SARDI

TO:	**PIRSA FISHERIES AND AQUACULTURE (PROF. GAVIN BEGG – EXECUTIVE DIRECTOR)**
FROM:	**SARDI AQUATIC AND LIVESTOCK SCIENCES (DR CAMILLE MELLIN, DR JOHN FEENSTRA, AND DR TROY ROGERS)**
SUBJECT:	**PROJECTION MODEL OUTPUTS TO SUPPORT THE SNAPPER REBUILDING PLAN – PART 2: APPLY POTENTIAL MANAGEMENT SCENARIOS**
DATE:	**16 JULY 2025**

KEY POINTS

- PIRSA Fisheries and Aquaculture requested information regarding the potential timeframes for recovery for the Spencer Gulf / West Coast (SG/WC) and Gulf St Vincent (GSV) Snapper stocks to inform development of the Snapper Rebuilding Plan.
- This Advice Note summarises the projection model outputs for the SG/WC and GSV stocks under six potential management scenarios, based on those recommended for model-based evaluation by the Marine Scalefish Fishery Management Advisory Committee (MSFMAC) on 10 June 2025.
- For the SG/WC stock, projections of relative biomass reached 20% of unfished levels (the biomass limit reference point, $B_{est}20$) under one of the six management scenarios modelled (i.e., no catch below $B_{est}20$).
- For the GSV stock, projections of relative biomass exceeded $B_{est}20$ under five of the six scenarios modelled.
- The projections of relative biomass for each stock demonstrated that increases in biomass were heavily dependent on periodic recruitment events and that exploitation, even at very low levels, prolonged the estimated time to reach $B_{est}20$.

BACKGROUND

There are three recognised stocks of Snapper throughout the coastal waters of South Australia (SA): the Spencer Gulf / West Coast (SG/WC) stock, the Gulf St Vincent (GSV) stock, and the Western Victoria Stock that extends into the South-East Region of SA (Fowler et al. 2017, Bertram et al. 2023). The SG/WC and GSV stocks experienced significant declines in fishable biomass during the 2010s that related to extended periods of poor juvenile recruitment and the concurrent exploitation of the remaining population (Fowler 2023). The declines in biomass and stock status for the SG/WC and GSV stocks prompted a suite of management actions from 2012 that culminated in the complete closure of the two stocks to commercial and recreational fishing on 1 November 2019. The most recent stock assessment was delivered in November 2022 which indicated that the closures had arrested the decline in biomass for the two stocks, but there was not yet sufficient evidence of recovery (Drew et al. 2022). Consequently, the fishery closures were extended to 30 June 2026.

The Snapper Rebuilding Plan is being developed by PIRSA Fisheries and Aquaculture to support the recovery of the SG/WC and GSV Snapper stocks. A key piece of information for the Rebuilding Plan is to estimate the potential timeframes for recovery for each stock that can be used to inform the development of appropriate reference points and management measures (e.g., decision rules).

The SA Snapper fishery assessment model, 'SnapEst', is a bespoke age- and length-structured model that integrates multiple biological and fishery-derived data sources to estimate trends in fishable biomass (referred to hereafter as 'biomass', unless defined otherwise), recruitment, harvest fraction, and egg production. The projection model for SnapEst was developed through Research Theme 2: 'Estimates of Biomass' (FRDC Project No. 2023-091) of the Snapper Science Program. Specifically, the projection model was developed to forecast trends in biomass for the SG/WC and GSV stocks under various recruitment and potential management scenarios to inform potential timeframes for recovery.

The first stage of projection model outputs was provided in an Advice Note on 28 May 2025 (i.e., Mellin et al. 2025, 'Projection model outputs to support the Snapper rebuilding plan – Part 1: Develop base model'). The projection model simulated the population dynamics for each stock and demonstrated the strong relationships between recruitment of juveniles, population age structures, and biomass. Projections of biomass were based on a reference period of recruitment that included a number of strong and weak year classes. Recruitment was randomly resampled from the reference period of 1982 to 2009 to estimate the unfished biomass (i.e., $B_{est}0$) for the SG/WC and GSV stocks. This was achieved by forward projecting biomass in the absence of fishing mortality for 200 years from the end of the last stock assessment (i.e., 2022–2221), with $B_{est}0$ calculated as the average biomass across all simulations over the last ten years of the projection period (i.e., 2212–2221).

This Advice Note provides the next stage of projection modelling by applying a range of potential management scenarios to estimate their influence on the potential timeframes for recovery for each stock. The MSFMAC met on 10 June 2025 and provided a series of recommendations that included:

- Maintaining the reference period of recruitment of 1982 to 2009 to estimate $B_{est}0$, noting this reference period includes the range of recruitment observed in the fishery, including some years of high recruitment that occurred when biomass was significantly higher than when the fishery closures were implemented.
- The next stage of projection modelling should consider a reference period of recruitment for each stock that corresponds to a time when biomass and egg production were at a lower level. A reference period of 2010 to 2019 was suggested.
- Fishing mortality should be modelled as a fixed annual total allowable catch (TAC) that is applied once relative biomass for each stock has reached $B_{est}15$ (scenario 1) and $B_{est}20$ (scenario 2) with application of the 'hockey stick'[1] above $B_{est}20$.
- The fixed annual TAC to be modelled should be calculated as a proportion of natural mortality (M) for each stock. The three indicative levels of fishing mortality recommended were $M/2$, M, and $2M$ (where M = 0.125 yr^{-1}). Fishing mortality is in

[1] Referring to the hockey stick decision rule of the harvest strategy framework within the Management Plan for the South Australian Commercial Marine Scalefish Fishery (2025).

addition to 'other mortality' (i.e., discard mortality, traditional fishery catches, and Snapper collected for research purposes).

This Advice Note provides a series of projection model outputs for the SG/WC and GSV Snapper stocks that show the potential timeframes to reach reference points of relative biomass, based on the management scenarios recommended by the MSFMAC.

METHODS

Model parameters

The projection model used biological parameters and data inputs up to March 2022, as reported in the 2022 Snapper stock assessment (Drew et al., 2022). The only difference in the model parameters used in the SnapEst projection model from the 2022 stock assessment was a change in fixed instantaneous natural mortality rate (*M*) from 0.05 yr^{-1} to 0.125 yr^{-1}. This change was supported by the MSFMAC and the effects on model outputs for each stock were presented in Appendix 1 of the previous Advice Note (Mellin et al., 2025).

Reference period of recruitment

Forward projections of biomass were simulated from annual recruitment events randomly resampled from a predefined reference period. The reference period of recruitment used to estimate $B_{est}0$ in the previous Advice Note was 1982 to 2009 (Mellin et al., 2025). For each stock, this reference period included strong and weak recruitment year classes and corresponded to a time when biomass and egg production (i.e., spawning potential) were significantly higher than when the fishery closures were implemented in late 2019 (Figure 1). The MSFMAC recommended that the next stage of projection modelling should consider a reference period of recruitment for each stock that corresponds to a time when biomass and egg production were at a lower level comparable to the current status, and would therefore be expected to provide a more plausible range of biomass projections.

The time series of recruitment for each stock was retrospectively estimated from the relative proportion of each year class in the annual age structures developed since 1999 (Figure 1) (Fowler 2023). The age structures were developed by subtracting the estimated age of each Snapper sampled from its date of capture to determine its year of birth (i.e., year class). Prior to the fishery closures in late 2019, biological samples were primarily accessed from commercial catches through the market sampling program, and therefore all fish sampled were above the minimum legal length (MLL) of 38 cm total length. As it takes at least 3-4 years for Snapper to reach the MLL and enter the fishery, there is a lag of approximately five years from when the fish were spawned to when they manifest in the annual age structures. Consequently, the most recent year classes modelled have the lowest sample sizes and the highest uncertainty and were not considered appropriate for projection modelling.

