Stock Status Summary – 2021/22

NSW Stock Status Summary – Pipi *(Donax deltoides)*

Assessment Authors and Year

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Stock Status

Current stock status	On the basis of the evidence contained within this assessment, Pipi are currently assessed as **sustainable**

Stock structure & distribution

This stock assessment report provides a determination of stock status of the NSW biological stock. Results of a recent collaborative study which used microsatellite and mitochondrial DNA marker techniques on samples collected from sites along the New South Wales, Victoria and South Australian (SA) coasts indicated that there were three reproductively isolated populations of Pipis (Miller *et al*., 2013). There is a high level of bidirectional gene flow along the east coast of Australia resulting in a single panmictic population stretching along the NSW coast and most likely extending as far north as Fraser Island, Queensland (Murray-Jones & Ayre, 1997).

Biology

For the population of Pipi in NSW, the size at which 50% (SAM_{50}), and 95% (SAM_{95}) were sexually mature was 3.4, and 4.4 cm, respectively (Murray-Jones 1999). Estimates of SAM_{50} (2.8 cm) and Sam_{95} (3.2 cm) for Pipi from SA are considerably smaller than NSW (Ferguson & Ward 2014). A minimum legal length of 4.5 cm is in place in NSW to allow spawning to occur before recruitment to the fishery. Growth rates in Pipi are size dependent. Maximum length (~ 8.0 cm) is reached after approximately 4 years (Murray-Jones 1999).

FISHERY STATISTICS

Catch information

Commercial

Total annual reported commercial catches of Pipi increased steadily from 15 tonnes (t) to 80 t from 1984/85 to 1988/89, and then increased rapidly to a peak of 670 t in 2000/01. Catches exceeded 250 t per-year from 1996/97 to 2005/06 then rapidly declined to 9 t in 2010/11 (Fig. 1). In response to the declines in landings a series of input controls including; spatially explicit management strategies (i.e., conditional area closures), temporal closures of the commercial fishery (i.e., 6 months per-annum), minimum legal size limit (i.e., 4.5 cm total length) and output controls limiting catch to 40 kg per fisher per day were implemented by NSW DPI in an attempt to stabilize the fishery. Catches then increased to ~180 t in 2016 before declining to 155 t in 2018 (1st June - 31st December). Total reported commercial landings constrained by a Total Allowable Catch (TAC) of 147.4 t were 110.1 and 115.0 t for the 2019/20 and 2020/21 fishing periods, respectively.

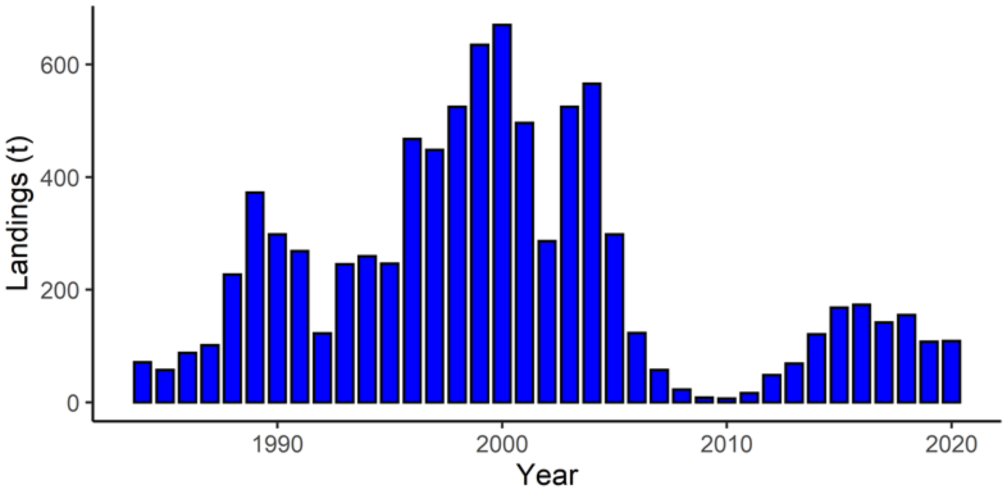

Figure 1. Annual reported commercial landings (t) from 1984/85 to 2020/21.

