Fisheries

Southern Zone Abalone
(*Haliotis rubra* and *H. laevigata*) Fishery

S. Mayfield, G. Ferguson, A. Hogg and J. Carroll

SARDI Publication No. F2007/000552-5
SARDI Research Report Series No. 850

SARDI Aquatic Sciences
2 Hamra Avenue West Beach SA 5024

July 2015

Fishery Assessment Report to PIRSA Fisheries and Aquaculture

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This publication may be cited as:
Mayfield, S., Ferguson, G., Hogg, A. and Carroll, J. (2015). Southern Zone Abalone (*Haliotis rubra* and *H. laevigata*) Fishery. Fishery Assessment Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2007/000552-5. SARDI Research Report Series No. 850. 57pp.

Cover photo: Blacklip abalone (*Haliotis rubra*), B. Stobart.

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Printed in Adelaide: July 2015

SARDI Publication No. F2007/000552-5
SARDI Research Report Series No. 850

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Date: 3 July 2015

Distribution: PIRSA Fisheries and Aquaculture, Southern Zone Abalone Fishery Licence Holders, SAASC Library, University of Adelaide Library, Parliamentary Library, State Library and National Library

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ACKNOWLEDGEMENTS

Funds for this research were provided by PIRSA Fisheries and Aquaculture, obtained through licence fees. We are grateful to Brian Foureur, Peter Hawthorne, Kylie Howard and Damian Matthews for assistance with diving. Sou'West Seafoods, Dover Fisheries and Southern Canning, along with Joe Austin, Michael Buhlmann, Chris Carrison, Jim Cope, Andrew Dihm, Jim Godden, Sam Godden, Brett Hosking, Peter Kelly, Dwayne Kelly, Leigh Kent, Aaron Leopold, Dick Perry, Graham Pollard and Stan Sunderland provided shells to aid this assessment. Jay Dent created the harvest strategy plots in the Appendix. Dr Ben Stobart assisted with data interpretation and, along with Jay Dent, provided editorial suggestions. This report was formally reviewed by Dr Annabel Jones (PIRSA Fisheries and Aquaculture), Drs Adrian Linnane and Crystal Beckman (SARDI Aquatic Sciences) and Prof. Gavin Begg, Research Chief, SARDI Aquatic Sciences. The report was formally approved for release by A/Professor Qifeng Ye, Science Leader, Inland Waters and Catchment Ecology, SARDI Aquatic Sciences.

EXECUTIVE SUMMARY

This fishery assessment report updates the 2013 report and assesses the current status of the blacklip (*Haliotis rubra*) and greenlip (*Haliotis laevigata*) abalone resources in the Southern Zone (SZ) of the South Australian Abalone Fishery (SAAF).

This assessment is required under the Management Plan of the SAAF (PIRSA 2012) which specifies the need for annual application of the harvest strategy to determine stock status and review the total allowable commercial catch (TACC). As the harvest strategy is relatively new and some limitations have been identified, the stock status outcome from the harvest strategy was compared to the traditional, weight-of-evidence analysis using the National Fishery Status Reporting Framework to classify stock status (NFSRF; Flood *et al.* 2014).

Blacklip abalone

Prior to 2011/12, the fishery for blacklip was characterised by large, stable total catches, increasing catch per unit effort (CPUE), stable length-frequency distributions from commercial catches, and consistent survey estimates of sub-legal-sized and legal-sized blacklip density. Consequently, assessments of stock status from the harvest strategy and by weight-of-evidence ranged between ‘lightly fished’, ‘underfished’ and ‘sustainable’.

Since 2011/12, considerable changes were evident in the SZ. These changes included declining CPUE, re-distribution of catches among spatial assessment units (SAUs), lower percentages of large blacklip (and smaller modal lengths) in the commercial catch samples and observed on fishery-independent surveys, and reductions in blacklip density estimates from most fishery-independent survey sites.

Notably, (1) the TACC was not harvested in 2013/14 and the total catch of 126 t was 25 t (17%) below the TACC; (2) the CPUE on blacklip across the SZ – the primary index of relative abalone abundance – has declined steadily since 2010/11 to be at the lowest level since 2001/02 in 2013/14; (3) decreases in CPUE were evident in nearly all SAUs (for the three high-importance SAUs, CPUE has declined by between 8% (Middle Point) and 38% (Gerloffs Bay) since 2011/12; and (4) survey estimates of legal-sized blacklip in 2014/15 in the Rivoli Bay and Gerloffs Bay SAUs were at the lowest levels recorded.

