Fisheries

Assessment of the Southern Zone Abalone (*Haliotis rubra* and *H. laevigata*) Fishery in 2019/20

O. Burnell, S. Mayfield and A. Hogg

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SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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EXECUTIVE SUMMARY

This report provides an assessment of stock status for blacklip (*Haliotis rubra*) and greenlip (*H. laevigata*) abalone (hereafter referred to as blacklip and greenlip, respectively) in the Southern Zone (SZ) of the South Australian Abalone Fishery (SAAF) for the 2019/20 fishing season.

Blacklip abalone

The SZ blacklip fishery experienced almost two decades of stable catches and increasing catch-per-unit-effort (CPUE) throughout the 1990s and 2000s. After 2010/11, CPUE and fishery-independent survey (FIS) densities began to decline, followed by decreases in blacklip catch and, shortly thereafter, total allowable commercial catches (TACCs). During this period, the fishery also experienced a widespread summer mortality event (2012/13) and the introduction of a new spatial management regime (2013/14). Following a contemporary low of 97 $kg.hr^{-1}$ in 2015/16, CPUE has increased and stabilised at 109 $kg.hr^{-1}$ in 2019/20. FIS estimates of legal and sub-legal sized blacklip have remained relatively stable throughout recent surveys, albeit at levels considerably below historical peaks. In 2019/20, blacklip catches totalled ~118 t of the 132 t TACC (89%), despite disruptions to market access and diving activity related to the COVID-19 pandemic.

Despite stable biomass at the fishery level, there was evidence of contrasting levels of harvestable biomass among different spatial assessment units (SAUs) within the fishery. Two key SAUs, which have supported >40% of the total historical blacklip catches, Middle Point and Number 2 Rocks, show evidence of high harvestable biomass. Comparatively, Gerloffs Bay, Port MacDonnell and Rivoli Bay exhibited lower levels of harvestable biomass.

Application of the proposed harvest strategy (HS) in 2019/20 resulted in a **zone score of 6.8** that, in combination with the zone trend score of 5.2 (reflecting an increasing trend), defines the stock status for blacklip in the SZ in 2019/20 as '**sustainable**'. This is consistent with the status since 2016/17. The zone score of 6.8 translates to a recommended zonal catch of 132 t for 2021/22, which is the target catch level for the SZ blacklip fishery.

Greenlip abalone

Due to the ongoing low catches and limited data available for greenlip in the SZ, and the consequent inability to estimate either biomass or fishing mortality, the stock status for this species is classified as '**undefined**', which is consistent with previous classifications (Burnell *et al.* 2020).

Key statistics for the SZ blacklip and greenlip fisheries from 2013/14 to 2019/20 including number of active licences; total allowable commercial catch (TACC); total commercial catch (TCC); catch-per-unit-effort (CPUE); and stock status from the harvest strategy in the management plan and from the national fishery status reporting framework (NFSRF).

Blacklip

Season	No. licences	TACC (t)	TCC (t)	CPUE (kg.hr^{-1})	Stock Status
2013/14	6	151.5	125.7	100.3	Depleting
2014/15	6	151.5	134.6	96.8	Depleting
2015/16	6	126.0	122.6	97.5	Depleting
2016/17	6	126.0	125.9	99.5	Sustainable
2017/18	6	126.0	126.3	108.2	Sustainable
2018/19	6	132.0	131.5	111.0	Sustainable
2019/20	6	132.0	117.8	109.1	Sustainable*

Greenlip

Season	No. licences	TACC (t)	TCC (t)	CPUE (kg.hr^{-1})	Stock Status^
2013/14	6	7.2	3.6	na	Undefined
2014/15	6	7.2	4.4	na	Undefined
2015/16	6	6.0	3.8	na	Undefined
2016/17	6	3.6	3.2	na	Undefined
2017/18	6	3.6	3.1	na	Undefined
2018/19	6	1.8	1.9	na	Undefined
2019/20	6	1.8	1.9	na	Undefined

*In 2019/20 blacklip stock status was determined using the outcome from the new Harvest Strategy. Prior to this stock status was determined using the weight-of-evidence from the National Fishery Status Reporting Framework.
^The Harvest Strategy is not applied to greenlip. Stock status classifications are determined using the National Fishery Status Reporting Framework.

Keywords: Blacklip abalone, *Haliotis rubra*, greenlip abalone, *Haliotis laevigata*, stock assessment, harvest strategy, South Australia.

1 INTRODUCTION

1.1 Background

This document provides a fishery assessment report for blacklip and greenlip abalone in the Southern Zone (SZ) of the South Australian Abalone Fishery (SAAF; Figure 1-1), as part of the ongoing assessment program for these fisheries by the South Australian Research and Development Institute (SARDI). The assessment updates previous fishery assessment (Burnell *et al.* 2019) and status reports (Burnell *et al.* 2020) for the SZ. The aims of the report are to: (1) assess the current status of the blacklip and greenlip abalone resources in the SZ; (2) identify the uncertainty associated with the assessments; and (3) identify future research needs.

In this report, blacklip stock status was determined using the proposed harvest strategy (HS), which has been designed to deliver stock status outcomes consistent with the national fishery status reporting framework (NFSRF; Table 1-1; Piddocke *et al.* 2021). The proposed HS used in this report is included in a draft management plan that is currently being finalised (PIRSA in prep.). The proposed HS outcome presented in this report for blacklip utilises fishery-dependent (FD) data until the conclusion of the 2019/20 fishing season (i.e. 30 September 2020), and fishery-independent (FI) data from the 2018/19 fishing season. The proposed HS is not applied to greenlip, where stock status is determined using a weight-of-evidence approach.

Table 1-1. Terminology for the status of key Australian fish stocks (from Piddocke *et al.* 2021).

	Stock status	**Description**	**Potential implications for management of the stock**
	Sustainable	Biomass (or biomass proxy) is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (*i.e.* recruitment is not impaired) and for which fishing mortality (or proxy) is adequately controlled to avoid the stock becoming recruitment impaired	Appropriate management is in place
	Depleting	Biomass (or proxy) is not yet depleted and recruitment is not yet impaired, but fishing mortality (or proxy) is too high (overfishing is occurring) and moving the stock in the direction of becoming recruitment impaired	Management is needed to reduce fishing mortality and ensure that the biomass does not become depleted
	Recovering	Biomass (or proxy) is depleted and recruitment is impaired, but management measures are in place to promote stock recovery, and recovery is occurring	Appropriate management is in place, and there is evidence that the biomass is recovering
	Depleted	Biomass (or proxy) has been reduced through catch and/or non-fishing effects, such that recruitment is impaired. Current management is not adequate to recover the stock, or adequate management measures have been put in place but have not yet resulted in measurable improvements	Management is needed to recover this stock; if adequate management measures are already in place, more time may be required for them to take effect
	Undefined	Not enough information exists to determine stock status	Data required to assess stock status are needed
	Negligible	Catches are so low as to be considered negligible and inadequate information exists to determine stock status	Assessment will not be conducted unless catches and information increase

1.2 History and description of the fishery

1.2.1 Commercial fishery

A review of the management history of the SAAF since its inception in 1964 is provided by Mayfield *et al.* (2012). Major management milestones are listed in Table 1-2. The SZ includes all coastal waters of South Australia east of meridian 139°E, with the exception of the Coorong and waters inside the Murray River mouth (Figure 1-1). The fishing season currently runs from 1 October to 30 September. There are currently six licences in the SZ. Total allowable commercial catches (TACCs) were introduced in 1988 (Table 1-2). In 2019/20, the blacklip TACC was 132 t whole weight, while the greenlip TACC was 1.8 t whole weight.

From 1 September 2013, substantial changes were made to the management arrangements for the SZ, following completion of a FRDC-funded project (FRDC 2004/019; Mayfield and Saunders 2008). Key among these changes was the implementation of spatial management, with area-specific minimum legal lengths (MLLs) and catch caps, which recognised the differing morphology and biology of blacklip across the SZ (Mayfield and Saunders 2008; Saunders and Mayfield 2008; Saunders et al. 2009a; 2009b). There were three key changes: (1) the four designated areas with historically lower MLLs and a separate TACC, termed ‘fish-down areas’ (FDAs), were removed (Figure 1-2); (2) 13 spatial assessment units (SAUs) were identified, that incorporated one to several of the existing mapcodes (Figure 1-3); and (3) different MLLs, catch targets and catch caps were assigned to the individual SAUs (Table 1-3).

Two other notable impacts on the SZ fishery in recent years include summer mortalities in 2012/13 and the recent COVID-19 pandemic. During the summer of 2012/13, blacklip stocks in the SZ were impacted by a period of anomalously high water temperatures (Government of South Australia 2013; Mayfield et al. 2013). While reports of mortalities were widespread, extending from Robe to Port MacDonnell, the severity of the stock decline remained largely unquantified. More recently, the COVID-19 pandemic, which occurred throughout the latter half of the 2019/20 season, has presented logistic and market related challenges for abalone divers, licence holders and processors.

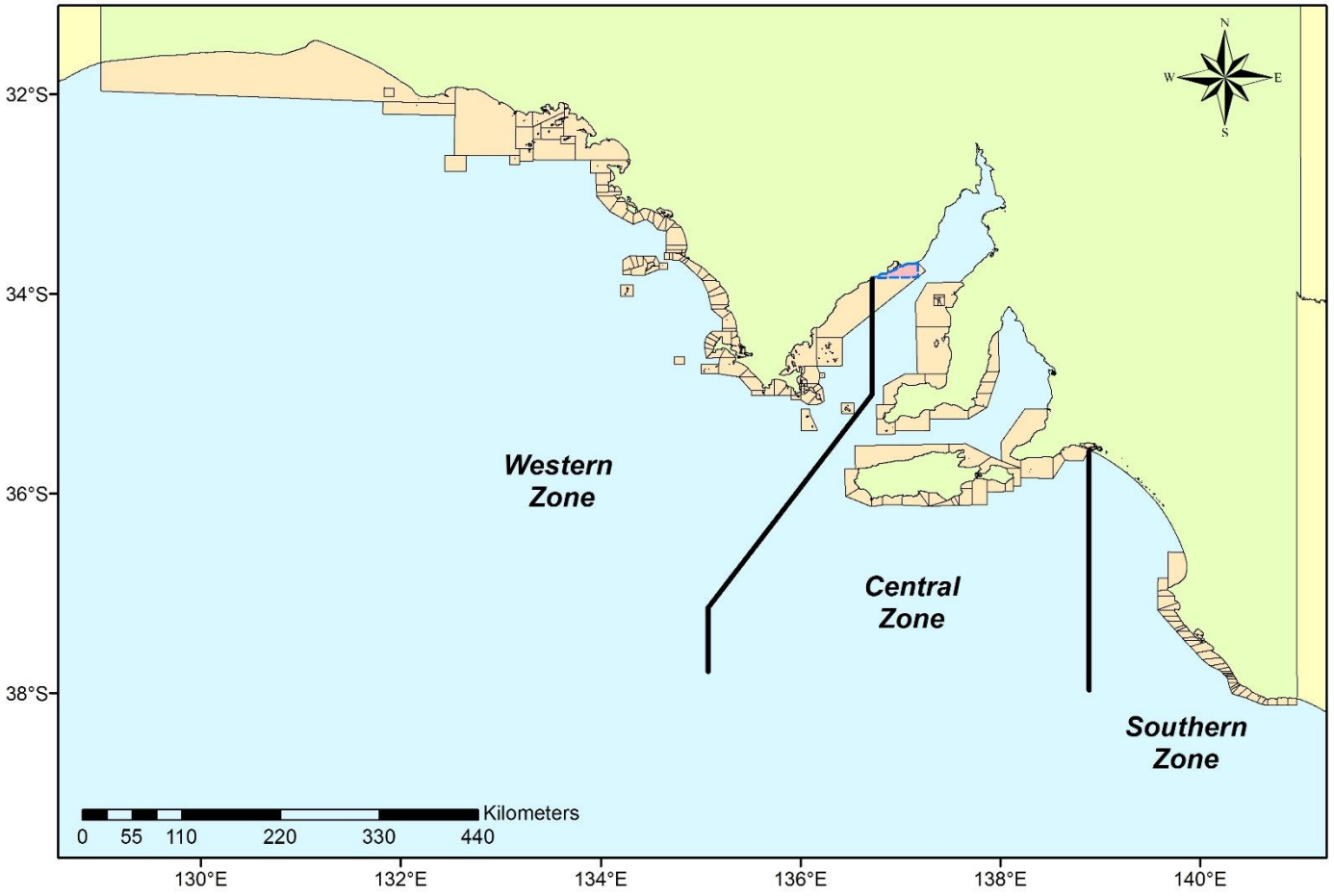

Figure 1-1. Fishing zones and mapcodes of the South Australian Abalone Fishery.

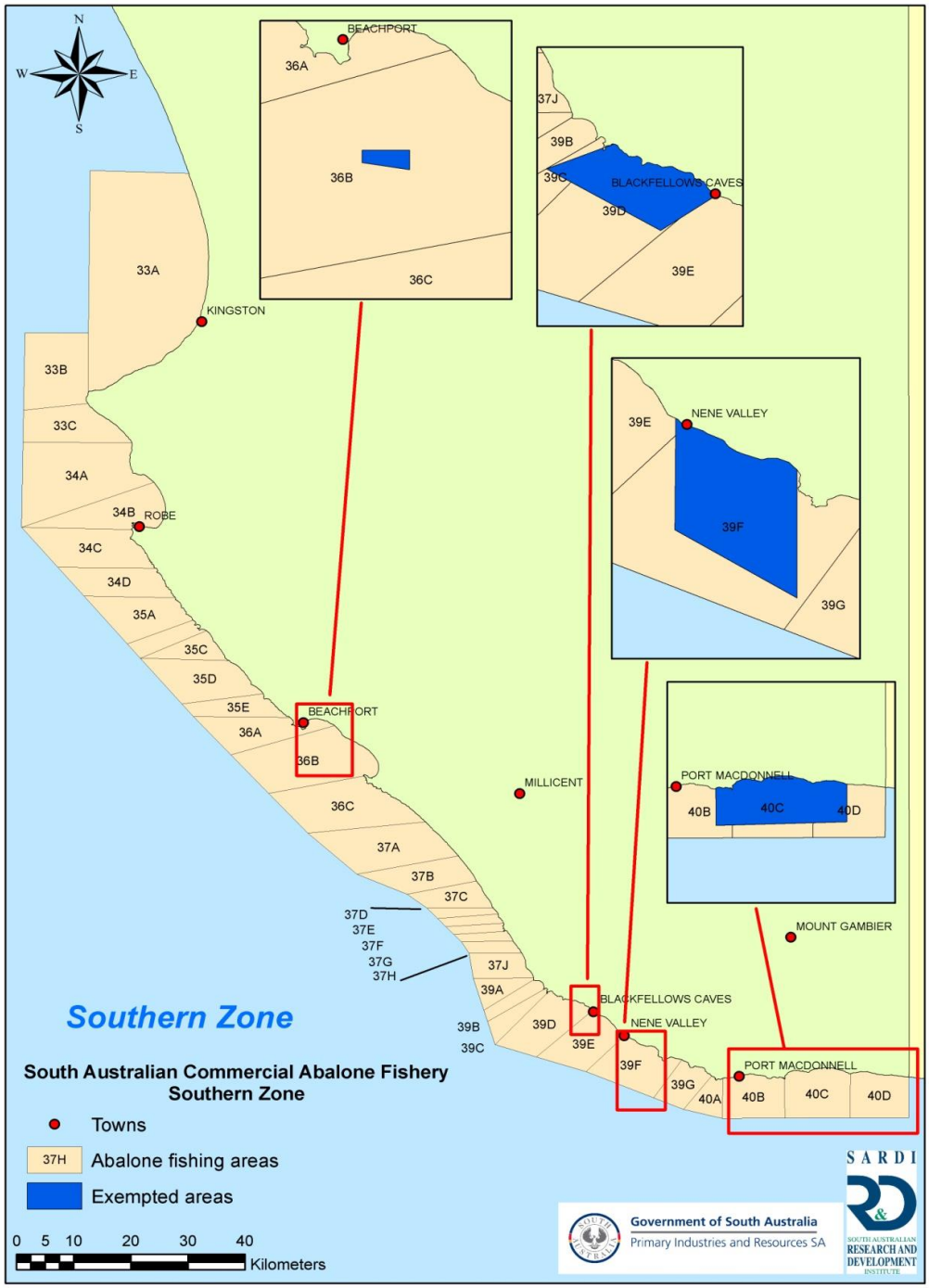

Figure 1-2. Abalone fishing areas (mapcodes, orange polygons) and historic 'fish-down' areas (i.e. exempted areas with lower historical minimum legal lengths between the early 1990s and 2012/13, blue polygons in inset maps) in the Southern Zone Abalone Fishery.

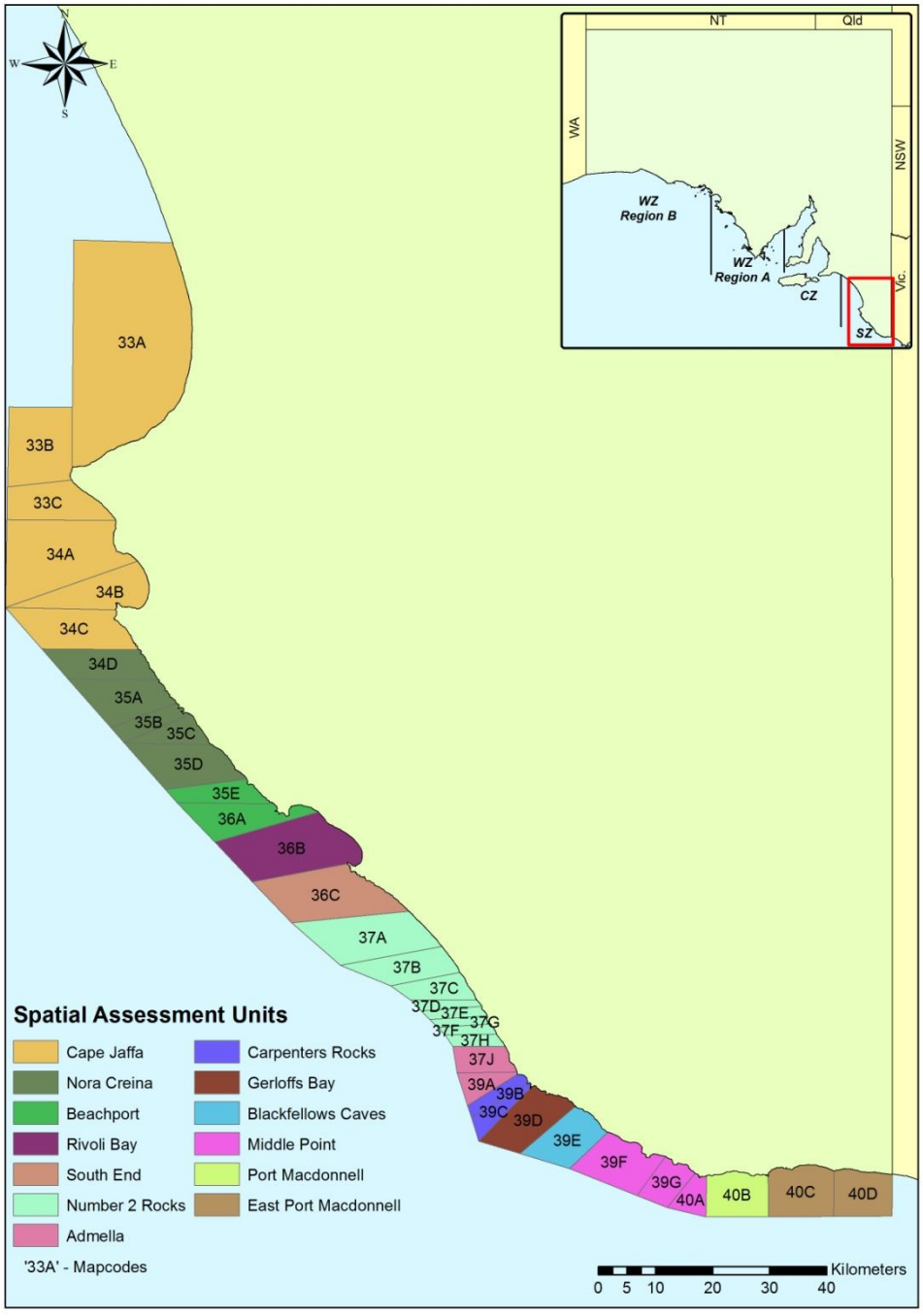

Figure 1-3. Spatial assessment units (SAUs) and mapcodes in the Southern Zone Abalone Fishery.

