Fisheries New Zealand

Tini a Tangaroa

# Management strategy evaluation of New Zealand ling stocks

New Zealand Fisheries Assessment Report 2024/….

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ISSN 1179-5352 (online)
ISBN XXXX (online)

**Month 2024**

Te Kāwanatanga o Aotearoa
New Zealand Government

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Please cite this report as:
Mormede, S. (2024). Management strategy evaluation of New Zealand ling stocks. *New Zealand Fisheries Assessment Report 20xx/xx.* xx p.

**TABLE OF CONTENTS**

# 1. Executive Summary

Mormede, S.[1] Management strategy evaluation of New Zealand ling stocks.

New Zealand Fisheries Assessment Report 2024/xx. xx p.

Ling (*Genypterus blacodes*) are an important commercial species with adults found throughout the middle depths of the New Zealand Exclusive Economic Zone (EEZ) typically in depths of 100 m to 800 m. Ling are caught mainly by deepwater trawlers, demersal longliners and more recently by potting.

Full management strategy evaluation simulations were carried out for the three main New Zealand ling stocks. The simulations showed that the shape of the harvest control rule was not duly influential, and nor was the maximum allowed total allowable catch change. This is not unexpected given all three ling stocks are above the target spawning stock biomass of 40% of initial stock spawning biomass.

The main uncertainties in these stocks were tested, namely the value of natural mortality, the value of the stock recruit relationship steepness parameter, and future recruitment strength. As expected, the natural mortality term was the most influential, followed by the value of potential future recruitment, although there has been little change in the long-term strength of recruitment to date for those stocks. The value of steepness had some influence, particularly on the more extreme scenarios of low natural mortality and low future recruitment. None of the stocks reached the soft limit of 20% of initial spawning biomass.

A potential target range was developed for ling based on the variability seen in the simulations. A range of 33-55% of initial biomass could be used. Under such target range, only a small number of simulations would not achieve 50% probability of being above the lower target range.

[1] soFish Consulting Ltd.

## 2. INTRODUCTION

Ling (*Genypterus blacodes*) are an important commercial species with adults found throughout the middle depths of the New Zealand Exclusive Economic Zone (EEZ) typically in depths of 100 m to 800 m (Hurst et al. 2000). Ling are caught mainly by deepwater trawlers, often as bycatch in hoki (*Macruronus novaezelandiae*) target fisheries, by demersal longliners (Mormede et al. 2021a, 2022, 2023a), and more recently by potting (Mormede et al. in prep). Small quantities of ling are also caught by inshore trawls and set nets.

Ling are managed as eight administrative Quota Management Areas (QMAs, Figure 1), with five (LIN 3, 4, 5, 6, and 7) reporting about 95% of landings. There are at least five major biological stocks of ling in New Zealand waters (Horn 2005)—the Chatham Rise, the Sub-Antarctic (including the Stewart-Snares shelf and Puysegur Bank), the Bounty Plateau, the west coast of the South Island, and the Cook Strait. Recent analyses have indicated that the Bounty Plateau might be an offshoot of the Sub-Antarctic stock (Mormede et al. in prep), and these two areas were assessed as a single stock in 2024 (Mormede et al. in prep).

The ling biological stocks were defined using statistical areas as described in Figure 1. Stock assessments are carried out regularly for the main ling stocks, and were last updated in 2022 for the Chatham Rise (LIN 3&4, Mormede et al. 2023b), in 2023 for the west coast South Island (LIN 7WC, Mormede et al. 2024), and in 2024 for the Sub-Antarctic (LIN 5&6 and LIN 6B, Mormede et al. in prep). These were carried out using a Bayesian stock model implemented using the general-purpose stock assessment program CASAL (Bull et al. 2012) or Casal2 (Doonan et al. 2016; Casal2 Development Team 2023). Stock status at the latest assessments was 56%, 66% and 55% of the initial spawning stock biomass for LIN 3&4, LIN 5&6 and LIN 6B, and LIN 7WC respectively. The status of ling stocks are summarised annually by Fisheries New Zealand (2024). Adjustments to the ling catch limits have been based on the stock assessments and five year projections (Fisheries New Zealand 2024).

Assessments for other stocks were last updated in 2007 (LIN 6B when assumed a stand-alone stock, Bounty Platform, with a CPUE update in 2014), and 2010 (LIN 7CK, Cook Strait, with an assessment in 2013 rejected). These are not considered further in the present analysis.

This report summarises the results of a Management Strategy Evaluation (MSE) framework developed for the three regularly-assessed ling stocks (LIN 3&4, LIN 5&6 and LIN 6B, and LIN 7WC) using the latest population models used for management purposes (Fisheries New Zealand 2024). The work was funded by the Deepwater Council, Seafood New Zealand and reviewed by the Fisheries New Zealand Deepwater Working Group.

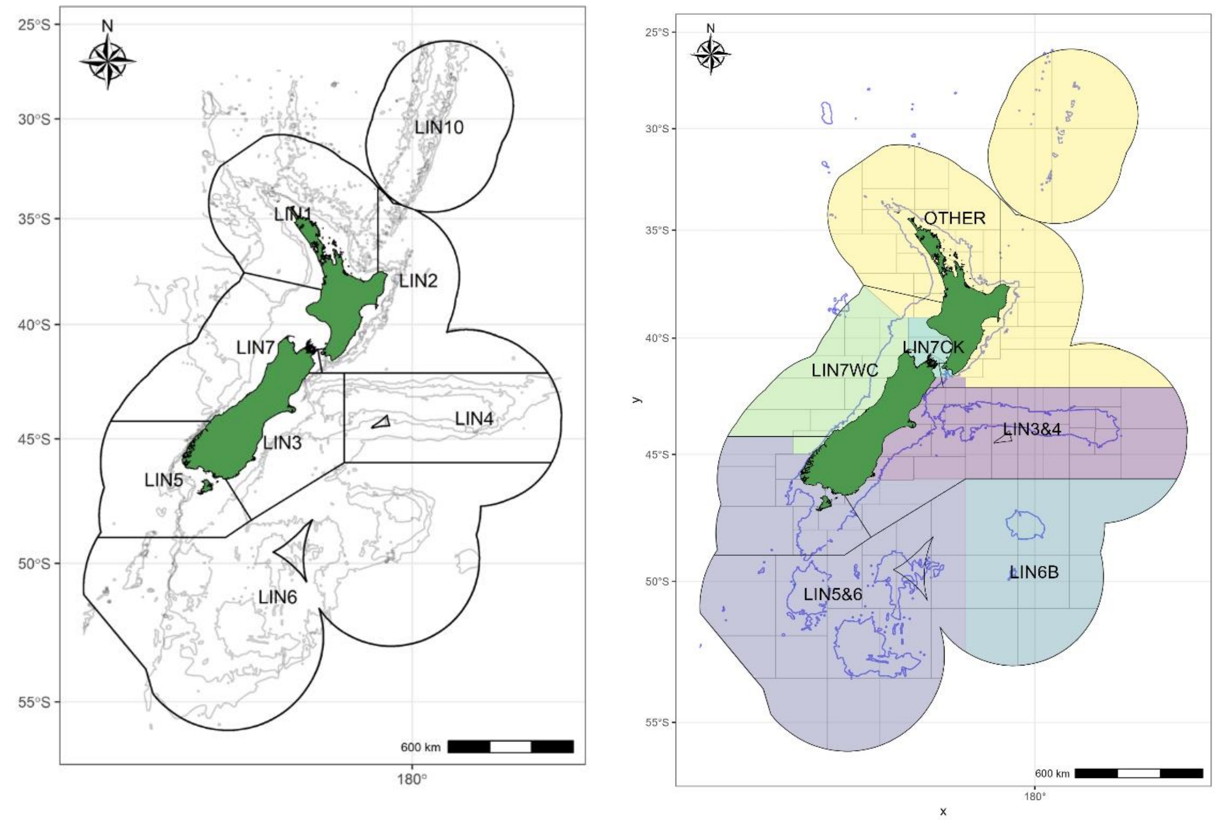



**Figure 1: Quota Management Areas (QMAs, left) and biological stock boundaries (right) for ling, as used in this analysis. In 2024, LIN 5&6 and LIN 6B was assessed as a single stock for the first time.**

## 3. METHODS

The MSE was carried out using Casal2 (Casal2 Development Team 2023) as the modelling platform. The base case models adopted for management purposes (Fisheries New Zealand 2024) were used, using the Markov Chain Monte Carlo (MCMC) outputs as a starting point for the projections, and modified as required for each simulation. Population models were updated and run for each simulation using the R Project for Statistical Computing software (R Core Team 2019). Simulation outputs were extracted and processed in R.

### 3.1 Management framework

The investigation was guided by the Marine Stewardship Council (MSC) Fisheries Standard v3.0 (Marine Stewardship Council 2022), in particular:

- Performance Indicator (PI) 1.2.1 Scoring Guidepost (SG) 100 includes: "*harvest strategy has been evaluated and is achieving the objectives in PI 1.1.1 including being clearly able to maintain stocks at target levels*".
- PI 1.2.2 SG 100 includes: "*the HCR* (harvest control rule) *is expected to keep the stock fluctuating at or above the target level consistent with MSY* (maximum sustainable yield)" and "*HCR take account of a wide range of uncertainties {…} and robust to main uncertainties*".

Options for the shape of the harvest control rule were based on the harvest strategy standard developed by Fisheries New Zealand (Ministry of Fisheries 2008, 2011). The harvest strategy standard defines the default target spawning stock biomass (*SSB*) as 40% of initial spawning stock biomass ($B_0$), and soft and hard limits at 20% $B_0$ and 10% $B_0$ respectively (Figure 2). These values are currently used for the management of ling (Fisheries New Zealand 2024). $F_{MSY}$ is defined as the long-term exploitation rate that achieves $B_{MSY}$, $B_{40}$ in this instance, and could therefore actually more appropriately named $U_{40}$.

Alternative shapes of harvest control rule were tested as part of this project, by varying the location of the two inflection points:

- The low inflection point was set at either 10% $B_0$ (as per Figure 2) or 20% $B_0$.
- The top inflection point was set at either 20% $B_0$, $(1 – M)×40\%$ $B_0$ (as per Figure 2) where $M$ is natural mortality, or 40% $B_0$.

Alternative targets and limits were not tested although a potential target range was developed based on the results of the simulations.

