was likely negligible.

Year	ICCAT	IOTC	WCPFC	Total
2007	6.26	4.00	18.73	28.99
2008	4.11	1.83	15.81	21.75
2009	2.90	4.15	17.97	25.02
2010	3.23	8.78	46.30	58.31
2011	2.62	3.43	22.50	28.55
2012	2.76	4.05	29.40	36.21
2013	8.91	5.42	29.61	43.94
2014	3.26	6.45	31.54	41.25
2015	2.62	8.49	37.42	48.53
2016	3.55	13.24	22.36	39.15
2017	3.35	24.20	31.89	59.44
2018	2.96	23.03	31.15	57.14
2019	2.61	23.70	29.29	55.60
2020	2.91	21.77	37.67	62.35
2021	6.54	18.63	35.33	60.50
2022	7.35	22.43	24.94	54.72
2023	4.76	20.77	26.71	52.24

Table 2: Sum of non-member effort (million hooks) per CCSBT statistical area. Effort outside of the spatio-temporal domain of the CCSBT effort data (defined per quarter and grid cell) were discarded under the assumption that SBT catch was likely negligible.

Year	2	4	5	6	7	8	9	10	11	12	14	15	Total
2007	0.68	1.03	0.08	0.00	0.00	0.00	1.68	0.04	2.54	17.63	1.63	3.68	28.99
2008	0.48	0.23	0.03	0.00	0.00	0.01	0.17	0.78	1.39	15.54	1.20	1.92	21.75
2009	0.13	0.54	0.08	0.00	0.00	0.66	2.44	0.02	2.56	17.35	0.93	0.32	25.03
2010	3.25	0.63	0.05	0.00	0.00	0.09	2.73	0.00	0.90	45.62	2.90	2.13	58.30
2011	1.56	0.00	0.01	0.00	0.00	0.18	0.75	0.52	0.42	22.49	0.94	1.67	28.54
2012	3.48	0.35	0.25	0.00	0.00	0.00	0.04	0.38	1.56	28.80	0.53	0.81	36.20
2013	3.27	4.11	0.09	0.00	0.08	0.09	0.50	0.24	2.76	25.33	1.72	5.75	43.94
2014	0.76	1.51	0.09	0.08	0.00	0.00	1.98	0.03	1.58	29.86	3.71	1.64	41.24
2015	0.50	3.24	0.93	0.06	0.00	0.46	1.83	0.17	0.25	33.19	5.69	2.20	48.52
2016	0.77	2.07	0.71	0.00	0.05	0.86	6.53	0.05	1.43	19.53	5.08	2.07	39.15
2017	0.47	1.88	0.99	0.00	0.00	4.39	2.83	0.05	1.44	29.02	16.49	1.86	59.42
2018	3.07	1.46	2.49	0.00	0.00	1.68	6.56	0.65	0.98	27.21	11.72	1.32	57.14
2019	1.06	0.68	1.28	0.00	0.00	1.82	5.85	0.27	0.32	27.33	14.97	2.02	55.60
2020	4.51	2.46	1.36	0.00	0.00	0.90	5.20	0.02	0.31	33.85	11.15	2.58	62.34
2021	3.22	7.30	1.02	0.04	0.00	1.08	4.66	0.49	3.38	26.97	9.67	2.67	60.50
2022	6.27	1.11	0.49	0.03	0.00	4.53	2.54	0.12	2.69	23.32	9.09	4.54	54.73
2023	3.86	0.63	0.66	0.03	0.00	4.11	2.48	0.13	2.52	25.38	10.32	2.12	52.24

2.4. Predictive model

A two-part (delta) log-normal statistical model was used to fit to the CCSBT catch rates and predict the unreported catches from non-member effort. All fitting and prediction was carried out using native functions in the R statistical package (R Core Team 2026).

The model follows that used by Edwards & Hoyle (2023), including the year–area interaction and without further modification or development. In that work, we reported results from a global model fitted to combined data from the Atlantic, Indian and Pacific Oceans, which improved our ability to estimate an interaction term for CCSBT Areas 4 and 7 (previously split between separate models for the Pacific and Indian/Atlantic Oceans) and we follow the same approach here. As before, because the catchability for each non-member fleet is unknown, we bounded the range of possible values using the JP and TW catchability coefficients estimated from the CCSBT data. These are referred to as "surrogate" flags and represent fisheries in which SBT is assumed to be a target (JP) or a bycatch species (TW).

3. RESULTS

3.1. Application of catch-rate model to updated CCSBT data

We fitted the global model from Edwards & Hoyle (2023) to the updated CCSBT data extract. Fits to the catch rate and catch are shown in Figures 10 and 11 respectively, with fits to the 2023 data extract also shown for comparative purposes. Residuals, calculated as the observed minus predicted values, are shown for the catch rate and catch in the Appendix (Figures A4 and A5). In Figures 12 and 13 we map the observed and model predicted catch rates for the Adjusted 2026 data, and demonstrate reasonable predictive ability of the global model.

