Fisheries

Assessment of the Southern Zone Abalone (*Haliotis rubra* and *H. laevigata*) Fishery in 2022/23

O. Burnell and A. Hogg

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PO Box 120 Henley Beach SA 5022

September 2023

Report to PIRSA Fisheries and Aquaculture

Government of South Australia
Department of Primary Industries and Regions

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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ABBREVIATIONS

AVG	Abalone Viral Ganglioneuritis
BL	Blacklip Abalone
CPUA	Catch Per Unit Area
CPUE	Catch Per Unit Effort
FDA	Fish Down Area
FIS	Fishery Independent Survey
GL	Greenlip Abalone
GPS	Global Positioning System
HS	Harvest Strategy
KUD	Kernel Utilisation Distribution
MDS	Multi-Dimensional Scaling
MLL	Minimum Legal Length
NFSRF	National Fishery Status Reporting Framework
PI	Performance Indicator
PIRSA	Department of Primary Industries and Regions
SAAF	South Australian Abalone Fishery
SARDI	South Australian Research and Development Institute
SAU	Spatial Assessment Unit
SLA	Service Level Agreement
SZ	Southern Zone
SZAF	Southern Zone Abalone Fishery
TACC	Total Allowable Commercial Catch
VMS	Vessel Monitoring System
YTD	Year-to-Date

EXECUTIVE SUMMARY

This report provides an assessment of stock status for Blacklip Abalone (*Haliotis rubra*) and Greenlip Abalone (*H. laevigata*; hereafter referred to as blacklip and greenlip, respectively) in the Southern Zone (SZ) of the South Australian Abalone Fishery (SAAF) for the year-to-date (YTD) 2022/23 fishing season. Blacklip stock status is determined using the Harvest Strategy (HS) from the Abalone Management Plan (PIRSA 2021), that has been designed to deliver outcomes consistent with the national fishery status reporting framework (NFSRF). The HS is not applied to greenlip in the SZ (PIRSA 2021). As the 2022/23 fishing season is incomplete, this assessment considers data between 1 October 2022 and 30 April 2023. These YTD data provide a reliable measure of stock status in the SZ (see Dent *et al.* 2016). The stock status from the completed 2022/23 fishing season will be provided in the next iteration of this report. Unless otherwise stated, all years in this report refer to fishing season and are indicated by the first year (e.g., 2022/23 fishing season will be referred to as 2022).

Blacklip Abalone

The year-to-date (YTD) blacklip catch of 115.2 t, constituted 87% of the 132 t Total Allowable Commercial Catch (TACC) in 2022. The key sources of fishery-dependent and fishery-independent data collectively indicated that harvestable biomass of blacklip stocks were above target levels. Estimates of CPUE for most spatial assessment units (SAUs) were above their target range from the HS. The density of legal-sized abalone recorded during fishery-independent surveys (FIS) in the two SAUs with the greatest catch (Middle Point and Number 2 Rocks) were at their highest levels since 2014 and were at, or above, their target range from the HS. However, FIS estimates from the other two surveyed SAUs, with lower catch (Gerloffs Bay and Rivoli Bay), were below the target range from the HS. There is an ongoing discrepancy between the two Performance Indicators (PIs) from the HS (CPUE average HS score 8.3 / 10, FIS average HS score 4.2 / 10), which will be considered during the next review of the HS.

This is the first assessment report to include GPS data from the Vessel Monitoring System (VMS) collected since 2010. These data are important as they enable estimation of the area fished as a measure of effort, rather than existing PIs that use fishing time (i.e., CPUE).

Application of the HS to the YTD data resulted in a **zone score (i.e., biomass proxy) of 7.47 / 10** that, in combination with the **zone trend score (i.e., fishing mortality proxy) of 5.51 / 10** (reflecting an increasing trend), defines the stock status for blacklip in the SZ in 2022 as '**sustainable**'. This is consistent with the status classifications since 2016. The zone score of 7.47 translates to a recommended zonal catch of 138.2 t for 2023, which is 4.7% above the current TACC of 132.0 t.

Greenlip Abalone

Catches of greenlip have remained at the lowest levels recorded since the mid-1980s for five consecutive fishing seasons, which is consistent with the current low TACC of 1.8 t. Greenlip is considered a bycatch species in the SZ, and there are insufficient data available to estimate either biomass or fishing mortality. The stock status for this species is classified as **'undefined'** in 2022 under the NFSRF (Piddocke *et al.* 2021), which is consistent with previous status classifications for greenlip (Burnell *et al.* 2022).

Key statistics for the SZ blacklip and greenlip fisheries from 2013 to 2022 including number of licences; total allowable commercial catch (TACC); total commercial catch (TCC); catch-per-unit-effort (CPUE); stock status (complete season) and stock status (year-to-date). #Year-to-date data for the incomplete Fishing Season as prescribed by the Harvest Strategy. *Since 2019 blacklip stock status has been determined using the Harvest Strategy (PIRSA 2021). 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, instead stock status classifications are determined using the National Fishery Status Reporting Framework.

Blacklip

Season	No. licences	TACC (t)	TCC (t)	CPUE (kg.hr^{-1})	Stock Status (Complete season)	Stock Status (YTD)
2013/14	6	151.5	125.7	95.9	Depleting	
2014/15	6	151.5	134.6	93.5	Depleting	
2015/16	6	126.0	122.6	98.2	Depleting	
2016/17	6	126.0	125.9	98.3	Sustainable	
2017/18	6	126.0	126.3	107.9	Sustainable	
2018/19	6	132.0	131.5	109.8	Sustainable	
2019/20	6	132.0	117.8	104.4	Sustainable*	
2020/21	6	132.0	132.3	103.4	Sustainable*	
2021/22	6	132.0	132.2	117.0	Sustainable*	Sustainable#,*
2022/23	6	132.0	115.2#	116.8#	TBA in next report	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
2020/21	6	1.8	1.4	na	Undefined
2021/22	6	1.8	1.6	na	Undefined
2022/23	6	1.8	1.6#	na	Undefined

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 Abalone (*Haliotis rubra*; hereafter referred to as 'blacklip') and Greenlip Abalone (*H. laevigata*; hereafter referred to as 'greenlip') in the Southern Zone (SZ) of the South Australian Abalone Fishery (SAAF) in 2022. These reports form part of the South Australian Research and Development Institute (SARDI) Aquatic and Livestock Sciences ongoing assessment program for these fisheries. The assessment updates previous fishery assessment (Burnell *et al.* 2021b) and status reports (Burnell *et al.* 2022) for the SZ. The aims of the report are to: (1) assess the 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, stock status for blacklip was determined using the 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 HS used in this report is part of the Management Plan for the South Australian Commercial Abalone Fisheries (PIRSA 2021). The Management Plan specifies annual application of the HS to determine stock status for blacklip and determination of the Total Allowable Commercial Catch (TACC). The management plan specifies for the SZ that '*year-to-date data derived from the fishing season currently underway will be used (i.e., the assessment will consider data between 1 October in the previous calendar year to the latest available data at the time of the assessment';* PIRSA 2021). The 'latest available data' captured to allow sufficient time for report review, approval and TACC setting in 2022 was 30th April. On average 86% of the TACC is harvested by the end of April, with this number rising to 91% by the end of May. Previous research indicates there is a strong association between year-to-date CPUE estimates and full fishing season CPUE estimates in the SZ (see Dent *et al.* 2016). The HS is not applied to greenlip in the SZ (PIRSA 2021), instead stock status is determined using a weight-of-evidence approach.

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, except for 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 2022, the blacklip TACC was 132 t whole weight, while the greenlip TACC was 1.8 t whole weight.

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

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 Spatial Assessment Unit (SAU)-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 SAUs were identified, that incorporated from 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). In 2021, a new SAU (i.e., Nene Valley) was created by splitting mapcode 39F in the Middle Point SAU into a western (i.e., 39FW) and eastern section (39FE; see Figure 1-3). This new SAU was designed to align with the

historical Nene Valley FDA 1, which formerly existed from 1997 to 2012. The MLL in the Nene Valley SAU is currently 110mm (Table 1-3).

Two other notable impacts on the SZ fishery in recent years include summer mortalities in 2012 and the recent COVID-19 pandemic. During the summer of 2012/13, blacklip stocks in the SZ were exposed to 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 season, has presented logistical and market related challenges for abalone divers, licence holders and processors, which extended into the 2020 fishing season.

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
	MLL 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 MLL 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 MLL 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 Season extended from 1 September 2016 to 30 September 2017 (13 months)
2017	2017 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
2021	Management Plan revised (PIRSA 2021) – new harvest strategy
	Mapcode 39F split into 39FW (new Nene Valley SAU) and 39FE (remains part of Middle Point SAU)

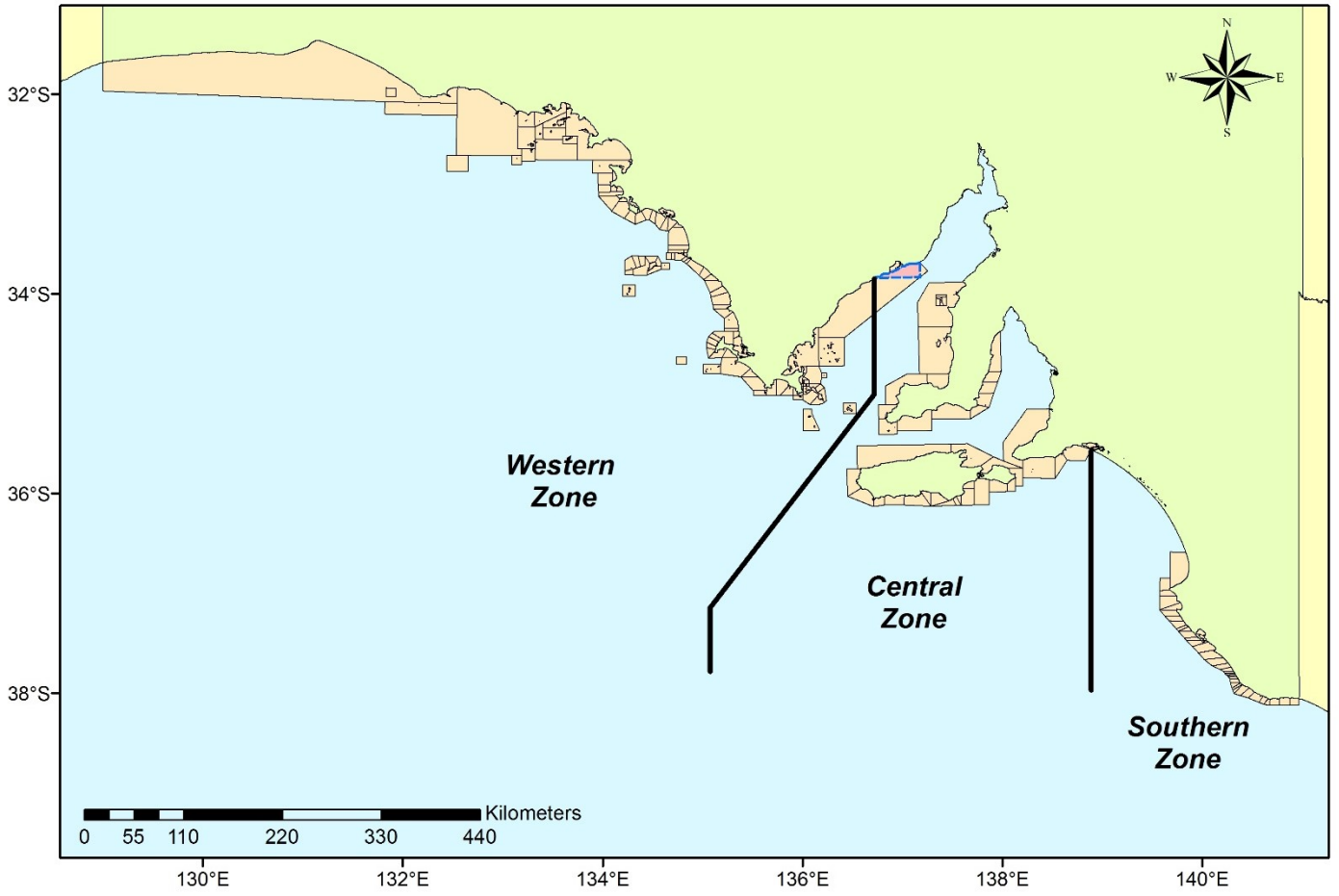

Figure 1-1. Fishing zones (labelled) and mapcodes (unlabelled) of the South Australian Abalone Fishery.

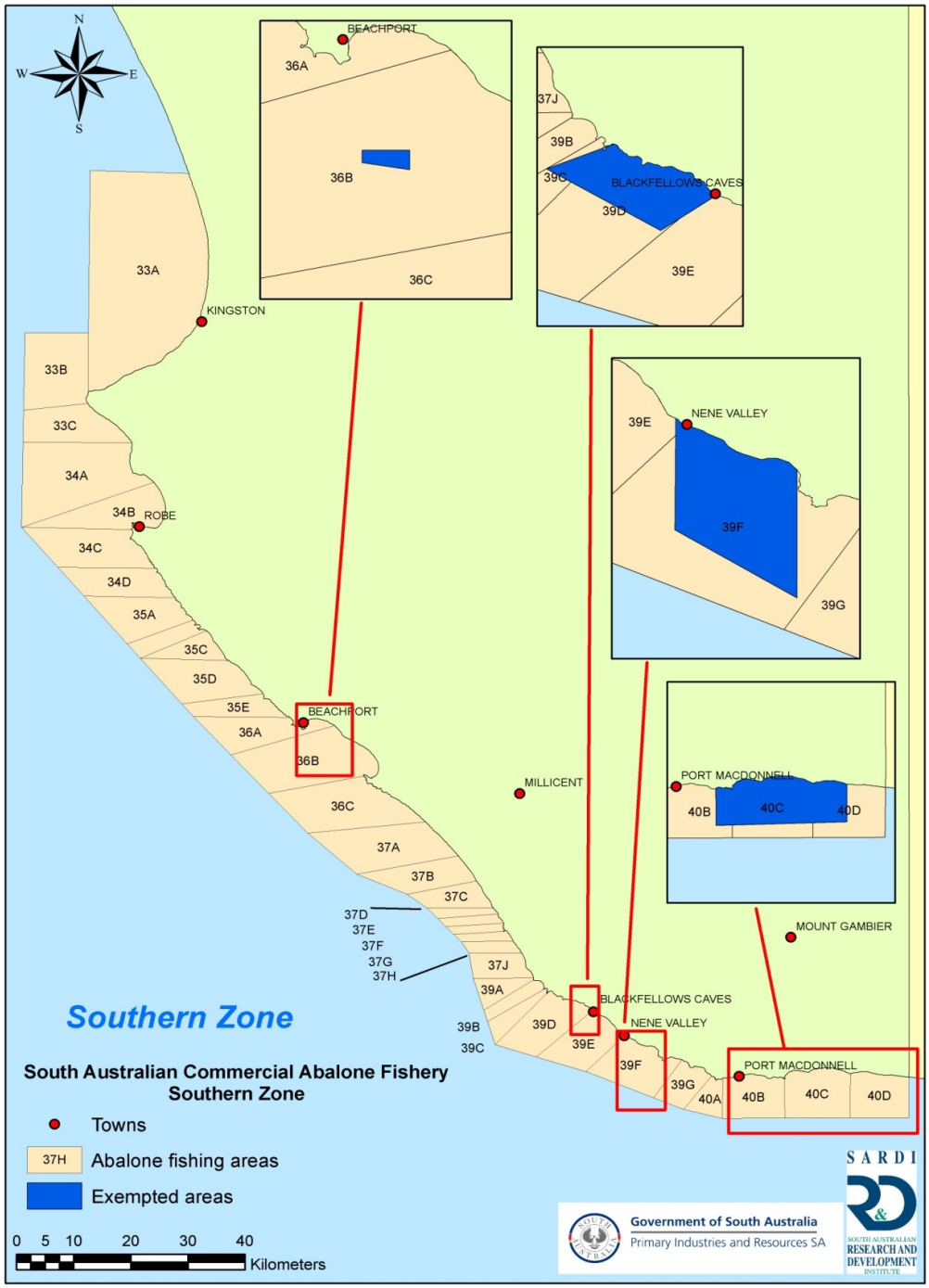

Figure 1-2. Abalone fishing areas (mapcodes, orange polygons) and historic 'fish-down' areas (i.e., exempted areas with lower historical minimum legal lengths between the early 1990s and 2012; blue polygons in inset maps) in the Southern Zone Abalone Fishery.