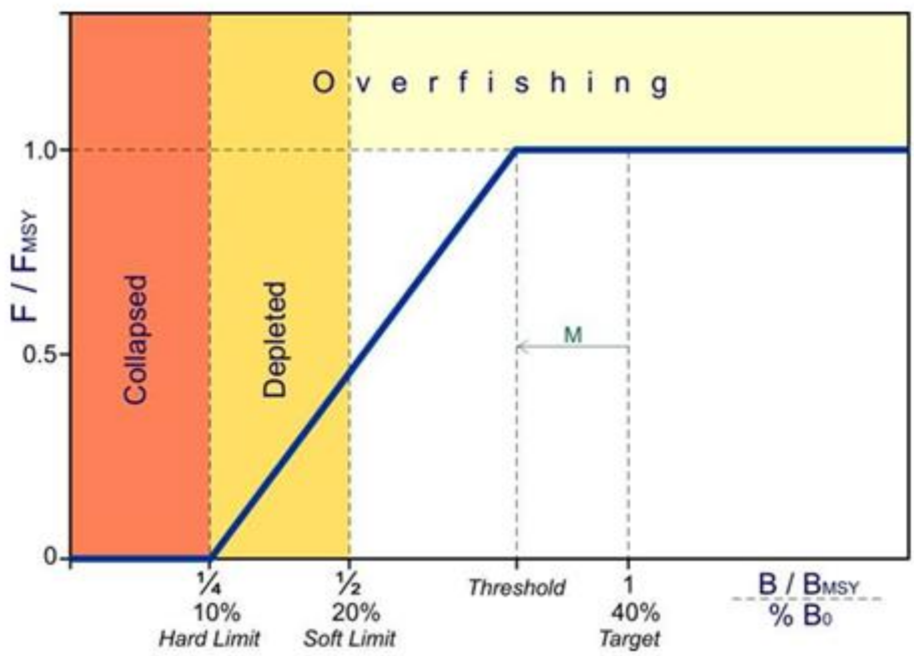



**Figure 2: Example of harvest control rule provided in the Fisheries New Zealand Harvest Strategy Standard (Ministry of Fisheries 2011, Figure 6).**

## 3.2 Calculation of $U_{40}$

$U_{40}$ was calculated for each stock by projecting all 1000 MCMC chains of each stock assessment base case model forward 100 years under randomly sampled recruitment from the entire time series of estimated recruitment for that MCMC chain, and a constant exploitation rate $U$ defined as catch divided by vulnerable biomass. Vulnerable biomass for all ling stocks was assumed equal to the trawl selected biomass as the trawl selectivity has a logistic shape and is to the left of the longline selectivity for all ling stocks (Mormede et al. 2023b, 2024, in prepc).

The exploitation rate applied was iteratively changed. $U_{40}$ for each stock was the highest exploitation rate that achieved the probability of projected *SSB* below 40% $B_0$ less than 0.5 over the last 50 years of the projections in all 1000 chains, with a tolerance of 0.0005.

## 3.3 Management strategy evaluation process applied

For each simulation scenario, the following process was carried out (Figure 3):

1. One of the MCMC chains was selected as the basis of the simulation run.
2. Future recruitment deviates (year class strength, YCS) were sampled from a pre-determined range of estimated YCS for all projected years, including the most recent years of the model where YCS was not estimated. The range tested was either all years, or the 10-year block of lowest YCS.
3. If an assessment year, a new total allowable catch (TAC) was calculated given the HCR tested. The simulations assumed a new TAC was calculated every three years, in line with the current assessment process. If not an assessment year, the TAC was rolled over.
4. If the simulation assumed a maximum TAC change allowed, the TAC calculated was mediated by that maximum allowed change. Maximum allowed TAC changes tested were either ±10%, ±20%, +10% / -20%, or none.
5. The model was updated by one year with the new TAC if applicable or existing TAC otherwise. The TAC was applied to the different fisheries in the same catch split as the last four years of the base case model (the last three years of the fishery as the last year of the model assumes the same catch and catch split as the last year of the fishery).
6. If a “full” MSE was run (see below), an additional year of observations was simulated with the same error structure as the previous year (cv and process error). For survey observations, the same frequency was assumed in the future as per recent surveys (surveys carried out every two years in this instance).
7. If a “full” MSE, the parameters in the model were then re-estimated with the one additional year of catch and simulated observations. Sensitivities were carried out whereby the model was then run rather than re-estimated, also referred to as “shortcut” MSE, see below.
8. Points 3-7 were repeated for the 50 years of the projected simulation.
9. Points 1-7 were repeated for 50 simulation runs.
10. Performance indicators were calculated over the 50 simulation runs for each specific simulation scenario.

This process was repeated for many combinations of HCR rules and model assumptions.

The various simulation scenarios were compared with each other based on performance indicators, which included:

- the mean and 95% credible interval of *SSB* in the final 20 years of the projection,
- the probability that *SSB* in the last 20 years of the projection is above 20%, 33% and 40% $B_0$, or within 10% of 40% $B_0$,
- the mean and 95% credible interval of the catch for the entire projection time,
- the median and maximum catch change over the entire projection time, and the next catch limit calculated,
- the mean future CPUE (catch per unit effort) by fishery and for the survey when these were included in the model as observations,

- the mean future age of fish caught by fishery.

The option of running the model after each iteration as opposed to re-estimating parameters was investigated (points 6 and 7 above). Runs, also sometimes referred to as “shortcut” MSE are fast and therefore allow the use of complex models and many investigations of alternative options. Such a process has been used for New Zealand rock lobster, with 100-year projections on all 1000 MCMCs typically run (Webber & Starr 2020). Alternatively, “full” MSE require the simulation of observations and re-estimation of parameters each projected year and are therefore much slower to run than “shortcut” MSE. They might also require a simplification of the model to allow each simulation to run in an acceptable amount of time. This was the case for hoki MSE, for which “full” estimations were carried out on a simplified population model in R with 10-year projections and 100 simulations (Langley 2023). “Shortcut” MSE can speed up the simulations, but often provide less robust results and different outcomes (Punt et al. 2016; harveststrategies.org 2024). The two options were tested for one model for ling, with the “shortcut” MSE resulting in a higher status (see further results below). The “full” MSE process was taken forward in this instance.

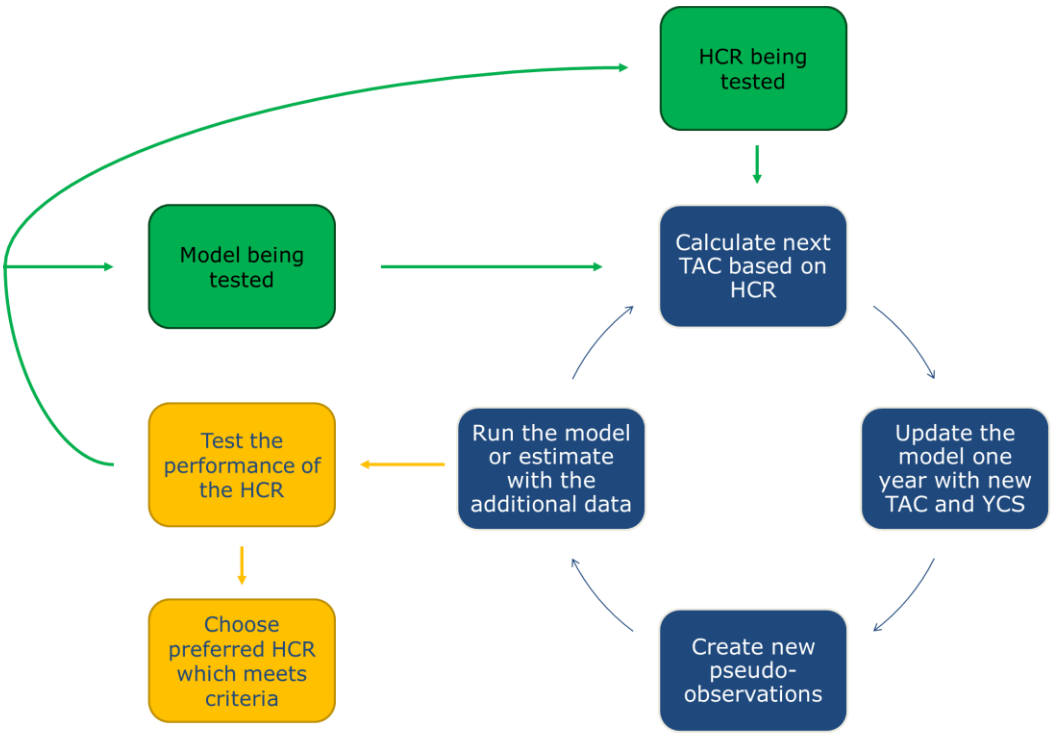



**Figure 3: MSE process carried out. Note that final simulations all had re-estimations of the models. The blue boxes represent the process of each simulation scenario, the green boxes the inputs to the simulation scenarios, and the yellow boxes the analysis of the outputs to the simulation scenarios.**

## 3.4 Range of model assumptions tested

The MSC Fisheries Standard v3.0 requires that the HCR takes account of a wide range of uncertainties (Marine Stewardship Council 2022). The main uncertainties in the stock assessments of ling tested here were natural mortality, the strength of future recruitment and, to a lesser extent, the steepness of the stock recruit relationship (Fisheries New Zealand

2024). Other uncertainties such as fisheries selectivities or future catch split between fisheries were expected to have very little influence and therefore were not tested.

Natural mortality ($M$) was estimated in the model for LIN 3&4 but assumed for the other stocks based on external analyses (Horn 2005; Edwards 2017); it was deemed to be poorly estimated for LIN 5&6, and with bias (Mormede et al. 2021b). For all three stocks, sensitivities are typically carried out with values of $M$ which flank the value of the base case model (Fisheries New Zealand 2024). MSE simulation scenarios were carried out with the three values of $M$ used in each the stock assessment. Because the aim of the MSE was to test the robustness of the HCR to model misspecifications and uncertainties in the main parameters, $F_{MSY}$ ($U_{40}$) was not recalculated for the simulations with alternative values of $M$. Similarly, the HCR with top inflection point of (1 – $M$) × 40% $B_0$ values were not updated to the alternative values of $M$ but kept constant within each stock.

