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Rapid updates for New Zealand rock lobster (*Jasus edwardsii*) stocks in 2021

New Zealand Fisheries Assessment Report 2022/36

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Rudd, M.B.[1]; Webber, D.N.[2]; Starr, P.J.[3] (2022). Rapid updates for New Zealand rock lobster (*Jasus edwardsii*) stocks in 2021.

***New Zealand Fisheries Assessment Report 2022/36*. 60 p.**

This document describes the operation of rapid updates done in October 2021 that can be used to guide management decisions of New Zealand red rock lobster (*Jasus edwardsii*) Quota Management Areas (QMAs).

Full stock assessments for each rock lobster stock are generally done once every five years. Full stock assessments require significant time and effort, including a review of the previous stock assessment and data inputs, updates to data processing code, the addition of new data, implementation of new structural changes to the model, review of prior specifications for model parameters, and runs of many sensitivities to key model assumptions. For rock lobsters, the last few stock assessments have involved five stock assessment scientists working for over five weeks to complete two stock assessments, working under the guidance of the Rock Lobster Working Group.

Rapid updates differ from a full stock assessment because they repeat the previous base case stock assessment model(s), with the same model settings and assumptions, and only update inputs with new covariates and data (e.g., additional years of catch, length frequencies, sex ratios, and tag-recapture data). This significantly speeds up the required process, with the result being that every stock can have a rapid update done each year. Rapid updates do not aim to replace full stock assessments but complement them by providing inference about stock status in the interim years between full assessments.

This document presents rapid updates for five rock lobster QMAs: CRA 1, CRA 2, CRA 3, CRA 4, and CRA 5. The first stock assessment for CRA 7&8 using the lobster stock dynamics model was done in 2021 so this stock assessment will be integrated into the rapid update system in 2022. There is no accepted stock assessment for CRA 9.

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[2] Quantifish Ltd, New Zealand.
[3] Independent consultant.

1. INTRODUCTION

The red rock lobster (*Jasus edwardsii*) supports the most valuable inshore commercial fishery in New Zealand, with exports worth NZ$300 million in 2019 (Seafood New Zealand 2020), and is also valuable to customary Māori and recreational fishers. Commercial rock lobster fisheries have been managed since April 1990 with Individual Transferable Quotas (ITQs) in nine Quota Management Areas (QMAs) which are usually treated as independent stocks for stock assessment (Breen et al. 2016a, Figure 1).

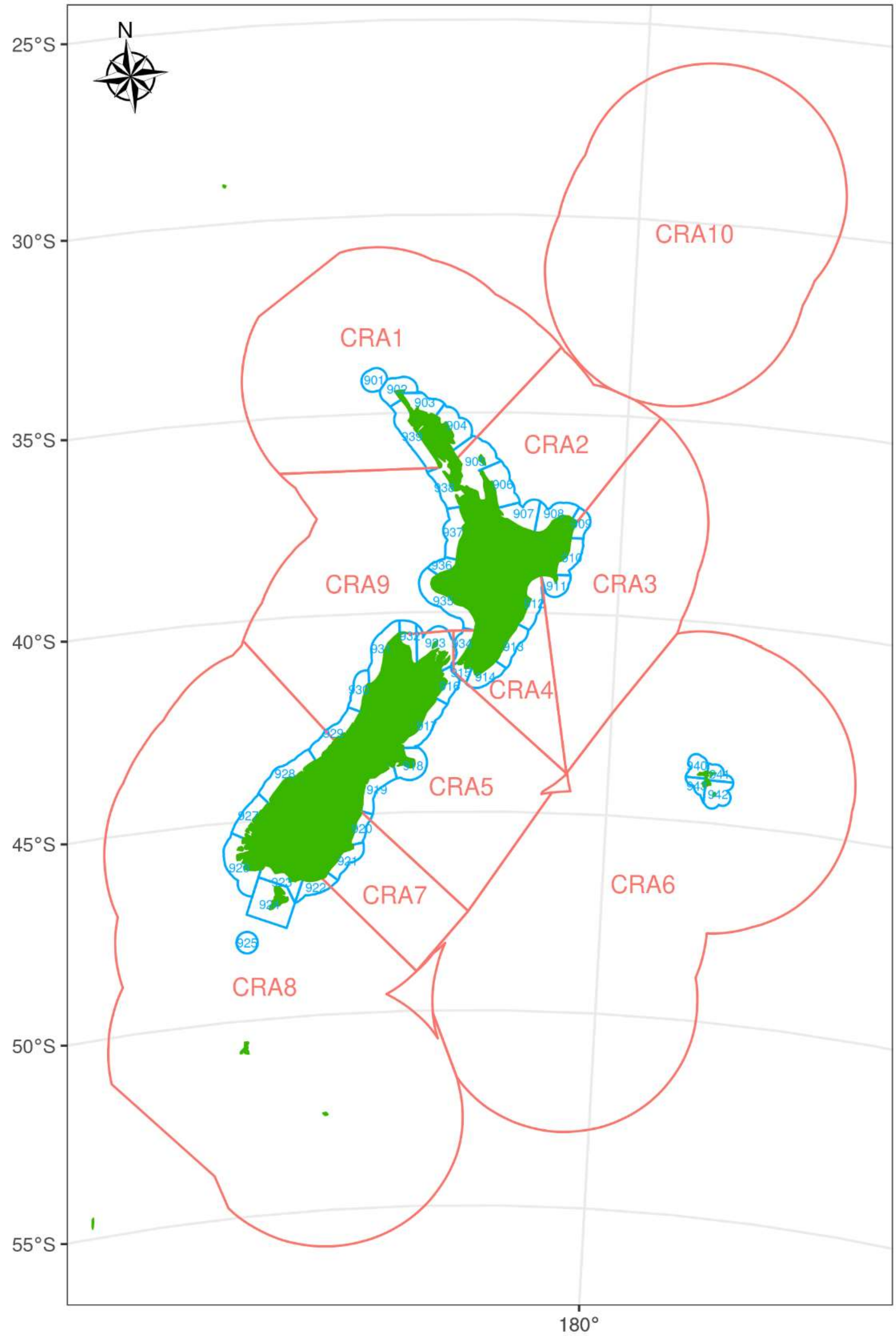


Figure 1: New Zealand red rock lobster (*Jasus edwardsii*) Quota Management Areas (QMAs) in red and Statistical Areas in blue.

Full stock assessments for eight of the nine rock lobster QMAs are generally done once every five years. Full stock assessments require significant time and effort, including a review of the previous stock assessment and data inputs, updates to data processing code, the addition of new data, implementation of new structural changes to the model, review of prior specifications for model parameters, and runs of many sensitivities to key model assumptions. The last few rock lobster stock assessments have involved five stock assessment scientists working for over five weeks to complete two stock assessments, working under the guidance of the Rock Lobster Working Group (RLWG).

Up to the 2020–21 fishing year[4], management procedures (MPs) were used to manage New Zealand stocks of red rock lobsters (Bentley et al. 2003, Bentley & Stokes 2009, Breen et al. 2009, 2016a, 2016b, Webber & Starr 2020). MPs are an important management tool globally (Edwards & Dankel 2016). They are used to manage rock lobsters in South Africa (Johnston & Butterworth 2005, Johnston et al. 2014), South Australia (Punt et al. 2012), and Victoria (Punt et al. 2013). MPs, also often referred to as harvest control rules, are simulation-tested decision rules or functions (Butterworth & Punt 1999) that specify one or more inputs and return an output value. In the past, New Zealand rock lobster MPs used standardised CPUE as the input and a catch limit as the output.

The 2019–20 fishing year marked the transition of the collection of rock lobster catch and effort data from the paper-based Catch Effort Landing Return (CELR) system to an electronic reporting (ER) system dependent on a user interface operated from tablets or smart phones. Presently, there are three different ER reporting ‘platforms’, each with different user interfaces and slightly different underlying software. Preliminary analyses of the 2019–20 data indicated that the estimated catches returned using the new ER system differed from the equivalent estimates generated by the previous CELR forms (see appendix B of Starr 2021). Therefore, the RLWG agreed to temporarily suspend updating CPUE indices beginning with the 2019–20 spring/summer (SS) season; the RLWG concluded that, with the exception of CRA 7, there remained sufficient CELR data for each of the QMAs to ensure comparability with previous indices for the 2019–20 autumn/winter (AW) data. This meant that, after 2019–20 AW, CPUE was no longer available to monitor the abundance of New Zealand rock lobster and was not available for use in MPs.

This document describes the rapid update framework for New Zealand rock lobster stocks and the application of this system to five stocks (CRA 1, CRA 2, CRA 3, CRA 4, and CRA 5). This framework was first applied in 2020 to CRA 1, CRA 2, and CRA 3 (Webber et al. 2021a) and it is planned to continue this system into the future for all rock lobster stocks which are not the subject of a full stock assessment. A stock assessment for CRA 6 was done in 2018 (Rudd et al. 2019) but has not been incorporated into the rapid update system due to time constraints. The first full stock assessment for CRA 7&8 using the lobster stock dynamics (LSD) model was done in 2021 (Webber et al. 2022) so no rapid update was required in 2021, but this stock assessment will be integrated into the rapid update system in 2022. There is no accepted stock assessment for CRA 9 so this stock cannot be included in the rapid update system for the time being.

Rapid updates differ from a full stock assessment because they repeat the previous base case stock assessment model(s), with all the same model settings and assumptions, only updating inputs including additional years of catch, length frequencies (LFs), and tag-recapture data. This significantly speeds up the process, with the result being that every stock not undergoing a full stock assessment can have a rapid update done each year. The rapid update system has been designed to provide fishery advice even in the absence of an updated catch per unit effort (CPUE) series, the main abundance index, and serves to temporarily replace the management procedures (MPs) previously used to manage these stocks (Webber & Starr 2020. Rapid updates could also form the basis for developing new MPs in the future.

[4] Most years in this document refer to the 1 April to 31 March statutory fishing year, for example, 1 April 2019 to 31 March 2020 is designated the 2019–20 fishing year. Two seasons are defined per fishing year: 1 April to 30 September is referred to as autumn/winter (AW) and 1 October to 31 March is referred to as spring/summer (SS). Sometimes specific seasons within a fishing year are referred to, for example, 2019–20 AW refers to 1 April 2019 to 30 September 2020 or 2019–20 SS refers to 1 October 2019 to 31 March 2020. Calendar years are simply referred to as usual (e.g., 2019).

Rapid updates do not aim to replace full stock assessments but complement them by providing inference about stock status in the interim years between full assessments.

2. METHODS

The additional covariates and data that are used in rapid updates include catch series, length frequency data, tag-recapture data, and an updated CPUE index when applicable. Data requests are the first step in the operation of rapid updates. Data requests were submitted to Fisheries New Zealand for monthly harvest returns (MHRs) (replog 13890), observer catch sampling (replog 13862), and tag-recapture data (replog 13863). The voluntary logbook data extract came directly from FishServe. Although the CPUE series has been temporarily discontinued, catch and effort data were requested from Fisheries New Zealand (replog 13890) because these data were used to weight the LF data (e.g., see section 5 of Starr et al. 2020a).

CPUE standardisations were done in the R package *brms* (Bürkner 2017) for each stock. The last CPUE index was 2019–20 AW. All CPUE standardisations had been done in 2020 up to the 2019–20 fishing year during either the 2020 rapid updates (Webber et al. 2021a) or full stock assessments (Rudd et al. 2021b, Webber et al. 2021b). Therefore, these series remained static for the 2021 rapid updates.

Commercial catches were updated to what was actually taken by season each fishing year using the MHR data extract. Five-year projected catches were updated with revised predictions, given the new catch information and known future changes due to planned management interventions.

Non-commercial catches were updated using the procedures used for the base case models for each respective stock assessment. Recreational catches were assumed to be proportional to the SS abundance as reflected in the SS CPUE. The following steps were taken to scale recreational catch in CRA 1, CRA 2, CRA 3, CRA 4, and CRA 5.

1) Surveyed recreational catch in tonnes was a function of the mean number of lobsters in each survey year multiplied by the mean recruited SS weight for sampled lobsters in the survey year. These mean weight estimates either came from direct sampling at recreational landing sites or from commercial sampling data, depending on availability.
2) The estimated recreational catch from 1979–80 onwards was assumed to be either: a) directly proportional to a scalar quantity, estimated by obtaining the best fit to the survey estimates when minimising a lognormal distribution using the coefficient of variation for each survey to the SS CPUE in the same year (CRA 1, CRA 2, CRA 3, CRA 4) or b) a power function with two parameters to relate SS CPUE to the survey estimates (CRA 5).
3) For CRA 2, a National Panel Survey was conducted from October 2017 to September 2018 that had not been included in the original base case assessment. This survey was included when updating the CRA 2 recreational scalar quantity described above.
4) These scalars were then applied to the SS CPUE for all years, beginning with 1979–80, to estimate the time series of recreational catch.
5) Recreational catch in 1945–46 was assumed to be 20% of 1979–80 recreational catch and followed a linear trajectory from 1945–46 to 1979–80. This step was unnecessary for CRA 2, which used 1979–80 as the first year in the stock assessment.
6) The steps described above duplicated the calculations adopted by the original base case stock assessments (see references in Table 1).
7) Because SS CPUE was unavailable for 2019–20 SS and beyond due to the change associated with the shift to electronic reporting, the 2019–20 and 2020–21 SS CPUE indices were assumed to be the average of the 2016–17 to 2018–19 SS CPUE indices.

For assessments since 2006, the RLWG had also included recreational landings by commercial vessels under section 111 of the Fisheries Act. The maximum annual catch with destination code ‘F’ was included as a constant addition to the recreational catch trajectory for each year since 1945–46.

The handling of illegal catch in these rapid updates reflected the changes in approach adopted by the RLWG over the past five years, evolving from using a poorly documented ‘export discrepancy’ procedure for the early years and fisheries compliance estimates from 1990–91 onwards to using fixed percentages of the commercial catches. The approaches used to set the illegal catches in each rapid update varied by QMA (Table 1). Because CPUE was unavailable for 2019–20 and 2020–21 due to the change associated with the shift to electronic reporting, the 2019–20 and 2020–21 annual CPUE indices were assumed to be the average of the 2016–17 to 2018–19 annual CPUE indices.

Table 1: Methods over applicable periods used for setting illegal catches in the five QMAs included in the 2021 rapid update system. This table uses calendar years from 1945 to 1978 and fishing years, designated with the first year of the pair, from 1979–80 (1979) to 2020–21 (2020).

QMA	Description	Reference
CRA 1	1945–1980: export discrepancy 1981–2020: 20% of total commercial catch from this period scaled by annual CPUE. Assumed CPUE in 2020 average of 2017, 2018, and 2019.	Starr et al. 2020a
CRA 2	1945–1989: export discrepancy 1990–2020: modified compliance estimates	Starr & Webber 2018
CRA 3	1945–1980: export discrepancy 1981–2020: 20% of total commercial catch from this period constant across years.	Starr et al. 2020b
CRA 4	1945–1989: 10% of total commercial catch from this period 1990–2020: 5% of total commercial catch from this period. Scaled by annual CPUE from 1979–2019. Assumed CPUE in 2020 average of 2017, 2018, and 2019.	Starr et al. 2021a
CRA 5	1945–1989: 10% of total commercial catch from this period 1990–2020: 5% of total commercial catch from this period. Scaled by annual CPUE from 1979–2019. Assumed CPUE in 2020 average of 2017, 2018, and 2019.	Starr et al. 2021b

Catch was split between seasons from 1979–80 onwards, where 90% of recreational and customary catch were assumed to be taken in the SS and the remainder in the AW. Illegal catch was assumed to have the same seasonal split by year as the commercial catch.

All catch projections were made for the next five fishing years, beginning with 2021–22. Projected recreational, customary, and illegal catches were fixed at the assumed value in the final fishing year. Projected commercial catch was assumed to be the TACC and split by season and by region (if applicable) based on the seasonal and regional split of commercial catch in 2020–21.

The LF data were derived from individual lobster tail width (TW) measurements and came from both observer catch sampling and the voluntary logbook programme, with the years contributed by each data source varying by QMA. Observer catch sampling data were extracted from the Fisheries New Zealand Rock Lobster Catch Sampling (*rlcs*) database (Mackay & George 2018).

Each LF data record comprised pooled measurements taken from all months in the season and statistical area within the QMA or region by fishing year. For each month/area stratum, the numbers-at-length were summed for each sex and divided by the total numbers-at-length to calculate proportion-at-length. Proportions-at-length were then adjusted for their ‘representativeness’ based on the commercial catch in the month/area compared with total catch for the season, then re-normalised to sum to one across each sex. A relative weight was assigned to each sex and data record which combined the representativeness of each month/area cell, the cube root of the number of fish measured, and the cube root of the number of days sampled (see Table 1 references to data New Zealand Fisheries Assessment Reports).

LF data were removed if there was only a single participant in the logbook programme during a fishing year, or less than 100 TW measurements were taken to characterise the length distribution within a season/sample type stratum. Data were aggregated into 2 mm TW bins starting at 30 mm TW as the minimum and usually with 90 mm as the maximum accumulator bin (although the maximum bin varied by QMA).

Tag-recapture data were extracted and processed up to 2020–21 for each QMA in the rapid updates. Key steps in data processing included:

1. removing duplicate records, tags not recaptured, records missing any type of length measurement (TW and carapace length), and records with unreasonable TW, time at liberty, or growth increment;
2. assigning period, stage, statistical area based on latitude and longitude (or the statistical area included in the data extract if the latitude and longitude are missing), and QMA determined by statistical area; and
3. formatting the data for the LSD model input.

The results of this data updating procedure allowed for additional recruitment deviations to be estimated relative to the last full stock assessment. For example, typically recruitment deviations were estimated from the first model year to two years prior to the final model year. When the final model year was increased for the rapid update with additional years of LF data, more years of recruitment deviates could be estimated. To account for an additional year (CRA 4, CRA 5) or years (CRA 1, CRA 2, and CRA 3) of data, the data were iteratively re-weighted until the standard deviation of normalised residuals (SDNRs) for each data type were as close as possible to one, except for tag data which are self-weighting through the estimation of an observation error parameter in the model. Otherwise, all model specifications remained as they were in the original base case stock assessment. These static specifications included the priors and bounds for estimated model parameters, the reference level B_R (Rudd et al. 2021c), and all structural assumptions which applied to growth, maturity, selectivity, and vulnerability. All rapid update models were run using the LSD model coded in Stan (Webber et al. 2018a, Stan 2017). A list of parameter and derived quantity definitions is provided in Table 2 and Table 3.

Table 2: Definitions of parameters discussed in the text.

Parameter	Definition
R_0	initial numbers recruiting
M	instantaneous rate of natural mortality
Rdevs	annual recruitment deviations
sigmaR	standard deviation of *Rdevs*
qCR	catchability coefficient (relationship between the vulnerable biomass and CR series)
qFSU	catchability coefficient (relationship between the vulnerable biomass and FSU CPUE series)
qCELR	catchability coefficient (relationship between the vulnerable biomass and CELR CPUE series)
Mat50	TW at which 50% of immature females become mature
Mat95add	difference between *Mat50* and the TW at which 95% of immature females become mature
Galpha	annual growth increment at 50 mm TW
Gbeta	annual growth increment at 80 mm TW
Gdiff	the ratio of *Gbeta* to *Galpha*
Gshape	parameter for shape of growth curve: 1 implies von Bertalanffy straight line; >1 implies a concave upwards curve
GCV	standard deviation of growth-at-TW divided by growth-at-TW
Gobs	standard deviation of observation error for tag recaptures
SelL	shape of the left-hand limb of the selectivity curve (as if it were a standard deviation)
SelM	TW at maximum selectivity
vuln	relative vulnerability by sex and season
qdrift	additive change in catchability coefficient each year
U_0	initial exploitation rate (first year is in equilibrium using this estimate)
Gdd	density-dependent growth parameter

Table 3: Definitions of derived quantities discussed in the text including reference points and performance indicators. The 'YEAR' subscript is replaced with the relevant fishing year in the text and tables (e.g., B_{2021} is the beginning of season AW adjusted vulnerable biomass for the 2021–22 fishing year).

Variable	Description
Reference points	
B_0	beginning of season AW adjusted vulnerable biomass before fishing
B_{YEAR}	beginning of season AW adjusted vulnerable biomass for the specified fishing year
B_R	reference level in terms of AW adjusted vulnerable biomass (Rudd et al. 2021c)
U_R	exploitation rate associated with the reference level
SSB_0	mature female spawning stock biomass in the AW season before fishing
SSB_{YEAR}	mature female spawning stock biomass in the AW season at beginning of the specified fishing year
Performance indicators	
B_{YEAR} / B_0	ratio of B_{YEAR} to B_0
B_{YEAR} / B_R	ratio of B_{YEAR} to B_R
U_{YEAR} / U_R	ratio of U_{YEAR} to U_R
B_{YEAR1} / B_{YEAR2}	ratio of B_{YEAR1} to B_{YEAR2}
SSB_{YEAR} / SSB_0	ratio of SSB_{YEAR} to SSB_0
$SSB_{YEAR1} / SSB_{YEAR2}$	ratio of SSB_{YEAR1} to SSB_{YEAR2}

3. RESULTS

3.1 CRA 1 Rapid update

CRA 1 is the northernmost rock lobster stock in New Zealand, extending from Kaipara Harbour on the west coast, to the Three Kings Islands north of the North Island, and to the Waipu River, south of Bream Bay and Whangarei on the east coast (Figure 1, Figure 2).

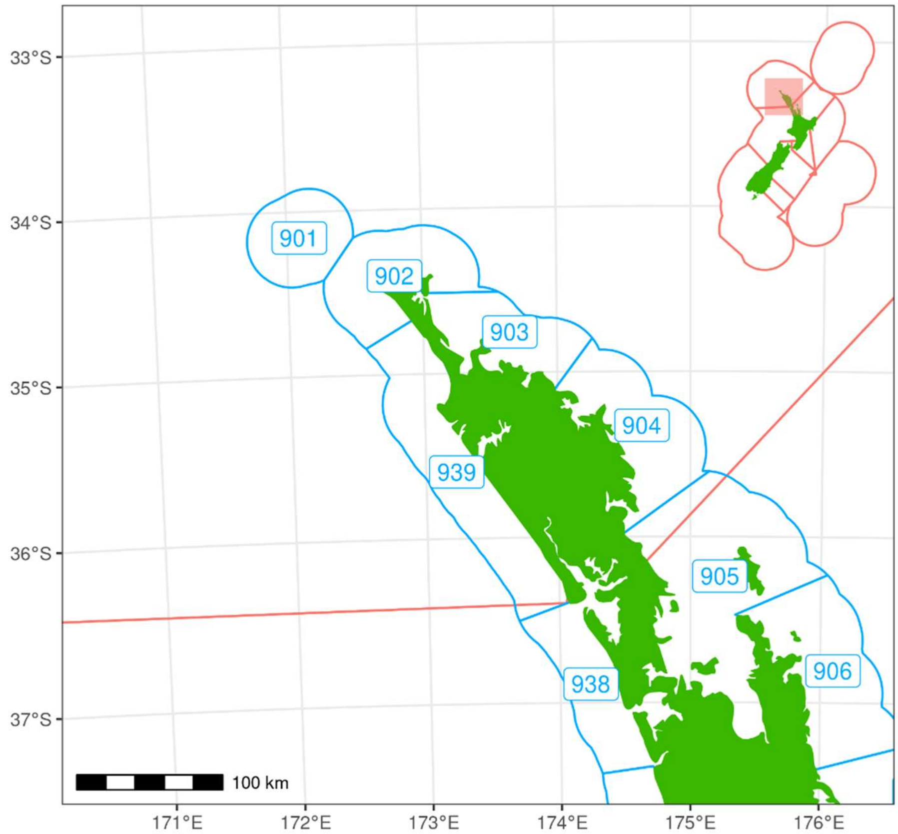


Figure 2: CRA 1 QMA and its statistical areas.

The CRA 1 stock assessment was last done in 2019 as a single-region model (Rudd et al. 2021a). The model was fitted to standardised CPUE indices, LF data, sex ratio data, and tag-recapture data. The stock assessment estimated increasing fishing mortality from the mid-1940s to the late 1960s, resulting in a decline in biomass. Since the 1990s, size-limited catch remained relatively stable, with an increase in non-size-limited catches over time. The stock assessment estimated that the spawning stock biomass (SSB) remained above the soft limit of 20% SSB_0. Although CPUE had been increasing, the projections done in 2019 suggested that continued harvest at existing catch levels would likely lead to a decline in the vulnerable biomass and SSB.

The 2021 rapid update for CRA 1 added two years of additional data to the 2019 stock assessment including: a single CPUE index for 2019–20 AW (2019–20 SS and beyond were not included because of the change from paper to electronic forms); logbook and catch sampling LFs up to 2020–21; and additional tags. The commercial catch that was actually taken was included up to 2020–21, and the projected catch from 2021–22 to 2025–26 was updated to reflect management changes (Table 4).

Markov chain Monte Carlo (MCMC) trace plots for the rapid update suggested that mixing was adequate with no signs of non-convergence (see Appendix I for MCMC diagnostic plots). The 2021 rapid update fit to the CPUE was good and almost indistinguishable from the fits in the 2019 assessment and the 2020 rapid update (Figure 3). The 2021 rapid update fits to the LFs from 2018–19 to 2020–21 were almost indistinguishable from the equivalent fits made by the 2019 stock assessment and the 2020 rapid update (Figure 4).

The rapid update suggested that recruitment was higher in 2016–17 and lower in 2017–18 compared with the same years estimated by the 2019 assessment (Figure 5). Projected recruitment for the next five years was assumed to be about the same as the original base assessment. The rapid update suggested that the adjusted vulnerable biomass was lower than projected in 2020–21, but remained roughly the same for the next five years (Figure 6). The SSB was projected to increase over the next five years, but not as quickly as was projected in 2019 (Figure 7).

The rapid update suggested that the stock was, at the beginning of 2021–22, at 15% of B_0, 36% of SSB_0, and 4% above B_R. It was estimated to be below the U_R on average in 2020–21 (Table 5). At the assumed projected levels of catch and recruitment, the stock was projected to increase and therefore will remain above the reference level.

Table 4: CRA 1 catch (tonnes) for the last four fishing years and the five projection years in the 2019 base case model compared with the last five fishing years and the five projection years in the 2020 rapid update and last six fishing years and five projection years for the 2021 rapid updates. All projection years are highlighted in grey.

