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Updated harvest control rule for SBW 6B to allow for partial uptake of catch allowance

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PLAIN LANGUAGE SUMMARY

Southern blue whiting (SBW) on the New Zealand Bounty Plateau (SBW 6B) is managed by using a harvest control rule (HCR) to set the Total Allowable Catch (TAC). The HCR as first developed depended on an industry acoustic spawning biomass survey conducted in the year before its use. It was later adapted to account for years with missing surveys (gap years). It was found, through simulation studies, that for each successive gap year the initial TAC should be reduced by a scalar, which was estimated to be between 0.87 and 0.83. The scalar reduced the catch to ensure that the stock remained above the limit reference point (20% of unfished spawning stock biomass) with an acceptable probability. The revised HCR assumed that the allowed TACs were fully caught, but this has not been the case in recent years. The current report investigated the effect of part utilised TACs. It found that:

- For a one-year gap there was a linear relationship between the proportion of TAC taken in the gap year and the level of 'safe' catch possible in the second year. This safe catch could be greater than the initial TAC set for the gap year if catch in the gap year had been less than 90% of the initial TAC.
- For a two-year gap 'safe' catches in the third year could be greater than the initial TAC depending on the proportion of TAC taken in the first gap year and proportion of first gap year catch taken in the second gap year.
- For a three-year gap one combination of proportion of TAC taken in the first gap year and proportion of first gap year catch taken in the second gap year corresponding to the most recent set TAC and subsequent recorded landings was investigated. 'Safe' catches in the fourth year could be greater than the initial TAC depending on the proportion of second gap year catch taken in the third gap year.

These results are dependent on the life history and other modelling assumptions that were made for the stock.

EXECUTIVE SUMMARY

Holmes, S.J.[1] (2026). Updated harvest control rule for SBW 6B to allow for partial uptake of catch allowance.

***New Zealand Fisheries Assessment Report 2026/24.* 9 p.**

Southern blue whiting (*Micromesistius australis*, SBW) on the New Zealand Bounty Plateau (SBW 6B) is managed by using a harvest control rule (HCR) to set the Total Allowable Catch (TAC), which is then adjusted by subtracting catch from other sources to give the Total Allowable Commercial Catch (TACC). The HCR was developed in 2016 and first used in 2017 (denoted HCR_{2017}). The HCR_{2017} depended on an industry acoustic spawning biomass survey conducted in the year before its use.

In 2022, a new HCR (denoted HCR_{2022}) was developed that was adapted to apply to years without surveys. The HCR was estimated from model simulations, and, apart from survey gaps, these followed the methods and parameterisation used for deriving HCR_{2017}. The new HCR_{2022} recommended that if future gaps in surveys occurred, the TAC should be reduced each year by a scalar (denoted *D*), which was estimated to be between 0.87 and 0.83. The HCR_{2022} simulations assumed that the allowed TACs would be fully caught.

This report describes simulation studies to investigate the effect of partially utilised TACs on the amount of catch in the following year that still allowed the management risk objective (less than 10% probability of current spawning stock biomass (SSB) falling below 20% virgin SSB) to be fulfilled. For a one-year gap in surveys, the scalar became greater than one for catches less than 90% of the TAC_{t+1} from HCR_{2017}, i.e. if there was a survey in 2024 and the TAC for 2025 (TAC_{t+1}) were set at, say, 100 t, but the catch in 2025 were 90 t or less, then the TAC for 2026 (TAC_{t+2}) could be set above 100 t (the exact value depending on the 2025 catch value). For a two-year gap in surveys, new scalars (named *NewD2*) were found for combinations of the proportion of TAC_{t+1} taken ($propTAC_{t+1}$) and proportion of catch in year t+1 taken in year t+2 ($prop_{t+2}$). Depending on the values of $propTAC_{t+1}$ and $prop_{t+2}$ it was possible for the TAC_{t+3} to be greater than the TAC_{t+1} from HCR_{2017}. This occurred when $propTAC_{t+1} \times prop_{t+2} \times NewD2$ was greater than 1.