Table 1-2. Management milestones in the Southern Zone of the South Australian Abalone Fishery by fishing season (blacklip, BL; greenlip, GL).

Season	Milestone
1964	Fishery started
1971	>100 licences; licences made non-transferable
	Fishery divided into three zones
	Minimum legal length set at 130 mm shell length (SL) for both species
1976	30 Licences remained; 5 additional licences issued
1978	Sub Zones and fishing blocks replaced by map numbers and codes
1984	Blacklip minimum legal length amended to 120 mm SL in the Southern Zone
1988	Quota introduced to the SZ (108 t plus ad hoc fish-downs for blacklip and 3 t for greenlip)
	Blacklip minimum legal length amended to 125 mm SL in the Southern Zone
1992	Greenlip TACC increased from 3 to 6 t
1993	Abolition of owner-operator regulation
1994	Four 'fish-down' areas defined in the Southern Zone
	Blacklip TACC in non-FDA and FDAs set at 108 t and 36 t, respectively (total 144 t)
1995	Blacklip TACC in non-FDA and FDAs set at 84 t and 60 t, respectively (total 144 t)
1996	Blacklip TACC in non-FDA and FDAs set at 96 t and 48 t, respectively (total 144 t)
1997	Management Plan implemented (Zacharin 1997)
	Blacklip TACC in non-FDA and FDAs set at 108 t and 36 t, respectively (total 144 t)
2000	Greenlip TACC reduced from 6 to 3 t
	Blacklip TACC in the FDAs increase from 36 to 39 t (total 147 t)
2003	'fish-down' and non-'fish-down' areas with separate TACC and MLL formalised into regulations
	Blacklip TACC in non-FDA and FDAs set at 96 t and 51 t, respectively (total 147 t)
2004	Management Plan Revised (Nobes *et al.* 2004)
	Fishery assessed against the principles of ecologically sustainable development
2005	Greenlip TACC increased from 3 to 6 t
	Blacklip TACC in non-FDAs increased from 96 to 99 t
	Blacklip TACC in the FDAs reduced from 51 to 45 t
2010	Greenlip TACC increased from 6 to 7.2 t
2011	Blacklip TACC in the FDAs increased from 45 to 46.5 t
	Blacklip TACC in non-FDAs increased from 99 to 105 t
2012	New Management Plan including harvest strategy (PIRSA 2012)
	Blacklip TACC in FDAs increased from 45 t to 46.5 t
	Zonal TACCs for BL and GL were 105 t and 7.2 t, respectively
2013	Amalgamation of mapcodes into 13 SAU individual MLLs, catch targets and catch limits
	Zonal TACC for BL and GL were 151.5 t and 7.2 t, respectively
2014	Zonal TACC for BL and GL were 151.5 t and 7.2 t, respectively
2015	Zonal TACC for BL reduced from 151.5 t to 126 t. Zonal TACC for GL decreased from 7.2 t to 6 t
2016	Zonal TACC for BL and GL were 126 t and 3.6 t, respectively
	2016/17 Season extended from 1 September 2016 to 30 September 2017 (13 months)
2017	2017/18 Season reduced to 1 October 2017 to 30 September 2018 (12 months)
2018	Zonal TACC for BL increased from 126 t to 132 t. Zonal TACC for GL decreased to 1.8 t
2019	COVID-19 pandemic impacts fishery access and market access
	Provisions established for quota rollover of uncaught TACC to future seasons, due to COVID-19 pandemic
2020	Draft Management Plan including harvest strategy released for public consultation (PIRSA in prep.)

Table 1-3. Blacklip SAUs, mapcodes, catch caps in 2019/20 (shell weight), minimum legal shell lengths (MLLs) since 2013/14, historical MLLs for the areas inside and outside of the fishdown areas (FDAs) prior to 2013/14 and FDA number.

SAU	Mapcodes	Catch cap	Minimum legal length									FDA
		2019/20	2019/20	2018/19	2017/18	2016/17	2015/16	2014/15	2013/14	pre 2013/14	pre 2013/14	number
		(tonnes)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm outside FDA)	(mm inside FDA)	
Cape Jaffa	33A, 33B, 33C, 34A, 34B, 34C	5	125	125	125	125	125	125	125	125	NA	NA
Nora Creina	34D, 35A, 35B, 35C, 35D	8	125	125	125	125	125	125	125	125	NA	NA
Beachport	35E, 36A	8	125	125	125	125	125	125	125	125	NA	NA
Rivoli Bay	36B	11	110	110	110	120	120	120	120	125	110	3
South End	36C	8	125	125	125	125	125	125	125	125	NA	NA
Number 2 Rocks	37A, 37B, 37C, 37D, 37E, 37F, 37G, 37H	30	125	125	125	125	125	125	125	125	NA	NA
Admella	37J, 39A	16	125	125	125	120	120	120	120	125	NA	NA
Carpenters Rocks	39B, 39C	12	125	125	125	125	125	125	125	125	110	4
Gerloffs Bay	39D	15	110	110	110	110	120	120	120	125	110	4
Blackfellows Caves	39E	7	125	125	125	125	125	125	125	125	110	1 & 4
Middle Point	39F, 39G, 40A	35	120	120	120	120	120	120	120	125	110	1
Port MacDonnell	40B	15	120	120	120	120	120	120	120	125	110	2
East Port MacDonnell	40C, 40D	3	100	110	110	110	110	110	110	125	110	2

1.2.2 Recreational and traditional fishing

The total recreational abalone harvest in South Australia was estimated at 17,780 abalone.yr^{-1} for 2000/01 (Henry and Lyle 2003). Previous surveys in South Australia suggested that 19.5% of recreational fishing effort was expended in the SZ (Mayfield *et al.* 2001). Under this assumption, approximately 3,500 abalone (1.6 t) are recreationally harvested from the SZ annually, equivalent to 1% of the TACC. A creel survey undertaken in 2007/08 estimated the total annual recreational harvest in the SZ at <500 abalone (Jones 2009), further confirming the low recreational harvest in this fishery. The most recent telephone-based survey estimated that in 2013/14 the number (± SE) of recreationally-harvested abalone across SA was 282 ± 280 (0.11 t) blacklip and 4,395 ± 1,876 (1.93 t) greenlip (Giri and Hall, 2015). The estimates for blacklip from the 2013/14 survey are considered unreliable, given the large error range. The 2021/22 Statewide recreational fishing survey (FRDC Project 2020-056) is currently underway. Estimates of the levels of Aboriginal/Traditional fishing are currently unknown.

1.3 Biology of abalone

The biology of blacklip and greenlip abalone throughout South Australia is well documented in previous scientific and assessment reports (see Mayfield and Saunders 2008; Stobart *et al.* 2014, 2015; Burnell *et al.* 2016). Briefly, the distribution of blacklip and greenlip abalone overlaps throughout southern Australia but they have different overall ranges and habitat preferences. Blacklip range from Coffs Harbour (New South Wales) to Rottnest Island (Western Australia), while greenlip range from Flinders Island (Tasmania) to Cape Naturaliste (Western Australia). Typically, these two species occupy different habitats, with blacklip mostly inhabiting crevices and caves or the bottom of steep rock faces of topographically complex rocky reefs (1 to 30 m depth), whilst greenlip tend to inhabit the edge of reefs and boulders near sand or seagrass (5 to >50 m depth).

Blacklip have a broad-scale population structure (Brown 1991), although significant genetic differentiation can occur between sites less than 15 km apart (Shepherd and Brown 1993; Temby *et al.* 2007; Miller *et al.* 2009), suggesting limited dispersal among ‘metapopulations’ (Fleming 1997; Miller *et al.* 2009). In contrast, dispersal of greenlip appears to be more widespread, which is reflected in population genetics where metapopulations occur at the distances of up to 135 km (Miller *et al.* 2014). The relatively limited dispersal of abalone has implications for the recovery of depleted stocks from localised depletion, and contrasts with many other marine organisms, that have greater capacity for dispersal.

2 METHODS

2.1 Information sources for the assessment

Fishery-dependent and FI data are available for assessment of the SZ blacklip and greenlip fisheries. Details on data quality assurance and the methods used for analysing the FD and FI data are provided in Appendices 1 and 2, and are described briefly below.

2.2 Fishery-dependent data

The FD data have been collected since 1968 by fishers completing a catch and effort logbook for each fishing day. Catch length-frequency data was also obtained from commercial catches between 2000/01 to 2019/20. Fishery statistics are provided at four spatial scales: (1) the whole of the SZ, (2) individual SAUs, (3) combined data-limited SAUs, as required by the proposed HS, and (4) mapcodes. Multi-dimensional scaling (MDS) is used to examine temporal changes in the spatial distribution of blacklip catch. For a more detailed description of the FD methods see Appendix 2.2.1.

2.3 Fishery-independent data

Fishery-independent data consisted of estimates of blacklip densities for legal-sized and sub-legal-sized individuals in four surveyed SAUs (i.e. Middle Point, Number 2 Rocks, Gerloffs Bay and Rivoli Bay). Estimates of sub-legal and legal-sized blacklip are derived by combining fixed area total abalone counts and population length-frequency information. In some seasons, inclement weather and changes to the survey design prevented access to all survey sites. Consequently, some historical data were excluded to match the 2018/19 sampling locations, and historical density estimates were recalculated.

Estimates of total greenlip density are presented for Ringwood Reef, from the Rivoli Bay SAU. For a more detailed description of the FI methods see Appendix 2.2.2.

2.4 Harvest strategy

The proposed HS is based on two performance indicators (PIs), CPUE and legal-sized abalone density from FIS. Each SAU is designated as surveyed (i.e. FIS undertaken), unsurveyed (i.e. no FIS undertaken) or data-limited (i.e. limited FD data and no FIS undertaken). The data-limited SAUs are pooled for the estimation of CPUE and scoring in the proposed HS.

The PIs for CPUE and FIS legal-density for each SAU are scored based on reference points (a lower limit - score of 0; target range - score of 5; and upper limit -score of 10) derived from a reference period. The upper and lower limit reference points and the target range are indicated

on relevant plots of the proposed PIs for CPUE and FIS legal density. For CPUE, the reference period is from 1990 to 2000. For FIS, the reference period varies by SAU and is dependent on the number of years surveys have been undertaken. A minimum of four years of surveys are required for a score function to be applied and the reference period requires at least 10 surveys before it becomes fixed (similar to the CPUE reference period). The SAUs that fulfil these criteria (i.e. ≥4 years of FIS) in the SZ, are Middle Point, Gerloffs Bay and Rivoli Bay.

Scores for each SAU range from 0 to 10. For surveyed SAUs, SAU scores reflect equal weighting (i.e. 50:50) of the CPUE and FIS PIs. For unsurveyed and data-limited SAUs, the SAU scores are based on CPUE only. Scores for each SAU are then assigned relative weightings based on the last 12 years of catch, and summed to a zone score between 0 and 10, which represents the biomass proxy from the NFSRF. The slope from the last four zone scores is used as the proxy for fishing mortality, via a score function (see PIRSA in prep.).

The zone score (i.e. biomass proxy) translates directly to a recommended zonal catch, via a function which adjusts the target catch level (see PIRSA in prep.). The target catch for the SZ blacklip fishery is 132 t. For zone scores between 5 and 7, there is no adjustment to the target catch. For zone scores between 7 and 10, there is an optional linear increase from 1.0 (i.e. no adjustment) to a maximum of 1.3 (i.e. 30% above the target catch). Consequently, the theoretical maximum recommendable zonal catch for a score of 10 is 171.6 t (i.e. 132 t x 1.3 = 171.6 t). For a zone score between 5 and 1, the adjustment decreases linearly from 1.0 (i.e. no adjustment) to 0.1 (i.e. 90% below the target catch). Consequently, the recommended zonal catch for a score of 1 is 13.2 t (i.e. 132 t x 0.1 = 13.2 t). For zone scores <1 the recommended catch is zero.

A year-to-date (YTD) proposed HS outcome is also included in Appendix 3, which utilises FD and FI data to the end of June from the current fishing season (i.e. 2020/21). Upon collating this report, FIS in the Middle Point SAU are only partially completed. Therefore FIS scores for this SAU were used in two ways. First, the FIS score was ‘carried-forward’ 3 years from 2018/19 . This approach was presented to Industry in May 2021, with an updated outcome provided in July 2021. Second, the incomplete FIS were excluded from HS scoring, and the SAU Score and Weighted SAU Score for Middle Point, were based solely on CPUE. This approach is consistent with the harvest strategy described in the draft Management Plan. Again, this outcome was proved to Industry in July 2021.

The proposed HS is not applied to greenlip, due to an inability to estimate CPUE or undertake representative FIS.

3 RESULTS

3.1 Blacklip

3.1.1 Southern Zone

During the early formative years of the SZ fishery, catches of blacklip increased from approximately 25 t.yr^{-1} in the late 1960s to above 100 t by 1972 (Figure 3-1a). Throughout the 1970s and 1980s annual catches often varied considerably, averaging 108 t.y^{-1} over these two decades. After the highest recorded catch of 186 t in 1992/93, total annual catches were stable from 1994/95 to 2010/11 (range: 142–147 t.yr^{-1}; mean: 144 t.yr^{-1}) following the introduction of a combined SZ TACC for the FDA and non-FDAs. Slightly higher catches of ~150 t, were harvested in 2011/12 and 2012/13, before a period of lower catches since 2013/14 (mean: 126 t.yr^{-1}). In 2019/20, the catch of 118 t was 89% of the 132 t TACC.

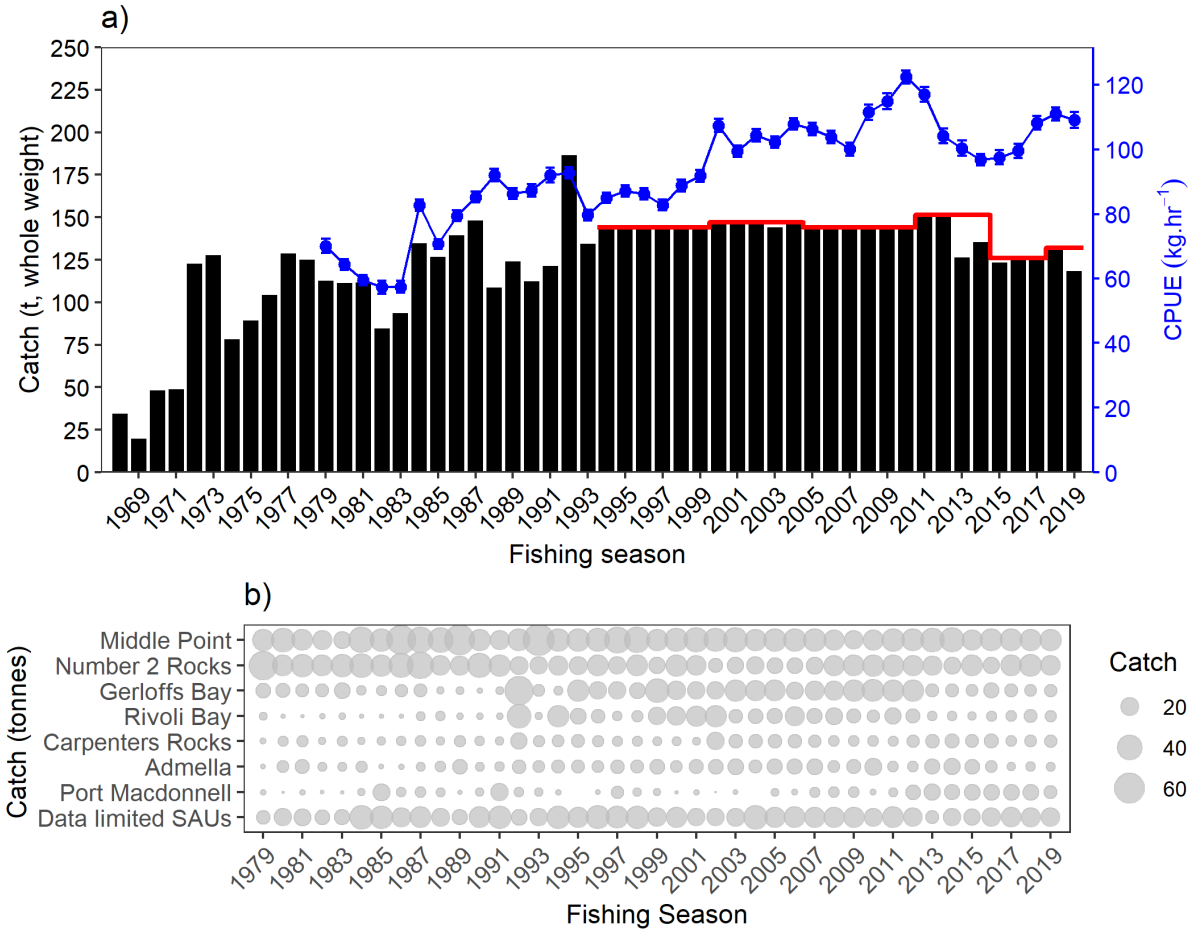

Figure 3-1. a) Total catch (tonnes, black bars), CPUE (± SE, kg.hr^{-1}, blue line and circles) & TACC (red line) of blacklip in the Southern Zone from 1968/69 to 2019/20 (denoted 2019). b) Bubble plot showing the spatial distribution of the blacklip catch (grey symbols) among each of the SAUs in the SZ from 1979/80 to 2019/20 (data-limited SAUs from the proposed HS are combined).

The CPUE of blacklip in the SZ has generally increased throughout the history of the fishery, despite numerous periods of fluctuation over this time. From 1993/94 until 2010/11, during the period of stable catches consistent with the TACC, CPUE increased from <80 kg.hr^{-1} to greater than 120 kg.hr^{-1}. The CPUE of 122 kg.hr^{-1} in 2010/11 was the highest recorded. After 2010/11, CPUE declined over four consecutive seasons to a contemporary low of 97 kg.hr^{-1} in 2014/15. From 2015/16, CPUE increased again reaching 111 kg.hr^{-1} in 2018/19, and remained relatively stable at 109 kg.hr^{-1} in 2019/20.

