Assessment Authors and Year

Johnson, D. 2021. NSW Stock Status Summary 2020/21 – Pipi – (*Donax deltoides).* NSW Department of Primary Industries. Fisheries NSW. 9 pp.

Stock Status

Current stock status	On the basis of the evidence contained within this assessment, Pipi is currently assessed as **Sustainable** for the NSW component of the stock.

Stock Structure

Results of a recent collaborative study which used microsatellite and mitochondrial DNA marker techniques on samples collected from sites along the New South Wales (NSW), Victoria (Vic) 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). The patterns of gene flow and population genetic structure revealed in this study are consistent with the trajectory of ocean currents in south-eastern Australia. It is likely therefore that Pipis on beaches in NSW comprise a single metapopulation, however, in any given year most recruits are likely to be self-seeded or to come from nearby, adjacent beaches (Murray-Jones, 1999).

Stock Status – New South Wales

Catch Trends - Commercial fisheries

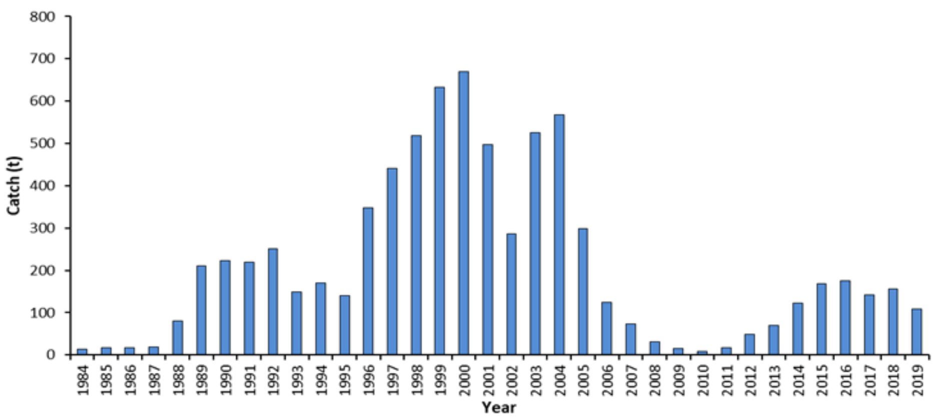


Figure 1. Commercial reported landings of Pipi for NSW from 1984/85 to 2019/20.

Total annual reported commercial catches of Pipi increased steadily from 15 t to 80 t from 1984/85 – 1988/89, and then increased rapidly to a peak of 670 t in 2000/01. Catches exceeded 250 t yr^{-1} 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. 45 mm 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 tonnes in 2019/20 were 108.4 tonnes for the 12 month fishing period. Total reported quota usage during 2019/20 was 112.8 tonnes.

Recreational and Indigenous

Estimates of state-wide recreational harvest are available from the National Recreational and Indigenous Fishing Survey and New South Wales state-wide surveys completed in the 2000/01, 2013/14 and 2017/18 financial years, respectively (Henry & Lyle 2003, West et al. 2015, Murphy et al. 2020). In 2000/01, the catch from New South Wales was estimated to be 7 t (1, 076, 765 ± 169, 937 Pipis), representing one per cent of total harvest. In 2013/14 and 2017/18 the state-wide survey estimated the catch to be 1.3 t (87, 760 ± 31, 272 Pipis) and 1.1 t (75, 696 ± 42, 423 Pipis), respectively. In 2000, regulations were implemented to prohibit recreational harvesting of Pipi for human consumption, thus restricting recreational fishers to harvesting for bait on only.

Fishing effort trends

Reported effort$_{dy}$ in the 2019/20 fishing season (1, 960 days) was approximately 35% of the historical peak of 5, 610 days in 2001/02 (Fig. 2). From 2009, 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, 786 hours in 2019/20 (Fig 2). Under revised management arrangements in 2019/20, effort in FisherDays 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.