With each increase in gap year the number of dimensions of proportions to investigate increases by one. For a three-year gap in surveys the $propTAC_{t+1}$ and $prop_{t+2}$ values were fixed to approximately those recorded in the 2024–25 and 2025–26 fishing years and only the proportion of catch in year t+2 taken in year t+3 ($prop_{t+3}$) varied. Again, the new scalar (*NewD3*) was often greater than one and it was also possible for the TAC_{t+4} to be greater than the TAC_{t+1} from HCR_{2017} (occurring when $propTAC_{t+1} \times prop_{t+2} \times prop_{t+3} \times NewD3$ was greater than 1).

These results are dependent on the life history and other assumptions that were made for the stock.

[1] Earth Sciences New Zealand (ESNZ).

1. INTRODUCTION

Southern blue whiting (*Micromesistius australis*, SBW) on the New Zealand Bounty Plateau (SBW 6B) is managed by a harvest control rule (HCR) to set the Total Allowable Catch (TAC), which is then adjusted by subtracting catch from other sources to give the Total Allowable Commercial Catch (TACC). The HCR was developed in 2016 (Doonan 2017) and first used in 2017 (denoted HCR_{2017}) (Fisheries New Zealand 2025). The HCR_{2017} depended on an industry acoustic survey in the year before its use. The HCR_{2017} was based on simulations in which the key assumption was that the catchability (q) distribution for the acoustic survey was known, i.e., the real q was within this assumed distribution, although the true q was unknown (Doonan 2017).

The HCR_{2017} was used twice, in 2017 and 2018 (Fisheries New Zealand 2025), but there followed a period of years where no surveys were conducted. A revised HCR was developed using the same structure as Doonan (2017) but allowing for periods of consecutive years with no surveys. Denoted HCR_{2022} the revised HCR used as its base the HCR_{2017} calculated catch for the year after an acoustic survey, but it cumulatively 'discounted' this catch for each consecutive year with no survey (Doonan 2023). The target catches represented the total allowable catch (TAC), i.e., including allowances for other sources of mortality in addition to the TACC, and the simulation assumed that the TAC was fully taken in each year.

The most recent acoustic survey was conducted in fishing year 2023–24. The TAC for 2024–25 was set according to HCR_{2017} but reported catches were less than 70% of the TAC. Catches in 2025–26 were just over 75% of those from 2024–25, representing 60% of the TAC discounted for one year without a survey. For this study, further simulation runs were conducted in which catches other than those resulting from HCR_{2022} were taken to determine revised scalars for the following year. The simulated catches covered a range of values representing partial utilisation of TAC (i.e., catches less than those indicated as 'safe' under HCR_{2022}) but also values greater than those indicated as 'safe' under HCR_{2022}. This wider spread of simulated catch values allowed functional forms to be fit to the simulation results.

This report fulfils the reporting requirements for Objective 1 of Fisheries New Zealand research project SEA2025-20, "To evaluate how, under the scenario of years of missing absolute abundance estimate, recommended TACCs change in response to different levels of TACC uptake".

2. METHODS

For HCR_{2017} and HCR_{2022}, risk was defined as the probability of the spawning stock biomass (*SSB)* being below 20% of the virgin biomass SSB_0 (the Fisheries New Zealand "soft limit"). The target risk was 10%. The HCR_{2017} rule specified the TAC for the year after a survey as $TAC_{t+1} = p\ (B_t - C_t/\ 2)$, where B_t is acoustic abundance, C_t is catch, and p is a fixed proportion estimated from simulations to achieve the target risk (Doonan 2017). The HCR_{2017}, and subsequent HCR_{2022}, depend on the values of natural mortality and Beverton-Holt recruitment steepness, and these were specified by Fisheries New Zealand to be 0.2 y^{-1} and 0.9, respectively.

In all cases, including this study, assuming the last acoustic survey was completed in year t, the TAC for the following year (TAC_{t+1}) is given by the original HCR_{2017}. When an acoustic survey is not completed in year t+1 (this then becomes the first 'gap year') or subsequent years, HCR_{2022} calculated the TAC for year t+2 onwards by adjusting TAC_{t+1} with a series of scalars, *D1* for the first gap year (TAC for year $t+2$), $D1 \times D2$ for the second gap year to give the TAC for year $t+3$, $D1 \times D2 \times D3$ for the third gap year to give the TAC for year $t+4$, and so on.

For this project, multiple values of scalar were established for each gap year. For the second year after a survey, year t+2, each '*NewD1*' depended on the proportion of the TAC_{t+1} taken in year t+1 ($propTAC_{t+1}$). *NewD1* values were sought such that if

$$Landings_{t+1} = TAC_{t+1} * propTAC_{t+1}$$
$$Landings_{t+2} = TAC_{t+1} * NewD1, \quad (1)$$

the management risk objective was achieved.