3.1.1.1 Distribution of catch among spatial assessment units

The introduction of spatial management in 2013/14 influenced the distribution of blacklip catches among SAUs within the SZ (Figure 3-1b). Catches from Gerloffs Bay and Rivoli Bay declined from an average of 33.0 t.y^{-1} and 16.2 t.y^{-1}, respectively, between 1994/95 and 2012/13, to 10.0 t.y^{-1} and 6.4 t.y^{-1} after 2013/14. Meanwhile, catches from Port MacDonnell increased from an average of 3.4 t.y^{-1} between 1994/95 and 2012/13, to 14.6 t.y^{-1}, thereafter.

The MDS ordination identified six clusters of fishing seasons where the distribution of blacklip catches among SAUs were similar between 1990/91 and 2019/20 (Figure 3-2). The temporal nature of these clusters, indicates that changes in the distribution catch occur gradually and are unlikely to reflect random inter-annual processes. The length and direction of the vectors highlight the post-spatial management shift away from SAUs such as Gerloffs Bay and Rivoli Bay, and into SAUs such as Port MacDonnell (as mentioned above). Since 2013/14, there have been three different clusters (i.e. 2013/14–2015/16, 2016/17 and 2017/18–2019/20). The ordination vectors indicate the most recent cluster of catches (i.e. 2017/18–2019/20) can be differentiated from the post-spatial management cluster (i.e. 2013/14–2015/16) by lower catches from Admella and Carpenters Rocks, and consistently high catches from Number 2 Rocks.

A detailed breakdown of catch by mapcode within the surveyed and unsurveyed SAUs is included in Appendix 4.

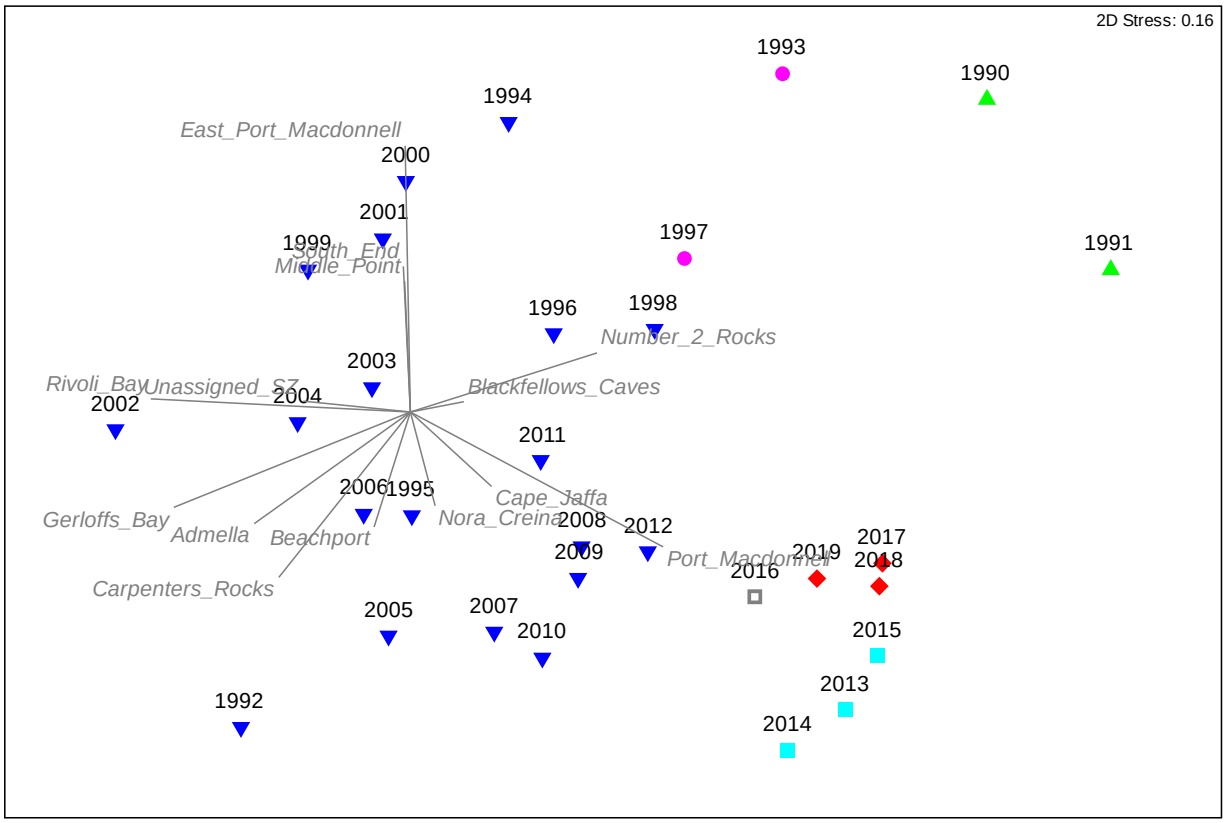

Figure 3-2. Multi-dimensional scaling (MDS) plot for SAUs showing similarity among seasons based on the spatial distribution of annual blacklip catch from the Southern Zone from 1990/91(denoted 1990) to 2019/20. Coloured symbols indicate different spatial distributions (SIMPROF; α = 0.05). Vector length and direction show the influence of each individual SAU on the MDS.

3.1.1.2 Temporal patterns in surveyed SAUs

Middle Point

Since 1979/80, ~26% of the blacklip catch from the SZ has been obtained from Middle Point (Figure 3-3a). Annual catches generally increased from ~30 t in 1979/80 to the maximum of 65 t in 1993/94. Since 1994/95, catches have been relatively stable averaging 33 t. The lowest catch observed throughout this period was 23 t in 2009/10, and the highest was 44 t in 1997/98. In 2019/20, 30 t of blacklip catch was reported for this SAU, which was below the current catch-cap of 35 t.

The estimated CPUE from Middle Point increased consistently from 1979/80 until a peak of 125 kg.hr^{-1} in 2010/11 (Figure 3-3a). From 2011/12, CPUE declined steadily to 91 kg.hr^{-1} in 2015/16, before rising consistently over the past four seasons to reach 114 kg.hr^{-1} in 2019/20, which equates to a score of **9.0 out of 10** for the CPUE PI in the proposed HS.

Interpreting size frequency distributions for Middle Point is difficult because, from 2013/14, the MLL was reduced from 125 to 120 mm in mapcodes 39F, 39G and 40A, but was increased in the historic FDA 1 – within mapcode 39F – from 110 mm to 120 mm. Following these MLL changes, in 2013/14 and 2014/15, the length distribution and mean length of blacklip in commercial catches were lower, before increasing until 2017/18 (Figure 3-3b,c). In 2019/20, the mean length of blacklip in commercial catch of 134 mm was among historical averages.

Fishery-independent estimates of legal-sized blacklip (i.e. ≥120 mm) have been stable in recent seasons (Figure 3-3d), yielding a score of **4.5 out of 10** in the proposed HS in 2018/19. While current legal densites are below those recorded between 2006/07 and 2011/12, they remain at or above levels recorded between 2002/03 and 2005/06. The density of sub-legal sized abalone has generally been low in recent seasons compared with surveys undertaken prior to 2014/15.

The SAU score for Middle Point in 2019/20 is **6.7 out of 10** (Table 3-1).

Table 3-1. Outcome of application of the harvest strategy described in the Management Plan for SZ blacklip in 2019/20.

SAU	CPUE (kg.hr^{-1})	CPUE score	Legal density (abs.m^{-2})	Legal density score	SAU score	Catch 19/20 (tonnes)	Proportion of 12year catch	Weighted SAU score
Middle Point	113.9	9.0	0.39	4.5	6.7	29.7	0.23	1.52
Number 2 Rocks	121.3	8.6	0.48	-	8.6	25.4	0.19	1.65
Data limited SAUs	104.1	7.6	-	-	7.6	21.9	0.16	1.23
Gerloffs Bay	96.9	5.2	0.38	3.0	4.1	9.6	0.13	0.52
Port Macdonnell	95.1	5.0	-	-	5.0	10.3	0.09	0.43
Admella	98.1	6.6	-	-	6.6	4.5	0.07	0.48
Rivoli Bay	118.2	7.9	0.55	2.7	5.3	7.2	0.07	0.36
Carpenters Rocks	101.0	10.0	-	-	10.0	9.2	0.06	0.64
							Zone Score	**6.84**

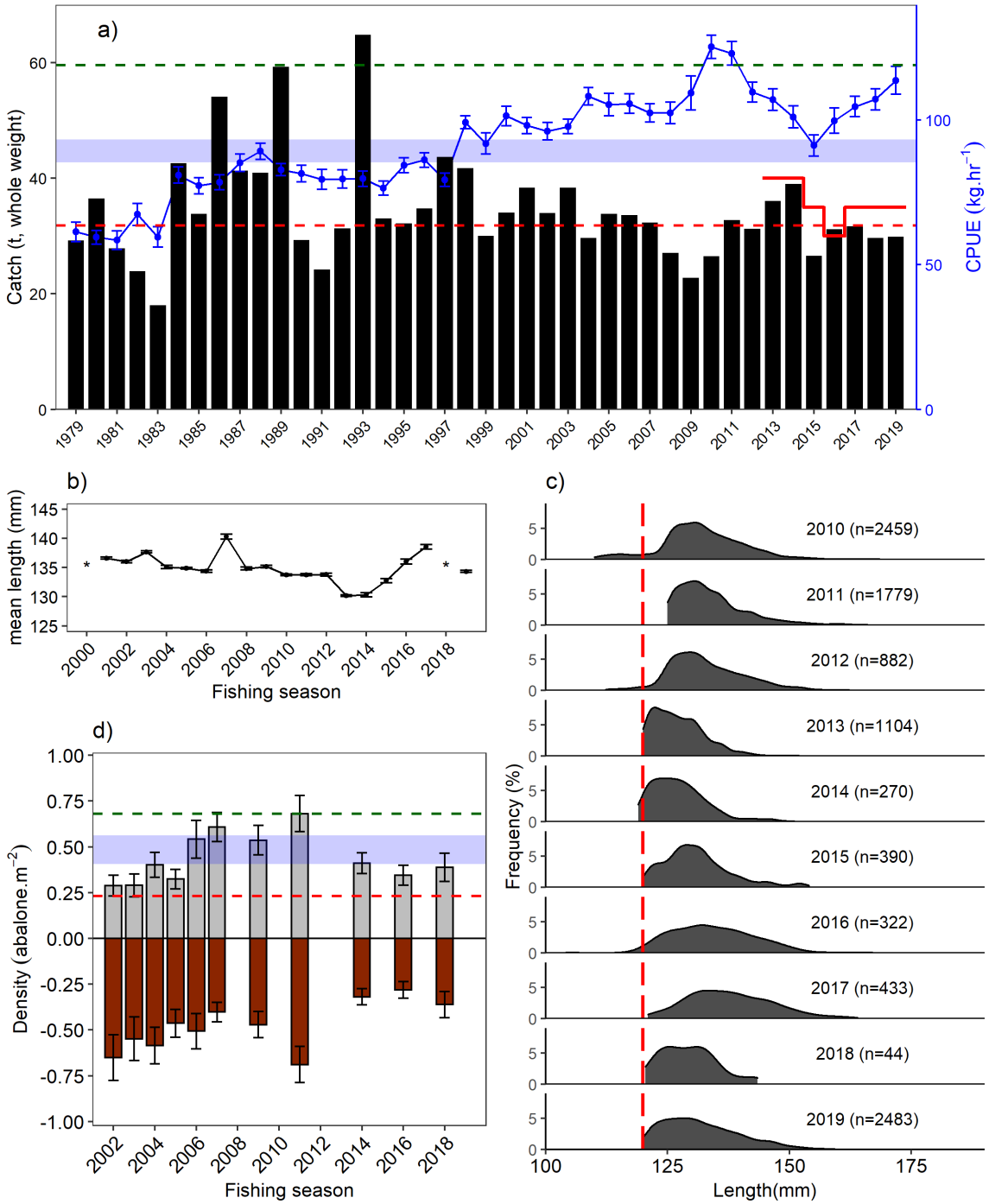

Figure 3-3. Middle Point data available from 1979/80 (denoted 1979) to 2019/20: a) Blacklip catch (tonnes, black bars), annual catch cap (tonnes, red line) & CPUE (± SE, kg.hr^{-1}, blue line/symbols) b) Mean length of blacklip in the commercial catch, * indicates no data available. c) Estimated distribution of commercial catch from shell sampling, current MLL of 120mm = dashed red line. d) Density of blacklip (abalone.m^{-2}; ± se) counted in transects during fishery-independent surveys. Red and grey bars show blacklip <120 and ≥120 mm SL, respectively. Scoring from the harvest strategy is shown for panels a) and d): Target Range (score of 5, blue shading), upper limit (score of 10, green dashed line), lower limit (score of 0, red dashed line).

Number 2 Rocks

Approximately 20% of the total blacklip catch from the SZ since 1979/80 has been harvested from Number 2 Rocks (Figure 3-4a). The highest annual catch was in 1979/80 (51 t), whereafter catches varied among seasons while gradually decreasing to the lowest recorded value of 12 t in 2002/03. From 2002/03, annual catches gradually increased to 30 t in 2010/11. Since 2012/13 catches have varied between 17 and 31 t. The catch of 25 t in 2019/20 was below the current catch-cap of 30 t.

The CPUE for blacklip in Number 2 Rocks has generally increased through time (Figure 3-4a). The highest recorded CPUE of 144 $kg.hr^{-1}$ occurred in 2002/03. Over the next decade CPUE values were relatively stable at levels generally above 120 $kg.hr^{-1}$. After 2012/13, CPUE declined to 102 $kg.hr^{-1}$ in 2014/15, before increasing and stabilising at ~120 $kg.hr^{-1}$ in each of the past three seasons. The estimate of 121 $kg.hr^{-1}$ in 2019/20 was above the target range, scoring **8.6 out of 10**.

The mean length of blacklip in the commercial catch at Number 2 Rocks has been relatively stable, varying between 136 mm and 141 mm (Figure 3-4b). In 2019/20, the mean length of 138 mm was at the centre of this historical range. There were no obvious temporal changes in the overall size frequency distributions from the commercial catch (Figure 3-4c).

Fishery-independent estimates of legal-sized blacklip (≥125 mm) were similar among the three surveys undertaken for Number 2 Rocks (Figure 3-4d). Due to the short time-series of surveys, the proposed HS does not assign a FIS score for Number 2 Rocks. The density of sub-legal-sized blacklip (<125 mm) was consistent from 2014/15 to 2016/17, but increased by more than two-fold in 2018/19. These is no FIS score for Number 2 Rocks given there has been fewer than four surveys of this SAU (see methods).

In the absence of a FIS score, the SAU score for Number 2 Rocks in 2019/20 is the CPUE score (i.e. **8.6 out of 10**; Table 3-1).

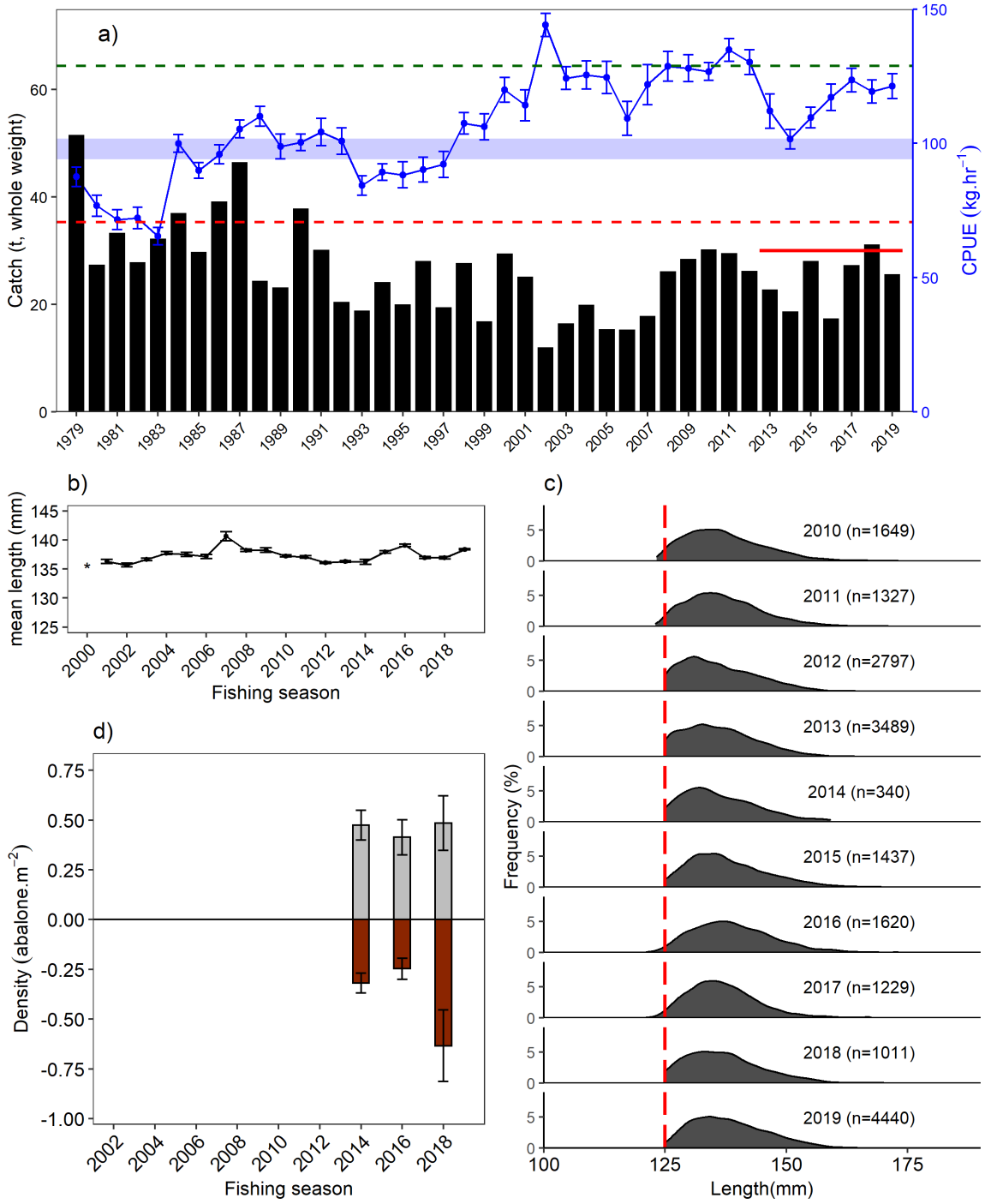

Figure 3-4. Number 2 Rocks data available from 1979/80 (denoted 1979) to 2019/20: a) Blacklip catch (tonnes, black bars), annual catch cap (tonnes, red line) & CPUE (± SE, kg.hr^{-1}, blue line/symbols). b) Mean length of blacklip in the commercial catch, * indicates no data available. c) Estimated distribution of commercial catch from shell sampling, current MLL of 125mm = dashed red line. d) Density of blacklip (abalone.m^{-2}; ± se) counted in transects during fishery-independent surveys. Red and grey bars show blacklip <125 and ≥125 mm SL, respectively. Scoring from the harvest strategy is shown for panels a) and d): Target Range (score of 5, blue shading), upper limit (score of 10, green dashed line), lower limit (score of 0, red dashed line).

Gerloffs Bay

Since 1979/80, ~12% of the total SZ harvest of blacklip abalone has been obtained from Gerloffs Bay (Figure 3-5a). Total annual catches from this SAU were relatively low throughout the 1980s and early 1990s. Shortly after, the largest annual catch of 51 t was obtained in 1992/93 (during unrestricted fishing in the previous FDA 4 at a lower MLL). Catches were relatively stable at high levels between 1995/96 and 2012/13, ranging from 15 to 36 t. Since 2013/14 when the FDAs were removed, catches have remained relatively low, ranging from 8 to 14 t, with 10 t harvested in 2019/20.