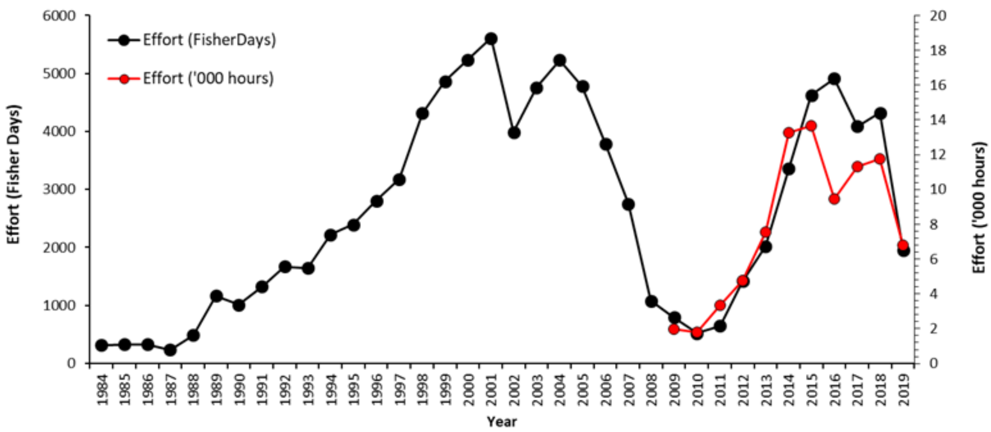


Figure 2. Annual reported commercial effort in units of FisherDays (1984/85 to 2019/20) and hours (2009/10 to 2019/20). Note: changes in reporting requirements limit consistent interpretation of the effort (FisherDays) time series.

Catch rate trends

Pipi standardised catch rates were predicted from generalised linear models (GLM). The GLM statistical modelling provided an estimate of mean catch rates that were corrected for a variety of variables that bias raw data. The GLM models were fitted using the statistical software packages

Cede (Haddon *et al*., 2018) and R (R Development Core Team 2017). Explanatory model terms considered different catch rates between fishing years, months, individual fisher operations (Authorised fisher ID), their transformed fishing effort and EGF management regions. Factors selected for standardisation of catches within EGF regions were; year, month and Authorised fisher ID.

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 2019/20), catch rates (regions combined) have remained stable and above the 10-year average over the last 8 years (Fig. 3). However, catch rates within the three main regions of the fishery are variable. For example, catch rates in Region 1 have declined consistently each year from 2015, and were below the 10-year average in 2019/20 (Fig. 3). In contrast, catch rates in Region 3 have remained stable over the last 5 years, but are lower than Region 1 (Fig. 3). Despite an increase in total catches and the proportion of the state-wide harvest taken in Region 4, catch rates have remained stable and above the 10-year average for the last 6 years (Fig. 3). Data presented at the regional level is limited to Regions 1- 4, where >98% of the catch is harvested (2009/10-2018/19).