	Commercial			Recreational			Customary			Illegal		
Fishing year	AW	SS	Total	AW	SS	Total	AW	SS	Total	AW	SS	Total
2019/base												
2015–16	66.14	63.24	129.38	3.54	31.86	35.40	1.00	9.00	10.00	15.74	15.05	30.79
2016–17	60.04	70.57	130.61	2.27	20.43	22.70	1.00	9.00	10.00	14.48	17.02	31.50
2017–18	54.72	69.54	124.26	3.07	27.65	30.72	1.00	9.00	10.00	15.42	19.60	35.02
2018–19	67.98	62.58	130.56	3.15	28.33	31.48	1.00	9.00	10.00	19.62	18.06	37.68
2019–20	–	–	130.56	–	–	31.48	–	–	10.00	–	–	37.68
2020–21	–	–	130.56	–	–	31.48	–	–	10.00	–	–	37.68
2021–22	–	–	130.56	–	–	31.48	–	–	10.00	–	–	37.68
2022–23	–	–	130.56	–	–	31.48	–	–	10.00	–	–	37.68
2023–24	–	–	130.56	–	–	31.48	–	–	10.00	–	–	37.68
2020/base												
2015–16	66.14	63.24	129.38	3.54	31.86	35.40	1.00	9.00	10.00	15.68	15.00	30.68
2016–17	60.04	70.57	130.61	2.27	20.43	22.70	1.00	9.00	10.00	14.43	16.97	31.40
2017–18	54.72	69.54	124.26	3.07	27.65	30.72	1.00	9.00	10.00	15.37	19.53	34.90
2018–19	67.98	62.58	130.56	3.15	28.33	31.48	1.00	9.00	10.00	19.55	18.00	37.55
2019–20	70.06	56.85	126.91	2.83	16.1	28.30	1.00	9.00	10.00	16.10	13.06	29.16
2020–21	–	–	110.00	–	–	28.30	–	–	10.00	–	–	29.16
2021–22	–	–	110.00	–	–	28.30	–	–	10.00	–	–	29.16
2022–23	–	–	110.00	–	–	28.30	–	–	10.00	–	–	29.16
2023–24	–	–	110.00	–	–	28.30	–	–	10.00	–	–	29.16
2024–25	–	–	110.00	–	–	28.30	–	–	10.00	–	–	29.16
2021/base												
2015–16	66.14	63.24	129.38	3.51	31.87	35.14	1.00	9.00	10.00	15.55	14.87	30.43
2016–17	60.04	70.57	130.61	2.24	20.43	22.44	1.00	9.00	10.00	14.31	16.83	31.14
2017–18	54.72	69.54	124.26	3.05	27.41	30.45	1.00	9.00	10.00	15.24	19.37	34.61
2018–19	67.98	62.59	130.57	3.12	28.09	31.22	1.00	9.00	10.00	19.39	17.85	37.23
2019–20	70.06	56.85	126.91	2.80	25.23	28.04	1.00	9.00	10.00	18.95	15.38	34.33
2020–21	51.46	58.53	109.99	2.80	25.23	28.04	1.00	9.00	10.00	16.56	18.83	35.39
2021–22	51.47	58.43	110.00	2.80	25.23	28.04	1.00	9.00	10.00	16.56	18.83	35.39
2022–23	51.47	58.43	110.00	2.80	25.23	28.04	1.00	9.00	10.00	16.56	18.83	35.39
2023–24	51.47	58.43	110.00	2.80	25.23	28.04	1.00	9.00	10.00	16.56	18.83	35.39
2024–25	51.47	58.43	110.00	2.80	25.23	28.04	1.00	9.00	10.00	16.56	18.83	35.39
2025–26	51.47	58.43	110.00	2.80	25.23	28.04	1.00	9.00	10.00	16.56	18.83	35.39

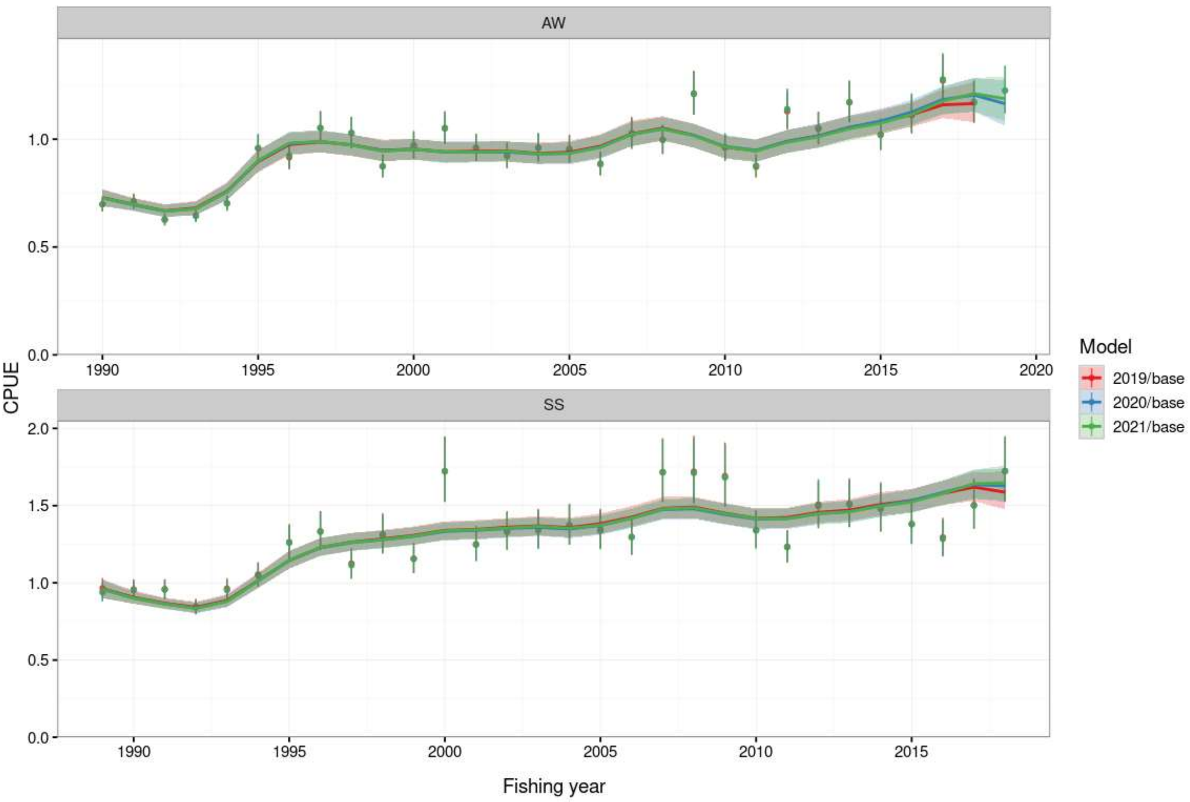


Figure 3: CRA 1 CPUE observations (points) and posterior distribution showing the median (line) and 90% credible interval (shaded region) by season (AW = autumn/winter, SS = spring/summer) and fishing year (labelled using the first year in the pair) for the 2019 stock assessment and the 2020 and 2021 rapid updates.

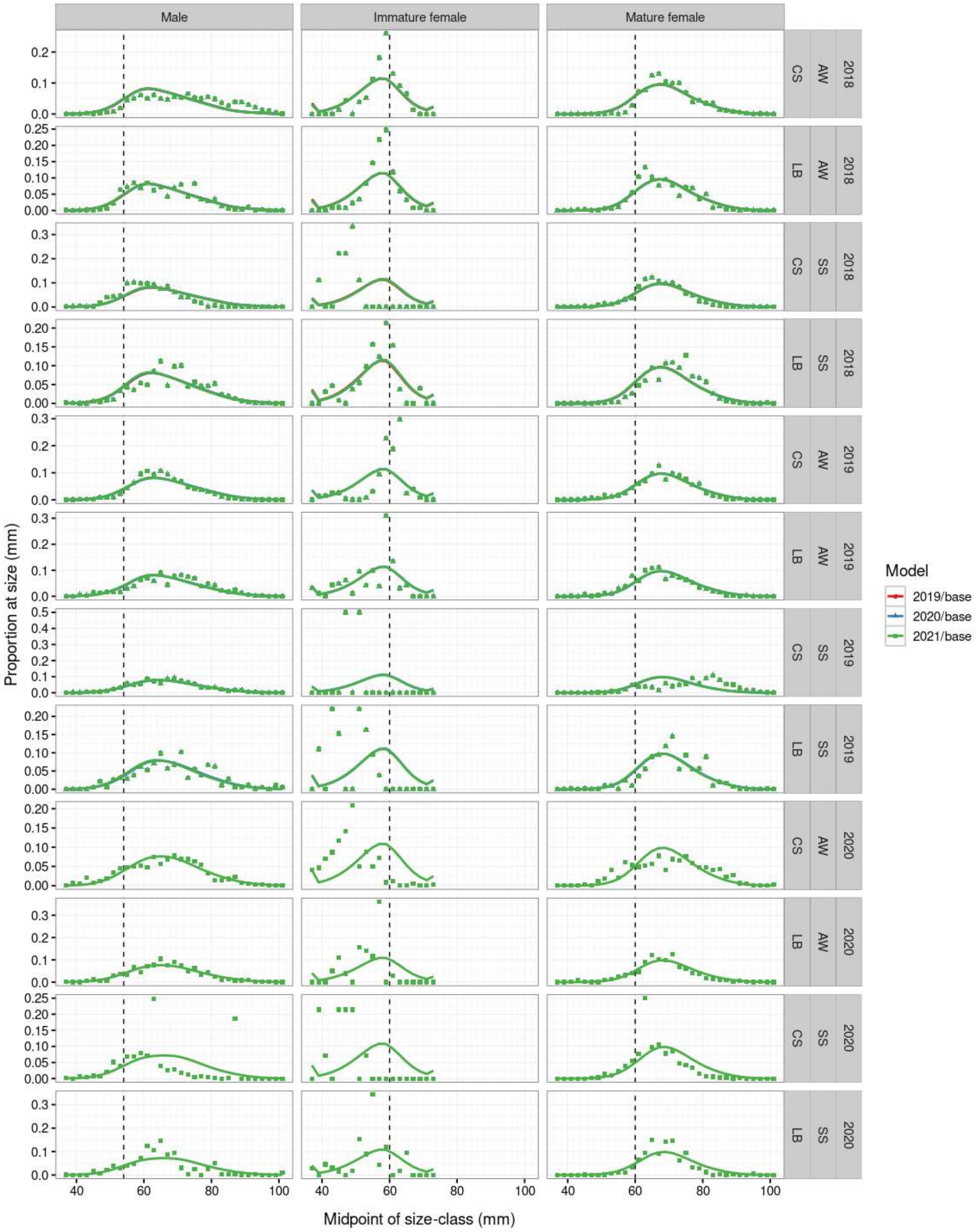


Figure 4: CRA 1 length frequency observations (points) and median of the posterior distribution (line) by year, season (AW = autumn/winter, SS = spring/summer), and data source (CS = catch sampling, LB = logbook) for the 2019 stock assessment and the 2020 and 2021 rapid updates.

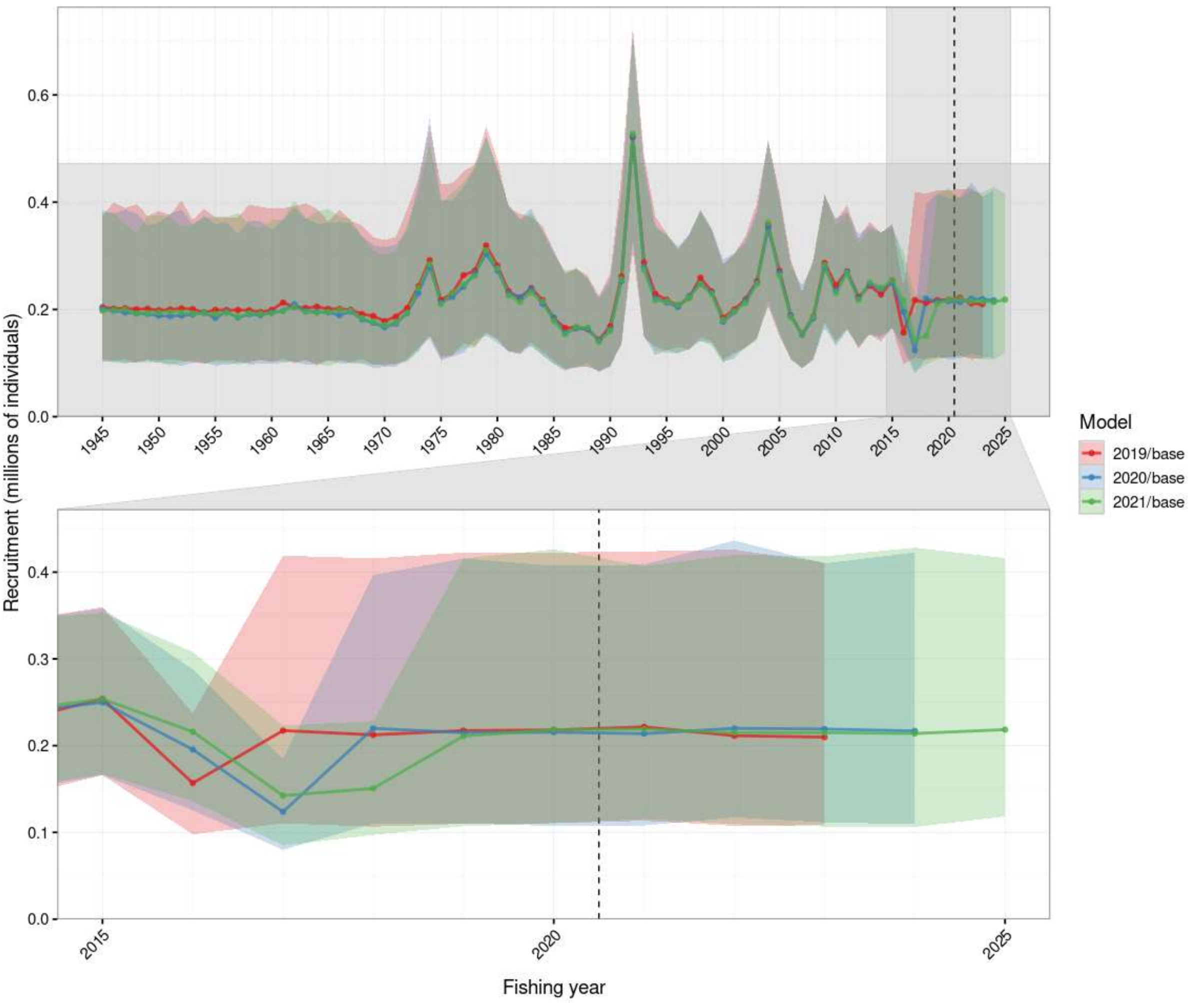


Figure 5: CRA 1 posterior distribution of recruitment showing the median (line and points) and 90% credible interval (shaded region) for the 2019 stock assessment and the 2020 and 2021 rapid updates. The top panel shows the recruitment for all model years, and the lower panel shows recruitment for the last ten years.

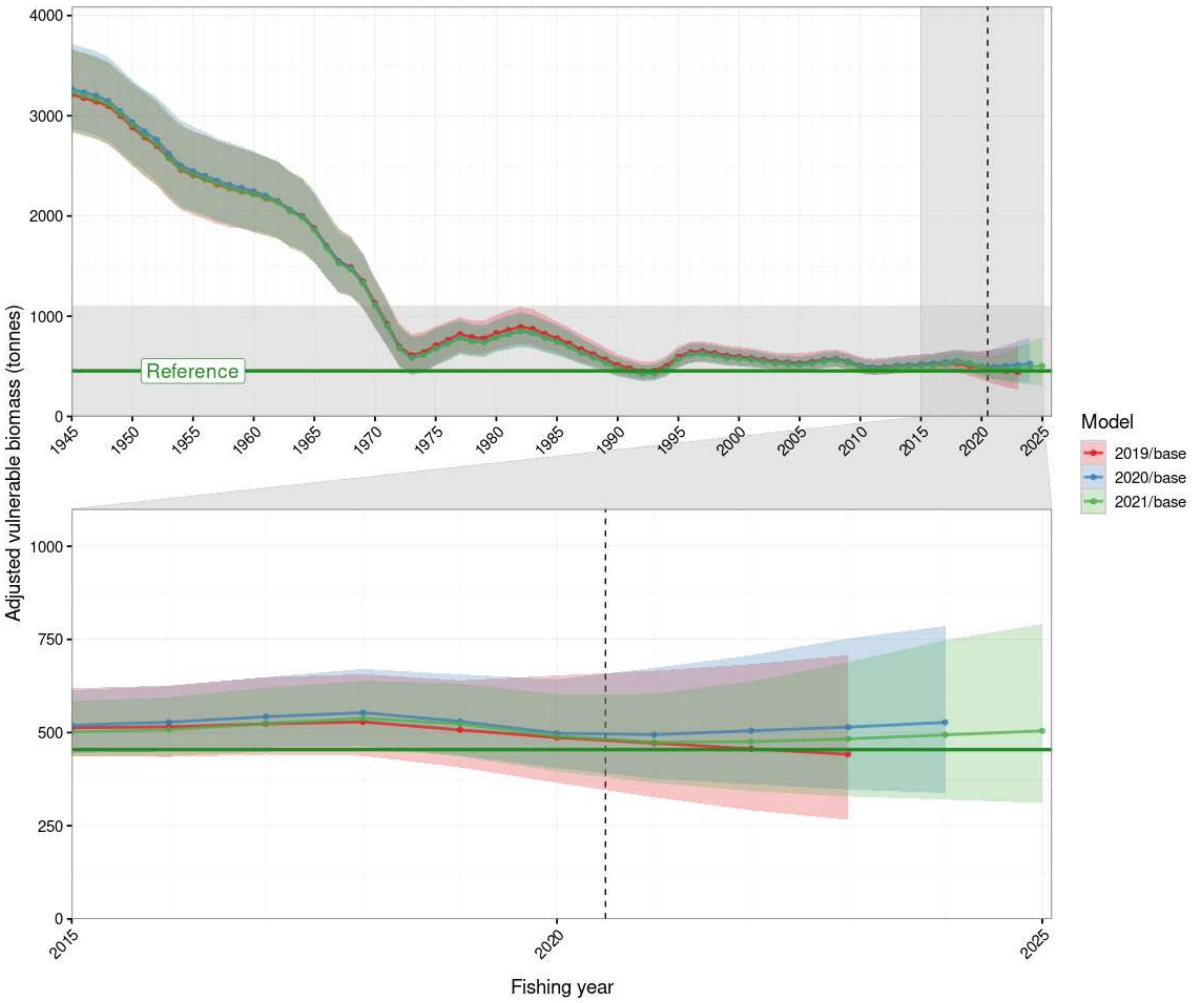


Figure 6: CRA 1 posterior distribution of adjusted vulnerable biomass (tonnes) showing the median (line and points) and 90% credible interval (shaded region) for the 2019 stock assessment and the 2020 and 2021 rapid updates. The top panel shows the adjusted vulnerable biomass for all model years, and the lower panel shows adjusted vulnerable biomass for the last ten years. The reference level is also shown (horizontal green line).

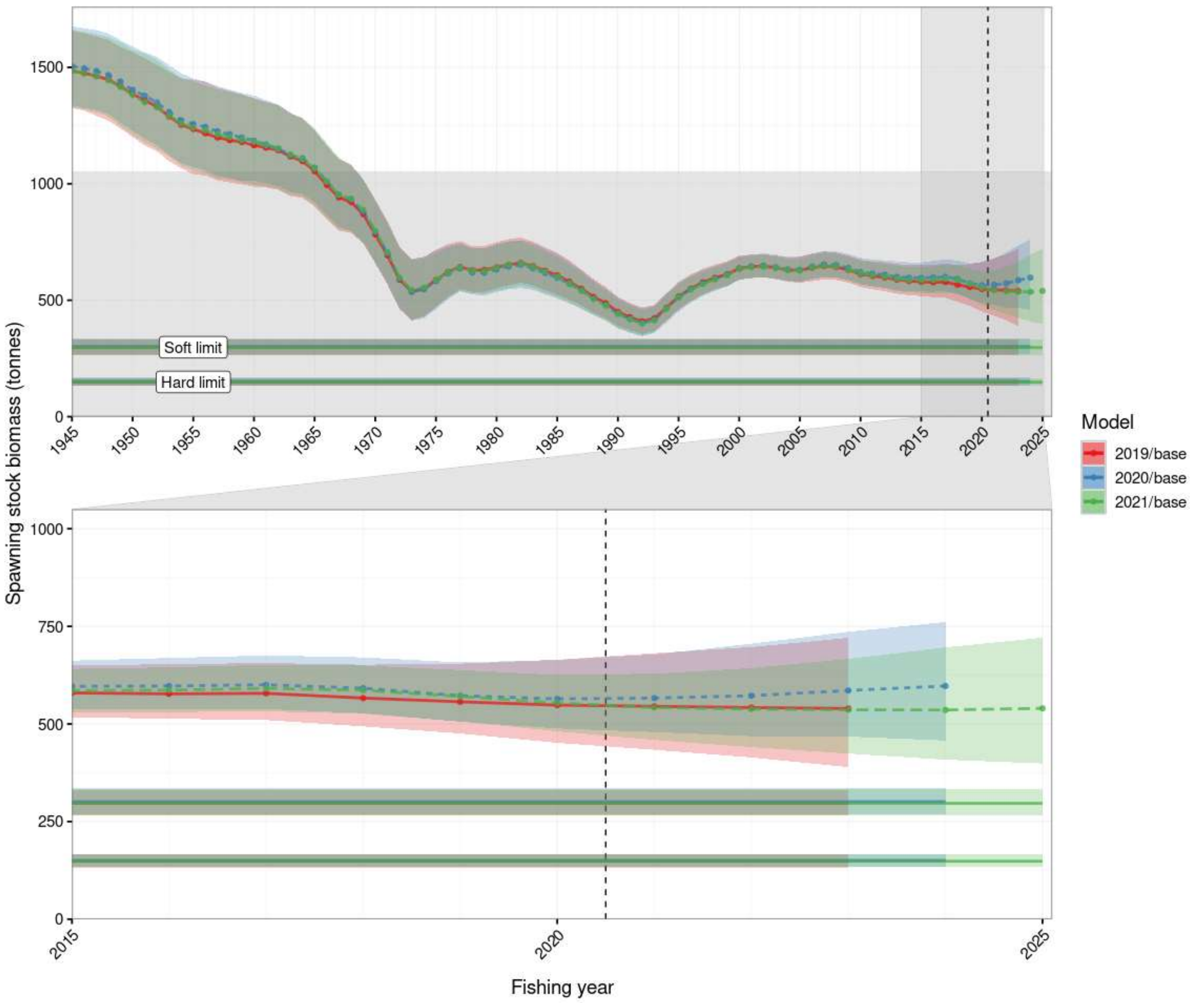


Figure 7: CRA 1 posterior distribution of spawning stock biomass (tonnes) showing the median (line and points) and 90% credible interval (shaded region) for the 2019 stock assessment and the 2020 and 2021 rapid updates. The top panel shows the spawning stock biomass for all model years, and the lower panel shows spawning stock biomass for the last ten years. The horizontal lines and shaded regions represent the soft limit (top horizontal line and shaded region) and the hard limit (lower horizontal line and shaded region).

Table 5: CRA 1 rapid update indicators summarising the mean, 5% credible interval (CI), median, and 95% CI.

Indicator	Mean	5%	Median	95%
B_0	3 241	2 829	3 236	3 669
B_R	454	–	–	–
B_{2021}	477	364	475	604
B_{2025}	538	295	521	841
B_{2021} / B_0	0.149	0.109	0.146	0.198
B_{2021} / B_R	1.050	0.802	1.044	1.330
B_{2025} / B_0	0.168	0.092	0.158	0.268
B_{2025} / B_R	1.185	0.649	1.147	1.850
B_{2025} / B_{2021}	1.119	0.745	1.095	1.569
SSB_0	1 488	1 328	1 484	1 663
SSB_{2021}	542	458	542	628
SSB_{2025}	548	399	541	721
SSB_{2021} / SSB_0	0.366	0.307	0.363	0.438
SSB_{2025} / SSB_0	0.370	0.264	0.364	0.496
SSB_{2025} / SSB_{2021}	1.006	0.823	0.998	1.211
U_R	0.215	–	–	–
U_{2021} / U_R	0.550	0.700	0.713	0.910
U_{2025} / U_R	0.689	0.420	0.659	1.069

3.2 CRA 2 Rapid update

The CRA 2 fishery extends from Te Arai Point, south of Whangarei, to East Cape at the easternmost end of the Bay of Plenty (Figure 1, Figure 8). This QMA includes the Hauraki Gulf, both sides of the Coromandel Peninsula, and all of the Bay of Plenty to East Cape.

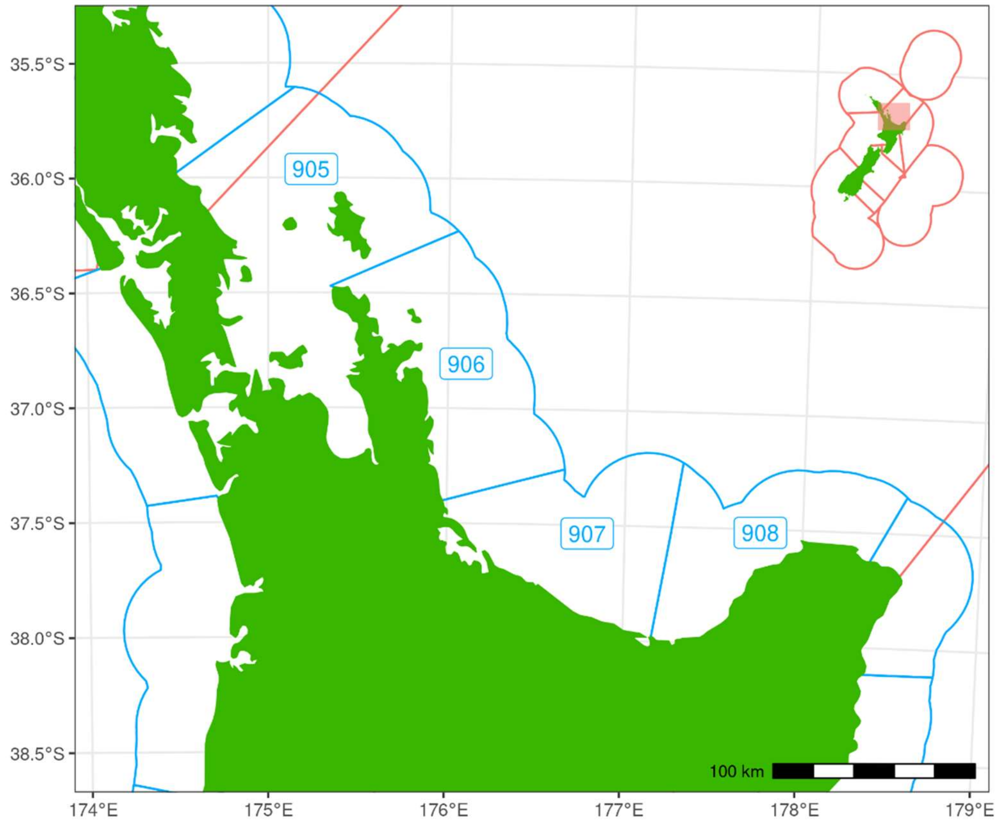


Figure 8: CRA 2 QMA and its statistical areas.