CPUE increased from approximately 80 $kg.hr^{-1}$ in the mid-1990s to a peak of 125 $kg.hr^{-1}$ in 2010/11 (Figure 3-5a). Thereafter, catch rates declined to 79 $kg.hr^{-1}$ in 2016/17, before increasing to ~96 $kg.hr^{-1}$ during the last three seasons. The estimate in 2019/20 of 96.9 $kg.hr^{-1}$ was above the target range, scoring **5.2 out of 10** in the proposed HS.

Interpreting size-frequency distributions for Gerloffs Bay is difficult because, between 2013/14 and 2015/16 the MLL was increased to 120 mm, associated with the removal of FDA 4, before being lowered to 110 mm again in 2016/17 (Figures 3-5b,c). However, the most obvious trend is a gradual reduction in the mean length of abalone in the commercial catches from 2011/12 onwards. In 2019/20, the mean length of blacklip was not estimated due to insufficient samples.

Estimates of legal-sized blacklip (≥110 mm) from FIS have been variable among seasons (Figure 3-5d). In general, greater densities were recorded prior to 2014/15, and have been lower in recent surveys. After record low densities in 2014/15, estimates during the last two surveys have been generally higher, yielding a score of **3.0 out of 10** in the proposed HS. Estimates of sub-legal-sized blacklip (<110 mm) were highest between 2002/03 to 2007/08. Thereafter, estimates of sub-legal-sized blacklip have been consistently lower, but have remained relatively stable since 2008/09. For FIS densities from the incomplete 2020/21 fishing season for Gerloffs Bay, see Appendix 3, Figure A3-3.

The SAU score for Gerloffs Bay in 2019/20 is **4.1 out of 10** (Table 3-1).

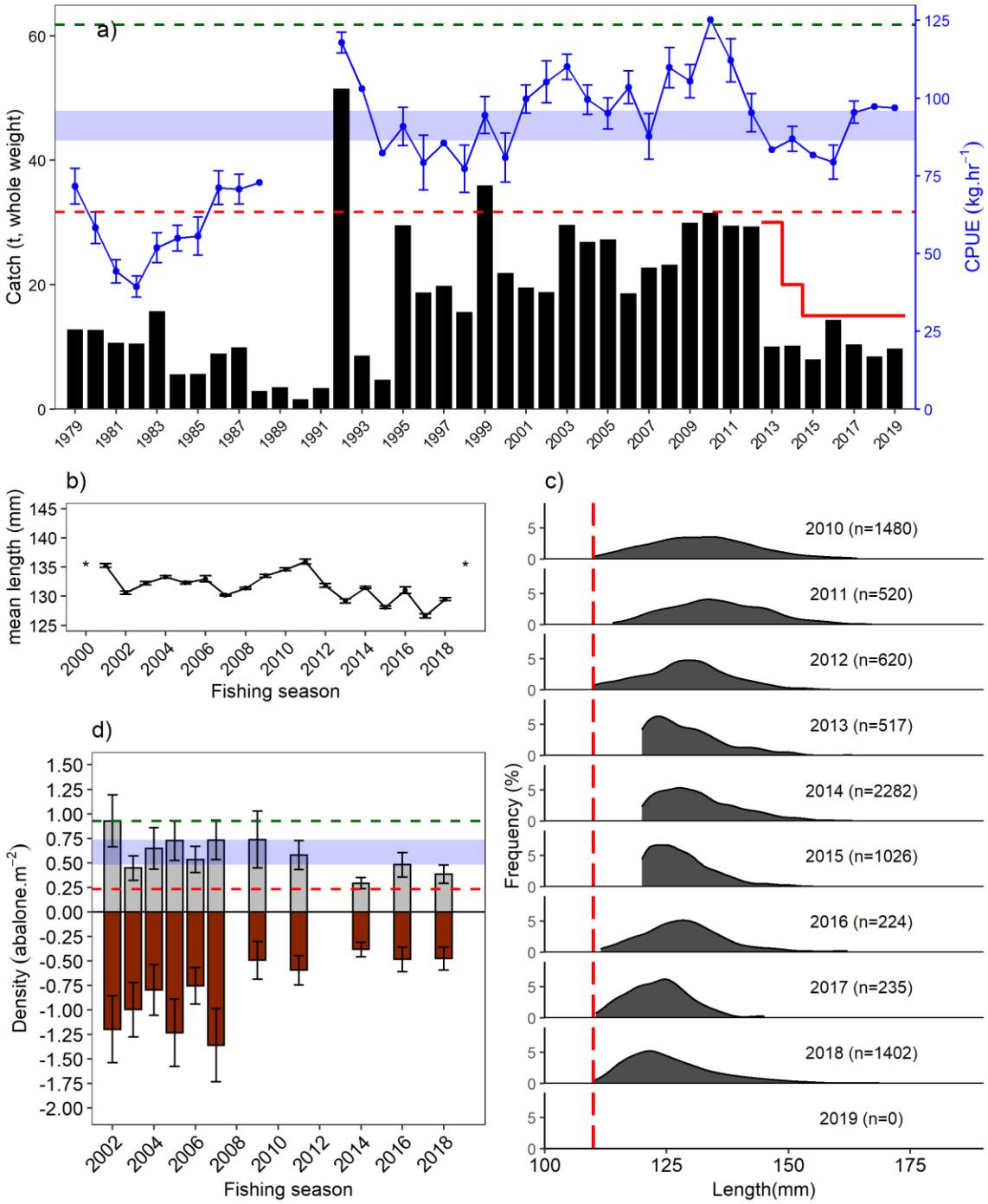

Figure 3-5. Gerloffs Bay data available from 1979/80 (denoted 1979) to 2019/20: a) Blacklip catch (tonnes, black bars), annual catch cap (tonnes, red line) & CPUE (± SE, kg.hr^{-1}, blue line/symbols). CPUE estimates with no error bar are generated using a 3-year running mean. b) Mean length of blacklip in the commercial catch, * indicates no data available. c) Estimated distribution of commercial catch from shell sampling, current MLL of 110mm = dashed red line. d) Density of blacklip (abalone.m^{-2}; ± se) counted in transects during fishery-independent surveys. Red and grey bars show blacklip <110 and ≥110 mm SL, respectively. Scoring from the harvest strategy is shown for panels a) and d): Target Range (score of 5, blue shading), upper limit (score of 10, green dashed line), lower limit (score of 0, red dashed line).

Rivoli Bay

Total annual catches of blacklip from Rivoli Bay were small (≤5 t.yr^{-1}; Figure 3-6a) prior to 1992/93, when 36 t was harvested (unrestricted fishing at a lower MLL in FDA 3). Since 1992/93, catches have been variable among seasons ranging from 3 to 30 t. Following a sustained period of higher catches between 1999/00 and 2012/13, catches during the last seven seasons have generally remained lower following the removal of the FDAs. The 2019/20 catch of 7.2 t was below the 11 t catch cap for Rivoli Bay.

CPUE was relatively stable over 12 seasons from 2000/01 to 2011/12, ranging from 108–126 kg.hr^{-1}. In 2012/13, CPUE declined to 99 kg.hr^{-1}, and remained close to the target scoring range of 5 until 2015/16. Subsequently, CPUE increased to ~120 kg.hr^{-1} during the last three seasons. The estimate of 118 kg.hr^{-1} in 2019/20 equated to a score of **7.9 out of 10** in the proposed HS.

Interpreting size frequency distributions for the Rivoli Bay SAU is difficult because, from 2013/14, the MLL was reduced from 125 to 120 mm in mapcode 36B, in the area outside the historic FDA 3, and increased from 110 mm to 120 mm inside the historic FDA 3 (reflecting removal of FDAs). Then, in 2017/18, the MLL was reduced from 120 to 110 mm for the entire SAU. However, the most obvious trend is a reduction in the mean length of abalone in the commercial catches up until 2018/19 (Figures 3-6b,c). In 2019/20 the mean length was not estimated due to fewer than 100 shell measurements of abalone ≥120 mm in this season.

The densities of legal- and sub-legal-sized blacklip obtained from FI surveys in Rivoli Bay were relatively stable at high levels throughout the 2000s, with the greatest densities recorded in 2006/07 (Figures 3-6d). In 2012/13, low densities of both size classes were recorded. These densities immediately followed a reported summer mortality (Mayfield *et al.* 2013, 2014). Subsequently, the density of legal-sized blacklip remained low in 2014/15, then it increased in 2016/17, before declining again in 2018/19, yielding a score **2.7 out of 10** in the proposed HS. The densities of sub-legal-sized blacklip have been variable among seasons. The highest density was recorded in 2014/15, but subsequently density has declined to the lowest recorded value in 2018/19. For FIS densities from the incomplete 2020/21 fishing season for Rivoli Bay, see Appendix 3, Figure A3-3.

The SAU score for Rivoli Bay in 2019/20 is **5.3 out of 10** (Table 3-1).

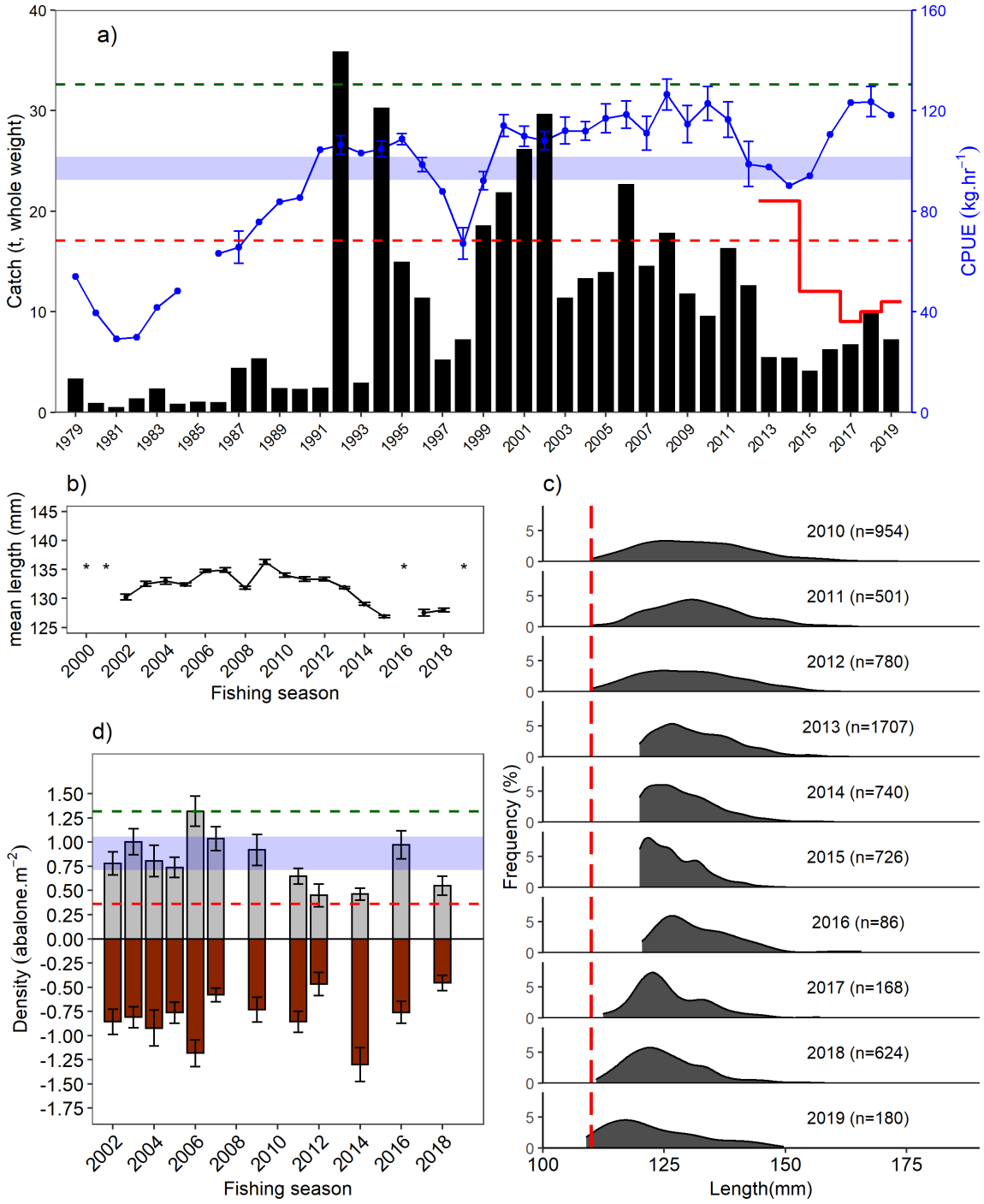

Figure 3-6. Rivoli Bay data available from 1979/80 (denoted 1979) to 2019/20: a) Blacklip catch (tonnes, black bars), annual catch cap (tonnes, red line) & CPUE (± SE, kg.hr^{-1}, blue line/symbols). CPUE estimates with no error bar are generated using a 3-year running mean. b) Mean length of blacklip in the commercial catch, * indicates no data available. c) Estimated distribution of commercial catch from shell sampling, current MLL of 110mm = dashed red line. d) Density of blacklip (abalone.m^{-2}; ± se) counted in transects during fishery-independent surveys. Red and grey bars show blacklip <110 and ≥110 mm SL, respectively. Scoring from the harvest strategy is shown for panels a) and d): Target Range (score of 5, blue shading), upper limit (score of 10, green dashed line), lower limit (score of 0, red dashed line).

3.1.1.3 Temporal patterns in unsurveyed SAUs

Admella

Catches from Admella reached a peak of 17 t in 2010/11 (Figure 3-7a), but have generally been lower and variable during the last decade. Catches were low in 2011/12 and 2012/13 (~7 t), followed by three seasons of higher catches from 2013/14 to 2015/16 (~15 t), before decreasing again over the last three seasons (~5 t), and remaining markedly below the 2019/20 catch cap of 16 t.

The CPUE for Admella increased from ~75 kg.hr^{-1} in the early/mid-1990s to an average of 97 kg.hr^{-1} between 2000/01 and 2010/11. Following the highest estimated value of 108 kg.hr^{-1} in 2010/11, CPUE declined to 83 kg.hr^{-1} by 2012/13. Over the next four seasons CPUE remained within the target scoring range, averaging ~83 kg.hr^{-1}, before higher estimates over the last three seasons. The estimate in 2019/20 of 98 kg.hr^{-1} scored a **6.6 out of 10** in the proposed HS

Interpreting size frequency distributions for Admella is difficult because, from 2013/14, the MLL was reduced from 125 to 120 mm (Figures 3-7b,c), before being increased back to 125 mm in 2017/18. The mean length of abalone in the commercial catch peaked in 2009/10 at 140 mm, with the lowest mean length of 133 mm recorded in 2011/12 and 2019/20.

In the absence of any FIS, **6.6 out of 10** is the SAU score for Admella (Table 3.1).

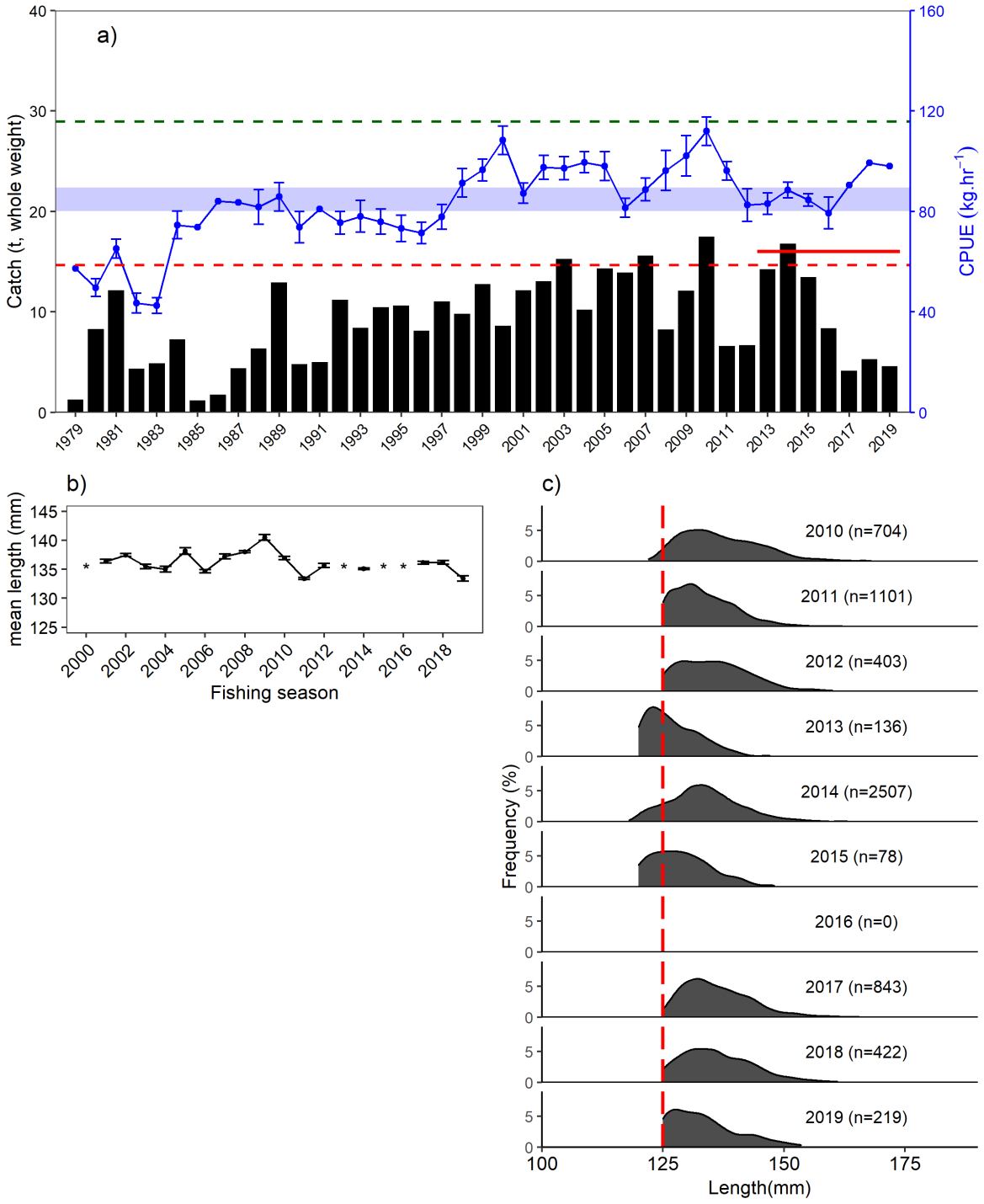

Figure 3-7. Admella data available from 1979/80 (denoted 1979) to 2019/20: a) Blacklip catch (tonnes, black bars), annual catch cap (tonnes, red line), & CPUE (± SE, kg.hr^{-1}, blue line/symbols). CPUE estimates with no error bar are generated using a 3-year running mean. b) Mean length of blacklip in the commercial catch, * indicates insufficient data for % Large estimate. c) Estimated distribution of commercial catch from shell sampling, current MLL of 125mm = dashed red line. Scoring from the harvest strategy for CPUE is shown in panel a): Target Range (score of 5, blue shading), upper limit (score of 10, green dashed line), lower limit (score of 0, red dashed line).