Recreational & Charter boat

Estimates of state-wide recreational catches are available from the National Recreational and Indigenous Fishing Survey and New South Wales state-wide surveys completed in 2000/01 (Henry and Lyle 2003), 2013/14 (West *et al*., 2015) and 2017/18 (Murphy *et al*., 2020). The estimated recreational catch in 2000/01 was 7 t, and in 2017/18 was 1.1 t, representing less than 1% of the combined recreational and commercial harvest in each survey period.

Indigenous

Although Indigenous fishers harvest Pipi throughout New South Wales, there are no state-wide estimates of Indigenous harvest. Onsite interviews of Indigenous fishers in the Tweed Heads region (Northern New South Wales) estimated an annual Pipi harvest in that region of 3, 056 – 7, 380 individuals (Schnierer 2011). Using a regional weight multiplier estimated at 14.81 g per Pipi (Murphy *et al*., 2020), indigenous harvest was estimated to be less than 0.12 t.

Illegal, Unregulated and Unreported

The level of Illegal, Unregulated and Unreported (IUU) fishing is unknown. In 2019/20, 4.36 t of quota usage was not reported in catch and effort logbooks.

Fishing effort information

Reported days effort ($effort_{dy}$) in the 2020/21 fishing season (2, 489 days) was approximately 45% of the historical peak of 5, 610 days in 2001/02 (Fig. 2). From 2009/10, with the introduction of daily catch and effort reporting, fishers have reported hours spent hand-gathering per fishing day. From a minimum of 1, 802 hours in 2010/11, $effort_{hr}$ increased to 13, 688 hours in 2015/16 and was 6, 780 hours in 2019/20 (Fig. 2). Under revised management arrangements in 2019/20, $effort_{dy}$ and $effort_{hr}$ declined by 2, 281 days and 4, 957 hours when compared to reported effort (4, 322 days) and hours spent handgathering (11, 740 h) in 2018/19. In 2020/21, fishers reported a total of 7, 670 hours handgethering (Fig. 2).

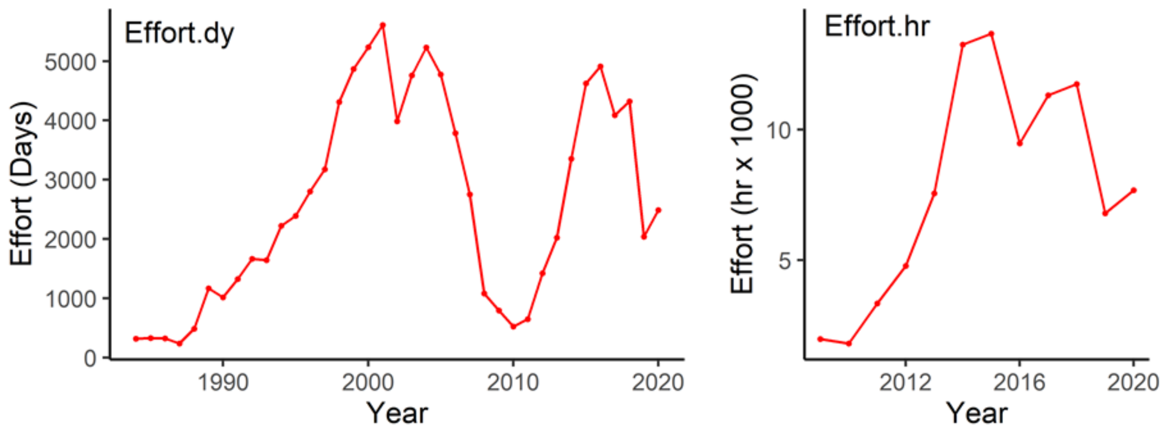

Figure 2. Reported days effort (left) and hours spent handgathering (right).

Catch Rate information

Catch per-fisher-day ($CPUE_{dy}$) increased from less than 100 kg.day^{-1} (1984/85-1987/88) to a maximum of 218 kg.day^{-1} in 1990 then declined to 58 kg.day^{-1} in 1995/96 (Fig. 3). From 1996/97 to 2000/01 $CPUE_{dy}$ exceeded 100 kg.day^{-1}, then rapidly declined to 17 kg.day^{-1} in 2010/11. The trend in catch per-hour ($CPUE_{hr}$) is similar to that of $CPUE_{dy}$ (2009/10 - 2019/20). From a minimum of 5.0 kg.hr^{-1}, $CPUE_{hr}$ increased to 18.6 kg.hr^{-1} in 2016/17 and was 13.2 kg.hr^{-1} in 2018/19 (Fig. 3). Following the removal of the 40 kg daily possession limit in 2019/20, $CPUE_{dy}$ and $CPUE_{hr}$ increased to 55.1 kg.day^{-1} and 16.0 kg.hr^{-1}, respectively (Fig. 3).