The CRA 2 stock assessment was last done in 2017 as a single-region model (Webber et al. 2018b). The model was fitted to standardised CPUE indices, LF data, sex ratio data, and tag-recapture data. The stock assessment estimated the stock to have low SSB relative to the unfished stock level (SSB_0) in spite of the small TW at maturity. Depletion of the stocks vulnerable biomass was recognised by all stakeholders even before the stock assessment. Because the stock was estimated to be below the soft limit, a rebuilding plan was required at the time. The chosen rebuilding plan used a fixed catch rather than an MP.

The 2021 rapid update for CRA 2 added four years of additional data, including: CPUE from 2017–18 AW to 2019–20 AW (2019–20 SS was not included because of the change from paper to electronic forms), logbook and catch sampling LFs for both AW and SS up to 2020–21, any additional tags, and an additional recreational catch survey in 2017–18 (Wynne-Jones et al. 2019). The additional recreational catch survey required re-calculation of the scalar value relating estimated recreational catch with SS abundance from 1979–80 onwards, which estimated slightly lower recreational catch over the time series than was assumed in the 2017 assessment (Table 6). Actual commercial catch was included up to 2020–21, and the projected catch from 2021–22 to 2025–26 was updated to reflect management changes (Table 6).

MCMC trace plots for the rapid update suggested that mixing was adequate with no signs of non-convergence (see Appendix I for MCMC diagnostic plots).

The updated CPUE resulted in some minor differences compared with the CPUE series used in the 2017 stock assessment, particularly during the SS season (Figure 9). These differences were most notable from SS 1989–90 to 2000–01 where the updated series was consistently higher than the 2017 series in all years. The rapid updates fit to the overall CPUE was similar to the fit in the 2017 assessment and the fit to the new CPUE points was good (Figure 9). The fits to the LFs were almost indistinguishable during 2016–17 and the fits to the 2017–18, 2018–19, and 2019–20 LFs were excellent (Figure 10). The rapid update fits to the LFs for recent years after the last full assessment were also good (Figure 11).

The 2021 rapid update suggested that there had been a substantial pulse of recruitment in 2015–16, a year for which recruitment deviates were not estimated in the 2017 assessment. The 2016–17 to 2018–19 recruitments estimated in the 2021 rapid update were slightly lower than those estimated by the 2020 rapid update (Figure 12). The rapid update suggested that the adjusted vulnerable biomass was higher in all years compared with the 2017 assessment, and that vulnerable biomass had increased rapidly since the 2017 assessment (Figure 13). At current catch levels, the vulnerable and spawning stock biomass were projected to increase over the next five years, but at a lower rate than estimated by the 2020 rapid update (Figure 14).

The 2021 rapid update suggested that the CRA 2 stock was, at the beginning of 2021–22, at 14% of B_0, 30% of SSB_0, and at the reference level. It was below the exploitation rate associated with the reference level on average in 2021–22 (Table 7). At the assumed projected levels of catch and recruitment, the stock was projected to increase and therefore to increase above the reference level.

Table 6: CRA 2 catch (tonnes) for the last two fishing years and the five projection years in the 2017 base case model compared with the last five fishing years and the five projection years in the 2020 rapid update and last six fishing years and five projection years for the 2021 rapid updates. All projection years are highlighted in grey.

	Commercial			Recreational			Customary			Illegal		
Fishing year	AW	SS	Total	AW	SS	Total	AW	SS	Total	AW	SS	Total
2017/base												
2015–16	51.40	123.31	174.71	7.19	27.07	34.26	0.50	4.50	5.00	12.47	29.92	42.40
2016–17	38.16	104.14	142.30	7.20	27.10	34.30	0.50	4.50	5.00	10.73	29.27	40.00
2017–18	–	–	142.30	–	–	34.30	–	–	5.00	–	–	40.00
2018–19	–	–	142.30	–	–	34.30	–	–	5.00	–	–	40.00
2019–20	–	–	142.30	–	–	34.30	–	–	5.00	–	–	40.00
2020–21	–	–	142.30	–	–	34.30	–	–	5.00	–	–	40.00
2021–22	–	–	142.30	–	–	34.30	–	–	5.00	–	–	40.00
2020/base												
2015–16	51.40	123.31	174.71	2.73	24.55	27.28	0.50	4.50	5.00	12.47	29.93	42.40
2016–17	38.16	104.37	142.53	2.73	24.60	27.34	0.50	4.50	5.00	10.71	29.29	40.00
2017–18	41.99	100.77	142.75	2.56	23.01	25.57	0.50	4.50	5.00	11.77	28.23	40.00
2018–19	32.52	47.46	79.97	4.22	37.95	42.16	0.50	4.50	5.00	16.26	23.74	40.00
2019–20	45.55	30.46	76.01	3.17	28.52	31.69	0.50	4.50	5.00	23.97	16.03	40.00
2020–21	–	–	83.97	–	–	31.69	–	–	5.00	–	–	40.00
2021–22	–	–	80.00	–	–	31.69	–	–	5.00	–	–	40.00
2022–23	–	–	80.00	–	–	31.69	–	–	5.00	–	–	40.00
2023–24	–	–	80.00	–	–	31.69	–	–	5.00	–	–	40.00
2024–25	–	–	80.00	–	–	31.69	–	–	5.00	–	–	40.00
2021/base												
2015–16	51.40	123.31	174.71	2.94	26.41	29.35	0.50	4.50	5.00	12.47	29.93	42.40
2016–17	38.16	104.37	142.53	2.94	26.46	29.40	0.50	4.50	5.00	10.71	29.29	40.00
2017–18	41.99	100.77	142.75	2.74	24.62	27.35	0.50	4.50	5.00	11.77	28.23	40.00
2018–19	32.52	47.46	79.97	5.02	45.22	50.24	0.50	4.50	5.00	16.26	23.74	40.00
2019–20	45.55	30.46	76.01	3.57	32.10	35.66	0.50	4.50	5.00	23.97	16.03	40.00
2020–21	37.61	46.29	83.90	3.57	32.10	35.66	0.50	4.50	5.00	17.93	22.07	40.00
2021–22	35.86	44.14	80.00	3.57	32.10	35.66	0.50	4.50	5.00	17.93	22.07	40.00
2022–23	35.86	44.14	80.00	3.57	32.10	35.66	0.50	4.50	5.00	17.93	22.07	40.00
2023–24	35.86	44.14	80.00	3.57	32.10	35.66	0.50	4.50	5.00	17.93	22.07	40.00
2024–25	35.86	44.14	80.00	3.57	32.10	35.66	0.50	4.50	5.00	17.93	22.07	40.00
2025–26	35.86	44.14	80.00	3.57	32.10	35.66	0.50	4.50	5.00	17.93	22.07	40.00

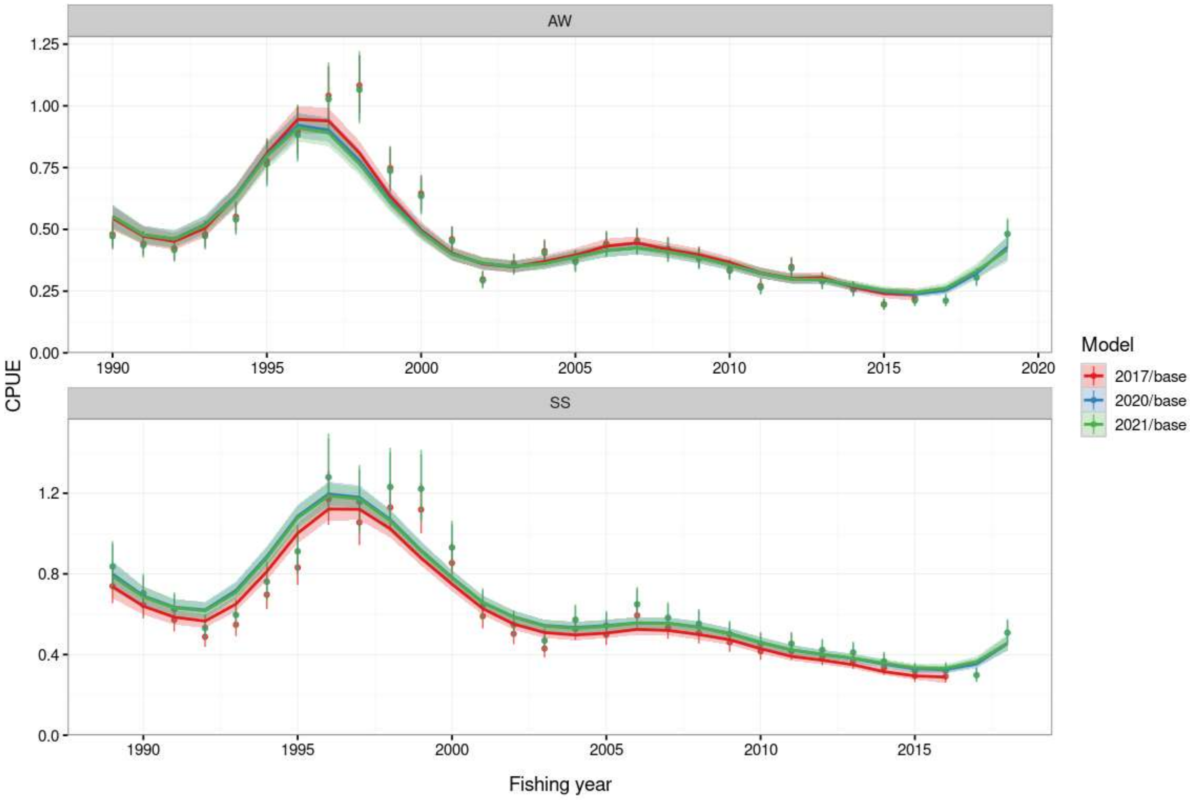


Figure 9: CRA 2 CPUE observations (points) and posterior distribution showing the median (line) and 90% credible interval (shaded region) by season (AW = autumn/winter, SS = spring/summer) for the 2017 stock assessment and the 2020 and 2021 rapid updates.

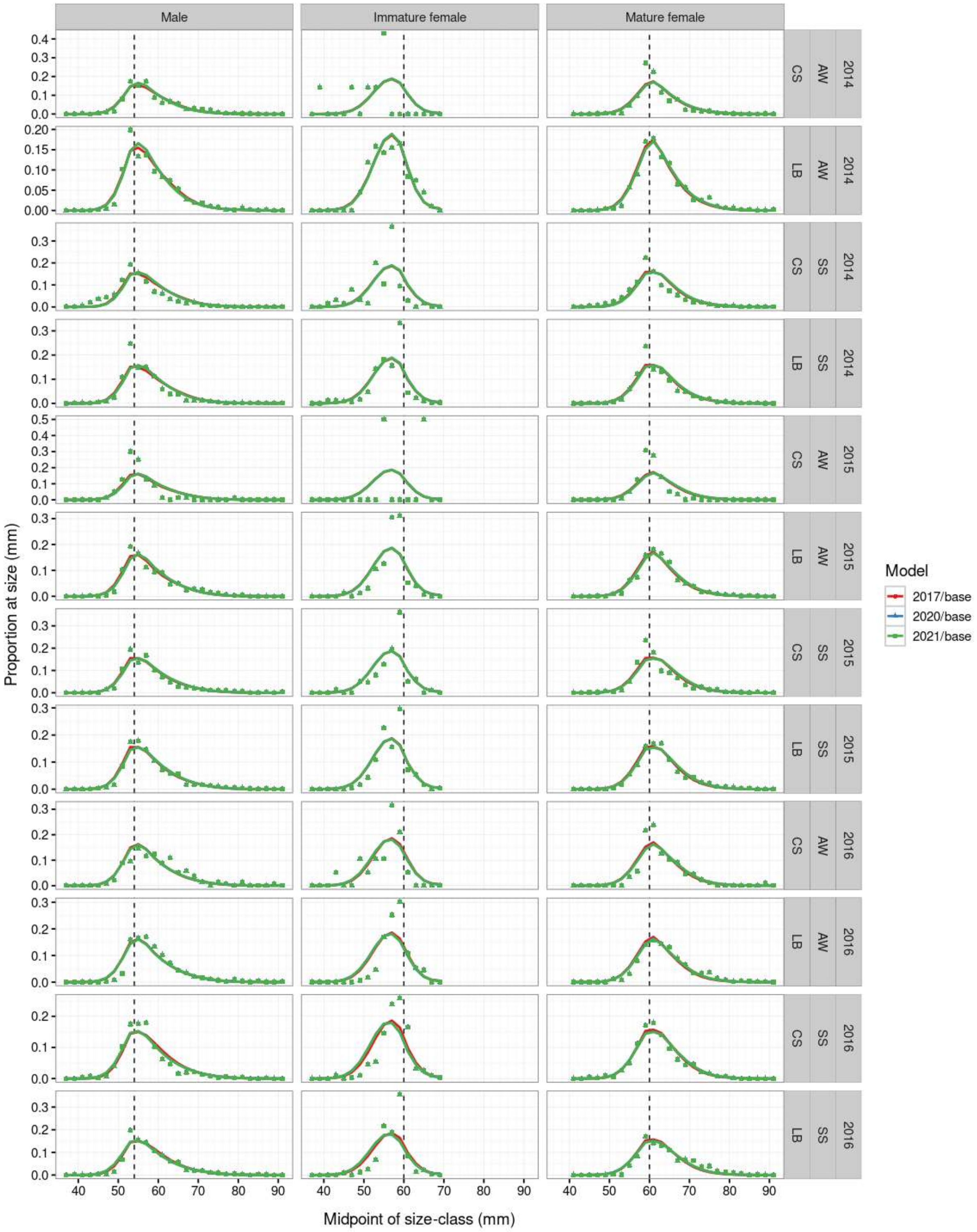


Figure 10: CRA 2 length frequency observations (points) and median of the posterior distribution (line) by year, season (AW = autumn/winter, SS = spring/summer), and data source (CS = catch sampling, LB = logbook) for the 2017 stock assessment and the 2020 and 2021 rapid updates.

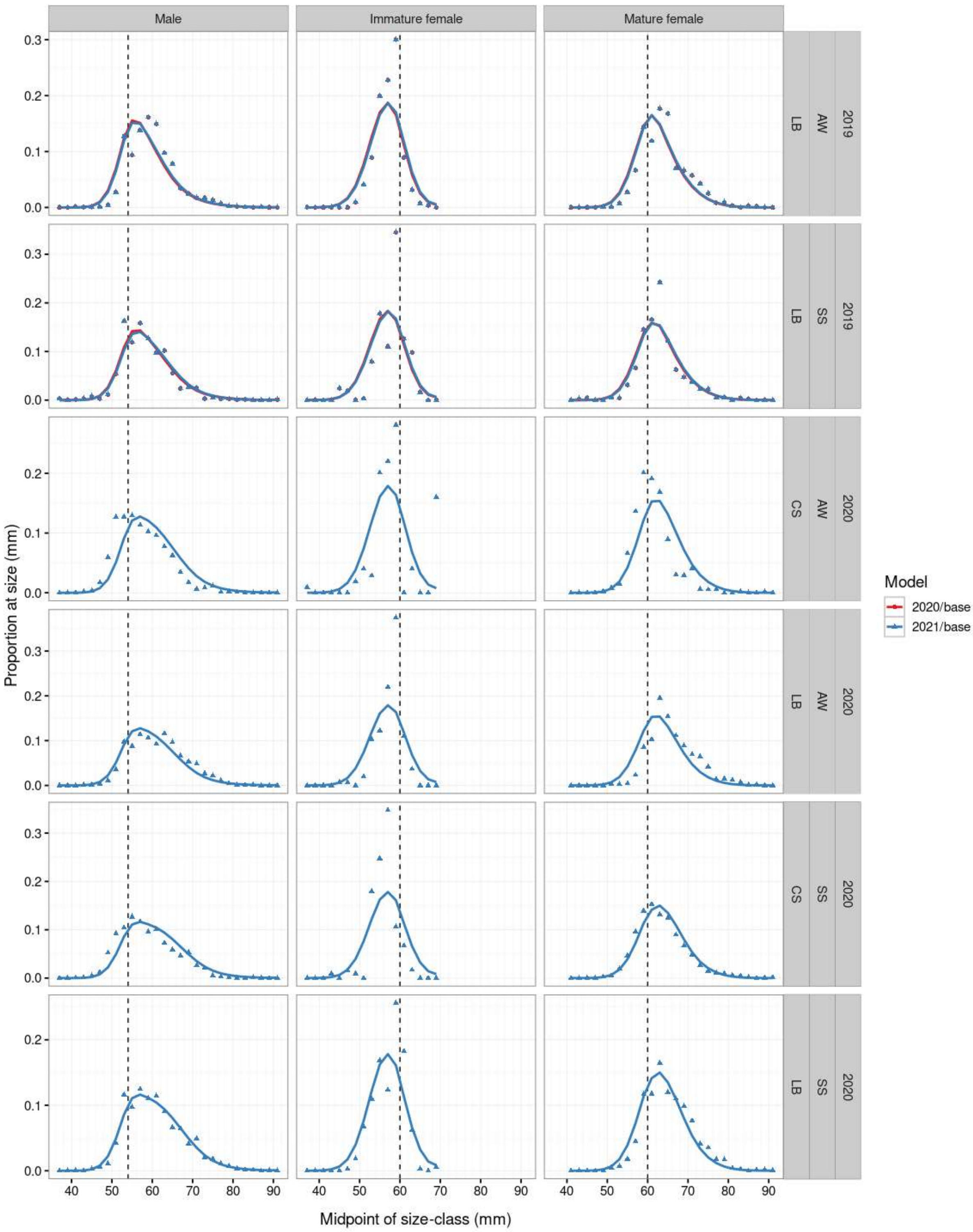


Figure 11: CRA 2 length frequency observations (points) and median of the posterior distribution (line) by year, season (AW = autumn/winter, SS = spring/summer), and data source (CS = catch sampling, LB = logbook) for the last two years of the 2021 rapid update, compared with fits from the 2020 rapid update for 2019 LFs.

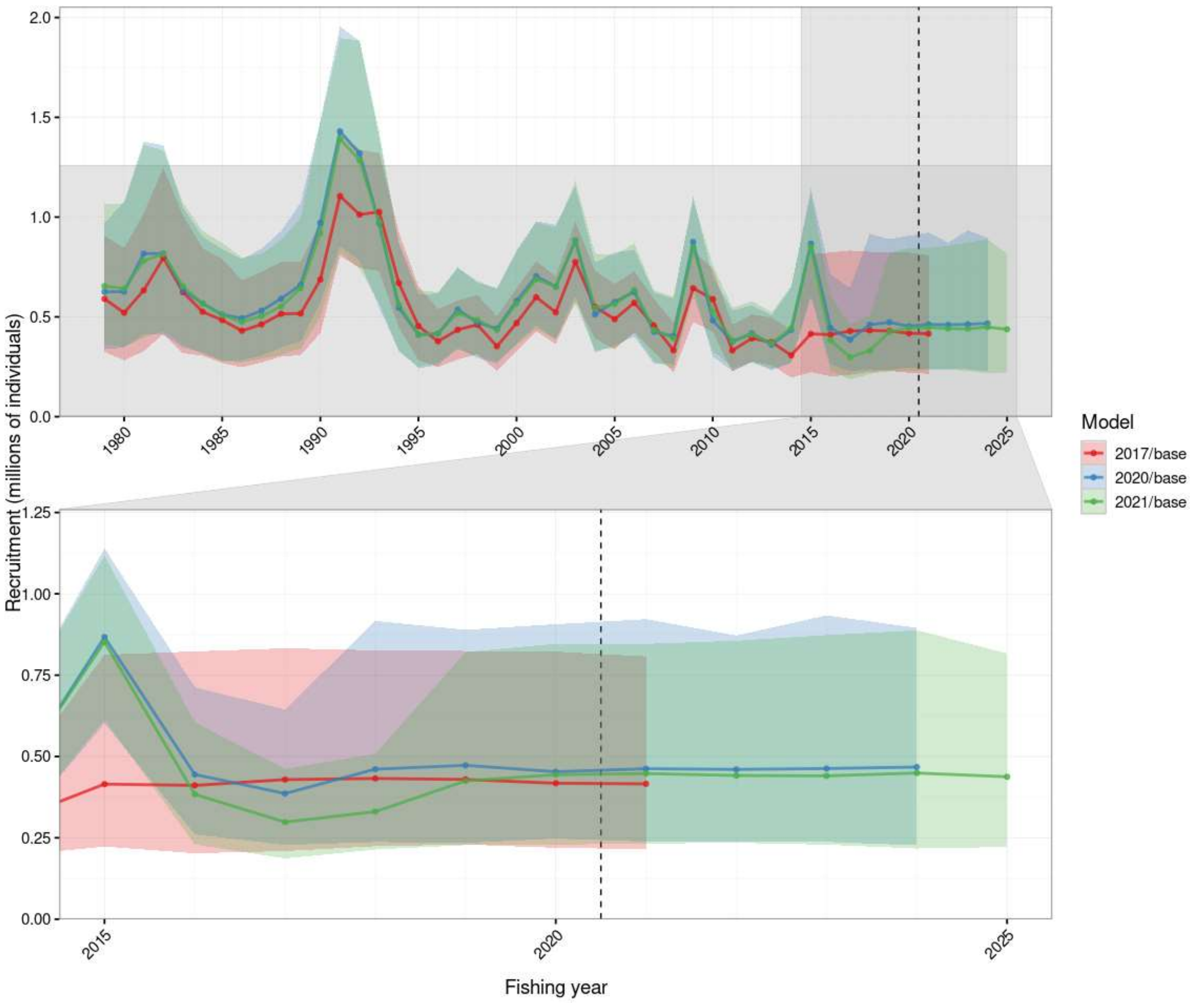


Figure 12: CRA 2 posterior distribution of recruitment showing the median (line) and 90% credible interval (shaded region) for the 2017 stock assessment and the 2020 and 2021 rapid updates. The top panel shows the recruitment for all model years, and the lower panel shows recruitment for the last ten years.

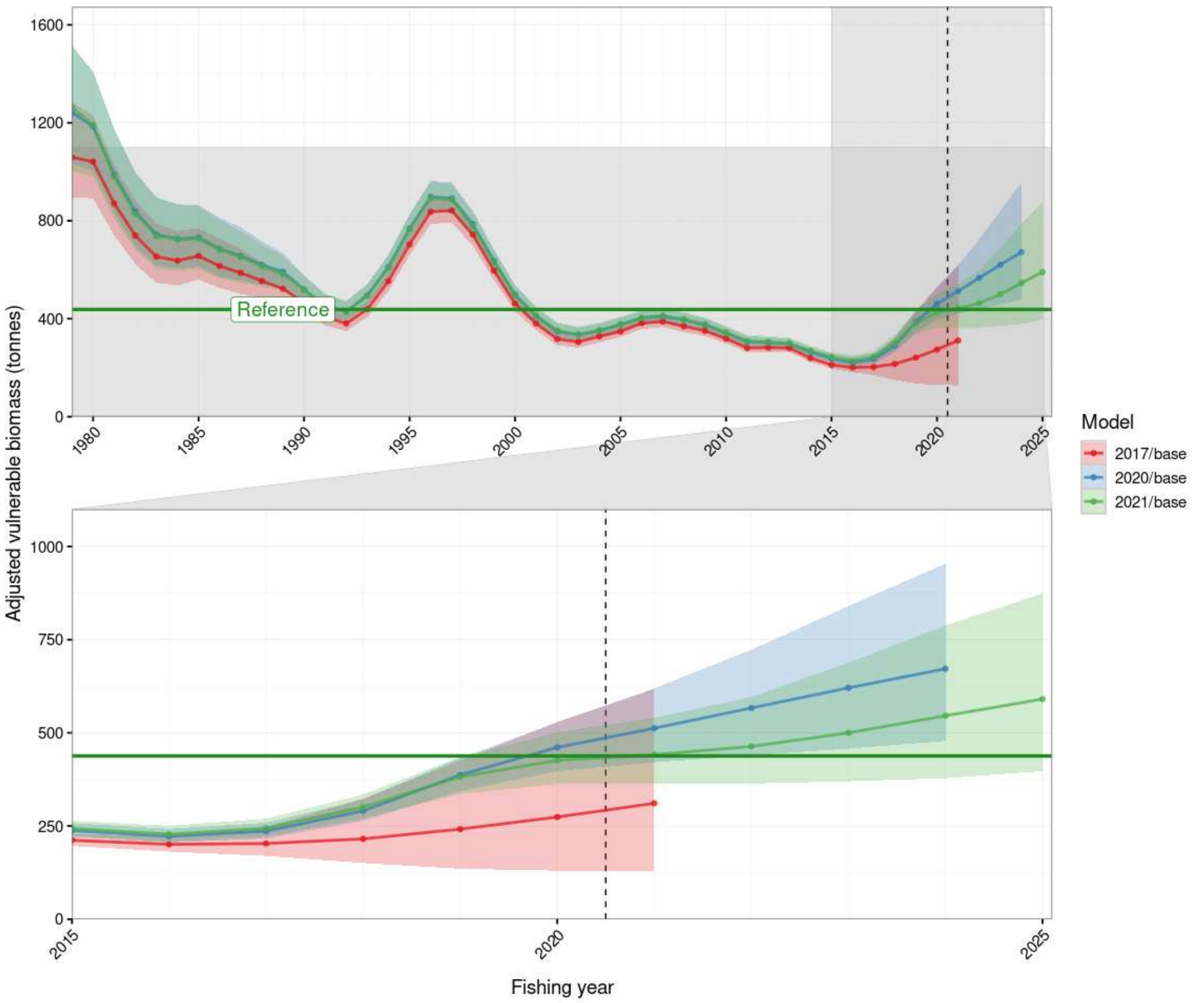


Figure 13: CRA 2 posterior distribution of adjusted vulnerable biomass (tonnes) showing the median (line) and 90% credible interval (shaded region) for the 2017 stock assessment and the 2020 and 2021 rapid updates. The top panel shows the adjusted vulnerable biomass for all model years, and the lower panel shows adjusted vulnerable biomass for the last ten years.

