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Minimum TRPs for WCPO yellowfin consistent with alternative LRP risk levels

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Summary

In this paper, we compute median levels of spawning biomass depletion ($SB/SB_{F=0}$) and fishing mortality relative to the fishing mortality at maximum sustainable yield (F/F_{MSY}) that are consistent with specified risk levels of breaching the limit reference point (LRP) of $0.2SB_{F=0}$. To do this, we used the structural uncertainty grid of models used by SC13 for advice from the 2017 yellowfin tuna assessment to generate 30 year projections that included stochastic variability in future recruitment under a variety of fishing levels scaled to the 2013-2015 averages. The main results obtained are summarised in the following table:

Median levels of $SB_{2045}/SB_{F=0}$ and $F_{2042\text{-}2045}/F_{MSY}$ for the four nominated levels of risk of breaching the LRP.

Risk level	Scalar relative to 2013-2015	$SB_{2045}/SB_{F=0}$	$F_{2042\text{-}2045}/F_{MSY}$
5%	1.180	0.36	0.58
10%	1.285	0.34	0.63
15%	1.380	0.31	0.67
20%	1.465	0.29	0.70

The values of $SB/SB_{F=0}$ and F/F_{MSY} if achieved on average are predicted to result in the specified levels of risk of breaching the LRP, and thus may be interpreted as minimum levels of $SB/SB_{F=0}$ and maximum levels of F/F_{MSY} consistent with those risk levels, under the current uncertainty framework.

SC14 is invited to:

1. Note the results of the analysis conducted and consider providing advice to WCPFC on minimum levels of $SB/SB_{F=0}$ (or maximum levels of F/F_{MSY}) that would be consistent with specific levels of risk of breaching the LRP;
2. Encourage WCPFC to further consider the matter of acceptable level of risk of breaching the LRP; and
3. Consider if there are relevant ecological and/or socio-economic factors that WCPFC should consider in choosing a specific TRP for yellowfin tuna.

Introduction

The specification of target and limit reference points (TRPs and LRPs) are a critical part of the harvest strategy approach. LRPs are places we want to stay away from, while TRPs represent places we want to be. The choice of a LRP is based primarily on biological considerations relating to the resilience of the stock in question, i.e. what is the level of spawning biomass where the risk of recruitment overfishing becomes unacceptable. WCPFC has decided that the LRP for key tuna stocks is 20% of the unfished spawning biomass ($SB_{F=0}$). The choice of TRP is normally based on a combination of biological, ecological and socio-economic considerations. The main biological consideration is that a TRP should be sufficiently above the LRP so that if the TRP is achieved on average, the risk of breaching the LRP will be acceptably small. To inform WCPFC's consideration of potential TRPs for yellowfin tuna, this paper attempts to answer the question "what is the minimum setting for a spawning-biomass-depletion-based TRP (or maximum fishing-mortality-based TRP) that avoids breaching the LRP with a specified level of probability?"

The paper MOW3-WP-02 (SPC-OFP 2014) provided preliminary answers to this question for skipjack, yellowfin, bigeye and South Pacific albacore, at 5%, 10%, 15% and 20% levels of probability of breaching the LRP. For that analysis, a small number of models from the respective structural uncertainty grids presented for the 2014 assessments for skipjack, yellowfin and bigeye and the 2012 assessment for South Pacific albacore were used. The models were run in projection mode with future recruitment sampled from the historical estimated time series. Various scalars of fishing effort and/or catch were applied and the results for runs that produced the specified levels of risk of breaching the LRP were recorded, in particular the median level of $SB/SB_{F=0}$. In other words, based on the assessments and their uncertainty frameworks available at the time, it was possible to specify median levels of $SB/SB_{F=0}$ that were consistent with breaching the LRP with the specified probabilities. These median levels could then be interpreted as minimum settings for a spawning-biomass-depletion-based TRP, for each probability level of breaching the LRP.

In this paper we repeat the MOW3-WP-02 analysis for yellowfin tuna using the 2017 yellowfin tuna assessment (Tremblay-Boyer *et al*. 2017) as the basis. Once SC14 has chosen the uncertainty framework for bigeye tuna, the analysis will be undertaken for that species also.

Methods

We used the most recent yellowfin stock assessment presented in 2017 (Tremblay-Boyer *et al.* 2017). SC13 choose a grid of 48 model runs to represent the structural uncertainty in the assessment. The grid consisted of five axes – regional structure (2), steepness (3), tag over-dispersion (2), tag mixing (2) and size composition weighting (2) – resulting in 48 separate model combinations. The analysis proceeded as follows:

- Run 200 simulations for 30 years (2016-2045) for each model in the grid – each simulation representing a possible 'future' trajectory for recruitment, under a specific level of fishing effort or catch;
- Recruitment trajectories were constructed by computing a mean recruitment resulting from the estimated stock-recruitment relationship and adding recruitment deviations randomly sampled from the last 10 years of the assessment (2005-2014), with recruitments then distributed to seasons and regions according to the average distributions within the same 10-year period;

- Combine the results across model runs and calculate the % of projections that had a terminal (final year) biomass that was below the agreed LRP (20% of the average spawning biomass that would have occurred in the absence of fishing over the penultimate 10-year period of the projections (2035-2044)). Also calculate the median level of terminal spawning biomass compared to $SB_{F=0}$ ($SB_{2045}/SB_{F=0}$) and average, spatially-aggregated fishing mortality in relation to F_{MSY} for the last four years of the projection ($F_{2042-2045}/F_{MSY}$); and
- Repeat the above steps with different scalars of effort/catch until the future fishing levels that resulted in risk levels of 5, 10, 15, and 20% were identified. Scalars were applied to the seasonal average of the catch or effort for the last three years of the assessment period for each fishery. The same scalars were applied to all fisheries simultaneously. Future scenarios for longline fisheries were expressed as constant catch[1], while scenarios for all other fisheries were expressed as constant effort. In order to determine the multipliers associated with the four levels of risk of breaching the LRP in the last year of the projection (2045), 44 combinations of multipliers in the range 1.0-1.5 were considered.