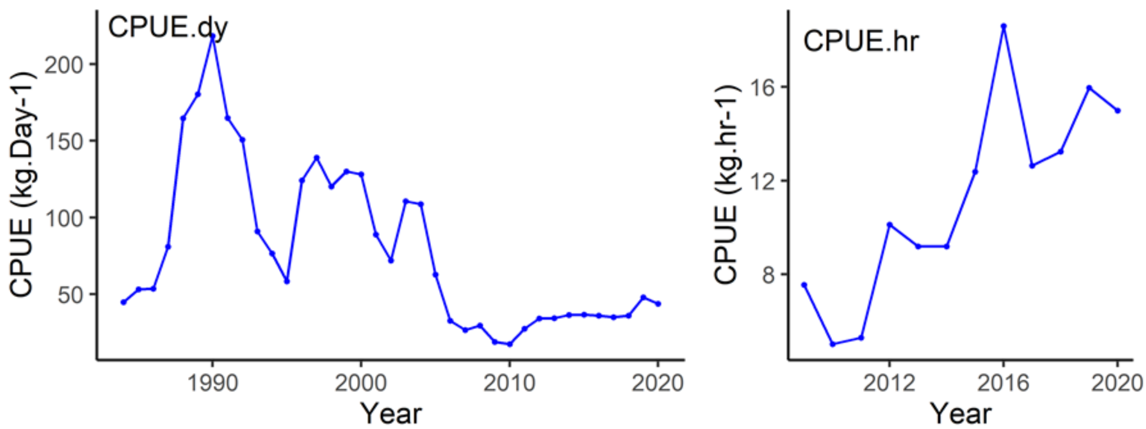

Figure 3. CPUE in kg/ day^{-1} (left) and kg/ hr^{-1} (right).

STOCK ASSESSMENT

Stock Assessment Methodology

Year of most recent assessment:

2021

Assessment method:

A weight-of-evidence approach has been used to assess the NSW Pipi stock. It incorporates the results from standardised catch rates (2009/10 to 2020/21) for the main regions of the fishery, simple stock depletion models applied at the scale of regions and beaches, length-based spawning potential ratio, optimized catch-only model outputs and modified Catch-MSY analyses of commercial catch.

Main data inputs:

The following raw data inputs were used in analyses:

- Commercial catch rates in kg.h^{-1} derived from fisher-reported daily records (2009/10 – 2020/21) ;
- Commercial catches – reported annual catches by fiscal years (1984/85–2020/21).
- Length composition of commercial catches of Pipis for the periods from 2005/06, 2008/09, 2013/14 to 2015/16 and 2019/20;
- Historical estimates of biological parameters derived from a combination of modal progression analyses and tag recapture studies (Murray-Jones 1999).

Key model structure & assumptions:

1. Standardised catch rates (using cede v. 0.04, Haddon, 2018). *Assumptions*: that annual catch rates are a relative index of abundance and not unduly influenced by other factors that are not accounted for through standardisation.
2. Depletion models; Leslie and DeLury models (each including the Ricker modification) were applied to seasonal Pipi catch and effort data and involve regression fits of linear models (Hilborn & Walters 2001). *Assumptions*: i) a closed population (no recruitment, natural mortality, immigration or emigration); (ii) constant catchability; (iii) sufficient removals such that CPUE is substantially reduced; (iv) equal vulnerability of individuals to capture; (v) independence of units of effort and (vi) the assumptions associated with linear regression (Liggins 2018). Depletion analyses estimate depletion of the component of the stock above the selectivity point, not depletion of the spawning stock.
3. The length-based spawning potential ratio (LBSPR) method uses maximum likelihood methods to find the values of relative fishing mortality (F/M) and selectivity-at-length that minimise the difference between the observed and the expected length composition of the catch and calculates the resulting spawning potential ratio (SPR) (Hordyk *et al*., 2015, 2016). LBSPR is an equilibrium-based method with the following assumptions: (i) asymptotic selectivity, (ii) growth is adequately described by the von Bertalanffy equation, (iii) a single growth curve can be used to describe both sexes, (iv) length-at-age is normally distributed, (v) rates of natural mortality are constant across adult age classes, (vi) recruitment is constant over time, and (vii) growth rates remain constant across the cohorts within a stock (Hordyk *et al*., 2015, Pons *et al*., 2020). The size composition of commercial landings is also assumed to be representative of the stock.
4. The optimized catch-only model (OCOM) uses time series of catches and employs a stock reduction analysis using priors for *r* and stock depletion derived from natural mortality and saturation estimated using the Zhou-BRT method, respectively (Zhou *et al*., 2018). The stock reduction analysis employs a Schaefer biomass dynamics model and an algorithm for identifying feasible parameter combinations to estimate biomass, fishing mortality, and stock status. *Assumptions*: include those associated with the use of the simple Schaefer surplus production model, such as limited variation in many parameters over time. For more information on assumptions refer to Martell and Froese (2013), Froese *et al*., (2017) and Zhou *et al*., (2018).
5. Catch-MSY model-assisted catch-only assessment (Martell and Froese, 2013) using the 'simpleSA' package in R (Haddon *et al*., 2018).This uses population productivity (*r*) and carrying capacity (*K*) parameters of an underlying Schaefer production model, applied to