The *NewD1* value is directly analogous to the *D1* from HCR_{2022} in that, although its value will be different depending on the value of $propTAC_{t+1}$ it can be directly applied to the TAC_{t+1} value. For subsequent gap years this was not possible, i.e., it was not possible to define TAC_{t+3} in terms of TAC_{t+1}×*NewD1*×*NewD2* because there are multiple possible *NewD1* values compared to a single possible *D1* value and multiple possible proportions of that *NewD1* value taken in year t+2. Values of *NewD2* and *NewD3* were therefore defined in terms of a multiplier on the realised landings from the previous year (and landings in all gap years from year t+2 become defined in terms of a multiple of the realised landings from the previous year).

For year t+3, a grid of '*NewD2*' values that allowed the management risk objective to be fulfilled was generated for combinations of the proportion of TAC_{t+1} taken ($propTAC_{t+1}$) in year t+1 and the proportion of year t+1 catch taken in year t+2 ($prop_{t+2}$). That is, *NewD2* values were sought such that if

$$Landings_{t+1} = TAC_{t+1} * propTAC_{t+1}$$
$$Landings_{t+2} = TAC_{t+1} * propTAC_{t+1} * prop_{t+2}$$
$$Landings_{t+3} = TAC_{t+1} * propTAC_{t+1} * prop_{t+2} * NewD2, \quad (2)$$

the management risk objective was achieved.

For year t+4 *NewD3* values were sought such that if

$$Landings_{t+1} = TAC_{t+1} * propTAC_{t+1}$$
$$Landings_{t+2} = TAC_{t+1} * propTAC_{t+1} * prop_{t+2}$$
$$Landings_{t+3} = TAC_{t+1} * propTAC_{t+1} * prop_{t+2} * prop_{t+3}$$
$$Landings_{t+4} = TAC_{t+1} * propTAC_{t+1} * prop_{t+2} * prop_{t+3} * NewD3, \quad (3)$$

the management risk objective was achieved.

The simulations were conducted using the same selected parameter sets as used in Doonan (2017) and Doonan (2023). The coefficient of variation (CV) for process error of the acoustic survey was set to 20% throughout, since Doonan (2017) found this parameter had little effect on the results, i.e., within simulation error of less than 0.008. Following Doonan (2017), other parameters were sampled randomly including recruitment, autocorrelation of recruitment, and acoustic survey catchability. There were 1000 vectors of randomly sampled parameters. Risk was evaluated over the 1000 runs by taking the number of times the spawning stock biomass (*SSB)* fell below 20% of the virgin biomass (SSB_0) over all 1000 runs divided by the total number of years in the 1000 runs. The natural mortality ($M = 0.2$) and Beverton-Holt steepness ($h = 0.9$) were fixed in all simulations.

For year t+2, for each of a range of $propTAC_{t+1}$ values, 1000 model runs were repeated over a range of *NewD1* values chosen to ensure that the risk of falling below 20% SSB_0 was both above and below 10%. The *NewD1* value for a risk of 10% was estimated by interpolation from the nearest risk values either side of 10%. For year t+3, the process of making 1000 model runs over a range of *NewD2* values and interpolating to find the *NewD2* value for a risk of 10% was repeated for a grid of $propTAC_{t+1}$ and $prop_{t+2}$ values. With each successive gap year, the number of permutations of $propTAC_{t+1}$ and successive $prop_{t+1+gap}$ values increases multiplicatively. Therefore, *NewD3* values were estimated over a range of $prop_{t+3}$ values but with the $propTAC_{t+1}$ and $prop_{t+2}$ values set to the values seen from the fishery in 2024–25 and 2025–26 (to the nearest 0.05) (Table 1).

For each set of 1000 model runs the same multiplier was applied in each gap year of the projection, e.g. when testing for *NewD2* values, the same proportion of the TAC_{t+1} ($propTAC_{t+1}$) was applied in each year after a survey was simulated and the same proportion of t+1 landings ($prop_{t+2}$) taken in each second gap year.