Carpenters Rocks

Since 1979/80, ~6% of the total SZ harvest of blacklip abalone has been taken from Carpenters Rocks. Prior to 2002/03, mean annual catches from Carpenters Rocks were generally low, averaging ~6 $t.yr^{-1}$. Since 2002/03, average catches have increased to ~10 $t.yr^{-1}$. The catch of 9 t in 2019/20 reflects an increase over the last two seasons, but remained below the catch cap of 12 t (Figure 3-8a).

The highest CPUE on record of 110 $kg.hr^{-1}$ occurred in 2010/11, before CPUE declined to a contemporary low of 80 $kg.hr^{-1}$ in 2015/16. Since 2015/16, CPUE has increased reaching 101 $kg.hr^{-1}$ in 2019/20, with a proposed HS score of **10.0 out of 10.**

The mean length of blacklip in the commercial catch has varied among seasons (Figure 3-8b). Notably, the mean length was the lowest ever recorded for four consecutive seasons between 2014/15 and 2017/18 (~133 mm), but has since increase to above 136 and 134 mm in 2018/19 and 2019/20, respectively.

In the absence of any FIS, **10.0 out of 10** is the SAU score for Carpenters Rocks (Table 3.1).

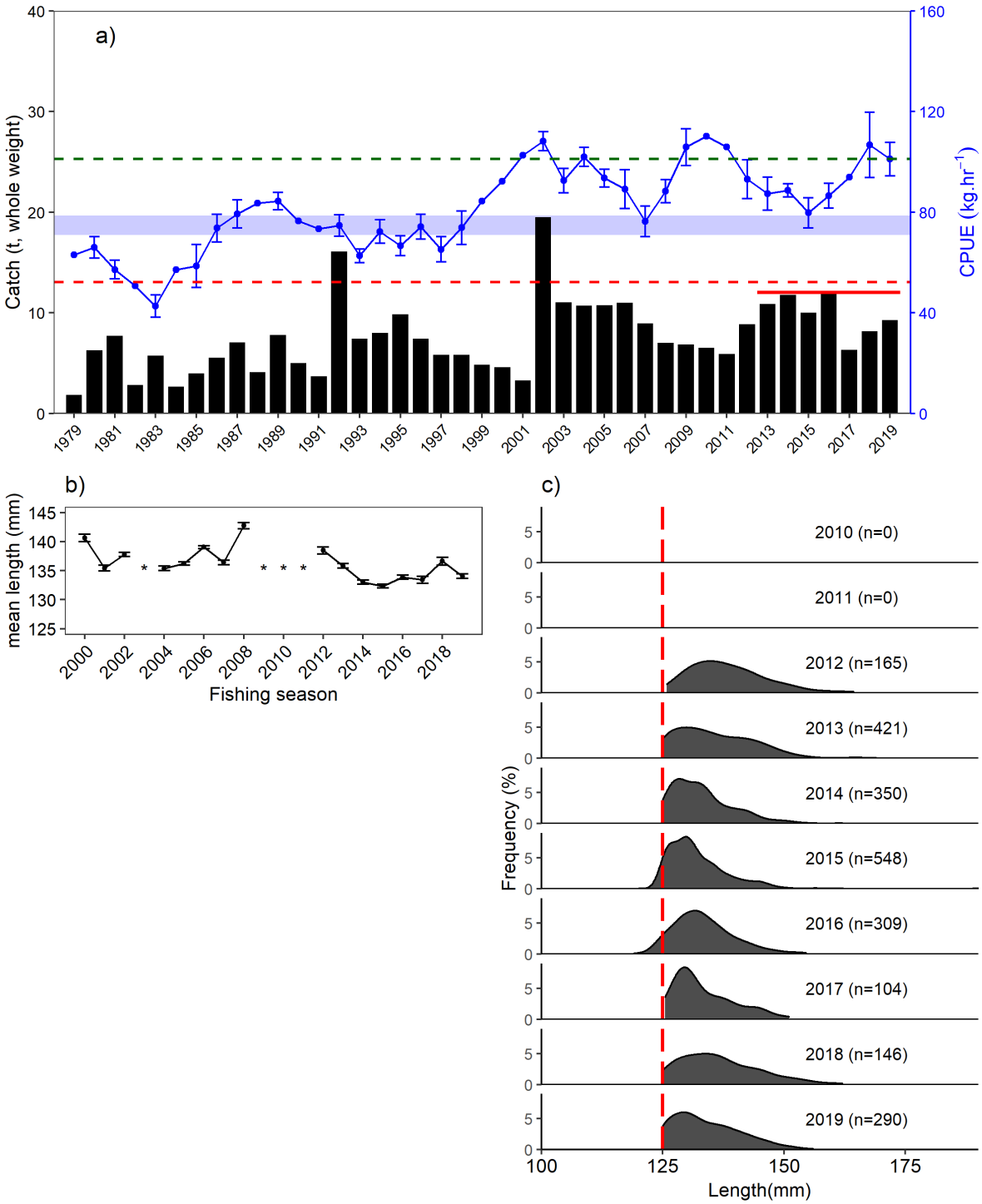

Figure 3-8. Carpenters Rocks data available from 1979/80 (denoted 1979) to 2019/20: a) Blacklip catch (tonnes, black bars), annual catch cap (tonnes, red line), & CPUE (± SE, kg.hr^{-1}, blue line/symbols). CPUE estimates with no error bar are generated using a 3-year running mean. b) Mean length of blacklip in the commercial catch, * indicates no data available. c) Estimated distribution of commercial catch from shell sampling, current MLL of 125mm = dashed red line. Scoring from the harvest strategy for CPUE is shown in panel a): Target Range (score of 5, blue shading), upper limit (score of 10, green dashed line), lower limit (score of 0, red dashed line).

Port MacDonnell

Catches from Port MacDonnell have varied among seasons, including historical peaks of 18 t in 1985/86 and 19 t in 1991/92, while catches in most other seasons remained low until 2012/13. During the last eight seasons catches have consistently exceeded 10 t, with many recent catches seemingly constrained by the 15 t catch-cap, (Figure 3-9a).

The highest recorded CPUE value of 150 kg.hr^{-1} was reported in 2010/11, two years prior to the period of sustained high catches from 2012/13 to 2019/20. Since this peak, CPUE has declined considerably, reaching 95 kg.hr^{-1} in 2019/20, which is the lowest recorded value since 1999/00. Despite this decline, the CPUE score remains within the target scoring range, accordingly scoring a **5.0 out of 10** in the proposed HS.

Interpreting size frequency distributions for the Port MacDonnell SAU is difficult because, from 2013/14, the MLL was reduced from 125 to 120 mm and increased from 110 to 120 mm inside the historic FDA 2 (reflecting removal of the FDAs). However, the most recent trend is the generally lower mean length of blacklip recorded in the commercial catches (132 mm in 2019/20), following the peak of 140 mm observed in 2012/13 (Figure 3-9b,c).

In the absence of any FIS, **5.0 out of 10** is the SAU score for Port MacDonnell (Table 3.1).

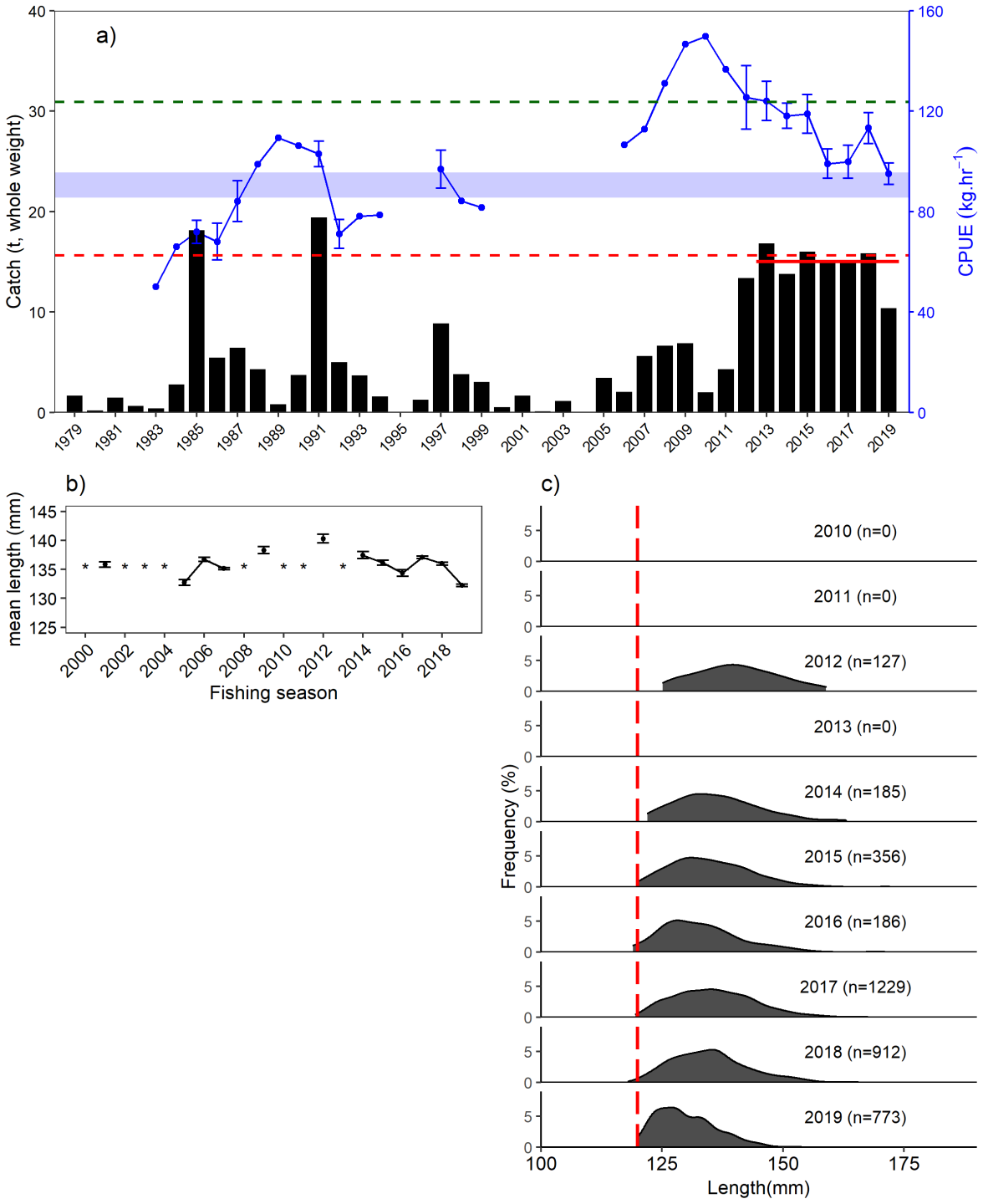

Figure 3-9. Port MacDonnell data available from 1979/80 (denoted 1979) to 2019/20: a) Blacklip catch (tonnes, black bars), annual catch cap (tonnes, red line), & CPUE (± SE, kg.hr^{-1}, blue line/symbols). CPUE estimates with no error bar are generated using a 3-year running mean. b) Mean length of blacklip in the commercial catch, * indicates no data available. c) Estimated distribution of commercial catch from shell sampling, current MLL of 120mm = dashed red line. Scoring from the harvest strategy for CPUE is shown in panel a): Target Range (score of 5, blue shading), upper limit (score of 10, green dashed line), lower limit (score of 0, red dashed line).

3.1.1.4 Temporal patterns in data-limited SAUs

Collectively the data-limited SAUs have supported ~18% (averaging 23 $t.y^{-1}$) of the total blacklip harvest in the SZ (Figure 3-10a). The combined CPUE estimate for these six SAUs has followed a similar trajectory to the zonal CPUE – peaking around 2010/11, before a decline to 2013/14 and recovery thereafter. However, over the last four seasons CPUE has decreased, from 115 $kg.hr^{-1}$ in 2016/17 to 104 $kg.hr^{-1}$ in 2019/20, equating to a proposed HS score of **7.6 out of 10**.

Among the data-limited SAUs, catches have varied substantially among fishing seasons. For several SAUs (e.g. East Port MacDonnell, Blackfellows Caves) the current catches are lower than those observed historically, while for others (e.g. Nora Creina, Southend, Beachport) recent catches have been among historical average levels. Insufficient data prevented estimation of CPUE in most seasons for these SAUs (Figure 3-10b). No running mean CPUE was estimated, because these SAUs are not individually assessed in the proposed HS.

In the absence of any FIS, **7.6 out of 10** is the SAU score for the data-limited SAUs (Table 3.1).

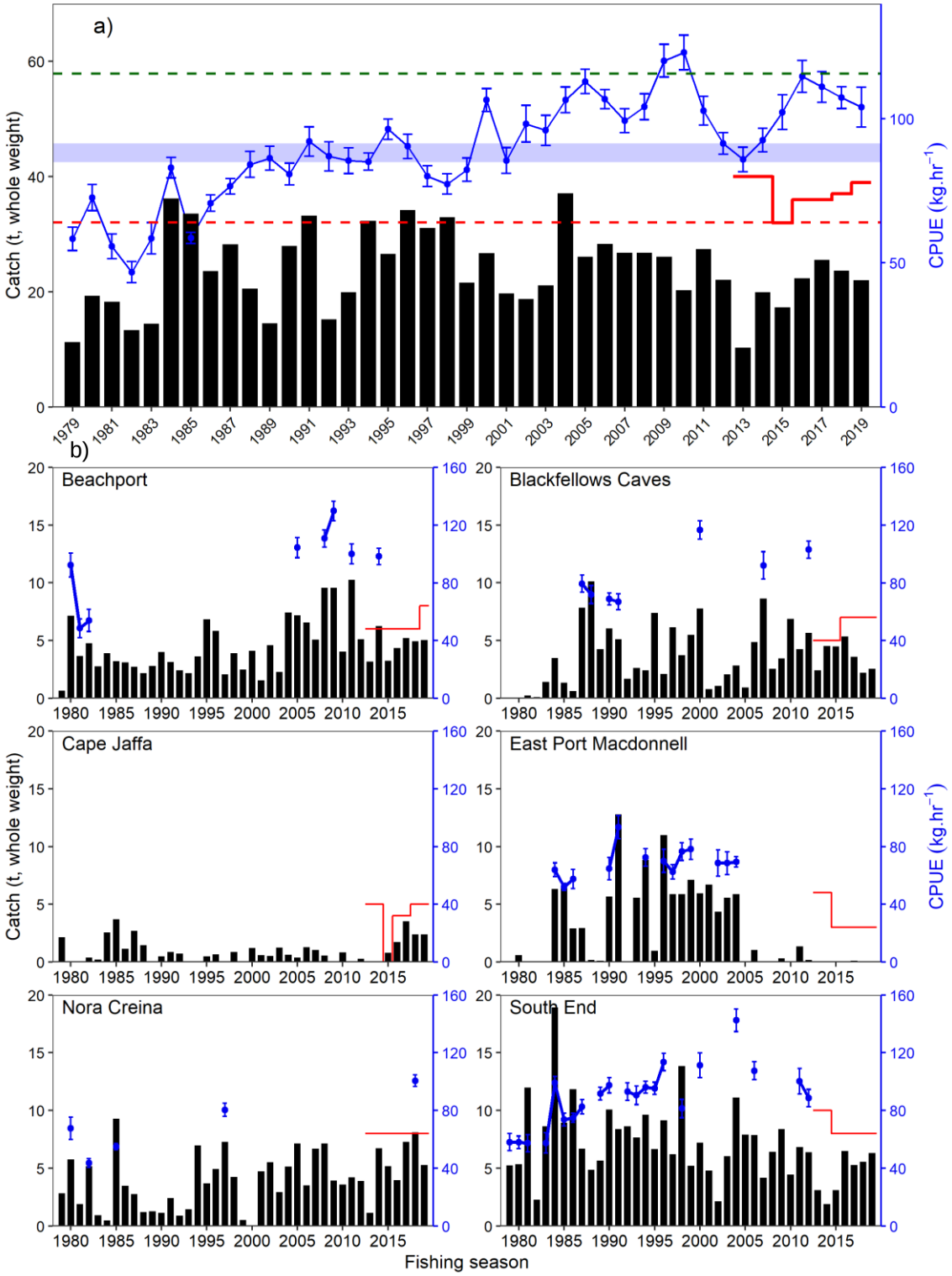

Figure 3-10. a) Combined data-limited SAUs from 1979/80 to 2019/20. CPUE Target Range (score of 5, blue shading), CPUE upper limit (score of 10, green dashed line), CPUE lower limit (score of 0, red dashed line). b) Individual data-limited SAUs from 1979/80 to 2019/20. Catch (tonnes, black bars), annual catch cap (tonnes, red line), and CPUE (± SE, kg.hr^{-1}, blue line).

3.1.2 Harvest strategy – zone score and stock status

The catch-weighted, zone score for 2019/20 was **6.8 out of 10** (Table 3.1, Figure 3.11). In combination with the zone trend score in 2019/20 of **5.2 out of 10** (reflecting an increasing trend), these define the zonal stock status for blacklip in the SZ in 2019/20 as 'sustainable' (Figure 3.12). A table of historical proposed HS outcomes is provided in Appendix 5.

The YTD proposed HS outcome for the current 2020/21 fishing season is included in Appendix 3. Using the two methods, the catch-weighted zone score ranged between **6.3 and 6.5 out of 10**, and the zone trend score ranged between **4.9 and 5.0 out of 10**.

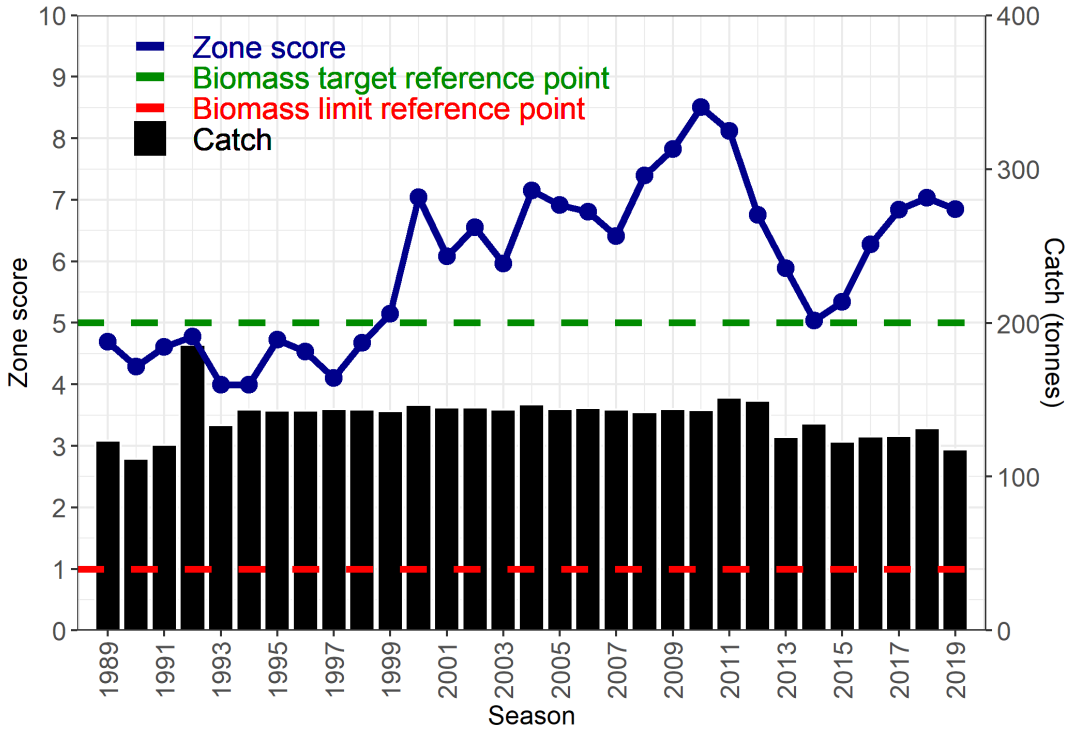

Figure 3-11. Zone score plot for SZ blacklip between 1989/90 (denoted 1989) and 2019/20. Zone score (blue symbols and line), biomass target reference point (green line), biomass limit reference point (red line) and catch (black bars, tonnes).