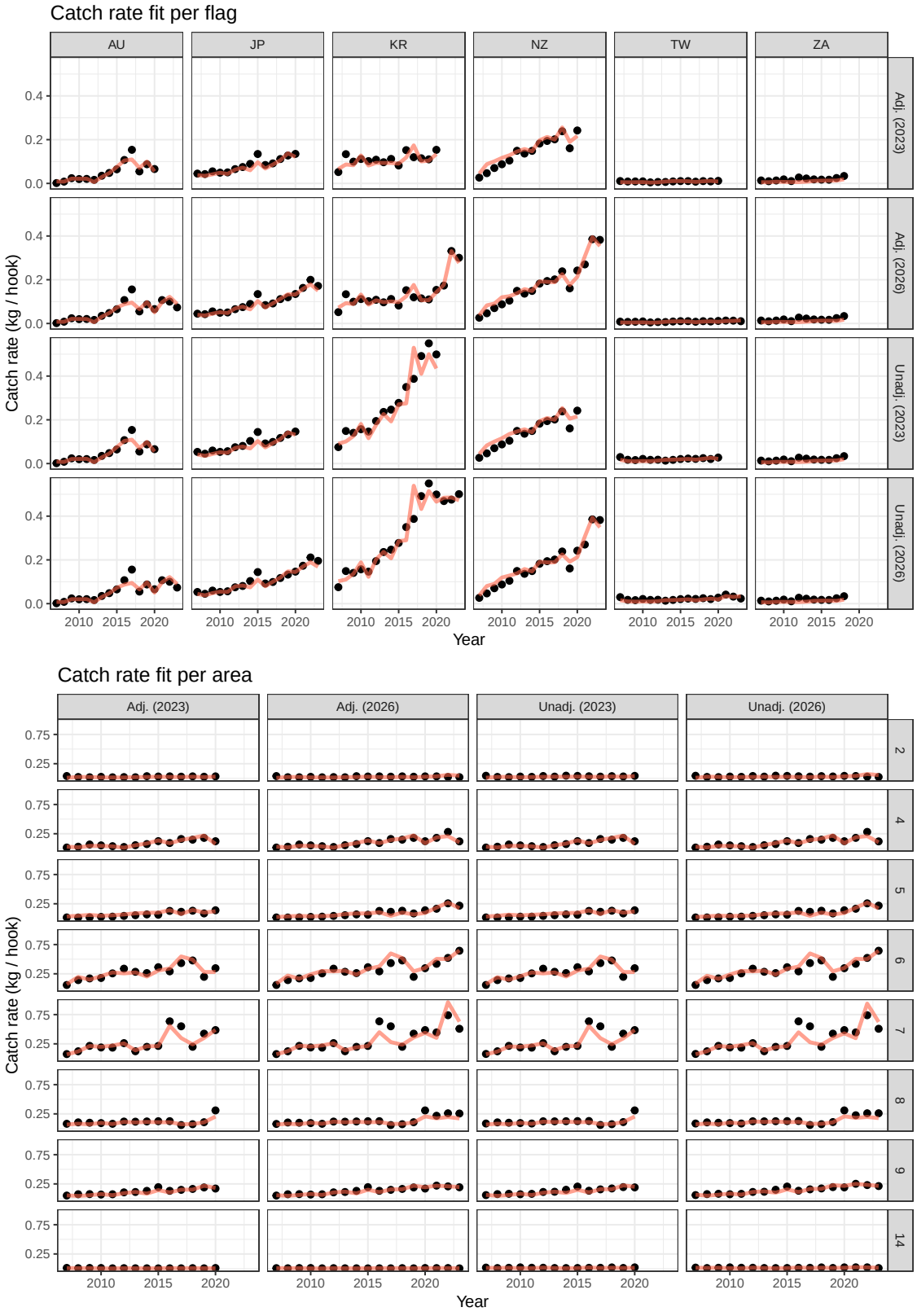


Figure 10: Model fits to empirical CCSBT catch rate data per CCSBT member flag (top panel) and statistical area (bottom panel). Catch rate is calculated as the mean of the catch over effort. Only a subset of the most important areas, in terms of catch, are shown. Observed values are shown as points. Model runs assume either Unadjusted or Adjusted catch rates, using the previous (2023) and updated (2026) data extracts.

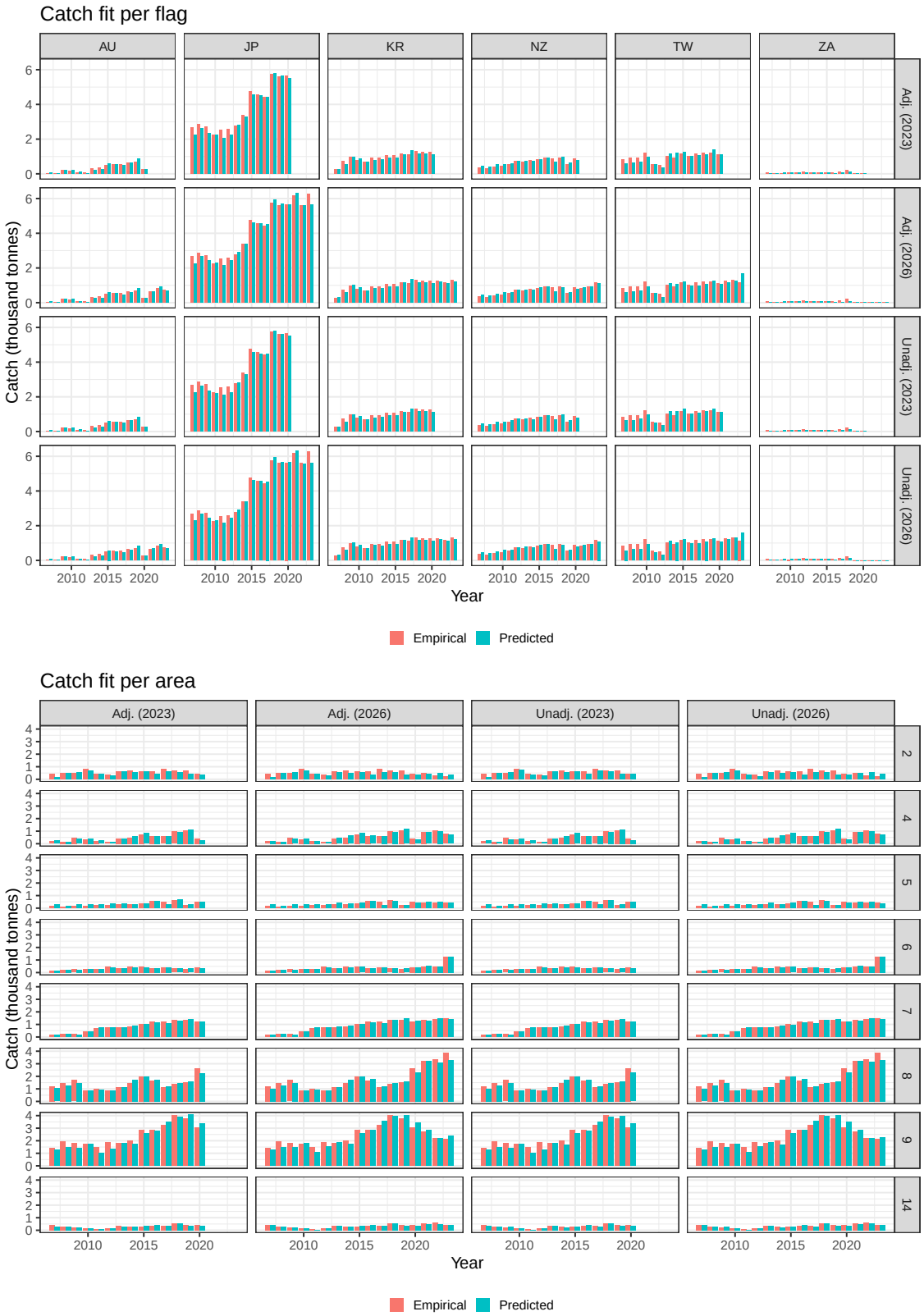


Figure 11: Prediction of empirical CCSBT catch data per CCSBT member flag (top panel) and statistical area (bottom panel). Only a subset of the most important areas, in terms of catch, are shown. Model runs assume either Unadjusted or Adjusted catch rates, using the previous (2023) and updated (2026) data extracts.

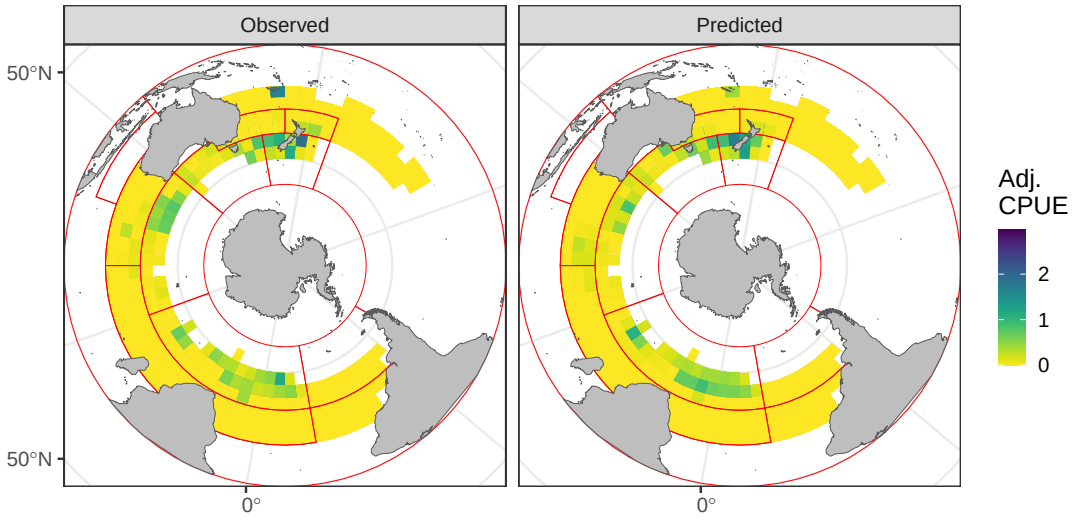


Figure 12: Global prediction of empirical CCSBT catch rate data, assuming an Adjusted catch rate. Catch rate is calculated as the mean of the catch over effort per grid cell