Several different reference periods of recruitment were considered in a stepwise process:

- 2008 to 2016 – for the SG/WC stock, very low levels of recruitment that resulted in projections of relative biomass below $B_{est}15$ throughout the projection period in the absence of fishing (Appendix 1); and, for the GSV stock, low to moderate annual recruitment that produced plausible projections of relative biomass. This reference period was retained for the GSV stock (Figure 1D).

- 2000 to 2016 for the SG/WC stock – an extended period of low recruitment interspersed with some years of slightly higher recruitment that produced slightly higher projections of relative biomass. This reference period was retained for the SG/WC stock (Figure 1C).
- For the SG/WC stock, an alternative scenario was considered that used the reference period of recruitment from the GSV stock for 2008 to 2016. This scenario produced very similar, but more uncertain, projections of relative biomass to the SG/WC 2000 to 2016 reference period and was not retained (Appendix 1).

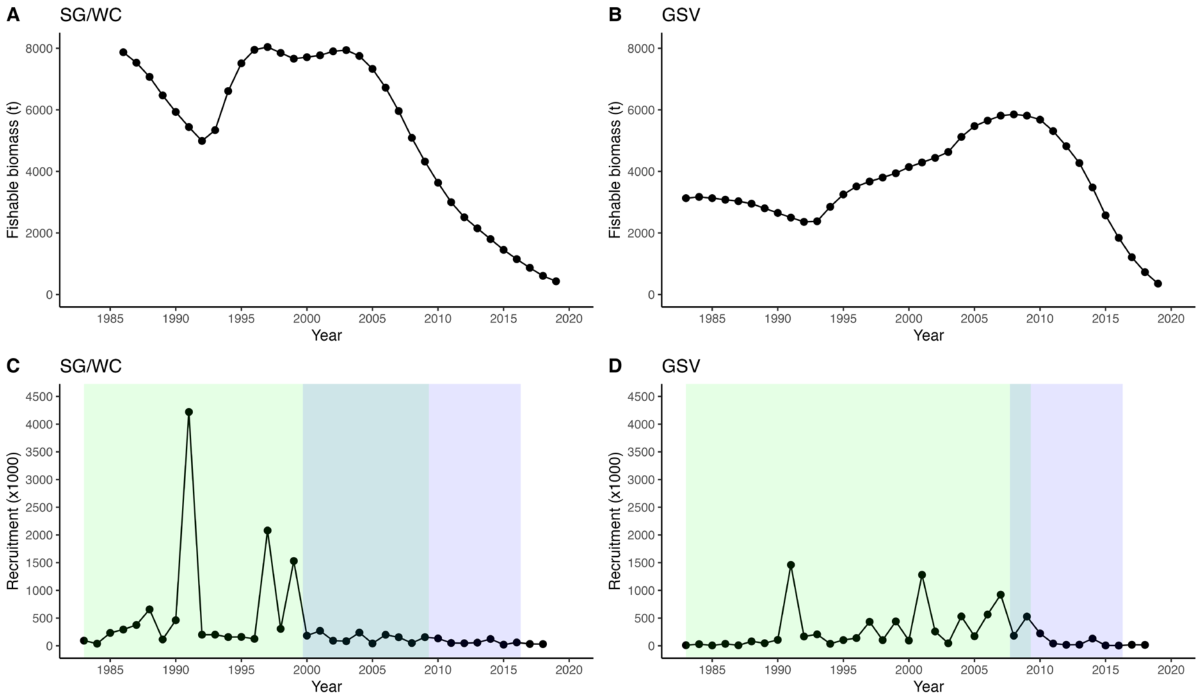

Figure 1. Time series of biomass and recruitment estimates for the Spencer Gulf / West Coast (SG/WC – left) and Gulf St Vincent (GSV – right) stocks assuming M = 0.125 yr^{-1}. The green shading shows the recruitment reference period used to calculate $B_{est}0$. The overlapping blue shading shows the recruitment reference period used in the simulated management scenarios.

Simulated potential management scenarios

Six potential management scenarios were applied to the forward projections of relative biomass for each stock (A-F; Table 1).

For scenarios A-D, a nominal harvest fraction (H) of 5% 'other mortality' was applied in each year since the fishery closures were implemented (i.e., since 1 November 2019) until relative biomass reached $B_{est}15$. The estimate of 'other mortality' was calculated independently for each stock as 5% of the model estimated total biomass (across all lengths and both sexes) at the start of the fishery closure in November 2019, which was then applied as a constant annual catch in each subsequent year. The nominal estimate of 5% 'other mortality' represents discard mortality of incidentally captured Snapper across all fisheries and sectors, retained traditional fishery catches, and Snapper collected for research purposes. While this nominal estimate of 5% 'other mortality' was consistently applied when relative biomass was below $B_{est}15$ in scenarios A-D, these scenarios subsequently differed based on the constant annual TAC applied above $B_{est}15$ (i.e., 5% 'other mortality', 0.5M, 1M, or 2M; Table 1).

Scenarios E and F implemented two versions of the 'hockey stick' decision rule defined in the MSF harvest strategy framework (PIRSA 2024). Scenario E followed the specifications of the 'hockey stick' rule, with no fishing below $B_{est}20$ (Table 1). Scenario F was based on scenario E, except that a nominal harvest fraction (*H*) of 5% of the model estimated total biomass (across all lengths and both sexes) at the start of the fishery closure in November 2019 was applied in each year below $B_{est}20$. Note that for scenarios E and F, total annual catch for each year was calculated based on the estimate of total biomass in the previous year (i.e., dynamic) at or above $B_{est}20$, whereas scenarios A-D applied a fixed annual TAC throughout the projection period (i.e., static) (Table 2).

Components of the 'hockey stick' rule that are specified in terms of fishing mortality (*F*), rather than harvest fraction (*H*), require *F* be converted to *H* so that catch can be calculated as the product of *H* and total biomass. The SnapEst model is catch-conditioned and applies mortality dynamics by reducing the population by a factor of half natural survival, then subtracting the full catch, followed by population reduction of the remaining factor of half natural survival. Equating this population mortality model with the continuous total mortality model, yields the following approximation to *H*, given *M and F*:

$$H = e^{-\frac{M}{2}} \cdot (1 - e^{-F}) \qquad \text{Equation 1}$$

Table 1. Description of the simulated management scenarios applied to projection model outputs for the Spencer Gulf / West Coast and Gulf St Vincent stocks. Scenarios A-D applied a fixed annual TAC (i.e., static) throughout the projection period, whereas scenarios E and F applied a dynamic annual catch calculated as a proportion of biomass in the preceding year. $B/B_{est}0$ = relative biomass, *F* = fishing mortality, *H* = harvest fraction, *M* = natural mortality (where $M = 0.125\ yr^{-1}$), TAC = total allowable catch.

	Scenario	**Description**
A	'Base'	*H* = 5% 'other mortality' throughout.
B	'0.5*M*'	*H* = 5% 'other mortality' when $B/B_{est}0$ is below $B_{est}15$, then a constant annual TAC calculated as 0.5 × *M* (i.e., *F* = 0.0625 and *H* = 0.057) when $B/B_{est}0$ is above $B_{est}15$.
C	'1*M*'	*H* = 5% 'other mortality' when $B/B_{est}0$ is below $B_{est}15$, then a constant annual TAC calculated as 1.0 × *M* (i.e., *F* = 0.125 and *H* = 0.11) when $B/B_{est}0$ is above $B_{est}15$.
D	'2*M*'	*H* = 5% 'other mortality' when $B/B_{est}0$ is below $B_{est}15$, then a constant annual TAC calculated as 2.0 × *M* (i.e., *F* = 0.25 and *H* = 0.208) when $B/B_{est}0$ is above $B_{est}15$.
E	'Hockey stick'	Hockey Stick Rule as per the MSF harvest strategy framework. i.e., *F* = 0 when $B/B_{est}0$ is below $B_{est}20$, then *F* increases linearly to 0.1 when $B/B_{est}0$ is between $B_{est}20$ and $B_{est}40$, after which *F* remains at 0.1 when $B/B_{est}0$ is above $B_{est}40$.
F	Base then 'hockey stick'	As Scenario E ('hockey stick'), except for *H* = 5% 'other mortality' (*F* = 0.055) when $B/B_{est}0$ is below $B_{est}20$.