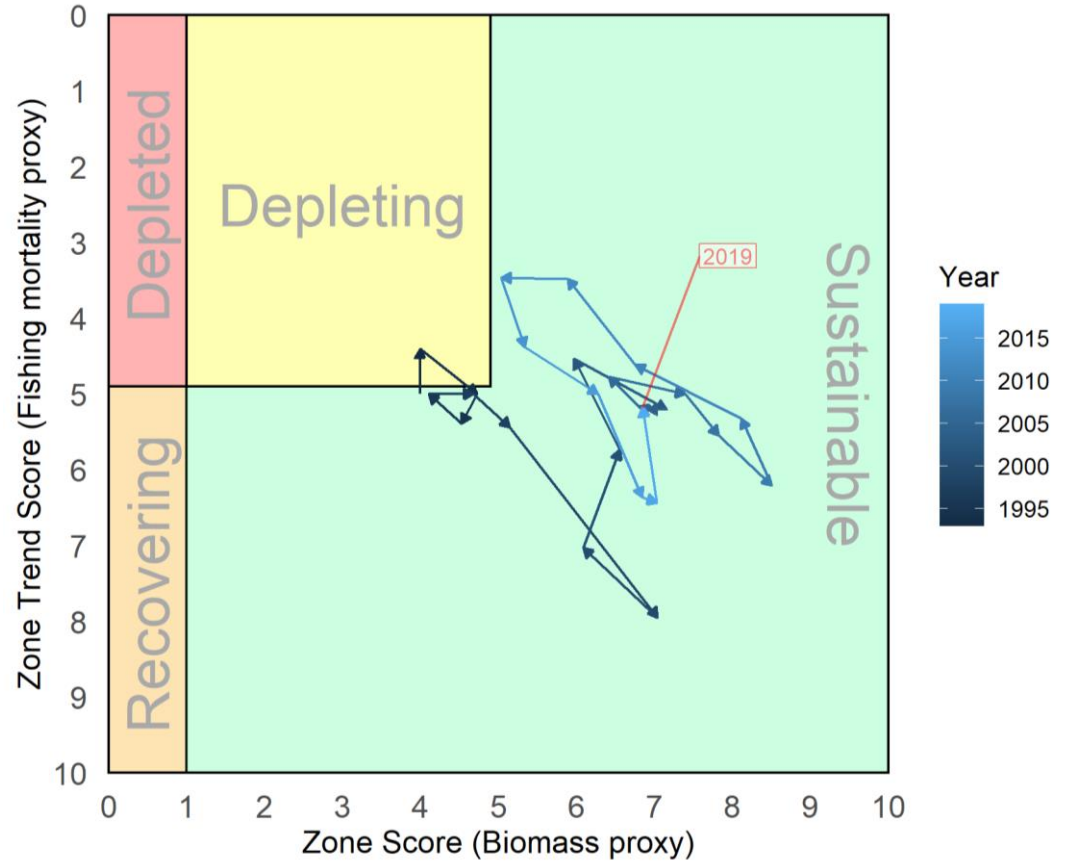

Figure 3-12. Phaseplot indicating changes in SZ blacklip stock status between 1993/94 and 2019/20 (denoted 2019).

3.2 Greenlip

Since 1968/69, when almost 19 t of greenlip was landed, annual greenlip catches in the SZ have generally remained below 8 t (Figure 3-13a). Throughout the 1990s and 2000s greenlip catches fluctuated between 2 and 6 $t.y^{-1}$. After reaching 7.2 t in 2011/12, catches of greenlip have been steadily declining in recent seasons, with catches in some years constrained by the TACC. In 2018/19, the TACC was reduced to 1.8 t, which were the lowest recorded catches since the mid to late 1980s.

The contribution of different SAUs to the greenlip catch have varied over time (Figure 3-13b). Recent contributions from Gerloffs Bay and Rivoli Bay to the total catch have been relatively small in a historical context. Conversely, Nora Creina and Port MacDonnell have supported a higher relative proportion of the greenlip catch in recent years. In many instances, recent changes in the spatial distribution of greenlip catch are consistent with corresponding changes in blacklip catch.

The mean length and length frequency of greenlip in the commercial catch has not shown a notable trend over time, varying between 143 and 151 mm (Figures 3-13c, d). After two years at ~150 mm in 2016/17 and 2017/18, the mean length of greenlip declined to 144 mm in 2018/19 and 2019/20.

Estimates of total greenlip density at Ringwood Reef in the Rivoli Bay SAU have generally increased since surveys commenced, with the highest value recorded in 2016/17 (Figure 3-13e). However, in 2018/19, the estimate declined by more than 50%, to similar levels recorded in the early to mid-2000s. For greenlip FIS densities from the incomplete 2020/21 fishing season for Rivoli Bay, see Appendix 3, Figure A3-3.

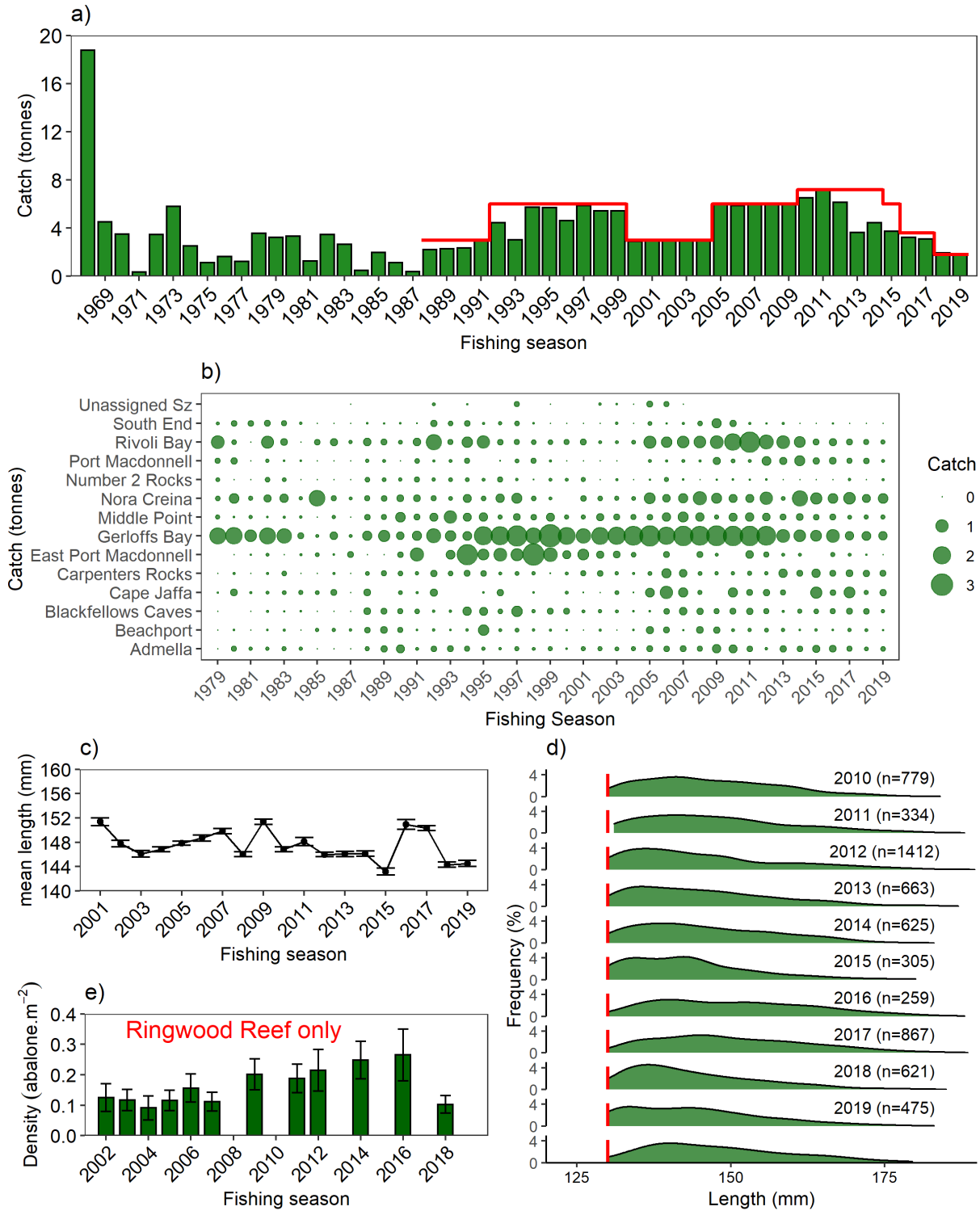

Figure 3-13. Greenlip data available from 1968/69 to 2019/20 (denoted 2019): a) Greenlip catch (tonnes, coloured bars) & TACC (red line). b) Bubble plot showing the spatial distribution of the catch (green symbols) by SAU. c) Mean length of greenlip in the commercial catch. d) Estimated distribution of commercial catch from shell sampling, MLL of 130mm = dashed red line. e) Density of greenlip (abalone.m^{-2}; ± se) counted in transects during fishery-independent surveys at Ringwood Reef.

4 DISCUSSION

4.1 Current status of blacklip and greenlip in the Southern Zone

The proposed HS for the South Australian Abalone Fishery, applied in this report, is a requirement under the new management plan (PIRSA in prep.). The proposed HS was developed following an extensive review process that commenced in 2015 through the Abalone Fishery Harvest Strategy Working Group (AFHSWG). The proposed HS has been designed to provide recommended catches to assist annual TACC setting, and assign stock status classifications consistent with the NFSRF (Piddocke *et al.* 2021). The two key PIs used to assign stock status and provide recommended catches in the proposed HS are commercial CPUE and abalone legal-sized density from the FIS.

4.1.1 Blacklip

Following the introduction of TACCs in the late 1980s, the SZ blacklip fishery was characterised by stable catches and increasing CPUE for almost two decades. After 2010/11, CPUE began to decline, followed by decreases in blacklip catch and, shortly thereafter, TACCs. Fishery-independent estimates of legal and sub-legal abalone also generally declined throughout this period. Consequently, between 2013/14 and 2015/16 the fishery was classified as 'depleting' (formerly 'transitional-depleting') under the NFSRF (Mayfield *et al.* 2015; Ferguson *et al.* 2016, 2017; Piddocke *et al.* 2021). This period, in which the stock was classified as depleting, was preceded by reported abalone mortalities from a warm water event during the summer of 2012/13, the severity of which remained largely unquantified (Government of South Australia 2013; Mayfield *et al.* 2013, 2014).

In more recent fishing seasons, there is evidence that the harvestable biomass of blacklip in the SZ has generally improved and stabilised. Catch-per-unit-effort increased after the 2015/16 season, reaching a contemporary peak of 111 $kg.hr^{-1}$ in 2018/19, before stabilising at 109 $kg.hr^{-1}$ during the 2019/20 season. Meanwhile, FIS densities of legal and sub-legal sized blacklip have remained relatively stable over this period, but remain among the lower end of estimates when compared with historical surveys.

Among different spatial assessment units within the fishery, there was also evidence of contrasting trends in harvestable biomass reflected in the SAU scores. Two key SAUs which have supported >40% of the total historical blacklip catches, Middle Point (6.7 out of 10) and Number 2 Rocks (8.6 out of 10), show evidence of high harvestable biomass. Comparatively, Gerloffs Bay

(4.1 out of 10), Port MacDonnell (5 out of 10) and Rivoli Bay (5.3 out of 10) have current SAU scores reflective of relatively lower levels of harvestable biomass.

Total blacklip catch was ~118 t (89% of the TACC) in 2019/20, during which the COVID-19 pandemic, amongst other international developments, created unpredictable market conditions and some access challenges for interstate divers. These circumstances, resulted in a prolonged period of depressed catches between April and June 2020, as well as the establishment of provisions by PIRSA Fisheries and Aquaculture for the possible rollover of uncaught TACC to future seasons. While difficult to accurately quantify, these market conditions undoubtably impacted overall blacklip catches in the 2019/20 fishing season.

Application of the proposed HS in 2019/20 resulted in a **zone score of 6.8** that, in combination with the **zone trend score of 5.2** (reflecting an increasing trend), define the stock status for blacklip in the SZ in 2019/20 as **'sustainable'**. This outcome indicates that the harvestable biomass of blacklip in the SZ is likely to be at levels sufficient to ensure future levels of recruitment are adequate, and fishing mortality is sufficiently controlled to avoid the stock becoming recruitment impaired. This is consistent with the stock being classified as sustainable over the last three fishing seasons (since 2016/17) using the weight-of-evidence assessment. The zone score of 6.8 translates to a recommended zonal catch of 132 t for 2021/22, which is the target catch level for the SZ blacklip fishery.

4.1.2 Greenlip

The low current and historical catches, and limited FD and FI data on greenlip abalone in the SZ, prevent reliable estimation of biomass or fishing mortality for this stock. This occurs because the species is generally only caught as a bycatch, with insufficient targeted fishing events to generate a reliable proxy for biomass. Consequently, the proposed HS is not applied to greenlip in the SZ, and an '**undefined**' stock status has been assigned in 2019/20 under the NFSRF (Piddocke *et al.* 2021), which is consistent with previous classifications (e.g. Burnell *et al.* 2020).

4.2 Uncertainty in the assessment

There were a few key limitations to this assessment. Outcomes from the new proposed HS are based on just two PIs (CPUE and FIS legal-density). While these PIs were assessed (through the AFHSWG) to best represent the available data to reflect abundance, and, therefore inform abalone stock status, they may be influenced by a multitude of factors. Catch-per-unit-effort is commonly considered among abalone fisheries to be impacted by hyperstability and effort creep. Additionally, recent changes in fishing practices in the SZ, including beach weighing of catch since

2018/19 and lowering of MLLs in selected SAUs (i.e. Gerloffs Bay, Rivoli Bay), may have positively biased CPUE in recent years. It is important to note, however, beach weighing of catch—before potential water loss later in the processing chain—has effectively reduced the number of abalone harvested each season, and hence is likely to provide a net benefit to the sustainability of stocks over the longer-term. Likewise, spatial management has introduced numerous benefits for the management and sustainability of the SZ, which are considered to outweigh the ongoing complexities it presents for data interpretation. In reference to abalone legal-density, FIS only cover a portion of the fishery and, for some surveyed SAUs, there remains an insufficient time series to enable historical comparisons (e.g. Number 2 Rocks).

Using the most up-to-date data could reduce uncertainty in the SZ assessment. As such, a decision is pending on whether to formalise the use of YTD data for assigning stock status and providing recommended TACCs for blacklip in the HS. The proposed HS is also currently undergoing Management Strategy Evaluation as part of FRDC Project 2019/118, 'Drawing strength from each other: simulation testing of Australia's abalone harvest strategies'. Key outcomes from this project will be communicated to the SZ via port meetings.

4.3 Future research needs

The most immediate research needs for the SZ are to: (1) commence an active surveillance program for Abalone Viral Ganglioneuritis (AVG) near the SA border following the recent outbreak in western Victoria. This surveillance will be designed to detect and provide warning of any detection of the virus in SA waters; (2) review the locations of some FIS sites and their vicinity to commercial abalone fishing grounds, following the collection of Vessel Monitoring System (VMS) data since 2013; and (3) finalise the split of mapcode 39F into east and west sub-components, the latter of which will constitute a new 'Nene Valley' SAU, and is designed to align with the former FDA1. This will enable a specific MLL and catch-cap to be assigned to this area, which has seen a reduction in fishing effort since its incorporation into the Middle Point SAU, following the introduction of spatial management.

Assessment of abalone stocks in the SZ may also benefit from: (4) further integrating the GPS information from the VMS and depth logger data into the assessment to develop FD logger PIs; (5) analysing external influences (e.g. diver, location, month, selectivity associated with changing MLLs and beach weighing) on CPUE; and (6) use of a diver assessment survey to integrate into

the harvest strategy. A suitable mobile phone app is currently under development (Minehan et al. FRDC Project 2019-038), and could potentially be adopted by the SZ if deemed beneficial.

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1. APPENDIX 1 – Performance Indicators for blacklip and greenlip

Table A1-1. Summary of the Performance Indicators and other metrics and the formulae and data constraints underpinning their computation.

Metric use	Description	Formulae	Data constraints
Performance indicator			
CPUE	Commercial catch-per-unit effort (kg.hr^{-1})	$CPUE_{wp} = \frac{\Sigma_{i=1}^{n} Proportion_i \left(\frac{Catch_i}{Effort_i * Proportion_i}\right)}{\Sigma_{i=1}^{n} Proportion_i}$	All records where: CPUE (total catch/total effort) was >66.66 kg.hr^{-1}; fishing effort was >10 hr; fishing effort was <3 hr.; the reported catch of the species for which CPUE was being estimated was <95% of the total catch were excluded. Minimum sample size: 10 records.year^{-1} (and 10 records.3years^{-1} when calculated as a running mean for the harvest strategy)
Density$_{legal}$	Density of legal-sized abalone on surveys	$Density_{legal} = \frac{\sum Denisty_{total} * Proportion_{legal}}{Total\ Area\ Surveyed}$	>90% of survey completed Blacklip ≥ current MLL for each SAU defined as legal-sized
General assessment			
Mean Length	Mean length of abalone from shell sampling program of commercial catch	$Length_{mean} = \frac{\sum Shell\ length}{n\ shells}$	Abalone <125 mm SL excluded in all SAUs, except Gerloffs Bay and Rivoli Bay, where all abalone <120 mm SL were excluded Minimum sample size: 100 measurements
Density$_{sublegal}$	Density of sublegal (i.e. those under the MLL) abalone on surveys	$Density_{sublegal} = \frac{\sum Denisty_{total} * Proportion_{sublegal}}{Total\ Area\ Surveyed}$	>90% of survey completed Blacklip < current MLL for each SAU defined as sublegal-sized

2. APPENDIX 2 – Methods

2.1 Quality Assurance

Research planning

The requirements of PIRSA are discussed every two years and subsequently provided to representatives of the SZ abalone fishery to confirm their understanding of proposed deliverables. This ensures that the research undertaken and deliverables provided are consistent with the needs of PIRSA to meet their obligations under the *Fisheries Management Act 2007*.

Data collection

The data provided by commercial fishers are checked by SARDI prior to acceptance and potential errors corrected through direct correspondence with individual commercial fishers. SARDI staff are trained to undertake FI data collection using the standardised method described in the SARDI Abalone Research Group Quality Assurance and Fishery-Independent Survey Manual (QAFISM).

Data entry, validation, storage and security

All logbook data are entered and validated according to quality assurance protocols identified for the abalone fisheries in the SARDI Information Systems Quality Assurance and Data Integrity Report. The data are stored in an Oracle database, backed up daily, with access restricted to SARDI Information Systems staff. Database copies are provided to SARDI abalone researchers on request. All FI data are entered into Excel. A subset of the data (20%) is checked against the original data downloads in accordance with the Abalone Data Library Management Protocol (DLMP). Validated data are uploaded to an Access database on the network drive in Port Lincoln that is regularly backed up to an external hard drive and to Objective, a secure government network.