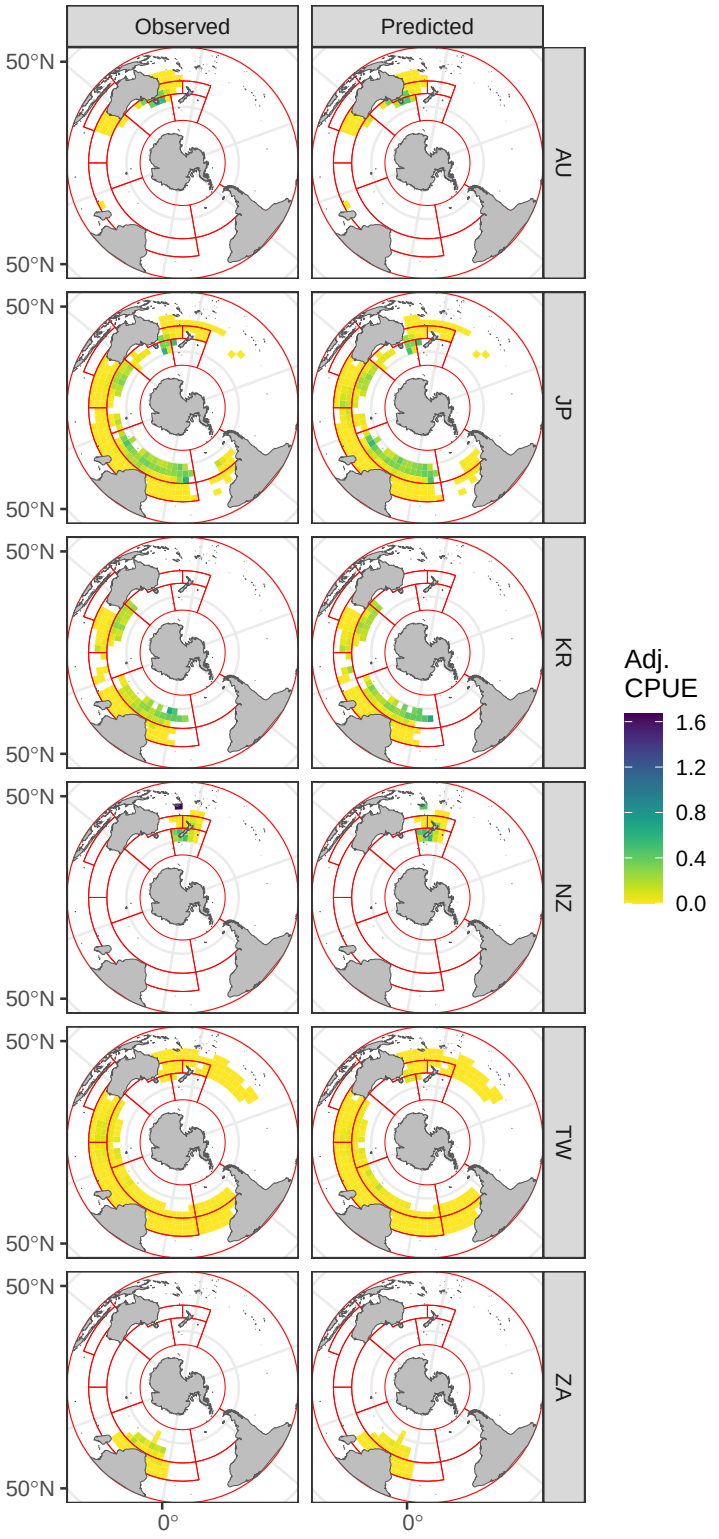


Figure 13: Global prediction of empirical CCSBT catch rate data, assuming an Adjusted catch rate, per CCSBT member flag. Catch rate is calculated as the mean of the catch over effort per grid cell and flag.

3.2. Prediction of non-member catches

Estimated catch rates were applied to predict non-member catches using the updated effort from other tRFMOs. Predictions over time are compared to the 2023 estimates in Figures 14, demonstrating reasonable consistency for the overlapping period when using the Adjusted catch rate data.

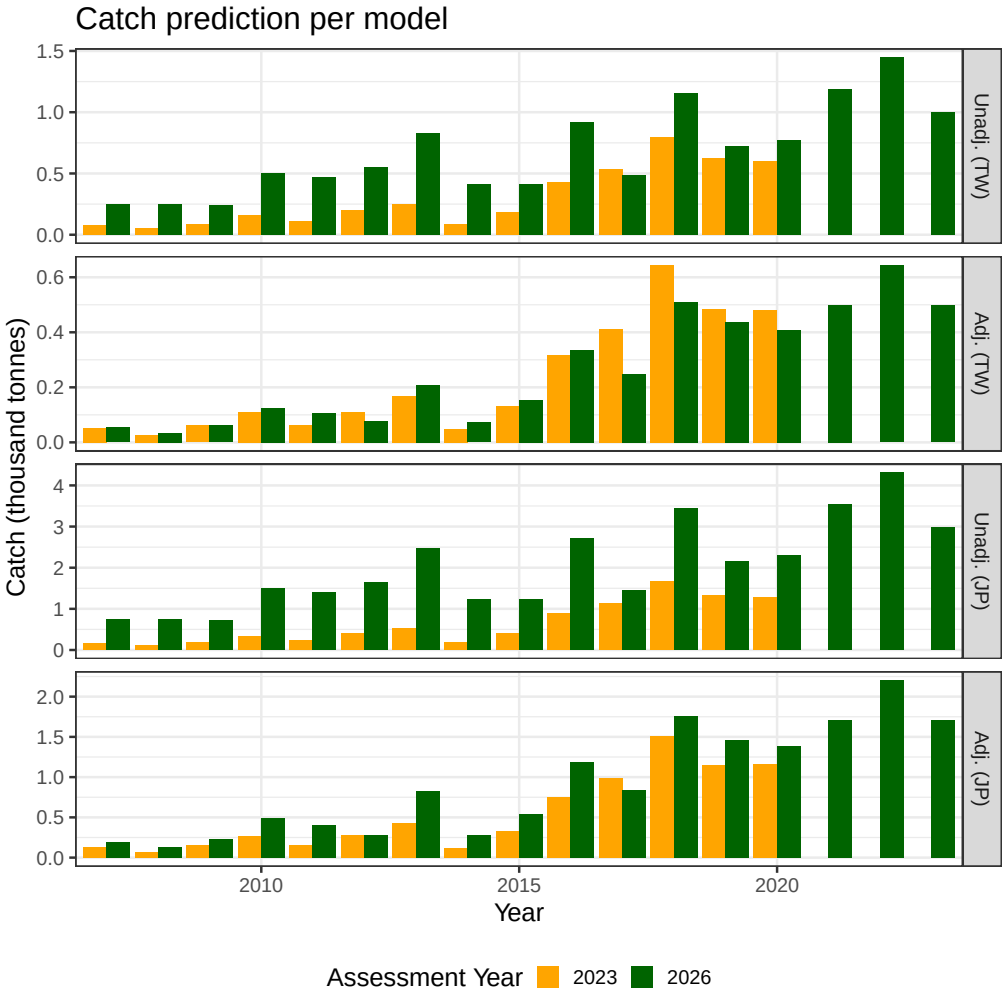


Figure 14: Prediction of total non-member catches per year, assuming Adjusted and Unadjusted CCSBT catch rate data (for estimation of the catch rates) and either TW or JP surrogate flags assumed for the non-member fishing effort.