Results

The time-series of $SB/SB_{F=0}$ through the historical period of the assessment and for the projections is shown in Figure 1. As expected, there is greater uncertainty in the projection periods and the terminal period of the assessment than in historical periods because of the effect of recruitment uncertainty.

The median $SB_{2045}/SB_{F=0}$ and $F_{2042-2045}/F_{MSY}$ associated with each of the four levels of risk of breaching the LRP are provided in Table 1, along with equivalent estimates from the status quo projection. These values can be interpreted as the minimum levels of $SB/SB_{F=0}$ and maximum levels of F/F_{MSY} that, if achieved on average, would be consistent with remaining above the LRP at each level of risk. Figure 2 and Figure 3 present the distributions of $SB_{2045}/SB_{F=0}$ and $F_{2042-2045}/F_{MSY}$, respectively, for the status quo and for each risk level. Breakdowns of these distributions according to the different uncertainty axes are provided in Appendix Figures A1-A5. These figures indicate that most of the risk of breaching the LRP is due to models with down-weighted size composition data and the lower level of steepness (0.65).

For context with current stock status, the 2017 stock assessment for yellowfin tuna (Tremblay-Boyer *et al.* 2017) estimated the median recent four-year average $SB/SB_{F=0}$ to be 0.32 and the 2015 level to be 0.35. The median F/F_{MSY} was estimated to be 0.75. These estimated levels of spawning biomass depletion would be consistent with risks of breaching the LRP of 10-15%, while the estimated F/F_{MSY}, if maintained into the future, would exceed the 20% risk of breaching the LRP. Note however that F/F_{MSY} is predicted to decline to 0.5 under the status quo projection.

We note that the scalar on future effort or catch is applied equally to all fisheries within the 2017 yellowfin assessment. The gear specific combination of harvest, along with the overall pattern of recruitment, will therefore be different to that estimated in 2015. This will affect values of MSY and the fishing mortality required to achieve it, as estimated within the projections.

[1] In a number of projections, the constant-catch scenarios for longline fisheries resulted in some age-classes in some regions tending towards zero abundance. In such cases, the catches of the longline fisheries in those regions were reduced to avoid negative numbers-at-age.

Conclusions

The method used here to estimate 'limiting' TRPs is consistent with that used in the past (MOW3-WP-02) and seems to be generally accepted by WCPFC. However, it should be noted that the results of such analyses are conditioned on the uncertainty framework used. In the analysis reported here, the structural uncertainty framework used in the 2017 yellowfin tuna assessment, plus stochastic variability in future recruitment, was used. The amount of uncertainty recognised will impact the 'spread' of the distributions of $SB/SB_{F=0}$ and F/F_{MSY}, which in turn will affect the estimated risks of breaching the LRP. In general, more uncertainty = greater risk, and higher median levels $SB/SB_{F=0}$ (and lower F/F_{MSY}) would be required to meet a particular risk of breaching the LRP.

The median values of $SB_{2045}/SB_{F=0}$ and $F_{2042\text{-}2045}/F_{MSY}$ estimated here can be interpreted as 'limiting' TRP's for yellowfin tuna, consistent with the nominated levels of risk of breaching the LRP. In order to recommend a specific level of $SB/SB_{F=0}$ (or F/F_{MSY}) as a TRP for yellowfin tuna, it is therefore necessary to:

- Agree on an acceptable level of risk of breaching the LRP in order to define the minimum TRP in terms of $SB/SB_{F=0}$, (or maximum TRP in terms of F/F_{MSY}). This issue was summarised previously (SPC-OFP 2014) in the following terms:
    - "The acceptable level of risk is a management decision and will be strongly influenced by the severity of the consequences of exceeding the LRP, be those consequences biological, economical, ecological or social. Low stock size is likely to be associated with lower production (catches) and higher variability in productivity, along with the increased potential for other unexpected but bad consequences that we have not experienced in the past ('unknown unknowns'). When considering the acceptable level of risk, the importance of the stock to the people of the region and to the ecosystem may be important factors to consider."
- Consider other ecological and socio-economic factors that might be relevant in recommending specific TRPs that may be more conservative than the risk-based 'limiting' levels described in this paper.

SC14 is therefore invited to:

1. Note the results of the analysis conducted and consider providing advice to WCPFC on minimum levels of $SB/SB_{F=0}$ (or maximum levels of F/F_{MSY}) that would be consistent with specific levels of risk of breaching the LRP;
2. Encourage WCPFC to further consider the matter of acceptable level of risk of breaching the LRP; and
3. Consider if there are relevant ecological and/or socio-economic factors that WCPFC should consider in choosing a specific TRP for yellowfin tuna.

References

SPC-OFP (2014). Consideration of acceptable levels of risk of exceeding Limit Reference Points for the four main tuna stocks: uncertainty and implications for Target Reference Points and Harvest Control Rules. MOW3-WP-02.