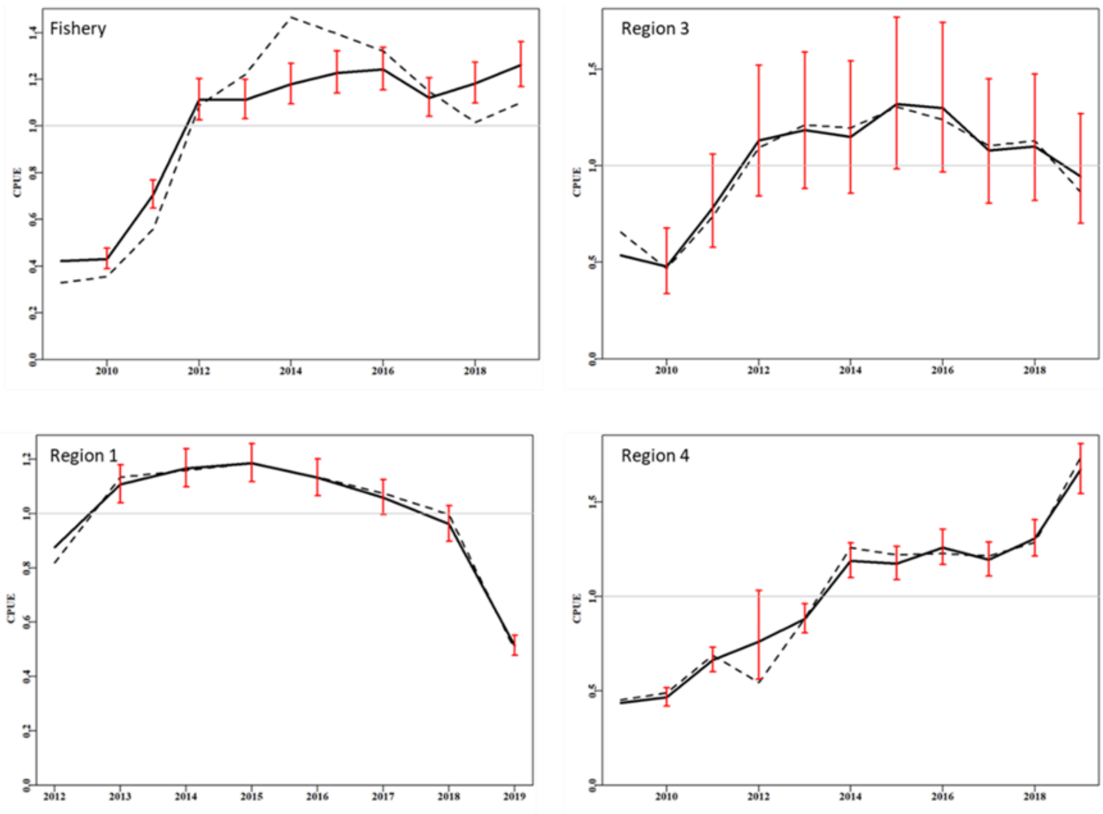


Figure 3. Standardised commercial catch rates (nominal scale; CPUE kg h^{-1} from daily records) of Pipi in the NSW EGF. The dashed line is the geometric mean CPUE while the solid line with 95% confidence intervals is the standardised CPUE. The horizontal line represents the average catch rate (2009/10 – 2019/20).

Stock Assessment Methodology

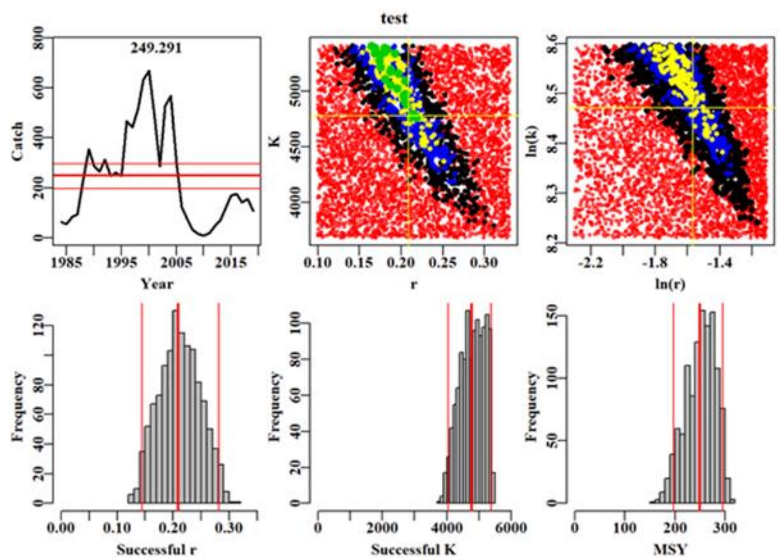
Year of most recent assessment	2021
Assessment method	Weight of evidence approach, including; standardised catch rates, estimation of within-season depletion of Pipis and Catch-MSY model-assisted catch-only assessment.
Main data inputs	1. Landed commercial catch -1984/85 to 2018/19. 2. CPUE- kg.FisherDay^{-1} 2009/10 to 2018/19.
Key model structure and 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. 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, with parameters that remain constant through time; the model outcomes are quite dependent on the lower bound of *r* selected (Martell and Froese 2013). 'Resilience' was set to low in the Catch MSY model specification, which allows for a possible range in population growth rate (*r*) of 0.1 - 0.6. 3. Depletion models; Leslie and DeLury models (each including the Ricker modification) were applied to the seasonal Pipi data and involve regression fits of linear models. These depletion models are usually expressed in terms of abundance (numbers) rather than biomass (weight). Biomass (B) replaces abundance (N) in the formulae describing the Leslie and DeLury models here. Because a minimum legal length of 45 mm applies to the harvest of Pipis in NSW, the biomass that is modelled and, by definition, the biomass of Pipis >= 45 mm (Liggins, G.W. 2018). *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 (see; Hilborn & Walters, 2001; Ogle, 2015).
Sources of uncertainty evaluated	The effect of four different constant catch scenarios on the 5-year projections of estimated biomass and harvest rate trajectories.