Results are listed in Table 3 and summarised over time and space in Figures 15 and 16, respectively. The non-member catches per non-member flag state are listed in Table 4 and per statistical area in Table 5.

Table 3: Global estimates of UAM summed across statistical areas and assuming Adjusted and Unadjusted CCSBT catch rates. Either JP or TW surrogate flags are assumed for the non-member effort. The range of values assumes lower and upper limits from the TW and JP catchabilities respectively.

Year	Unadj. (TW)	Adj. (TW)	Unadj. (JP)	Adj. (JP)	Mean and range (Unadj.)	Mean and range (Adj.)
2007	247	54	733	196	490 (247 – 733)	125 (54 – 196)
2008	248	34	736	129	492 (248 – 736)	82 (34 – 129)
2009	243	61	721	224	482 (243 – 721)	142 (61 – 224)
2010	505	124	1501	487	1003 (505 – 1501)	306 (124 – 487)
2011	471	106	1399	404	935 (471 – 1399)	255 (106 – 404)
2012	553	77	1641	286	1097 (553 – 1641)	182 (77 – 286)
2013	830	209	2465	822	1648 (830 – 2465)	516 (209 – 822)
2014	411	73	1222	276	816 (411 – 1222)	174 (73 – 276)
2015	413	154	1228	543	820 (413 – 1228)	348 (154 – 543)
2016	915	337	2722	1182	1818 (915 – 2722)	760 (337 – 1182)
2017	490	248	1458	843	974 (490 – 1458)	546 (248 – 843)
2018	1159	509	3447	1755	2303 (1159 – 3447)	1132 (509 – 1755)
2019	723	437	2156	1455	1440 (723 – 2156)	946 (437 – 1455)
2020	773	407	2303	1379	1538 (773 – 2303)	893 (407 – 1379)
2021	1185	499	3528	1710	2356 (1185 – 3528)	1104 (499 – 1710)
2022	1446	642	4307	2201	2876 (1446 – 4307)	1422 (642 – 2201)
2023	1001	498	2981	1704	1991 (1001 – 2981)	1101 (498 – 1704)

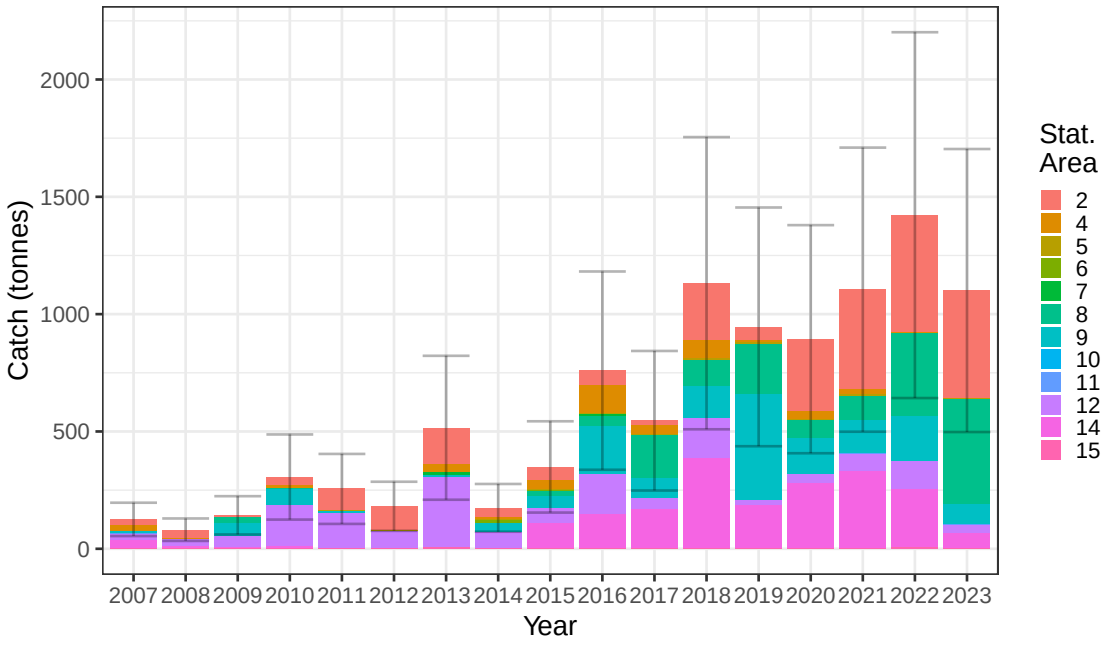


Figure 15: Prediction of total UAM catches by CCSBT non-members assuming Adjusted CCSBT catch rates. Surrogate JP and TW flags provide upper and lower bounds per year. Filled bars represent the mean of JP and TW values per statistical area.

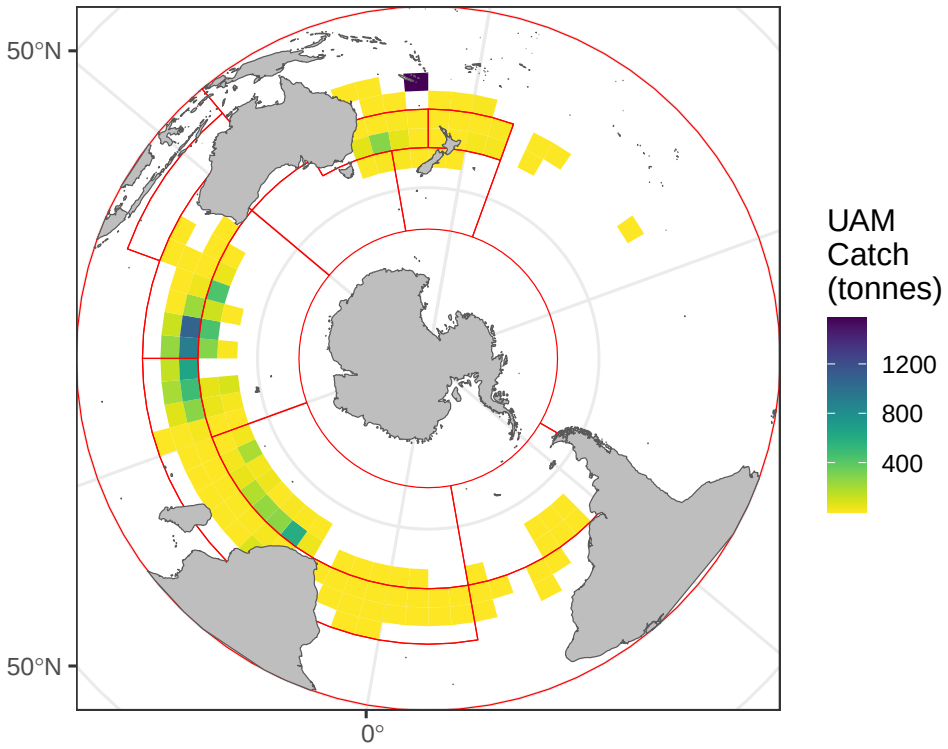


Figure 16: Prediction of average UAM catches per year by CCSBT non-members assuming Adjusted CCSBT catch rates. Surrogate JP and TW flags provide upper and lower bounds per year and figure illustrates the mean of JP and TW values per grid.

Table 4: Global estimates of UAM per non-member flag state assuming Adjusted CCSBT catch rates. Either JP or TW surrogate flags are assumed for the non-member effort. The range of values assumes lower and upper limits from the TW and JP catchabilities respectively and represents uncertainty in the fishing behaviour of non-member vessels.