Data and statistical analyses

Data are extracted from the databases using established protocols. A subset (10%) of data are checked in two ways to ensure extraction accuracy. First, data are compared to those extracted previously. Second, the extractions are undertaken by two SARDI researchers and subsequently compared. Most of the data are analysed using the open-source software R (R Core Team 2018). A subset (~10%) of the outputs from R are compared against estimates made in an alternative package (e.g. Excel).

Data interpretation and report writing

The results, their interpretation and conclusions provided in the reports are formally reviewed by senior SARDI fisheries scientists and discussed with PIRSA Fisheries and Aquaculture and abalone licence holders before the report is finalised. All co-authors review the report prior to the report being formally reviewed by two independent scientists at SARDI in accordance with the SARDI report review process. Following necessary revision, the report is reviewed by PIRSA Fisheries and Aquaculture to ensure it is consistent with their needs and objectives for the fishery.

2.2 Blacklip and Greenlip

2.2.1 Fishery dependent data

The FD data have been collected since 1968 by fishers completing a catch and effort logbook for each fishing day, which comprises catch (t, shell weight), effort, fishing location (mapcode, SAU), catch rate (CPUE, kg shell weight.hr^{-1}). Fishery statistics are provided at three spatial scales – the whole of the SZ, individual SAUs and mapcodes – and are presented by season. Prior to 2016/17, season was 1 September to 31 August (12 months). In 2016/17, a 13 month season was used (i.e. 1 September to 30 September) to facilitate a shift in the season opening to October (i.e. 1 October to 30 September).

Catch (t, shell weight) was determined from all daily logbook returns.

Multi-dimensional scaling (MDS) was used to evaluate temporal changes in the distribution of the proportion of blacklip catches among SAUs, where proximity among seasons indicates their similarity. MDS results were further interpreted with similarity profile analysis (SIMPROF, α=0.05) which allows null hypothesis testing to detect spatial structure of catches among seasons.

CPUE for blacklip was computed using the method listed in Appendix 1. A review of the method utilised to estimate CPUE was undertaken in 2017 (for details of outcomes for the SZ see Ferguson *et al.* 2018). Prior to calculation of CPUE, daily data were filtered to remove records where effort was <3 or >10 hours, the ratio of total catch over total hours was >200 kg.hr^{-1}, blacklip was <95% of catch or daily catch was >1500 kg. Annual CPUE estimates were determined for the SZ and each SAU. Limited daily records (i.e. n<10) prevented calculation of CPUE in some seasons at some spatial scales. For the surveyed and unsurveyed SAUs in seasons where n<10, a 3-year running mean CPUE was applied, as is a requirement under the proposed HS (PIRSA in prep.). CPUE was not estimated for greenlip due to the limited data available.

Data on the shell size of the commercial catch were obtained by SARDI observers measuring samples provided by commercial fishers from September 2001 to September 2020. Recorded shell lengths were used to estimate the mean length of blacklip and greenlip using the method listed in Appendix 1. Length Frequency of the commercial catch is also presented for blacklip for each season in the surveyed and unsurveyed SAUs as a predicted distribution using the geom_density function from the ggplot2 package (Wickam 2016).

2.2.2 Fishery-independent data

Fishery-independent data consisted of estimates of blacklip densities (mean ± se) for sub-legal-sized (<110 to 125 mm SL dependent on SAU) and legal-sized (≥110 to 125 mm SL dependent on SAU) abalone, estimated from the combination of count data and population length-frequency.

Estimates of blacklip density were obtained from FI diver surveys initiated in 2002/03 (see Mayfield *et al.* 2003) that, in more recent seasons, have been undertaken biennially as part of an overall rationalisation of the research program. Survey sites were historically located in non-fish-down areas (Douglas Bay, Middle Point, Cape Northumberland) and fish-down areas (Ringwood Reef, FDA 3; Jones Bay, FDA 2; and Gerloffs Bay, FDA 4) (Mayfield *et al.* 2009). The survey method involved counting blacklip abalone in paired (i.e. left and right), 20-m long transects distributed along ten 170-m, leaded-line transects at each survey site that are laid from the vessel using GPS co-ordinates for the start and end point (Mayfield *et al.* 2004, 2013; McGarvey 2006; McGarvey *et al.* 2008; Mayfield *et al.* 2013). Population length-frequency data were obtained by collecting and then measuring blacklip from within the surveyed area, but not from within transects. Following a review of diving procedures, the survey method in the Middle Point and Gerloffs Bay SAUs were changed in 2014/15 from leaded-line transects to cross-drops. This change was necessary to eliminate the risk of the transect line becoming entangled in the vessel's propeller, posing a risk to vessel safety. The cross-drop method developed by Chick *et al.* (2012) is used throughout the Western Zone of the SAAF (Stobart *et al.* 2015). The leaded-line and cross-drop methods are based on the same sampling principals (McGarvey 2006; McGarvey *et al.* 2008) and yield comparable changes in blacklip density following fishing (Chick *et al.* 2012). Briefly, cross-drops involve counting blacklip abalone in 10-m long by 1-m wide transects radiating from a central point. To increase independence among samples, the inner 2-m is not sampled (i.e. transect lines are 12 m long with the first 2 m not sampled). To enable direct comparison with historical survey estimates of density, 10-m cross-drops were located using GPS to ensure sampling encompassed selected 20-m transects from the original 170-m leaded-line surveys. This required re-estimation of historical abalone densities using only those data from the leaded-line

survey locations that were re-sampled using the cross drops. As before, population length-frequency data were obtained by collecting and then measuring blacklip from within the surveyed area, but not within transects. All surveys conducted in the Rivoli Bay SAU were undertaken using the original leaded-line method. However, following the same review of diving procedures, only five of the historical 10 leaded-lines were sampled. To enable direct comparison with historical survey estimates of density, historical abalone densities were re-estimated using only those data from the consistent leaded-line survey locations. Cross-drop surveys were commenced at Number 2 Rocks in 2014/15.

Estimates of total greenlip density (i.e. combined sub-legal sized and legal sized individuals) were recorded for the Rivoli Bay SAU. Counts were undertaken simultaneously along the same leaded-lines that are used for blacklip surveys at Ringwood Reef. The only difference in methodology, was that no population length-frequency data was recorded for greenlip, therefore estimates are presented as total densities only. Counts of greenlip recorded in other SAUs are not presented because they are considered too low to provide a reliable estimate of abalone density.

3. APPENDIX 3 – Proposed harvest strategy, zone score and stock status for 2020/21 year-to-date data

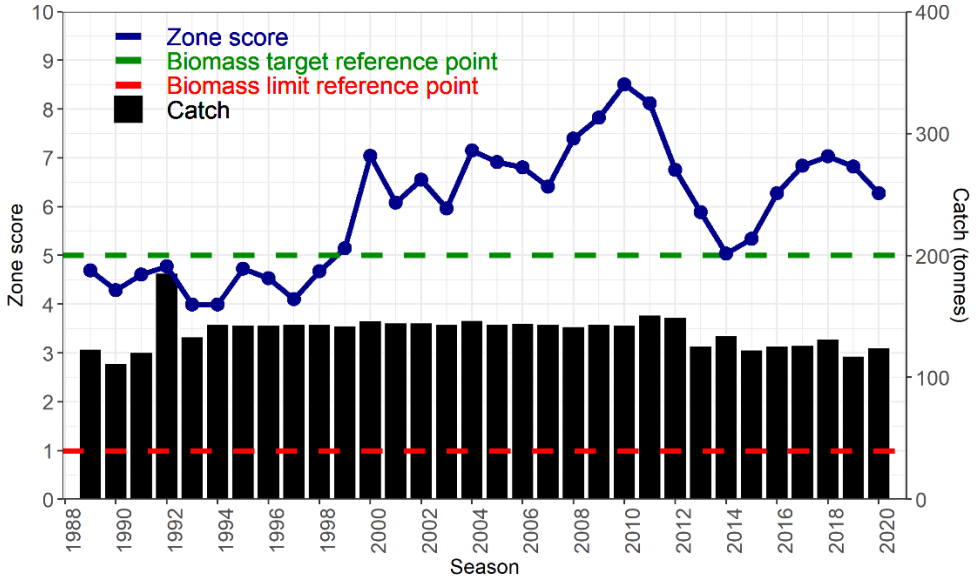

Figure A3-1. Year-to-date (data until 30 June 2021) zone score plot for SZ blacklip between 1989/90 (denoted 1989) and 2020/21. Zone score (blue symbols and line), biomass target reference point (green line), biomass limit reference point (red line) and catch (black bars, tonnes). Note, FIS were 'carried-forward' 3-years for the Middle Point SAU.

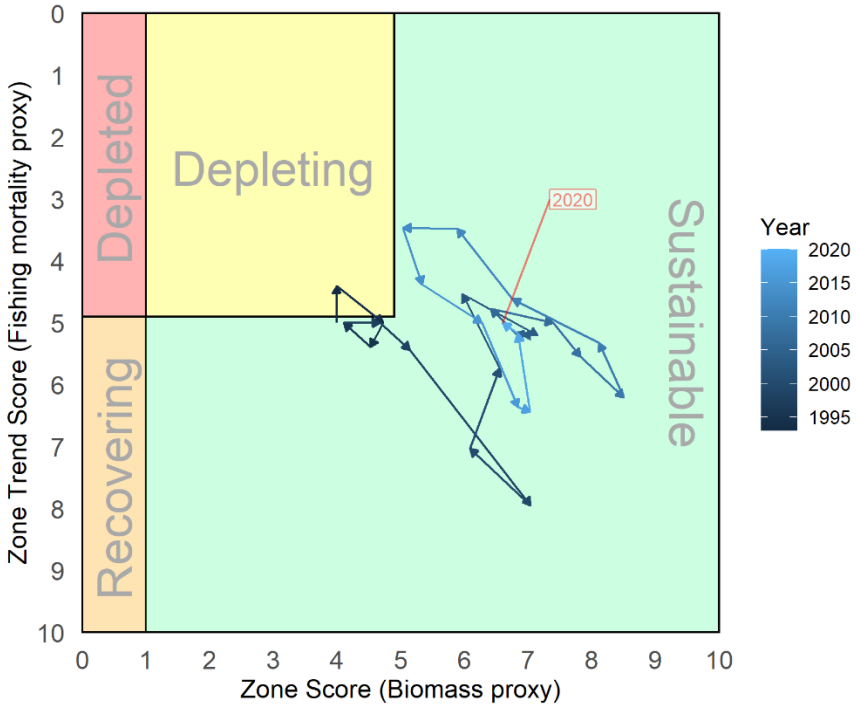

Figure A3-2. Year-to-date (data until 30 June 2021) phaseplot indicating changes in SZ blacklip stock status between 1993/94 and 2020/21 (denoted 2020). Note, FIS were 'carried-forward' 3-years for the Middle Point SAU.

Table A3-1. Year-to-date (data until 30 June 2021) outcome of application of the harvest strategy SZ blacklip in 2020/21. The primary table shows the HS outcome where FIS were 'carried-forward' 3-years for the Middle Point SAU. The two additional columns indicate an outcome consistent with the harvest strategy described in the draft Management Plan, where FIS >2 years old are excluded from HS scoring, and the SAU Score and Weighted SAU Score for Middle Point, are based solely on CPUE.

SAU	CPUE ($kg.hr^{-1}$)	CPUE score	Legal density ($abs.m^{-2}$)	Legal density score	SAU score	Catch 20/21 (tonnes)	Proportion of 12year catch	Weighted SAU score	SAU score (no MP FIS score)	Weighted SAU score (no MP FIS score)
Middle Point	102.3	6.7	0.39	4.5	5.6	25.7	0.23	1.28	6.7	1.53
Number 2 Rocks	121.8	8.7	NA	NA	8.7	31.0	0.20	1.72	8.7	1.72
Data limited SAUs	99.7	6.7	NA	NA	6.7	25.5	0.16	1.09	6.7	1.09
Gerloffs Bay	101.4	6.0	0.32	1.8	3.9	5.3	0.12	0.46	3.9	0.46
Port Macdonnell	96.0	5.1	NA	NA	5.1	14.5	0.09	0.47	5.1	0.47
Admella	94.4	5.9	NA	NA	5.9	3.8	0.07	0.42	5.9	0.42
Carpenters Rocks	87.8	7.0	NA	NA	7.0	8.8	0.07	0.47	7.0	0.47
Rivoli Bay	115.0	7.3	0.68	4.6	5.9	9.8	0.06	0.38	5.9	0.38
							Zone Score	**6.28**	**Zone Score**	**6.54**

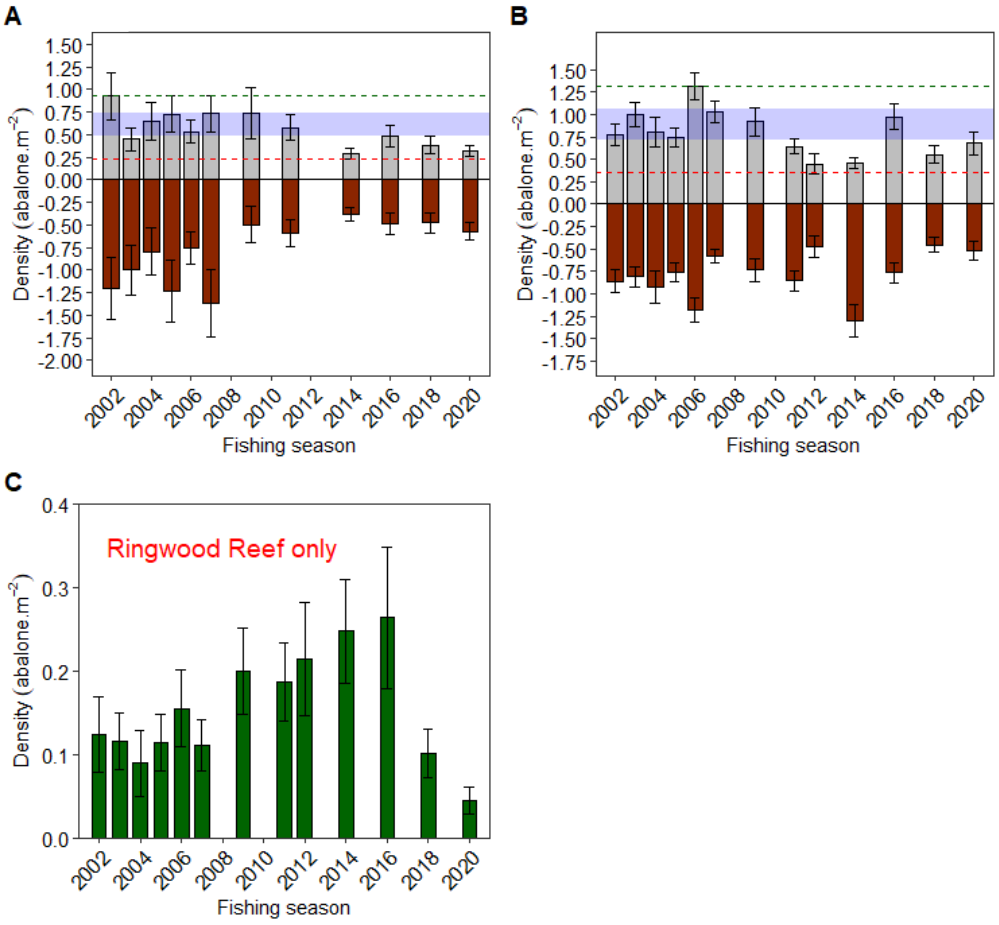

Figure A3-3. Year-to-date data from fishery-independent-surveys for a) blacklip at Gerloffs Bay, b) blackilp at Rivoli Bay and c) greenlip at Rivoli Bay. For blacklip, red and grey bars show the density of blacklip ($abalone.m^{-2}$; ± se) counted along transects <110 and ≥110 mm SL, respectively. Scoring from the harvest strategy is shown for panels a) and b): Target Range (score of 5, blue shading), upper limit (score of 10, green dashed line), lower limit (score of 0, red dashed line). For greenlip, green bars show the total density of greenlip ($abalone.m^{-2}$; ± se) for Ringwood Reef, within the Rivoli Bay SAU.

4. APPENDIX 4 – Catch by mapcode for surveyed and unsurveyed SAUs

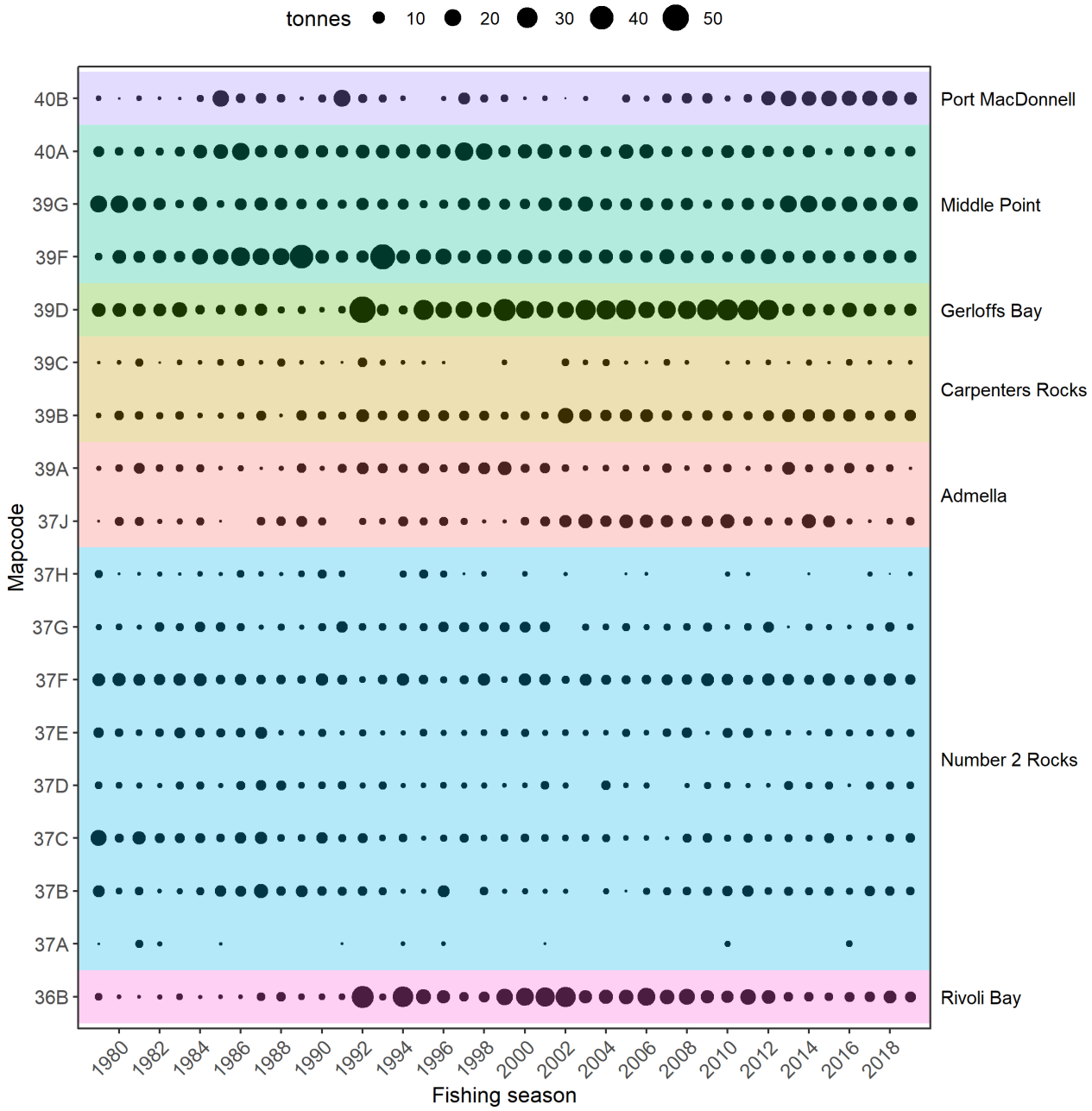

Figure A4-1. Bubble plot of catch (tonnes) by mapcode for surveyed and unsurveyed SAUs in SZ blacklip fishery.