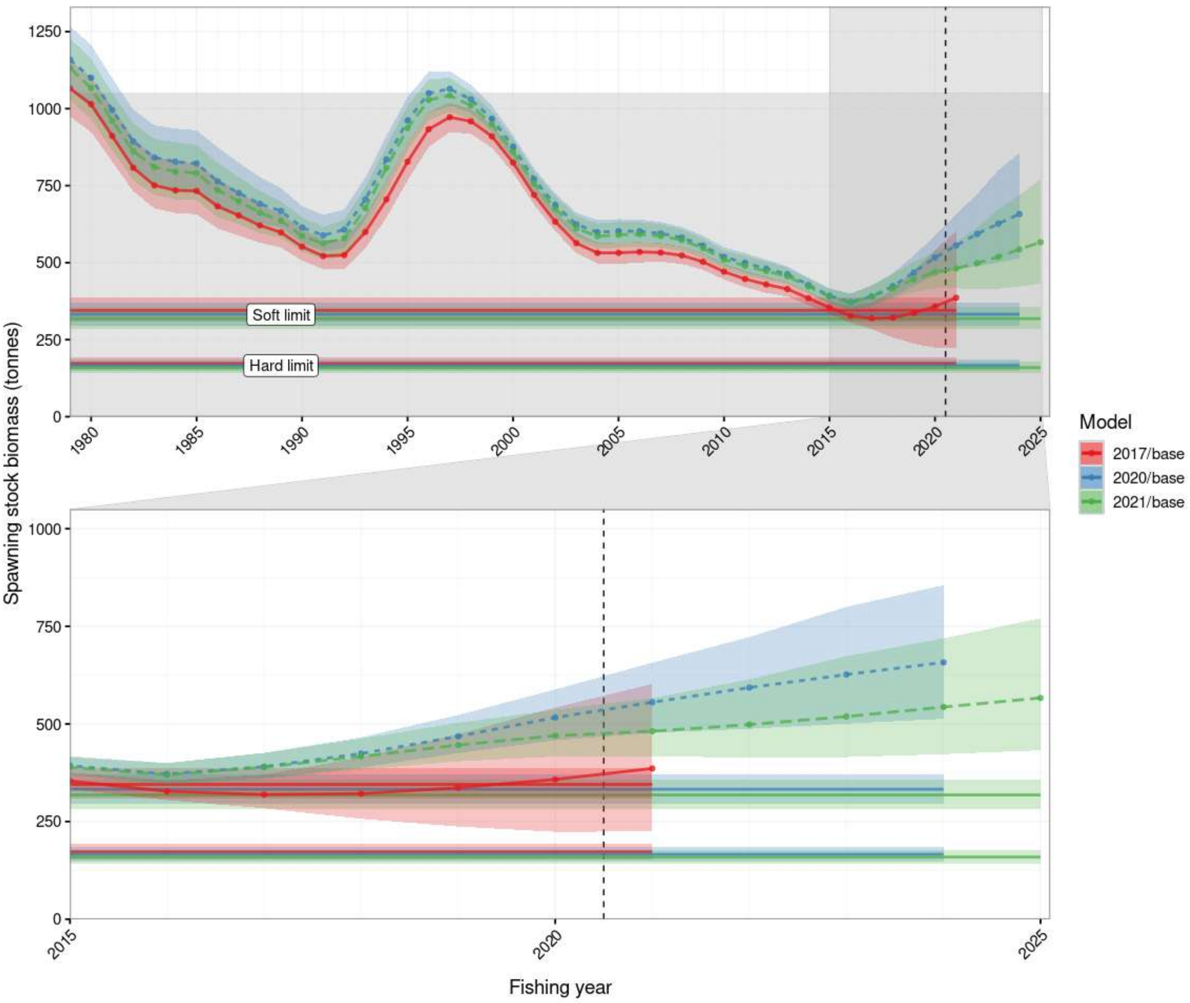


Figure 14: CRA 2 posterior distribution of spawning stock biomass (tonnes) showing the median (line) and 90% credible interval (shaded region) for the 2017 stock assessment and the 2020 and 2021 rapid updates. The top panel shows the spawning stock biomass for all model years, and the lower panel shows spawning stock biomass for the last ten years. The horizontal lines and shaded regions represent the soft limit (top horizontal line and shaded region) and the hard limit (lower horizontal line and shaded region).

Table 7: CRA 2 rapid update indicators summarising the mean, 5% credible interval (CI), median, and 95% CI.

Indicator	Mean	5%	Median	95%
B_0	3 100	2 701	3 095	3 536
B_R	438	–	–	–
B_{2021}	445	362	441	541
B_{2025}	654	413	630	959
B_{2021} / B_0	0.145	0.114	0.142	0.183
B_{2021} / B_R	1.016	0.827	1.008	1.235
B_{2025} / B_0	0.212	0.131	0.207	0.319
B_{2025} / B_R	1.494	0.942	1.439	2.189
B_{2025} / B_{2021}	1.466	0.997	1.436	2.010
SSB_0	1 593	1 416	1 591	1 780
SSB_{2021}	485	417	481	566
SSB_{2025}	581	433	567	771
SSB_{2021} / SSB_0	0.306	0.257	0.302	0.366
SSB_{2025} / SSB_0	0.366	0.268	0.360	0.492
SSB_{2025} / SSB_{2021}	1.196	0.952	1.183	1.470
U_R	0.315	–	–	–
U_{2021} / U_R	0.419	0.340	0.416	0.507
U_{2025} / U_R	0.321	0.210	0.311	0.462

3.3 CRA 3 Rapid update

The CRA 3 fishery extends from East Cape south to the Wairoa River (Figure 1, Figure 15) and includes East Cape (909), Gisborne (910), and the Mahia Peninsula (911).

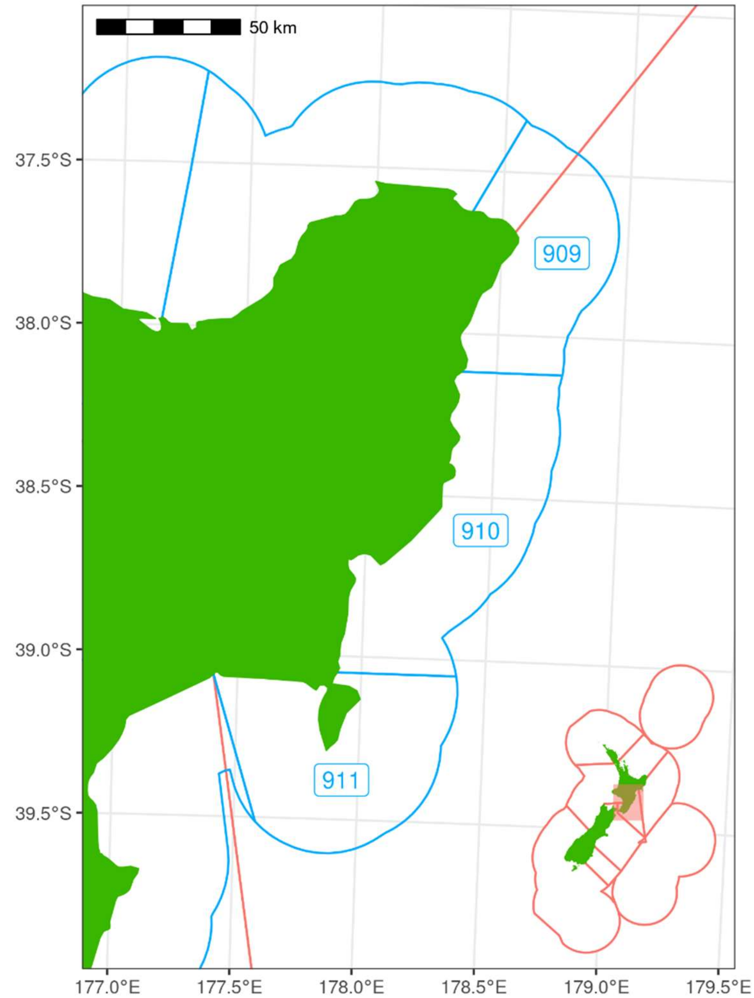


Figure 15: CRA 3 QMA and its statistical areas.

The CRA 3 stock assessment was last done in 2019 as a two-region model: region 1 included statistical areas 909+910 and region 2 consisted of area 911 (Webber et al. 2020). The RLWG selected two base case models that tested alternative growth assumptions, based on the choice of tagging data used to estimate growth, which were designated *r1_qdrift* and *r2_qdrift*. Each model was fitted to standardised CPUE indices, LF data, sex ratio data, and tag-recapture data. The stock assessment portrayed a stock that had declined rapidly between 1960–61 and 1970–71, followed by a levelling off until about 1980–81. After 1980–81, the stock size oscillated over roughly a 10-year cycle, with the stock increasing slightly after 1980–81 and then steadily declining until 1992–93. From there it increased strongly up to 1998–99, declined to a trough in 2004–05, increased again to 2013–14, and has since declined. However, at no point did the spawning stock biomass fall below the soft limit (the default of 20% SSB_0). This is due, in part, to the small TW at maturity in CRA 3.

The 2021 rapid update for CRA 3 added two years of additional data including: a single CPUE index for 2019–20 AW (2019–20 SS is not included because of the change from paper to electronic forms), logbook and catch sampling LFs up to 2020–21, and additional tag-recapture data. Commercial catch was included up to 2020–21, and the projected catch from 2021–22 to 2025–26 was updated to reflect management changes (Table 8).

Table 8: CRA 3 *r1_qdrift* and *r2_qdrift* catch (tonnes) for the last four fishing years and the five projection years in the 2019 base case model compared with the last five fishing years and the five projection years in the 2020 rapid update and last six fishing years and five projection years for the 2021 rapid updates. All projection years are highlighted in grey.

	Commercial			Recreational			Customary			Illegal		
Fishing year	AW	SS	Total	AW	SS	Total	AW	SS	Total	AW	SS	Total
2019/base												
2015–16	193.90	66.95	260.85	1.29	11.66	12.95	2.00	18.00	20.00	45.28	15.63	60.91
2016–17	181.95	78.90	260.85	1.31	11.79	13.10	2.00	18.00	20.00	42.48	18.42	60.90
2017–18	167.21	70.52	237.73	1.16	10.43	11.59	2.00	18.00	20.00	42.84	18.07	60.91
2018–19	168.92	71.04	239.96	1.08	9.64	10.72	2.00	18.00	20.00	42.87	18.03	60.90
2019–20	–	–	239.96	–	–	10.72	–	–	20.00	–	–	60.90
2020–21	–	–	239.96	–	–	10.72	–	–	20.00	–	–	60.90
2021–22	–	–	239.96	–	–	10.72	–	–	20.00	–	–	60.90
2022–23	–	–	239.96	–	–	10.72	–	–	20.00	–	–	60.90
2023–24	–	–	239.96	–	–	10.72	–	–	20.00	–	–	60.90
2020/base												
2015–16	193.90	66.95	260.85	1.29	11.66	12.95	2.00	18.00	20.00	44.77	15.46	60.23
2016–17	181.95	78.90	260.85	1.31	11.79	13.10	2.00	18.00	20.00	42.01	18.22	60.23
2017–18	167.28	70.45	237.73	1.16	10.42	11.58	2.00	18.00	20.00	42.37	17.84	60.21
2018–19	166.91	71.16	238.07	1.08	9.64	10.72	2.00	18.00	20.00	42.22	18.00	60.22
2019–20	135.53	53.12	188.65	1.18	10.61	11.79	2.00	18.00	20.00	43.26	16.96	60.22
2020–21	–	–	244.24	–	–	11.79	–	–	20.00	–	–	60.22
2021–22	–	–	222.90	–	–	11.79	–	–	20.00	–	–	60.22
2022–23	–	–	222.90	–	–	11.79	–	–	20.00	–	–	60.22
2023–24	–	–	222.90	–	–	11.79	–	–	20.00	–	–	60.22
2024–25	–	–	222.90	–	–	11.79	–	–	20.00	–	–	60.22
2021/base												
2015–16	231.54	66.95	260.85	1.34	12.02	13.36	2.00	18.00	20.00	45.56	15.73	61.29
2016–17	181.95	78.91	260.86	1.35	12.15	13.50	2.00	18.00	20.00	42.75	18.54	61.29
2017–18	167.34	70.39	237.73	1.20	10.79	11.99	2.00	18.00	20.00	43.14	18.15	61.29
2018–19	166.33	71.74	238.08	1.11	10.00	11.11	2.00	18.00	20.00	42.82	18.47	61.29
2019–20	122.93	66.06	188.99	1.22	10.98	12.20	2.00	18.00	20.00	39.87	21.42	61.29
2020–21	105.44	109.94	215.39	1.22	10.98	12.20	2.00	18.00	20.00	30.00	31.28	61.29
2021–22	95.46	99.54	195.00	1.22	10.98	12.20	2.00	18.00	20.00	30.00	31.28	61.29
2022–23	95.46	99.54	195.00	1.22	10.98	12.20	2.00	18.00	20.00	30.00	31.28	61.29
2023–24	95.46	99.54	195.00	1.22	10.98	12.20	2.00	18.00	20.00	30.00	31.28	61.29
2024–25	95.46	99.54	195.00	1.22	10.98	12.20	2.00	18.00	20.00	30.00	31.28	61.29
2025–26	95.46	99.54	195.00	1.22	10.98	12.20	2.00	18.00	20.00	30.00	31.28	61.29

MCMC trace plots for the rapid update suggested that mixing was adequate with no signs of non-convergence (see Appendix I for MCMC diagnostic plots).

The rapid update fit to the CPUE was generally very similar to the fit in the 2019 assessment and acceptably fitted the single new CPUE point (Figure 16). There were some differences in fit to the CPUE series in AW to account for the new CPUE point (Figure 16) but it was an acceptable adjustment. The fits to the LFs were very similar during the 2018–19 fishing year and reasonable for 2019–20 and 2020–21 (Figure 17, Figure 18, Figure 19, Figure 20).

The 2021 rapid update estimated small recruitment pulses in 2017–18 and 2018–19 in both regions and model runs due to the inclusion of the additional years of LF data and the estimation of recruitment deviates to 2019–20 (Figure 21). Both the 2020 and 2021 rapid updates suggested that overall recruitment had been lower in the last few years in region 1 in both model runs and about the same in region 2, again for both model runs, when compared with the 2019 assessment (Figure 21). Because of this, projected recruitment over the next five years was lower in region 1 and about the same in region 2 in both model runs. The rapid update estimated adjusted vulnerable biomass to be lower than was projected in 2019 and 2020 in both model runs (Figure 22).

Because of the small recruitment pulses in 2017–18 and 2018–19, the adjusted vulnerable biomass was predicted to increase over the projection years (Figure 22). There was little difference between the 2019–20 and 2020–21 SSB for the two (*r1_qdrift* and *r2_qdrift*) model runs, but the SSB from the 2021 rapid update was predicted to be higher than the 2020 rapid update estimate over the next five years because of the continuing effect from the small 2017–18 and 2018–19 recruitment pulses (Figure 23).

The 2021 rapid update suggested that overall (i.e., region 1 and region 2 combined) the 2021–22 stock size was at 16% of B_0, 80–82% of SSB_0, 24–34% above the reference level, and below the exploitation rate associated with the reference level (Table 9, Table 10). Ranges in percentages represent the range from the two base models.

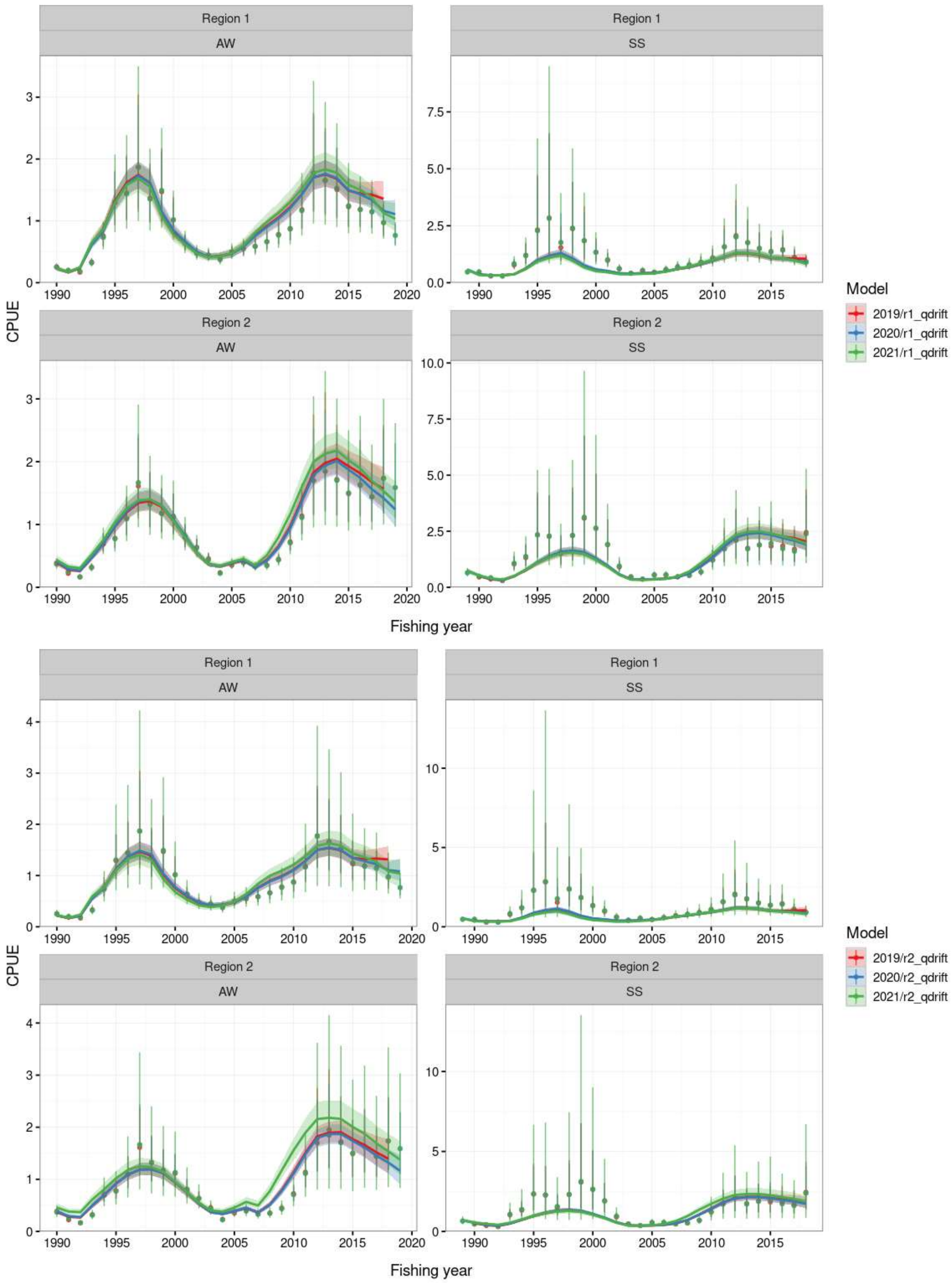


Figure 16: CRA 3 CPUE observations (points) and posterior distribution showing the median (line) and 90% credible interval (shaded region) by region and season (AW = autumn/winter, SS = spring/summer) for the 2019 stock assessment and the 2020 and 2021 rapid updates. The *r1_qdrift* and *r2_qdrift* model runs are presented top and bottom, respectively.

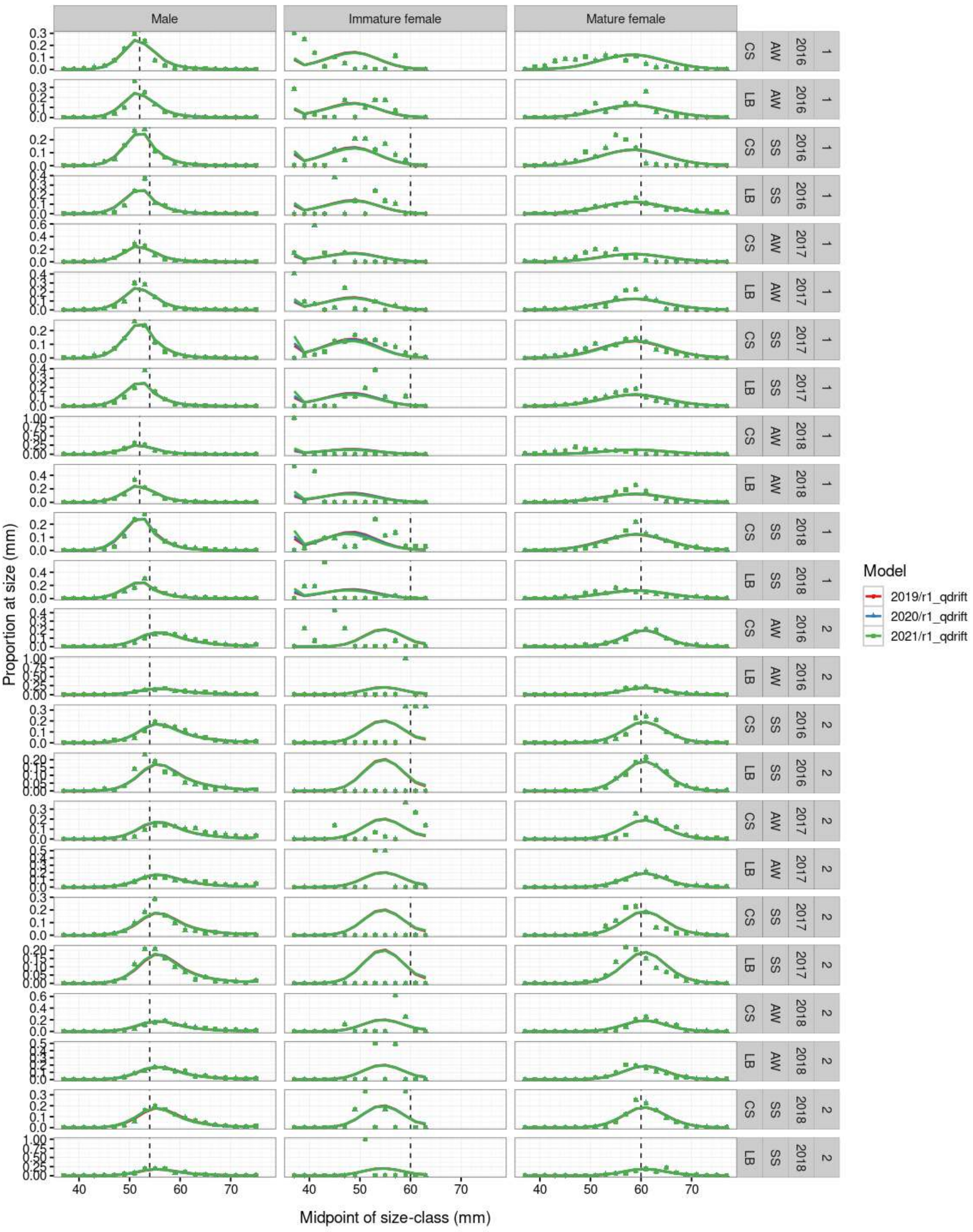


Figure 17: CRA 3 length frequency observations (points) and median of the posterior distribution (line) by region, year, season (AW = autumn/winter, SS = spring/summer), and data source (CS = catch sampling, LB = logbook) for the 2019 stock assessment and the 2020 and 2021 rapid updates for *r1_qdrift*.

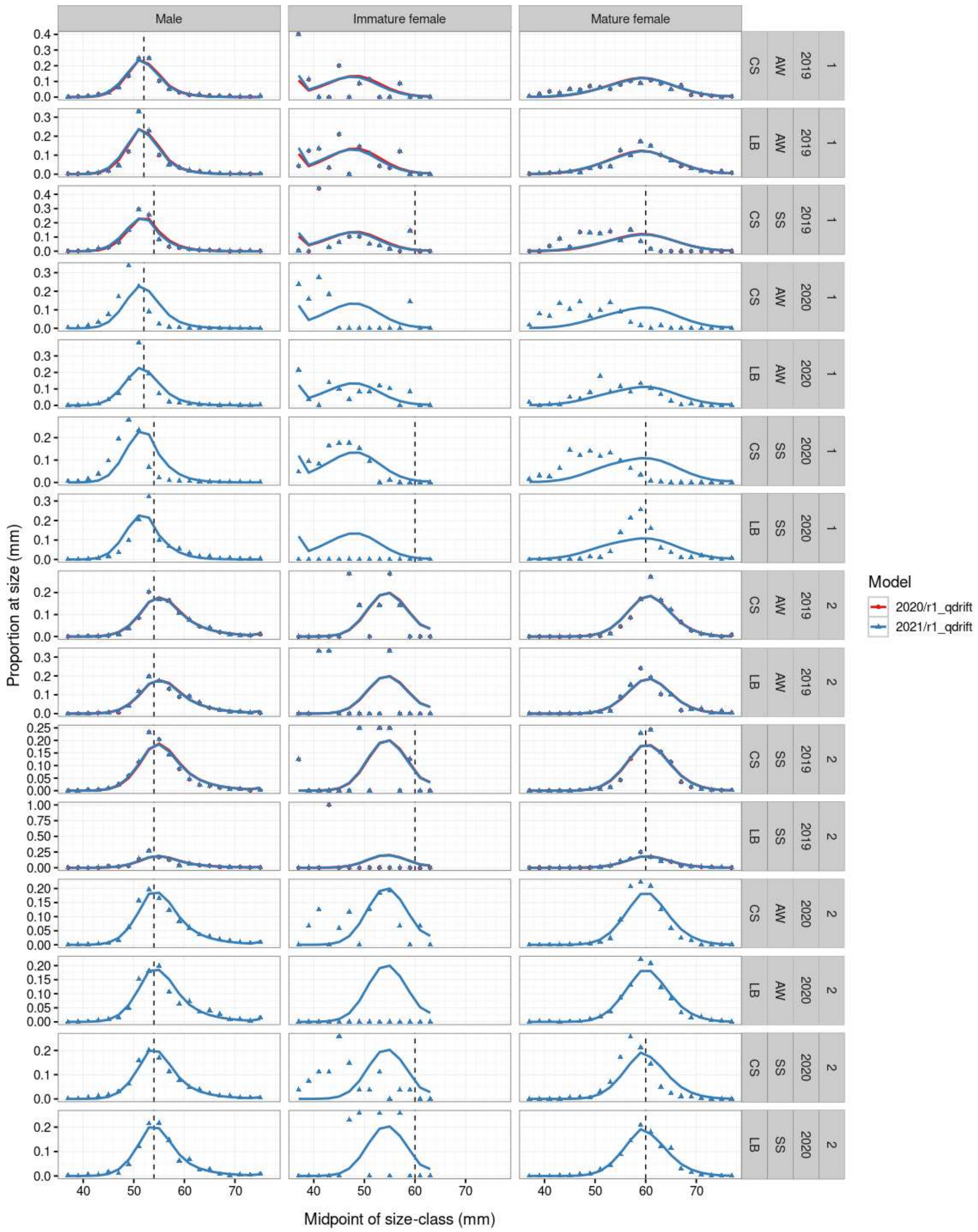


Figure 18: CRA 3 length frequency observations (points) and median of the posterior distribution (line) by region, year, season (AW = autumn/winter, SS = spring/summer), and data source (CS = catch sampling, LB = logbook) for years not included in the 2019 assessment for the 2020 and 2021 rapid updates for *r1_qdrift*.