Tremblay-Boyer L., S. McKechnie, G. Pilling and J. Hampton (2017). Stock assessment of yellowfin tuna in the western and central Pacific Ocean Rev 1 (26 July 2017). WCPFC-SC13-2017/SA-WP-06

Figures and tables

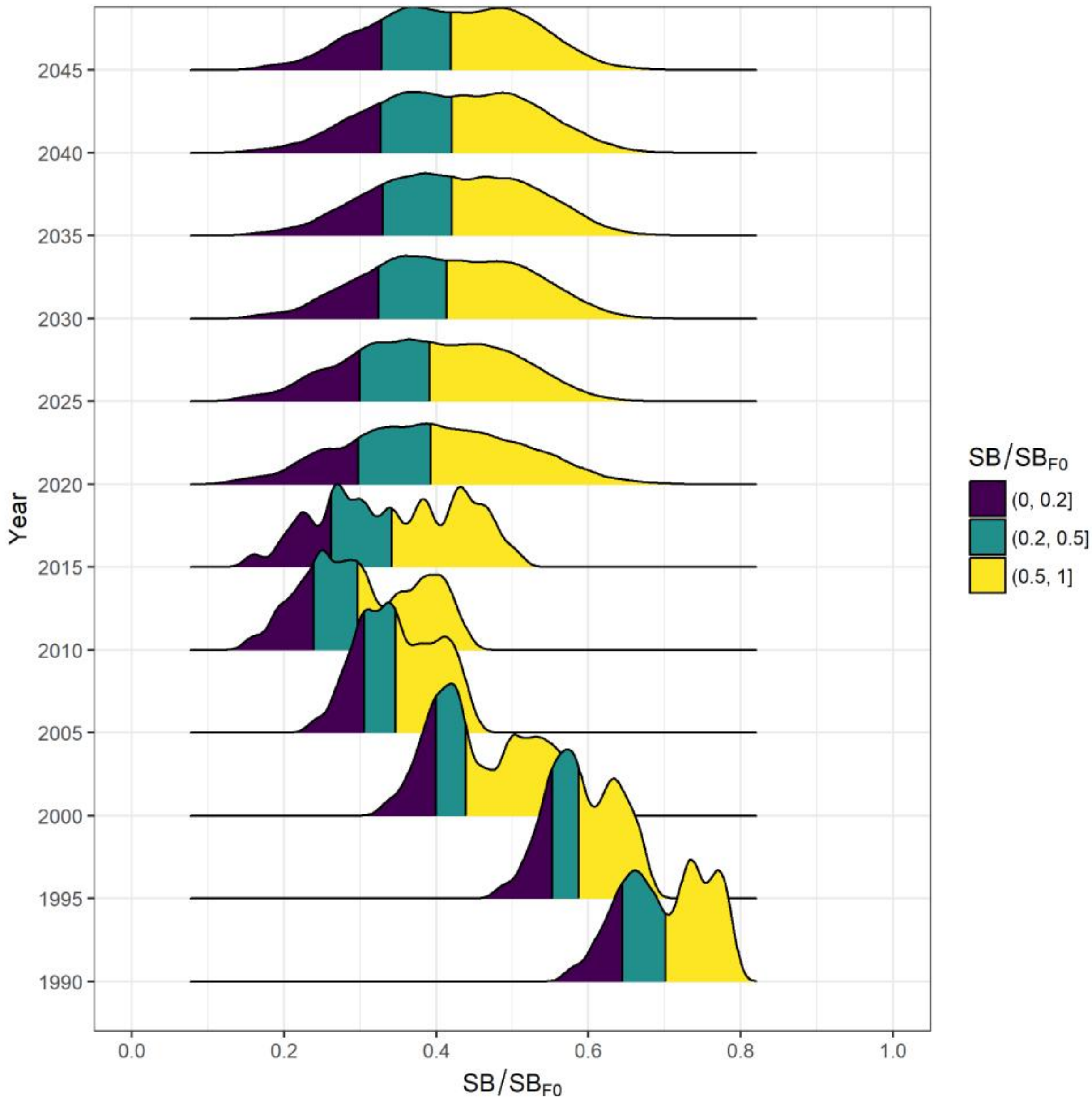

Figure 1. Time-series evolution of smoothed distributions of $SB/SB_{F=0}$ by five-year periods from 1990 to 2045. Borders of zones with different colours (dark blue, green and yellow) represent the lower 20 percentiles and the medians (50 percentiles) of the distributions.