Year	China (CN)	Seychelles (SC)	Namibia (NA)	Uruguay (UY)	Fiji (FJ)	Solomon Islands (SB)	Vanuatu (VU)	Other
2007	8 – 27	22 – 73	0 – 1	0 – 0	0 – 2	0 – 0	12 – 41	12 – 53
2008	16 – 55	5 – 20	0 – 0	0 – 0	1 – 3	0 – 0	2 – 7	10 – 44
2009	37 – 124	7 – 24	0 – 0	0 – 0	0 – 0	0 – 0	2 – 8	15 – 68
2010	45 – 153	9 – 33	0 – 0	0 – 0	1 – 3	0 – 1	9 – 35	60 – 262
2011	87 – 322	4 – 14	0 – 0	0 – 0	1 – 7	0 – 0	3 – 12	11 – 50
2012	61 – 213	0 – 0	0 – 0	0 – 0	2 – 11	0 – 0	1 – 7	12 – 54
2013	168 – 650	4 – 16	0 – 1	2 – 9	2 – 9	0 – 0	10 – 35	22 – 103
2014	26 – 89	19 – 64	0 – 1	0 – 0	0 – 2	3 – 15	5 – 16	19 – 89
2015	86 – 288	37 – 124	0 – 2	0 – 0	0 – 2	0 – 2	7 – 23	23 – 103
2016	148 – 490	88 – 291	0 – 1	0 – 0	0 – 2	0 – 1	2 – 8	98 – 389
2017	102 – 336	104 – 350	0 – 0	0 – 0	0 – 1	0 – 0	20 – 67	21 – 89
2018	354 – 1173	75 – 258	0 – 0	0 – 0	0 – 1	0 – 0	37 – 128	44 – 194
2019	153 – 515	158 – 533	0 – 1	0 – 0	0 – 1	1 – 3	3 – 11	121 – 390
2020	279 – 931	97 – 330	0 – 1	0 – 0	0 – 1	0 – 1	18 – 59	12 – 57
2021	334 – 1105	95 – 329	0 – 2	0 – 0	1 – 2	0 – 0	10 – 36	60 – 236
2022	500 – 1661	19 – 70	2 – 9	0 – 0	1 – 3	0 – 0	2 – 9	118 – 450
2023	430 – 1447	48 – 171	1 – 5	0 – 0	0 – 1	0 – 0	1 – 5	17 – 75

Table 5: Global estimates of UAM per CCSBT statistical area assuming Adjusted CCSBT catch rates. The range of values assumes lower and upper limits from the TW and JP catchabilities respectively.

Year	2	4	5	6	7	8	9	10	11	12	14	15
2007	12 – 40	11 – 37	0 – 0	0 – 0	0 – 0	0 – 0	5 – 18	0 – 0	0 – 0	10 – 46	15 – 53	0 – 1
2008	17 – 59	1 – 5	0 – 0	0 – 0	0 – 0	0 – 0	1 – 2	0 – 0	0 – 0	10 – 45	5 – 18	0 – 0
2009	3 – 10	1 – 4	0 – 0	0 – 0	0 – 0	11 – 35	27 – 90	0 – 0	0 – 0	16 – 72	3 – 13	0 – 0
2010	15 – 51	7 – 23	0 – 0	0 – 0	0 – 1	1 – 4	32 – 109	0 – 0	0 – 0	64 – 279	6 – 20	0 – 0
2011	45 – 143	0 – 0	0 – 0	0 – 0	0 – 0	1 – 3	3 – 12	0 – 0	0 – 0	57 – 245	0 – 0	0 – 0
2012	49 – 160	0 – 1	0 – 1	0 – 0	0 – 0	0 – 0	0 – 0	0 – 0	0 – 0	27 – 124	0 – 0	0 – 0
2013	69 – 243	16 – 56	0 – 0	0 – 0	5 – 14	0 – 1	4 – 16	0 – 0	0 – 0	112 – 479	0 – 2	2 – 10
2014	18 – 62	5 – 17	1 – 3	6 – 17	0 – 0	0 – 0	18 – 62	0 – 0	0 – 0	23 – 109	1 – 5	0 – 1
2015	26 – 88	18 – 61	1 – 3	2 – 6	0 – 0	10 – 32	25 – 84	0 – 0	0 – 0	23 – 103	50 – 165	0 – 2
2016	28 – 95	57 – 184	1 – 5	0 – 0	4 – 12	21 – 69	97 – 314	0 – 0	0 – 0	61 – 274	67 – 227	0 – 1
2017	8 – 27	20 – 64	1 – 5	0 – 0	0 – 0	88 – 283	37 – 127	0 – 0	0 – 0	17 – 77	77 – 261	0 – 0
2018	117 – 373	33 – 113	5 – 20	0 – 0	0 – 0	50 – 165	64 – 214	0 – 0	0 – 0	62 – 280	178 – 589	0 – 0
2019	27 – 89	3 – 11	3 – 11	0 – 0	0 – 0	102 – 331	214 – 691	0 – 0	0 – 0	7 – 33	82 – 288	0 – 1
2020	142 – 474	15 – 50	3 – 10	0 – 0	0 – 0	33 – 112	73 – 241	0 – 0	0 – 0	14 – 64	127 – 427	0 – 1
2021	198 – 651	9 – 31	5 – 17	0 – 0	0 – 0	46 – 155	65 – 223	0 – 0	0 – 0	26 – 124	150 – 507	0 – 2
2022	227 – 772	1 – 3	1 – 3	1 – 2	0 – 0	167 – 539	87 – 294	0 – 0	0 – 0	42 – 194	115 – 385	2 – 9
2023	205 – 714	0 – 1	1 – 5	0 – 0	0 – 0	212 – 683	39 – 138	0 – 0	0 – 0	13 – 61	27 – 97	1 – 5

4. CONCLUSIONS AND FURTHER WORK

In the current work we have applied the model scripts developed by Edwards & Hoyle (2023) to updated data extracts, allowing prediction of the NCNM catches up to 2023 inclusive. Results show that catches have fluctuated around a thousand tonnes per year since 2018 (Figure 15), but the range of possible values is wide, and may have reached up to two thousand tonnes in 2022. Most of the catches are predicted to be from the Indian Ocean (Figure 16), particularly CCSBT statistical areas 2 and 14.

Outstanding issues remain, which could warrant further exploration, the most important of which concerns the existence of spatio-temporal patterns in the data. These were partially addressed through inclusion of a year-area interaction in the model of the non-zero catches (Section 2.4., Edwards & Hoyle 2023), however moving to a fully spatio-temporal representation of the data would likely yield a more stable and accurate result. As part of this model development, uncertainty could be properly estimated in a manner that accounts for the multiple modelling stages (i.e., conversion of JP catch data from numbers to weight followed by application of a two-part model to the predicted values). At present, estimation uncertainty is not reported.

The current approach of bounding uncertainty in the predicted catches using the estimated TW and JP catchabilities as surrogate flags no doubt includes much of the estimation error, but this approach could also be improved. The TW fleet is assumed to catch SBT as bycatch, whereas the JP fleet is assumed to catch SBT through targeted fishing, however the two fleets have very different spatial distributions and it is unlikely that the estimated flag-specific catchability effects are being fully separated from spatio-temporal changes in the underlying population biomass distribution. An assumption that NCNM fleets operating at lower latitudes can have a catchability equal to the high latitude JP fleet, especially when operating at different times of the year, may lead to an overestimation of the predicted catches. This may be more of a problem than the assumption of a TW catchability for NCNM fleets because the TW fleet appears to have a higher degree of spatio-temporal overlap. We propose that the current approach of calculating a range of possible catches using TW and JP surrogate flags only be used for strata in which CCSBT catch rate data from both TW and JP are recorded. Otherwise, we would make an alternate assumption, such as only using the flag of the fleet or fleets present in that strata.