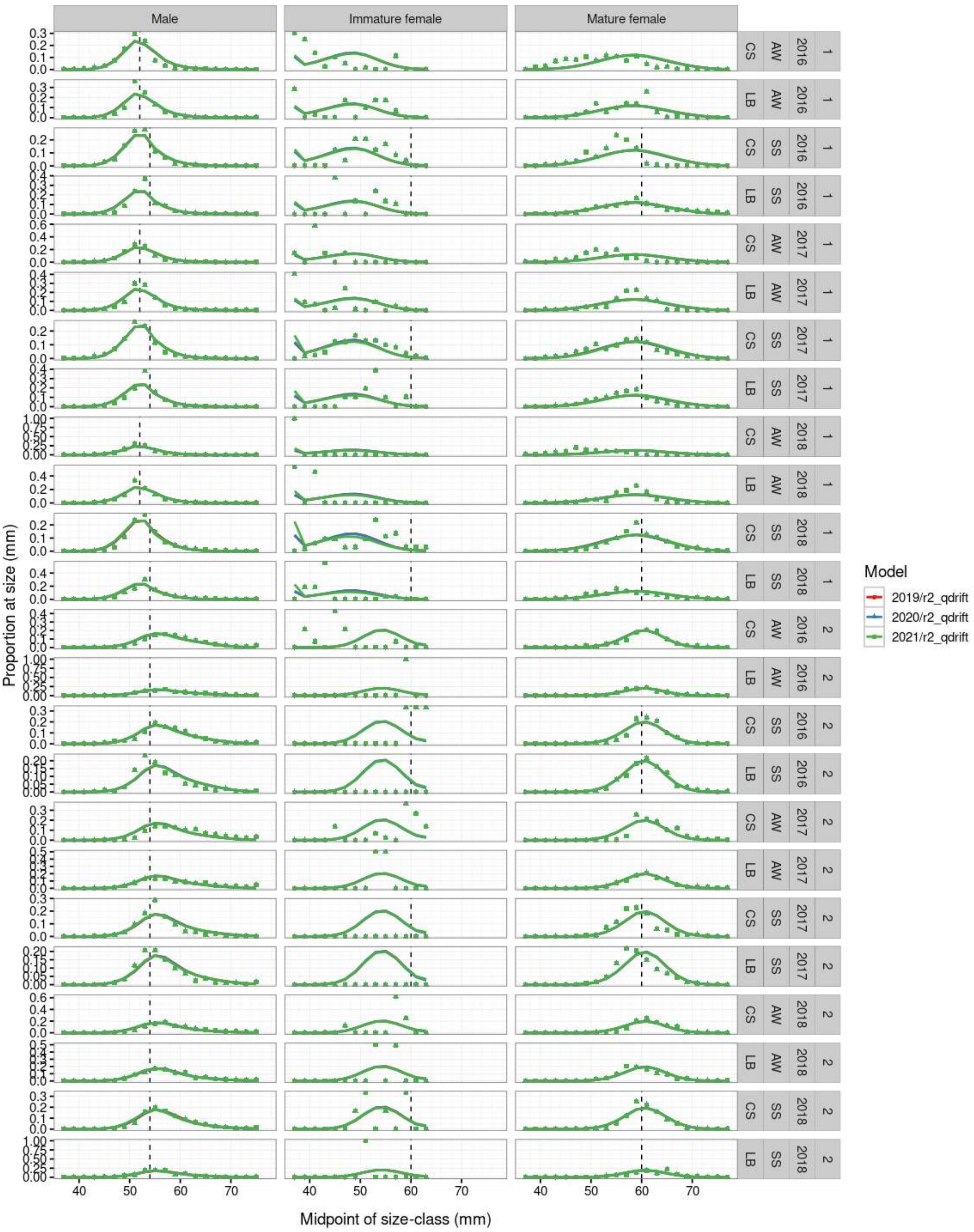


Figure 19: CRA 3 length frequency observations (points) and median of the posterior distribution (line) by region, year, season (AW = autumn/winter, SS = spring/summer), and data source (CS = catch sampling, LB = logbook) for the 2019 stock assessment and the 2020 and 2021 rapid updates for *r2_qdrift*.

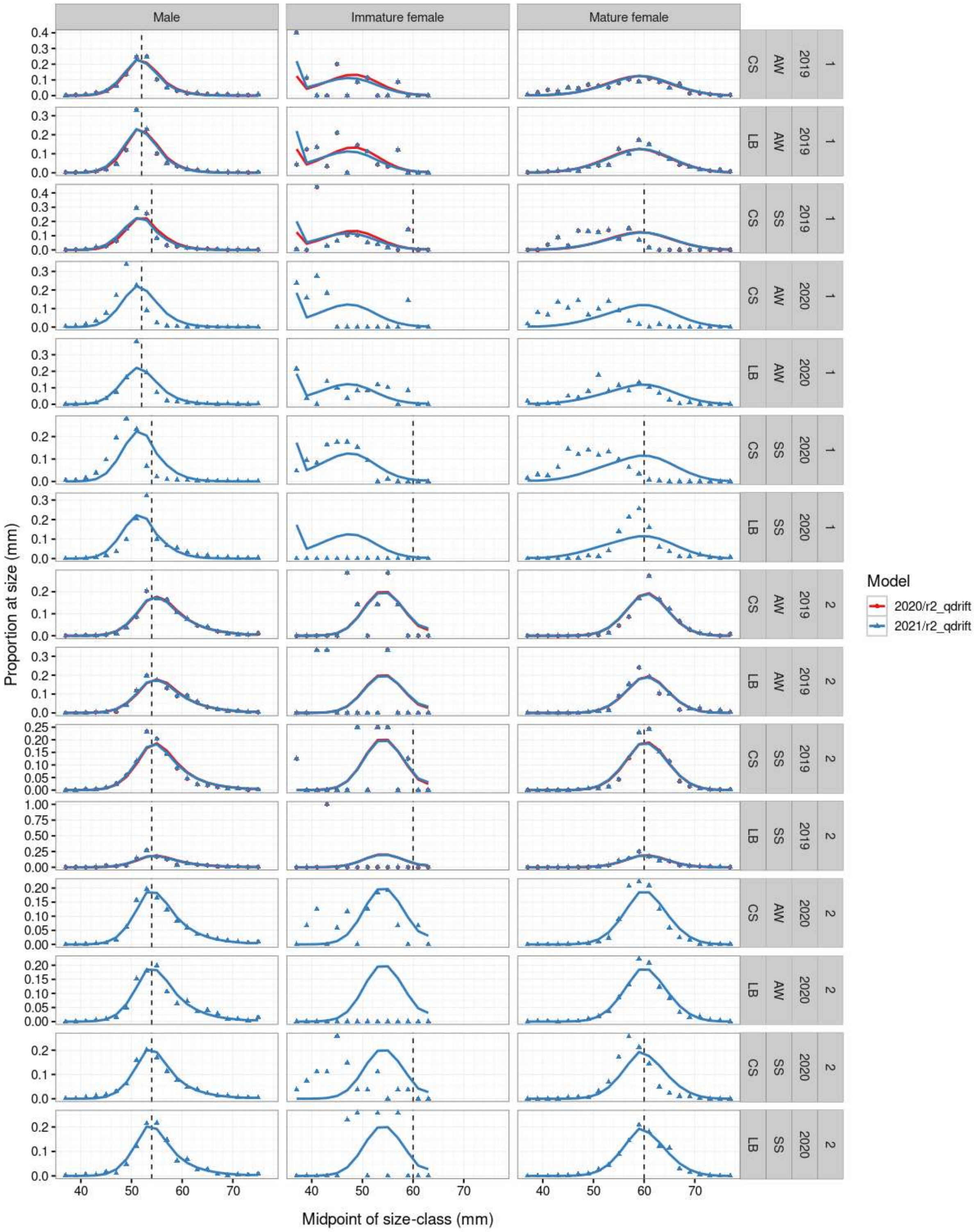


Figure 20: CRA 3 length frequency observations (points) and median of the posterior distribution (line) by region, year, season (AW = autumn/winter, SS = spring/summer), and data source (CS = catch sampling, LB = logbook) for years not included in the 2019 assessment for the 2020 and 2021 rapid updates for *r2_qdrift*.

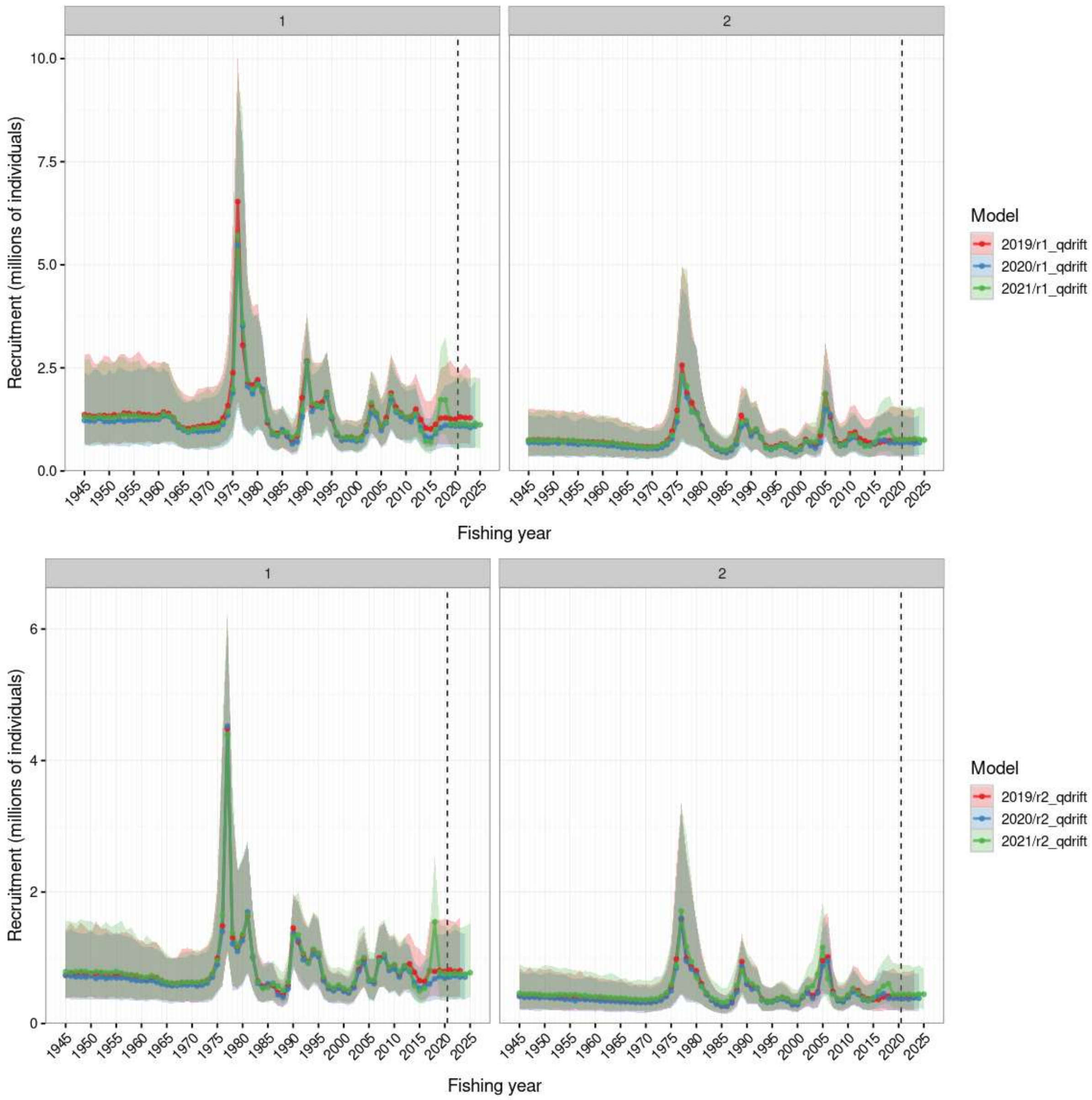
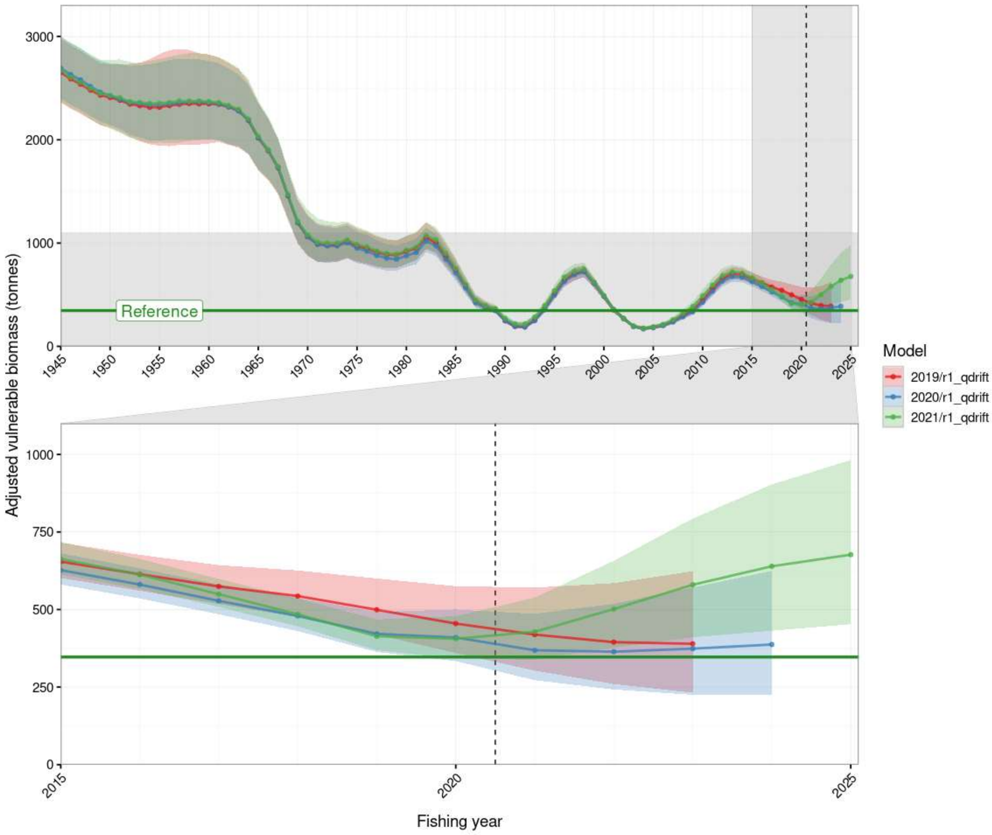


Figure 21: CRA 3 posterior distribution of recruitment by region showing the median (line and points) and 90% credible interval (shaded region) for the 2019 stock assessment and the 2020 and 2021 rapid updates. The *r1_qdrift* and *r2_qdrift* model runs are presented top and bottom, respectively.



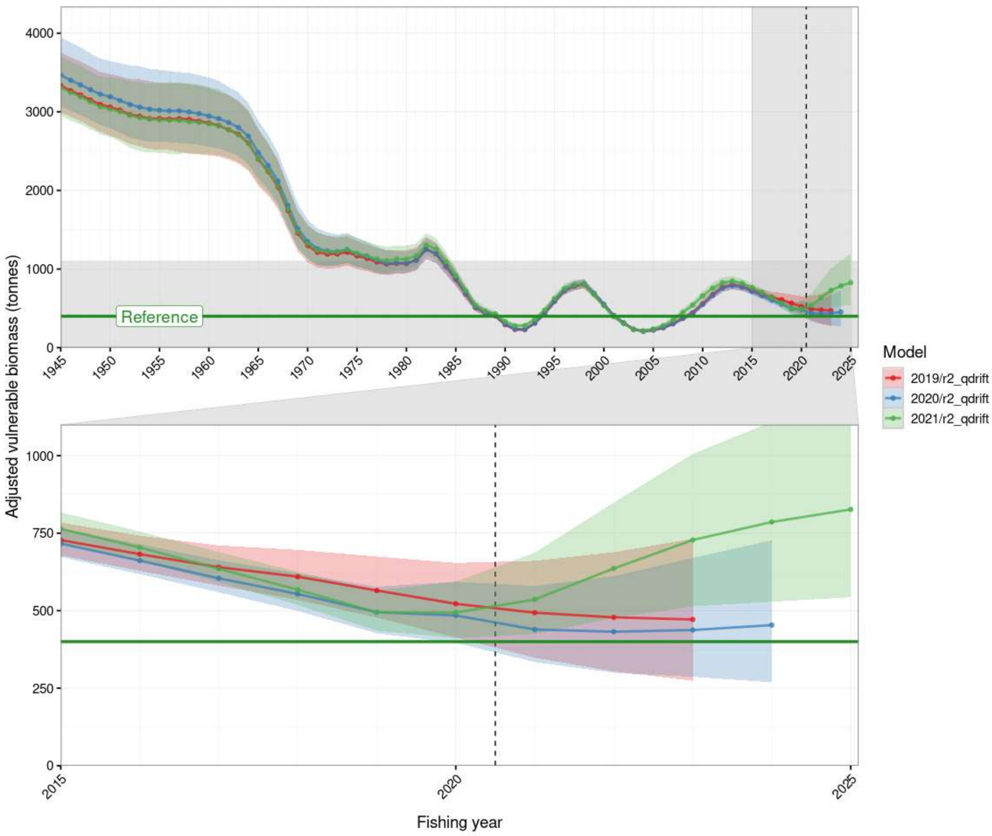


Figure 22: CRA 3 (summed region 1 and region 2) posterior distribution of adjusted vulnerable biomass (tonnes) showing the median (line) and 90% credible interval (shaded region) for the 2019 stock assessment and the 2020 and 2021 rapid updates. The top panel shows the adjusted vulnerable biomass for all model years, and the lower panel shows adjusted vulnerable biomass for the last ten years. The *r1_qdrift* and *r2_qdrift* model runs are presented top and bottom, respectively.

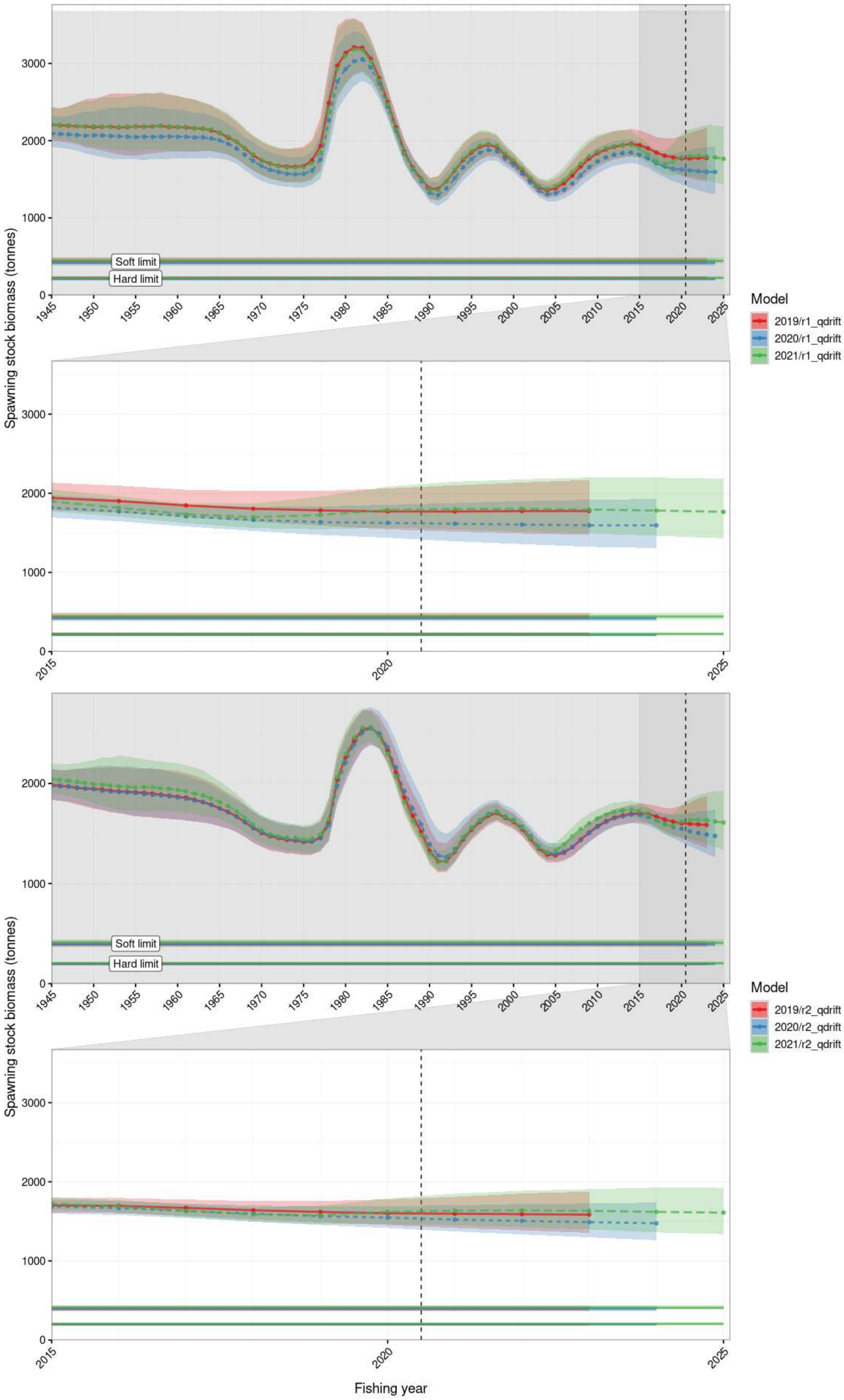


Figure 23: CRA 3 (summed region 1 and region 2) posterior distribution of spawning stock biomass (tonnes) showing the median (line) and 90% credible interval (shaded region) for the 2019 stock assessment and the 2020 and 2021 rapid updates. The top panel shows the spawning stock biomass for all model years, and the lower panel shows spawning stock biomass for the last ten years. The horizontal lines and shaded regions represent the soft limit (top horizontal line and shaded region) and the hard limit (lower horizontal line and shaded region). The *r1_qdrift* and *r2_qdrift* model runs are presented top and bottom, respectively.

Table 9: CRA 3 *r1_qdrift* rapid update indicators for region 1 and region 2 combined summarising the mean, 5% credible interval (CI), median, and 95% CI.

Indicator	Mean	5%	Median	95%
B_0	2 682	2 370	2 666	3 003
B_R	347	–	–	–
B_{2021}	431	338	428	539
B_{2025}	727	468	708	1 053
B_{2021} / B_0	0.162	0.125	0.160	0.205
B_{2021} / B_R	1.244	0.975	1.235	1.553
B_{2025} / B_0	0.272	0.172	0.265	0.399
B_{2025} / B_R	2.097	1.350	2.042	3.037
B_{2025} / B_{2021}	1.678	1.216	1.656	2.217
SSB_0	2 222	2 028	2 213	2 435
SSB_{2021}	1 824	1 545	1 801	2 146
SSB_{2025}	1 788	1 431	1 766	2 184
SSB_{2021} / SSB_0	0.821	0.709	0.816	0.951
SSB_{2025} / SSB_0	0.805	0.660	0.798	0.982
SSB_{2025} / SSB_{2021}	0.979	0.875	0.974	1.098
U_R	0.736	–	–	–
U_{2021} / U_R	0.413	0.325	0.408	0.517
U_{2025} / U_R	0.253	0.165	0.246	0.362

Table 10: CRA 3 *r2_qdrift* rapid update indicators for region 1 and region 2 combined summarising the mean, 5% credible interval (CI), median, and 95% CI.

Indicator	Mean	5%	Median	95%
B_0	3 314	2 951	3 308	3 709
B_R	400	–	–	–
B_{2021}	544	425	536	687
B_{2025}	875	563	858	1 246
B_{2021} / B_0	0.165	0.127	0.162	0.212
B_{2021} / B_R	1.361	1.062	1.340	1.717
B_{2025} / B_0	0.265	0.171	0.257	0.384
B_{2025} / B_R	2.188	1.408	2.145	3.114
B_{2025} / B_{2021}	1.600	1.217	1.588	2.070
SSB_0	2 046	1 899	2 043	2 203
SSB_{2021}	1 640	1 452	1 635	1 849
SSB_{2025}	1 617	1 339	1 610	1 924
SSB_{2021} / SSB_0	0.802	0.715	0.801	0.900
SSB_{2025} / SSB_0	0.791	0.664	0.786	0.939
SSB_{2025} / SSB_{2021}	0.985	0.889	0.982	1.095
U_R	0.634	–	–	–
U_{2021} / U_R	0.381	0.296	0.379	0.478
U_{2025} / U_R	0.236	0.151	0.228	0.342

3.4 CRA 4 Rapid update

The CRA 4 fishery extends from the Wairoa River in northern Hawke's Bay, southwards through Hawke Bay, the Wairarapa and the Wellington coasts, then passing north to the Manawatu River on the Kapiti coast (Figure 1, Figure 24).

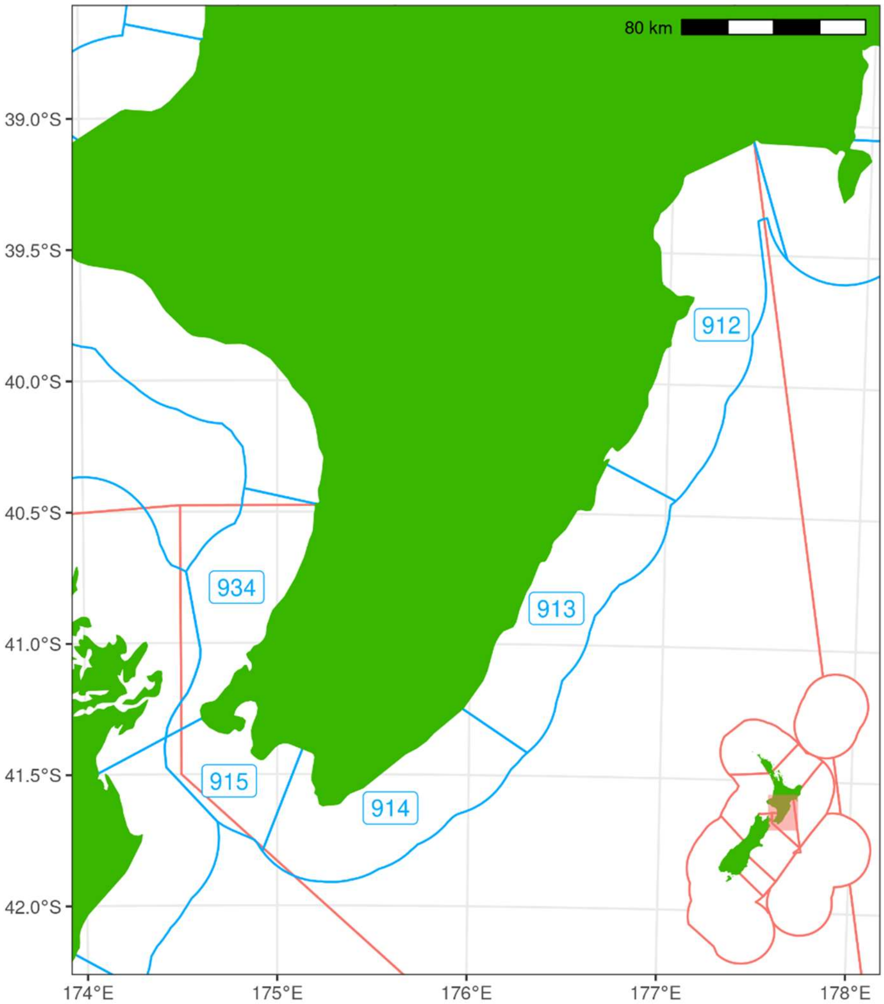


Figure 24: CRA 4 QMA and its statistical areas.