Table 1: Biomass (derived from an acoustic survey) of Bounty Plateau southern blue whiting (SBW 6B) in 2023–24, TAC set for 2024–25, the landings of SBW in the 2024–25 and 2025–26 seasons, the 2024–25 landings as a proportion of the TAC (*$propTAC_{t+1}$*) and the 2025–26 landings as a proportion of the 2024–25 landings (*$prop_{t+2}$*).

Year	Biomass (t)	TAC from HCR_{2017} (t)	Landings (t)	$propTAC_{t+1} \equiv Landings_{24\text{-}25} / TAC_{24\text{-}25}$	$prop_{t+2} \equiv Landings_{25\text{-}26} / Landings_{24\text{-}25} \equiv Landings_{25\text{-}26} / (propTAC_{24\text{-}25} \times TAC_{24\text{-}25})$
2023–24	21 791	--	--	--	--
2024–25	--	4 988	3 418.4	0.69	--
2025–26	--	--	2 627.3	--	0.76

3. RESULTS

3.1 Year t+2

Values of *NewD1* that allowed the management risk objective to be achieved are given in Table 2. The relationship between the *NewD1* and $propTAC_{t+1}$ values appears linear (Figure 1). A linear regression on the simulation results gave a relationship of

$$NewD1 = 2.07 - 1.2 * propTAC_{t+1} \tag{4}$$

For values of $propTAC_{t+1}$ less than 0.9 the TAC_{t+1} is no longer discounted to obtain TAC_{t+2}.

Table 2: Multiplier on TAC_{t+1} to obtain TAC_{t+2} (*NewD1*) for given proportions of TAC_{t+1} taken in year t+1 (*$propTAC_{t+1}$*).

$propTAC_{t+1}$	*NewD1*	$propTAC_{t+1}$	*NewD1*
1.00	0.88	0.70	1.23
0.98	0.90	0.65	1.29
0.96	0.92	0.60	1.35
0.94	0.94	0.55	1.41
0.92	0.97	0.50	1.47
0.90	0.98	0.45	1.53
0.88	1.02	0.40	1.59
0.86	1.04	0.35	1.65
---		0.30	1.72
0.8	1.11	0.25	1.78
0.75	1.16		