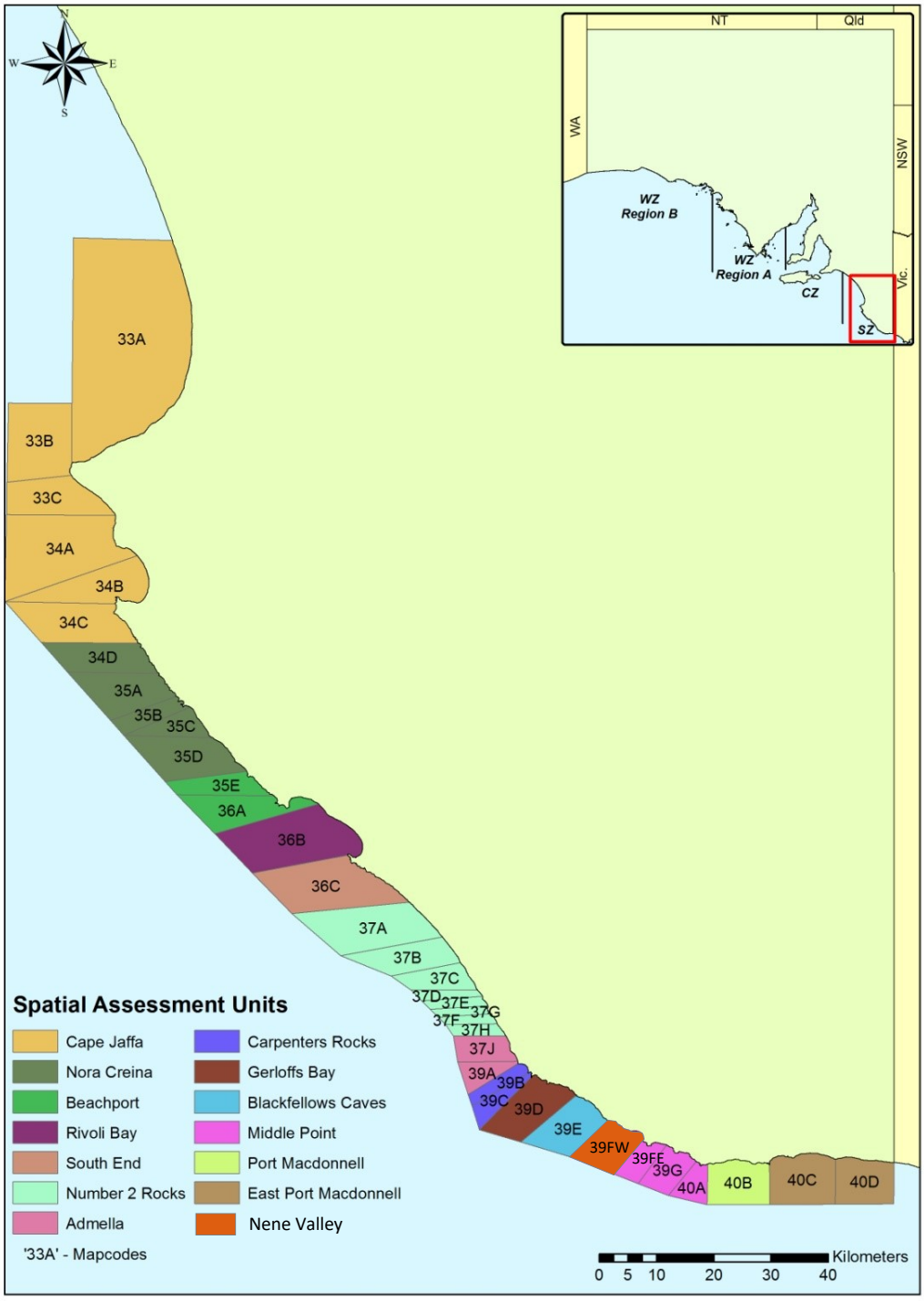

Figure 1-3. Spatial assessment units (SAUs) and mapcodes in the Southern Zone Abalone Fishery.

Table 1-3. Blacklip SAUs, mapcodes, catch caps in 2022 (whole weight), minimum legal shell lengths (MLLs) since 2013, historical MLLs for the areas inside and outside of the fish-down areas (FDAs) prior to 2013 and FDA number.

SAU	Mapcodes	Catch cap 2022/23 (tonnes)	Minimum legal length											FDA number
			2022/23 (mm)	2021/22 (mm)	2020/21 (mm)	2019/20 (mm)	2018/19 (mm)	2017/18 (mm)	2016/17 (mm)	2015/16 (mm)	2014/15 (mm)	2013/14 (mm)	pre 2013/14 (mm outside FDA)	pre 2013/14 (mm inside FDA)	
Cape Jaffa	33A, 33B, 33C, 34A, 34B, 34C	5	125	125	125	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	125	125	125	NA	NA
Beachport	35E, 36A	7	125	125	125	125	125	125	125	125	125	125	125	NA	NA
Rivoli Bay	36B	10	110	110	110	110	110	110	120	120	120	120	125	110	3
South End	36C	8	125	125	125	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	125	125	125	NA	NA
Admella	37J, 39A	8	125	125	125	125	125	125	120	120	120	120	125	NA	NA
Carpenters Rocks	39B, 39C	12	125	125	125	125	125	125	125	125	125	125	125	110	4
Gerloffs Bay	39D	15	112	112	110	110	110	110	110	120	120	120	125	110	4
Blackfellows Caves	39E	7	125	125	125	125	125	125	125	125	125	125	125	110	1 & 4
Middle Point	39FE, 39G, 40A	35	120	120	120	120	120	120	120	120	120	120	125	110	1
Nene Valley	39FW	6	110	110	NA	NA	NA	NA	NA	NA	NA	NA	NA	110	1
Port MacDonnell	40B	15	122	122	120	120	120	120	120	120	120	120	125	110	2
East Port MacDonnell	40C, 40D	3	100	100	100	100	110	110	110	110	110	110	125	110	2

1.2.2 Recreational and traditional fishing

The total recreational abalone harvest of both species combined in South Australia was estimated at 7,091 abalone for 2021/22 (Beckmann *et al.* 2023). This represents a total statewide recreational harvest of 2.94 t, equating to ~0.5% of the combined 2021/22 commercial catch of 561.8 t. Previous estimates of Statewide abalone recreational catch (by number) were 17,030 in 2000/01 (Henry and Lyle 2003), 5,147 in 2007/08 (Jones 2009) and 4,677 in 2013/14 (Giri and Hall, 2015). In 2021/22, less than half of the estimated Statewide recreational abalone catch was blacklip (3,296 abalone or 46.5%; Beckmann *et al.* 2023). 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 1,347 abalone would have been recreationally harvested from the SZ in 2021/22. 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. 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) (Edgar 2008). 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, particularly blacklip, 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 fishery-independent data are available for assessment of the SZ blacklip and greenlip fisheries. Details on data quality assurance and the methods used for analysing the fishery-dependent and fishery-independent data are provided in Appendices 1 and 2, and are described briefly below.

2.2 Fishery-dependent data

The fishery-dependent 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 to February 2023. Fishery statistics are provided at three spatial scales: (1) the whole of the SZ, (2) individual SAUs, and (3) combined data-limited SAUs. Multi-dimensional scaling (MDS) is used to examine temporal changes in the spatial distribution of blacklip catch.

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 - mapcodes 39F, 39G, 40A, Number 2 Rocks - mapcodes 37C, 37D, 37E, 37F, Gerloffs Bay - mapcode 39D and Rivoli Bay - mapcode 36B). Estimates of sub-legal and legal-sized blacklip are derived by combining fixed area total abalone counts and population length-frequency information. In some fishing seasons, inclement weather and changes to the survey design prevented access to all survey sites. Consequently, some historical data were excluded to match the most recent sampling locations, and historical density estimates were recalculated.

Estimates of total greenlip density are presented for Ringwood Reef, from the Rivoli Bay SAU.

2.4 Harvest strategy

In the HS, each SAU is designated as surveyed (i.e., FIS undertaken), unsurveyed (i.e., no FIS undertaken) or data-limited (i.e., limited fishery-dependent data and no FIS undertaken; PIRSA 2021). The data-limited SAUs are pooled for the estimation of CPUE and scoring in the HS (PIRSA 2021).

The HS is based on two performance indicators (PIs), CPUE and legal-sized abalone density from FIS. The PIs for CPUE and FIS legal-sized 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 PIs for CPUE and FIS legal-sized 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, Number 2 Rocks, Gerloffs Bay and Rivoli Bay. The FIS at Breaksea Reef in the Port MacDonnell SAU are not yet used in the HS due to insufficient years to create a reference period. Historical abalone density estimates are also displayed for Nene Valley, but are no longer used in the HS (see Section 2.5 - Review of the research program).

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 then 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 (PIRSA 2021). Stock status is detemined based on the the combination of the zone score and the zone trend score, shown in Table 2-1.

The zone score (i.e., biomass proxy) translates directly to a recommended zonal catch, via a function applied to the target catch level (PIRSA 2021). The target catch for the SZ blacklip fishery is 132 t whole weight. For zone scores between 5 and 7, the recommended zonal catch is equal to the target catch (i.e., no adjustment). For zone scores between 7 and 10, there is an 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 blacklip 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 blacklip 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 zonal catch is zero. The HS is not applied to greenlip, due to an inability to estimate CPUE or undertake representative FIS.

Table 2-1. Potential stock status outcomes from the Harvest Strategy

Status	Zone Score	Zone Trend Score
Sustainable	≥5	
Sustainable	<5 & ≥1	≥5
Depleting	<5 & ≥1	<5
Recovering	<1	≥5
Depleted	<1	<5

2.5 Review of the research program

In 2022/23, a review of the SARDI research program in the SZ abalone fishery was undertaken as part of the Service Level Agreement (SLA). Some of the key outcomes included; 1) cease the FIS at Nene Valley; 2) modify and improve the FIS at Gerloffs Bay (see Appendix 3) and Cape Northumberland (the latter are part of the Middle Point SAU); and 3) delay the 2022 FIS at Middle Point and Port MacDonnell until 2023. Due to this delay, some of the FIS used in the HS at Middle Point in this report are three years old, which exceeds the two-year carry forward rule from the HS (PIRSA 2021).

2.6 GPS and depth logger data

GPS location data have been collected on some fishing days since 2010, when the Vessel Monitoring Systems (VMS) were first adopted. Data provision to SARDI is a licence requirement. Divers also carry a Sensus depth logger that is activated during diving. The time-stamped integration of these two data sources enables recording of the area of the boat track and the time spent diving on each fishing day, following methods developed by Mundy (2012) and Mundy *et al.* (2018). While there are numerous potential PIs that can be calculated using this data (see Burnell *et al.* 2021a), the results in this report focus only on catch-per-unit-area (CPUA), which is the whole weight (kg) of abalone harvested for each hectare the boat covers. This metric is calculated from the Kernel Density (KUD_{50}), which represents the spatial footprint of the 50% isopleth derived from the GPS data for each dive event.

To enable direct comparisons between the potential GPS derived PI (i.e., CPUA) and logbook CPUE, GPS logger data were cross-referenced against the logbook data. Any logbook days without corresponding GPS data were discarded. Summarised GPS data were also filtered to remove likely equipment breakdowns and partial days from the VMS data. This was undertaken

where effort recorded on the VMS was less than two thirds of the effort reported in the logbook. To aid visual comparisons the CPUE, CPUA and FIS time-series were all normalised to a mean of 1. CPUE and CPUA were then scaled so the starting value in both times-series (i.e., 2010) was equal to 1. Direct visual comparison with the FIS required different scaling because there were no FIS estimates available in 2010, and data availability varies among the SAUs. At Middle Point, Rivoli Bay and Gerloffs Bay, where there was FIS data available in 2009 and 2011, the time-series was scaled so the average of these two years was equal to 1. At Number 2 Rocks, the FIS time-series only begun in 2014, and therefore estimates were scaled so the starting value in the FIS time-series (i.e., 2014) was equal to the average of the CPUE and CPUA estimates in 2014.

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.yr^{-1} 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, total annual catches were stable from 1994 to 2010 (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 and 2012, before a period of lower catches since 2013 (mean: 126 t.yr^{-1}). Since 2018, catches have been consistent with the TACC of 132 t, besides 2019, which was impacted by the COVID-19 pandemic. The YTD catch in 2022 was 115 t, at 30 April 2023.

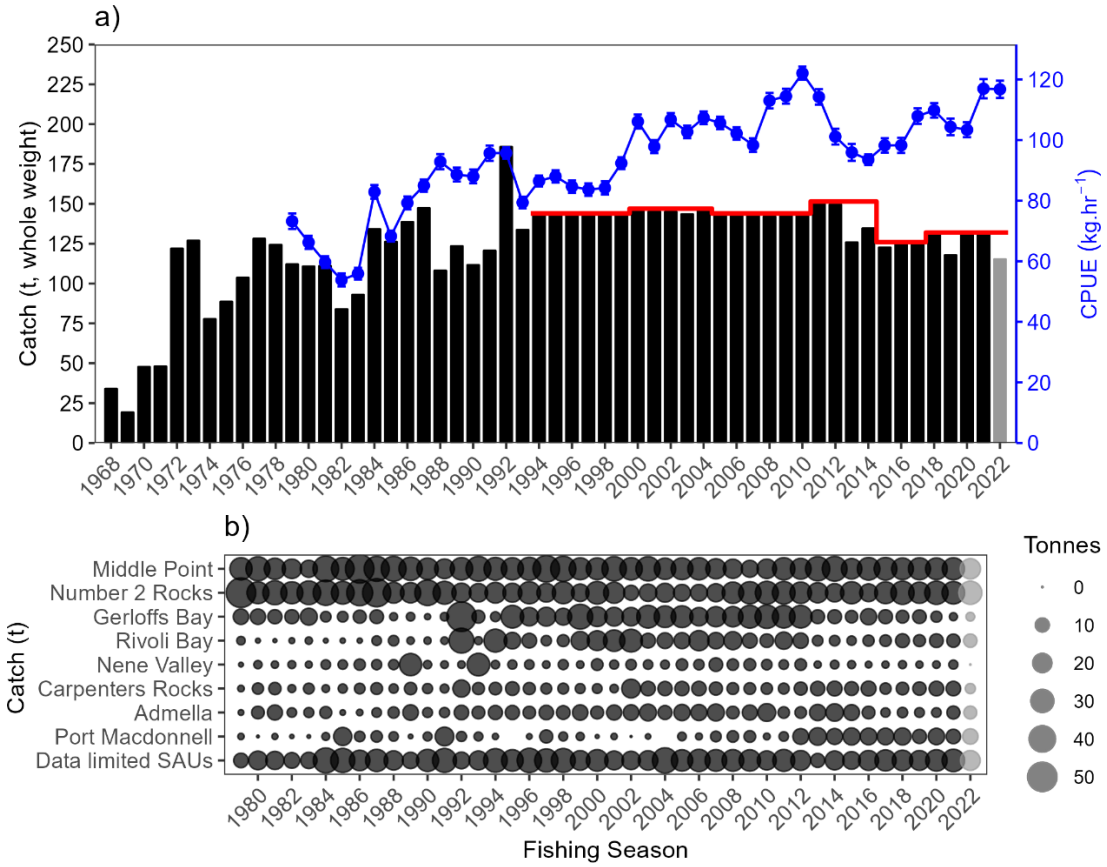

Figure 3-1. Zonal catch, CPUE and the distribution of catch among SAUs available from 1969/70 to 2022/23 (denoted 2022) a) Total catch (tonnes, black bars), CPUE (± SE, kg.hr^{-1}, blue line and circles) & TACC (red line) of blacklip in the Southern Zone from 1968/69 to 2022/23 (denoted 2022). b) Bubble plot showing the spatial distribution of the blacklip catch (black symbols) among each of the SAUs in the SZ from 1979/80 to 2022/23 (data-limited SAUs from the HS are combined). Grey bars and grey symbols indicate year-to-date catch from the incomplete 2022/23 fishing season.

The CPUE of blacklip in the SZ has generally increased throughout the history of the fishery, but with some fluctuations over time (Fig.3-1a). From 1993 until 2010, during a period of stable catches, CPUE increased from <80 kg.hr^{-1} to greater than 120 kg.hr^{-1}. The CPUE of 122 kg.hr^{-1} in 2010 was the highest recorded. After 2010, CPUE declined over four consecutive fishing seasons to a low of 94 kg.hr^{-1} in 2014. From 2015, CPUE increased again reaching 117 kg.hr^{-1} in 2021 and 2022.

3.1.1.1 Distribution of catch among SAUs

The introduction of spatial management in 2013 influenced the distribution of blacklip catches among SAUs within the SZ, principally due to the abolition of the FDA specific TACC, which required a certain amount of the catch to be harvested from the four FDAs (Figure 3-1b). Most notably, catches from Gerloffs Bay and Rivoli Bay declined from an average of 23.7 t.y^{-1} and 16.2 t.y^{-1}, respectively, between 1994 and 2012, to 8.3 t.y^{-1} and 7.1 t.y^{-1} after 2013. Meanwhile, catches from Port MacDonnell increased from an average of 3.4 t.y^{-1} between 1994 and 2012, to 14.2 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 and 2022 (Figure 3-2). The temporal nature of these clusters indicates that changes in the spatial distribution of catch generally occurs gradually and is unlikely to reflect random inter-annual processes. The length and direction of the vectors highlight the post-spatial management shift away from SAUs with historic FDAs such as Gerloffs Bay, Rivoli Bay and Nene Valley, and into SAUs such as Port MacDonnell. Since 2013, the four different clusters identified by the MDS, remain quite tightly grouped. Therefore, while statistically significant changes in the distribution of the catch are ongoing, these recent changes in the spatial distribution of catch, have remained relatively minor in a historical context.

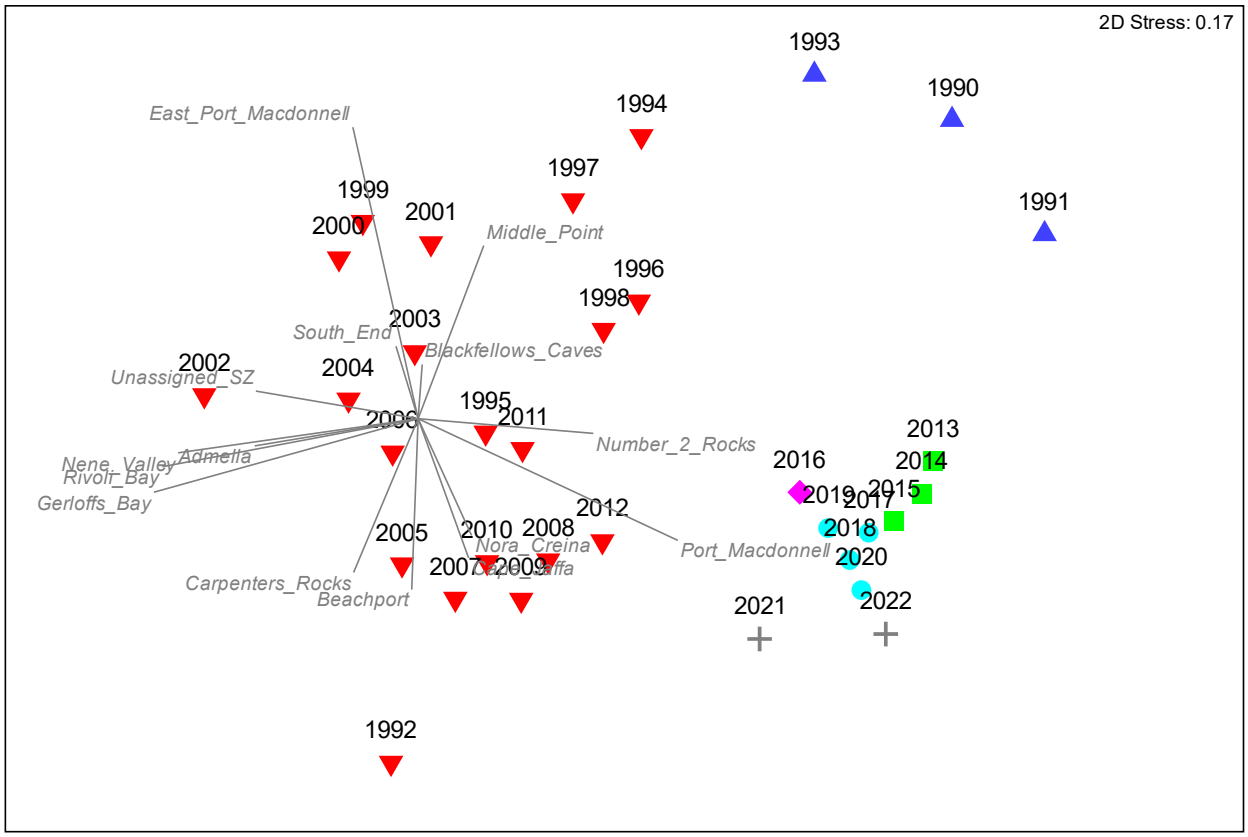

Figure 3-2. Multi-dimensional scaling (MDS) plot for SAUs showing similarity among fishing seasons based on the spatial distribution of annual blacklip catch from the Southern Zone from 1990/91 to 2022/23 (denoted 2022).Coloured symbols indicate different spatial distributions (SIMPROF; α = 0.05). Vector 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, ~22% of the blacklip catch from the SZ has been obtained from Middle Point (Figure 3-3a). This SAU has a relatively stable catch history, averaging 28.5 $t.y^{-1}$ since 1979. Annual catches peaked at 48 t in 1986, with the lowest reported catch of 15.5 t recorded in 2009. During the last decade catches have averaged 28.5 $t.y^{-1}$, which is below the 35 t catch-cap for this SAU. The 2022 YTD catch to the end of April was 23.2 t.