total annual catches, to estimate the ranges in biomass and harvest rate that could have resulted in the annual catches. *Assumptions*: Estimated ranges of the population growth rate parameter (*r*) and carrying capacity (*K*) of the stock are pre-determined through an assumed resilience; the underlying population biomass model is very generic and simplistic.

Sources of uncertainty evaluated:

The utility of the LBSPR model was tested using a number of robustness tests to understand the sensitivity of the model to various values of the input parameters.

The effect of four different constant catch scenarios on the 5-year projections of estimated biomass and harvest rate trajectories from Catch-MSY analyses.

To understand the sensitivity of the OCOM model to various values of the input parameters, analyses were completed for a range of natural mortalities.

Status Indicators - Limit & Target Reference Levels

Biomass indicator or proxy	None specified in a formal harvest strategy. In the interim, for the purposes of this stock assessment a weight-of-evidence approach was used, which included: the mean estimated biomass depletion (as a percentage of the estimated unfished biomass) from Catch-MSY analyses and OCOM analyses; estimated biomass and the depletion of this biomass over the season from stock depletion models; and annual standardised catch rates from the fishery and three main regions.
Biomass Limit Reference Point	None specified in a formal harvest strategy. For the purpose of this stock assessment, 20% of the estimated unfished biomass was selected for the limit reference point (B_{lim}).
Biomass Target Reference Point	None specified in a formal harvest strategy. For the purpose of this stock assessment, 48% of the estimated unfished biomass was selected as the target reference point (B_{targ}).
Fishing mortality indicator or proxy	None specified in a formal harvest strategy. For the purposes of this stock assessment a weight-of-evidence approach was used, which included: estimates of exploitation rate (calculated as catch / initial biomass) from stock depletion models; estimates of relative fishing pressure (F/M) and SPR from length based spawning potential ratio; and

	mean annual relative fishing mortality from Catch-MSY analyses.
Fishing mortality Limit Reference Point	None specified in a formal harvest strategy. For the purposes of this stock assessment the estimated harvest rate corresponding to 20% of estimated maximum biomass for the limit reference point (F_{lim}) and the estimated harvest rate corresponding to when the stock is a 40% of estimated maximum biomass for the target reference point (F_{targ}) were selected.
Fishing Mortality Target Reference Point	None specified in a formal harvest strategy.

Stock Assessment Results

Standardised commercial catch rates (in mean CPUE kg h^{-1}) is likely to be the most reliable index of relative abundance for Pipi. For recent data analysed as mean daily catch rates (available from 2009/10 to 2020/21, Fig. 4), catch rates (regions combined) have remained stable and average over the last 9 years.