It is likely that further improvements could also be made in the grooming and preparation of the effort data from other tRFMOs. For example, it has been assumed that SBT catches are zero in strata for which no CCSBT effort data have been reported, meaning that effort data from other tRFMOs can be ignored. However, the definition of these strata does not consider the possibility that the spatial distribution of SBT may have changed over time, and could likely be improved. These suggested updates are left for further work.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

CCSBT (2016). Report of the Twenty First Meeting of the Scientific Committee, 10 September 2016. *Commission for the Conservation of Southern Bluefin Tuna*

CCSBT (2019). Report of the Twenty Fourth Meeting of the Scientific Committee, Cape Town, South Africa, 7 September 2019. *Commission for the Conservation of Southern Bluefin Tuna*

CCSBT (2021). Report of the Twenty Sixth Meeting of the Scientific Committee, Online meeting, 31 August 2021. *Commission for the Conservation of Southern Bluefin Tuna*

Chambers, M.; Hoyle, S. (2015). Estimates of non-Member catch of SBT in the Indian and Pacific Oceans. *20th Meeting of the CCSBT Extended Scientific Committee. Australian Bureau of Agricultural and Resource Economics and Sciences, Australia. Document No. CCSBT-ESC/1509/10*

Edwards, C.; Hoyle, S. (2022). Estimates of unreported longline effort by CCSBT non-cooperating non-member states between 2007 and 2020. *12th Operating Model and Management Procedure Technical Meeting. Ministry for Primary Industries, New Zealand. Document No. CCSBT-OMMP/2206/10*

Edwards, C.; Hoyle, S. (2023). Estimates of unreported SBT catch by CCSBT non-cooperating non-member states between 2007 and 2020. *13th Operating Model and Management Procedure Technical Meeting. Ministry for Primary Industries, New Zealand. Document No. CCSBT-OMMP/2306/07*

Edwards, C.; Parsa, M.; Williams, A.; Hoyle, S. (2019). Estimates of SBT catch by CCSBT non-cooperating non-member states between 2007 and 2017. *24th Meeting of the CCSBT Extended Scientific Committee. Ministry for Primary Industries, New Zealand. Document No. CCSBT-ESC/1909/33*

Edwards, C.; Parsa, M.; Williams, A.; Hoyle, S. (2020). Estimates of SBT catch by CCSBT non-cooperating non-member states between 2007 and 2017 (Supplementary Material). *11th Operating Model and Management Procedure Technical Meeting. Ministry for Primary Industries, New Zealand. Document No. CCSBT-OMMP/2006/04*

Edwards, C.; Williams, A.; Hoyle, S. (2016). Updated estimates of Southern Bluefin Tuna catch CCSBT Non-Member states. *21st Meeting of the CCSBT Extended Scientific Committee. Ministry for Primary Industries, New Zealand. Document No. CCSBT-ESC/1609/BGD02 (Rev.1)*

Francis, M.; Hoyle, S. (2019). Estimation of fishing effort in the Southern Hemisphere. *New Zealand Aquatic Environment and Biodiversity Report No. 213*

Hoyle, S.; Chambers, M. (2015). Estimating Southern Bluefin Tuna Catches by Non-Members of CCSBT. *20th Meeting of the CCSBT Extended Scientific Committee. Ministry for Primary Industries, New Zealand. Document No. CCSBT-ESC/1509/2*

Larcombe, J. (2014). Fleet overlap in the IOTC area. *19th Meeting of the CCSBT Extended Scientific Committee. Australian Bureau of Agricultural and Resource Economics and Sciences, Australia. Document No. CCSBT-ESC/1409/13*

Polacheck, T. (2012). Assessment of IUU fishing for Southern Bluefin Tuna. *Marine Policy 36*: 1150 – 1165.

R Core Team (2026). R: A Language and Environment for Statistical Computing (v4.5). R Foundation for Statistical Computing, Vienna, Austria

7. APPENDIX

7.1. Other tRFMO effort data

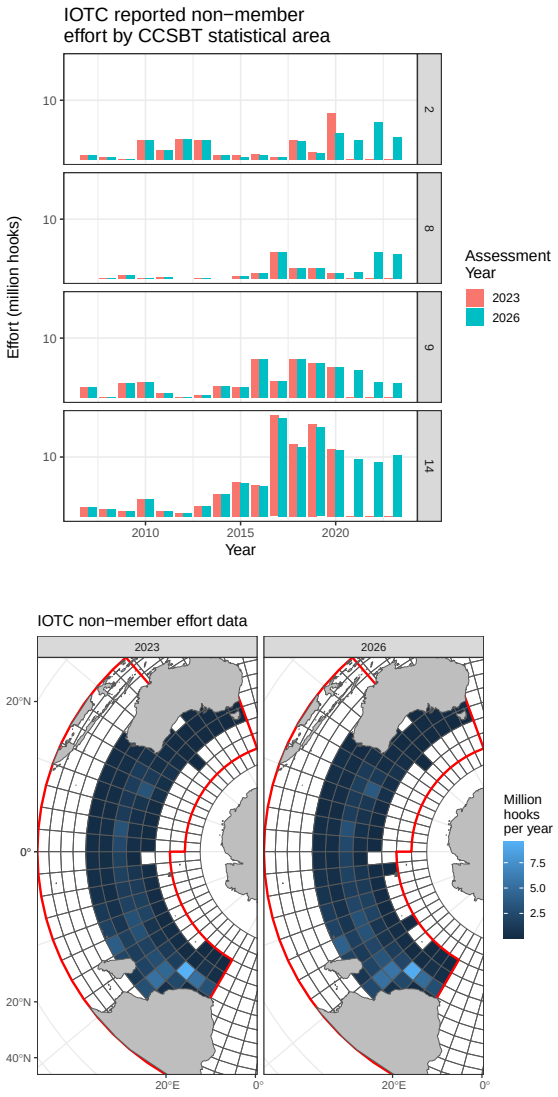


Figure A1: Validation of IOTC data extract. Groomed effort data from the previous (Edwards & Hoyle 2023) and current (2026) assessments are compared over time (top panel) and spatially (bottom panel).