Collectively, this evidence demonstrates that the blacklip harvestable biomass is declining and that overfishing is most likely occurring. As the stocks are not yet considered to be recruitment overfished, the SZ blacklip fishery is classified as ‘**transitional depleting**’ under the NFSRF. This was different to the stock status classification for this fishery in 2012/13 (‘sustainable’).

Greenlip abalone

The low current and historical catch and limited data available prevents unambiguous assessment of the current status of greenlip in the SZ. Consequently, under the NFSRF, the stock status of this species in the SZ is classified as '**undefined**'.

1 GENERAL INTRODUCTION

1.1 Overview

This fishery assessment report for the Southern Zone (SZ) of the South Australian Abalone Fishery (SAAF) updates the previous fishery assessment (Mayfield *et al*. 2013) and status reports (Mayfield *et al.* 2014) for the SZ. The report covers the period from 1 September 1968 to 31 August 2014 and is part of the South Australian Research and Development Institute (SARDI) Aquatic Sciences' ongoing assessment program for the blacklip (*Haliotis rubra*) and greenlip (*H. laevigata*) fisheries (hereafter referred to as blacklip and greenlip, respectively) in this zone. This is the first stock assessment report for the SZ since the substantive changes to the management arrangements from 1 September 2013. Key among these was the implementation of spatial management, with area specific minimum legal lengths and catch caps that followed an extensive program that evaluated spatial variability in blacklip across this zone (Mayfield and Saunders 2008).

The aims of the report are to (1) determine the risk-of-overfishing in spatial assessment units (SAUs) of 'high' and 'medium' importance; (2) determine and assess the current status of the blacklip and greenlip fisheries in the SZ using the spatially-explicit, quantitative assessment of stock status and harvest strategy specified in the Fishery Management Plan for the commercial Abalone Fishery (PIRSA 2012); (3) compare the outputs from the harvest strategy with those obtained from the traditional, weight-of-evidence approach and the National Fishery Status Reporting Framework (NFSRF; Flood *et al.* 2014; Table 1-1); (4) identify uncertainty associated with the assessment; and (5) identify future research needs. The report is divided into four sections. Section 1 is the General Introduction, which provides a general overview of the report and the history and a description of the fishery, including the Management Plan. Sections 2 and 3 provide an assessment of fishery-dependent (FD) and fishery-independent (FI) data for blacklip and greenlip. For each of these species, where appropriate, this includes spatial and temporal analyses of catch, effort, catch-per-unit-effort (CPUE), commercial catch size-structure, FI survey data and application of the harvest strategy that determines (1) the risk that stocks within SAUs are overfished and (2) the status of the abalone fishery in the SZ. Spatial analysis of the fishery is based on SAUs which were implemented on 1 September 2013 (see Section 1.1.1). Each of Sections 2 and 3 are concluded by a discussion that provides a synthesis of the information presented, identifies assessment uncertainty and summarises stock status. Finally, in the General Discussion (Section 4), the stock status for greenlip and blacklip are compared and future research needs for the fishery identified.

Table 1-1. National stock status reporting framework classifications (from Flood *et al*. 2014).

	Stock status	Description	Potential implications for management of the stock
	Sustainable	Stock for which biomass (or biomass proxy) is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (i.e. not recruitment overfished) and for which fishing pressure is adequately controlled to avoid the stock becoming recruitment overfished	Appropriate management is in place
↑	Transitional–recovering	Recovering stock—biomass is recruitment overfished, but management measures are in place to promote stock recovery, and recovery is occurring	Appropriate management is in place, and the stock biomass is recovering
↓	Transitional–depleting	Deteriorating stock—biomass is not yet recruitment overfished, but fishing pressure is too high and moving the stock in the direction of becoming recruitment overfished	Management is needed to reduce fishing pressure and ensure that the biomass does not deplete to an overfished state
	Overfished	Spawning stock biomass has been reduced through catch, so that average recruitment levels are significantly reduced (i.e. recruitment overfished). 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
	Environmentally limited	Spawning stock biomass has been reduced to the point where average recruitment levels are significantly reduced, primarily as a result of substantial environmental changes/impacts, or disease outbreaks (i.e. the stock is not recruitment overfished). Fisheries management has responded appropriately to the environmental change in productivity	Appropriate management is in place
	Undefined	Not enough information exists to determine stock status	Data required to assess stock status are needed