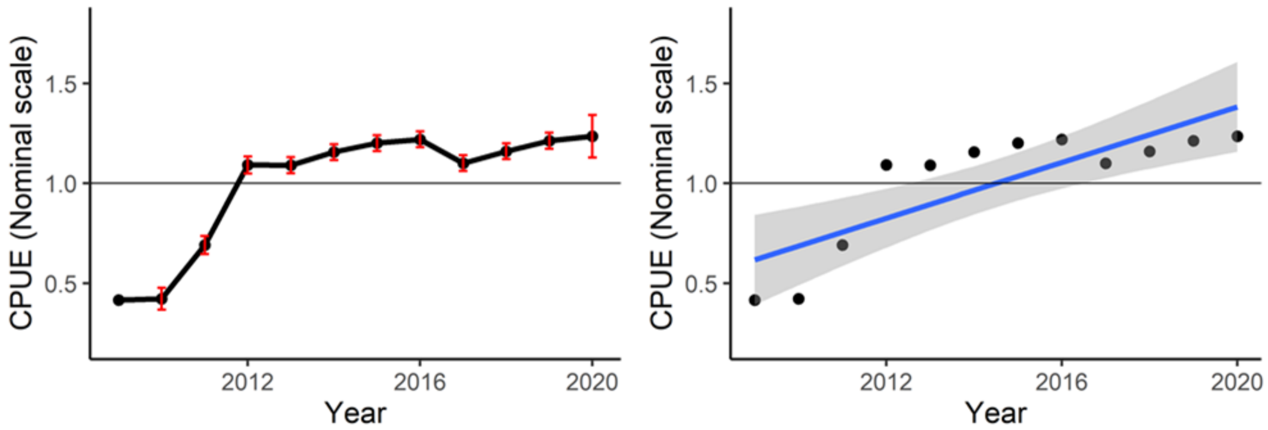

Figure 4. Standardised commercial catch rates for combined regions (nominal scale) and fit of linear regression model to standardised catch rates with standard error of the regression line shown (right plot).

Simple stock depletion models were applied to 9 combinations of regions and 10 beaches during the period 2009 to 2018. In the majority of years, the commercial harvest did not result in declining CPUE across the 5 - 6 month fishing season, suggesting that the fishing mortality was not significantly impacting abundance/biomass. Estimates of regional exploitation rate (calculated as catch / initial biomass) ranged between 0.24 and 0.29 for the years examined for Regions 1 and 4 and between 0.28 and 0.73 for the years examined for Region 3. For individual beaches, estimates of exploitation rate ranged between 0.20 and 0.83. In 2018, reported landings of 73.2 t from Stockton Beach (Fig. 5) were estimated to remove 40 – 46% of the biomass of Pipis (≥ 4.5 cm) during the fishing season (June - December).

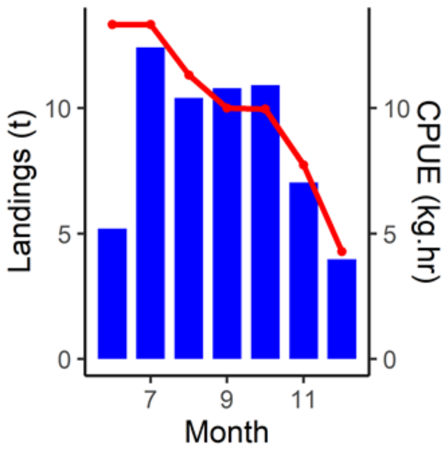

Figure 5. Monthly catch (t - blue bars) and CPUE (kg/hr^{-1} - red line) from Stockton Beach in 2018.

For the optimized catch-only analyses at the fishery level, B/B_{msy} remained above 1 from 1984 to 1999, after which it decreased substantially to a minimum of 0.07 (0.06 – 0.10) in 2008 (Fig. 6). For the range of *M* examined (1.0 - 1.4), B/B_{msy} in 2020/21 was estimated to range between 0.25 to 0.28. The trend in F/F_{msy} was mostly similar between analysis completed for the fishery and the three main regions separately.

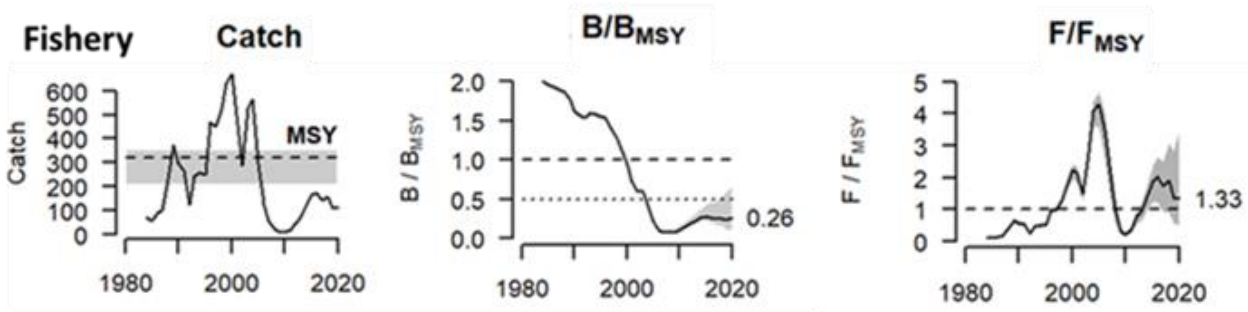

Figure 6.OCOM outputs for the historical commercial catch series of Pipi for M = 1.2. Grey shading indicates uncertainty (95% confidence intervals) in parameter estimates.