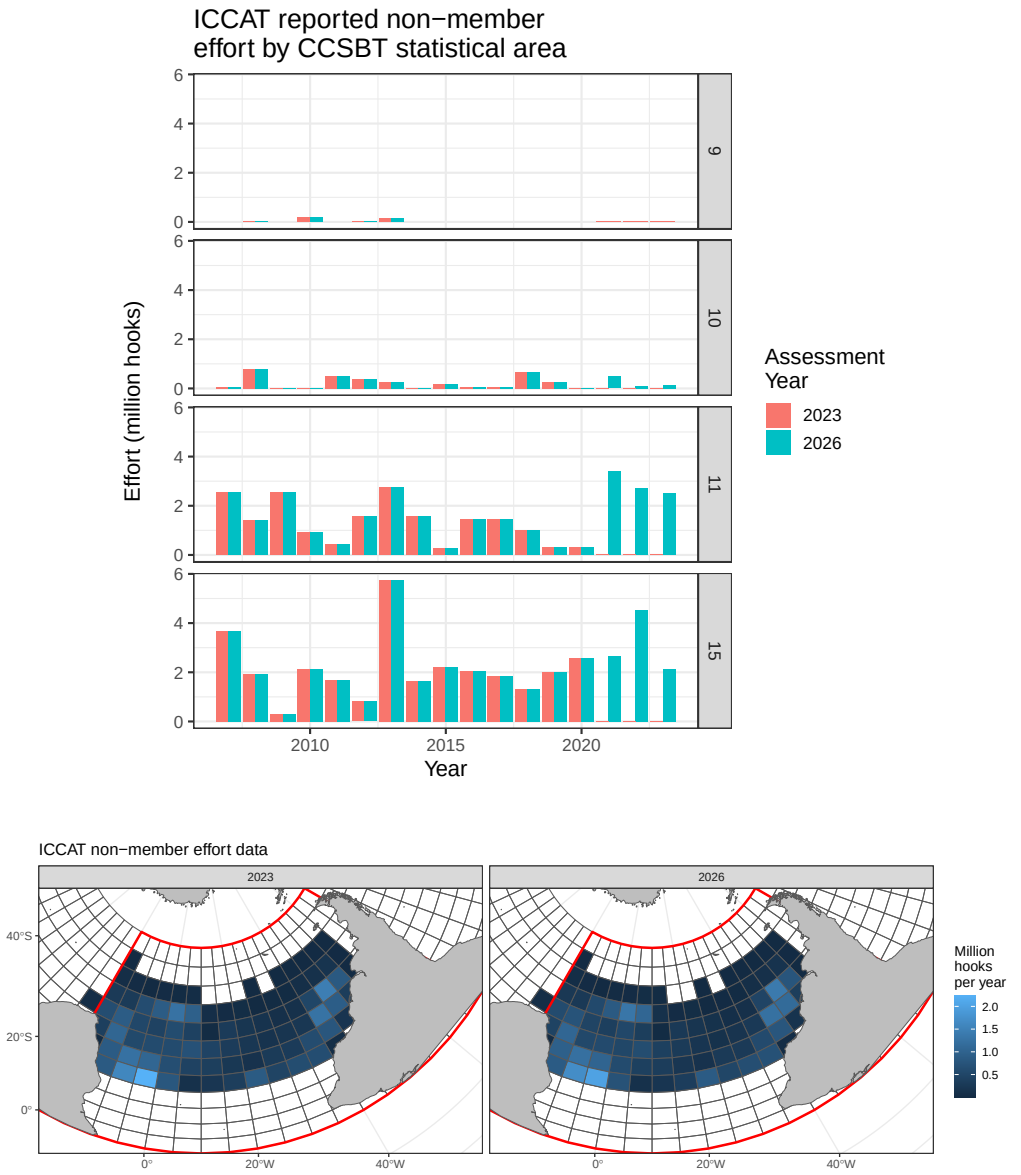


Figure A2: Validation of ICCAT data extract. Groomed effort data from the previous (Edwards & Hoyle 2023) and current (2026) assessments are compared over time (top panel) and spatially (bottom panel). The large increase in effort reported in Area 11 since 2021, is attributed to Brazil.

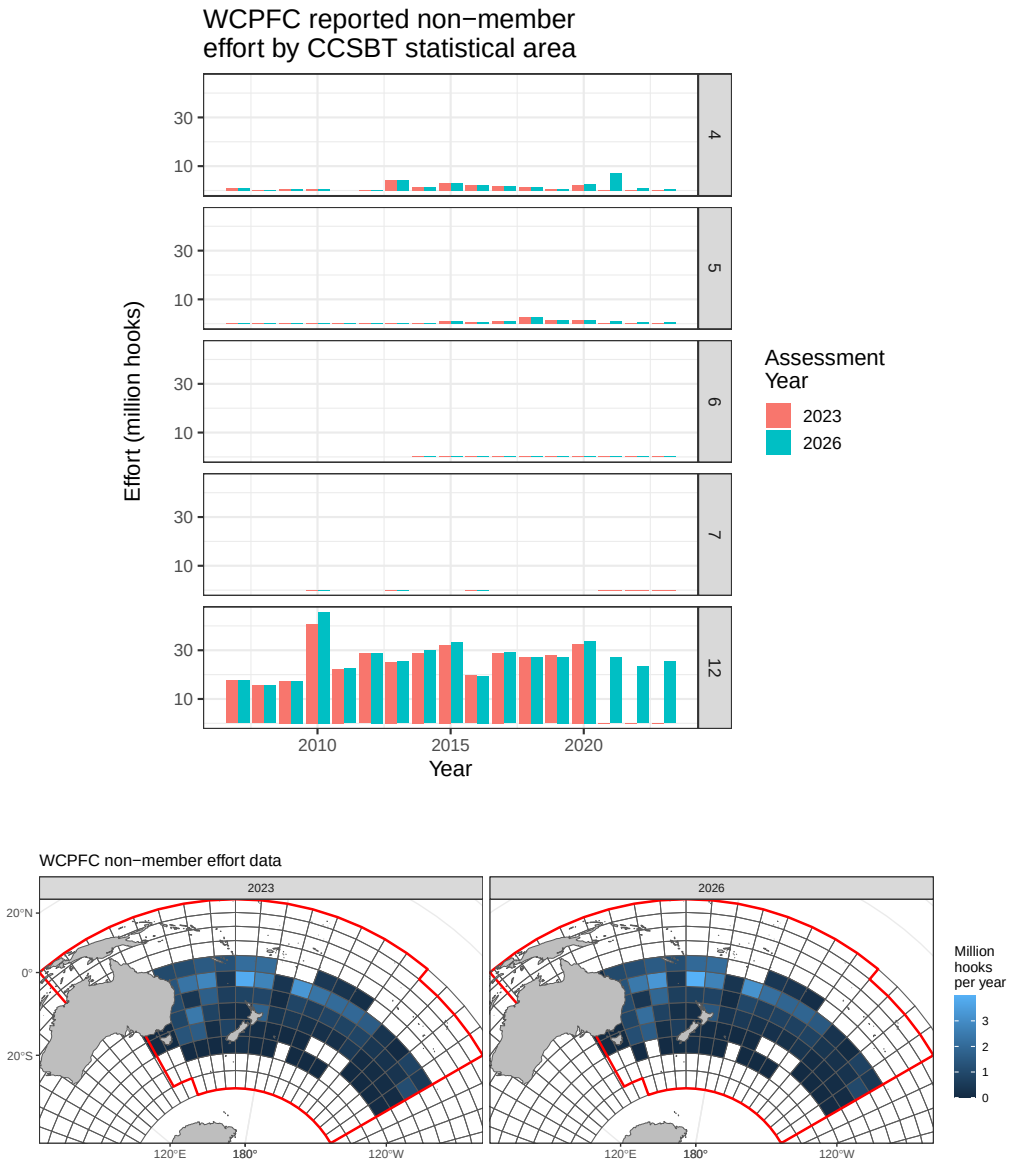


Figure A3: Validation of WCPFC data extract. Effort data from the previous (Edwards & Hoyle 2023) and current (2026) assessments are compared over time (top panel) and spatially (bottom panel).

7.2. Residual diagnostics

Residual diagnostics were generated from the predicted model catches. The residual was calculated as:

$$r = y - \hat{y}$$

where $\hat{y}$ is the catch predicted by the two-part model, and y is the observed value. Residuals were plotted against model fixed effects, with trends across values for each predictor indicative of model mis-specification. Figures A4 and A5 illustrate residual distributions for catch rate and catch predicted by the global model. There are no apparent trends in the residual distributions across covariate factor levels.