Any projection of a stock assessment will be affected by the assumption around the strength of future recruitment (year class strength, YCS). Projections used for assessing catch limits of New Zealand ling stocks usually resample from either all estimated YCS or the last ten estimated YCS (Fisheries New Zealand 2024). In the case of ling in New Zealand, recent recruitment has been close to average recruitment, and therefore for the purposes of MSE testing we resampled YCS from either all estimated YCS or the estimated YCS representing the lowest 10-year average YCS. In all instances, this period was early in the models (in the 1980s).

The three ling stocks investigated assumed a Beverton-Holt stock-recruit relationship with steepness $h = 0.84$. The value of steepness is unknown for these ling stocks because their status is not expected to have dropped below 50% $B_0$ (e.g., Mormede et al. in prep). Because the SSB target is 40% $B_0$, it is expected that alternative values of steepness are unlikely to be strongly influential in this instance. A subset of simulation scenarios was carried out with an alternative steepness value of $h = 0.59$, based on estimates from other ling stocks worldwide (Horn 2022).

# 4. RESULTS

## 4.1 Deriving $U_{40}$ values

The target exploitation rate value ($U_{40}$) is affected by the vulnerable selectivity as well as many other characteristics of the model such as when in the model the catch it taken. This resulted in different $U_{40}$ values between the three ling stocks:

- LIN 3&4: $U_{40} = 0.090$
- LIN 5&6 and LIN 6B: $U_{40} = 0.139$
- LIN 7WC: $U_{40} = 0.169$

Furthermore, the target exploitation rate initially calculated for LIN 3&4 externally from the simulations was higher, at 0.14, and resulted in simulations with final $SSBs$ well below the target of 40% $B_0$. This value was reduced until simulations using the base case stabilised at 40% $B_0$. In both other cases, the externally calculated $U_{40}$ resulted in a long-term SSB of about 40% $B_0$ as expected (see section 4.4).

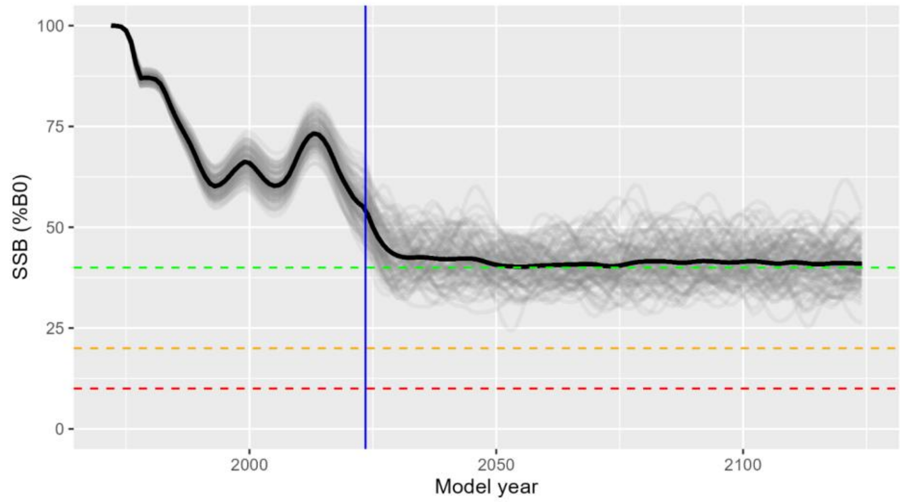
## 4.2 Investigating “shortcut” vs. “full” MSE

In the initial stages of developing an MSE framework for ling, the option of "shortcut" or "full" MSE was tested. The base case model for LIN 7WC was used, 100 simulations carried out sampled from the MCMC chain and projected for 100 years. Future YCS were resampled from all estimated YCS in the relevant MCMC chain, the HCR rule applied was a per Figure 2, and no maximum allowed TAC change was applied.

The "shortcut" MSE resulted in a higher long term stock status compared with the "full" MSE (Figure 4). The "full" MSE resulted in a long term *SSB* of about 41% $B_0$, consistent with the target of 40% $B_0$ as defined by the target exploitation rate $U_{40}$. The "shortcut" MSE was more optimistic at about 46% $B_0$ and therefore inconsistent with the definition of $U_{40}$. This result is consistent with those reported elsewhere (e.g., Punt et al. 2016; harveststrategies.org 2024).

Based on these results, all further work on the ling MSE was carried out using a "full" MSE framework whereby the model parameters were re-estimated at each timestep given the new TAC and simulated observations.

"Full" MSE




"Shortcut" MSE

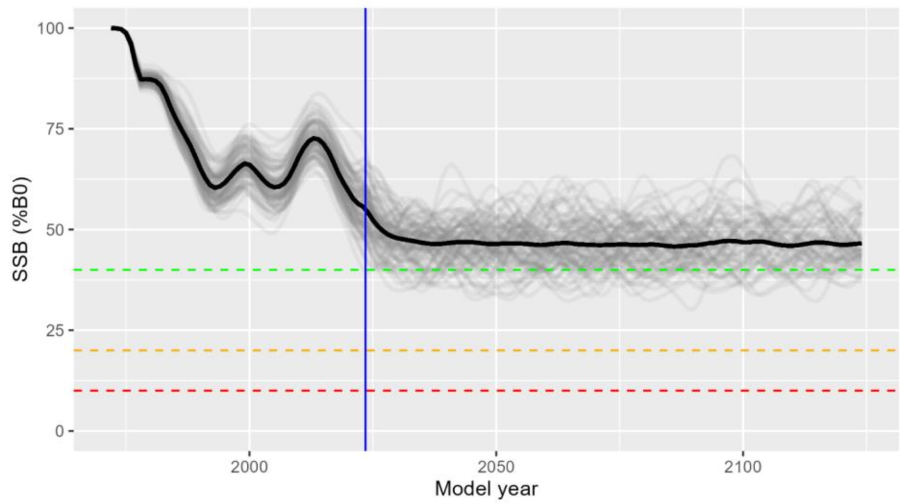



**Figure 4: Projected stock spawning stock biomass (*SSB*) as a proportion of initial spawning stock biomass ($B_0$) the a "full" (top) or "shortcut" (bottom) MSE simulation for LIN 7WC. Each grey line represents one of the 100 simulations, and the black line is the median of all**

**simulations. The green horizontal line represents $B_{target}$ = 40% $B_0$, the orange line the soft limit of 20% $B_0$ and the red line the hard limit of 10% $B_0$. The vertical blue line represents the start of the projections.**

## 4.3 Choosing the base HCR setup

Initial simulation scenarios were carried out using LIN 7WC as a test case to help determine the preferred shape of the harvest control rule and other parameters. "Full" MSE simulations were carried out following the parameters detailed in the Section 3.3, with the full combination of:

- *M* = low (0.15), base (0.18) or high (0.21) value as per the LIN 7WC assessment
- YCS range of all estimated YCS or the lowest 10-year block of estimated YCS
- Maximum TAC change allowed of ±10%, ±20%, or +10% / -20%
- HCR low inflection point of 10% $B_0$ or 20% $B_0$
- HCR top inflection point of 40% $B_0$ or (1 – *M*) × 40% $B_0$

Results showed that the two parameters of most influence on stock status, mean future catch and mean future CPUE were the value of the natural mortality *M* and the range of YCS resampled (Figure 5). Increasing stock status were obtained with higher projected average YCS and / or lower natural mortality values, whilst base case mortality and average long-term recruitment resulted in a final *SSB* close to 40% $B_0$, which is the design of this HCR.

The other parameters tested had little influence on the outcome in this instance, which is not surprising given the stock is estimated to be well above 40% $B_0$.

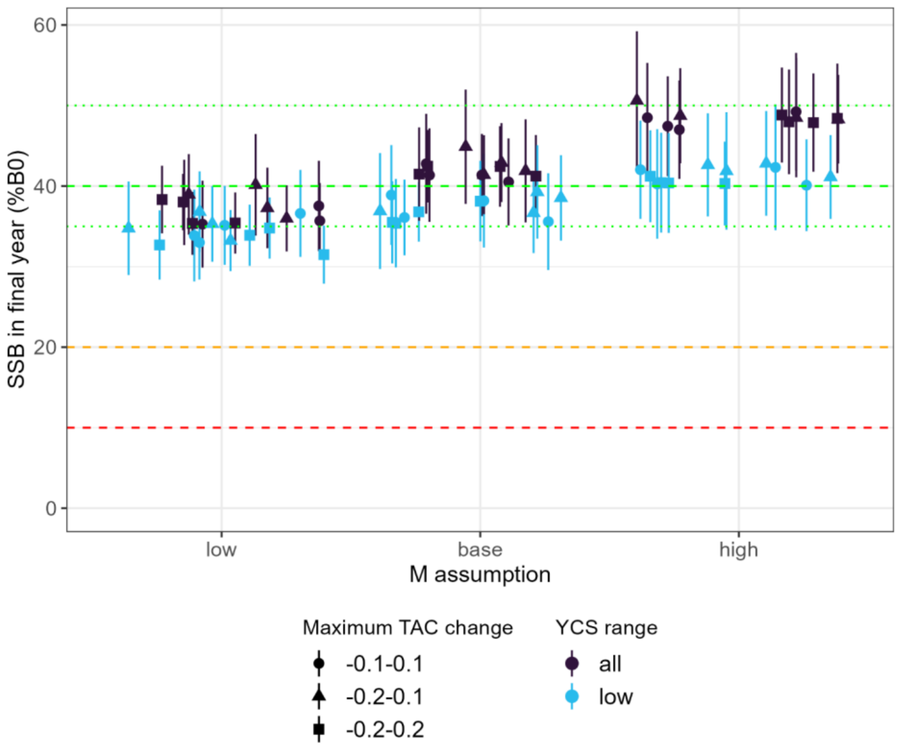
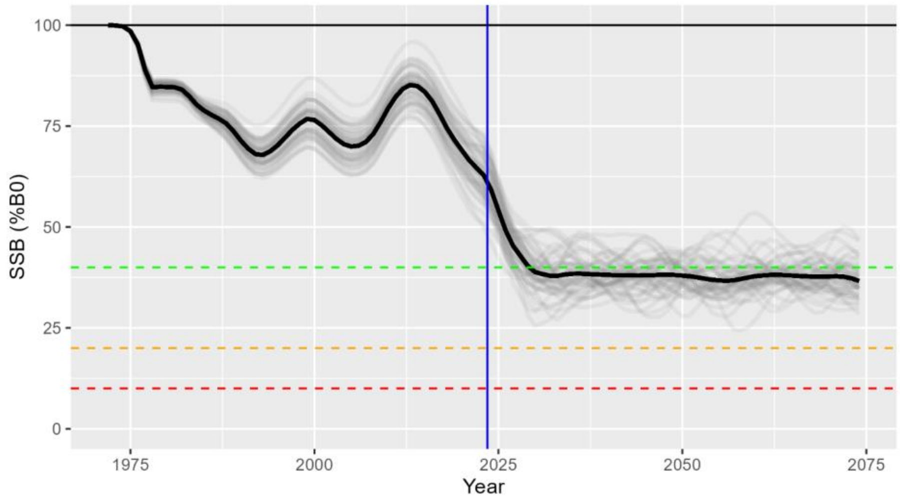