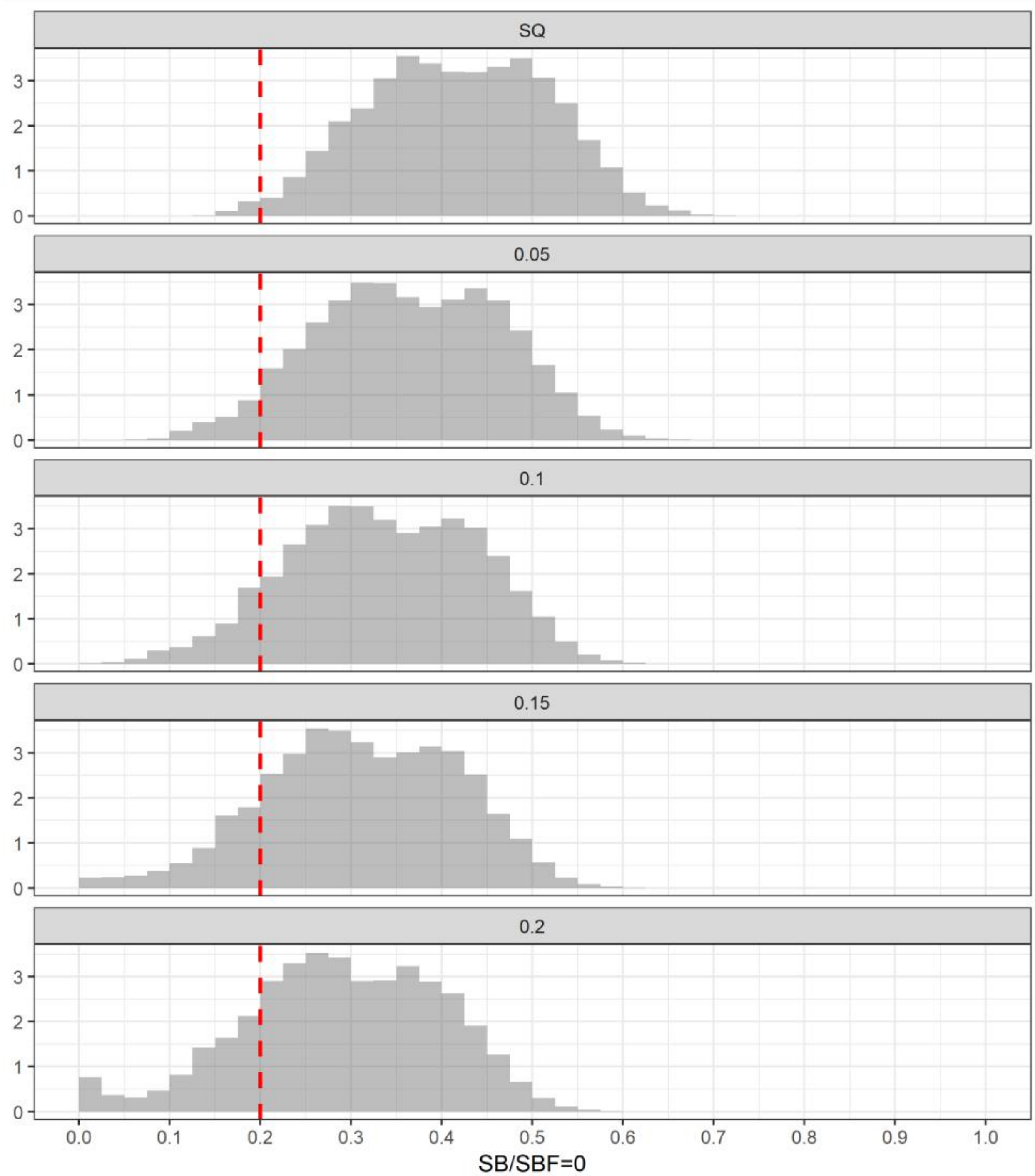

Figure 2. The distribution of $SB_{2045}/SB_{F=0}$ for the status quo (multiplier = 1, SQ) and the four nominated levels of risk of breaching the LRP. Red vertical line in each panel represent 20% of $SB_{F=0}$

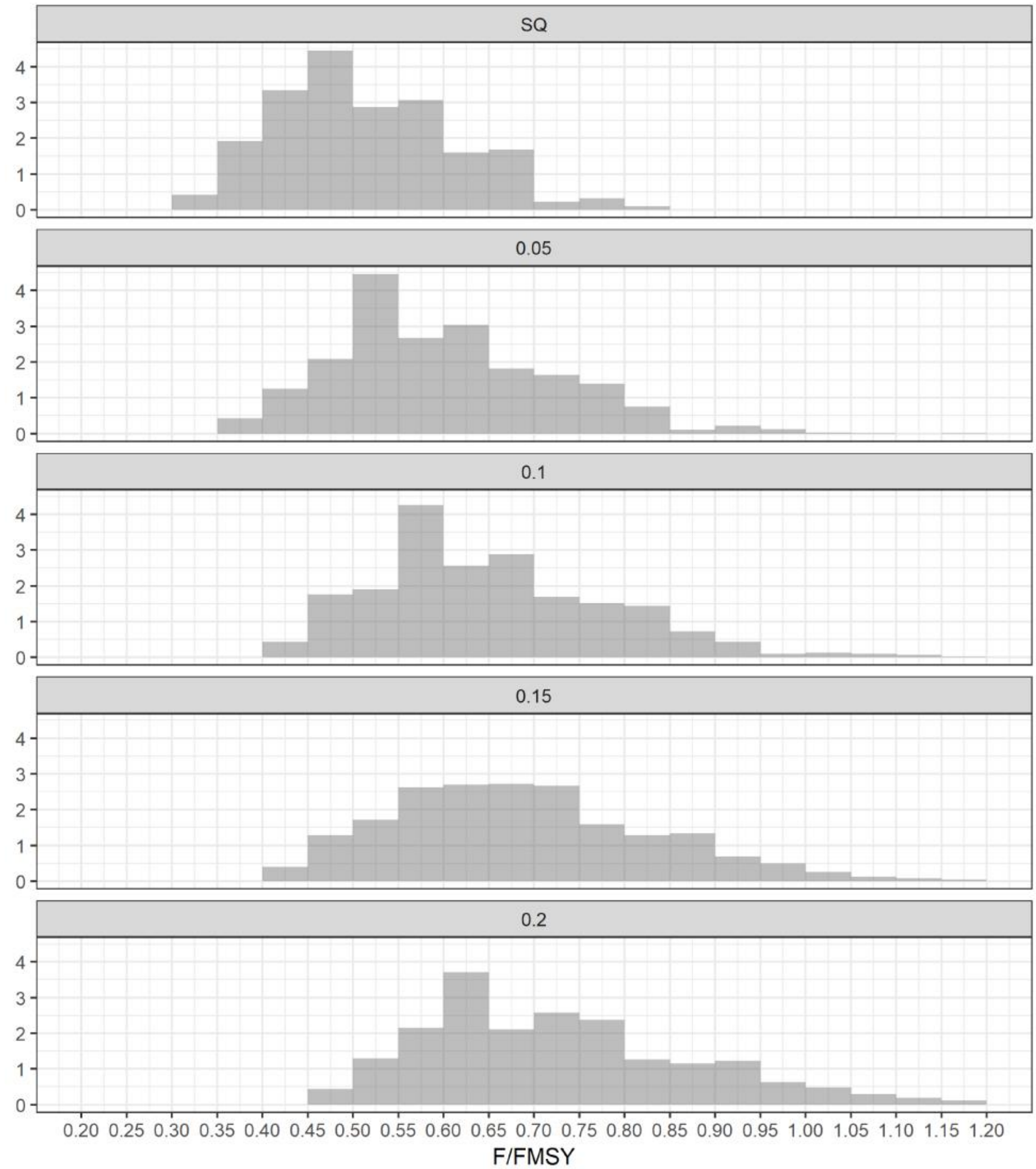

Figure 3. The distribution of $F_{2042\text{-}2045}/F_{MSY}$ for the status quo (multiplier = 1, SQ) and the four nominated levels of risk of breaching the LRP.