Table 2. Summary of annual catch in tonnes (t) applied at different levels of relative biomass ($B/B_{est}0$) in each simulated management scenario for the Spencer Gulf / West Coast (SG/WC) and Gulf St Vincent (GSV) stocks. Scenarios are described in Table 1. An asterisk (*) denotes approximate non-constant (i.e., dynamic) annual catch according to the hockey stick rule.

		Relative biomass ($B/B_{est}0$)			
Stock	**Scenario**	< $B_{est}15$	$B_{est}15$ ≥ $B_{est}20$	$B_{est}20$ ≥ $B_{est}40$	> $B_{est}40$
SG/WC	A – Base	32	32	32	32
	B – 0.5*M*	32	36	36	36
	C – 1*M*	32	70	70	70
	D – 2*M*	32	133	133	133
	E – 'Hockey stick'	0	0	0–434*	> 434*
	F – Base then 'hockey stick'	32	32	122–434*	> 434*
GSV	A – Base	37	37	37	37
	B – 0.5*M*	37	42	42	42
	C – 1*M*	37	81	81	81
	D – 2*M*	37	153	153	153
	E – 'Hockey stick'	0	0	0–294*	> 294*
	F – Base then 'hockey stick'	37	37	82–294*	> 294*

Model outputs

For each modelled scenario and simulation, annual estimates of total biomass (B), relative biomass (i.e., $B/B_{est}0$), numbers-at-age, and recruitment (i.e., annual number of recruits and year class) were extracted for each model year. These data were plotted for a selection of individual simulations to illustrate the relationships among the predicted biomass, recruitment, and the population age structure. Individual simulations were ranked based on the estimated time for relative biomass to reach $B_{est}15$ (i.e., rank 1 = fastest to rank 200 = slowest).

Reference points of relative biomass (i.e., $B/B_{est}0$)

The estimated time when various reference points of relative biomass were reached, namely $B_{est}10$, $B_{est}15$, $B_{est}20$, $B_{est}40$, and $B_{est}50$ (i.e., 50% of $B_{est}0$), were calculated for each simulation, as well as the mean and 90% simulation intervals (SI) across all simulations. Here, the 90% SI were defined as intervals that encompass 90% of the 200 simulations around the mean biomass level (*sensu* Bessel-Browne et al., 2024).

RESULTS / DISCUSSION

SPENCER GULF / WEST COAST STOCK

Base model

Projections of relative biomass that included a nominal estimate of 5% ‘other mortality’ showed a moderate level of variation among individual simulations (Figure 2). Accordingly, a moderate level of variation was observed in the estimated time to reach $B_{est}15$, which ranged from 2031 to 2076 for the SG/WC stock.

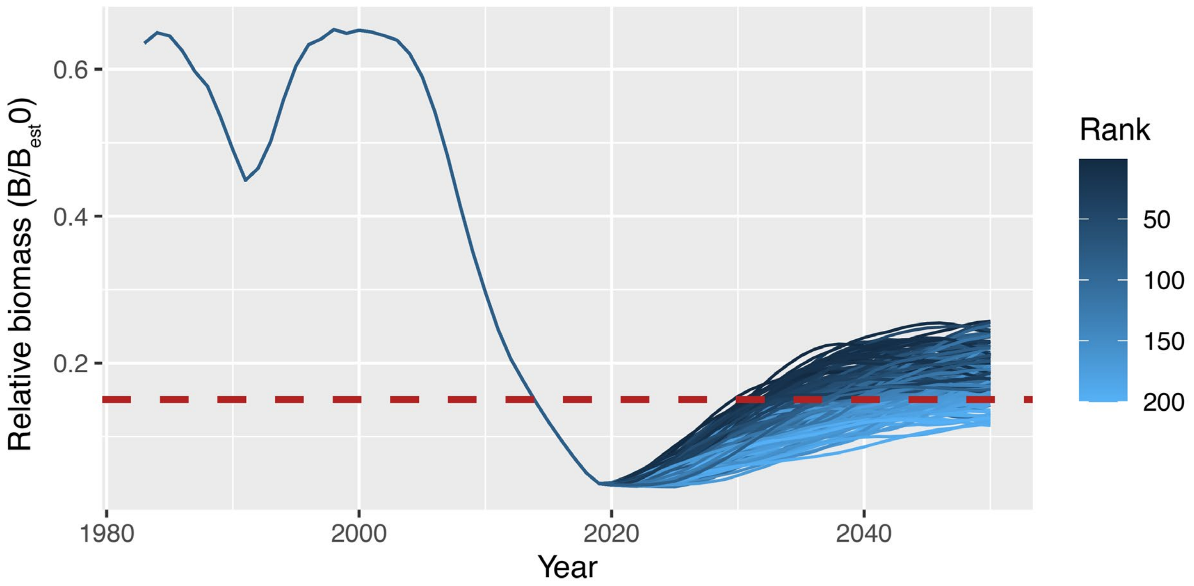

Figure 2. Projections of relative biomass ($B/B_{est}0$) to 2050 for the Spencer Gulf / West Coast stock (SG/WC) assuming a nominal estimate of 5% ‘other mortality’ in each year since the fishery closure was implemented (i.e., 2019). Individual projections (n = 200) of relative biomass are shown as continuous lines and ranked according to the year when $B_{est}15$ (red dashed line) was reached, from rank 1 (fastest, dark blue) to rank 200 (slowest, light blue). The same colour coding is used in Figure 3.

Visual inspection of a selection of individual biomass projections for fast (rank 1 and 2), moderate (rank 101 and 102), and slow (rank 199 and 200) simulations to reach $B_{est}15$ showed that the rate of biomass increase was driven by recruitment, which was reflected in the annual population age structures (Figure 3). For the SG/WC stock, the simulations with fast increases in biomass reflected random recruitment resampling from the reference period (2000 to 2016) that had relatively larger recruitment event(s) at the start of the simulation period, and which resulted in a year class that persisted in the annual age structures (Figure 3; rank 1 and 2). Conversely, the simulations with slower increases in biomass were from random recruitment resampling that had a series of consistent low recruitment years at the beginning of the simulation period, such that no strong year classes were evident in the population age structures in the first three years of the simulation (Figure 3; rank 199 and 200).