**Figure 5: Projected stock spawning stock biomass (*SSB*) in the final year of the projections as a proportion of initial spawning stock biomass ($B_0$) for LIN 7WC simulations testing various HCR options. Each point represents the median of a simulation scenario and the bar represents the 95% credible interval of all 50 simulation runs for that scenario. The green horizontal line represents $B_{target}$ = 40% $B_0$, the orange line the soft limit of 20% $B_0$ and the red line the hard limit of 10% $B_0$. The vertical blue line represents the start of the projections.**

An extreme value of 20% $B_0$ was tested for the top inflection point. However, it resulted in a lower *SSB* on average, and less proportion of the time above the *SSB* target of 40% $B_0$, particularly under the assumptions of low natural mortality *M* or low future recruitment (Figure 6). Therefore, this option was not carried forward.

Low future YCS, top inflection point of 40% $B_0$




“Low future YCS, top inflection point of 20% $B_0$

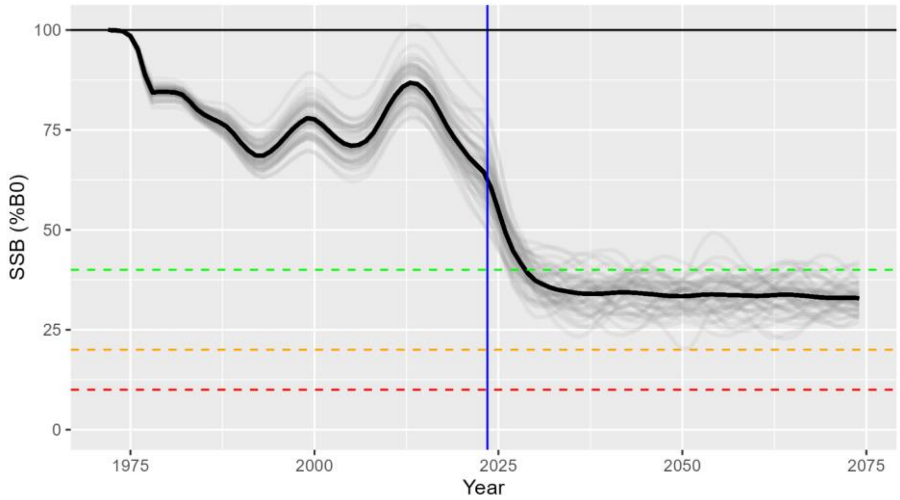



**Figure 6: Projected stock spawning stock biomass (*SSB*) as a proportion of initial spawning stock biomass ($B_0$) for the MSE simulation scenario for LIN 7WC with low future YCA and a top inflection point of either 40% $B_0$ (top) or 20% $B_0$ (bottom). Each grey line represents one of the simulations, and the black line is the median of all simulations. The green horizontal line represents $B_{target}$ = 40% $B_0$, the orange line the soft limit of 20% $B_0$ and the red line the hard limit of 10% $B_0$. The vertical blue line represents the start of the projections.**

## 4.4 Final simulation scenarios for all ling stocks

Based on these investigations, the final MSE simulation scenarios carried out on all three ling stocks were chosen in conjunction with industry representatives and Fisheries New Zealand:

- Harvest control rule: low inflection point at 10% $B_0$ and top inflection point at $(1 – M) \times B_0$
- Maximum TAC change allowed: ±20% or no maximum
- YCS: resampled from all estimated YCS or from the lowest estimated 10-year period
- Natural mortality: the three values of *M* used in each of the stock assessments
- Steepness: $h$ = 0.84 as per the base case models, and $h$ = 0.59 for two scenarios

Full results are summarised in Appendix A and outcomes of the base case scenarios for all three stocks are plotted in Appendix B. Spawning stock biomass was most sensitive to the assumption of natural mortality and recruitment (Table A.1 to Table A.3). This result is unsurprising as $U_{40}$ is dependent upon the assumption of natural mortality and average future recruitment. Any change to these assumptions affects the final status of the stock through the HCR. The LIN 7WC stock was most sensitive to the simulation assumptions (Table A.3), possibly because it has the highest $U_{40}$ (Section 4.1) and the highest variability in YCS of all three stocks (Figure B.8). All simulations had a 100% probability that SSB would remain above 20% $B_0$ (the soft limit for ling).

The assumption of steepness had a bearing on the outcome of the simulations, particularly on the more extreme case of low *M* and low recruitment, but also to a lesser extent on the base simulation with base *M* and average future recruitment.

Mean future catch (Table A.4 to Table A.6) followed a similar pattern to that of *SSB*, with higher catches associated with higher natural mortality and/or higher average future YCS (and higher SSB). Maximum allowed catches were associated with scenarios with no TAC change limitations, as were the next catch. Future CPUE showed similar trends to future catches, and mean age of fish caught the opposite trend (Table A.7 to Table A.9).

## 4.5 Deriving a potential target range for ling

Ling stocks in New Zealand have a single target spawning stock biomass status of 40% of initial biomass. Other stocks such as orange roughy or hoki have a target range (Fisheries New Zealand 2024).

A range of naturally varying *SSB* for the ling stocks could be defined as the range of *SSB* that the base case population models projected with average recruitment could achieve (the base simulation scenarios). Based on the 95% credible interval of those simulations, a target range for all ling stocks could be defined as 33-50% $B_0$ (Table 1). The value of (1 – M) × 40% $B_0$ used in the harvest control rule was designed to capture that same variability in stock status (Ministry of Fisheries 2008), and would result in a lower target range for ling of about 33%.

Based on a target range lower value of 33% $B_0$, all simulations for LIN 3&4 would have a probability of being above the lower target range greater than 50% (Table A.1). Only one simulation for LIN 5&6 and LIN 6B would not have the probability of being above the lower target range greater than 50%, under a combination of low future recruitment and low steepness assumptions (Table A.2). As discussed above, LIN 7WC was the stock most sensitive to simulation assumptions, and four out of the 14 final simulation scenarios would result in long term SSB below the lower target range with over 50% probability: the two scenarios with low natural mortality and low recruitment assumptions combined, and the two scenarios with low steepness assumption (Table A.3).

**Table 1: Potential $B_{target}$ range for ling, based on the 95% credible interval of the last 20 years of the simulated *SSB* for the base simulations of each ling stock. The base simulations are defined as the simulation scenarios with base case natural mortality (*M*), future recruitment sampled from all estimated past recruitment, base steepness of 0.84 and either no limit of TAC change or a maximum of 20% change. The lower range is compared with the (1 – *M*) × 40% $B_0$ value.**

| Stock | 1 - $M$ | Lower range ($SSB$ as % $B_0$) 2.5%ile of base simulation | Upper range ($SSB$ as % $B_0$) 97.5%ile of base simulation |
|---|---|---|---|
| LIN 3&4 | 33.6 | 32.7 – 33.6 | 50.7 – 50.9 |
| LIN 5&6 and LIN 6B | 32.8 | 32.9 – 34.0 | 51.5 – 51.9 |
| LIN 7WC | 32.8 | 32.6 – 32.8 | 49.9 – 50.1 |
| All stocks (proposed) | | 33 | 50 |

## 5. DISCUSSION

Full management strategy evaluation simulations were carried out for the three main New Zealand ling stocks.

The simulations showed that the shape of the harvest control rule was not duly influential, and nor was the maximum allowed total allowable catch change. This is not unexpected given all three ling stocks are above the target spawning stock biomass of 40% of initial stock spawning biomass.

The main uncertainties in these stocks were tested, namely the value of natural mortality, the value of the stock recruit relationship steepness parameter, and future recruitment strength. As expected, the natural mortality term was the most influential, followed by the value of potential future recruitment, although there has been little change in the long-term strength of recruitment to date for those stocks. The value of steepness had some influence, particularly on the more extreme scenarios of low natural mortality and low future recruitment. None of the stocks went below the soft limit of 20% of initial spawning biomass.

A potential target range was developed for ling based on the variability seen in the simulations. A range of 33-55% of initial biomass could be used. Under such target range, only a small number of simulations would not achieve a 50% probability of being above the lower target range.

## 6. ACKNOWLEDGEMENTS

We thank the Fisheries New Zealand Data Management Team for the data extracts and additional information used in these analyses and their assistance in its interpretation. We also thank members of the Deepwater Fisheries Assessment Working Group for their discussions on this work, and Alistair Dunn for reviewing this report. This work was funded by the Deepwater Council, Seafood New Zealand.