Table 1. Median levels of $SB_{2045}/SB_{F=0}$ and $F_{2042\text{-}2045}/F_{MSY}$ for the status quo projection (multiplier = 1, SQ), and the four nominated levels of risk of breaching the LRP.

Risk level	Scalar	This paper	
		$SB_{2045}/SB_{F=0}$	$F_{2042\text{-}2045}/F_{MSY}$
SQ	1.000	0.42	0.50
5%	1.180	0.36	0.58
10%	1.285	0.34	0.63
15%	1.380	0.31	0.67
20%	1.465	0.29	0.70

Appendix Distributions of $SB_{2045}/SB_{F=0}$ by uncertainty axis in the 2017 yellowfin tuna assessment grid

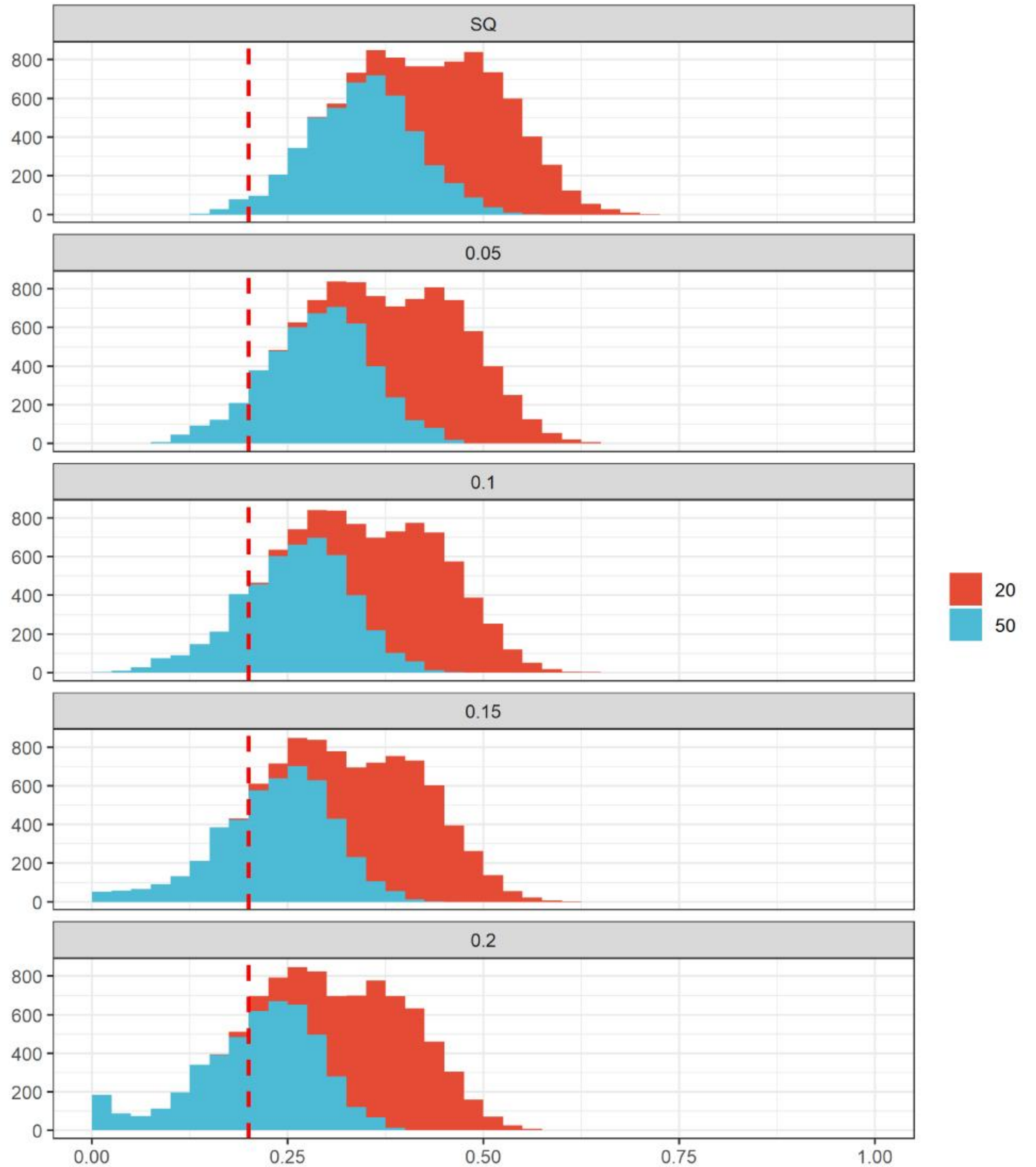

Figure A1. The distribution of $SB_{2045}/SB_{F=0}$ for the status quo projection (multiplier = 1, SQ), and the four nominated levels of risk of breaching the LRP, showing the components of the distribution according to the weighting of size composition data used in the assessment grid. Higher weight is indicated by 20 (red) and lower weight indicated by 50 (blue). Red vertical line in each panel represent 20% of $SB_{F=0}$