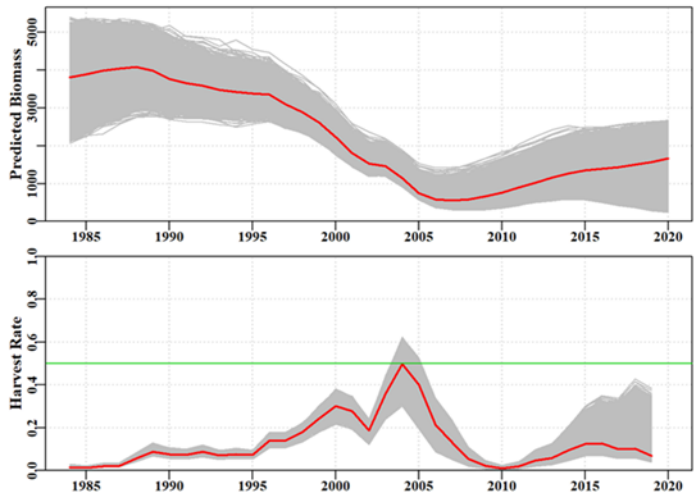
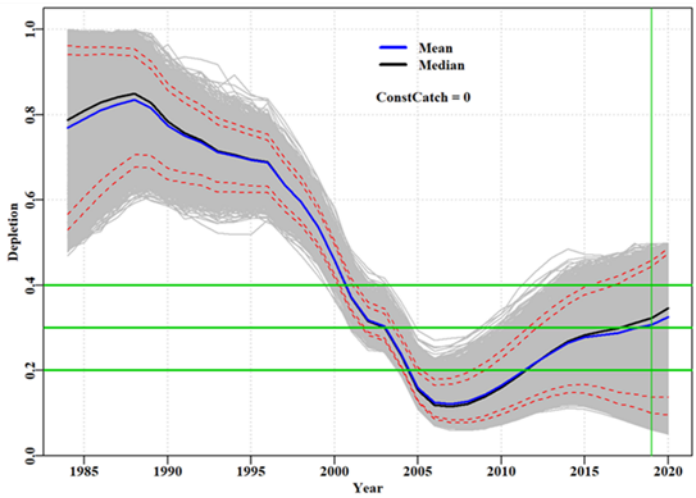
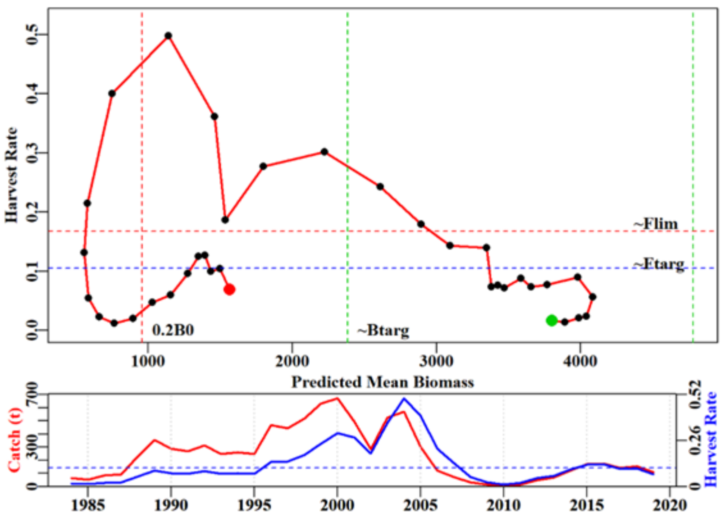
Status Indicators and Limits Reference Levels