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## 8. Appendix A – results of the final simulations

**Table A.1: Summary of the spawning stock biomass (SSB) in the last 20 years of the simulations for stock LIN 3&4 with $U_{40}$ = 0.09. Stock recruit steepness (*h*), natural mortality (*M*), maximum TAC change allowed (Max change) and YCS recruitment range for future recruitment (YCS range) assumptions are reported for each scenario. YCS resample range: all = 1978 – 2016, low = 1981 – 1990. * denotes that natural mortality was estimated in the base case model. The mean SSB for the last 20 years of the simulation over all the simulations, 95% credible interval (CI) as well as the probability of being above 40% $B_0$ (pab40), above 33% $B_0$ (pab33) and within 10% of 40% $B_0$ (p36to44) are reported. Base case assumptions of natural mortality and steepness are highlighted in grey. Sensitivities on steepness are reported below the empty line and values with base steepness duplicated in blue to allow easy comparison.**

| *h* | *M* | YCS range | Max change | SSB mean (% $B_0$) | SSB CI (% B0) | pab40 | pab33 | p36to44 |
|---|---|---|---|---|---|---|---|---|
| 0.84 | 0.13 | all | 20% | 37.3 | 32.3-43.3 | 16.4 | 95.0 | 65.2 |
| 0.84 | 0.13 | all | any | 37.3 | 32.1-44.1 | 19.1 | 95.1 | 59.5 |
| 0.84 | 0.13 | low | 20% | 36.3 | 30.5-42.2 | 14.1 | 85.7 | 54.0 |
| 0.84 | 0.13 | low | any | 36.4 | 31.2-43.2 | 12.5 | 89.7 | 48.7 |
| 0.84 | 0.16* | all | 20% | 41.5 | 33.6-50.9 | 60.4 | 98.0 | 64.2 |
| 0.84 | 0.16* | all | any | 40.0 | 32.7-50.7 | 43.8 | 96.6 | 64.7 |
| 0.84 | 0.16* | low | 20% | 39.8 | 31.0-50.9 | 46.5 | 92.9 | 59.1 |
| 0.84 | 0.16* | low | any | 39.2 | 31.7-49.7 | 36.1 | 93.7 | 62.7 |
| 0.84 | 0.18 | all | 20% | 40.2 | 33.0-49.2 | 50.5 | 97.3 | 67.2 |
| 0.84 | 0.18 | all | any | 39.1 | 33.0-48.5 | 37.2 | 97.5 | 57.6 |
| 0.84 | 0.18 | low | 20% | 38.7 | 31.1-48.9 | 36.3 | 92.3 | 60.3 |
| 0.84 | 0.18 | low | any | 38.4 | 31.7-47.5 | 30.9 | 92.6 | 60.9 |
| | | | | | | | | |
| 0.84 | 0.13 | low | any | 36.4 | 31.2-43.2 | 12.5 | 89.7 | 48.7 |
| 0.59 | 0.13 | low | any | 33.2 | 27.8-40.0 | 2.6 | 51.6 | 18.6 |
| 0.84 | 0.16* | all | any | 40.0 | 32.7-50.7 | 43.8 | 96.6 | 64.7 |
| 0.59 | 0.16* | all | any | 34.1 | 28.0-41.7 | 6.7 | 58.7 | 26.4 |

**Table A.2: Summary of the spawning stock biomass (SSB) in the last 20 years of the simulations for stock LIN 5&6 with $U_{40}$ = 0.139. Stock recruit steepness (*h*), natural mortality (*M*), maximum TAC change allowed (Max change) and YCS recruitment range for future recruitment (YCS range) assumptions are reported for each scenario. YCS resample range: all = 1976 – 2020, low = 1983 – 1992. The mean SSB for the last 20 years of the simulation over all the simulations, 95% credible interval (CI) as well as the probability of being above 40% $B_0$ (pab40), above 33% $B_0$ (pab33) and within 10% of 40% $B_0$ (p36to44) are reported. Base case assumptions of natural mortality and steepness are highlighted in grey. Sensitivities on steepness are reported below the empty line and values with base steepness duplicated in blue to allow easy comparison.**

| *h* | *M* | YCS range | Max change | SSB mean (% $B_0$) | SSB CI (% B0) | pab40 | pab33 | p36to44 |
|---|---|---|---|---|---|---|---|---|
| 0.84 | 0.16 | all | 20% | 39.6 | 32.6-49.2 | 44.6 | 96.9 | 63.4 |
| 0.84 | 0.16 | all | any | 39.0 | 32.6-48.1 | 36.8 | 96.4 | 63.2 |
| 0.84 | 0.16 | low | 20% | 38.8 | 29.5-48.4 | 37.7 | 91.2 | 60.7 |
| 0.84 | 0.16 | low | any | 38.7 | 29.5-47.9 | 36.9 | 90.8 | 60.0 |
| 0.84 | 0.18 | all | 20% | 41.4 | 34-51.8 | 59.8 | 99.1 | 65.2 |
| 0.84 | 0.18 | all | any | 41.6 | 32.9-51.5 | 58.4 | 97.4 | 55.5 |
| 0.84 | 0.18 | low | 20% | 41.2 | 32.6-49.9 | 60.8 | 96.5 | 67.4 |
| 0.84 | 0.18 | low | any | 41.1 | 31.9-52.1 | 56.6 | 95.3 | 59.9 |
| 0.84 | 0.20 | all | 20% | 43.1 | 31.8-55.0 | 72.3 | 96.5 | 47.5 |
| 0.84 | 0.20 | all | any | 44.5 | 34.9-55.5 | 81.1 | 99.3 | 43.8 |
| 0.84 | 0.20 | low | 20% | 43.6 | 32.8-55.8 | 71.4 | 97.3 | 47.1 |
| 0.84 | 0.20 | low | any | 43.1 | 35-52.8 | 73.7 | 99.0 | 53.7 |
| | | | | | | | | |
| 0.84 | 0.16 | low | any | 38.7 | 29.5-47.9 | 36.9 | 90.8 | 60.0 |
| 0.59 | 0.16 | low | any | 33.0 | 27.6-39.9 | 2.5 | 45.4 | 15.3 |
| 0.84 | 0.18 | all | any | 41.6 | 32.9-51.5 | 58.4 | 97.4 | 55.5 |
| 0.59 | 0.18 | all | any | 33.8 | 28.2-42.1 | 5.5 | 54.7 | 22.0 |

**Table A.3: Summary of the spawning stock biomass (SSB) in the last 20 years of the simulations for stock LIN 7WC with $U_{40}$ = 0.169. Stock recruit steepness (*h*), natural mortality (*M*), maximum TAC change allowed (Max change) and YCS recruitment range for future recruitment (YCS range) assumptions are reported for each scenario. YCS resample range: all = 1976 – 2016, low = 1976 – 1985. The mean SSB for the last 20 years of the simulation over all the simulations, 95% credible interval (CI) as well as the probability of being above 40% $B_0$ (pab40), above 33% $B_0$ (pab33) and within 10% of 40% $B_0$ (p36to44) are reported. Base case assumptions of natural mortality and steepness are highlighted in grey. Sensitivities on steepness are reported below the empty line and values with base steepness duplicated in blue to allow easy comparison.**

| *h* | *M* | YCS range | Max change | SSB mean (% $B_0$) | SSB CI (% B0) | pab40 | pab33 | p36to44 |
|---|---|---|---|---|---|---|---|---|
| 0.84 | 0.15 | all | 20% | 37.0 | 29.3-44.8 | 23.5 | 80.8 | 54.0 |
| 0.84 | 0.15 | all | any | 36.8 | 29.8-44.5 | 18.3 | 84.5 | 56.3 |
| 0.84 | 0.15 | low | 20% | 33.2 | 25.0-40.8 | 3.8 | 49.7 | 20.1 |
| 0.84 | 0.15 | low | any | 32.2 | 25.8-39.5 | 2.3 | 39.7 | 13.2 |
| 0.84 | 0.18 | all | 20% | 40.9 | 32.6-50.1 | 59.7 | 96.5 | 59.5 |
| 0.84 | 0.18 | all | any | 41.1 | 32.8-49.9 | 58.2 | 96.9 | 58.5 |
| 0.84 | 0.18 | low | 20% | 35.6 | 27.1-45.0 | 14.6 | 73.5 | 39.7 |
| 0.84 | 0.18 | low | any | 35.4 | 28.5-43.1 | 13.1 | 70.2 | 40.7 |
| 0.84 | 0.21 | all | 20% | 47.0 | 35.7-59.0 | 90.2 | 100.0 | 29.0 |
| 0.84 | 0.21 | all | any | 46.9 | 36.3-58.5 | 88.9 | 99.7 | 28.2 |
| 0.84 | 0.21 | low | 20% | 40.3 | 30.2-52.1 | 50.7 | 91.4 | 55.1 |
| 0.84 | 0.21 | low | any | 39.0 | 29.4-49.5 | 41.9 | 86.6 | 54.2 |
| | | | | | | | | |
| 0.84 | 0.15 | low | any | 32.2 | 25.8-39.5 | 2.3 | 39.7 | 13.2 |
| 0.59 | 0.15 | low | any | 29.0 | 24.2-34.5 | 0.0 | 6.3 | 1.4 |
| 0.84 | 0.18 | all | any | 41.1 | 32.8-49.9 | 58.2 | 96.9 | 58.5 |
| 0.59 | 0.18 | all | any | 33.8 | 27.2-40.8 | 4.7 | 59.6 | 23.6 |

**Table A.4: Summary of the future catches in the simulations for stock LIN 3&4 with $U_{40}$ = 0.09. Stock recruit steepness (*h*), natural mortality (*M*), maximum TAC change allowed (Max change) and YCS recruitment range for future recruitment (YCS range) assumptions are reported for each run. YCS resample range: all = 1978 – 2016, low = 1981 – 1990. Mean and 95% credible interval (CI) of future catches are reported, as well as maximum catch, median change and the catch limit to be assigned in the first year of simulations (next). Base case assumptions of natural mortality and steepness are highlighted in grey. Sensitivities on steepness are reported below the empty line and values with base steepness duplicated in blue to allow easy comparison.**

| *h* | *M* | YCS range | Max change | Catch (t) mean | Catch (t) CI | Change (t) max | Change (t) median | Catch (t) next |
|---|---|---|---|---|---|---|---|---|
| 0.84 | 0.13 | all | 20% | 4 645 | 3 609 - 5 599 | 932 | 207 | 3 885 |
| 0.84 | 0.13 | all | any | 4 626 | 3 590 - 5 587 | 1 260 | 121 | 4 962 |
| 0.84 | 0.13 | low | 20% | 4 454 | 3 361 - 5 418 | 909 | 235 | 3 885 |
| 0.84 | 0.13 | low | any | 4 497 | 3 363 - 5 572 | 1 492 | 130 | 5 067 |
| 0.84 | 0.16* | all | 20% | 5 923 | 3 885 - 7 724 | 1 611 | 402 | 3 885 |
| 0.84 | 0.16* | all | any | 6 137 | 4 614 - 8 324 | 1 359 | 187 | 7 367 |
| 0.84 | 0.16* | low | 20% | 5 536 | 3 884 - 7 946 | 1 611 | 428 | 3 885 |
| 0.84 | 0.16* | low | any | 5 800 | 3 840 - 8 381 | 2 709 | 197 | 7 461 |
| 0.84 | 0.18 | all | 20% | 8 699 | 3 885 - 13 010 | 2 319 | 932 | 3 885 |
| 0.84 | 0.18 | all | any | 9 731 | 7 067 - 13 523 | 2 920 | 249 | 12 904 |
| 0.84 | 0.18 | low | 20% | 8 086 | 3 885 - 11 672 | 2 319 | 890 | 3 885 |
| 0.84 | 0.18 | low | any | 9 407 | 6 386 - 14 008 | 3 847 | 297 | 12 998 |
| | | | | | | | | |
| 0.84 | 0.13 | low | any | 4 497 | 3 363 - 5 572 | 1 492 | 130 | 5 067 |
| 0.59 | 0.13 | low | any | 2 636 | 1 001 – 3 937 | 2 531 | 219 | 1 231 |
| 0.84 | 0.16* | all | any | 6 137 | 4 614 - 8 324 | 1 359 | 187 | 7 367 |
| 0.59 | 0.16* | all | any | 5 036 | 2 898 - 7 476 | 3 851 | 294 | 6 309 |