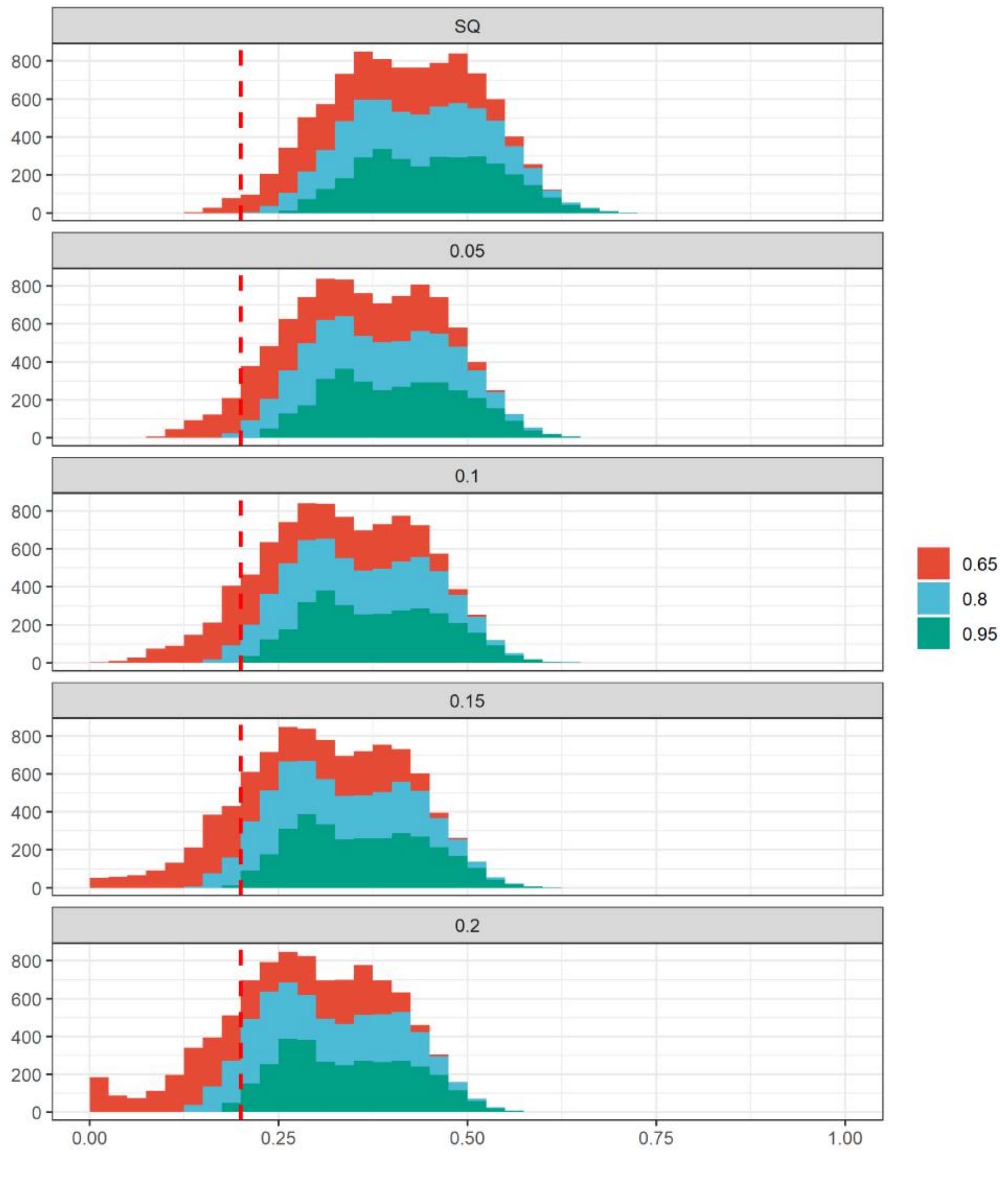

Figure A2. The distribution of $SB_{2045}/SB_{F=0}$ for the status quo projection (multiplier = 1, SQ), and the four nominated levels of risk of breaching the LRP, showing the components of the distribution according to the three values of stock-recruitment steepness used in the assessment grid. Red vertical line in each panel represent 20% of $SB_{F=0}$