The estimated CPUE from Middle Point increased consistently from 1979 reaching a peak of 124 $kg.hr^{-1}$ in 2010 (Figure 3-3a). From 2011, CPUE declined steadily to 92.4 $kg.hr^{-1}$ in 2015, before recovering and stabilising at ~110 $kg.hr^{-1}$ since 2018. The 2022 YTD CPUE to the end of April was 107.7 $kg.hr^{-1}$, which equates to a score of 7.7 in the HS.

The mean length of blacklip in commercial catches was lowest in 2013 and 2014, before a contemporary peak in 2017 (Figure 3-3b). In 2022, the mean length of blacklip in commercial catch was 136 mm. The MLL was reduced from 125 to 120 mm in 2013, which is reflected in the length frequency distributions (Figure 3-3c).

Fishery-independent estimates of legal-sized blacklip (i.e., ≥120 mm) have been increasing in recent surveys (Figure 3-3d), and in 2020 it was similar to values recorded in the late 2000s. No new estimates were available in 2022, therefore, the score of 5.0 in 2020 has been used in the HS. The density of sub-legal sized abalone has been relatively stable and consistent with values recorded since surveys commenced in 2002.

The YTD SAU score for Middle Point in 2022 is 6.4 (Table 3-1).

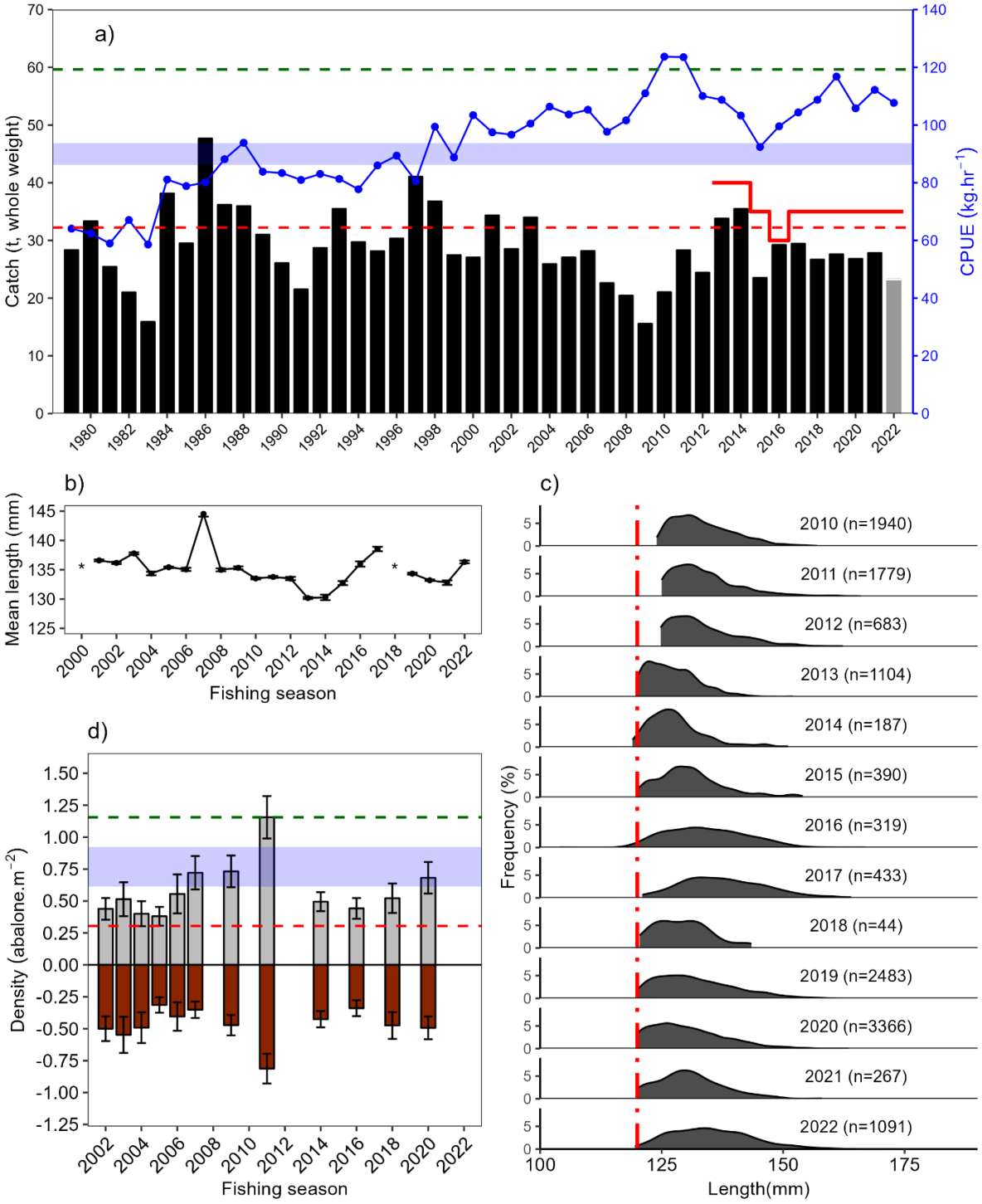

Figure 3-3. Middle Point data available from 1979/80 (denoted 1979) to 2022/23: a) Blacklip catch (tonnes, black bars, note: grey bar indicates year-to-date catch from the incomplete 2022/23 fishing season), annual catch cap (tonnes, red line) & CPUE (kg.hr^{-1}, blue line/symbols) b) Mean length of 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) CPUE and d) legal-sized density: 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 has been harvested from Number 2 Rocks (Figure 3-4a). The highest annual catch was 51 t in 1979, whereafter catches varied among fishing seasons while gradually decreasing to the lowest recorded value of 12 t in 2002. From 2002, annual catches gradually increased to 30 t in 2010. Since 2012 catches have varied between 17 and 31 t. The YTD catch of 30.8 t in 2022 is slightly above the current catch-cap of 30 t.

The CPUE for blacklip at Number 2 Rocks generally increased from 1979 to 2002 (Figure 3-4a). The highest recorded CPUE of 144 $kg.hr^{-1}$ occurred in 2002. Over the last two decades CPUE estimates have remained relatively high, generally at or above 120 $kg.hr^{-1}$, except for decreases between 2013 and 2016 when CPUE declined to 102 $kg.hr^{-1}$. The YTD estimate of 129 $kg.hr^{-1}$ in 2022 was above the upper limit, scoring 10 in the HS.

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). Following two fishing seasons at ~134 mm in 2020 and 2021, the mean length increased to 137 mm in 2022. There were very few obvious temporal changes in the overall size frequency distributions from the commercial catch (Figure 3-4c).

Fishery-independent estimates of legal- (≥125 mm) and sub-legal-sized blacklip (<125 mm) have more than doubled and tripled, respectively, since the second survey at Number 2 Rocks in 2016 (Figure 3-4d). 2022 is the first year the HS has assigned a score for Number 2 Rocks, which is 7.2.

The YTD SAU score for Number 2 Rocks in 2022 is 8.6 (Table 3-1).

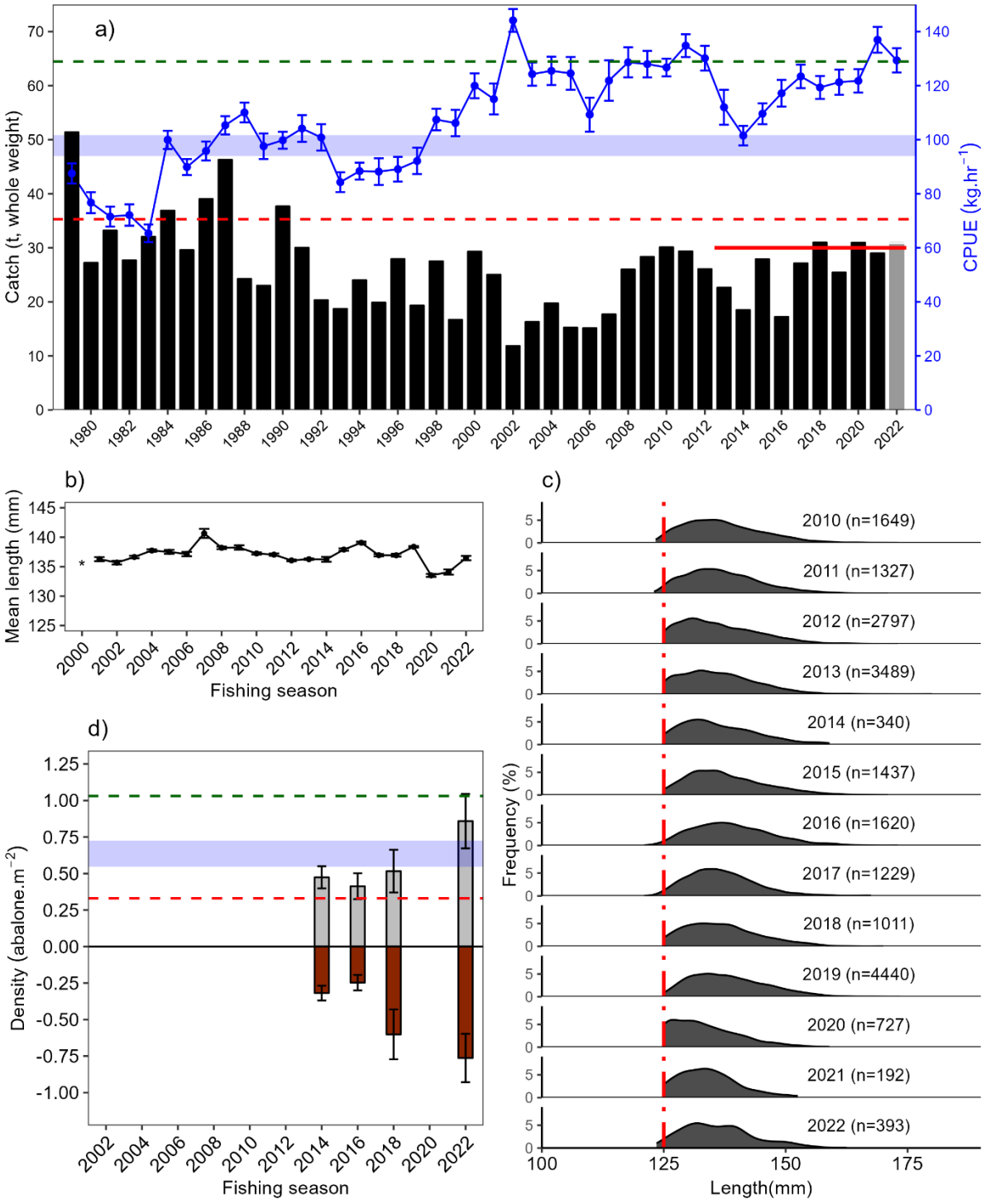

Figure 3-4. Number 2 Rocks data available from 1979/80 (denoted 1979) to 2022/23: a) Blacklip catch (tonnes, black bars, note: grey bar indicates year-to-date catch from the incomplete 2022/23 fishing season), annual catch cap (tonnes, red line) & CPUE (± SE, kg.hr^{-1}, blue line/symbols). B) Mean length 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) CPUE and d) legal-sized density: 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, ~12% of the total SZ harvest of blacklip abalone has been obtained from Gerloffs Bay. Total annual catches from this SAU were relatively low throughout the 1980s and early 1990s (Figure 3-5a). Shortly after, the largest annual catch of 51 t was taken in 1992 (during unrestricted fishing in the previous FDA 4 at a lower MLL). Catches were relatively stable at high levels between 1995 and 2012, ranging from 15 to 36 t. After the FDAs were removed, catches dropped, and have generally continued to decline, with less than 4 t harvested in 2021 and 2022 YTD.

CPUE increased from approximately 80 kg.hr^{-1} in the mid-1990s to a peak of 127 kg.hr^{-1} in 2010 (Figure 3-5a). Thereafter, CPUE declined to 73 kg.hr^{-1} in 2013, before increasing to ~97 kg.hr^{-1} in 2018, and declining again thereafter. The estimate in 2022 of 76 kg.hr^{-1} was below the target range, scoring 3.0 in the HS.

There has been a gradual reduction in the mean length of abalone in the commercial catches from 2011 onwards, although data has been limited in recent fishing seasons. In 2022, the mean length of blacklip was not estimated due to insufficient data (Figure 3-5b). Size-frequency distributions for Gerloffs Bay are impacted by historical changes to the MLL (Figure 3-5c). Between 2013 and 2015 the MLL was increased to 120 mm, associated with the removal of FDA 4, before being lowered to 110 mm in 2016, and subsequently increased to 112 mm in 2021.

Estimates of legal-sized blacklip (≥112 mm) from FIS have been variable among fishing seasons (Figure 3-5d). In general, greater densities were recorded prior to 2014, and have been lower in recent surveys. After record low densities in 2020, which were just above the limit reference point, estimates increased by 32% in 2022, yielding a score of 2.2 in the HS. Estimates of sub-legal-sized blacklip (<112 mm) were highest between 2002 to 2007. Thereafter, estimates of sub-legal-sized blacklip have been consistently lower but gradually recovered since 2009 and, in 2022, reached their highest level in the last 15 years.

The SAU score for Gerloffs Bay in 2022 is 2.6 in the HS (Table 3-1).

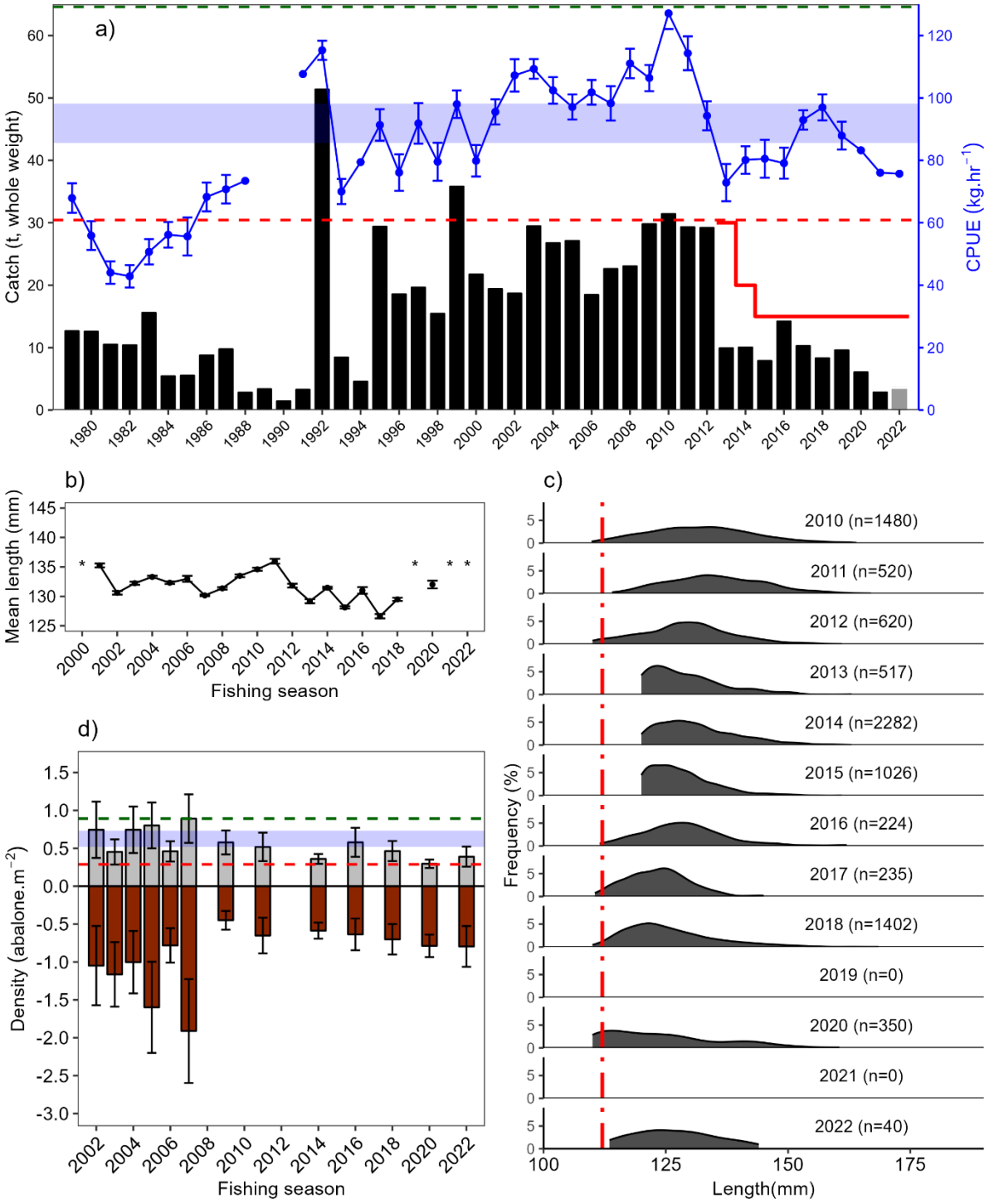

Figure 3-5. Gerloffs Bay data available from 1979/80 (denoted 1979) to 2022/23: a) Blacklip catch (tonnes, black bars, note: grey bar indicates year-to-date catch from the incomplete 2022/23 fishing season), annual catch cap (tonnes, red line) & CPUE (± SE, kg.hr^{-1}, blue line/symbols). CPUE estimates 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 112mm = dashed red line. D) Density of blacklip (abalone.m^{-2}; ± se) counted in transects during fishery-independent surveys. Red and grey bars show blacklip <112 and ≥112 mm SL, respectively. Scoring from the harvest strategy is shown for panels a) CPUE and d) legal-sized density: 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 low (≤5 $t.yr^{-1}$; Figure 3-6a) prior to 1992, when 36 t was harvested (unrestricted fishing at a lower MLL in FDA 3). Since 1992, catches have been variable among fishing seasons ranging from 3 to 30 t. Following a sustained period of higher catches between 1999 and 2012, catches were generally lower following the removal of the FDAs, before increasing again to an average of 9 t since 2018

CPUE was relatively stable over 12 fishing seasons from 2000 to 2011, ranging from 107–126 $kg.hr^{-1}$. After 2011, CPUE declined reaching 90 $kg.hr^{-1}$ in 2014, remaining among the target scoring range of 5 the following fishing season. Subsequently, CPUE increased to 130 $kg.hr^{-1}$ by 2022, equating to a score of 9.9 in the HS.