Biomass indicator or proxy	None specified in a formal harvest strategy. For the purposes of this assessment the mean estimated biomass depletion (as a percentage of the estimated maximum biomass, K) from modified Catch-MSY analyses (e.g., Martell and Froese 2013) was selected as a proxy.
Biomass Limit Reference Level	None specified in a formal harvest strategy. For the purposes of this stock assessment the values of 20% of estimated maximum biomass for the limit reference point (B_{lim}) and 40% of estimated maximum biomass as the target reference point (B_{targ}) were selected.
Fishing mortality indicator or proxy	None specified in a formal harvest strategy. For the purposes of this stock assessment the estimated harvest rate from modified Catch-MSY analyses was selected.
Fishing mortality Limit Reference Level	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 (H_{lim}) and the estimated harvest rate corresponding to when the stock is a 40% of estimated maximum biomass for the target reference point (H_{targ}) were selected.

Stock Assessment Results

2. Pipi CMSY assessment results showing: annual catch trajectory (t) with estimated MSY and 90th percentile; scatter plots of *K* vs *r* combinations explored with red dots depicting failure and other colours depicting combinations of initial depletion that succeeded for each *r*-*K* pair (right-hand plot is the log-transformed version of the left-hand plot); and histograms of the probability distributions of successful *r*-*K* pairs and the resulting MSY estimates, with red lines showing the median and 90th percentile confidence intervals.



2. Range of depletion trajectories for successful *r-K* pairs, showing mean and median annual depletion and 80th and 90th percentiles (dashed lines). The lower green line is the $0.2B_0$ limit reference point, while the upper is BMSY ($0.4B_0$) target reference point.	 
2. Pipi stock status trajectory from 1984 - 2019, showing annual stock status in estimated biomass (t) and harvest rate. Reference levels are shown for biomass target (BMSY) and limit ($0.2B_0$) reference levels, and for the corresponding harvest rates that should keep biomass at or above the target F_{targ} (FMSY) and above the limit F_{lim} (FB_{20}). The start of the trajectory in 1986 is indicated by a green point and final year 2019 by a	

<table>
<tr><td>red point. The red line on the bottom plot is catch and the blue line is harvest rate.</td><td></td></tr>
<tr><td>2. Summary output of key parameters from the Pipi Catch-MSY stock assessment, showing mean (50%) estimates for MSY and Current Depletion, with 95% intervals.</td><td>
<table>
<tr><td>Parameter</td><td>5%</td><td>50%</td><td>95%</td></tr>
<tr><td>MSY</td><td>175</td><td>246</td><td>293</td></tr>
<tr><td>CurrDepl</td><td>0.09</td><td>0.33</td><td>0.49</td></tr>
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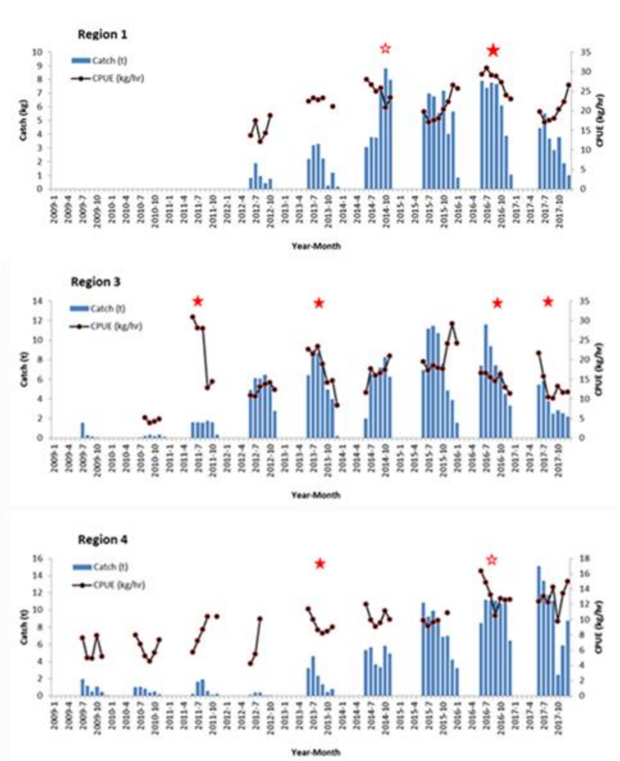
</td></tr>
<tr><td>3. Within-season CPUE declined during: 2014 and 2016 in Region 1; 2011, 2013, 2016 and 2017 in Region 3; 2013 and 2016 in Region 4. It was for these 8 combinations of region and fishing season for which depletion models were applied. During the other fishing seasons in each region, trends in CPUE were either stable or increasing.