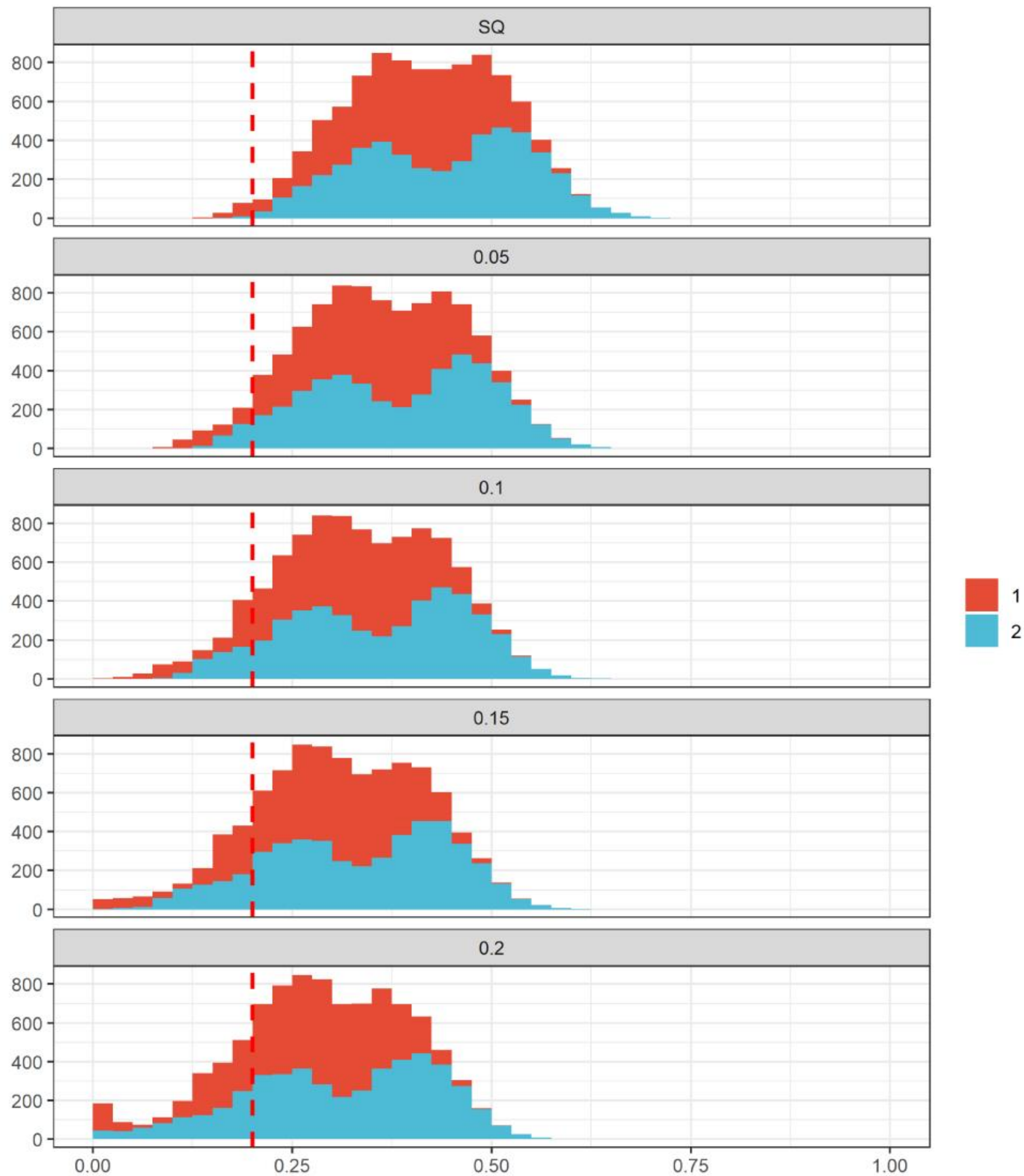

Figure A3. The distribution of $SB_{2045}/SB_{F=0}$ for the status quo projection (multiplier = 1, SQ), and the four nominated levels of risk of breaching the LRP, showing the components of the distribution according to two assumptions regarding post-release tag mixing (1 or 2 quarters) used in the assessment grid. Red vertical line in each panel represent 20% of $SB_{F=0}$