The mean length of abalone in the commercial catch declined after 2012, and has remained relatively low ever since, despite a gradual increase after 2015 (Figures 3-6b). In 2022, the mean length of abalone from Rivoli Bay was 128 mm. Interpreting size frequency distributions (Figure 3-6c) for the Rivoli Bay SAU is difficult because, from 2013, 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, the MLL was reduced from 120 to 110 mm for the entire SAU.

The densities of legal- and sub-legal-sized blacklip obtained from FIS in Rivoli Bay were relatively stable at high levels throughout the 2000s, with the greatest densities recorded in 2006 (Figures 3-6d). In 2012, low densities of both size classes were recorded. These densities immediately followed reported mortalities in the summer of 2012/13 (Mayfield *et al.* 2013, 2014). Subsequently, the density of legal-sized blacklip remained low in 2014, before fluctuating at a higher level during the next three surveys. The 2022 density was among the lower end of historical values, yielding a score of 2.6 in the HS. The densities of sub-legal-sized blacklip have been variable among fishing seasons. The highest density was recorded in 2014, but subsequently has declined to relatively low levels compared with historical estimates, despite small increases over the last two surveys.

The SAU score for Rivoli Bay in 2022 is 6.2 in the HS (Table 3-1).

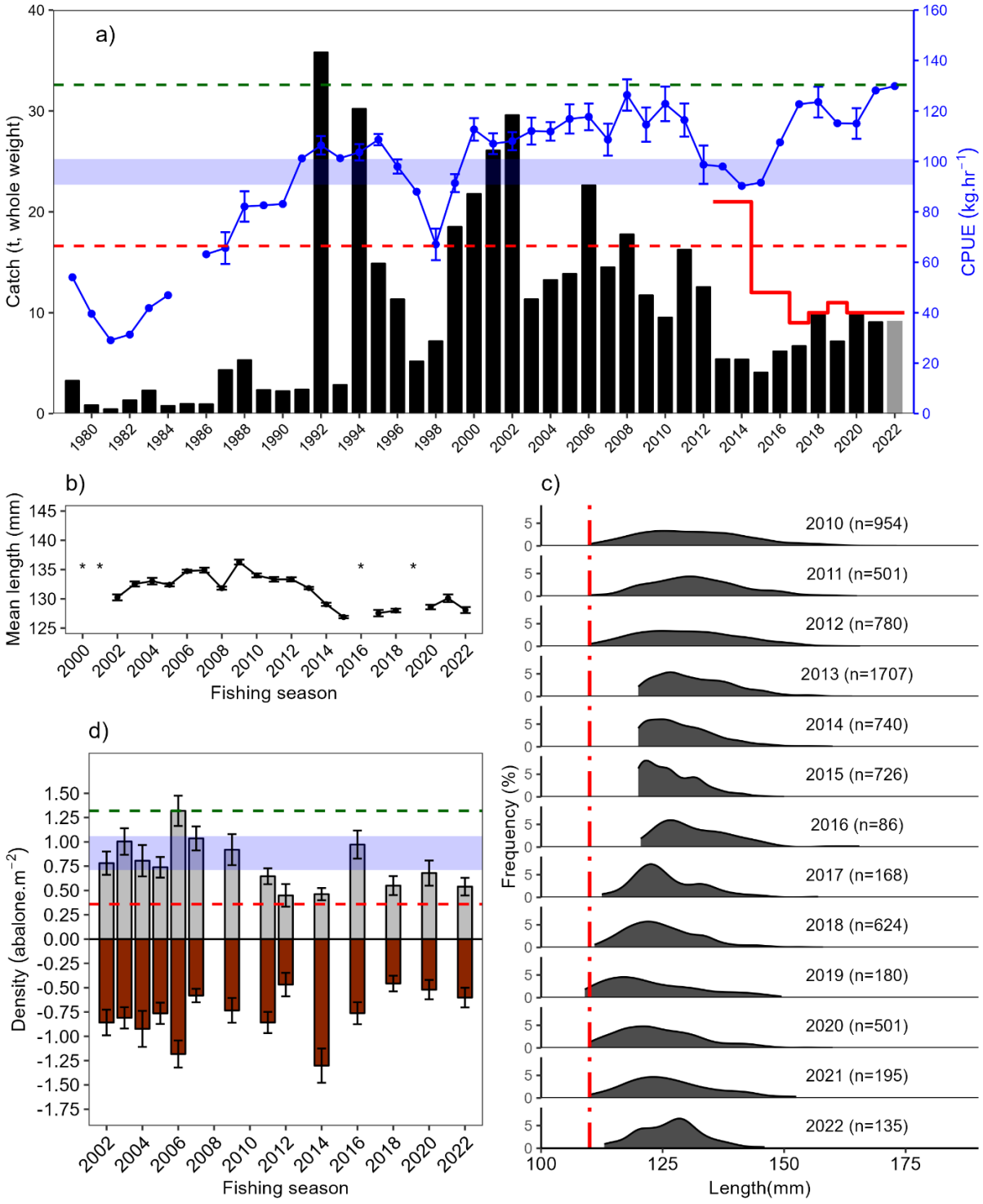

Figure 3-6. Rivoli Bay data available from 1979/80 (denoted 1979) to 2022/23: a) Blacklip catch (tonnes, black bars, note: grey bar indicates year-to-date catch from the incomplete 2022/23 fishing season), annual catch cap (tonnes, red line) & CPUE (± SE, kg.hr^{-1}, blue line/symbols). CPUE estimates 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) CPUE and d) legal-sized density: Target Range (score of 5, blue shading), upper limit (score of 10, green dashed line), lower limit (score of 0, red dashed line).

Nene Valley

Nene Valley was a newly created SAU in 2021, which was a reconstruction of the former FDA 1 that was in place from 1994 to 2012. As such, there are some uncertainties regarding the data presented for this SAU (see methods).

Since 1979, ~4% of the total SZ harvest of blacklip abalone has been obtained from Nene Valley. Total annual catches of blacklip were relatively small (≤6 $t.yr^{-1}$) prior to 1989 and 1993, when 28 and 29 t was harvested, respectively (during unrestricted fishing at a lower MLL in FDA 1; Figure 3-7a). Following a sustained period of higher catches between 2000 and 2012 (average 6 $t.yr^{-1}$), catches have generally remained low following the removal of the FDA in 2013. In 2022, zero catch has been harvested to date.

Catch-per-unit-effort increased gradually between 1979 and 1997, before rising sharply to >100 $kg.hr^{-1}$ by 1999 (Figure 3-7a). Catch-per-unit-effort then remained high in most fishing seasons during the 2000s and early-2010s, during a period where the MLL was 110 mm as part of FDA 1. In 2012, CPUE began to decline and by 2014 was ~80 $kg.hr^{-1}$. This period of lower CPUE estimates from 2013 to 2020, aligned with a period where the MLL was 120mm (as part of Middle Point SAU). In 2021, the MLL was returned to 110 mm and CPUE was 92 $kg.hr^{-1}$, equating to a score of 5.0 in the HS.

The size frequency and mean length data for Nene Valley is very limited (Figures 3-7b,c), particularly between 2013 and 2020, as this SAU did not exist. Prior to 2013 there is some available data, which was reported from the old FDA 1.

Fishery-independent surveys were discontinued in the Nene Valley SAU in 2022 (Figure 3-7d). Recent estimates of both legal density and sub-legal density were among the lowest recorded for this SAU. The most recent legal density score in the HS was 4.9 in 2020.

The SAU score for Nene Valley in 2022 is 4.9 (Table 3-1), which was carried forward from 2021 in the absence of either a CPUE or FIS score in 2022.

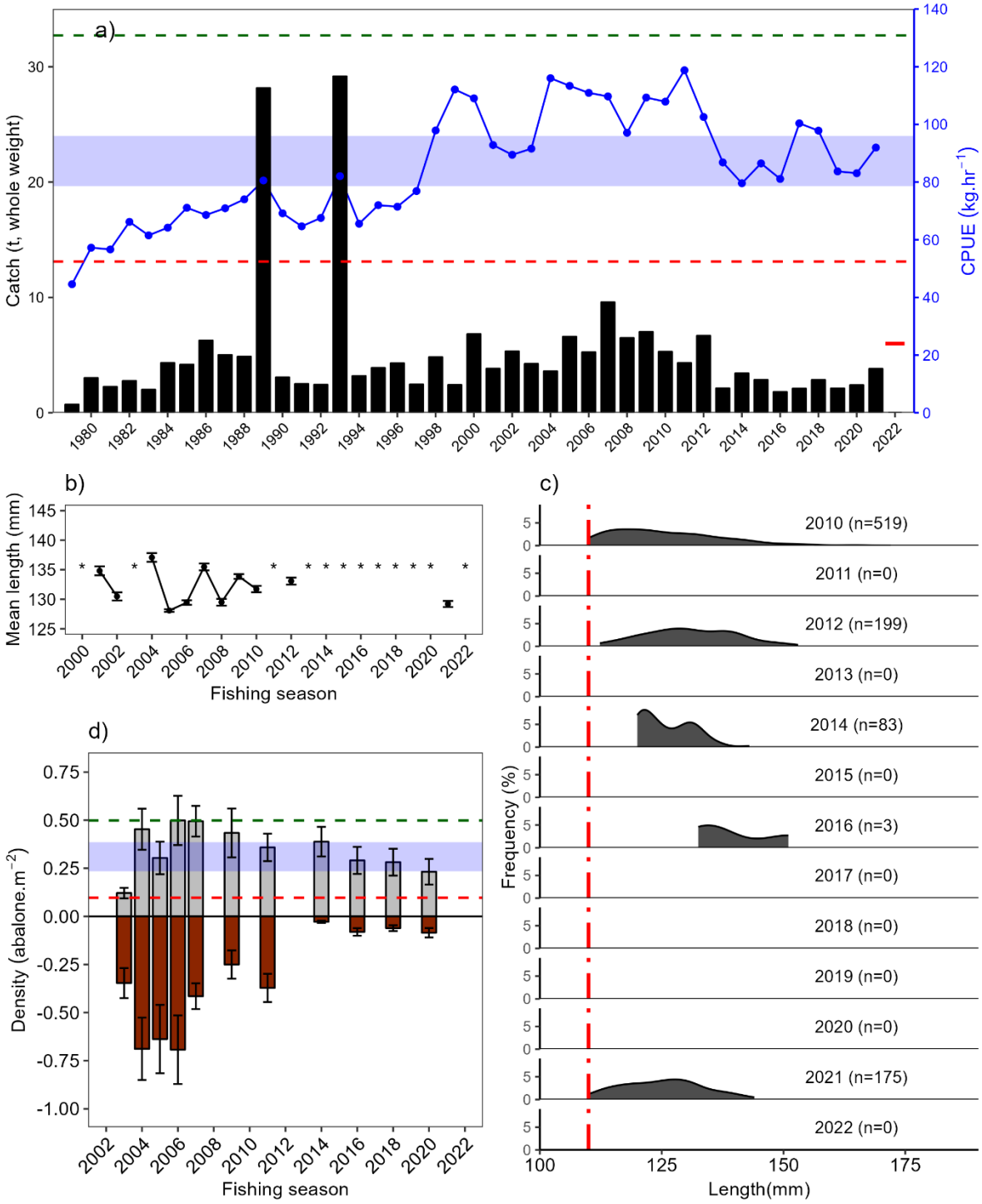

Figure 3-7. Nene Valley data available from 1979/80 (denoted 1979) to 2022/23: a) Blacklip catch (tonnes, black bars), annual catch cap (tonnes, red line) & CPUE (± SE, kg.hr^{-1}, blue line/symbols). CPUE estimates with no error bar are generated using a 3-year running mean. B) Mean length of blacklip 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) CPUE and d) legal-sized density: 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 contemporary peak of 17 t in 2014 (Figure 3-8a), before declining and stabilising at an average of 4.5 t between 2017 and 2020. During each of the last two fishing seasons higher catches of 8.5 t have been harvested, which marginally exceeded the catch-cap of 8 t in 2020.

The CPUE for Admella increased from ~75 kg.hr^{-1} in the early/mid-1990s to an average of 95 kg.hr^{-1} between 2000 and 2010. Following the highest estimated estimate of 112 kg.hr^{-1} in 2010, CPUE declined and stabilised within the target scoring range at an average of 84 kg.hr^{-1} between 2012 and 2016. Since 2016, CPUE has gradually increased reaching 104 kg.hr^{-1} in 2022, and yielding a score of 7.6 in the HS

The mean length of abalone in the commercial catch peaked in 2009 at 140 mm, with the lowest mean length of 132 mm recorded in 2020. The 2022 estimate of 136 mm was close to the historical average (Figure 3-8b). Interpreting size frequency distributions for Admella is challenging because, from 2013, the MLL was reduced from 125 to 120 mm, before being increased back to 125 mm in 2017 (Figure 3-8c).

In the absence of any FIS, the SAU score for Admella is 7.6 in 2022 (Table 3.1).

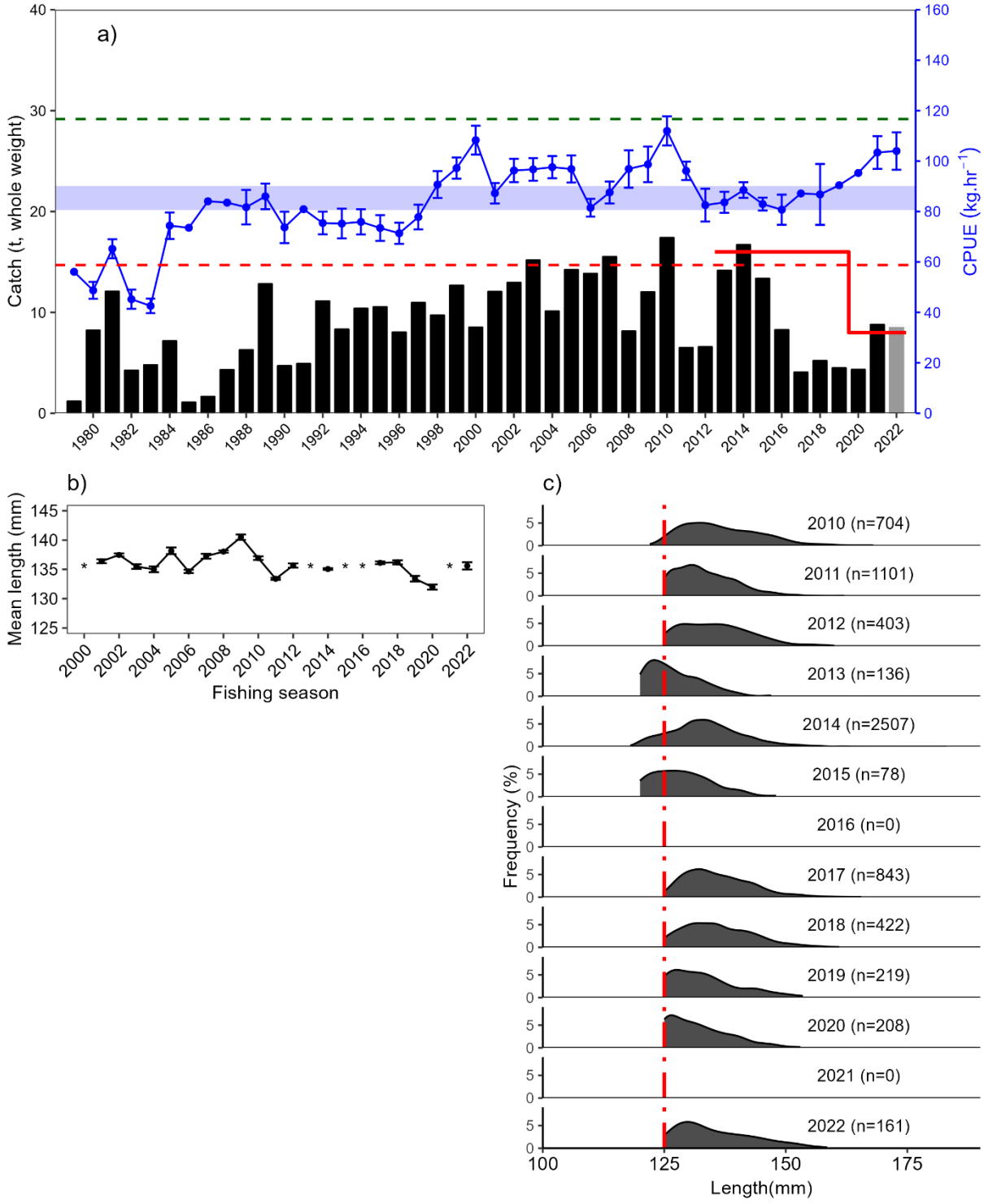

Figure 3-8. Admella data available from 1979/80 (denoted 1979) to 2022/23: a) Blacklip catch (tonnes, black bars, note: grey bar indicates year-to-date catch from the incomplete 2022/23 fishing season), annual catch cap (tonnes, red line), & CPUE (± SE, kg.hr^{-1}, blue line/symbols). CPUE estimates 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, ~6% of the total SZ harvest of blacklip has been taken from Carpenters Rocks. Prior to 2002, mean annual catches from Carpenters Rocks were generally low, averaging ~6 $t.yr^{-1}$ (Figure 3-9a). Since 2002, average catches have increased to ~10 $t.yr^{-1}$, although there has been considerable fluctuation in catch over this period. The YTD catch of 5 t in 2022 is currently less than half of the 11 $t.y^{-1}$ harvested in 2020 and 2021.