The Catch-MSY model-assisted catch-only assessment estimated biomass (B) to have been above B_{targ} from 1984 to 2001, although declining from ~1988 onwards as a result of increasing catches. Estimates of current biomass range from 9 – 49% of B_0 (Fig. 7).

Estimated mean harvest rate remained low from 1984 - 1995 and then increased rapidly, exceeding estimated F_{targ} in 1996 and exceeding estimated F_{lim} from 1998 to 2006, resulting in decreasing biomass over this period. Harvest rate declined rapidly from 2004 to 2010 as a result of decreased catches and has remained near F_{targ} from 2015 to 2021 (Fig. 7).

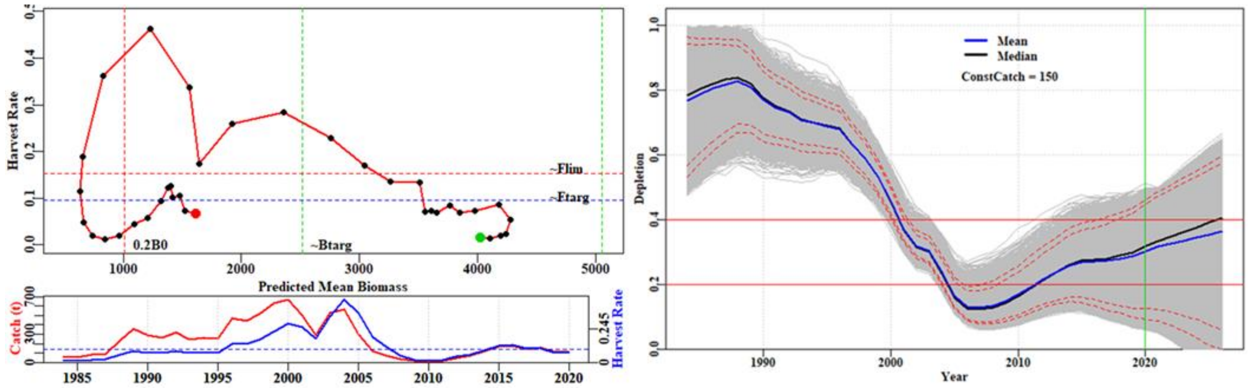

Figure 7. Phase plot (top) and predicted mean biomass (bottom, red line, tonnes) and harvest rates (blue line) in each year for a modified Catch-MSY model fitted to Pipi commercial catch. The first year of data is indicated by the green dot and the last by the red dot. Limit reference points (red dashed lines) of 20% maximum biomass ($0.2B_0$) and corresponding harvest rate ($\sim F_{lim}$), default 40% target biomass ($\sim B_{targ}$, green dashed line) and corresponding harvest rate ($\sim F_{targ}$, blue dashed line) also indicated. Right panel shows predicted depletion trajectory in each year for constant catch projections of 150 t.

LBSPR: The size of selectivity (SL_{50} ~5.1 cm) relative to the size of maturity (L_{50} ~3.4 cm) indicates that a high level of spawning potential of the Pipi stock is protected from fishing pressure (Fig. 8). Despite estimates of relative fishing pressure (F/M) being high (2.7–4.2), moderate levels of spawning potential (SPR) are being conserved (0.43 – 0.45). The expected size composition of catches at SPR targets of 60 and 75% include a greater number of individuals in all size classes > 6 cm but are dominated by individuals in the 6 – 7 cm size class.