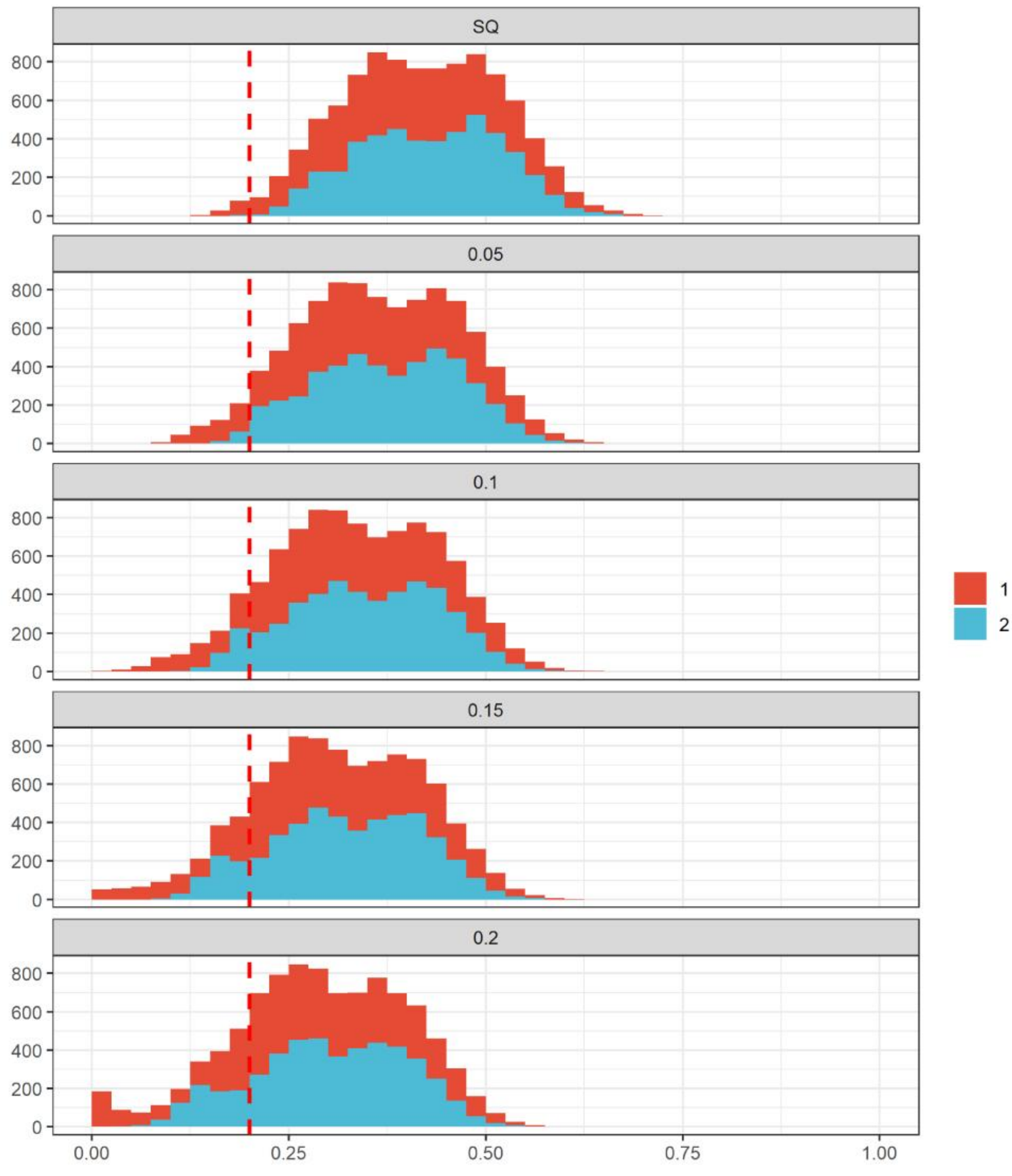

Figure A4. The distribution of $SB_{2045}/SB_{F=0}$ for the status quo projection (multiplier = 1, SQ), and the four nominated levels of risk of breaching the LRP, showing the components of the distribution according to the two assumed values of over-dispersion of the tagging data (1 = low, 2 = moderate) used in the assessment grid.

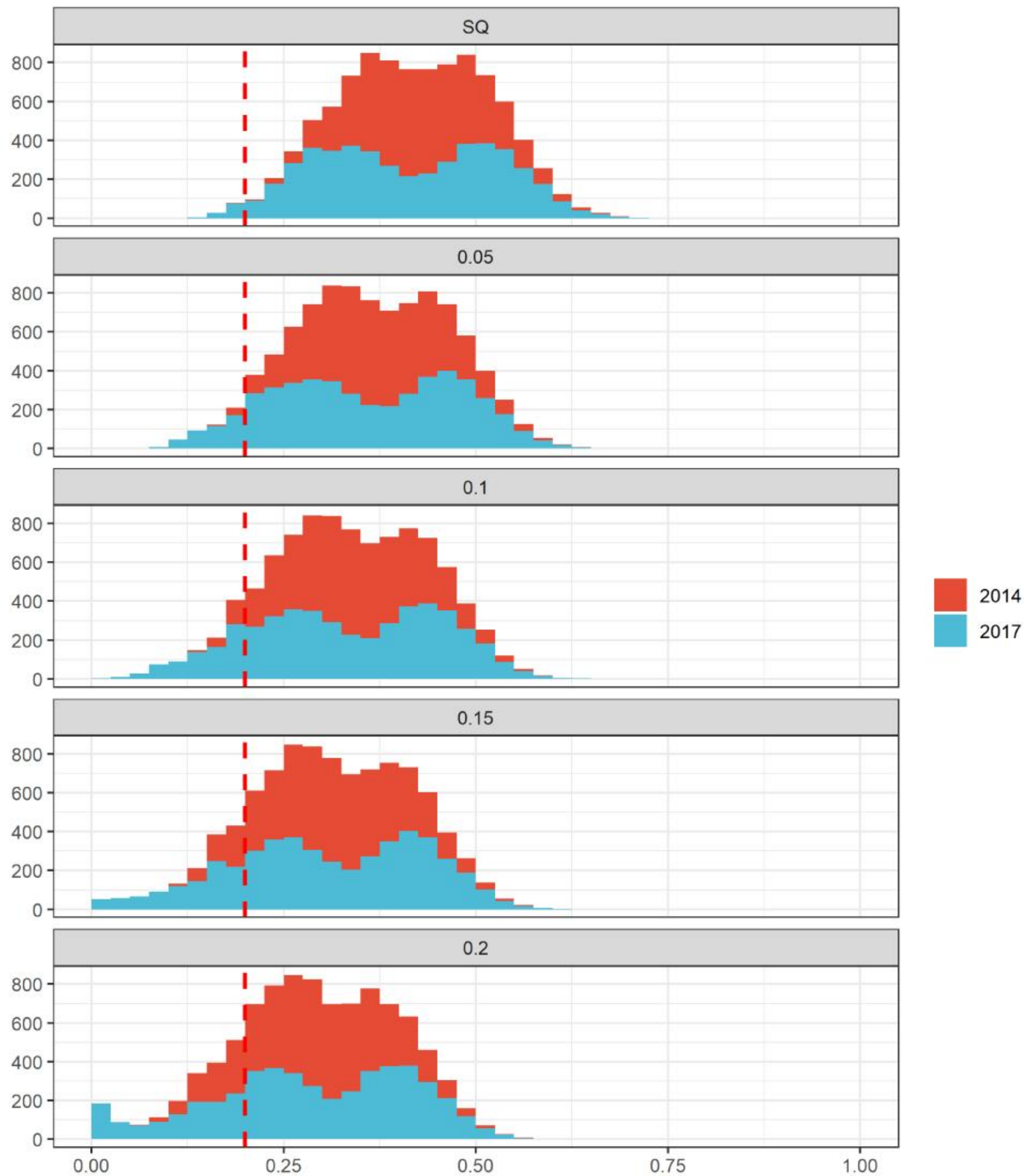

Figure A5. The distribution of $SB_{2045}/SB_{F=0}$ for the status quo projection (multiplier=1, SQ), and the four nominated levels of risk of breaching the LRP, showing the components of the distribution according to the alternative regional structure (2014 = 20ÎN boundary; 2017 = 10ÎN boundary) used in the assessment grid.