The CRA 4 stock assessment was last done in 2020 as a single region model (Rudd et al. 2021b). The model was fitted to standardised CPUE indices, LF data, sex ratio data, and tag-recapture data. The stock assessment showed a stock with high estimates of SSB relative to the unfished stock level (SSB_0) attributable to the relatively small size at maturity which lies well to the left of the MLS. Vulnerable biomass decreased strongly in the first decade of the fishery and has since undergone a range of fluctuations while gradually decreasing in size. Vulnerable biomass peaked in the mid-1960s, again in the early 1980s, peaked strongly in the late 1990s and lastly just after 2010–11.

The 2021 rapid update for CRA 4 added one year of additional data, including: catch to 2020–21, length data for 2020–21, and the updated tag data extract from 2021. The projected catch from 2021–22 to 2025–26 was updated to reflect management changes (Table 11).

MCMC trace plots for the rapid update suggested that mixing was adequate with no signs of non-convergence (see Appendix I for MCMC diagnostic plots).

Model fits for the 2021 rapid update were almost indistinguishable from the 2020 stock assessment. There were negligible changes to the CPUE fits because no further points in the CPUE series were added compared with the 2020 stock assessment because of the shift to electronic reporting (Figure 25). The fits to the LFs were almost indistinguishable from those obtained in 2020 for 2016–17, 2017–18, 2018–19, and 2019–20, and the fits to the 2020–21 LFs were excellent (Figure 26).

The rapid update suggested that there had been a pulse of recruitment in 2018–19 that had not been estimated by the 2020 assessment, since the last recruitment deviate estimated in the 2020 assessment was in 2017–18 (Figure 27). This led to a slightly higher average recruitment for the projection period of the 2021 rapid update compared with the projections for the 2020 assessment. The rapid update suggested that vulnerable biomass should increase over the projection period given the assumed catches and the elevated mean recruitment resulting from the 2018–19 recruitment pulse (Figure 28). At current catch levels, the vulnerable and spawning stock biomass were projected to increase to above the reference level over the next five years (Figure 29).

The rapid update suggested that CRA 4 at the beginning of 2021–22 was at 11% of B_0, 51% of SSB_0, and at 95% of the reference level. It was below the 2021–22 average exploitation rate associated with the reference level (Table 12).

Table 11: CRA 4 catch (tonnes) for the last five fishing years and the five projection years in the 2020 base case model compared with the last six fishing years and the five projection years in the 2021 rapid update. All projection years are highlighted in grey.

	Commercial			Recreational			Customary			Illegal		
Fishing year	AW	SS	Total	AW	SS	Total	AW	SS	Total	AW	SS	Total
2020/base												
2015–16	108.82	329.33	438.15	3.66	32.93	36.59	2.00	18.00	20.00	4.39	13.28	17.67
2016–17	79.09	303.78	382.87	3.52	31.68	35.20	2.00	18.00	20.00	3.17	12.17	15.34
2017–18	63.50	225.49	288.99	4.11	36.97	41.08	2.00	18.00	20.00	4.27	15.18	19.45
2018–19	90.27	228.10	318.37	4.24	38.16	42.40	2.00	18.00	20.00	6.02	15.22	21.24
2019–20	82.44	197.84	280.28	3.96	35.60	39.56	2.00	18.00	20.00	5.49	13.18	18.68
2020–21	–	–	350.60	–	–	39.56	2.00	18.00	20.00	5.49	13.18	18.68
2021–22	–	–	350.80	–	–	39.56	2.00	18.00	20.00	5.49	13.18	18.68
2022–23	–	–	350.80	–	–	39.56	2.00	18.00	20.00	5.49	13.18	18.68
2023–24	–	–	350.80	–	–	39.56	2.00	18.00	20.00	5.49	13.18	18.68
2024–25	–	–	–	–	–	–	2.00	18.00	20.00	5.49	13.18	18.68
2021/base												
2015–16	108.82	329.33	438.15	3.66	32.93	36.59	2.00	18.00	20.00	4.39	13.28	17.67
2016–17	79.09	303.78	382.87	3.52	31.67	35.19	2.00	18.00	20.00	3.17	12.17	15.34
2017–18	63.50	225.49	288.99	4.11	37.01	41.12	2.00	18.00	20.00	4.27	15.18	19.45
2018–19	90.27	228.10	318.37	4.25	38.22	42.46	2.00	18.00	20.00	6.02	15.22	21.24
2019–20	82.44	197.85	280.28	3.96	35.63	39.59	2.00	18.00	20.00	5.49	13.18	18.68
2020–21	117.90	232.64	350.53	3.96	35.63	39.59	2.00	18.00	20.00	6.28	12.40	18.68
2021–22	94.17	185.83	280.00	3.96	35.63	39.59	2.00	18.00	20.00	6.28	12.40	18.68
2022–23	94.17	185.83	280.00	3.96	35.63	39.59	2.00	18.00	20.00	6.28	12.40	18.68
2023–24	94.17	185.83	280.00	3.96	35.63	39.59	2.00	18.00	20.00	6.28	12.40	18.68
2024–25	94.17	185.83	280.00	3.96	35.63	39.59	2.00	18.00	20.00	6.28	12.40	18.68
2025–26	94.17	185.83	280.00	3.96	35.63	39.59	2.00	18.00	20.00	6.28	12.40	18.68

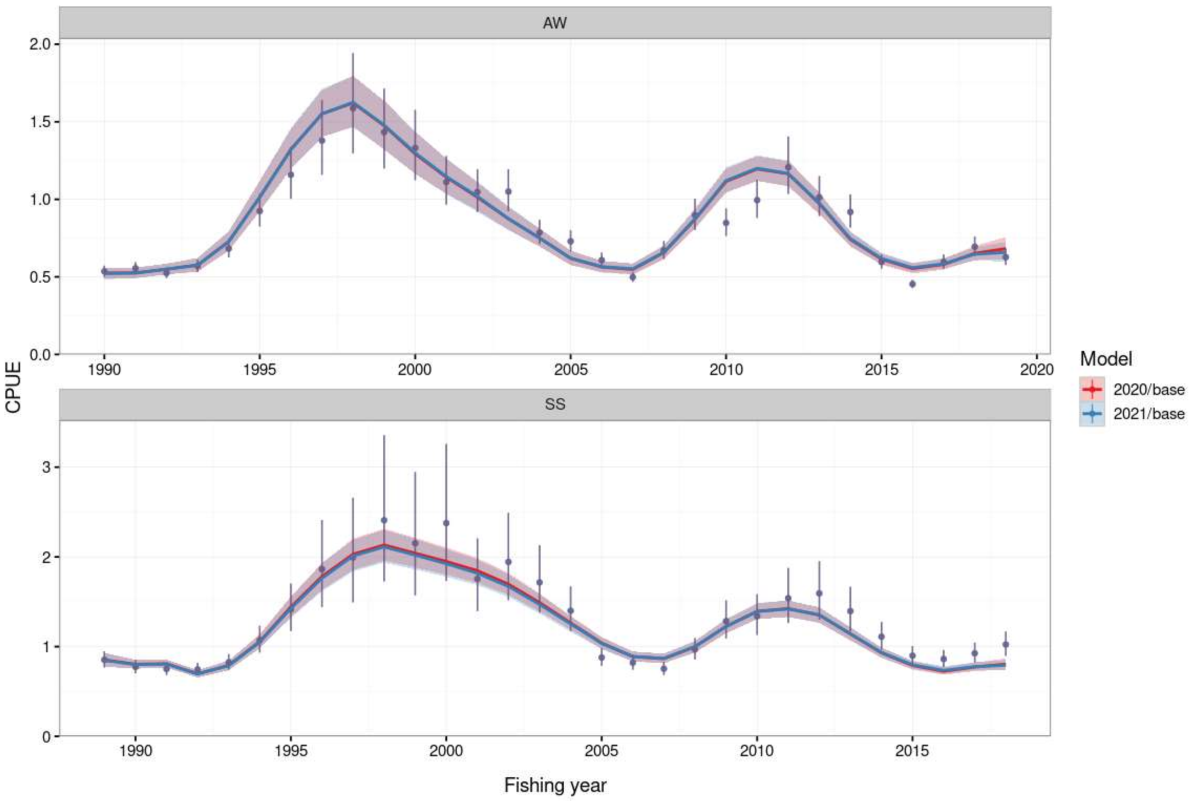


Figure 25: CRA 4 CPUE observations (points) and posterior distribution showing the median (line) and 90% credible interval (shaded region) by season (AW = autumn/winter, SS = spring/summer) for the 2020 stock assessment and the 2021 rapid update.

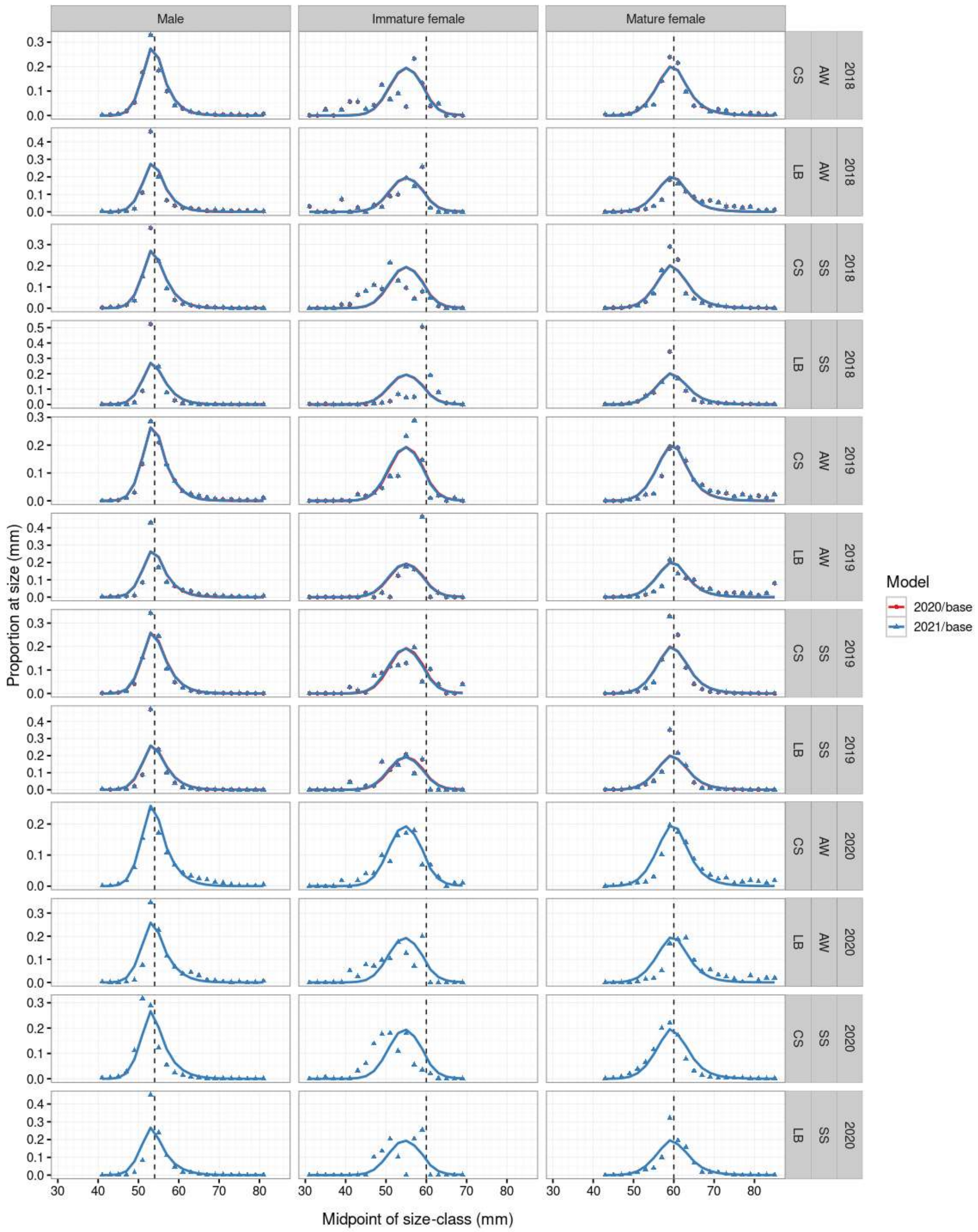


Figure 26: CRA 4 length frequency observations (points) and median of the posterior distribution (line) by year, season (AW = autumn/winter, SS = spring/summer), and data source (CS = catch sampling, LB = logbook) for the 2020 stock assessment and the 2021 rapid update.

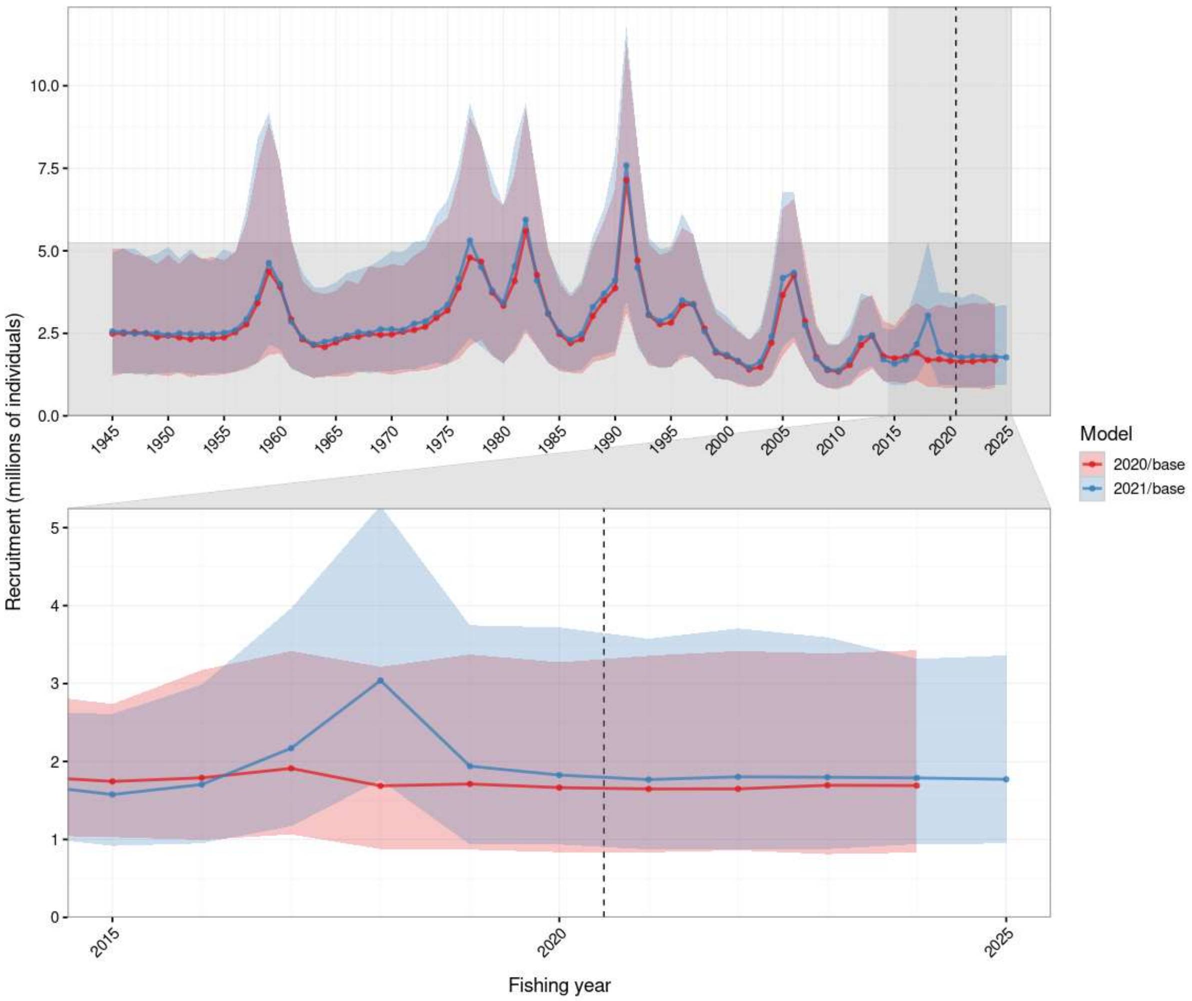


Figure 27: CRA 4 posterior distribution of recruitment showing the median (line) and 90% credible interval (shaded region) for the 2020 stock assessment and the 2021 rapid update. The top panel shows the recruitment for all model years, and the lower panel shows recruitment for the last ten years.

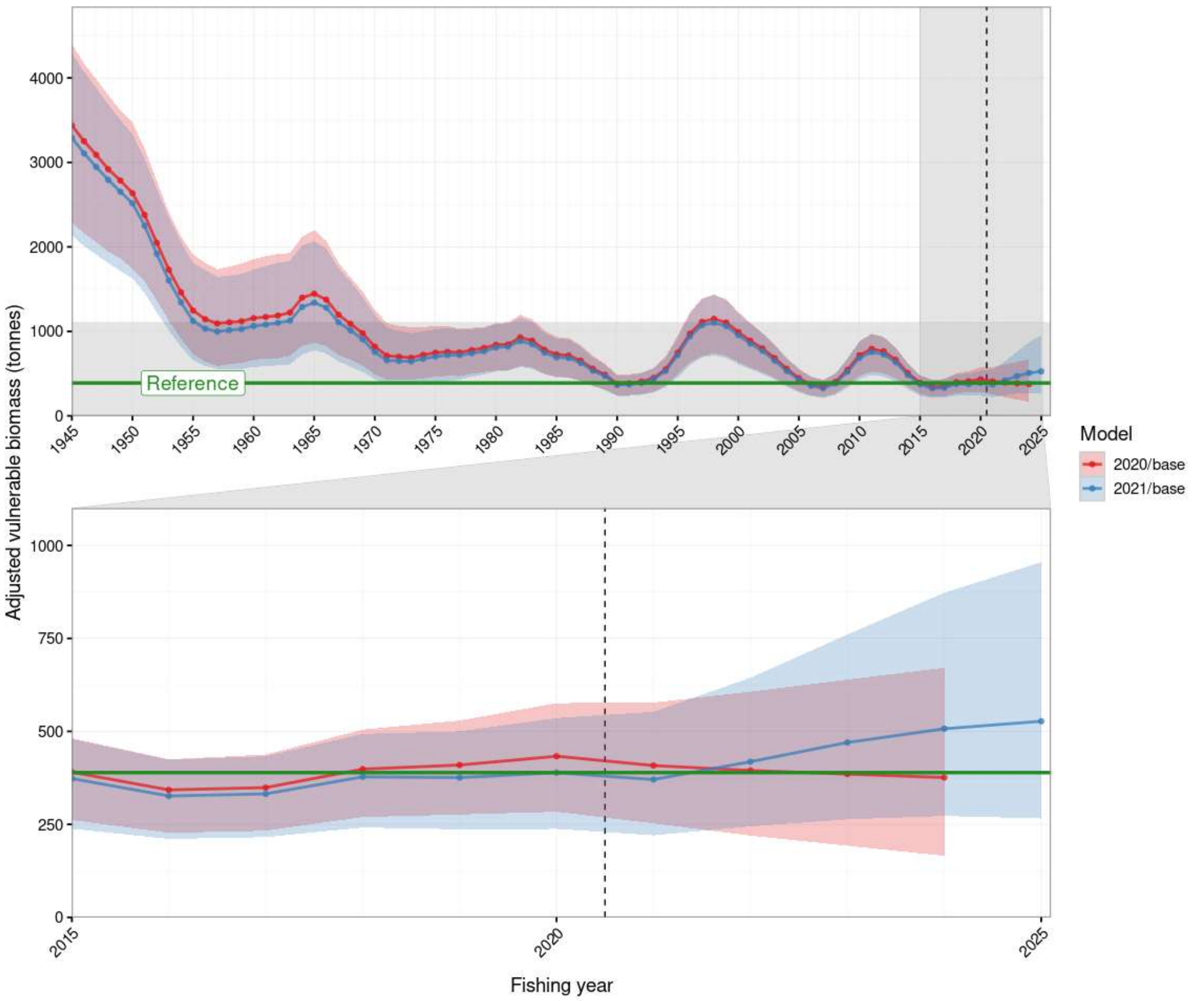


Figure 28: CRA 4 posterior distribution of adjusted vulnerable biomass (tonnes) showing the median (line) and 90% credible interval (shaded region) for the 2020 stock assessment and the 2021 rapid update. The top panel shows the adjusted vulnerable biomass for all model years, and the lower panel shows adjusted vulnerable biomass for the last ten years.

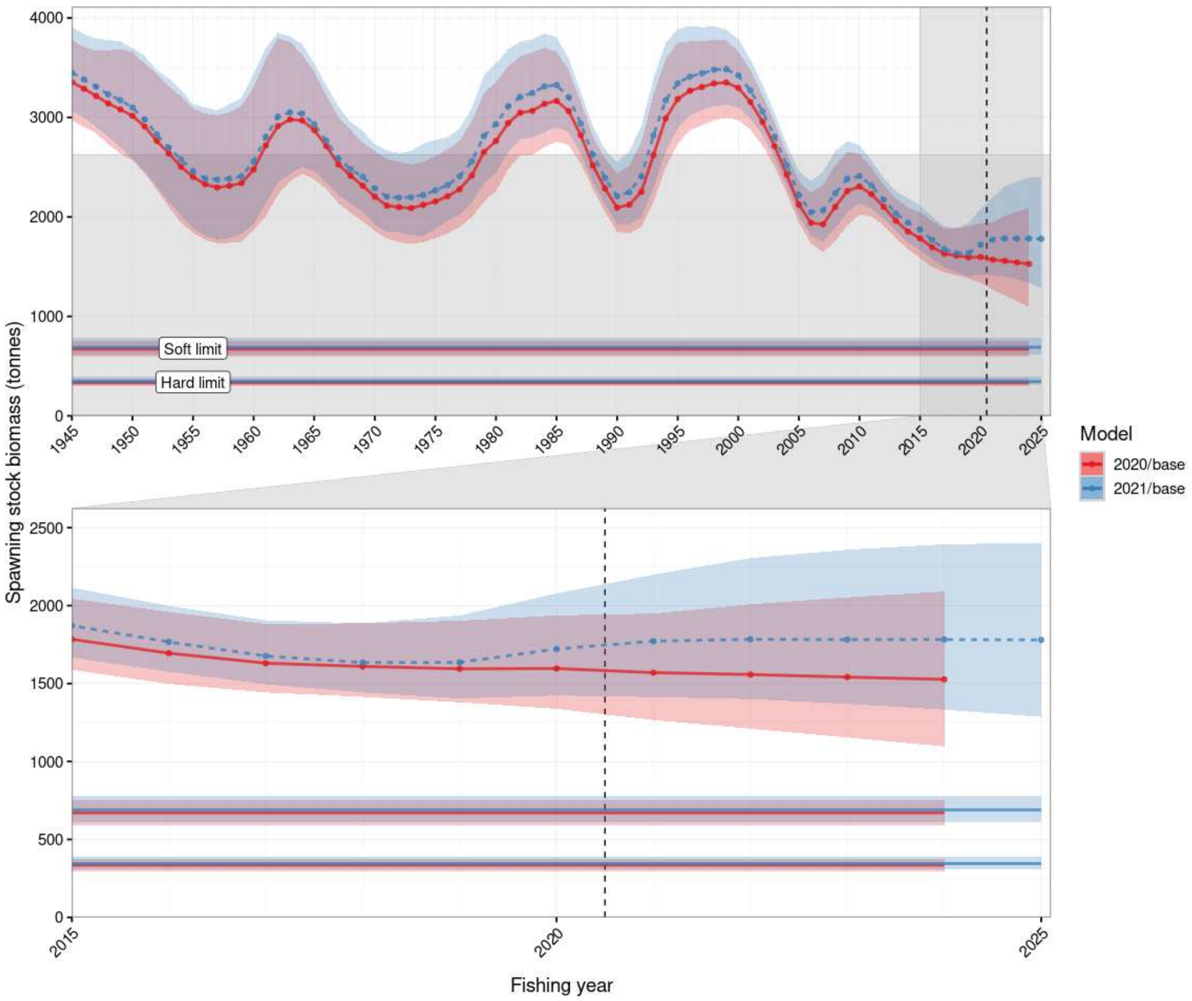


Figure 29: CRA 4 posterior distribution of spawning stock biomass (tonnes) showing the median (line) and 90% credible interval (shaded region) for the 2020 stock assessment and the 2021 rapid update. The top panel shows the spawning stock biomass for all model years, and the lower panel shows spawning stock biomass for the last ten years. The horizontal lines and shaded regions represent the soft limit (top horizontal line and shaded region) and the hard limit (lower horizontal line and shaded region).

Table 12: CRA 4 rapid update indicators summarising the mean, 5% credible interval (CI), median, and 95% CI.

Indicator	Mean	5%	Median	95%
B_0	3 264	2 136	3 292	4 295
B_R	389	–	–	–
B_{2021}	372	220	370	553
B_{2025}	568	247	531	1 000
B_{2021} / B_0	0.115	0.081	0.112	0.157
B_{2021} / B_R	0.956	0.567	0.952	1.420
B_{2025} / B_0	0.175	0.086	0.166	0.284
B_{2025} / B_R	1.460	0.634	1.363	2.569
B_{2025} / B_{2021}	1.516	0.865	1.469	2.308
SSB_0	3 464	3 063	3 449	3 908
SSB_{2021}	1 780	1 413	1 772	2 199
SSB_{2025}	1 804	1 286	1 780	2 403
SSB_{2021} / SSB_0	0.514	0.423	0.507	0.616
SSB_{2025} / SSB_0	0.521	0.386	0.511	0.679
SSB_{2025} / SSB_{2021}	1.011	0.842	1.005	1.187
U_R	0.463	–	–	–
U_{2021} / U_R	0.667	0.416	0.620	1.042
U_{2025} / U_R	0.483	0.241	0.436	0.865

3.5 CRA 5 Rapid update

The CRA 5 fishery includes all of Tasman Bay and Golden Bay as well as the Marlborough Sounds, then extends down the northern part of the east coast of the South Island, past Kaikōura and the Banks Peninsula as far down as the Waitaki River (Figure 1, Figure 30).