Catch-per-unit-effort at Carpenters Rocks has generally increased throughout the history of the fishery. The highest CPUE on record (108 $kg.hr^{-1}$) occurred in 2002, before peaking again at 106 $kg.hr^{-1}$ in 2010 and 2018. There is only one occasion during the last two decades where CPUE has been within the target scoring range (i.e., 2007), when CPUE reached a contemporary low of 76 $kg.hr^{-1}$. Since 2018, CPUE has remained near the upper limit, with the YTD estimate of 100 $kg.hr^{-1}$ scoring 10.0 in the HS.

The mean length of blacklip in the commercial catch has varied among fishing seasons (Figure 3-9b). Prior to 2014, when estimated, the average mean length was 138 mm, but has been notably lower averaging 134 mm thereafter. There was insufficient data to estimate mean length in this SAU in 2022.The length frequency generally reflects the small size of abalone harvested in most fishing seasons since 2014 (Figure 3-9c).

In the absence of any FIS, the SAU score for Carpenters Rocks is 10.0 in 2022 (Table 3.1).

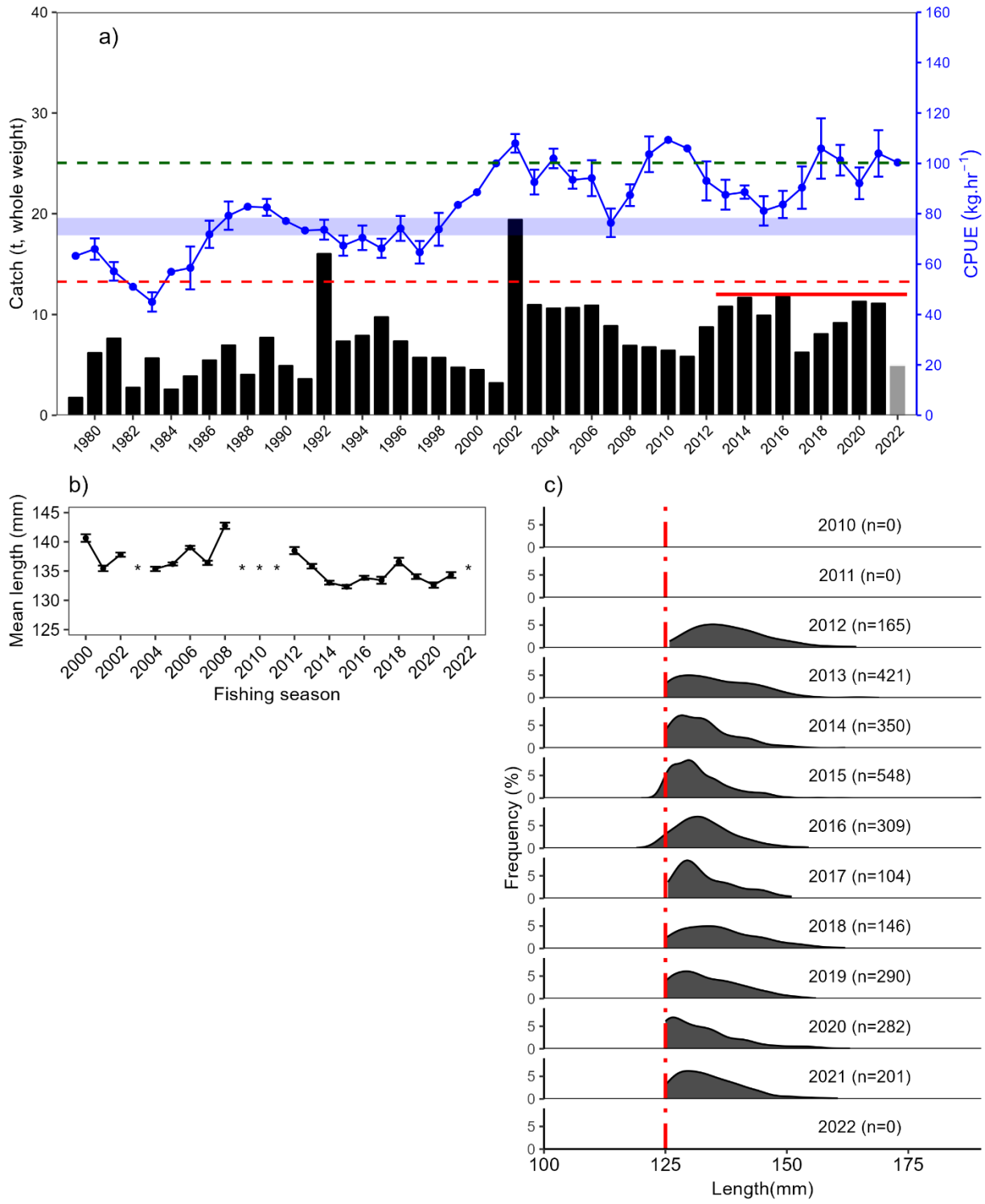

Figure 3-9. Carpenters Rocks data available from 1979/80 (denoted 1979) to 2022/23: a) Blacklip catch (tonnes, black bars, note: grey bar indicates year-to-date catch from the incomplete 2022/23 fishing season), annual catch cap (tonnes, red line), & CPUE (± SE, kg.hr^{-1}, blue line/symbols). CPUE estimates 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 fishing seasons, including historical peaks of 18 t in 1985 and 19 t in 1991, while catches in most other fishing seasons remained low until 2012 (Figure 3-10a). During the last decade catches have consistently exceeded 10 t, with 13 t harvested YTD in 2022.

The highest recorded CPUE estimate of 145 kg.hr^{-1} was reported in 2010, which preceded the subsequent period of sustained high catches since 2012. After this peak, CPUE declined, reaching 95 kg.hr^{-1} in 2019, which was the lowest recorded estimate since 1999. During the last two fishing seasons CPUE has increased, reaching 120 kg.hr^{-1} in 2022, and yielding a score of 9.4 in the HS.

The mean length of abalone in the commercial catch has varied over time and, following a peak of 140 mm observed in 2012, has been lower in recent fishing seasons, including a low of 132 mm in 2019 (Figure 3-10b). Interpreting size frequency distributions for the Port MacDonnell SAU is difficult because, from 2013, the MLL was reduced from 125 to 120 mm for the majority of the SAU, but then increased from 110 to 120 mm inside the historic FDA 2 (reflecting removal of the FDAs; Figure 3-10c). In 2021, the MLL was changed again from 120 to 122mm.

In the absence of any FIS, the SAU score for Port MacDonnell is 9.4 in 2022 (Table 3.1).

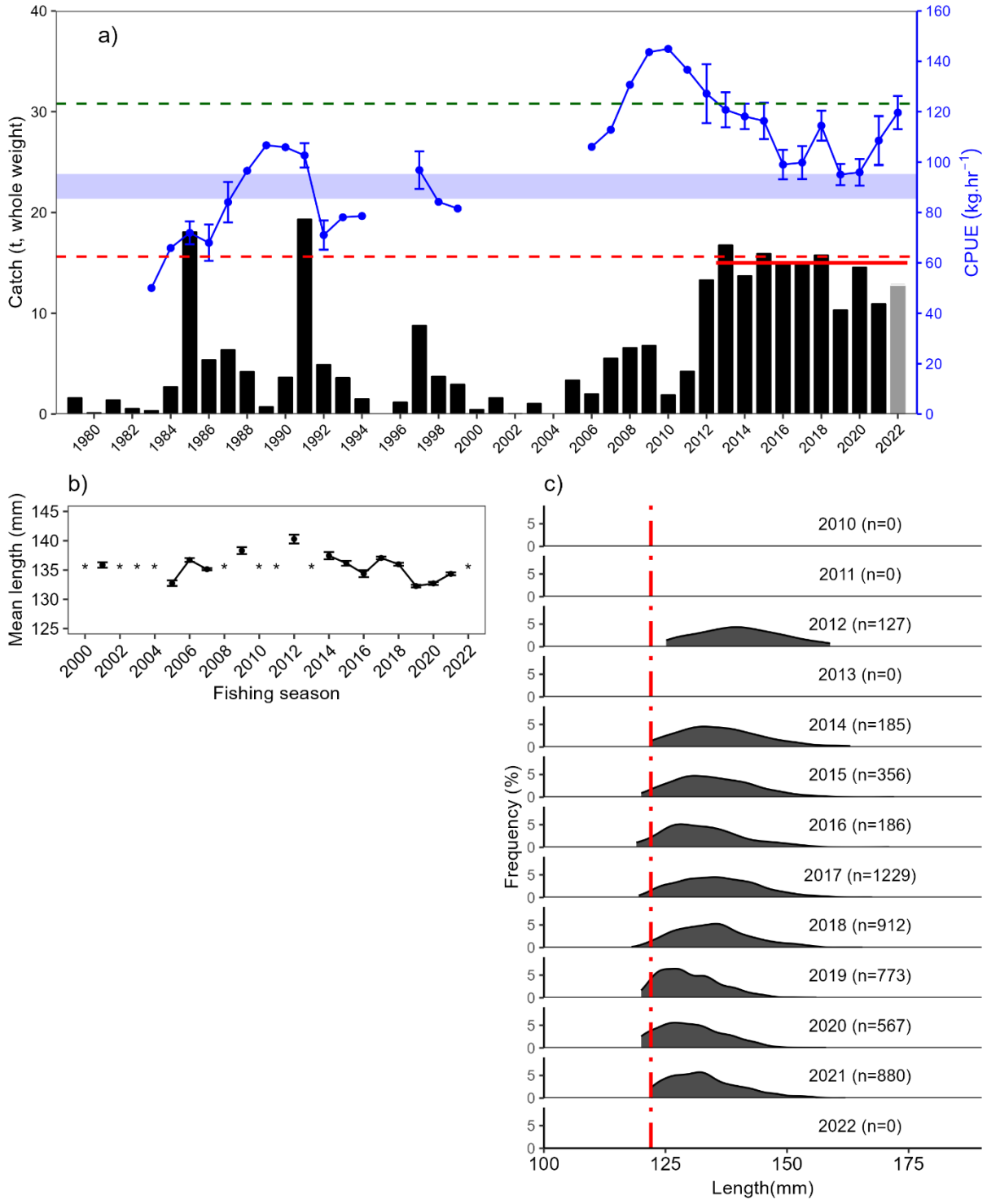

Figure 3-10. Port MacDonnell data available from 1979/80 (denoted 1979) to 2022/23: a) Blacklip catch (tonnes, black bars, note: grey bar indicates year-to-date catch from the incomplete 2022/23 fishing season), annual catch cap (tonnes, red line), & CPUE (± SE, kg.hr^{-1}, blue line/symbols). CPUE estimates 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 122mm = 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 six data-limited SAUs have supported ~18% (averaging 24 $t.y^{-1}$) of the total blacklip harvest in the SZ, with the aggregated catch remaining relatively stable throughout the history of these SAUs (Figure 3-11a). The combined CPUE estimate for these six SAUs has followed a similar trajectory to the zonal CPUE – peaking around 2010, before a sharp decline during the early 2010's and subsequent recovery to levels among the highest on record by 2021. The estimate of 106 $kg.hr^{-1}$ in 2022, equates to a score of 8.6 in the HS.

Among the individual data-limited SAUs, catches have varied substantially among fishing seasons (Figure 3-11b). 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 relatively high and consistent with their respective catch-caps. Insufficient data prevented estimation of CPUE in most fishing seasons for these SAUs. No running mean CPUE is applied to these SAUs, because they are not individually assessed in the HS.

In the absence of any FIS, the SAU score for the Data Limited SAUs is 8.6 in 2022 (Table 3.1).

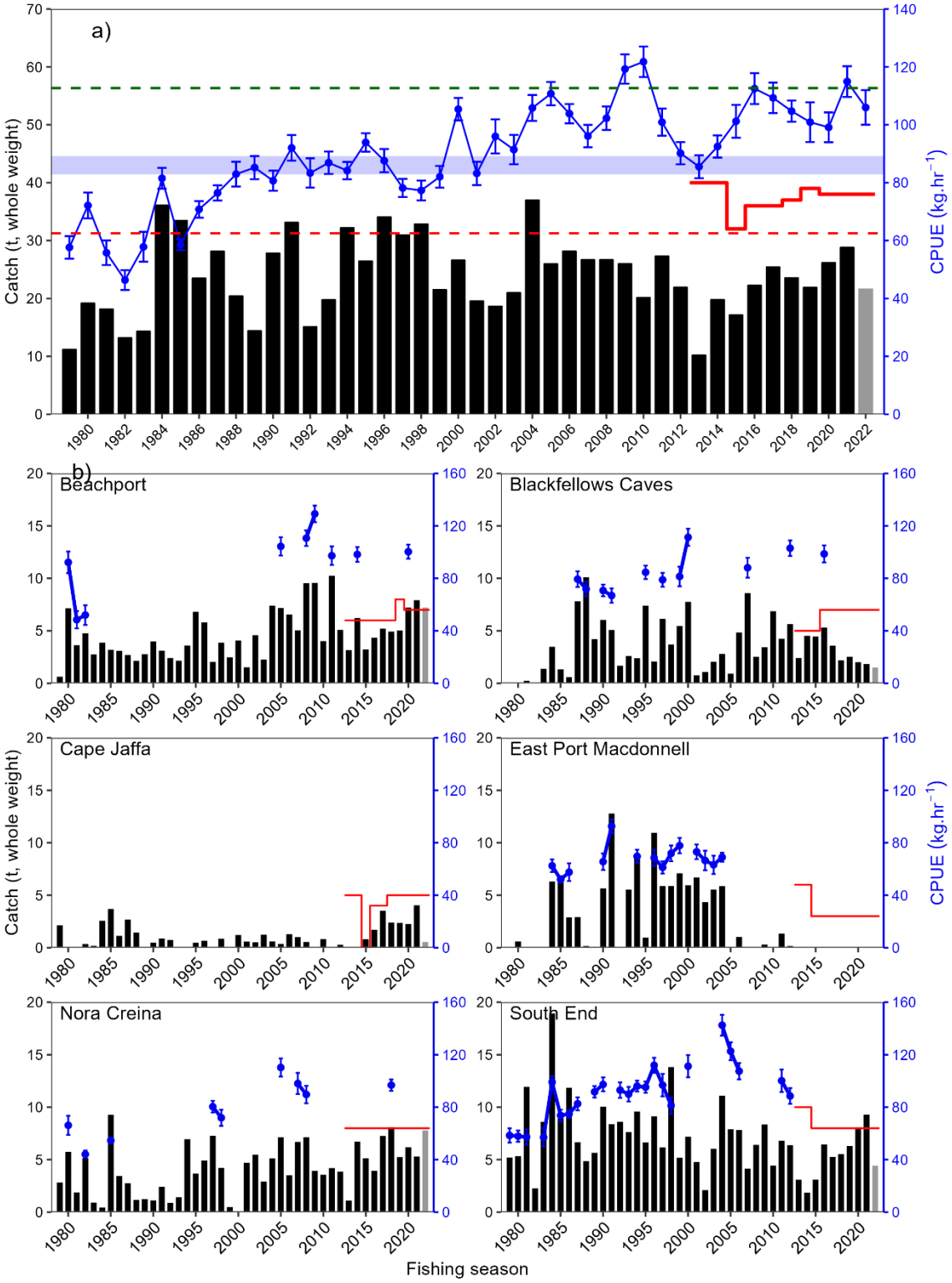

Figure 3-11. a) Combined data-limited SAUs from 1979/80 to 2022/23. CPUE Target Range (score of 5, blue shading), CPUE upper limit (score of 10, green dashed line), CPUE lower limit (score of 0, red dashed line). b) Individual data-limited SAUs from 1979/80 to 2022/23. Catch (tonnes, black bars, note: grey bar indicates year-to-date catch from the incomplete 2022/23 fishing season), 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 (i.e., biomass proxy) for the 2022 fishing season was **7.47 / 10** (Table 3.1, Figure 3.12). In combination with the zone trend score (i.e., fishing mortality proxy) in 2022 of **5.51 / 10** (reflecting an increasing trend), these define the zonal stock status for blacklip in the SZ in the 2022 fishing season as **'sustainable'** (Figure 3.13). A table of historical HS outcomes is provided in Appendix 4.

Table 3-1. Outcome of application of the harvest strategy described in the Management Plan for SZ blacklip in 2022/23. The SAU score for Nene Valley is dragged forward as there is no CPUE or FIS data in 2022/23.