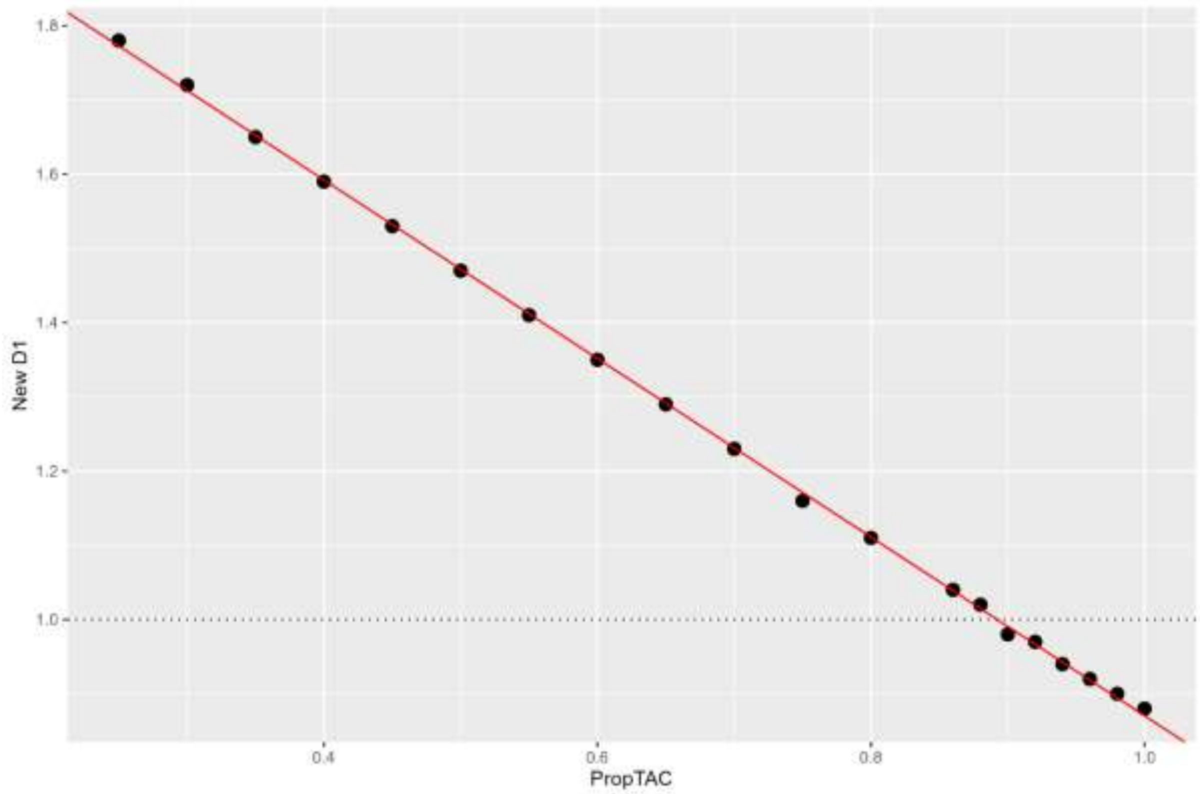

Figure 1: Multiplier on TAC_{t+1} to obtain TAC_{t+2} (*NewD1*) for given proportions of TAC_{t+1} taken in year t+1 (*$propTAC_{t+1}$*). Red line is the fit to the data given by equation 4.

3.2 Year t+3

Values of *NewD2* that allowed the management risk objective to be achieved are given in Table 3. The relationships between the *NewD2* and both the $propTAC_{t+1}$ and $prop_{t+2}$ values are non-linear (Figure 2). A quartic polynomial surface achieved an R^2 value of 0.9998 with the following coefficients

$$\begin{aligned} NewD2 = {} & 88.774 - 219.553X - 130.448Y \\ & + 258.055X^2 + 199.275X*Y + 100.579Y^2 \\ & - 152.339X^3 - 136.894X^2*Y - 85.046X*Y^2 - 40.911Y^3 \\ & +37.496X^4 + 30.455X^3*Y + 33.272X^2*Y^2 + 10.172X*Y^3 + 7.726Y^4 \end{aligned} \quad (5)$$

Where X ≡ $propTAC_{t+1}$ and Y ≡ $prop_{t+2}$

For TAC_{t+3}, from equation (2) any combination of $propTAC_{t+1} \times prop_{t+2} \times NewD2 \geq 1$ indicates that TAC_{t+3} does not need to be reduced compared to TAC_{t+1} while still achieving the management risk objective (10% risk of $SSB_{current}$ < 20% SSB_0). Values of $propTAC_{t+1} \times prop_{t+2} \times NewD2$ are given in Table 4.

Table 3: Multiplier to obtain TAC_{t+3} (*NewD2*) for given proportions of TAC_{t+1} taken in year t+1 (*$propTAC_{t+1}$*) and multiplier applied to landings in year t+1 to get landings in year t+2 (*$prop_{t+2}$*). The top row (*$propTAC_{t+1}$* = 1) represents the case when the TAC_{t+1} is fully taken. The second column (*$prop_{t+2}$* = 1) represents the case when the landings in year t+2 are equal to the landings in year t+1. Landings equivalent to the recommended TACs from HCR_{2022} would be for *$propTAC_{t+1}$* = 1 and *$prop_{t+2}$* = 0.87.

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$prop_{t+2}$	1.05	1.0	0.95	0.9	0.85	0.8	0.75	0.7	0.65	0.6
$propTAC_{t+1}$										
1.0	0.54	0.62	0.68	0.76	0.89	1.03	1.16	1.32	1.52	1.81
0.9	0.82	0.95	1.03	1.18	1.30	1.46	1.63	1.84	2.12	2.35
0.8	1.24	1.40	1.55	1.71	1.84	2.02	2.24	2.49	2.79	3.13
0.7	1.84	1.96	2.11	2.30	2.60	2.78	3.00	3.33	3.74	4.15
0.6	2.60	2.78	3.00	3.19	3.43	3.77	4.14	4.47	4.86	5.49
0.5	3.58	3.82	4.09	4.47	4.75	5.20	5.61	6.05	6.55	7.22
0.4	5.22	5.56	5.89	6.30	6.65	7.19	7.71	8.44	9.13	10.0