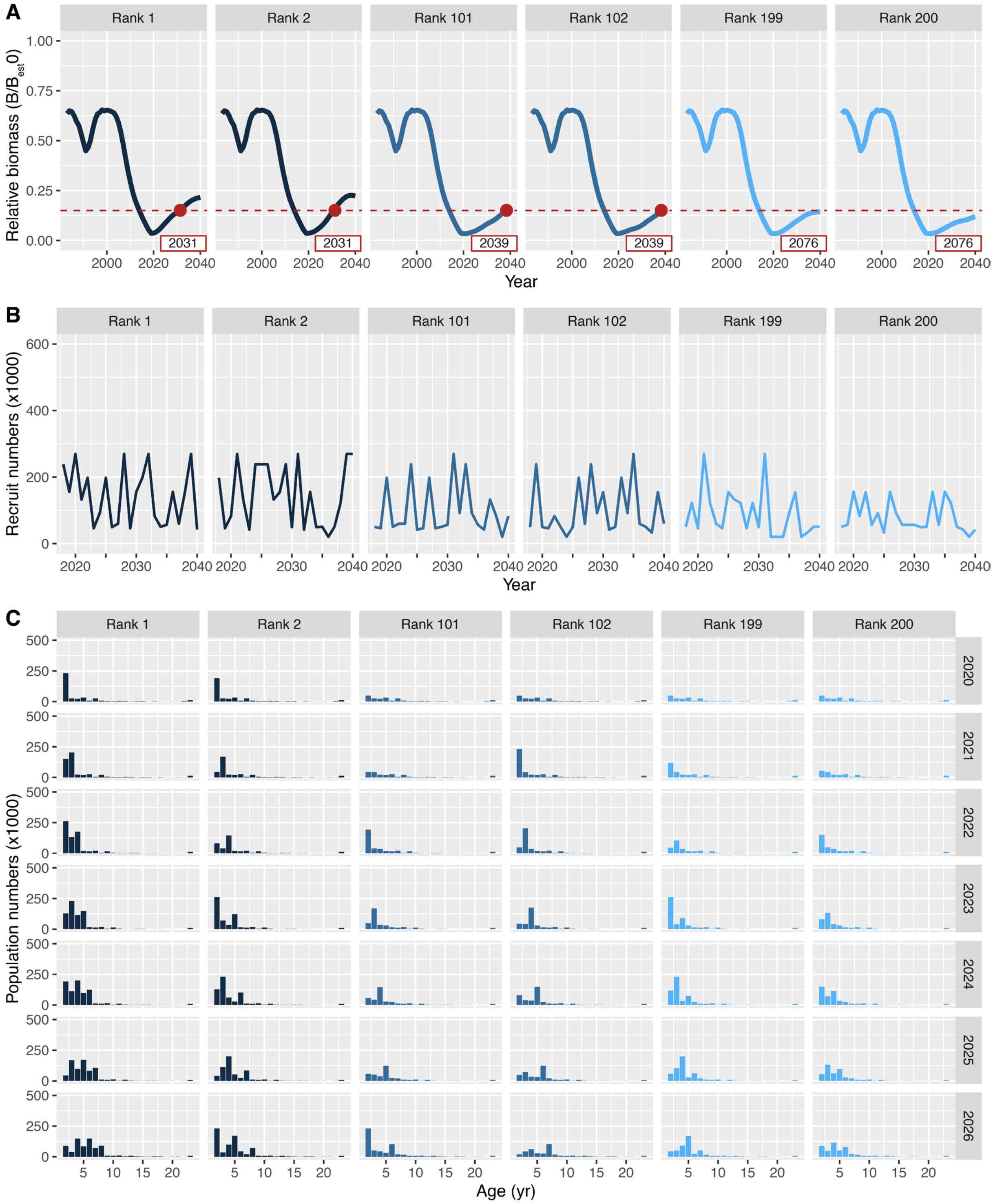

Figure 3. Projections of (a) relative biomass (B/B$_{est}$0), (b recruitment per cohort year, and (c) annual population age structure (2020–2026) for a selection of individual simulations for the Spencer Gulf / West Coast stock ordered by fast (rank 1 and 2), moderate (rank 101 and 102), and slow recovery (rank 199 and 200) to B$_{est}$15. The year that B$_{est}$15 was reached in each individual simulation is indicated in A (red dot). Rank colour coding is as per Figure 2.

Simulated potential management scenarios

There were consistent trends in projected mean relative biomass for the SG/WC stock under the six management scenarios considered. The only management scenario that resulted in mean relative biomass reaching $B_{est}20$ by 2050 was scenario E ('hockey stick'), and relative biomass did not exceed $B_{est}40$ under any modelled scenario.

There were similarities in the projected trends of relative biomass for scenarios A, B, and C (i.e., base, 0.5*M*, and 1*M*, respectively). On average, mean relative biomass reached $B_{est}10$ in 2031 and $B_{est}15$ in 2038 or 2039 (Figure 4, Figure 5, Table 3). However, mean relative biomass plateaued thereafter and did not reach $B_{est}20$ within the projection period. Scenario D (2*M*) initially followed a similar trend in relative biomass reaching $B_{est}10$ in 2031, before plateauing, and remaining at approximately $B_{est}15$ throughout the projection period.

Projections of relative biomass were highest under scenario E ('hockey stick'), which did not include fishing mortality when $B/B_{est}0$ was below $B_{est}20$ (Figure 4; Figure 5; Table 3). This demonstrates the impact on recovery time from even small levels of fishing mortality at low biomass and recruitment levels. Projected mean relative biomass under scenario E reached $B_{est}10$ in 2028, $B_{est}15$ in 2033, and $B_{est}20$ in 2041, and remained slightly above $B_{est}20$ for the remainder of the projection period when fishing mortality was applied.

For scenario F (base then 'hockey stick'), the mean projected relative biomass reached $B_{est}10$ in 2031 and $B_{est}15$ in 2038, closely following trends in scenarios A and B (Table 3).

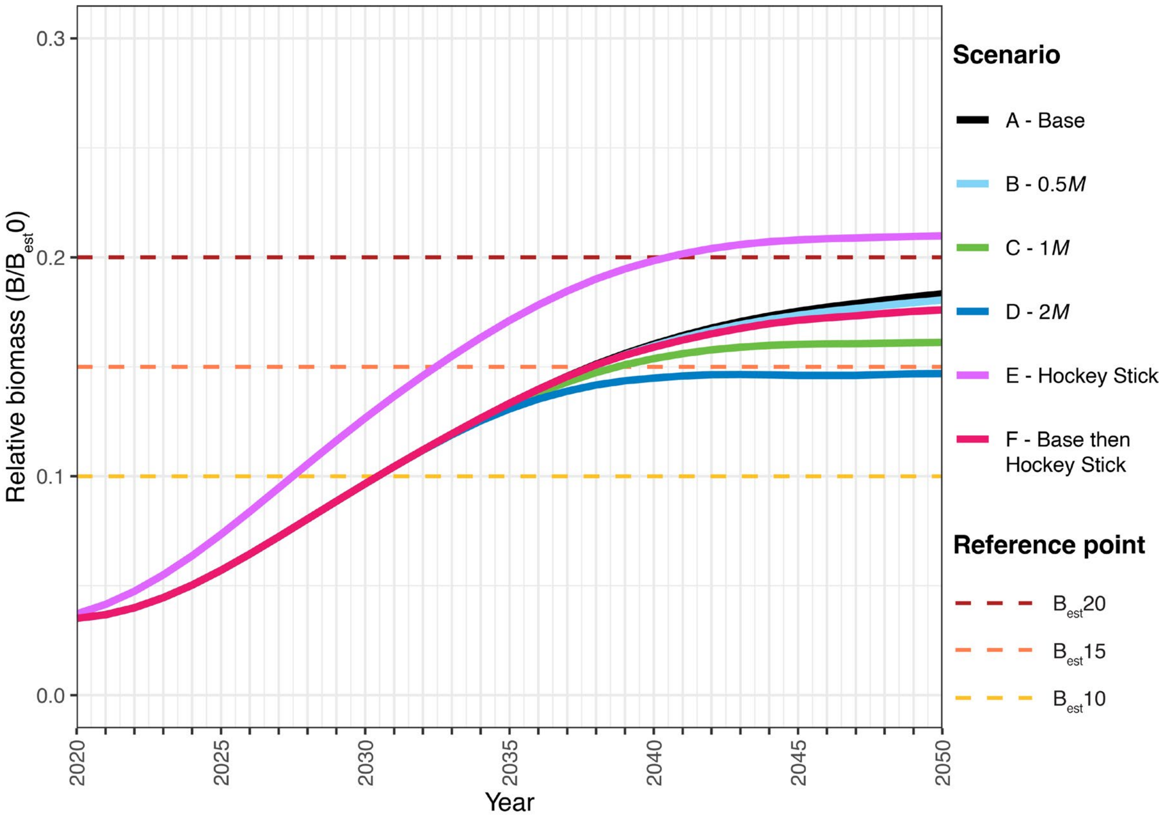

Figure 4. Mean projected relative biomass ($B/B_{est}0$) for the Spencer Gulf / West Coast stock from 2020 to 2050 under each simulated management scenario defined in Table 1 (A-F). Reference points of relative biomass are shown as dashed horizontal lines (i.e., $B_{est}10$, $B_{est}15$, and $B_{est}20$). The estimated year when reference points were reached is shown in Table 3.