1.1.1 Commercial fishery

The SAAF has been divided into three zones since 1971 (Western, Central and Southern) to facilitate more effective management (Figure 1-1). The SZ includes all coastal waters of South Australia east of Meridian 139°E, with the exception of the Coorong and waters inside the Murray River mouth (Figure 1-1). Management arrangements for blacklip in the SZ were substantially modified from 1 September 2013, following completion of an FRDC-funded project (FRDC 2004/019; Mayfield and Saunders 2008) and extensive consultation through 2012 and 2013. There were three key changes: (1) fish-down areas (FDAs, see below) were removed; (2) mapcodes were amalgamated into 13 SAUs (Figure 1-2); and (3) individual minimum legal lengths (MLLs), catch targets and catch limits were allocated to each SAU (Table 1-2). These changes recognised the broader spatial distribution of abalone populations with similar morphology and biology across the SZ (Mayfield and Saunders 2008) and reflect approaches adopted elsewhere (e.g. Prince *et al.* 2008).

Management arrangements have evolved since inception of the SAAF in 1964. These are reviewed by Shepherd and Rodda (2001) with the major management milestones listed in Table 1-3. Summaries of the fishery can be found in Prince and Shepherd (1992), Zacharin (1997), Nobes *et al.* (2004), Mayfield and Hogg (2011), and Mayfield *et al.* (2013). The SAAF expanded rapidly in the late 1960s, exceeding 100 entrants by 1970. Licences were made non-transferable in 1971 to reduce the number of operators in the fishery. By 1976, the number of operators had declined to 30 and an additional five licences were issued. There are currently 34 licence holders. Total Allowable Commercial Catches (TACCs) were introduced in 1988, with most of the TACC in the SZ comprised of blacklip (Table 1-4 a, b). In 2013/14, the blacklip TACC was 151.5 tonnes (t) whole weight (Table 1-4 b). A relatively small amount of greenlip is also harvested with the TACC in 2012/13 set at 7.2 t whole weight (Table 1-4 b). The TACCs for greenlip and blacklip have both been increased in recent years, following a long period of stability (Table 1-4). The fishing season runs from 1 September to 31 August.

From 1984/85 to 2012/13, prior to introduction of SAUs, there were four “fish-down” areas (FDAs; Figure 1-3) which were unique to the SZ. Within these FDAs, the blacklip were considered to be ‘stunted’ when compared to the remainder of the fishery. Stunted blacklip have a smaller maximum length, and/or a slower growth rate, when compared to other populations (Mayfield and Saunders 2008). The SZ divers developed and managed the FDA between 1984/85 and 1988/89, without regulation. From 1989/90, formal management arrangements for harvesting of ‘stunted’ (110.0 – 124.9 millimetres (mm) shell length (SL)) blacklip from the FDAs were developed through the former Abalone Management Liaison Committee and the later Abalone Fishery Management Committee. These arrangements included ministerial exemption notices issued under Section 59 of the *Fisheries Act 1982*. Prior to 2003/04, the TACC of ‘stunted’ blacklip from the FDAs ranged between 36 and 60 t. Fishers were also permitted to harvest blacklip >125 mm SL from the FDAs as part of the ‘normal’ blacklip TACC. Changes to the Fisheries Regulations in 1991 (Scheme of Management – Abalone Fisheries) formally provided for the harvesting of blacklip above a MLL of 110 mm SL in the four FDAs from 2003/04. These management arrangements were implemented from 1 September 2003 by dividing the SZ into two sub-regions – FDAs and non-FDAs. In 2003/04 and 2004/05 the blacklip TACC in the two sub-regions was 96 and 51 t, respectively. From 2011/12 to 2012/13, the blacklip TACC was 105 t in the non-FDAs and 46.5 t in the FDAs (Table 1-4).