**Table A.5: Summary of the future catches in the simulations for stock LIN 5&6 with $U_{40}$ = 0.139. Stock recruit steepness (*h*), natural mortality (*M*), maximum TAC change allowed (Max change) and YCS recruitment range for future recruitment (YCS range) assumptions are reported for each run. YCS resample range: all = 1976 – 2020, low = 1983 – 1992. Mean and 95% credible interval (CI) of future catches are reported, as well as maximum catch, median change and the catch limit to be assigned in the first year of simulations (next). Base case assumptions of natural mortality and steepness are highlighted in grey. Sensitivities on steepness are reported below the empty line and values with base steepness duplicated in blue to allow easy comparison.**

| *h* | *M* | YCS range | Max change | Catch (t) mean | Catch (t) CI | Change (t) max | Change (t) median | Catch (t) next |
|---|---|---|---|---|---|---|---|---|
| 0.84 | 0.16 | all | 20% | 13 239 | 9 530 - 18 033 | 2 842 | 724 | 11 181 |
| 0.84 | 0.16 | all | any | 13 655 | 9 423 - 21 692 | 5 440 | 544 | 21 089 |
| 0.84 | 0.16 | low | 20% | 12 845 | 8 983 - 17 519 | 3 229 | 632 | 11 181 |
| 0.84 | 0.16 | low | any | 13 223 | 8 956 - 21 832 | 5 764 | 462 | 20 617 |
| 0.84 | 0.18 | all | 20% | 15 037 | 10 798 - 20 853 | 4 238 | 1 102 | 11 181 |
| 0.84 | 0.18 | all | any | 15 606 | 10 969 - 23 544 | 5 777 | 555 | 21 965 |
| 0.84 | 0.18 | low | 20% | 15 276 | 10 947 - 21 913 | 4 637 | 1 029 | 11 181 |
| 0.84 | 0.18 | low | any | 15 915 | 9 905 - 24 080 | 6 189 | 484 | 23 629 |
| 0.84 | 0.20 | all | 20% | 16 369 | 11 180 - 23 182 | 4 637 | 1 575 | 11 181 |
| 0.84 | 0.20 | all | any | 17 809 | 11 195 - 33 508 | 18 885 | 863 | 23 463 |
| 0.84 | 0.20 | low | 20% | 16 139 | 11 011 - 23 183 | 4 637 | 1 536 | 11 181 |
| 0.84 | 0.20 | low | any | 17 472 | 11 335 - 31 478 | 17 800 | 810 | 23 467 |
| | | | | | | | | |
| 0.84 | 0.16 | low | any | 13 223 | 8 956 - 21 832 | 5 764 | 462 | 20 617 |
| 0.59 | 0.16 | low | any | 11 999 | 6 989 - 21 504 | 5 912 | 600 | 21 117 |
| 0.84 | 0.18 | all | any | 15 606 | 10 969 - 23 544 | 5 777 | 555 | 21 965 |
| 0.59 | 0.18 | all | any | 13 073 | 7 478 - 22 104 | 7 475 | 494 | 21 077 |

**Table A.6: Summary of the future catches in the simulations for stock LIN 7WC with $U_{40}$ = 0.169. Stock recruit steepness (*h*), natural mortality (*M*), maximum TAC change allowed (Max change) and YCS recruitment range for future recruitment (YCS range) assumptions are reported for each scenario. YCS resample range: all = 1976 – 2016, low = 1976 – 1985. Mean and 95% credible interval (CI) of future catches are reported, as well as maximum catch, median change and the catch limit to be assigned in the first year of simulations (next). Base case assumptions of natural mortality and steepness are highlighted in grey. Sensitivities on steepness are reported below the empty line and values with base steepness duplicated in blue to allow easy comparison.**

| *h* | *M* | YCS range | Max change | Catch (t) mean | Catch (t) CI | Change (t) max | Change (t) median | Catch (t) next |
|---|---|---|---|---|---|---|---|---|
| 0.84 | 0.15 | all | 20% | 2 993 | 1 978 - 3 923 | 679 | 174 | 3 580 |
| 0.84 | 0.15 | all | any | 3 161 | 2 030 - 4 588 | 1 308 | 206 | 4 359 |
| 0.84 | 0.15 | low | 20% | 2 259 | 1 245 - 3 923 | 543 | 225 | 3 649 |
| 0.84 | 0.15 | low | any | 2 208 | 1 211 - 4 136 | 1 256 | 199 | 4 078 |
| 0.84 | 0.18 | all | 20% | 3 587 | 2 571 - 4 708 | 889 | 188 | 3 861 |
| 0.84 | 0.18 | all | any | 3 655 | 2 616 - 5 313 | 2 754 | 191 | 4 991 |
| 0.84 | 0.18 | low | 20% | 2 743 | 1 518 - 4 361 | 785 | 250 | 3 904 |
| 0.84 | 0.18 | low | any | 2 723 | 1 490 - 4 996 | 1 258 | 185 | 4 989 |
| 0.84 | 0.21 | all | 20% | 3 978 | 2 779 - 5 518 | 1 130 | 260 | 3 910 |
| 0.84 | 0.21 | all | any | 4 222 | 2 866 - 6 229 | 2 635 | 226 | 5 588 |
| 0.84 | 0.21 | low | 20% | 3 057 | 1 707 - 4 708 | 942 | 210 | 3 902 |
| 0.84 | 0.21 | low | any | 3 054 | 1 680 - 5 748 | 4 165 | 178 | 5 328 |
| | | | | | | | | |
| 0.84 | 0.15 | low | any | 2 208 | 1 211 - 4 136 | 1 256 | 199 | 4 078 |
| 0.59 | 0.15 | low | any | 1 507 | 753 - 3 165 | 1 105 | 136 | 3 021 |
| 0.84 | 0.18 | all | any | 3 655 | 2 616 - 5 313 | 2 754 | 191 | 4 991 |
| 0.59 | 0.18 | all | any | 2 920 | 1 780 - 4 194 | 1 631 | 183 | 3 913 |

**Table A.7: Summary of the mean relative future CPUE and mean fish age (in years) by fishery in the simulations for stock LIN 3&4 with $U_{40}$ = 0.09. Stock recruit steepness (*h*), natural mortality (*M*), maximum TAC change allowed (Max change) and YCS recruitment range for future recruitment (YCS range) assumptions are reported for each scenario. YCS resample range: all = 1978 – 2016, low = 1981 – 1990. Base case assumptions of natural mortality and steepness are highlighted in grey. Sensitivities on steepness are reported below the empty line and values with base steepness duplicated in blue to allow easy comparison. "-" denotes no CPUE observations are used in the model.**

| *h* | *M* | YCS range | Max change | CPUE line | CPUE trawl | CPUE survey | Mean age line | Mean age trawl |
|---|---|---|---|---|---|---|---|---|
| 0.84 | 0.13 | all | 20% | - | - | 8 386 | 13.7 | 9.9 |
| 0.84 | 0.13 | all | any | - | - | 8 210 | 13.7 | 9.8 |
| 0.84 | 0.13 | low | 20% | - | - | 7 995 | 13.8 | 9.9 |
| 0.84 | 0.13 | low | any | - | - | 7 968 | 13.7 | 9.9 |
| 0.84 | 0.16* | all | 20% | - | - | 7 728 | 13.3 | 9.5 |
| 0.84 | 0.16* | all | any | - | - | 7 291 | 13.2 | 9.4 |
| 0.84 | 0.16* | low | 20% | - | - | 7 341 | 13.4 | 9.6 |
| 0.84 | 0.16* | low | any | - | - | 7 044 | 13.2 | 9.5 |
| 0.84 | 0.18 | all | 20% | - | - | 7 199 | 13.0 | 9.3 |
| 0.84 | 0.18 | all | any | - | - | 6 421 | 12.5 | 9.0 |
| 0.84 | 0.18 | low | 20% | - | - | 6 679 | 13.0 | 9.3 |
| 0.84 | 0.18 | low | any | - | - | 6 181 | 12.6 | 9.0 |
| | | | | | | | | |
| 0.84 | 0.13 | low | any | - | - | 7 968 | 13.7 | 9.9 |
| 0.59 | 0.13 | low | any | - | - | 6 954 | 14.1 | 10.1 |
| 0.84 | 0.16* | all | any | - | - | 7 291 | 13.2 | 9.4 |
| 0.59 | 0.16* | all | any | - | - | 6 143 | 13.2 | 9.5 |