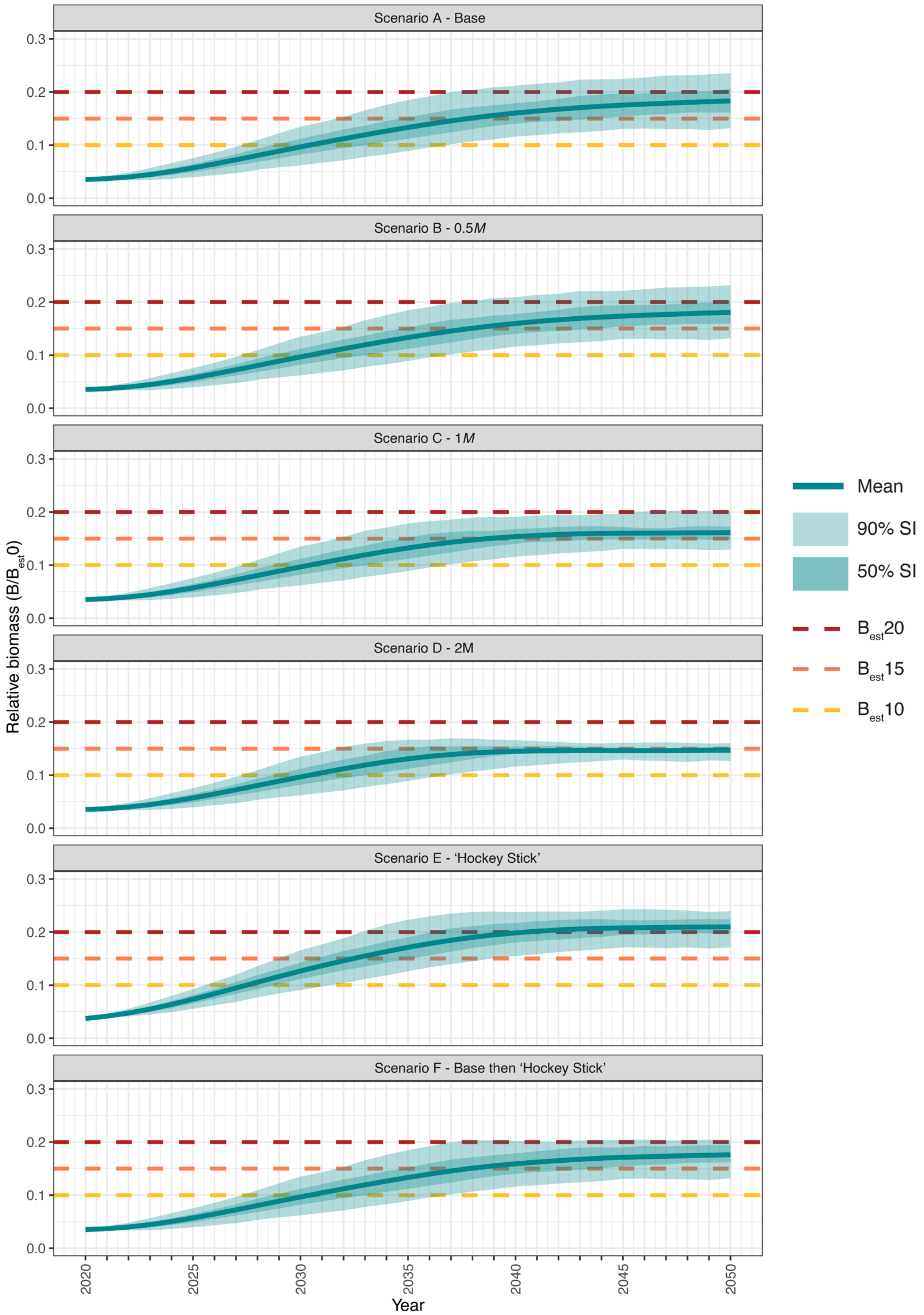

Figure 5. Projected relative biomass ($B/B_{est}0$) for the Spencer Gulf / West Coast stock from 2020 to 2050 under each simulated management scenario defined in Table 1 (A-F). Reference points of relative biomass are shown as dashed horizontal lines (i.e., $B_{est}10$, $B_{est}15$, and $B_{est}20$). For each scenario, ribbons show the 50% and 90% simulation intervals (SI), which encompass 50% (25th–75th percentiles) and 90% (5th–95th percentiles) of all simulations, respectively. The estimated year when reference points were reached is shown in Table 3.

Table 3. Estimated year when reference points of relative biomass (from $B_{est}10$ to $B_{est}50$) were reached for the Spencer Gulf / West Coast stock under each simulated management scenario. Shown are the mean and lower and upper limits (90% simulation intervals; SI) calculated over 200 simulations for each scenario. Dashes indicates reference points not reached throughout the projection period (2020-2221).

Scenario	Reference Point	Mean	90% SI
A – Base	$B_{est}10$	2031	2028-2037
	$B_{est}15$	2038	2032-2065
	$B_{est}20$	-	2038-
	$B_{est}40$	-	-
B – 0.5*M*	$B_{est}10$	2031	2028-2037
	$B_{est}15$	2038	2032-2083
	$B_{est}20$	-	2038-
	$B_{est}40$	-	-
C – 1*M*	$B_{est}10$	2031	2028-2037
	$B_{est}15$	2039	2032-
	$B_{est}20$	-	2046-
	$B_{est}40$	-	-
D – 2*M*	$B_{est}10$	2031	2028-2037
	$B_{est}15$	-	2032-
	$B_{est}20$	-	-
	$B_{est}40$	-	-
E – 'Hockey stick'	$B_{est}10$	2028	2026-2032
	$B_{est}15$	2033	2029-2039
	$B_{est}20$	2041	2033-
	$B_{est}40$	-	-
F – Base then 'hockey stick'	$B_{est}10$	2031	2028-2037
	$B_{est}15$	2038	2032-2083
	$B_{est}20$	-	2038-
	$B_{est}40$	-	-

GULF ST VINCENT STOCK

Base model

Projections of relative biomass that included a nominal estimate of 5% ‘other mortality’ showed a high level of variation among individual simulations (Figure 6). Accordingly, a high level of variation was observed in the estimated time to reach $B_{est}15$, which ranged from 2025 to 2077 for the GSV stock. There was larger variation in the projected trends of relative biomass for the GSV stock than the SG/WC stock, which related to the higher levels of recruitment during the reference period.