SAU	CPUE ($kg.hr^{-1}$)	CPUE score	Legal density ($abs.m^{-2}$)	Legal density score	SAU score	Catch 2022/23 (tonnes)	Proportion of 12year catch	Weighted SAU score
Middle Point	107.7	7.7	0.68	5.0	6.4	23.2	0.22	1.37
Number 2 Rocks	129.4	10.0	0.86	7.2	8.6	30.8	0.20	1.75
Data limited SAUs	106.0	8.6			8.6	21.9	0.17	1.46
Port Macdonnell	119.6	9.4			9.4	12.8	0.10	0.96
Gerloffs Bay	75.7	3.0	0.39	2.2	2.6	3.5	0.09	0.23
Carpenters Rocks	100.3	10.0			10.0	5.0	0.07	0.70
Admella	104.0	7.6			7.6	8.7	0.07	0.50
Rivoli Bay	129.9	9.9	0.54	2.6	6.2	9.3	0.06	0.40
Nene Valley					4.9	0.0	0.02	0.11
							Zone Score	7.47

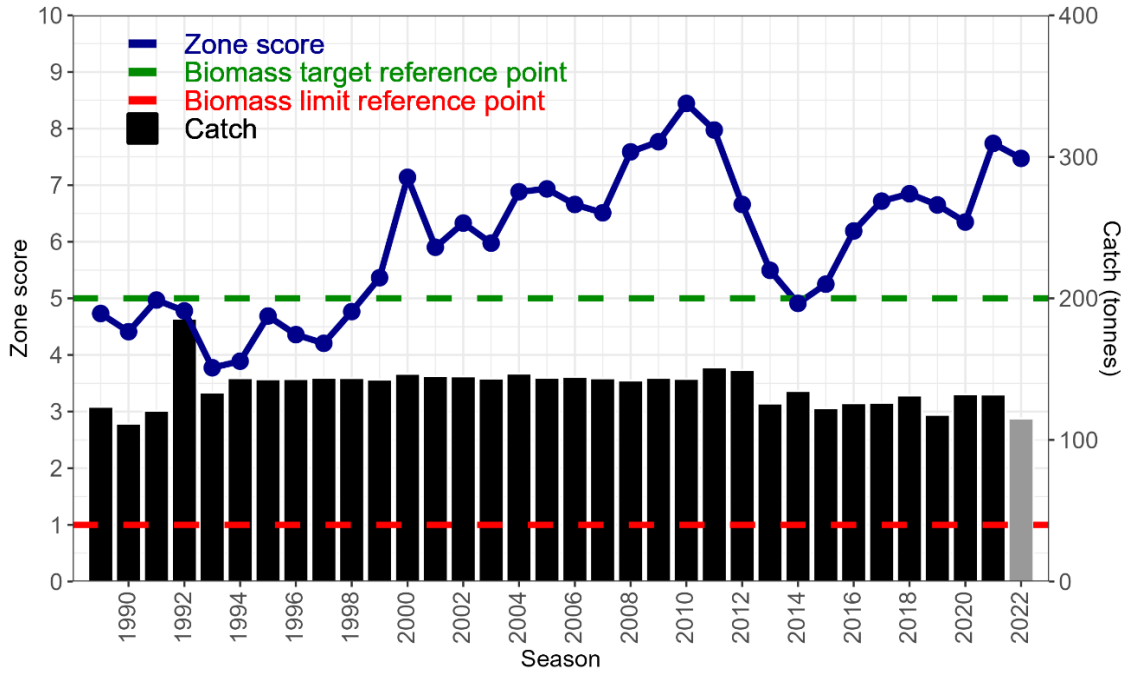

Figure 3-12. Zone score plot for SZ blacklip between 1989/90 and 2022/23 (denoted 2022). Zone score (blue symbols and line), biomass target reference point (green line), biomass limit reference point (red line) and catch (black bars, tonnes, note: grey bar indicates year-to-date catch from the incomplete 2022/23 season).

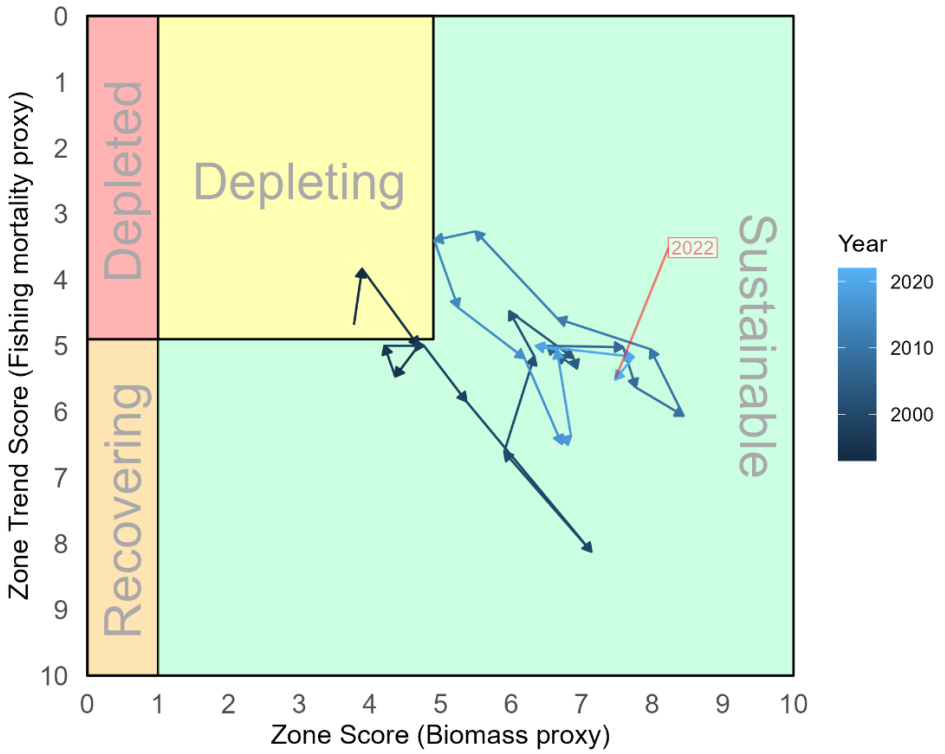

Figure 3-13. Phaseplot indicating changes in SZ blacklip stock status between 1993/94 and 2022/23 (denoted 2022).

3.2 Comparison between GPS data and existing performance indicators

There are now up to thirteen years of GPS location data available from the Vessel Monitoring System (VMS) in the SZ (Figure 3.14), which has enabled the development of potential PIs of stock abundance that utilise fishing area rather than fishing time. Comparisons are also possible between the GPS derived potential PIs and abalone densities recorded during FIS.

In most SAUs, the time series of CPUE and CPUA followed a similar trajectory. Comparisons between CPUE and CPUA from matched subsets of fishing days highlight CPUA shows greater long-term change, as well as short-term interannual variability, than CPUE. For example, at Middle Point CPUA declined by ~50% from 2010 to 2015, whereas CPUE only declined by ~15% over the same period. Similarly, at Port MacDonnell, CPUA declined by ~70% between 2010 and 2020, whereas CPUE declined by ~25% over the same period. The opposite also occurs, in that in some cases, CPUA increased at a faster rate than CPUE. For example, at Middle Point CPUA almost doubled between 2015 and 2021, whereas CPUE only increased by ~30% over the same period.

There was also greater short-term inter-annual variability evident in CPUA when compared to CPUE, as well as larger annual error estimates. For example, at Number 2 Rocks between 2014 and 2020 there was limited interannual change in CPUE, whereas CPUA fluctuated throughout this period. This short-term inter-annual variability could reflect real differences in stock abundance that were previously difficult to detect using CPUE. Nonetheless, a portion of this change appears to be driven by greater inherent variability in CPUA than CPUE, as the range of outcomes appear wider between individual fishing events within each fishing season.

Direct comparisons between CPUE / CPUA and FIS, are slightly more complex, as FIS data is not available in all SAUs or fishing seasons (Figure 3.14). Further, extracting temporally and spatially matched fishing events from the logbook and VMS data is complex and results in low volumes of data for direct comparison. The trends in FIS estimates are mostly consistent with both CPUA and CPUE. At Middle Point, the largest FIS survey in the SZ, the magnitude of the decline in legal-sized density and CPUA in the early to mid-2010s, and subsequent increase since 2016, is very similar. At Gerloffs Bay, the FIS follows a similar trend to both CPUA and CPUE. At Number 2 Rocks, the FIS time-series is relatively short, although broadly follows the same trend as both CPUE and CPUA. At Rivoli Bay, the FIS time series follows a similar trend to CPUE and CPUA, besides 2016 where there is limited data (i.e., only one fishing record) for CPUE / CPUA.

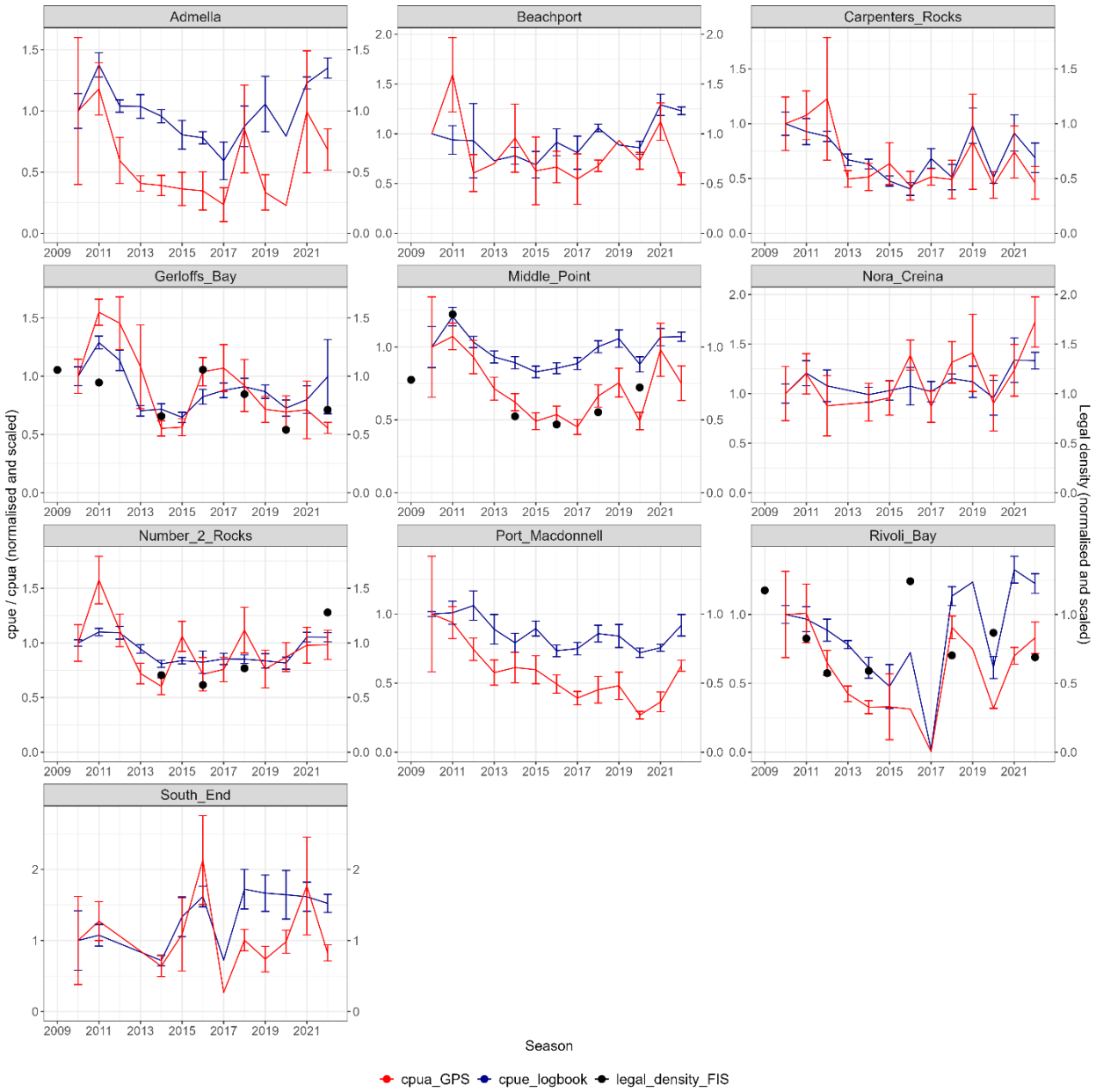

Figure 3-14. Comparison of catch-per-unit effort from logbook data (CPUE_logbook, blue line), catch-per-unit-area from the Vessel Monitoring System (CPUA_GPS, red line) and blacklip legal density from the FIS (legal_density_FIS, black symbols). Estimation of logbook CPUE only uses days where corresponding VMS data was available. All estimates were normalised to an average of 1 and scaled to align the starting value in each times series.

3.3 Greenlip

Since 1968, when almost 19 t of greenlip was landed, annual greenlip catches in the SZ have remained below 8 t (Figure 3-15a). Throughout the 1990s and 2000s greenlip catches fluctuated between 2 and 6 $t.y^{-1}$. After reaching 7.2 t in 2011, catches of greenlip have been steadily declining in recent fishing seasons, with catches in some years constrained by the TACC. In 2018, the TACC was reduced to 1.8 t, and has remained at that level for five consecutive fishing seasons, equating to the lowest recorded catches since the mid to late 1980s.

No attempt is made to estimate CPUE or generate an index of abundance for greenlip because there is insufficient data to do so. This reflects the fact that greenlip is taken primarily as a non-targeted species during mixed species fishing events.

The contribution of different SAUs to the greenlip catch have varied over time (Figure 3-15b). Recent contributions from Gerloffs Bay and Rivoli Bay to the total catch have been relatively small in a historical context. Conversely, Nora Creina has 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, which occurred when the blacklip FDAs were removed.

The mean length and length frequency of greenlip in the commercial catch has fluctuated over time, varying between 142 and 151 mm (Figures 3-15c, d).

Estimates of total greenlip density at Ringwood Reef in the Rivoli Bay SAU were stable during the 2000s, before increasing consistently from 2009 to the highest value on record in 2016 (Figure 3-15e). Thereafter, estimates declined markedly, culminating in the lowest value on record by 2022. The FIS data available from Ringwood Reef are not considered sufficient to assign stock status to this species, as greenlip catches from the Rivoli Bay SAU (which encompasses Ringwood Reef) only represent 13% of the historical greenlip catch from the SZ.

Given there is no framework to assign status for SZ greenlip under the HS (PIRSA 2021), and there is a lack of data available to estimate either biomass or fishing mortality for a weight of evidence assessment, the stock status of greenlip in the SZ under the NFSRF in the 2022 fishing season is **‘undefined’**.

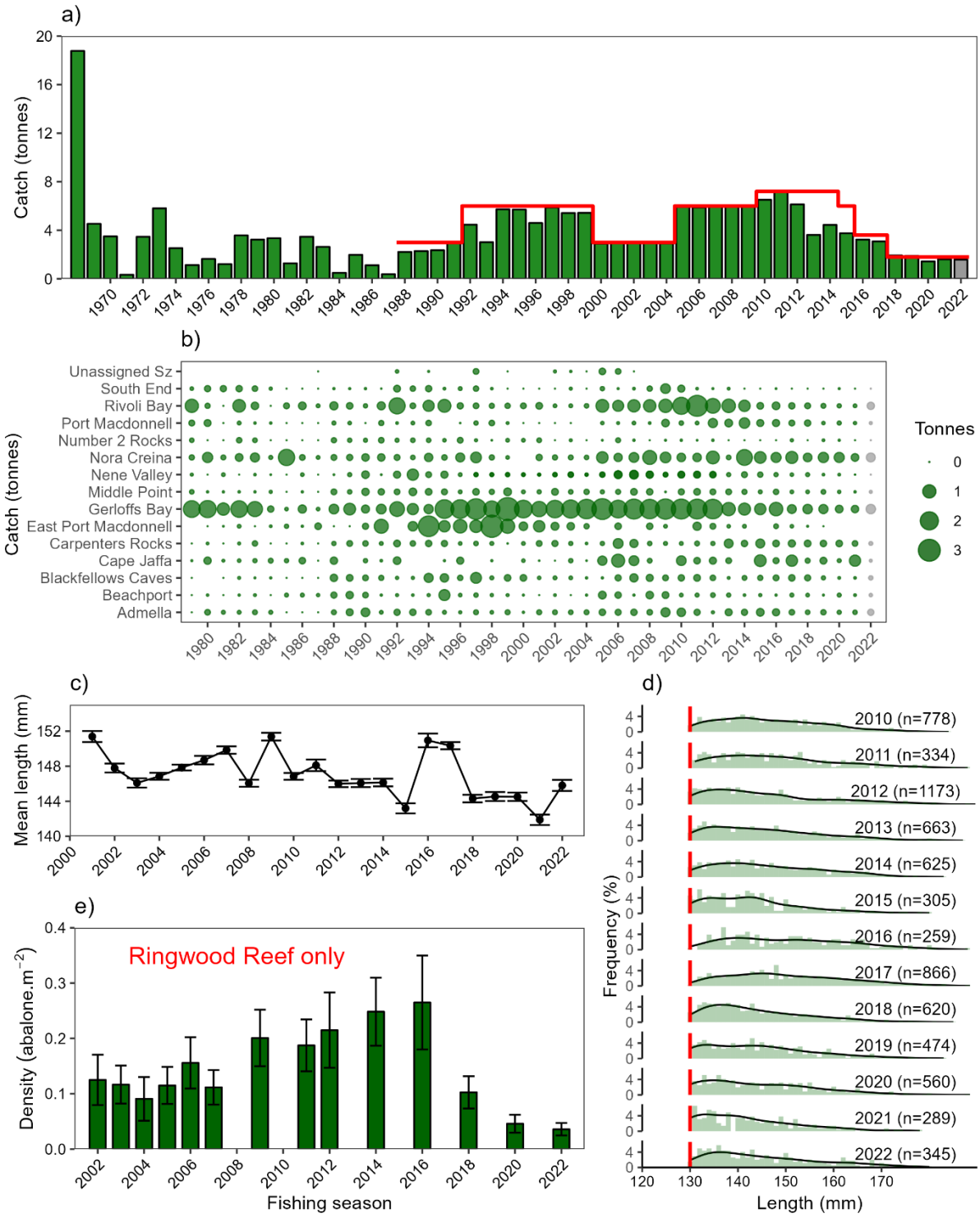

Figure 3-15. Greenlip data available from 1968/69 to 2022/23 (denoted 2022): a) Greenlip catch (tonnes, coloured bars) & TACC (red line). B) Bubble plot showing the spatial distribution of the catch (green symbols) by SAU. C) Mean length of greenlip in the commercial catch. D) Estimated distribution of commercial catch from shell sampling, MLL of 130mm = dashed red line. E) Density of all greenlip (abalone.m^{-2}; ± se) counted in transects during fishery-independent surveys at Ringwood Reef. Note: grey bar or symbols indicates year-to-date catch from the incomplete 2022/23 fishing season.

4 DISCUSSION

4.1 Current status of blacklip and greenlip in the Southern Zone

The stock status for blacklip was determined using the HS from the Abalone Management Plan (PIRSA 2021), which was designed to deliver outcomes consistent with the national fishery status reporting framework (Piddock *et al.* 2021). The HS applies two key indicators, CPUE and abalone legal-sized density from the FIS, to generate proxies for biomass and fishing mortality.