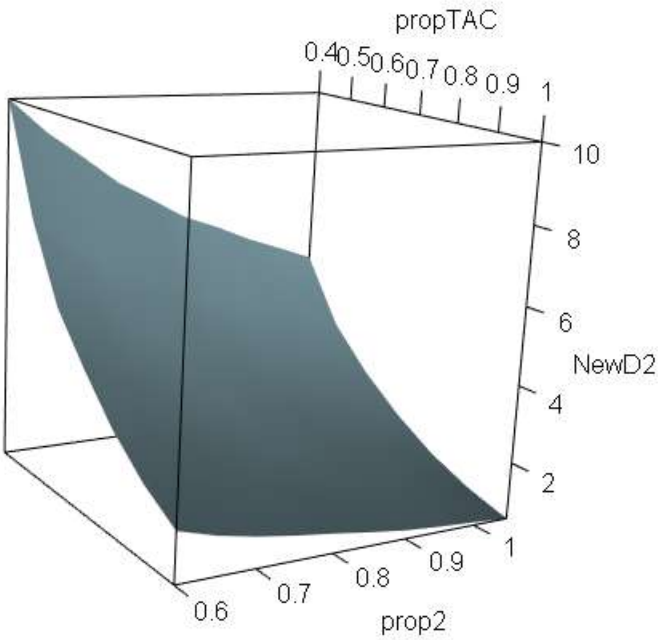

Figure 2: Multiplier to obtain TAC_{t+3} (*NewD2*) for given proportions of TAC_{t+1} taken in year t+1 (*$propTAC_{t+1}$*) and multiplier applied to landings in year t+1 to get landings in year t+2 (prop2 ≡ *$prop_{t+2}$*)

Table 4: Values of *$propTAC_{t+1}$* × *$prop_{t+2}$* × *NewD2* for given proportions of TAC_{t+1} taken in year t+1 (*$propTAC_{t+1}$*), multiplier applied to landings in year t+1 to get landings in year t+2 (*$prop_{t+2}$*) and for maximum 'safe' multipliers on landings in year t+2 to get landings in year t+3 (*NewD2*). *NewD2* values are as in Table 3. Any value ≥ 1 indicates the TAC_{t+3} can be ≥ TAC_{t+1} while still achieving the management risk objective (10% risk of $SSB_{current}$ < 20% SSB_0).

$prop_{t+2}$	1.05	1.0	0.95	0.9	0.85	0.8	0.75	0.7	0.65	0.6
$propTAC_{t+1}$										
1.0	0.57	0.62	0.65	0.68	0.76	0.82	0.87	0.92	0.99	1.09
0.9	0.77	0.86	0.88	0.96	0.99	1.05	1.10	1.16	1.24	1.27
0.8	1.04	1.12	1.18	1.23	1.25	1.29	1.34	1.39	1.45	1.50
0.7	1.35	1.37	1.40	1.45	1.55	1.56	1.58	1.63	1.70	1.74
0.6	1.64	1.67	1.71	1.72	1.75	1.81	1.86	1.88	1.90	1.98
0.5	1.88	1.91	1.94	2.01	2.02	2.07	2.10	2.12	2.13	2.17
0.4	2.19	2.22	2.24	2.27	2.26	2.30	2.31	2.36	2.37	2.40

3.3 Year t+4

At the time of this study the most recent acoustic biomass survey had occurred in 2023 and a $TAC_{t+1} \equiv TAC_{2024\text{–}25}$ established using the HCR_{2017}. To keep to a reasonable number of model runs, only $propTAC_{t+1}$ and $prop_{t+2}$ values approximately as seen from the fishery in 2024–25 and 2025–26 (Table 1) were used. Values of *NewD3* that fulfilled the management risk objective for a range of $prop_{t+3}$ values are given in Table 5. The *NewD2* value of 3.0 for when $propTAC_{t+1}$ and $prop_{t+2}$ values were as seen from the fishery in 2024–25 and 2025–26 was used as a maximum $prop_{t+3}$ value.

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Table 5: Multiplier to obtain TAC_{t+4} (*NewD3*) for a proportion of TAC_{t+1} of 0.7 ($propTAC_{t+1}$) and multiplier on landings in year t+1 to get landings in year t+2 of 0.75 ($prop_{t+2}$) and for different multipliers on landings in year t+2 to get landings in year t+3 ($prop_{t+3}$).