5. APPENDIX 5 – Annual zone score, score gradient, zonal trend and status for blacklip

Table A5-1. Annual zone score, score gradient, trend in zone score and status for blacklip from the harvest strategy (PIRSA 2021)

Fishing season	Zone score	Score Gradient	Zonal trend score	Stock status
1993/94	4.00	-0.02	5.00	Sustainable
1994/95	3.99	-0.06	4.40	Depleting
1995/96	4.72	0.00	5.00	Sustainable
1996/97	4.53	0.05	5.39	Sustainable
1997/98	4.11	0.00	5.00	Sustainable
1998/99	4.68	-0.01	5.00	Sustainable
1999/00	5.15	0.05	5.44	Sustainable
2000/01	7.04	0.20	7.95	Sustainable
2001/02	6.09	0.15	7.03	Sustainable
2002/03	6.56	0.07	5.73	Sustainable
2003/04	5.97	-0.05	4.53	Sustainable
2004/05	7.15	0.04	5.20	Sustainable
2005/06	6.91	0.04	5.20	Sustainable
2006/07	6.81	0.03	5.16	Sustainable
2007/08	6.41	-0.04	4.77	Sustainable
2008/09	7.39	0.01	5.00	Sustainable
2009/10	7.82	0.06	5.55	Sustainable
2010/11	8.51	0.10	6.21	Sustainable
2011/12	8.12	0.04	5.32	Sustainable
2012/13	6.76	-0.05	4.62	Sustainable
2013/14	5.89	-0.12	3.48	Sustainable
2014/15	5.04	-0.12	3.46	Sustainable
2015/16	5.34	-0.06	4.38	Sustainable
2016/17	6.28	0.02	5.00	Sustainable
2017/18	6.84	0.11	6.36	Sustainable
2018/19	7.03	0.11	6.43	Sustainable
2019/20	6.84	0.04	5.17	Sustainable

6. APPENDIX 6 – Catch and CPUE for blacklip and greenlip

Table A6-1. Blacklip catches (tonnes) by season from the Southern Zone abalone fishery, aggregated at the spatial assessment unit scale.

Season	Admella	Beachport	Blackfellows Caves	Cape Jaffa	Carpenters Rocks	East Port Macdonnell	Gerloffs Bay	Middle Point	Nora Creina	Number 2 Rocks	Port Macdonnell	Rivoli Bay	South End	Unassigned SZ
1979	1.2	0.7	0.1	2.2	1.7	0.0	12.7	29.1	2.9	51.4	1.6	3.3	5.3	0.0
1980	8.2	7.2	0.0	0.0	6.2	0.7	12.6	36.4	5.8	27.2	0.1	0.8	5.4	0.0
1981	12.1	3.7	0.3	0.0	7.6	0.1	10.5	27.7	2.0	33.2	1.4	0.4	12.0	0.0
1982	4.2	4.8	0.2	0.4	2.7	0.1	10.4	23.8	5.2	27.7	0.5	1.3	2.3	0.0
1983	4.8	2.8	1.5	0.3	5.7	0.1	15.6	17.9	1.0	32.1	0.3	2.3	8.7	0.0
1984	7.2	4.0	3.6	2.6	2.6	6.4	5.4	42.5	0.5	36.9	2.7	0.8	19.0	0.0
1985	1.1	3.3	1.4	3.8	3.9	6.6	5.5	33.7	9.4	29.6	18.0	1.0	9.0	0.0
1986	1.6	3.2	0.7	1.2	5.5	3.0	8.8	53.9	3.5	39.0	5.4	0.9	11.9	0.0
1987	4.3	2.8	7.9	2.8	7.0	3.0	9.8	41.2	2.8	46.3	6.4	4.3	6.8	2.1
1988	6.3	2.2	10.2	1.5	4.0	0.2	2.8	40.8	1.3	24.2	4.2	5.3	4.9	0.0
1989	12.8	2.9	4.3	0.0	7.7	0.2	3.4	59.1	1.3	23.0	0.7	2.3	5.7	0.0
1990	4.7	4.1	6.1	0.6	4.9	5.7	1.4	29.2	1.2	37.7	3.6	2.2	10.1	0.0
1991	4.9	3.2	5.2	1.0	3.6	12.9	3.2	24.0	2.5	30.0	19.3	2.4	8.5	0.0
1992	11.1	2.5	1.8	0.8	16.0	0.0	51.4	31.1	1.0	20.3	4.9	35.8	8.7	0.4
1993	8.3	2.2	2.7	0.0	7.3	5.6	8.4	64.6	1.5	18.7	3.6	2.8	7.7	0.0
1994	10.4	3.7	2.5	0.0	7.9	8.9	4.6	32.9	7.0	24.0	1.5	30.2	9.7	0.4
1995	10.5	6.9	7.5	0.6	9.7	1.0	29.4	32.0	3.8	19.9	0.0	14.9	6.7	0.0
1996	8.0	5.9	2.2	0.7	7.4	11.0	18.6	34.6	5.0	27.9	1.2	11.3	9.2	0.0
1997	11.0	2.1	6.2	0.0	5.7	5.9	19.6	43.5	7.4	19.3	8.8	5.2	6.3	3.0
1998	9.7	4.0	3.8	0.9	5.7	5.9	15.4	41.6	4.3	27.5	3.7	7.2	13.9	0.0
1999	12.7	2.6	5.5	0.0	4.8	7.2	35.8	29.9	0.6	16.7	2.9	18.5	5.3	0.4
2000	8.5	4.2	7.8	1.3	4.5	6.0	21.7	33.9	0.0	29.3	0.4	21.8	7.3	0.0
2001	12.1	1.6	0.8	0.7	3.2	6.8	19.4	38.2	4.8	25.0	1.6	26.1	4.9	0.0
2002	12.9	4.7	1.1	0.6	19.4	4.4	18.7	33.8	5.6	11.8	0.0	29.6	2.2	0.1
2003	15.2	2.3	2.1	1.3	11.0	5.6	29.5	38.2	3.0	16.3	1.0	11.3	6.1	0.4
2004	10.1	7.5	2.9	0.7	10.6	5.9	26.7	29.5	5.2	19.7	0.0	13.2	11.2	3.6
2005	14.2	7.3	1.0	0.4	10.7	0.0	27.1	33.6	7.2	15.2	3.3	13.9	8.0	2.1
2006	13.8	6.6	4.9	1.4	10.9	1.1	18.5	33.4	3.6	15.1	2.0	22.6	7.9	2.6
2007	15.5	5.1	8.7	1.1	8.9	0.0	22.6	32.2	6.8	17.7	5.5	14.5	4.2	0.8
2008	8.1	9.6	2.6	0.6	6.9	0.1	23.0	26.9	7.2	26.0	6.6	17.8	6.5	0.0
2009	12.0	9.6	3.5	0.0	6.8	0.4	29.8	22.6	4.0	28.3	6.8	11.7	8.4	0.0
2010	17.4	4.1	6.9	0.9	6.4	0.0	31.4	26.3	3.6	30.1	1.9	9.5	4.5	0.0
2011	6.5	10.3	4.3	0.0	5.8	1.4	29.3	32.6	4.3	29.4	4.2	16.2	6.9	0.0
2012	6.6	5.2	5.7	0.4	8.8	0.2	29.2	31.1	3.9	26.1	13.3	12.5	6.5	0.0
2013	14.2	3.2	2.5	0.0	10.8	0.1	9.9	35.9	1.2	22.6	16.7	5.4	3.2	0.0
2014	16.7	6.3	4.6	0.0	11.7	0.1	10.0	38.9	6.8	18.5	13.7	5.4	1.9	0.0
2015	13.4	3.3	4.5	0.9	9.9	0.0	7.9	26.4	5.2	27.9	15.9	4.1	3.2	0.0
2016	8.3	4.4	5.4	1.8	11.8	0.1	14.2	31.0	4.0	17.2	15.1	6.2	6.5	0.0
2017	4.1	5.3	3.7	3.6	6.2	0.2	10.3	31.5	7.3	27.1	15.0	6.7	5.3	0.0
2018	5.2	5.0	2.3	2.5	8.1	0.0	8.3	29.5	8.2	31.0	15.8	10.0	5.6	0.0
2019	4.5	5.1	2.6	2.5	9.2	0.0	9.6	29.7	5.3	25.4	10.3	7.2	6.4	0.0

Table A6-2. Blacklip catch per unit effort (CPUE) by season from the Southern Zone abalone fishery, aggregated at the spatial assessment unit scale. No data indicates estimate is not available for that season (i.e. <10 fishing records in the given season). * indicates running mean applied, as required for the harvest strategy. Estimates for data-limited SAUs are an aggregation of Beachport, Blackfellows Caves, Cape Jaffa, East Port MacDonnell, Nora Creina, and South End, as required for the harvest strategy

Season	Admella*	Beachport	Blackfellows Caves	Cape Jaffa	Carpenters Rocks*	East Port Macdonnell	Gerloffs Bay*	Middle Point*	Nora Creina	Number 2 Rocks*	Port Macdonnell*	Rivoli Bay*	South End	Data Limited SAUs*
1979	57.3				63.0		71.6	61.4		87.5		54.0	58.0	58.4
1980	49.6	92.2			66.0		58.2	59.5	67.7	76.7		39.6	57.9	72.7
1981	65.2	48.5			57.1		44.3	58.6		71.6		29.1	57.2	55.8
1982	43.4	53.9			50.7		39.4	67.4	43.6	72.1		29.8		46.8
1983	42.5				42.6		51.9	59.7		65.3	50.0	41.6	57.5	58.6
1984	74.6				57.1	63.9	54.9	81.1		100.0	65.9	48.3	99.2	83.1
1985	73.6				58.5	52.0	55.6	77.4	54.8	89.9	71.9		73.7	58.7
1986	84.1				73.6	57.6	71.1	78.6		95.8	68.0	63.2	74.9	70.8
1987	83.5		79.4		79.2		70.7	85.3		105.4	84.1	65.6	82.6	76.7
1988	81.7		71.8		83.5		72.8	89.3		110.1	98.9	75.6		84.2
1989	85.8				84.4			83.0		98.8	109.4	83.7	91.7	86.4
1990	73.7		68.7		76.5	64.7		81.6		100.4	106.2	85.4	97.4	80.9
1991	80.9		66.9		73.4	93.5		79.5		104.2	103.0	104.4		92.2
1992	75.4				74.7		117.9	79.7		100.8	71.1	106.3	93.0	87.0
1993	78.0				62.6		103.0	79.8		84.3	78.1	103.0	90.4	85.5
1994	75.9				72.3	72.5	82.4	76.6		89.3	78.6	104.8	96.0	85.2
1995	73.2				66.7		90.8	84.5		88.2		108.6	95.3	96.4
1996	71.4				74.2	70.1	79.2	86.3		90.2		98.5	113.5	90.5
1997	77.8				65.2	62.6	85.5	79.5	80.4	92.1	96.8	87.8		80.1
1998	91.3				73.8	76.5	77.3	99.3		107.4	84.2	67.1	81.3	77.5
1999	96.5				84.3	78.2	94.5	92.0		106.2	81.6	92.1		82.4
2000	108.3		116.6		92.2		80.9	101.5		120.0		114.0	111.2	106.6
2001	87.2				102.6		99.6	98.2		114.2		109.8		85.6
2002	97.5				108.2	68.6	105.2	96.2		144.1		108.0		98.4
2003	97.2				92.6	68.5	110.0	97.8		124.3		112.0		96.1
2004	99.5				101.9	69.5	99.5	108.3		125.5		111.9	142.5	106.7
2005	98.0	104.4			93.5		95.1	105.5		124.6		116.8		113.0
2006	81.4				89.1		103.4	105.8		109.3	106.6	118.4	107.4	106.9
2007	88.7		92.0		76.4		87.7	102.5		121.9	112.9	111.0		99.4
2008	96.3	110.6			88.4		109.7	102.5		128.6	131.1	126.3		104.3
2009	102.1	129.8			105.8		105.4	109.5		128.0	146.6	114.6		120.3
2010	112.0				110.1		125.1	125.4		126.7	149.8	122.8		123.1
2011	96.1	100.0			105.9		112.1	123.2		134.8	136.7	116.4	100.2	102.9
2012	82.5		103.0		93.0		95.2	109.8		130.2	125.5	98.7	88.5	91.5
2013	83.0				87.3		83.4	107.2		112.0	124.0	97.5		85.9
2014	88.5	98.2			88.6		86.8	101.2		101.5	118.1	90.1		92.7
2015	84.5				79.7		81.6	91.3		109.6	118.9	94.0		102.4
2016	79.3				86.4		79.4	99.9		117.2	99.0	110.5		114.8
2017	90.4				93.9		95.4	104.8		123.6	99.8	123.2		111.1
2018	99.3				106.7		97.3	107.3	100.6	119.3	113.3	123.5		107.4
2019	98.1				101.0		96.9	113.9		121.3	95.1	118.2		104.1

Table A6-3. Greenlip catches (tonnes) by season from the Southern Zone abalone fishery, aggregated at the spatial assessment unit scale

Season	Admella	Beachport	Blackfellows Caves	Cape Jaffa	Carpenters Rocks	East Port Macdonnell	Gerloffs Bay	Middle Point	Nora Creina	Number 2 Rocks	Port Macdonnell	Rivoli Bay	South End	Unassigned SZ
1979	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.1	0.1	0.1	0.2	1.0	0.0	0.0
1980	0.1	0.0	0.0	0.3	0.0	0.0	1.8	0.0	0.6	0.0	0.2	0.1	0.2	0.0
1981	0.1	0.0	0.0	0.0	0.0	0.0	0.9	0.1	0.1	0.0	0.0	0.0	0.2	0.0
1982	0.1	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.3	0.1	0.1	0.9	0.2	0.0
1983	0.1	0.0	0.0	0.1	0.1	0.0	1.4	0.0	0.4	0.1	0.0	0.3	0.1	0.0
1984	0.1	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	1.6	0.0	0.0	0.2	0.0	0.0
1986	0.0	0.1	0.0	0.2	0.0	0.0	0.3	0.1	0.1	0.0	0.0	0.3	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
1988	0.1	0.2	0.3	0.3	0.1	0.0	0.5	0.2	0.2	0.1	0.1	0.3	0.0	0.0
1989	0.2	0.3	0.2	0.0	0.2	0.0	0.8	0.1	0.2	0.1	0.0	0.2	0.0	0.0
1990	0.4	0.1	0.1	0.1	0.1	0.2	0.3	0.6	0.3	0.1	0.0	0.1	0.0	0.0
1991	0.0	0.0	0.1	0.0	0.1	1.2	0.5	0.2	0.3	0.1	0.1	0.3	0.0	0.0
1992	0.2	0.0	0.0	0.3	0.2	0.0	1.3	0.4	0.2	0.1	0.0	1.6	0.2	0.0
1993	0.2	0.0	0.0	0.0	0.1	0.5	0.7	1.0	0.1	0.1	0.0	0.1	0.1	0.0
1994	0.1	0.0	0.4	0.0	0.2	2.7	0.5	0.4	0.4	0.1	0.1	0.7	0.2	0.0
1995	0.1	0.7	0.4	0.0	0.2	0.7	2.1	0.4	0.1	0.0	0.0	1.0	0.0	0.0
1996	0.0	0.0	0.1	0.2	0.0	1.1	2.1	0.1	0.4	0.1	0.0	0.2	0.1	0.0
1997	0.1	0.1	0.7	0.0	0.1	0.9	2.7	0.3	0.6	0.0	0.1	0.1	0.1	0.1
1998	0.0	0.0	0.1	0.0	0.1	3.1	1.6	0.2	0.1	0.0	0.1	0.1	0.0	0.0
1999	0.1	0.0	0.2	0.0	0.0	1.2	3.3	0.4	0.0	0.0	0.0	0.1	0.0	0.0
2000	0.0	0.0	0.2	0.0	0.0	0.4	1.9	0.1	0.0	0.0	0.0	0.1	0.0	0.0
2001	0.1	0.0	0.0	0.0	0.1	0.7	1.4	0.1	0.2	0.1	0.0	0.2	0.0	0.0
2002	0.1	0.0	0.1	0.0	0.2	0.3	1.9	0.3	0.1	0.0	0.0	0.0	0.0	0.0
2003	0.1	0.0	0.0	0.1	0.1	0.3	2.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0
2004	0.1	0.0	0.0	0.0	0.0	0.1	2.4	0.2	0.1	0.0	0.0	0.1	0.0	0.0
2005	0.2	0.3	0.0	0.5	0.1	0.0	2.7	0.2	0.7	0.0	0.0	0.9	0.1	0.2
2006	0.2	0.2	0.2	1.0	0.5	0.2	1.9	0.4	0.4	0.1	0.0	0.7	0.0	0.1
2007	0.2	0.0	0.3	0.5	0.3	0.0	2.5	0.6	0.5	0.0	0.0	0.9	0.0	0.0
2008	0.1	0.3	0.2	0.1	0.1	0.2	2.3	0.4	1.1	0.0	0.0	0.9	0.1	0.0
2009	0.4	0.2	0.2	0.0	0.1	0.0	2.6	0.1	0.6	0.0	0.3	1.0	0.5	0.0
2010	0.4	0.0	0.2	0.5	0.1	0.0	2.5	0.4	0.4	0.0	0.1	1.8	0.2	0.0
2011	0.2	0.1	0.2	0.2	0.1	0.3	2.5	0.4	0.4	0.0	0.0	2.8	0.0	0.0
2012	0.0	0.1	0.1	0.2	0.1	0.2	2.4	0.3	1.0	0.0	0.4	1.3	0.0	0.0
2013	0.2	0.1	0.0	0.1	0.4	0.0	1.0	0.2	0.1	0.0	0.3	1.1	0.0	0.0
2014	0.2	0.0	0.1	0.0	0.2	0.0	0.8	0.3	1.5	0.0	0.6	0.7	0.0	0.0
2015	0.3	0.0	0.1	0.8	0.4	0.0	0.7	0.2	0.8	0.0	0.2	0.2	0.0	0.0
2016	0.3	0.0	0.2	0.2	0.2	0.1	1.1	0.2	0.5	0.0	0.2	0.3	0.0	0.0
2017	0.1	0.1	0.2	0.7	0.3	0.0	0.4	0.1	0.8	0.0	0.2	0.2	0.0	0.0
2018	0.1	0.0	0.2	0.1	0.2	0.0	0.5	0.1	0.4	0.0	0.2	0.2	0.0	0.0
2019	0.1	0.0	0.1	0.2	0.2	0.0	0.4	0.1	0.6	0.0	0.0	0.1	0.0	0.0