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, CPUE began to decline, followed by decreases in blacklip catch and, shortly thereafter, TACCs. Fishery-independent estimates of legal-sized and sub-legal-sized abalone also declined in most SAUs throughout this period. Consequently, between 2013 and 2015 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).

Since 2013 the average catch has been ~128 t, which is 17 t below the average catch (145 t) from the previous two decades (i.e., since TACCs were introduced). Over this nine-year period there is evidence that the harvestable biomass of blacklip in the SZ has stabilised and improved. Catch-per-unit-effort increased from 94 $kg.hr^{-1}$ in the 2014 fishing season, to 117 $kg.hr^{-1}$ in 2022. Meanwhile, FIS densities in the two SAUs with the greatest catch (Middle Point and Number 2 Rocks) were at their highest levels since 2014 and were at or above their target range from the HS. However, FIS estimates from the other two surveyed SAUs, with lower catch (Gerloffs Bay and Rivoli Bay) were below the target range from the HS, although they have remained relatively stable in recent fishing seasons. Sub-legal density within all four SAUs currently surveyed have increased during recent fishing seasons although, except for Number 2 Rocks, they remain below historical peaks.

Among the different SAUs within the fishery, there is 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 (6.4 out of 10) and Number 2 Rocks (8.6 out of 10), show evidence of high harvestable biomass. Comparatively, Gerloffs Bay (2.6 out of 10), currently has

a SAU score reflective of a relatively low level of harvestable biomass. In recent assessments there were two SAUs, Admella and Port MacDonnell, which demonstrated a decline in biomass following a period of sustained high catches at a reduced MLL following introduction of spatial management in 2013. Encouragingly, following a period of lower catches and industry-initiated increases to the MLL, the CPUE and CPUA in both the Admella and Port MacDonnell SAUs have improved in recent fishing seasons.

Application of the HS in the 2022 fishing season resulted in a YTD **zone score of 7.47** that, in combination with the **zone trend score of 5.51** that reflects an increasing trend, define the stock status for blacklip in the SZ in 2022 as **'sustainable'**. The zone score of 7.47 translates to a recommended zonal catch of 138.2 t for 2023, which is 6.2 t (4.7%) above the target catch level of 132 t for the SZ blacklip fishery. Following seven consecutive sustainable classifications, the current position of the SZ blacklip stock is encouraging, particularly given the widespread mortalities that occurred in this fishery in the summer of 2012/13, and sustained declines in blacklip catches across many abalone fisheries in southern Australia (Piddock *et al.* 2021).

4.1.2 GPS and depth logger data

There are now up to thirteen years of GPS location data available from the Vessel Monitoring System (VMS) in the SZ. In this report a single potential PI from this data is presented and discussed. Comparison between CPUE and CPUA seem largely consistent with the often-assumed hyperstable nature of CPUE (Mundy *et al.* unpublished), whereby CPUA in many SAUs declines at a faster rate and further than CPUE as stocks decline. This phenomenon likely occurs because divers cover more area as stocks decline to maintain CPUE at a relatively high level. This phenomenon also appears to operate in reverse in the SZ, as increases or recovery in CPUA were observed to exceed those for CPUE in most SAUs.

The ability of the comparisons between the FIS and CPUE / CPUA to detect hyperstability are somewhat inconclusive, and will benefit from an accumulation of more data, over different levels of stock abundance. In the Middle Point SAU (the most comprehensive FIS in the SZ) the FIS and CPUA time-series were very similar, in terms of both magnitude and trend, whereas changes in CPUE were more modest, which is indicative of CPUE hyperstability. At Gerloffs Bay, Rivoli Bay and Number 2 Rocks the CPUE, CPUA and FIS time-series generally followed a similar trend, with no clear evidence of a stronger association between FIS and either CPUE or CPUA.

Research to date suggest GPS data has the potential to provide an area-based PI, which is more directly related to stock abundance (i.e., less hyperstable) than CPUE. These data could be used to compliment, replace, or standardise existing time-based PIs, such as CPUE. Data from the

VMS is also more widely available than FIS, particularly if data coverage was improved. That withstanding, PIs from GPS data will always remain a fishery-dependent measure that can be impacted by various factors relating to selectivity, such as market demand and size-limits.

Further quantitative comparisons between these three data sources in the SZ would be premature because there is a need to; 1) incorporate diver into standardised measures of both CPUE and CPUA; 2) develop a greater understanding of the higher relative variability in CPUA compared to CPUE (e.g., diver differences, CPUE hyperstability or other causes); and 3) examine, and where beneficial, incorporate the findings from two ongoing FRDC projects, which are currently analysing GPS data from blacklip abalone fisheries in Tasmania (Mundy *et al.* unpublished, as part of FRDC Project 2017-026 - *Can spatial fishery-dependent data be used to determine abalone stock status in a spatially structured fishery?*) and Western Zone Victoria (Sainsbury *et al.* unpublished, as part of FRDC Project 2020-065 "*Indicators for density and biomass of exploitable abalone – developing and applying a new approach*").

4.1.3 Greenlip

Declining greenlip catches over the last decade potentially reflect a combination of declines in abundance, and/or the indirect influence of blacklip spatial management changes that were introduced in 2013. As there is no framework to assign status for this species under the HS (PIRSA 2021), and there are insufficient data available to estimate either biomass or fishing mortality needed to assess status under a weight of evidence approach. The stock status of greenlip in the SZ under the NFSRF in the 2022 fishing season is '**undefined**'. Given the low catches of greenlip, and its harvest primarily as a bycatch species, the classification is likely to remain undefined.

4.2 Uncertainty in the assessment

There were a number of limitations to this assessment. Outcomes from the HS are based on just two PIs (CPUE and FIS legal-sized density). While these PIs were considered the best available data to inform stock status, the degree to which they reflect abalone abundance may be influenced by many factors. There is increasing evidence CPUE in abalone fisheries is impacted by hyperstability (Mundy *et al.* unpublished, as part of FRDC Project 2017-026 - *Can spatial fishery-dependent data be used to determine abalone stock status in a spatially structured fishery?*), and the data presented from the VMS in Section 3.2 of this report highlight this phenomena is likely to occur in the SZ balcklip fishery. Similarly, effort creep as a result of increased diver efficiency, fisher knowledge and/or technological advance means direct comparison with historical CPUE estimates should be made with caution. Additionally, recent changes in fishing practices in the

SZ, including beach weighing of catch since 2018 and lowering of MLLs in some SAUs (e.g., Middle Point, Port MacDonnell), may have positively biased CPUE in recent years. It is important to note, however, that beach weighing of catch—before potential water loss later in the processing chain—has effectively reduced the number of abalone harvested each fishing 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-sized density, FIS provide consistent data through time that are less likely to be subject to biases associated with CPUE (mentioned above), however, they only cover a limited area of the key SAUs, and there remains a limited time series of data for some surveyed SAUs.

4.3 Future research needs

The most immediate research needs for the SZ are to: (1) complete the implementation of the new FIS design at Cape Northumberland (part of the Middle Point SAU), which will occur in 2023. The new FIS design at Gerloffs Bay was implemented in 2022 (see Appendix 3); (2) continue the development of potential spatial PIs from the VMS data that appear likely to provide a more direct estimate of stock abundance than CPUE; (3) consider potential improvements to CPUE where possible, to account for spatial management and changes to the MLL, beach weighing of catch, VMS data, and other influences (e.g., diver, month, swell); and (4) reconsider the most appropriate reference period for both FIS and CPUE during the next review of HS, giving consideration to the ongoing discrepancy between these two key PIs in the HS (average HS CPUE score is currently 8.3 while the FIS score is 4.2). The 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 also be considered in the next HS review.

The presence of Abalone Viral Ganglioneuritis (AVG) near the SA border following the recent outbreak in western Victoria remains a key threat to the SZ fishery. There is currently no active surveillance program undertaken by PIRSA, although this should be considered in the event there is evidence of increased transmission further west or other any other evidence of AVG spread.

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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 <90% 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 periodically as part of the SLA and subsequently communicated and 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 PIRSA Fisheries and Aquaculture prior to acceptance and potential errors corrected through direct correspondence with individual commercial fishers. SARDI staff are trained to undertake fishery-independent 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 Information Systems Quality Assurance and Data Integrity Report. The data are stored in an Oracle database, backed up daily, with access restricted to PIRSA Fisheries and Aquaculture Information Systems staff. Database copies are provided to SARDI abalone researchers on request. All fishery-independent 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 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, whole weight), effort, fishing location (mapcode, SAU), catch rate (CPUE, kg whole weight.hr^{-1}). Fishery statistics are provided at three spatial scales – the whole of the SZ, individual SAUs and combined data-limited SAUs – and are presented by fishing season. Prior to 2016, fishing season was 1 September to 31 August (12 months). In 2016, a 13 month fishing season was used (i.e., 1 September 2016 to 30 September 2017) to facilitate a shift in the fishing season opening to October (i.e., 1 October to 30 September).

Catch (t, whole 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 fishing 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 fishing 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} or the daily catch was >1500 kg. Data were also filtered to remove records where blacklip was <90% of the daily catch, which was a change from previous reports when <95% was used as the filter. This change was implemented to reduce the number of fishing seasons in some SAU with a

paucity of data to estimate CPUE and had only minor impacts on the HS outcomes. Annual CPUE estimates were determined for the SZ and each SAU. Limited daily records (i.e., n<10) prevented calculation of CPUE in some fishing seasons at some spatial scales. For the surveyed and unsurveyed SAUs in fishing seasons where n<10, a 3-year running mean CPUE was applied, as is a requirement under the HS (PIRSA 2021). 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 February 2023. 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 fishing 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 and legal-sized abalone (MLL ranging from ≥110 to ≥125 dependent on SAU), estimated from the combination of count data and population length-frequency.

Estimates of blacklip density were obtained from fishery-independent diver surveys that commenced in 2002 (see Mayfield *et al.* 2003). After 2009, surveys were switched to a biennial cycle 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 original 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 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 principles (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. The original leaded-line method has been retained in the Rivoli Bay SAU, where it can be applied safely. 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, and leaded-line surveys were commenced at Port MacDonnell in 2018. There are currently four surveyed SAUs (i.e., Middle Point, Number 2 Rocks, Rivoli Bay and Gerloffs Bay) scored in the HS, one SAU where a time-series is still being established (i.e., Port MacDonnell) and one SAU where surveys have been discontinued (i.e., Nene Valley).

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, in the Rivoli Bay SAU. 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 – Revised survey design at Gerloffs Bay

The total (Figure A3-1a), legal (Figure A3-1b) and sub-legal (Figure A3-1c) sized blacklip was similar when comparing the old survey design (n sites = 17) and the reduced survey design (n sites = 9). The discontinued sites from the old survey design had slightly fewer abalone, which reduced the mean density in most years. At the new survey locations in 2022, 63% of abalone measured were above the current MLL of 112mm, compared with 33% from the old survey design. When all years were combined the old survey design had 38% of the abalone measured above the current MLL (Figure A3-1d – Appendix 1). These new locations will be integrated into future FIS estimates for the HS as more data becomes available.

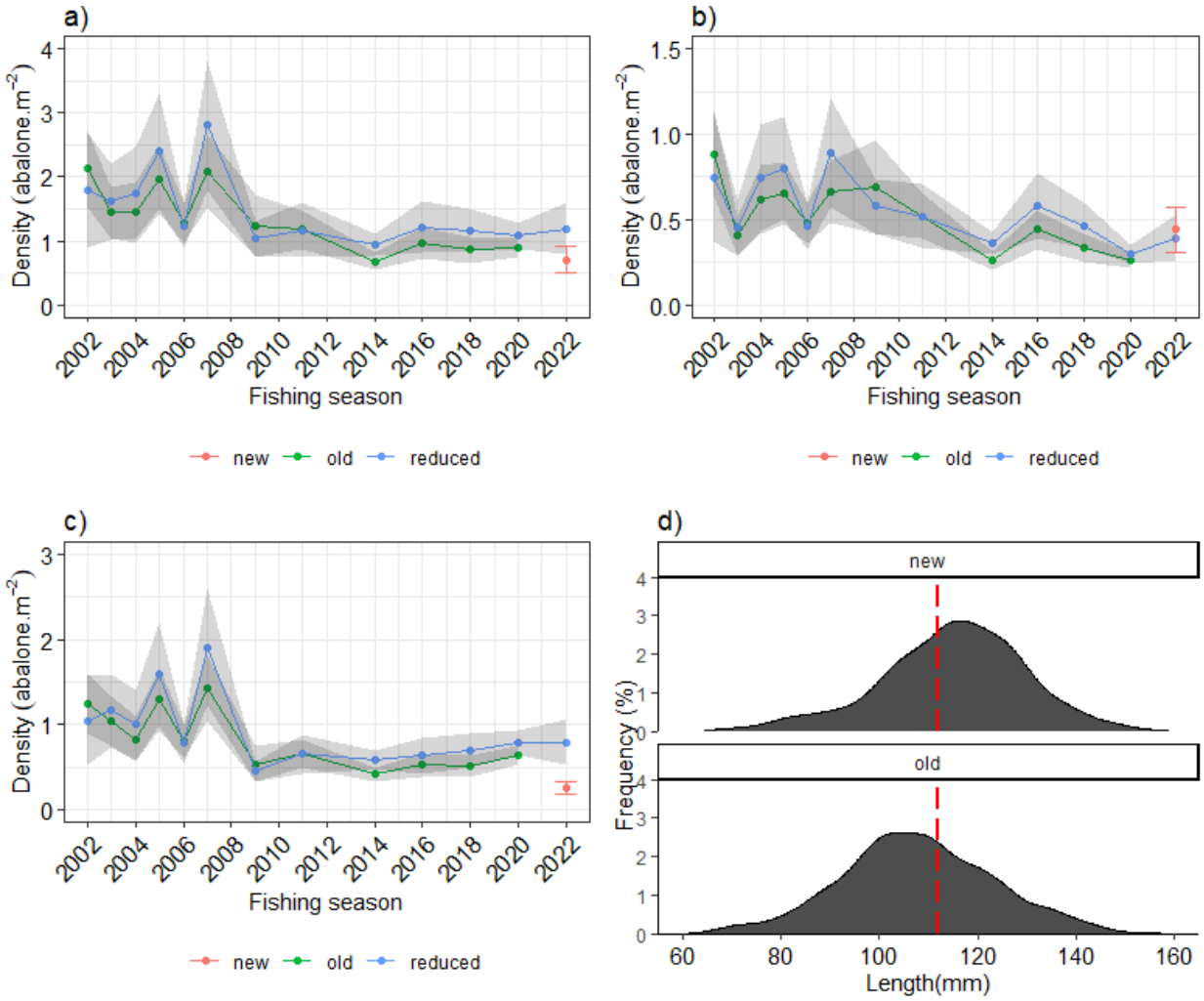

Figure A3-1. Density of blacklip (abalone.m^{-2}; ± se) counted in transects during fishery-independent surveys from the new survey locations (red symbols), old survey design (green symbols) and reduced survey design (blue symbols) at Gerloffs Bay. a) total density (all blacklip), b) legal density (blacklip ≥112 mm), c) sub-legal density (blacklip <112 mm), and d) predcited length frequency distributions from the new survey locations in 2022 compared with the old survey design (all years combined), current MLL of 112mm = dashed red line.

4. APPENDIX 4 – Annual zone score, score gradient, zonal trend and status for blacklip

Table A4-1. 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	3.78	-0.04	4.68	Depleting
1994/95	3.89	-0.10	3.83	Depleting
1995/96	4.69	0.00	5.00	Sustainable
1996/97	4.36	0.05	5.47	Sustainable
1997/98	4.21	0.02	5.00	Sustainable
1998/99	4.77	0.00	5.00	Sustainable
1999/00	5.37	0.08	5.84	Sustainable
2000/01	7.14	0.22	8.12	Sustainable
2001/02	5.90	0.12	6.61	Sustainable
2002/03	6.33	0.03	5.16	Sustainable
2003/04	5.98	-0.06	4.47	Sustainable
2004/05	6.88	0.04	5.18	Sustainable
2005/06	6.93	0.05	5.35	Sustainable
2006/07	6.66	0.03	5.13	Sustainable
2007/08	6.51	-0.02	5.00	Sustainable
2008/09	7.59	0.03	5.02	Sustainable
2009/10	7.77	0.06	5.63	Sustainable
2010/11	8.44	0.09	6.06	Sustainable
2011/12	7.97	0.03	5.05	Sustainable
2012/13	6.66	-0.05	4.59	Sustainable
2013/14	5.50	-0.13	3.27	Sustainable
2014/15	4.91	-0.12	3.40	Depleting
2015/16	5.25	-0.06	4.42	Sustainable
2016/17	6.19	0.04	5.19	Sustainable
2017/18	6.72	0.12	6.49	Sustainable
2018/19	6.85	0.11	6.37	Sustainable
2019/20	6.65	0.03	5.06	Sustainable
2020/21	6.35	-0.02	5.00	Sustainable
2021/22	7.74	0.04	5.17	Sustainable
2022/23	7.47	0.06	5.51	Sustainable