$propTAC_{t+1} \times prop_{t+2}$	$prop_{t+3}$	*NewD3*	$propTAC_{t+1} \times prop_{t+2}$	$prop_{t+3}$	*NewD3*
0.525	3.0	0.37	0.525	1.9	1.31
0.525	2.9	0.44	0.525	1.8	1.47
0.525	2.8	0.48	0.525	1.7	1.64
0.525	2.7	0.56	0.525	1.6	1.83
0.525	2.6	0.64	0.525	1.5	2.01
0.525	2.5	0.71	0.525	1.4	2.27
0.525	2.4	0.79	0.525	1.3	2.53
0.525	2.3	0.87	0.525	1.2	2.91
0.525	2.2	0.97	0.525	1.1	3.34
0.525	2.1	1.09	0.525	1.0	3.76
0.525	2.0	1.20	0.525	0.9	4.25

The relationship between the *NewD3* and $prop_{t+3}$ values is non-linear. A cubic fit achieved an R^2 value of 0.9989 with the following coefficients

$$NewD3 = 11.919 - 12.094prop_{t+3} + 4.586prop_{t+3}^2 - 0.615prop_{t+3}^3 \quad (3)$$

For TAC_{t+4}, from equation (3) any combination of $propTAC_{t+1} \times prop_{t+2} \times prop_{t+3} \times NewD3 \geq 1$ indicates TAC_{t+4} does not need to be reduced compared to TAC_{t+1}. Values of $propTAC_{t+1} \times prop_{t+2} \times prop_{t+3} \times NewD3$ (with $propTAC_{t+1}$ and $prop_{t+2}$ fixed to 0.7 and 0.75 respectively) are given in Table 6.

Table 6: Values of $propTAC_{t+1} \times prop_{t+2} \times prop_{t+3} \times NewD3$ assuming $propTAC_{t+1} = 0.7$, $prop_{t+2} = 0.75$ and for different multipliers on landings in year t+2 to get landings in year t+3 ($prop_{t+3}$). *NewD3* values are maximum 'safe' multipliers on landings in year t+3 to get landings in year t+4 and are as in Table 5. Any value ≥ 1 indicates the TAC_{t+4} can be ≥ TAC_{t+1} while still achieving the management risk objective (10% risk of $SSB_{current} < 20\% SSB_0$).

$propTAC_{t+1} \times prop_{t+2}$	$prop_{t+3}$	$propTAC_{t+1} \times prop_{t+2} \times prop_{t+3} \times NewD3$	$propTAC_{t+1} \times prop_{t+2}$	$prop_{t+3}$	$propTAC_{t+1} \times prop_{t+2} \times prop_{t+3} \times NewD3$
0.525	3.0	0.59	0.525	1.9	1.31
0.525	2.9	0.67	0.525	1.8	1.39
0.525	2.8	0.71	0.525	1.7	1.46
0.525	2.7	0.79	0.525	1.6	1.53
0.525	2.6	0.87	0.525	1.5	1.58
0.525	2.5	0.93	0.525	1.4	1.67
0.525	2.4	0.99	0.525	1.3	1.73
0.525	2.3	1.05	0.525	1.2	1.84
0.525	2.2	1.12	0.525	1.1	1.93
0.525	2.1	1.20	0.525	1.0	1.97
0.525	2.0	1.26	0.525	0.9	2.01

4. DISCUSSION

Table 2 shows values of $propTAC_{t+1}$ and Table 4 shows combinations of $propTAC_{t+1}$ and $prop_{t+2}$ values that allow the TAC_{t+2} and TAC_{t+3} to be ≥ TAC_{t+1} respectively. Table 6 shows values of $prop_{t+3}$ values that, for a specific combination of $propTAC_{t+1}$ and $prop_{t+2}$ values allow TAC_{t+4} to be ≥ TAC_{t+1}. So, for example, if 90% of TAC_{t+1} is taken in the first gap year ($propTAC_{t+1}$ = 0.9) and landings in the second gap year are 80% of those from the first gap year ($prop_{t+2}$ = 0.8) from Table 4 it can be seen TAC_{t+3} could be set a little greater than TAC_{t+1}. The simulation results reflect that if a lower amount (than the HCR_{2022} level) is caught, then the population would be expected (on average) to grow to a higher biomass than if the HCR_{2022} catch level were taken, supporting a higher catch in later year(s) for the same management risk objective.