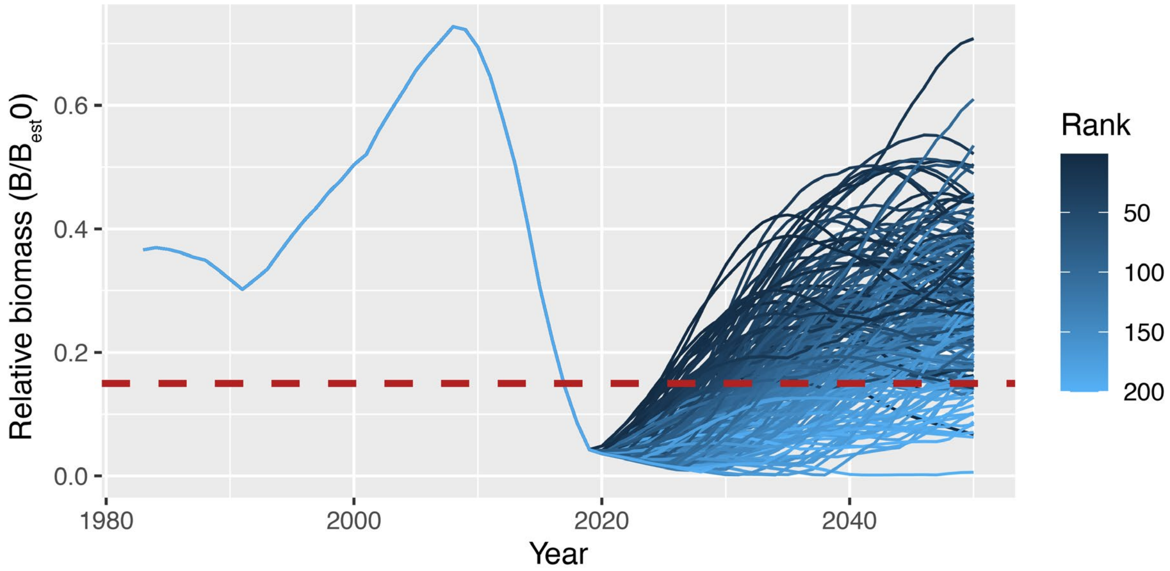

Figure 6. Projections of relative biomass ($B/B_{est}0$) to 2050 for the Gulf St Vincent stock assuming a nominal estimate of 5% ‘other mortality’ in each year since the fishery closure was implemented (i.e., 2019). Individual projections (n = 200) of relative biomass are shown as continuous lines and ranked according to the year when $B_{est}15$ (red dashed line) was reached, from rank 1 (fastest, dark blue) to rank 200 (slowest, light blue). The same colour coding is used in Figure 7.

Visual inspection of a selection of individual biomass projections for fast (rank 1 and 2), moderate (rank 101 and 102), and slow (rank 199 and 200) simulations to reach $B_{est}15$ showed that the rate of biomass increase was driven by recruitment, which was reflected in the annual population age structures (Figure 7). For the GSV stock, the simulations with fast increases in biomass reflected random recruitment resampling from the reference period (2008 to 2016) that had relatively higher recruitment event(s) at the start of the simulation period, and which resulted in a strong year class that persisted in the annual age structures (Figure 7; rank 1 and 2). Conversely, the simulations with slower increases in biomass were from random recruitment resampling that had a series of low recruitment years at the beginning of the simulation period, such that no strong year classes were evident in the population age structures in the first six years of the simulation (Figure 7; rank 199 and 200).

Figure 7. Projections of (a) relative biomass ($B/B_{est}0$), (b) recruitment per cohort year, and (c) annual population age structure (2020–2026) for a selection of individual simulations for the Gulf St Vincent stock ordered by fast (rank 1 and 2), moderate (rank 101 and 102), and slow (rank 199 and 200) recovery to $B_{est}15$. The year that $B_{est}15$ was reached in each individual simulation is indicated in A (red dot). Rank colour coding is as per Figure 6.

Simulated potential management scenarios

For the GSV stock, mean projections of relative biomass surpassed $B_{est}20$ under five of the six management scenarios tested (i.e., A, B, C, E, and F). However, mean relative biomass did not reach $B_{est}40$ within the projection period under any modelled management scenario (Figure 8, Figure 9, Table 4).

There were similarities in the projected trends of relative biomass for management scenarios A and B (i.e., base and 0.5*M*, respectively) (Figure 8, Figure 9). On average, mean relative biomass for each scenario reached $B_{est}10$ in 2029, $B_{est}15$ in 2034, and $B_{est}20$ in 2038, and continued to increase to above $B_{est}25$ by 2050 (Table 4).

For scenarios C and D (i.e., 1*M* and 2*M*, respectively), the mean projections of relative biomass initially followed a similar trajectory until $B_{est}10$, after which the rate of increase slowed as fishing mortality was applied. For scenario C, $B_{est}15$ was reached in 2034 and $B_{est}20$ was reached in 2042 (Figure 8, Figure 9, Table 4). For scenario D, mean relative biomass reached $B_{est}15$ in 2038 and then plateaued at that level for the remainder of the projection period.

Projections of relative biomass increased fastest under scenario E ('hockey stick'), which did not involve fishing mortality below $B_{est}20$. As with the SG/WC stock, this demonstrates the impact on recovery time from even small levels of fishing mortality at low biomass and recruitment levels. The mean of projected relative biomass under scenario E reached $B_{est}10$ in 2026, $B_{est}15$ in 2029, and $B_{est}20$ in 2033, and then plateaued above $B_{est}20$ for the remainder of the projection period as annual catch increased (Figure 8, Figure 9, Table 4).

For scenario F (base then 'hockey stick'), relative biomass initially increased at the same rate as scenarios A-D and reached $B_{est}10$ in 2028 and $B_{est}15$ in 2034 (Figure 8, Table 4). The mean relative biomass then plateaued as annual catch increased with biomass above $B_{est}20$, which was reached in 2047.

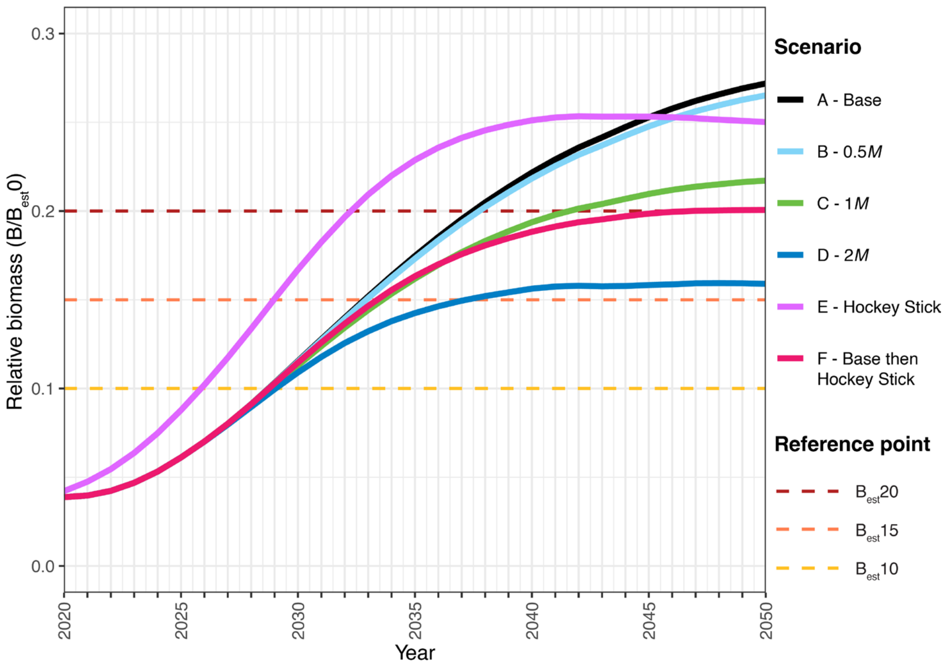

Figure 8. Mean projected relative biomass ($B/B_{est}0$) from 2020 to 2050 for the Gulf St Vincent stock under each simulated management scenario defined in Table 1 (A-F). Reference points of relative biomass are shown as dashed horizontal lines (i.e., $B_{est}10$, $B_{est}15$, and $B_{est}20$). The estimated year when reference points were reached is shown in Table 4.