5. APPENDIX 5 – Catch and CPUE for blacklip and greenlip

Table A5-1. Blacklip catches (tonnes) by fishing 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	Nene Valley	Nora Creina	Number 2 Rocks	Port Macdonnell	Rivoli Bay	South End	Unassigned SZ	Total
1979/80	1.2	0.7	0.1	2.2	1.7	0.0	12.7	28.3	0.7	2.9	51.4	1.6	3.3	5.3	0.0	112.0
1980/81	8.2	7.2	0.0	0.0	6.2	0.7	12.6	33.3	3.0	5.8	27.2	0.1	0.8	5.4	0.0	110.7
1981/82	12.1	3.7	0.3	0.0	7.6	0.1	10.5	25.4	2.3	2.0	33.2	1.4	0.4	12.0	0.0	111.0
1982/83	4.2	4.8	0.2	0.4	2.7	0.1	10.4	21.0	2.8	5.2	27.7	0.5	1.3	2.3	0.0	83.9
1983/84	4.8	2.8	1.5	0.3	5.7	0.1	15.6	15.9	2.0	1.0	32.1	0.3	2.3	8.7	0.0	92.9
1984/85	7.2	4.0	3.6	2.6	2.6	6.4	5.4	38.2	4.3	0.5	36.9	2.7	0.8	19.0	0.0	134.0
1985/86	1.1	3.3	1.4	3.8	3.9	6.6	5.5	29.5	4.2	9.4	29.6	18.0	1.0	9.0	0.0	126.2
1986/87	1.6	3.2	0.7	1.2	5.5	3.0	8.8	47.7	6.3	3.5	39.0	5.4	0.9	11.9	0.0	138.6
1987/88	4.3	2.8	7.9	2.8	7.0	3.0	9.8	36.2	5.0	2.8	46.3	6.4	4.3	6.8	2.1	147.3
1988/89	6.3	2.2	10.2	1.5	4.0	0.2	2.8	36.0	4.9	1.3	24.2	4.2	5.3	4.9	0.0	108.0
1989/90	12.8	2.9	4.3	0.0	7.7	0.2	3.4	31.0	28.2	1.3	23.0	0.7	2.3	5.7	0.0	123.4
1990/91	4.7	4.1	6.1	0.6	4.9	5.7	1.4	26.1	3.1	1.2	37.7	3.6	2.2	10.1	0.0	111.5
1991/92	4.9	3.2	5.2	1.0	3.6	12.9	3.2	21.5	2.5	2.5	30.0	19.3	2.4	8.5	0.0	120.6
1992/93	11.1	2.5	1.8	0.8	16.0	0.0	51.4	28.7	2.4	1.0	20.3	4.9	35.8	8.7	0.4	185.7
1993/94	8.3	2.2	2.7	0.0	7.3	5.6	8.4	35.5	29.2	1.5	18.7	3.6	2.8	7.7	0.0	133.6
1994/95	10.4	3.7	2.5	0.0	7.9	8.9	4.6	29.7	3.2	7.0	24.0	1.5	30.2	9.7	0.4	143.6
1995/96	10.5	6.9	7.5	0.6	9.7	1.0	29.4	28.1	3.9	3.8	19.9	0.0	14.9	6.7	0.0	142.9
1996/97	8.0	5.9	2.2	0.7	7.4	11.0	18.6	30.3	4.3	5.0	27.9	1.2	11.3	9.2	0.0	143.0
1997/98	11.0	2.1	6.2	0.0	5.7	5.9	19.6	41.1	2.5	7.4	19.3	8.8	5.2	6.3	3.0	144.0
1998/99	9.7	4.0	3.8	0.9	5.7	5.9	15.4	36.8	4.8	4.3	27.5	3.7	7.2	13.9	0.0	143.7
1999/00	12.7	2.6	5.5	0.0	4.8	7.2	35.8	27.5	2.4	0.6	16.7	2.9	18.5	5.3	0.4	142.7
2000/01	8.5	4.2	7.8	1.3	4.5	6.0	21.7	27.0	6.8	0.0	29.3	0.4	21.8	7.3	0.0	146.7
2001/02	12.1	1.6	0.8	0.7	3.2	6.8	19.4	34.4	3.8	4.8	25.0	1.6	26.1	4.9	0.0	145.1
2002/03	12.9	4.7	1.1	0.6	19.4	4.4	18.7	28.5	5.3	5.6	11.8	0.0	29.6	2.2	0.1	145.0
2003/04	15.2	2.3	2.1	1.3	11.0	5.6	29.5	34.0	4.2	3.0	16.3	1.0	11.3	6.1	0.4	143.4
2004/05	10.1	7.5	2.9	0.7	10.6	5.9	26.7	25.9	3.6	5.2	19.7	0.0	13.2	11.2	3.6	146.9
2005/06	14.2	7.3	1.0	0.4	10.7	0.0	27.1	27.0	6.6	7.2	15.2	3.3	13.9	8.0	2.1	144.0
2006/07	13.8	6.6	4.9	1.4	10.9	1.1	18.5	28.2	5.3	3.6	15.1	2.0	22.6	7.9	2.6	144.5
2007/08	15.5	5.1	8.7	1.1	8.9	0.0	22.6	22.6	9.6	6.8	17.7	5.5	14.5	4.2	0.8	143.6
2008/09	8.1	9.6	2.6	0.6	6.9	0.1	23.0	20.5	6.5	7.2	26.0	6.6	17.8	6.5	0.0	142.0
2009/10	12.0	9.6	3.5	0.0	6.8	0.4	29.8	15.6	7.0	4.0	28.3	6.8	11.7	8.4	0.0	144.0
2010/11	17.4	4.1	6.9	0.9	6.4	0.0	31.4	21.0	5.3	3.6	30.1	1.9	9.5	4.5	0.0	143.2
2011/12	6.5	10.3	4.3	0.0	5.8	1.4	29.3	28.3	4.3	4.3	29.4	4.2	16.2	6.9	0.0	151.3
2012/13	6.6	5.2	5.7	0.4	8.8	0.2	29.2	24.4	6.7	3.9	26.1	13.3	12.5	6.5	0.0	149.4
2013/14	14.2	3.2	2.5	0.0	10.8	0.1	9.9	33.8	2.1	1.2	22.6	16.7	5.4	3.2	0.0	125.7
2014/15	16.7	6.3	4.6	0.0	11.7	0.1	10.0	35.5	3.4	6.8	18.5	13.7	5.4	1.9	0.0	134.6
2015/16	13.4	3.3	4.5	0.9	9.9	0.0	7.9	23.5	2.9	5.2	27.9	15.9	4.1	3.2	0.0	122.6
2016/17	8.3	4.4	5.4	1.8	11.8	0.1	14.2	29.2	1.8	4.0	17.2	15.1	6.2	6.5	0.0	125.9
2017/18	4.1	5.3	3.7	3.6	6.2	0.2	10.3	29.4	2.1	7.3	27.1	15.0	6.7	5.3	0.0	126.3
2018/19	5.2	5.0	2.3	2.5	8.1	0.0	8.3	26.7	2.9	8.2	31.0	15.8	10.0	5.6	0.0	131.5
2019/20	4.5	5.1	2.6	2.5	9.2	0.0	9.6	27.6	2.1	5.3	25.4	10.3	7.2	6.4	0.0	117.8
2020/21	4.3	7.3	2.1	2.3	11.3	0.0	6.1	26.8	2.4	6.3	31.0	14.5	9.8	8.2	0.0	132.3
2021/22	8.8	8.0	1.9	4.1	11.1	0.0	2.8	27.8	3.8	5.4	29.0	10.9	9.1	9.4	0.0	132.2
2022/23	8.7	7.3	1.6	0.6	5.0	0.0	3.5	23.2	0.0	7.9	30.8	12.8	9.3	4.5	0.0	115.2

Table A5-2. Blacklip catch per unit effort (CPUE) by fishing season from the Southern Zone abalone fishery, aggregated at the spatial assessment unit scale. No data indicates estimate is not available for that fishing season (i.e., <10 records in the given fishing 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	Nene Valley	Nora Creina	Number 2 Rocks*	Port Macdonnell*	Rivoli Bay*	South End	Combined Data Limited SAUs
1978/79	72.6				74.1		68.2	81.3	57.3		87.6		62.0		83.7
1979/80	56.1				63.3		67.9	64.1	44.6		87.5		54.0	58.4	57.6
1980/81	48.7	92.2			66.0		55.9	62.4	57.2	66.2	76.7		39.6	57.9	72.1
1981/82	65.2	48.5			57.1		44.0	59.0	56.6		71.6		29.1	57.2	55.8
1982/83	45.2	52.0			51.0		42.9	67.1	66.2	44.1	72.1		31.3		46.4
1983/84	42.6				45.0		50.7	58.6	61.5		65.3	50.0	41.8	57.0	57.8
1984/85	74.4				57.0	62.5	56.2	81.1	64.2		100.0	65.9	46.9	99.2	81.5
1985/86	73.5				58.5	52.0	55.6	78.8	71.1	54.6	89.9	71.9		73.7	58.6
1986/87	84.1				71.8	57.6	68.3	80.1	68.6		95.8	68.0	63.2	74.9	70.8
1987/88	83.5		79.4		79.2		70.7	88.1	70.9		105.4	84.1	65.6	82.6	76.5
1988/89	81.7		71.8		82.8		73.4	93.9	74.0		110.1	96.6	82.1		82.9
1989/90	86.0				82.5			83.8	80.6		97.6	106.7	82.6	91.7	85.2
1990/91	73.7		70.7		77.1	65.6		83.4	69.2		99.8	105.9	83.1	97.4	80.7
1991/92	80.9		66.9		73.4	92.6	107.6	81.0	64.7		104.1	102.7	101.2		92.0
1992/93	75.4				73.7		115.3	83.0	67.6		100.8	71.1	106.3	93.0	83.3
1993/94	75.2				67.4		70.0	81.3	82.1		84.3	78.1	101.3	89.9	86.9
1994/95	75.9				70.5	69.7	79.4	77.7	65.6		88.4	78.6	103.6	96.0	84.2
1995/96	73.5		84.6		66.3		91.3	86.0	72.0		88.2		108.6	95.3	93.9
1996/97	71.4				74.2	68.5	76.1	89.4	71.5		89.1		98.0	111.9	87.6
1997/98	77.8		78.9		64.7	61.2	91.8	80.6	76.9	80.4	92.1	96.8	88.0	96.8	78.2
1998/99	90.7				73.8	71.9	79.5	99.4	97.9	71.9	107.4	84.2	67.1	81.3	77.3
1999/00	97.2		81.4		83.5	77.8	98.0	88.8	112.1		106.2	81.6	91.4		82.0
2000/01	108.3		111.3		88.5		79.9	103.4	109.0		120.0		112.7	111.2	105.4
2001/02	87.2				100.0	73.1	95.5	97.5	92.8		115.0		107.0		83.2
2002/03	96.3				107.9	66.5	107.2	96.7	89.5		144.1		108.0		96.0
2003/04	96.7				92.6	63.2	109.3	100.5	91.6		124.3		112.0		91.4
2004/05	97.6				101.9	69.0	102.4	106.3	116.0		125.5		111.9	142.5	105.8
2005/06	96.8	104.4			93.5		97.1	103.7	113.4	110.3	124.6		116.8	122.7	110.7
2006/07	81.5				94.2		101.8	105.3	110.9		109.3	106.0	117.7	107.4	103.9
2007/08	87.6		88.1		76.4		98.3	97.7	109.7	98.0	121.9	112.9	108.6		96.1
2008/09	96.9	110.6			87.4		111.0	101.6	97.1	89.7	128.6	130.7	126.3		102.3
2009/10	98.7	129.2			103.6		106.4	111.0	109.3		128.0	143.7	114.6		119.3
2010/11	112.0				109.3		127.1	123.7	107.9		126.7	144.9	122.8		121.8
2011/12	96.1	97.3			105.9		114.3	123.5	118.8		134.8	136.6	116.4	100.2	100.9
2012/13	82.5		103.0		93.0		94.3	110.1	102.6		130.2	127.2	98.7	88.5	90.2
2013/14	83.6				87.5		72.9	108.7	86.8		112.0	120.7	98.0		85.5
2014/15	88.5	98.2			88.6		80.1	103.3	79.6		101.5	118.1	90.3		92.5
2015/16	83.0				81.2		80.5	92.4	86.5		109.6	116.3	91.6		101.2
2016/17	80.7		98.6		83.7		79.1	99.6	81.1		117.2	99.0	107.6		112.5
2017/18	87.2				90.4		92.9	104.4	100.4		123.4	99.8	122.7		109.3
2018/19	86.8				105.9		97.0	108.7	97.8	96.8	119.3	114.5	123.5		104.7
2019/20	90.4				101.3		87.9	116.8	83.7		121.3	95.1	115.1		100.9
2020/21	95.3	100.3			92.1		83.2	105.8	83.1		121.8	96.0	115.0		99.1
2021/22	103.4				103.9		76.0	112.2	92.0		137.0	108.6	128.1		114.9
2022/23	104.0				100.3		75.7	107.7			129.4	119.6	129.9		106.0

Table A5-3. Greenlip catches (tonnes) by fishing 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	Nene Valley	Nora Creina	Number 2 Rocks	Port Macdonnell	Rivoli Bay	South End	Unassigned SZ	Total
1979/80	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.1	0.0	0.1	0.1	0.2	1.0	0.0	0.0	3.2
1980/81	0.1	0.0	0.0	0.3	0.0	0.0	1.8	0.0	0.0	0.6	0.0	0.2	0.1	0.2	0.0	3.3
1981/82	0.1	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0	1.3
1982/83	0.1	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.3	0.1	0.1	0.9	0.2	0.0	3.5
1983/84	0.1	0.0	0.0	0.1	0.1	0.0	1.4	0.0	0.0	0.4	0.1	0.0	0.3	0.1	0.0	2.6
1984/85	0.1	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.5
1985/86	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	1.6	0.0	0.0	0.2	0.0	0.0	2.0
1986/87	0.0	0.1	0.0	0.2	0.0	0.0	0.3	0.0	0.0	0.1	0.0	0.0	0.3	0.0	0.0	1.1
1987/88	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.4
1988/89	0.1	0.2	0.3	0.3	0.1	0.0	0.5	0.2	0.0	0.2	0.1	0.1	0.3	0.0	0.0	2.2
1989/90	0.2	0.3	0.2	0.0	0.2	0.0	0.8	0.1	0.1	0.2	0.1	0.0	0.2	0.0	0.0	2.3
1990/91	0.4	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.3	0.1	0.0	0.1	0.0	0.0	2.4
1991/92	0.0	0.0	0.1	0.0	0.1	1.2	0.5	0.2	0.0	0.3	0.1	0.1	0.3	0.0	0.0	3.0
1992/93	0.2	0.0	0.0	0.3	0.2	0.0	1.3	0.1	0.2	0.2	0.1	0.0	1.6	0.2	0.0	4.5
1993/94	0.2	0.0	0.0	0.0	0.1	0.5	0.7	0.3	0.7	0.1	0.1	0.0	0.1	0.1	0.0	3.0
1994/95	0.1	0.0	0.4	0.0	0.2	2.7	0.5	0.2	0.2	0.4	0.1	0.1	0.7	0.2	0.0	5.7
1995/96	0.1	0.7	0.4	0.0	0.2	0.7	2.1	0.2	0.2	0.1	0.0	0.0	1.0	0.0	0.0	5.7
1996/97	0.0	0.0	0.1	0.2	0.0	1.1	2.1	0.1	0.0	0.4	0.1	0.0	0.2	0.1	0.0	4.6
1997/98	0.1	0.1	0.7	0.0	0.1	0.9	2.7	0.2	0.1	0.6	0.0	0.1	0.1	0.1	0.1	5.9
1998/99	0.0	0.0	0.1	0.0	0.1	3.1	1.6	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	5.4
1999/00	0.1	0.0	0.2	0.0	0.0	1.2	3.3	0.3	0.1	0.0	0.0	0.0	0.1	0.0	0.0	5.4
2000/01	0.0	0.0	0.2	0.0	0.0	0.4	1.9	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	2.9
2001/02	0.1	0.0	0.0	0.0	0.1	0.7	1.4	0.1	0.0	0.2	0.1	0.0	0.2	0.0	0.0	3.0
2002/03	0.1	0.0	0.1	0.0	0.2	0.3	1.9	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	3.0
2003/04	0.1	0.0	0.0	0.1	0.1	0.3	2.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	3.0
2004/05	0.1	0.0	0.0	0.0	0.0	0.1	2.4	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	2.9
2005/06	0.2	0.3	0.0	0.5	0.1	0.0	2.7	0.1	0.1	0.7	0.0	0.0	0.9	0.1	0.2	5.9
2006/07	0.2	0.2	0.2	1.0	0.5	0.2	1.9	0.1	0.3	0.4	0.1	0.0	0.7	0.0	0.1	5.9
2007/08	0.2	0.0	0.3	0.5	0.3	0.0	2.5	0.2	0.4	0.5	0.0	0.0	0.9	0.0	0.0	5.9
2008/09	0.1	0.3	0.2	0.1	0.1	0.2	2.3	0.2	0.3	1.1	0.0	0.0	0.9	0.1	0.0	6.0
2009/10	0.4	0.2	0.2	0.0	0.1	0.0	2.6	0.0	0.1	0.6	0.0	0.3	1.0	0.5	0.0	6.0
2010/11	0.4	0.0	0.2	0.5	0.1	0.0	2.5	0.2	0.2	0.4	0.0	0.1	1.8	0.2	0.0	6.5
2011/12	0.2	0.1	0.2	0.2	0.1	0.3	2.5	0.2	0.2	0.4	0.0	0.0	2.8	0.0	0.0	7.2
2012/13	0.0	0.1	0.1	0.2	0.1	0.2	2.4	0.2	0.2	1.0	0.0	0.4	1.3	0.0	0.0	6.1
2013/14	0.2	0.1	0.0	0.1	0.4	0.0	1.0	0.1	0.1	0.1	0.0	0.3	1.1	0.0	0.0	3.6
2014/15	0.2	0.0	0.1	0.0	0.2	0.0	0.8	0.1	0.2	1.5	0.0	0.6	0.7	0.0	0.0	4.4
2015/16	0.3	0.0	0.1	0.8	0.4	0.0	0.7	0.1	0.1	0.8	0.0	0.2	0.2	0.0	0.0	3.8
2016/17	0.3	0.0	0.2	0.2	0.2	0.1	1.1	0.1	0.1	0.5	0.0	0.2	0.3	0.0	0.0	3.2
2017/18	0.1	0.1	0.2	0.7	0.3	0.0	0.4	0.0	0.0	0.8	0.0	0.2	0.2	0.0	0.0	3.1
2018/19	0.1	0.0	0.2	0.1	0.2	0.0	0.5	0.0	0.1	0.4	0.0	0.2	0.2	0.0	0.0	1.9
2019/20	0.1	0.0	0.1	0.2	0.2	0.0	0.4	0.1	0.0	0.6	0.0	0.0	0.1	0.0	0.0	1.9
2020/21	0.1	0.1	0.0	0.1	0.2	0.0	0.3	0.0	0.0	0.6	0.0	0.1	0.1	0.0	0.0	1.4
2021/22	0.1	0.0	0.0	0.7	0.1	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	1.6
2022/23	0.2	0.0	0.1	0.0	0.1	0.0	0.5	0.0	0.0	0.4	0.0	0.0	0.3	0.0	0.0	1.6