When full TACs were taken, the multipliers to get TACs for successive gap years were always discount factors and were labelled D1, D2 etc. Depending on the proportion of TAC taken in the first gap year, and/or proportions of catch from the previous year taken in subsequent years, the new multipliers can have values greater than one (i.e., no longer a discount). However, for continuity they have been labelled '*NewD#*', with the # denoting the gap year. Unlike under the assumption of full TACs taken there are also now multiple *NewD#* values for a given gap year. This can be accommodated by using a subscript to denote the percentage of the TAC_{t+1} taken in year *t*+1, i.e. the original *D1* becomes $NewD1_{100}$, and further subscripts to denote the percentage of catch taken in the previous year for subsequent gap years, e.g., the *NewD2* value for when the catch in year t+1 is 70% of the TAC_{t+1} and the catch in year t+2 75% of the catch in year t+1 could be denoted as $NewD2_{70,75}$.

A practical interpretation of the simulation results is that the real catches taken for 2024–25, and for the two-year series 2024–25 and 2025–26, are sufficiently below the TAC that the TACs for 2025–26 and 2026–27 can safely remain at the 2024–25 level, i.e., no discount factors need to be applied. Any beneficial biomass increase occurring from under-catching the TAC may be utilised when the next survey, and re-set of the TAC, takes place.

It is important to note that for a gap in surveys greater than one year, a *NewD#* value greater than one does not necessarily indicate a safe TAC for the following year can be ≥ TAC_{t+1}, because the *NewD#* value is simply the multiplier that can be applied to catches from the previous year, i.e., an indication the TAC set immediately after an abundance survey need not be reduced comes from Tables 4 and 6, not Tables 3 and 5. For example if 90% of TAC_{t+1} is taken in the first gap year ($propTAC_{t+1}$ = 0.9) and landings in the second gap year are 95% of those from the first gap year ($prop_{t+2}$ = 0.95) the *NewD2* value is 1.03 (from Table 3) but Table 4 shows the maximum safe TAC_{t+3} to be 0.88×TAC_{t+1} (i.e., 0.9×0.95×1.03× TAC_{t+1}).

The values in Tables 2, 4 and 6 give the maximum multiple that can be applied to TAC_{t+1} to get the TAC for the following year while satisfying the management risk objective. Values greater than one mean the TAC in the following year can be higher than TAC_{t+1}. Full use of the increased TAC, however, is a level of catch expected to only just satisfy the management risk objective. As demonstrated by HCR_{2022}, full use of a maximum permitted TAC leads to a need to reduce the TAC in the following year. For example, the catches in 2024–25 and 2025–26 gave $propTAC_{t+1}$ and $prop_{t+2}$ values of approximately 0.7 and 0.75 respectively. From Table 3 the *NewD2* value is 3.0 and from Table 4 a TAC_{t+3} value of 1.58×TAC_{t+1} can be used. Given the TAC_{t+1}≡$TAC_{24–25}$ was 4988 t, this indicates a maximum 'safe' TAC_{t+3}≡$TAC_{26–27}$ of 7881 t. If this level of catch was taken, however, then $prop_{t+3}$ = 3 and from Table 5 the *NewD3* value required would be 0.37 and from Table 6 the TAC_{t+4}≡$TAC_{27–28}$ would need to be restricted to 0.59×TAC_{t+1} = 2943 t.

The *NewD#* factor values estimated in this study are valid only for the life history parameters assumed for the stock and other assumptions of the simulation model. This includes the assumption of average recruitment (with variability). A period of lower-than-average recruitment would require lower *NewD#* values.

In addition, the simulations to derive the *NewD#* values are unrealistic in that

- *NewD1*: Over a 120 year period, every year after a survey (year t+1) the same proportion ($propTAC_{t+1}$) of the TAC is taken.
- *NewD2*: Over a 120 year period, every year after a survey (year t+1) the same proportion ($propTAC_{t+1}$) of the TAC is taken and in the following year the same proportion ($prop_{t+2}$) of landings from $year_{t+1}$ is taken.
- *NewD3*: Over a 120 year period, every year after a survey (year t+1) the same proportion ($propTAC_{t+1}$) of the TAC is taken, the following year the same proportion ($prop_{t+2}$) of landings from $year_{t+1}$ is taken and in the third year the same proportion ($prop_{t+3}$) of landings from $year_{t+2}$ is taken.

5. POTENTIAL RESEARCH

The simulations of this study are based on a regular number of gap years between abundance surveys (one gap year between each survey, two gap years between each survey etc.). Further research could consider varying the number of gap years between surveys in each individual forward projection.

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