For the eight instances in which stock depletion models were applied in this this study (i.e. when within-season declines in CPUE were apparent), estimated exploitation rates in 2 of the regions (Region 1 and Region 4) were within the range 0.24 – 0.29. Within-season exploitation rates during 4 years in Region 3 were greater and in the range 0.28 – 0.73.</td><td>


Monthly catch (t) and CPUE (kg/hr) by region between 2009 and 2017. Red stars indicate seasons for which depletion models could be applied. A solid red star indicates that the regression model underlying the Leslie model was statistically significant (P<0.05). Source; Liggins 2018.</td></tr>
<tr><td>Biomass status in relation to Limit</td><td>The assessment estimates biomass (B) to have been above B_{targ} from 1985 - 2001, although declining from ~1988 onwards as a result of increasing catches. Biomass is estimated to have remained between B_{targ} and B_{lim} from 2001-2005 and then decline below B_{lim} from 2004 to 2011.

The mean estimate of current Biomass is ~33% of B_0, with a 95% CI of 9% - 49%. Current estimated mean B is above</td></tr>
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	the B_{lim} level of $0.2B_0$. Five-year projections at the current TACC of ~150 t indicate that B is predicted to increase slowly at that catch level. In the majority of years, in each of the 3 regions examined here, 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.
Fishing mortality in relation to Limit	Estimated mean harvest rate remained low from 1986 - 1995 and then increased rapidly, exceeding estimated F_{targ} in 1996 and exceeding estimated F_{lim} from 1998 – 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 2015-2018.
Previous SAFS stock status	2018 sustainable.
Current SAFS stock status	Using the weight of evidence approach, Pipi is considered to be sustainable.

Qualifying Comments

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.

A key assumption in the Catch-MSY analysis is the ability to define a reasonable prior range for the parameters of the Schafer model. Estimated ranges of the population growth rate parameter (r) and carrying capacity (K) of the stock are pre-determined through an assumed resilience; the model outcomes are quite dependent on the lower bound of r selected (Martell & Froese, 2013). 'Resilience' was set to low in the Catch-MSY model specification, which allows for a possible range in population growth rate (r) of 0.1 - 0.6.

Catch-MSY modelling may perform poorly for short-lived species, particularly stocks characterised by episodic recruitment and long-term changes in productivity.

A key uncertainty not addressed in this assessment relates to stock structure. Pipi probably constitute a number of separate biological stocks with limited connectivity across the extent of the fishery, which have been subject to different exploitation patterns.

The uncertainty regarding the spatial variation in total removals hampers the interpretation of the modified Catch-MSY modelling results.

Likewise, the uncertainty around the accuracy of historical commercial catch data should be considered when interpreting the results of the modified Catch-MSY modelling.

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 reaggregation 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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