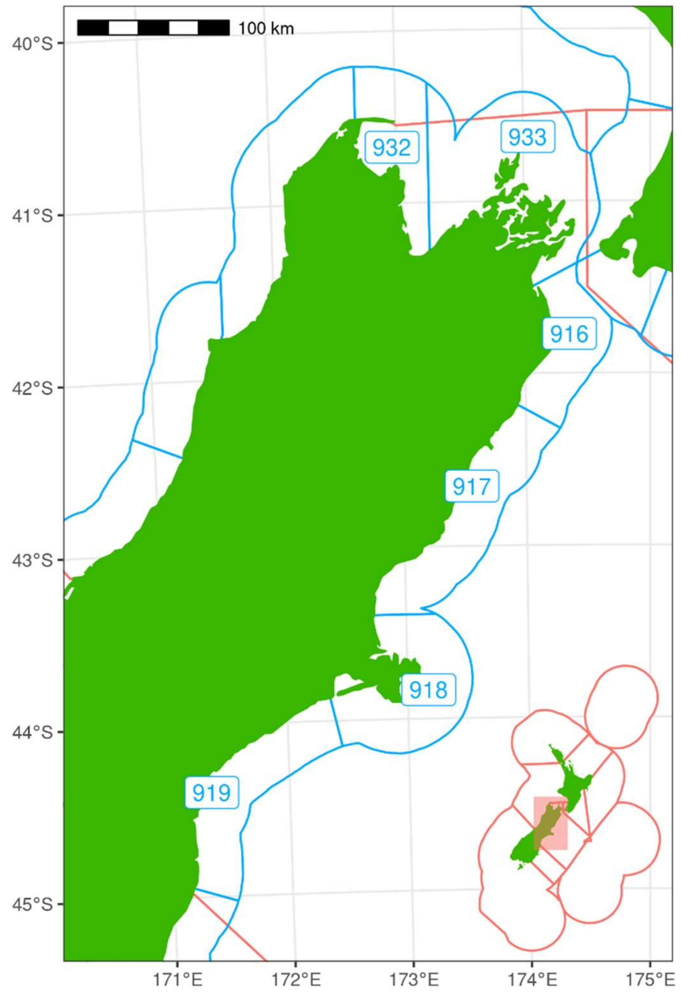


Figure 30: CRA 5 QMA and its statistical areas.

The CRA 5 stock assessment was last done in 2020 as a two-region model: region 1 included statistical areas 917+918+919 and region 2 consisted of statistical areas 916+932+933 (Webber et al. 2021b). The model was fitted to standardised CPUE indices, LF data, sex ratio data, and tag-recapture data. The stock assessment results differ between the two regions, with region 1 (917+918+919) declining steadily from the beginning of the reconstruction to the early 1990s, followed by a strong recovery to biomass levels near the size of the initial biomass, peaking around 2010–11. Region 1 has since declined to about half of the peak. Region 2 (916+932+933) declined strongly to the mid-1950s, followed by a period of relative stability. Biomass then peaked near 2000–01, followed by a decline to the mid-2010s and now appears to be rising again.

The 2021 rapid update for CRA 5 added a single year of additional data, including: an additional year of catch for 2020–21, length data for 2020–21, and the updated tag data extract for 2021. Projected catch from 2021–22 to 2025–26 was updated to reflect management changes (Table 13).

An initial rapid update model run for CRA 5 that included dataset reweighting showed differences in the MAP estimates that could not be explained from the single additional year of data. Without reweighting, the MAP trajectories matched between the 2020 base model and 2021 rapid update. The weights used in the 2020 base model were used rather than reweighting the data sets for this stock's rapid update.

MCMC trace plots for the rapid update suggested that mixing was adequate with no signs of non-convergence (see Appendix I for MCMC diagnostic plots).

The 2021 rapid update fit to the CPUE was very similar to the fit in the 2020 assessment with only minor differences (Figure 31). The fits to the LFs were very similar to the 2020 stock assessment up to 2019–20 and acceptable for 2020–21 in both regions (Figure 32).

The rapid update estimated approximately the same recruitment, adjusted vulnerable biomass, and SSB as were estimated by the 2020 stock assessment. This was not surprising given that there was only one additional year of LF data and no change to the CPUE data (Figure 33, Figure 34, Figure 35). The only difference was a small recruitment pulse in 2018–19 in region 1, a recruitment year that was fixed at the average recruitment for the 2020 assessment (Figure 33). With the small 2018–19 recruitment pulse and the updated projected catch to reflect management changes, the 2021 rapid update predicted the adjusted vulnerable biomass to be slightly greater than was projected by the 2020 stock assessment (Figure 34). Projected spawning biomass was predicted to be about the same or slightly lower than was projected by the 2020 stock assessment over the next five years (Figure 35).

The 2021 rapid update suggested that the overall (i.e., region 1 and region 2 combined) stock at the beginning of 2021–22 was at 40% of B_0, 70% of SSB_0, and more than double the reference level, with an exploitation rate well below that associated with the average reference level (Table 14).

Table 13: CRA 5 catch (tonnes) for the last five fishing years and the five projection years in the 2020 base case model compared with the last six fishing years and the five projection years in the 2021 rapid update. All projection years are highlighted in grey.

	Commercial			Recreational			Customary			Illegal		
Fishing year	AW	SS	Total	AW	SS	Total	AW	SS	Total	AW	SS	Total
2020/base												
2015–16	230.51	119.64	350.15	6.91	62.17	69.08	1.00	9.00	10.00	13.49	7.00	20.49
2016–17	241.54	108.42	349.96	7.93	71.39	79.32	1.00	9.00	10.00	15.67	7.03	22.70
2017–18	211.70	138.27	349.96	7.34	66.07	73.41	1.00	9.00	10.00	15.26	9.97	25.23
2018–19	223.01	126.91	349.92	7.09	63.75	70.84	1.00	9.00	10.00	14.31	8.14	22.45
2019–20	250.34	85.84	336.18	7.46	67.22	74.68	1.00	9.00	10.00	17.47	5.99	23.46
2020–21	293.45	70.36	363.80	7.46	67.22	74.68	1.00	9.00	10.00	17.47	5.99	23.46
2021–22	282.31	67.69	350.00	7.46	67.22	74.68	1.00	9.00	10.00	17.47	5.99	23.46
2022–23	282.31	67.69	350.00	7.46	67.22	74.68	1.00	9.00	10.00	17.47	5.99	23.46
2023–24	282.31	67.69	350.00	7.46	67.22	74.68	1.00	9.00	10.00	17.47	5.99	23.46
2024–25	282.31	67.69	350.00	7.46	67.22	74.68	1.00	9.00	10.00	17.47	5.99	23.46
2021/base												
2015–16	230.50	119.64	350.15	6.85	61.68	68.53	1.00	9.00	10.00	13.35	6.93	20.29
2016–17	241.54	108.42	349.96	7.88	70.90	78.78	1.00	9.00	10.00	15.51	6.96	22.47
2017–18	211.70	138.27	349.97	7.29	65.58	72.87	1.00	9.00	10.00	15.11	9.87	24.98
2018–19	222.98	126.94	349.92	7.03	63.27	70.30	1.00	9.00	10.00	14.16	8.06	22.23
2019–20	223.69	112.48	336.17	7.41	66.73	74.14	1.00	9.00	10.00	15.45	7.77	23.22
2020–21	174.74	188.95	363.69	7.41	66.73	74.14	1.00	9.00	10.00	11.16	12.07	23.22
2021–22	168.16	181.84	350.00	7.41	66.73	74.14	1.00	9.00	10.00	11.16	12.07	23.22
2022–23	168.16	181.84	350.00	7.41	66.73	74.14	1.00	9.00	10.00	11.16	12.07	23.22
2023–24	168.16	181.84	350.00	7.41	66.73	74.14	1.00	9.00	10.00	11.16	12.07	23.22
2024–25	168.16	181.84	350.00	7.41	66.73	74.14	1.00	9.00	10.00	11.16	12.07	23.22
2025–26	168.16	181.84	350.00	7.41	66.73	74.14	1.00	9.00	10.00	11.16	12.07	23.22

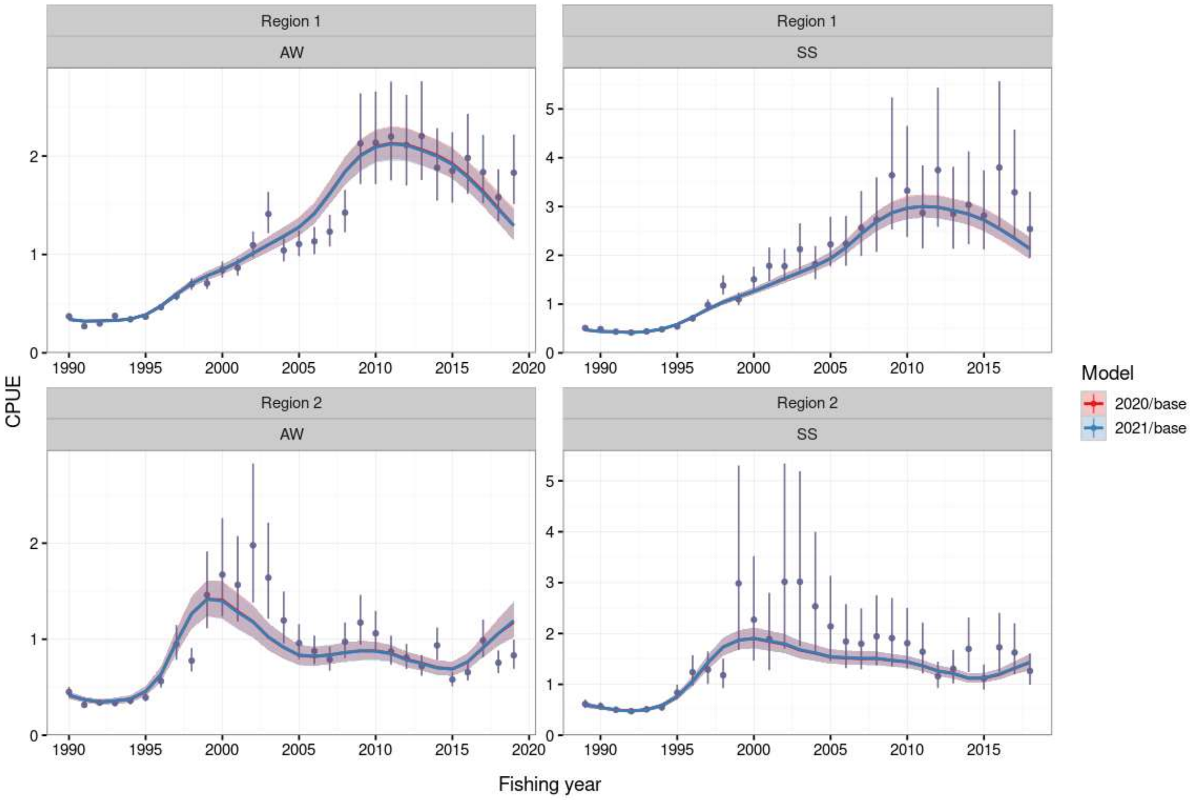


Figure 31: CRA 5 CPUE observations (points) and posterior distribution showing the median (line) and 90% credible interval (shaded region) by region and season (AW = autumn/winter, SS = spring/summer) for the 2020 stock assessment and the 2021 rapid update.

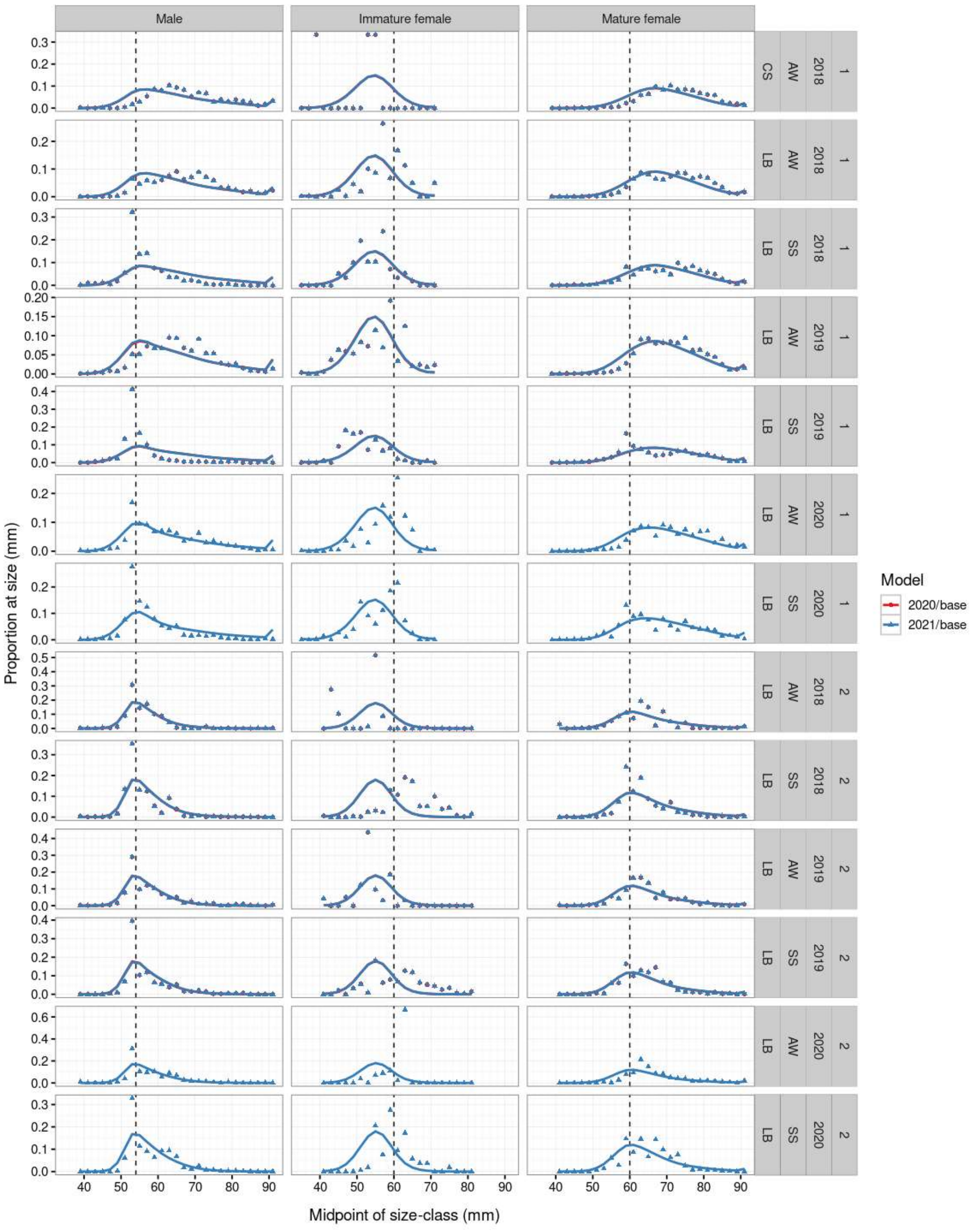


Figure 32: CRA 5 length frequency observations (points) and median of the posterior distribution (line) by region, year, season (AW = autumn/winter, SS = spring/summer), and data source (CS = catch sampling, LB = logbook) for the 2020 stock assessment and the 2021 rapid update.

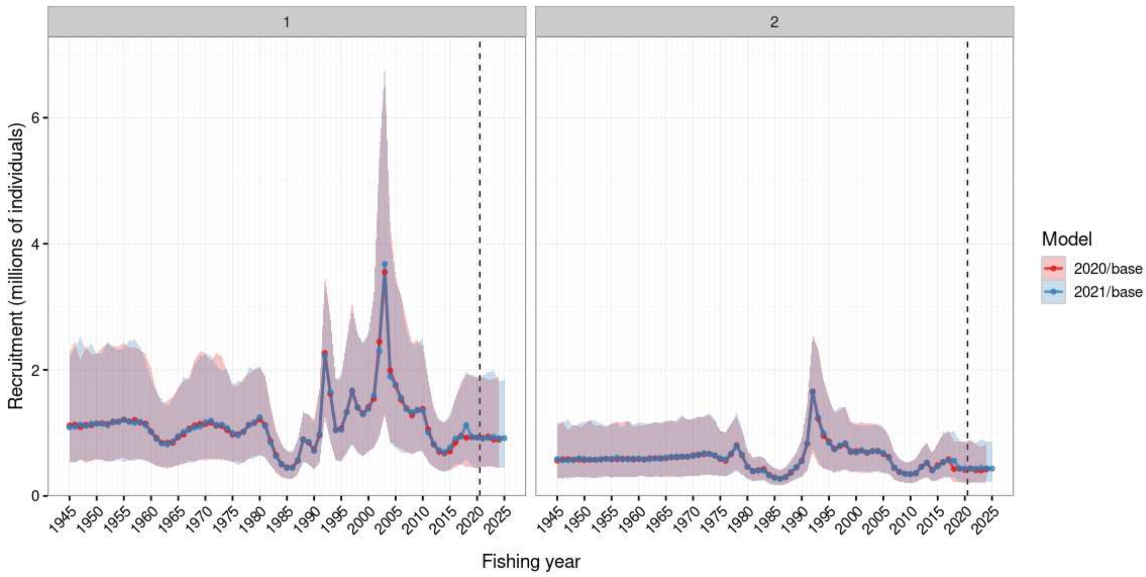


Figure 33: CRA 5 posterior distribution of recruitment by region showing the median (line and points) and 90% credible interval (shaded region) for the 2020 stock assessment and the 2021 rapid update.

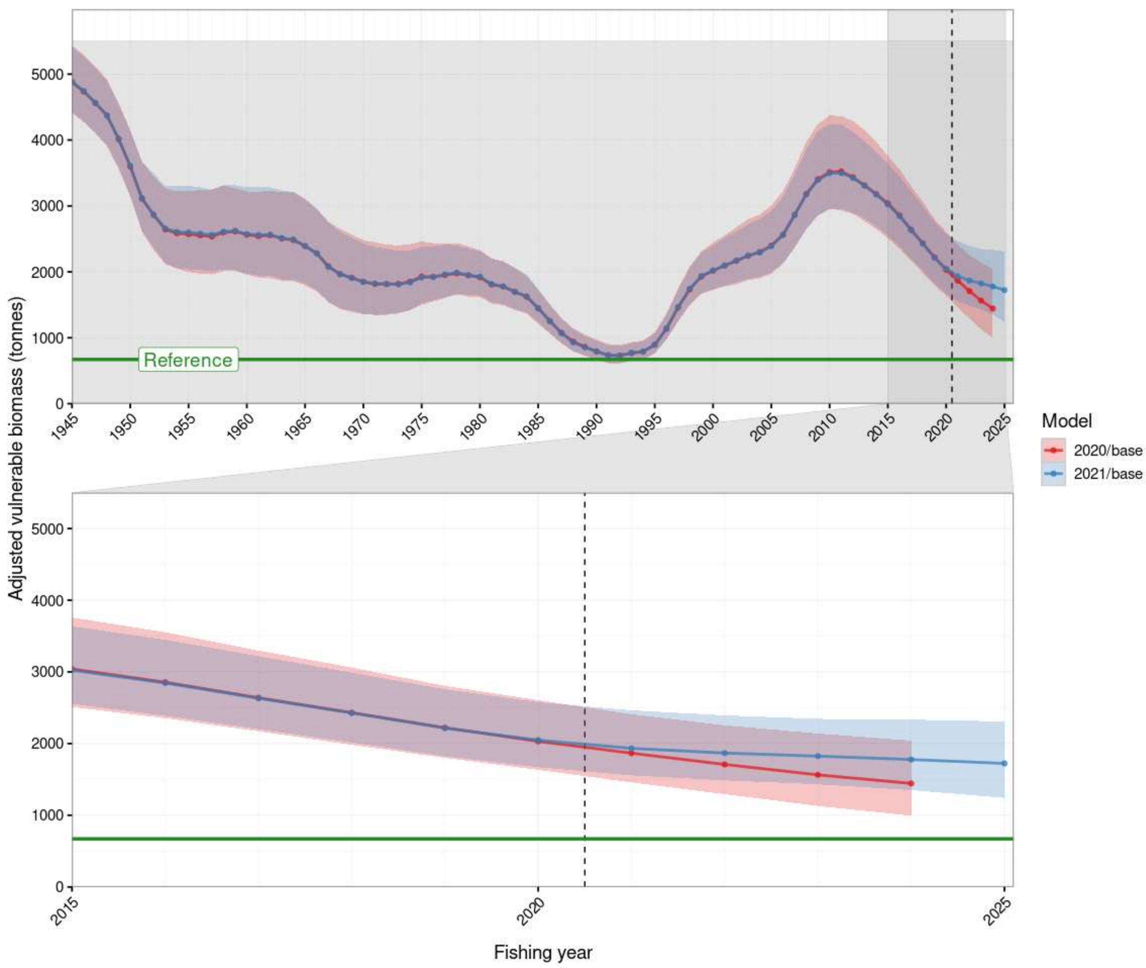


Figure 34: CRA 5 (summed region 1 and region 2) posterior distribution of adjusted vulnerable biomass (tonnes) showing the median (line) and 90% credible interval (shaded region) for the 2020 stock assessment and the 2021 rapid update. The top panel shows the adjusted vulnerable biomass for all model years, and the lower panel shows adjusted vulnerable biomass for the last ten years.

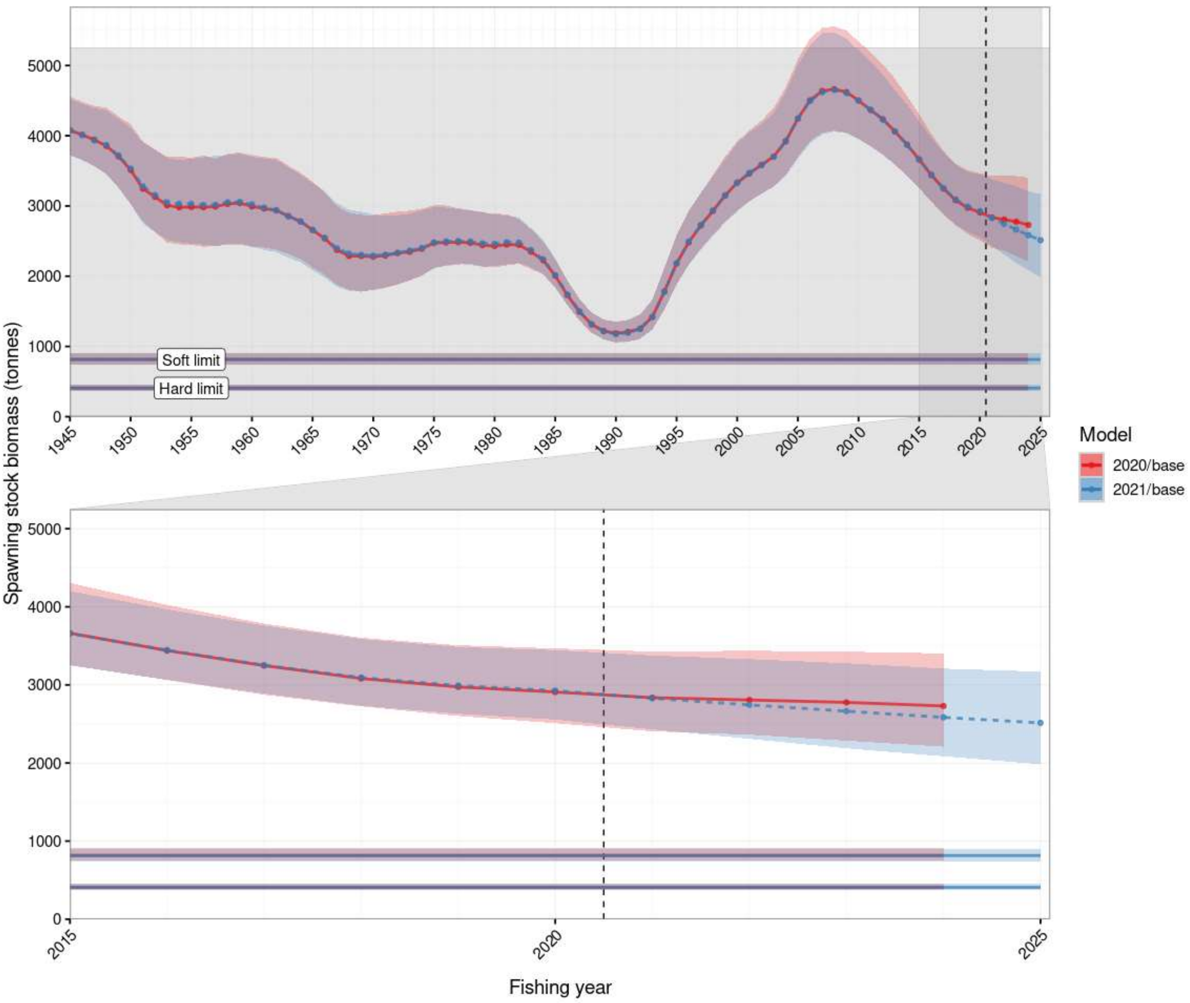


Figure 35: CRA 5 (summed region 1 and region 2) posterior distribution of spawning stock biomass (tonnes) showing the median (line) and 90% credible interval (shaded region) for the 2020 stock assessment and the 2021 rapid update. The top panel shows the spawning stock biomass for all model years, and the lower panel shows spawning stock biomass for the last ten years. The horizontal lines and shaded regions represent the soft limit (top horizontal line and shaded region) and the hard limit (lower horizontal line and shaded region).

Table 14: CRA 5 rapid update indicators for region 1 and region 2 combined summarising the mean, 5% credible interval (CI), median, and 95% CI.