**Table A.8: Summary of the mean relative future CPUE and mean fish age (in years) by fishery in the simulations for stock LIN 5&6 with $U_{40}$ = 0.139. Stock recruit steepness (*h*), natural mortality (*M*), maximum TAC change allowed (Max change) and YCS recruitment range for future recruitment (YCS range) assumptions are reported for each scenario. YCS resample range: all = 1976 – 2020, low = 1983 – 1992. Base case assumptions of natural mortality and steepness are highlighted in grey. Sensitivities on steepness are reported below the empty line and values with base steepness duplicated in blue to allow easy comparison. "-" denotes no CPUE observations are used in the model.**

| *h* | *M* | YCS range | Max change | CPUE line | CPUE trawl | CPUE survey | Mean age line | Mean age trawl |
|---|---|---|---|---|---|---|---|---|
| 0.84 | 0.16 | all | 20% | - | - | 15 786 | 12.0 | 9.7 |
| 0.84 | 0.16 | all | any | - | - | 15 260 | 11.9 | 9.6 |
| 0.84 | 0.16 | low | 20% | - | - | 15 423 | 12.0 | 9.7 |
| 0.84 | 0.16 | low | any | - | - | 14 898 | 11.9 | 9.6 |
| 0.84 | 0.18 | all | 20% | - | - | 16 210 | 11.6 | 9.4 |
| 0.84 | 0.18 | all | any | - | - | 15 736 | 11.4 | 9.3 |
| 0.84 | 0.18 | low | 20% | - | - | 16 217 | 11.6 | 9.4 |
| 0.84 | 0.18 | low | any | - | - | 15 144 | 11.4 | 9.3 |
| 0.84 | 0.20 | all | 20% | - | - | 17 025 | 11.2 | 9.1 |
| 0.84 | 0.20 | all | any | - | - | 16 082 | 11.0 | 9.0 |
| 0.84 | 0.20 | low | 20% | - | - | 16 953 | 11.2 | 9.1 |
| 0.84 | 0.20 | low | any | - | - | 15 794 | 10.9 | 9.0 |
| | | | | | | | | |
| 0.84 | 0.16 | low | any | - | - | 14 898 | 11.9 | 9.6 |
| 0.59 | 0.16 | low | any | - | - | 13 309 | 12.0 | 9.7 |
| 0.84 | 0.18 | all | any | - | - | 15 736 | 11.4 | 9.3 |
| 0.59 | 0.18 | all | any | - | - | 13 352 | 11.5 | 9.3 |

**Table A.9: Summary of the mean relative future CPUE and mean fish age (in years) by fishery in the simulations for stock LIN 7WC with $U_{40}$ = 0.169. Stock recruit steepness (*h*), natural mortality (*M*), maximum TAC change allowed (Max change) and YCS recruitment range for future recruitment (YCS range) assumptions are reported for each scenario. YCS resample range: all = 1976 – 2016, low = 1976 – 1985. Base case assumptions of natural mortality and steepness are highlighted in grey. Sensitivities on steepness are reported below the empty line and values with base steepness duplicated in blue to allow easy comparison. "-" denotes no CPUE observations are used in the model.**

| *h* | *M* | YCS range | Max change | CPUE line | CPUE trawl | CPUE survey | Mean age line | Mean age trawl |
|---|---|---|---|---|---|---|---|---|
| 0.84 | 0.15 | all | 20% | 832 | 19 761 | 1 021 | 13.0 | 10.7 |
| 0.84 | 0.15 | all | any | 794 | 19 446 | 1 007 | 13.0 | 10.6 |
| 0.84 | 0.15 | low | 20% | 675 | 15 489 | 818 | 13.3 | 10.8 |
| 0.84 | 0.15 | low | any | 680 | 15 580 | 834 | 13.1 | 10.8 |
| 0.84 | 0.18 | all | 20% | 801 | 20 166 | 1 020 | 12.3 | 10.2 |
| 0.84 | 0.18 | all | any | 782 | 19 622 | 995 | 12.2 | 10.1 |
| 0.84 | 0.18 | low | 20% | 623 | 15 355 | 791 | 12.4 | 10.3 |
| 0.84 | 0.18 | low | any | 612 | 15 032 | 771 | 12.4 | 10.3 |
| 0.84 | 0.21 | all | 20% | 783 | 20 799 | 1 019 | 11.8 | 9.8 |
| 0.84 | 0.21 | all | any | 740 | 20 423 | 1 023 | 11.7 | 9.7 |
| 0.84 | 0.21 | low | 20% | 587 | 15 501 | 774 | 11.9 | 9.8 |
| 0.84 | 0.21 | low | any | 583 | 15 150 | 770 | 11.7 | 9.8 |
| | | | | | | | | |
| 0.84 | 0.15 | low | any | 680 | 15 580 | 834 | 13.1 | 10.8 |
| 0.59 | 0.15 | low | any | 682 | 14 915 | 817 | 13.7 | 11.3 |
| 0.84 | 0.18 | all | any | 782 | 19 622 | 995 | 12.2 | 10.1 |
| 0.59 | 0.18 | all | any | 705 | 17 621 | 897 | 12.4 | 10.3 |

## 9. Appendix B – Outcomes of the base simulations

The base simulations are defined as those scenarios with the natural mortality and steepness used in the base case of each stock assessment model.

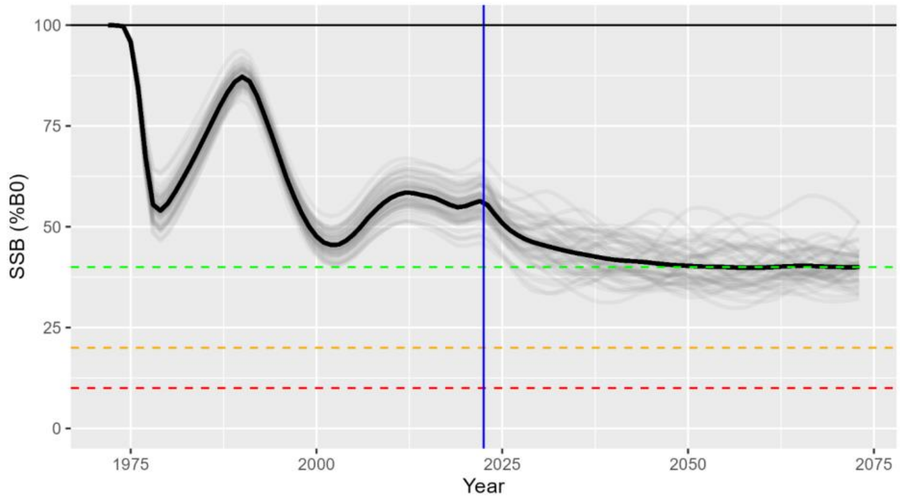


**Figure B.1: LIN 3&4 base simulation projected stock spawning stock biomass (*SSB*) as a proportion of initial spawning stock biomass ($B_0$) for the MSE simulation with average future YCS, a top inflection point of (1 – M) × 40% $B_0$ and no TAC constraint. Each grey line represents one of the simulations, and the black line is the median of all simulations. The green horizontal line represents $B_{target}$ = 40% $B_0$, the orange line the soft limit of 20% $B_0$ and the red line the hard limit of 10% $B_0$. The vertical blue line represents the start of the projections.**

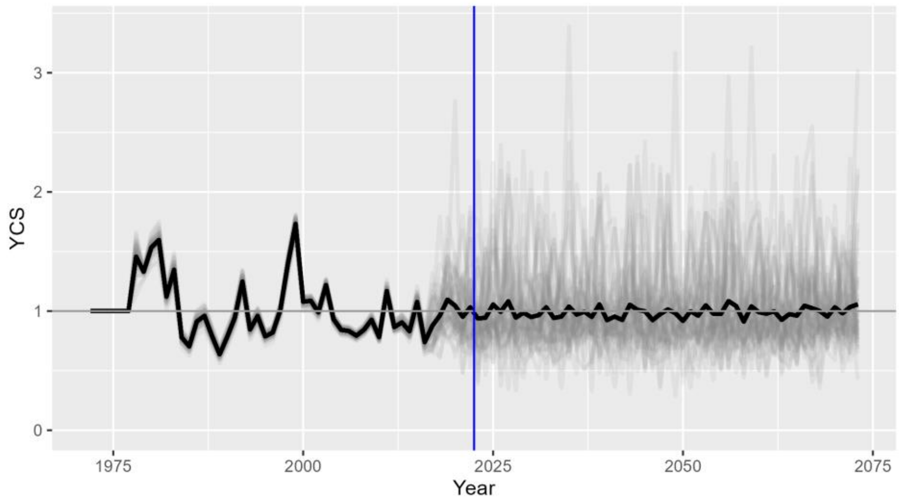


**Figure B.2: LIN 3&4 base simulation resampled YCS for the MSE simulation with average future YCS, a top inflection point of (1 – M) × 40% $B_0$ and no TAC constraint. Each grey line represents one of the simulations, and the black line is the median of all simulations. The vertical blue line represents the start of the projections.**

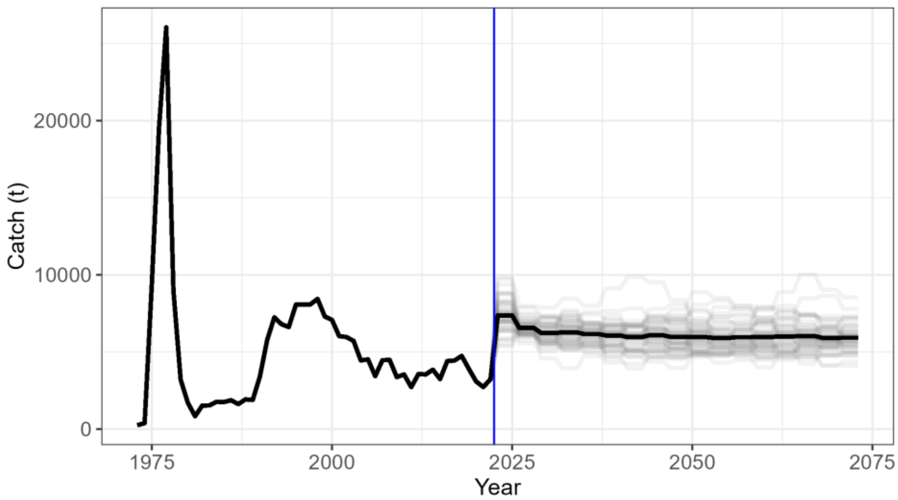


**Figure B.3: LIN 3&4 base simulation catch for the MSE simulation with average future YCS, a top inflection point of (1 – M) × 40% $B_0$ and no TAC constraint. Each grey line represents one of the simulations, and the black line is the median of all simulations. The vertical blue line represents the start of the projections.**