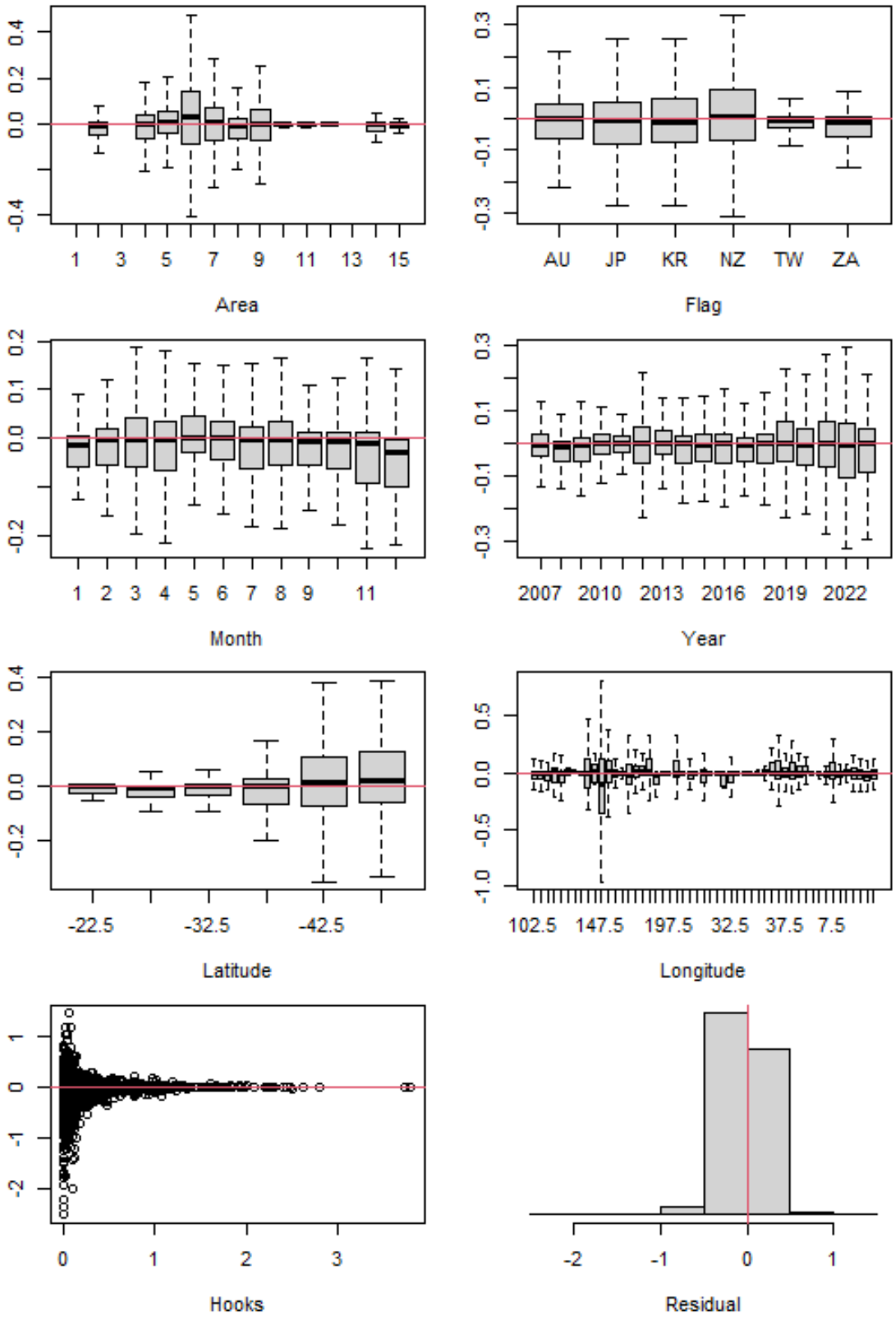


Figure A4: Unstandardised catch rate residual diagnostics for the global model fit, applied to the updated (2026) CCSBT data. Residuals are calculated using predicted values from the two-part model.

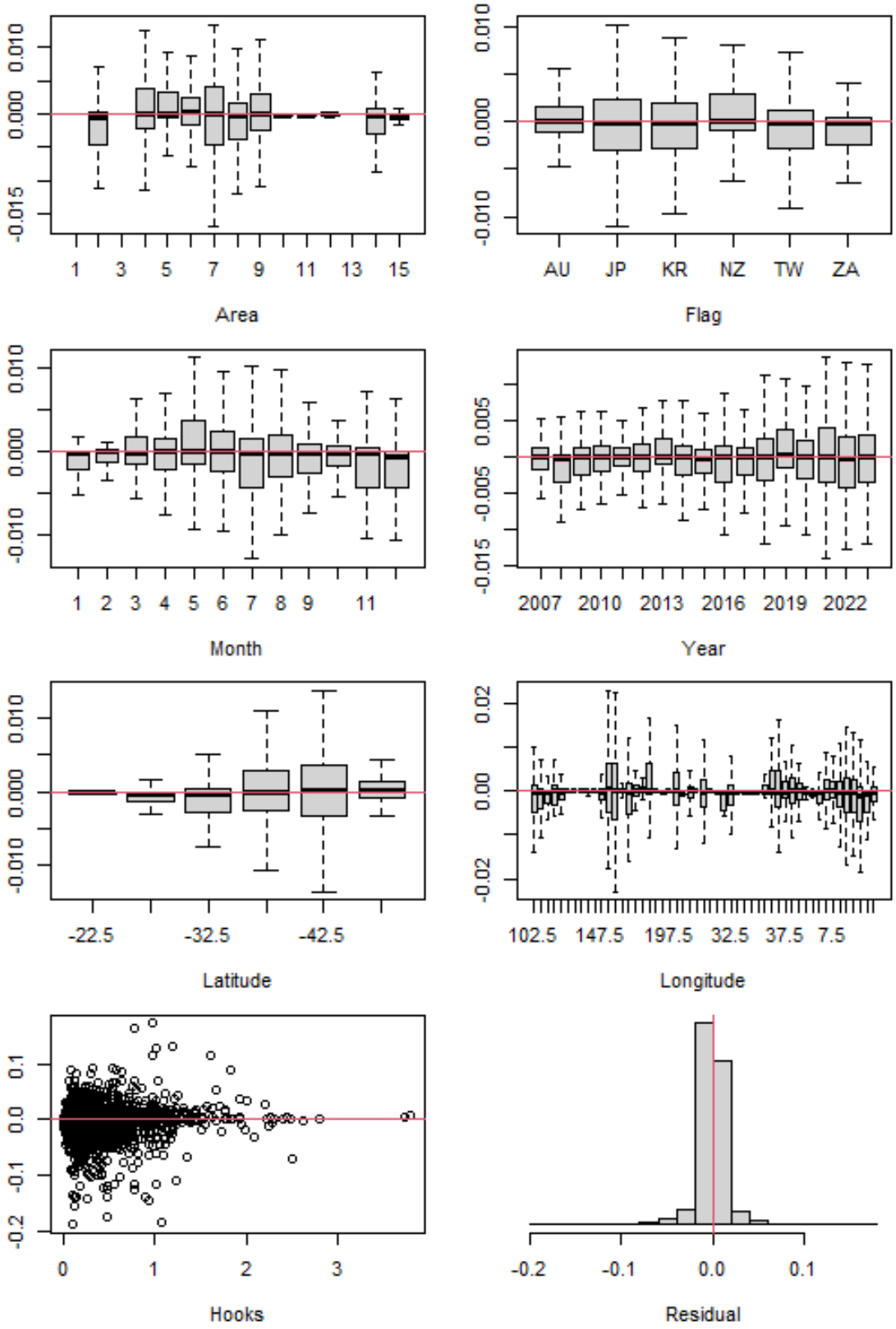


Figure A5: Unstandardised catch residual diagnostics for the global model fit, applied to the updated (2026) CCSBT data. Residuals are calculated using predicted values from the two-part model.