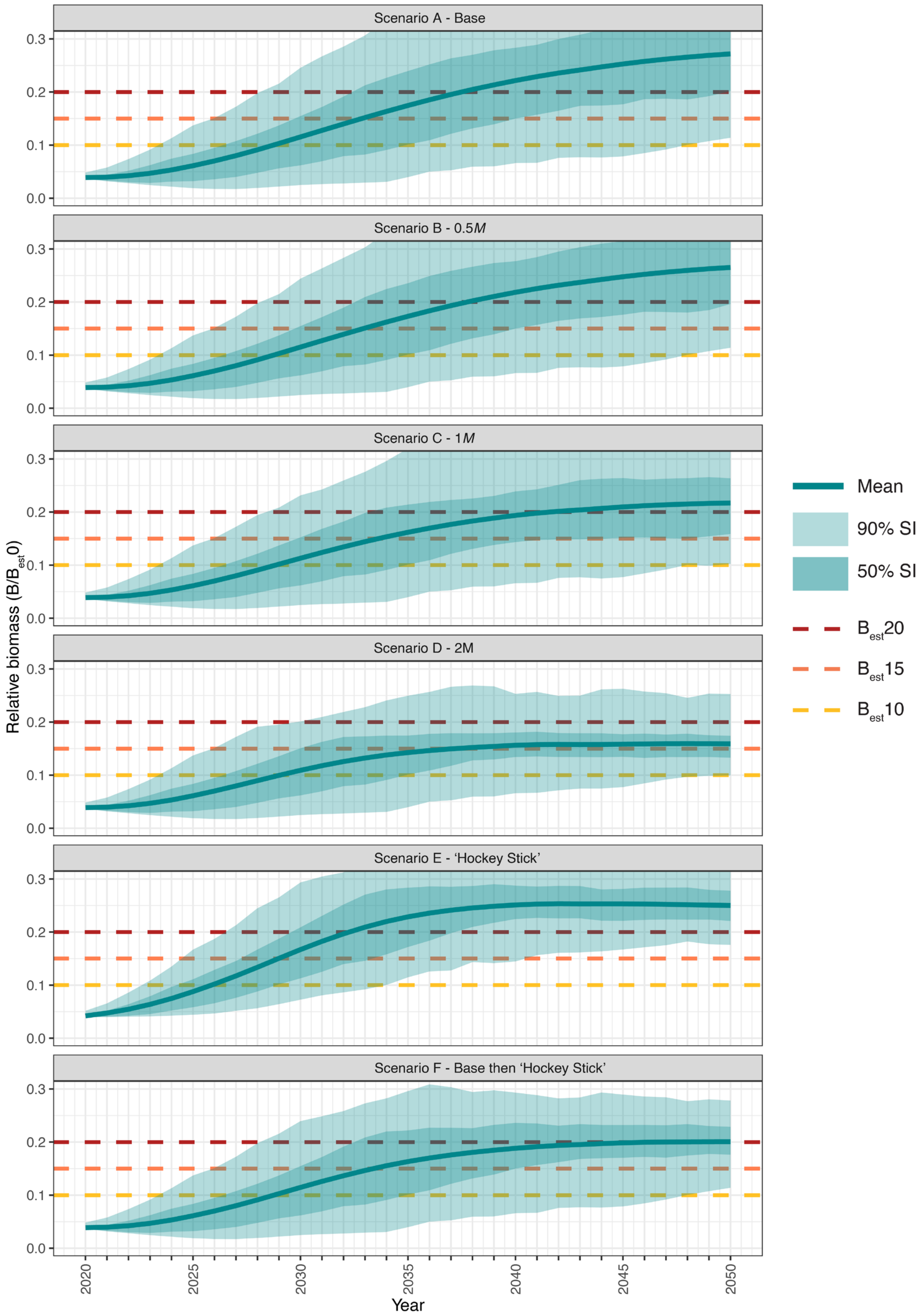

Figure 9. Projected relative biomass (B/B_{est}0) for the Gulf St Vincent stock from 2020 to 2050 under each simulated management scenario defined in Table 1 (A-F). Reference points of relative biomass are shown as dashed horizontal lines (i.e., B_{est}10, B_{est}15, and B_{est}20). For each scenario, ribbons show the 50% and 90% simulation intervals (SI), which encompass 50% (25th–75th percentiles) and 90% (5th–95th percentiles) of all simulations, respectively. The estimated year when reference points were reached are shown in Table 4.

Table 4. Estimated year when reference points of relative biomass ($B/B_{est}0$) were reached for the Gulf St Vincent (GSV) stock under each simulated management scenario. Shown are the mean and lower and upper limits (90% simulation intervals; SI) calculated over 200 simulations for each scenario. Dashes indicate that reference points were not reached throughout the projection period (2020-2221).

Scenario	**Reference Point**	**Mean**	**90% SI**
A – Base	$B_{est}10$	2029	2024-2048
	$B_{est}15$	2033	2026-2084
	$B_{est}20$	2038	2029-
	$B_{est}40$	-	2038-
	$B_{est}50$	-	2063-
B – 0.5*M*	$B_{est}10$	2029	2024-2048
	$B_{est}15$	2033	2026-2086
	$B_{est}20$	2038	2029-
	$B_{est}40$	-	2039-
	$B_{est}50$	-	2086-
C – 1*M*	$B_{est}10$	2029	2024-2048
	$B_{est}15$	2034	2026-
	$B_{est}20$	2042	2029-
	$B_{est}40$	-	2060-
	$B_{est}50$	-	-
D – 2*M*	$B_{est}10$	2030	2024-2051
	$B_{est}15$	2038	2026-
	$B_{est}20$	-	2030-
	$B_{est}40$	-	-
	$B_{est}50$	-	-
E – 'Hockey stick'	$B_{est}10$	2026	2023-2034
	$B_{est}15$	2029	2025-2041
	$B_{est}20$	2033	2027-
	$B_{est}40$	-	-
	$B_{est}50$	-	-
F – Base then 'hockey stick'	$B_{est}10$	2029	2024-2048
	$B_{est}15$	2034	2026-
	$B_{est}20$	2047	2029-
	$B_{est}40$	-	-
	$B_{est}50$	-	-

Dr Gretchen Grammer
A/Research Director, SARDI Aquatic and Livestock Sciences

Disclaimer

PIRSA and its employees do not warrant or make any representation regarding the use, or results of the use, of the information contained herein as regards to its correctness, accuracy, reliability, and currency or otherwise. PIRSA and its employees expressly disclaim all liability or responsibility to any person using the information or advice. Use of the information and data contained in this Note is at the user's sole risk. If users rely on the information, they are responsible for ensuring by independent verification its accuracy, currency, or completeness.

References

Bertram A., Bell J., Braur C.J., Fowler A.J., Hamer P., Sandoval-Castillo J., Stewart J., Wellenreuther M, Beheregaray L.B. (2023). Biogeographic provinces and genomically delineated stocks are congruent in Snapper (*Chrysophrys auratus*) from southeastern Australia. *ICES Journal of Marine Science*, fsad068. 9 pp.

Bessell-Browne P., Punt A., Tuck G., Burch P., Penney A. (2024). Management Strategy Evaluation of static and dynamic harvest control rules under long-term changes in stock productivity: a case study from the SESSF. *Fisheries Research*, 273:17. https://doi.org/10.1016/j.fishres.2024.106972

Drew M., Rogers T., McGarvey R., Feenstra J., Matthews D., Matthews J., Earl J., Smart J., Noell C., Fowler A.J. (2022). Snapper (*Chrysophrys auratus*) Stock Assessment Report 2022. Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2007/000523-7. SARDI Research Report Series No. 1155. 178 pp.