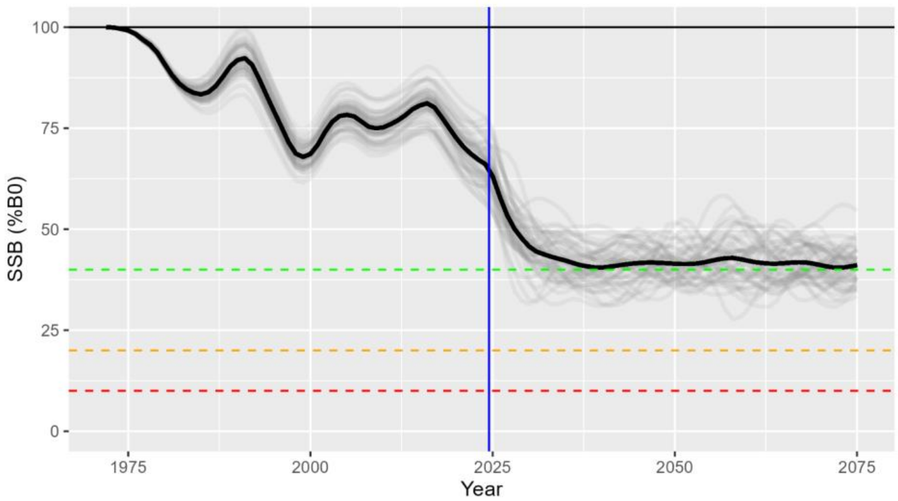


**Figure B.4: LIN 5&6 and LIN 6B base simulation projected stock spawning stock biomass (*SSB*) as a proportion of initial spawning stock biomass ($B_0$) for the MSE simulation with average future YCS, a top inflection point of (1 – M) × 40% $B_0$ and no TAC constraint. Each grey line represents one of the simulations, and the black line is the median of all simulations. The green horizontal line represents $B_{target}$ = 40% $B_0$, the orange line the soft limit of 20% $B_0$ and the red line the hard limit of 10% $B_0$. The vertical blue line represents the start of the projections.**

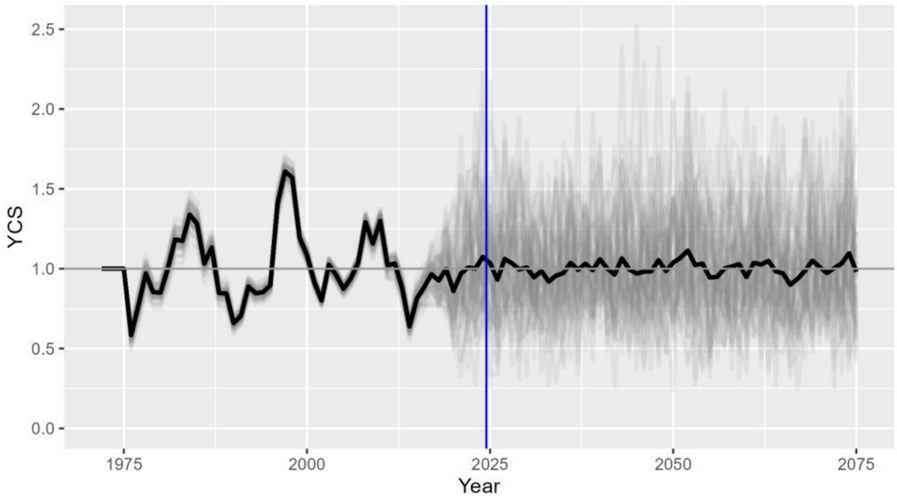


**Figure B.5: LIN 5&6 and LIN 6B base simulation resampled YCS for the MSE simulation with average future YCS, a top inflection point of (1 – M) × 40% $B_0$ and no TAC constraint. Each grey line represents one of the simulations, and the black line is the median of all simulations. The vertical blue line represents the start of the projections.**

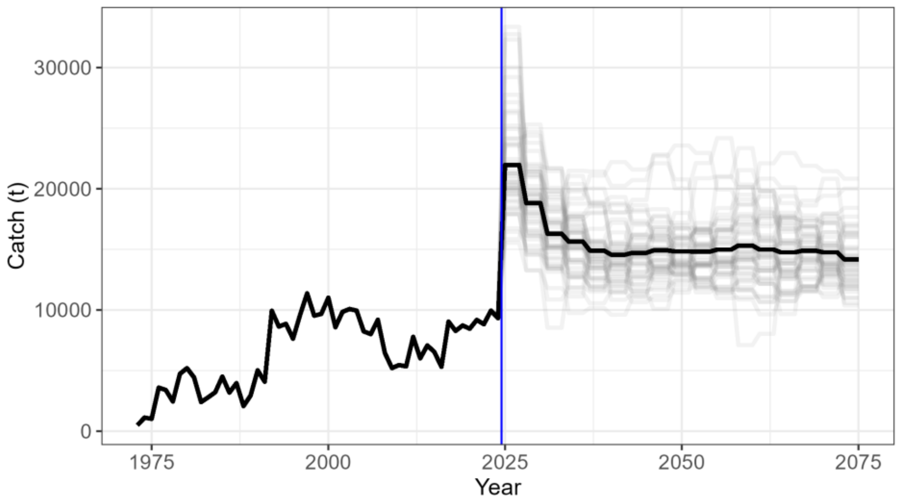


**Figure B.6: LIN 5&6 and LIN 6B base simulation catch for the MSE simulation with average future YCS, a top inflection point of (1 – M) × 40% $B_0$ and no TAC constraint. Each grey line represents one of the simulations, and the black line is the median of all simulations. The vertical blue line represents the start of the projections.**

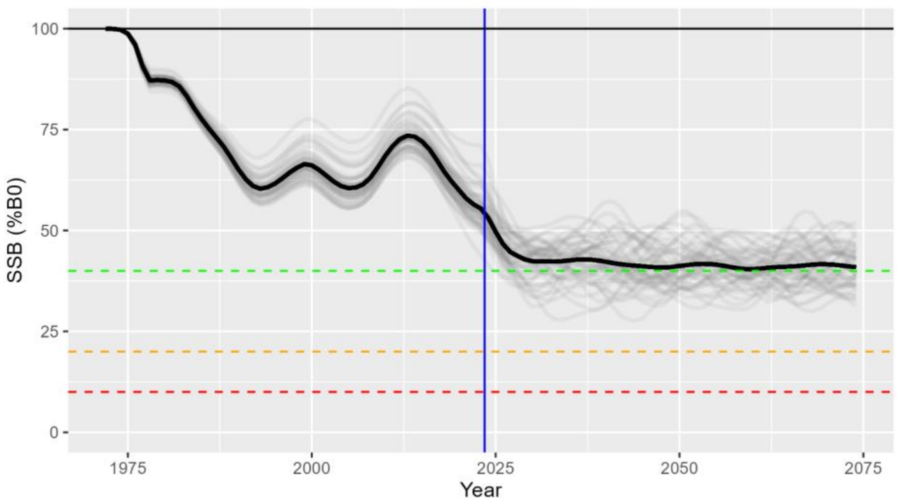

**Figure B.7: LIN 7WC base simulation projected stock spawning stock biomass (*SSB*) as a proportion of initial spawning stock biomass ($B_0$) for the MSE simulation with average future YCS, a top inflection point of (1 – M) × 40% $B_0$ and no TAC constraint. Each grey line represents one of the simulations, and the black line is the median of all simulations. The green horizontal line represents $B_{target}$ = 40% $B_0$, the orange line the soft limit of 20% $B_0$ and the red line the hard limit of 10% $B_0$. The vertical blue line represents the start of the projections.**

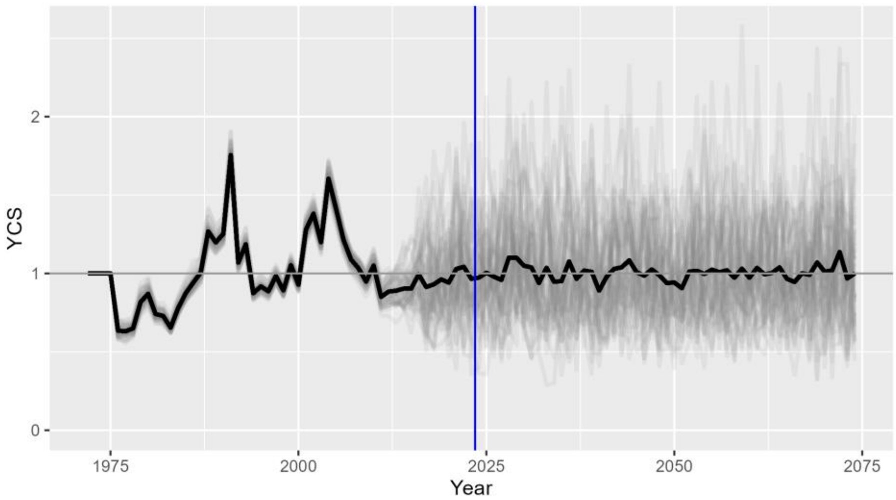


**Figure B.8: LIN 7WC base simulation resampled YCS for the MSE simulation with average future YCS, a top inflection point of (1 – M) × 40% $B_0$ and no TAC constraint. Each grey line represents one of the simulations, and the black line is the median of all simulations. The vertical blue line represents the start of the projections.**

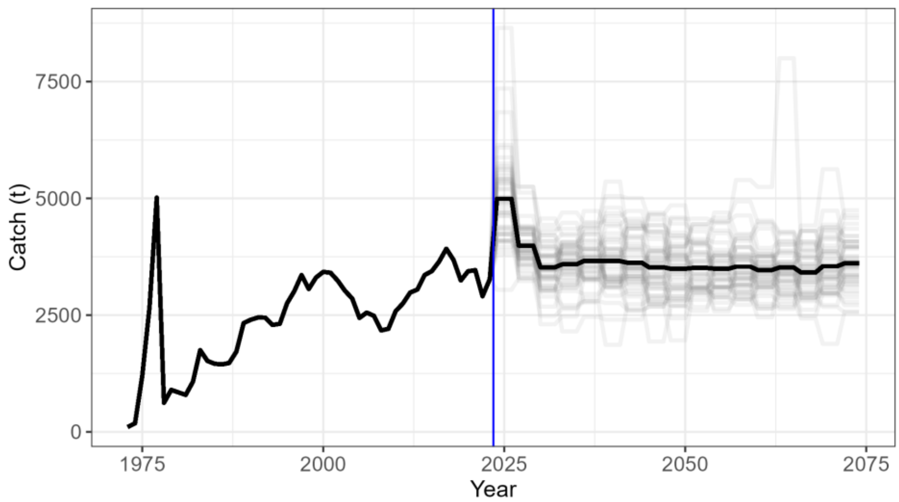


**Figure B.9: LIN 7WC base simulation catch for the MSE simulation with average future YCS, a top inflection point of (1 – M) × 40% $B_0$ and no TAC constraint. Each grey line represents one of the simulations, and the black line is the median of all simulations. The vertical blue line represents the start of the projections.**