Indicator	Mean	5%	Median	95%
B_0	4 892	4 424	4 884	5 413
B_R	671	–	–	–
B_{2021}	1 958	1 557	1 933	2 464
B_{2025}	1 688	1 166	1 670	2 263
B_{2021} / B_0	0.400	0.325	0.398	0.485
B_{2021} / B_R	2.918	2.319	2.880	3.671
B_{2025} / B_0	0.345	0.245	0.341	0.454
B_{2025} / B_R	2.515	1.737	2.488	3.372
B_{2025} / B_{2021}	0.859	0.686	0.853	1.048
SSB_0	4 091	3 719	4 075	4 518
SSB_{2021}	2 862	2 431	2 828	3 377
SSB_{2025}	2 541	1 984	2 514	3 170
SSB_{2021} / SSB_0	0.699	0.617	0.698	0.787
SSB_{2025} / SSB_0	0.621	0.502	0.616	0.748
SSB_{2025} / SSB_{2021}	0.886	0.784	0.883	0.993
U_R	0.588	-	-	-
U_{2021} / U_R	0.166	0.130	0.165	0.205
U_{2025} / U_R	0.190	0.138	0.185	0.257

4. DISCUSSION

Fisheries New Zealand has implemented electronic reporting of catch for rock lobster (from April to September 2019). It is not yet known how this change in the catch and effort data collection procedure will affect CPUE, but experience suggests that the new data will not be comparable with the previous paper-based data collection system. Preliminary evaluations of the lobster catch and effort data collected under the new system have pointed to substantial changes in the nature of the data, indicating that comparability has likely been lost (see appendix B of Starr 2021). Consequently, it is also likely that these changes to the collection of catch and effort data will require the development of new evaluation procedures that accommodate these changes.

The rapid update system will allow an annual update of stock status for the rock lobster stocks (CRA 1–8) which have been formally assessed. This should provide a framework for managing these stocks that will be responsive to annual changes, much as the previous MPs were. Although CPUE based on commercial catch and effort data will not be available for the next few years, we may be able to develop alternative CPUE series for some stocks (e.g., logbook CPUE for CRA 2, CRA 5, and CRA 8; see Webber in press) and other data sources (i.e., catch and LFs) which should also inform stock status.

The rapid update system was designed to replace MPs in the short term to help bridge the gap in knowledge while there is no reliable CPUE series. However, the system is likely to be useful even after the situation with CPUE has been resolved. For example, the previous MPs used offset-year CPUE as the only input to determine TACC for the next year. Instead, the rapid update system, based on the agreed-upon base case model for each QMA, could become the input to a more broadly defined MP that could determine the TAC or TACC for the following year. In this way, all data types (e.g., LFs, tags, and CPUE when available) will drive the new system, which could result in more stable MPs.

It is important to confirm that the rapid update framework can indeed predict stock status in the absence of a CELR CPUE series. This can be done using either: (a) a simulation study or (b) a retrospective analysis of rock lobster stock assessments. Simulation studies require a simulation model be developed, which can be a large task and is difficult to do well. Retrospective analyses, however, do not require such a large amount of additional work. A retrospective analysis was presented to the RLWG in 2021, and this indicated no systematic biases in the stock assessments in the CRA 2 and CRA 4 examples tested (Pons et al. 2022). These results suggest that the rapid update system should be adequate for predicting stock status in the absence of a CELR CPUE series over the next few years.

Future research considerations for rapid assessment updates include:

- evaluating the decision to reweight data inputs for rapid updates (given that this altered CRA 5 assessment output);
- constructing performance criteria to identify changes in parameter estimates and model fits between the full assessment and the rapid update;
- developing better diagnostics for specific model outcomes (e.g., interpreting productivity changes), particularly when CPUE is unavailable;
- including diagnostic procedures that may be added to the full stock assessments, such as presenting likelihood profiles to improve the understanding of contributions by model components.

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7. APPENDIX I: MCMC DIAGNOSTICS

This appendix presents the MCMC trace plots for the CRA 1 (Figure 36), CRA 2 (Figure 37), CRA 3 (Figure 38, Figure 39), CRA 4 (Figure 40), and CRA 5 (Figure 41) rapid updates.

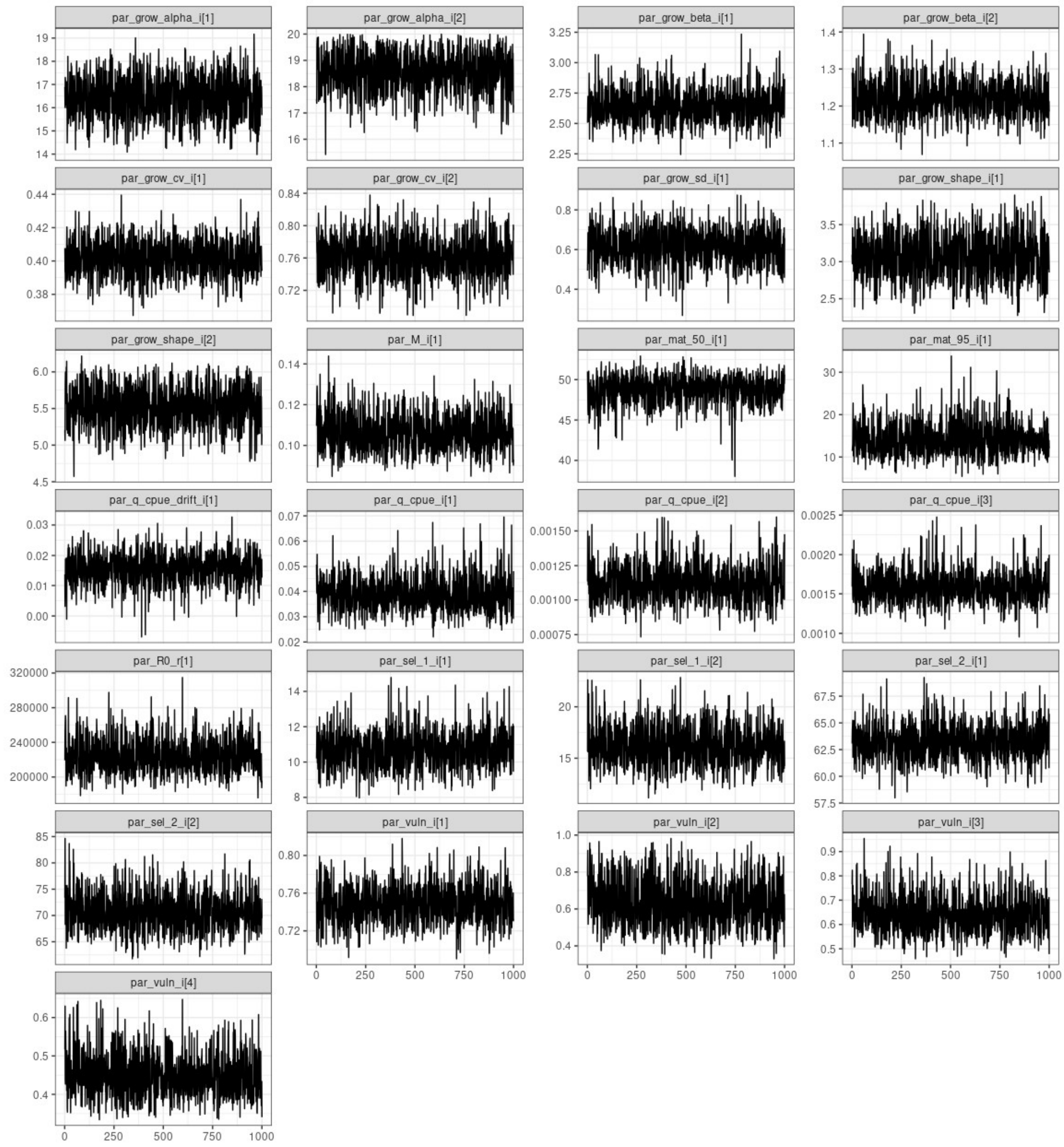

Figure 36: MCMC trace plots for model parameters in the CRA 1 rapid update (MCMC iteration on the x-axis and parameter value on y-axis).

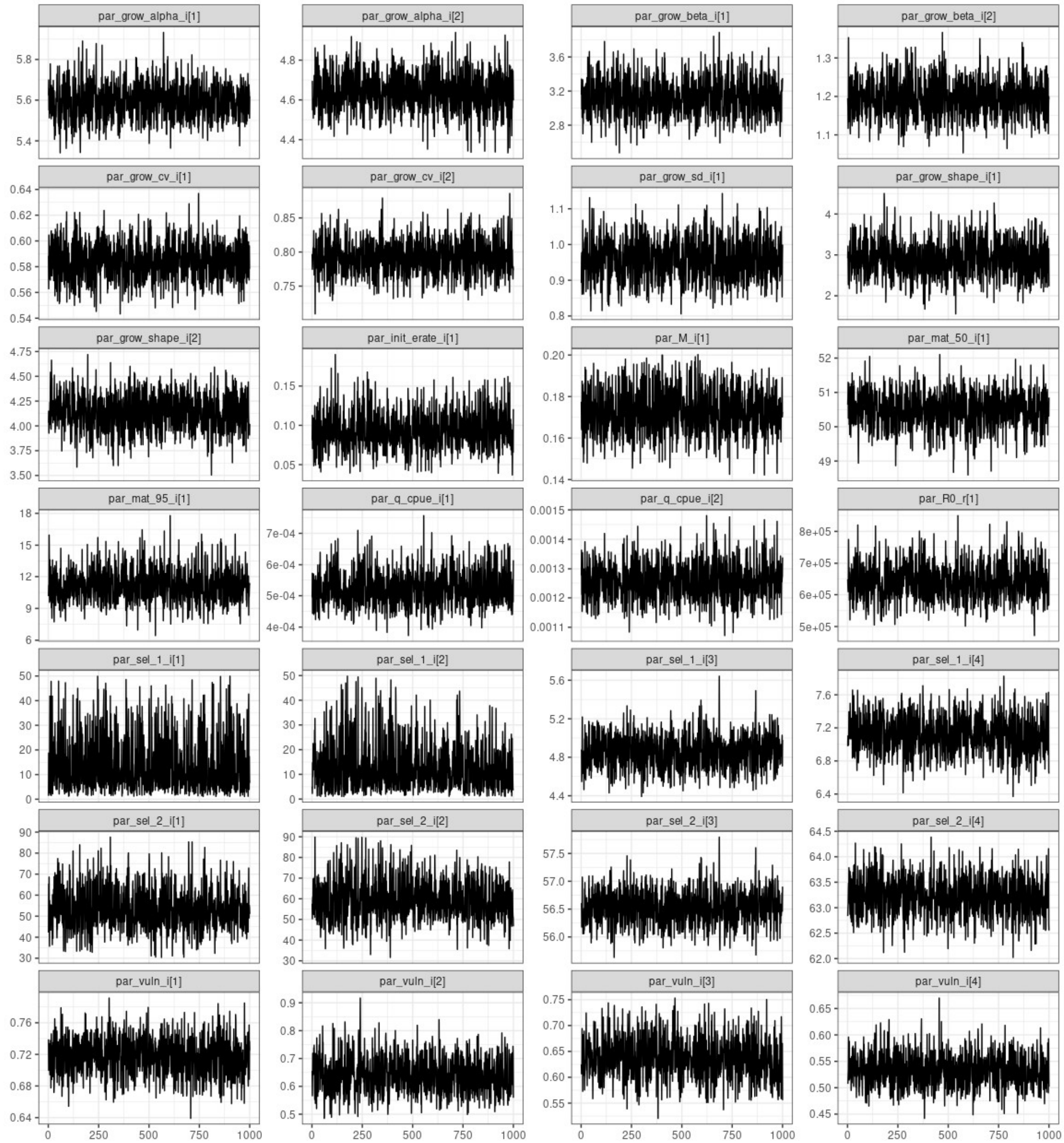

Figure 37: MCMC trace plots for model parameters in the CRA 2 rapid update (MCMC iteration on the x-axis and parameter value on y-axis).

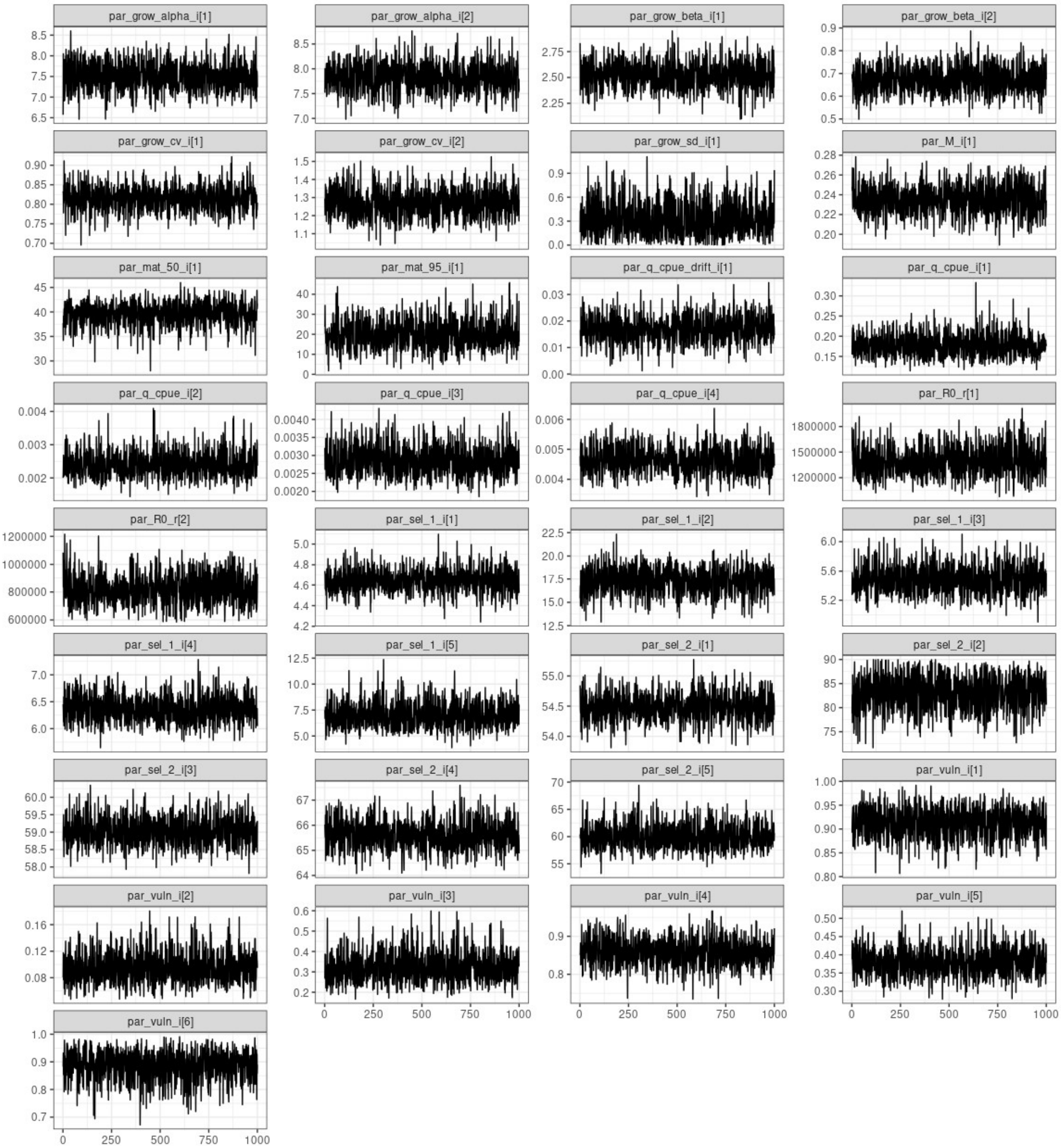

Figure 38: MCMC trace plots for model parameters in the *r1_qdrift* CRA 3 rapid update (MCMC iteration on the x-axis and parameter value on y-axis).

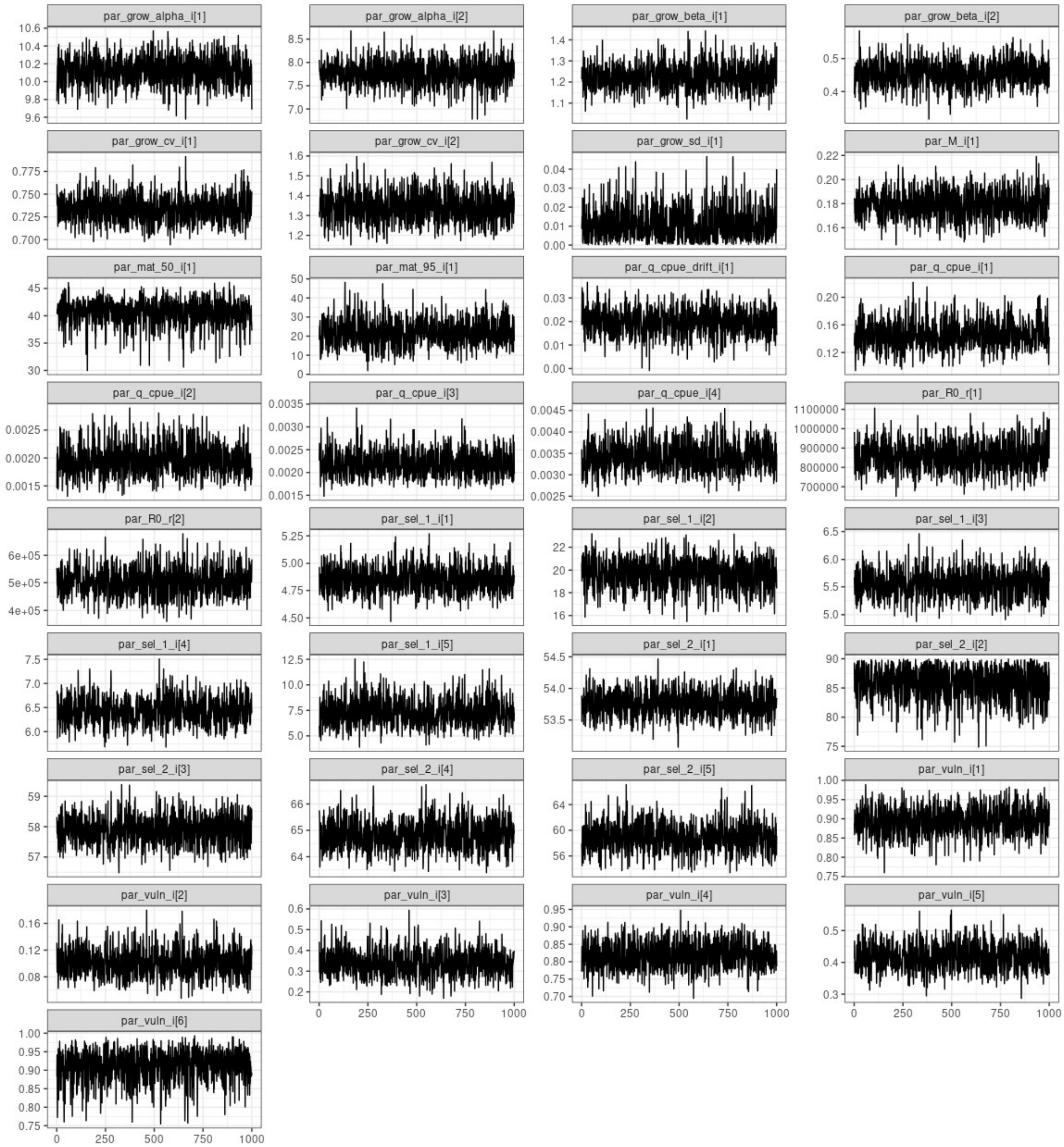

Figure 39: MCMC trace plots for model parameters in the *r2_qdrift* CRA 3 rapid update (MCMC iteration on the x-axis and parameter value on y-axis).

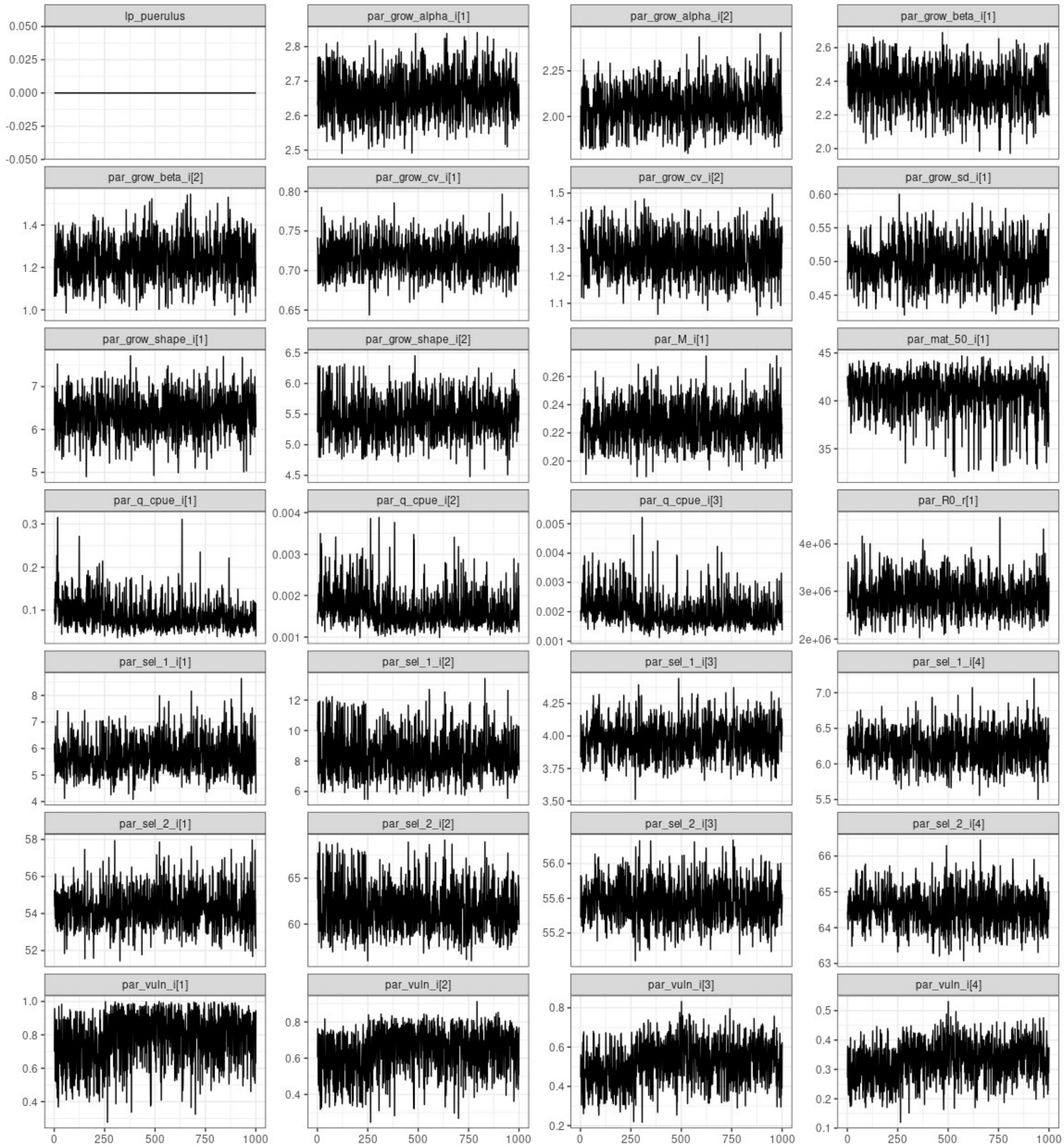

Figure 40: MCMC trace plots for model parameters in the CRA 4 rapid update (MCMC iteration on the x-axis and parameter value on y-axis).

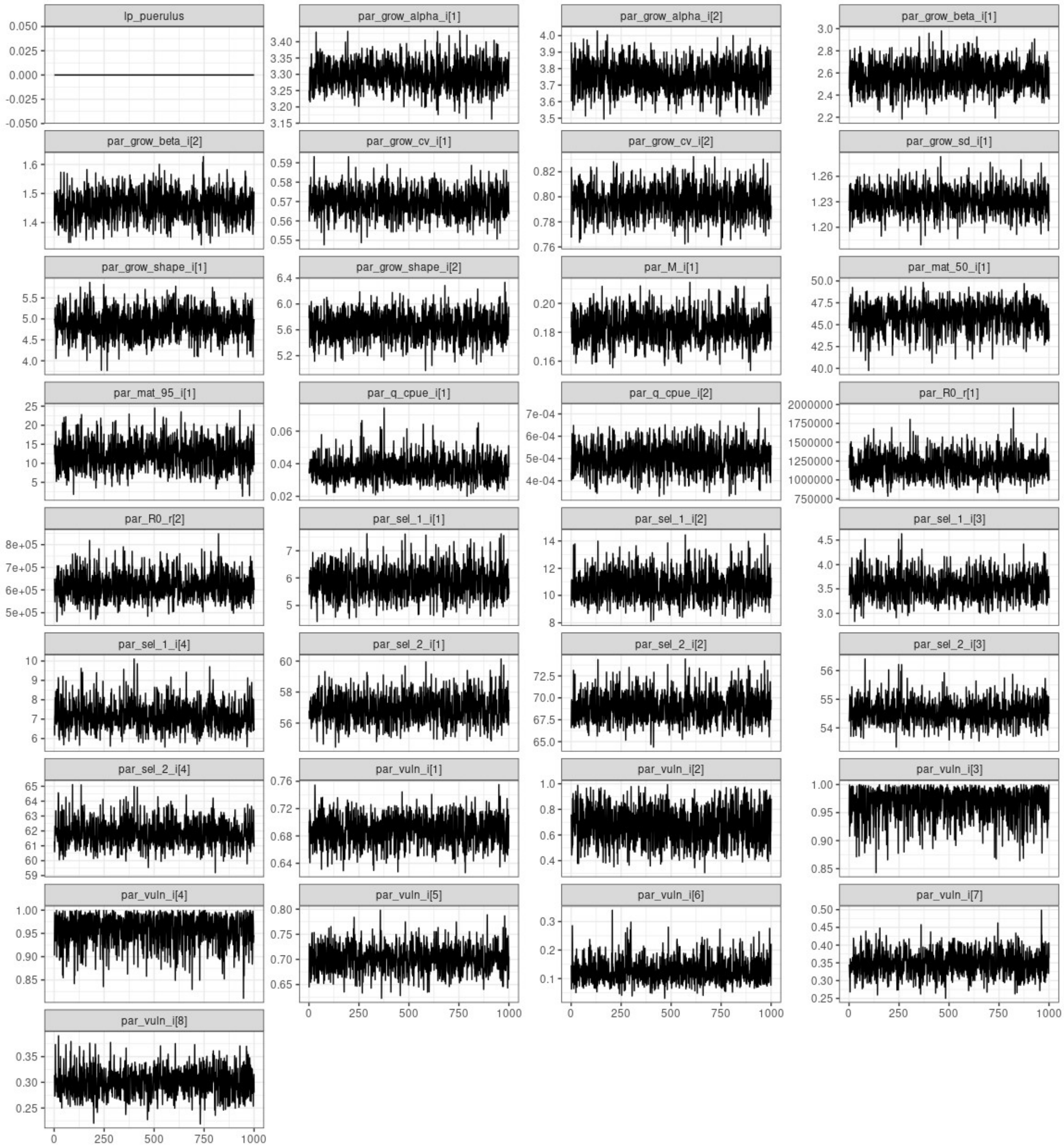

Figure 41: MCMC trace plots for model parameters in the CRA 5 rapid update (MCMC iteration on the x-axis and parameter value on y-axis).