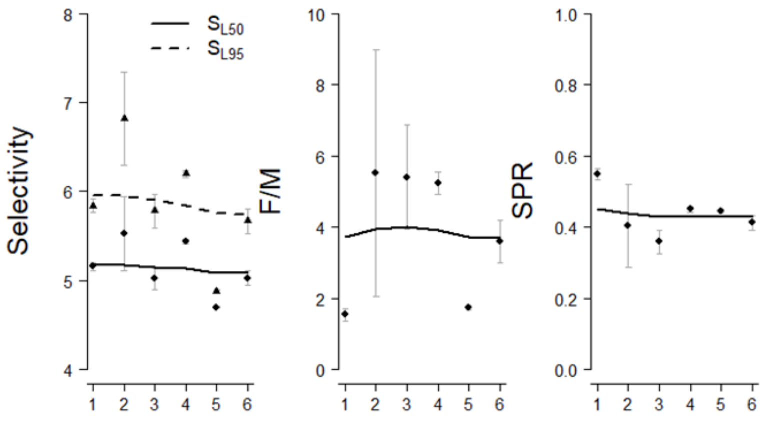

Figure 8. LBSPR model outputs including length at 50% (SL_{50}) and 95% (SL_{95}) selectivity, estimates of fishing/ natural mortality (F/M) and Spawning Potential Ratio (SPR).

Stock Assessment Result Summary

Biomass status in relation to Limit	Results of the current assessment varied depending on the spatial-scale selected. For recent data analysed as mean catch rates ($kg.hr^{-1}$), catch rates (regions combined) have remained stable and above average over the last 9 years. However, catch rates within the three main regions of the fishery are variable. Biomass depletion estimates from Catch-MSY for the fishery (9 - 49%) and regions were ≤ the

	target reference point of 48%. For OCOM analyses at the fishery level, B/B_{msy} in 2020/21 was estimated to range between 0.25 to 0.28. There is considerable uncertainty in these catch rate and model estimates and some model scenarios produced current biomass estimates below the limit reference point. For the years in which simple stock depletion models were applied to regional catch and CPUE, estimated exploitation rates in Region 1 and Region 4 were < 30 per cent while in Region 3 within-season exploitation rates ranged from 28 – 73%. Estimates of exploitation rate for individual beaches ranged between 34 and 63% for beaches examined in Region 3 and between 20 and 84% for the beaches examined in Region 4. Overall, the weight of evidence indicates that the biomass of the stock is unlikely to be recruitment impaired.
Biomass status in relation to Target	Biomass depletion estimates from Catch-MSY and OCOM analyses were ≤ the target reference point of 48%.
Fishing mortality in relation to Limit	Results of the modified Catch-MSY modelling suggest that the current harvest rate of Pipi is below F_{lim}. Despite estimates of relative fishing pressure (F/M) being high (2.7 – 4.2), moderate levels of spawning potential (SPR) are being conserved (0.40 – 0.58) for the range of natural mortalities examined.
Fishing mortality in relation to Target	NA
Current SAFS stock status	Sustainable (Ferguson *et al*., 2021)

Fishery interactions

Nil interactions have been reported between the Estuary General Handgathering Fishery and species protected under the Environment Protection and Biodiversity Conservation *Act 1999*.

Qualifying Comments

The depletion analyses presented estimate depletions of the component of stock above the selectivity point. As the SAM_{50} (~3.4 cm) for Pipi is below the MLL (4.5 cm) and the SL_{95} (~5.1 cm), depletion analyses do not estimate depletion of the spawning stock.

The modelling approaches used in the current assessment are very simplistic and generic; therefore, results should be interpreted with caution. There is high uncertainty in the estimates of biomass depletion, harvest rate and MSY derived from catch data using Schaefer production model-assisted Catch-MSY analysis. Production models are most applicable when exploitable biomass (or more accurately exploitable biomass that is above selectivity point) lines up with spawning biomass. The results of the LBSPR analyses illustrate a disconnect between exploitable and spawning biomasses for Pipis.

The relationship between CPUE and abundance is often disproportional and nonlinear (Harley *et al*. 2001). Aggregations of fish and fishing effort have been shown to produce hyperstability in the CPUE- abundance relationship, in which CPUE remains stable while actual abundance declines (Harley *et al*., 2001, Ferguson *et al*., 2015). Management regulations that restrict harvest to 40 kg of Pipi per fisher day (2011 - 2018) may have produced hyperstable catch rates. The potential for re-aggregation of Pipi following fishing suggests that the abundance of Pipi may decline faster than CPUE as the stock is depleted (Defeo, 2003). If fishers succeed in finding aggregations of Pipi, large declines in CPUE will only be observed when the number of aggregations is greatly reduced and catching operations become more random. Simple estimates of commercial CPUE remain a poor predictor of Pipi relative biomass compared to those obtained from fishery-independent surveys in SA (Ferguson *et al*. 2015).

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