Fowler A.J. (2023). A synthesis of fishery and biological information for Snapper (*Chrysophrys auratus*) in South Australia. South Australian Research and Development Institute (Aquatic and Livestock Sciences), Adelaide. SARDI Publication No. F2023/000382-1. SARDI Research Report Series No. 1206. 381 pp.

Fowler A.J., Hamer P.A., Kemp J. (2017). Age-related otolith chemistry profiles help resolve demographics and meta-popultion structure of a widely-dispersed, coastal fishery species. *Fisheries Research*, 189: 77-94.

Haddon M. (2023). South Australian Snapper Model Review. 37 pp.

PIRSA (2024). Implementation plan for the Marine Scalefish Fishery Harvest Strategy Framework (draft). Department of Primary Industries and Regions South Australia. 17 pp.

APPENDIX 1 – Comparison of recruitment reference period used for the SG/WC stock

The recruitment reference period used for the SG/WC stock strongly influenced projection outcomes in terms of biomass recovery rate, but also its uncertainty and the reference points that were reached during the projection period (2020-2221) (Figure A1; Table A1).

The first recruitment reference period (2008-2016 in SG/WC; based on the initial recommendation of the MSFMAC) resulted in mean relative biomass reaching $B_{est}10$ by 2039 under scenario A (Base). However, based on the mean projected trend, $B_{est}15$ was not reached during the projection period.

The second recruitment reference period (2000-2016 in SG/WC; subsequently retained in the simulated management scenarios) resulted in mean relative biomass reaching $B_{est}10$ by 2031, and $B_{est}15$ by 2038 under scenario A (Base).

The third recruitment reference period (2008-2016 in GSV) resulted in mean relative biomass reaching $B_{est}10$ and $B_{est}15$ in similar years as the first recruitment period, yet with greater uncertainty (i.e., wider 90% SI). $B_{est}20$ was reached in 2090.

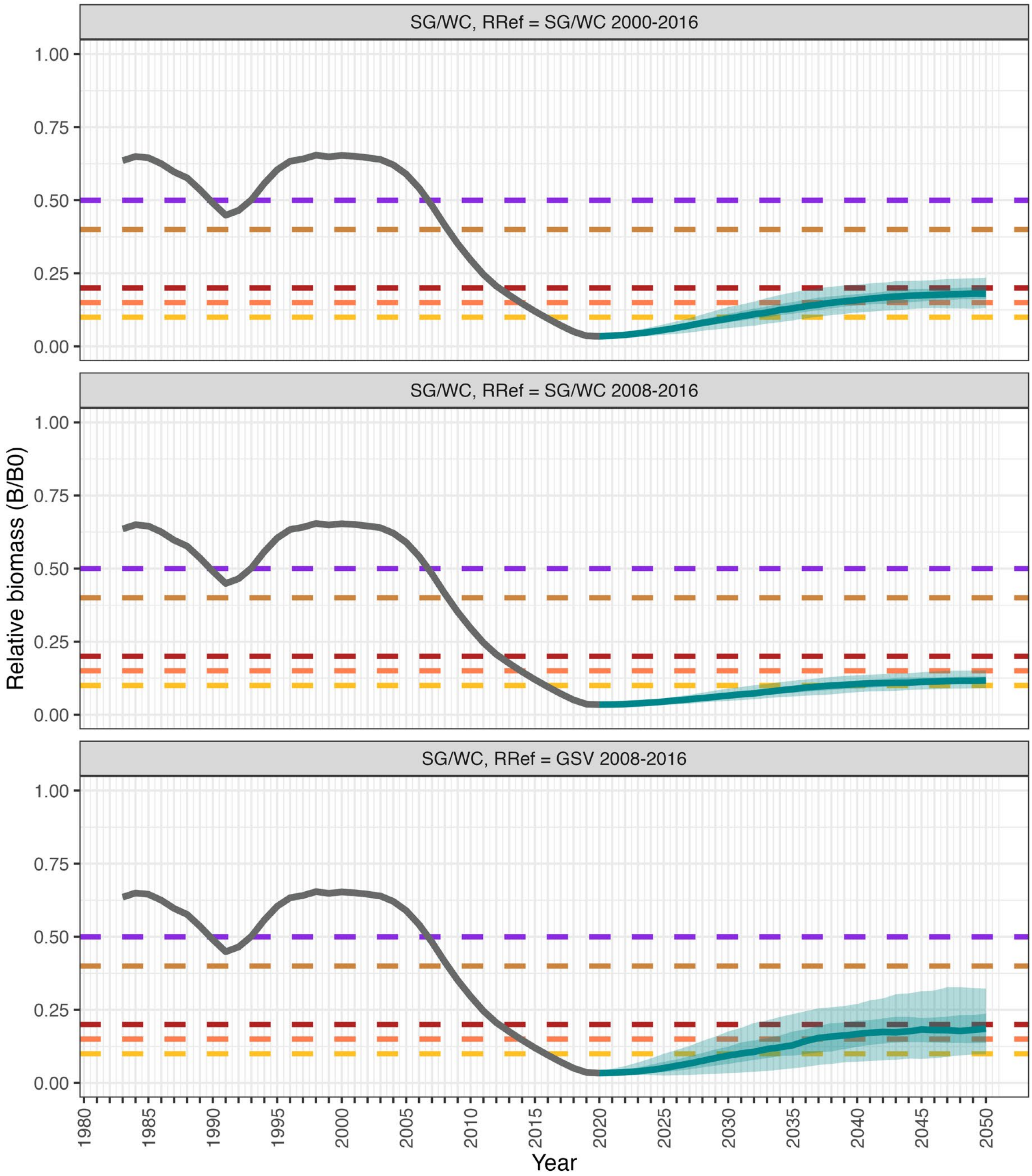

Figure A1. Projected relative biomass assuming a nominal estimate of 5% 'other mortality' since the fishery closures were implemented for the Spencer Gulf / West Coast stock (SG/WC) assuming different reference periods for recruitment resampling. Top – 2000-2016 from SG/WC, middle – 2008-2016 from SG/WC , and bottom – 2008-2016 from GSV. Reference points of relative biomass are shown as horizontal dashed lines (i.e., from $B_{est}10$ to $B_{est}50$). Ribbons show the 50% and 90% simulation intervals (SI), which encompass 50% (25^{th}–75^{th} percentiles) and 90% (5^{th}–95^{th} percentiles) of all simulations, respectively.

Table A1. Estimated year when reference points of relative biomass ($B/B_{est}0$) were reached for the Spencer Gulf/West Coast (SG/WC) stock based on different recruitment reference periods, including 2000-2016 in SG/WC as per the simulated management scenarios, 2008-2016 in SG/WC as per initial MSFMAC recommendation, and 2008-2016 in GSV. Shown are the mean, lower, and upper limits (90% simulation intervals; SI) calculated over 200 simulations for each recruitment reference period. Dashes indicate that the reference points were not reached throughout the projection period (2020-2221).

Recruitment reference	Reference Point	Mean	90% SI
SG/WC 2000-2016	$B_{est}10$	2031	2028-2037
	$B_{est}15$	2038	2032-2065
	$B_{est}20$	-	2038-
	$B_{est}40$	-	-
	$B_{est}50$	-	-
SG/WC 2008-2016	$B_{est}10$	2039	2032-2101
	$B_{est}15$	-	2047-
	$B_{est}20$	-	-
	$B_{est}40$	-	-
	$B_{est}50$	-	-
GSV 2008-2016	$B_{est}10$	2031	2026-2053
	$B_{est}15$	2037	2029-
	$B_{est}20$	2090	2032-
	$B_{est}40$	-	-
	$B_{est}50$	-	-