To monitor catches and facilitate compliance with quota limits, fishers must complete a Catch and Disposal Record form immediately upon landing. In addition, a research logbook must also be completed for each fishing day and submitted to SARDI Aquatic Sciences at the end of each month. Commercial catch and effort data for this fishery have been collected since 1968. The logbook provides information on the date of fishing, fishing area, amount of time spent fishing, whether or not an underwater vehicle was used, diving depth and total catch landed. Few changes have been made to the data collection system. However, in 1978, sub zones and fishing blocks were replaced by spatially smaller map numbers (Fishing Areas) and mapcodes (Figure 1.2). Supplementary, voluntary data fields (e.g. global positioning system (GPS) position, number of abalone harvested) were added to the logbook in 2002. The logbook data supplied by divers and licence holders are used by SARDI Aquatic Sciences for analyses of catch, effort and CPUE data that underpin assessments of the fishery for each zone for Primary Industries and Regions South Australia - Fisheries and Aquaculture (hereafter referred to as PIRSA).

1.1.2 Recreational fishery

The total recreational abalone harvest in South Australia was estimated at 17,780 abalone.yr^{-1} for 2000/01 (Henry and Lyle 2003). Previous surveys within South Australia suggested that 19.5% of recreational fishing effort was expended in the SZ (Mayfield *et al.* 2001). Under this assumption approximately 3,500 abalone (1.6 t) are recreationally harvested from the SZ annually. This represents about 1.06% of the TACC. A more recent creel survey undertaken in 2007/08 estimated the total recreational harvest in the SZ at <500 abalone (Jones 2009), further confirming the low recreational harvest in this fishery.

1.1.3 Illegal, unregulated and unreported catch

It is difficult to determine the level of the illegal, unregulated and unreported (IUU) catch, as limited quantitative data are available. For the 2014 calendar year, PIRSA received 16 Information Reports (IRs) relating to illegal take of abalone in the SZ. Of these 16 IRs, 9 detailed the quantity alleged to have been taken illegally to be 67 kilograms (kg) of abalone meat. An average weight of the IRs detailing illegal harvest is taken and a calculation is made multiplying that figure with the total number of IRs received. It is therefore estimated that the illegal take from the SZ was 118 kg meat weight. It should be noted that these estimates represent alleged quantities illegally taken in this zone during the 2014 calendar year and have not been validated.

Table 1-2. For blacklip in each SAU: catch caps (shell weight), and current minimum legal shell lengths (MLLs) in place from 1 September 2014, (2014/15 season). Also shown are historical MLLs for the areas inside and outside of the historical fishdown areas (FDAs) and associated mapcodes (MC) prior to 2013/14.

SAU	Mapcodes	2014/15 Catch cap (kg)	2014/15 Minimum legal length (SL, mm)	Historical minimum legal length outside/within FDA (SL, mm)
Cape Jaffa	33A, 33B, 33C, 34A, 34B, 34C	5,000	125	125
Nora Creina	34D, 35A, 35B, 35C, 35D	8,000	125	125
Beachport	35E, 36A	6,000	125	125
Rivoli Bay	36B	21,000	120	125 (outside FDA 3); 110 (FDA 3)
South End	36C	10,000	125	125
Number 2 Rocks	37A, 37B, 37C, 37D, 37E, 37F, 37G, 37H	30,000	125	125
Admella	37J, 39A	16,000	120	125
Carpenters Rocks	39B, 39C	12,000	125	125 (outside FDA 4); 110 (FDA 4)
Gerloffs Bay	39D	30,000	120	110 (FDA 4)
Blackfellows Caves	39E	5,000	125	125 (outside FDAs 1 and 4); 110 (FDA 4; FDA 1)
Middle Point	39F, 39G, 40A	40,000	120	125 (outside FDA 1); 110 (FDA 1)
Port MacDonnell	40B	15,000	120	125 (outside FDA 2); 110 (FDA 2)
East Port MacDonnell	40C, 40D	6,000	110	125 (outside FDA 2); 110 (FDA 2)

Table 1-3. Management milestones in the Southern Zone of the South Australian Abalone Fishery.

Season	Milestone
1964	Fishery started
1971	Licences made non-transferable
	Fishery divided into three zones
	Minimum legal length set at 130 mm shell length (SL) for both species
1976	30 Licences remained; 5 additional licences issued
1978	Sub Zones and fishing blocks replaced by map numbers and codes
1984	Blacklip minimum legal length amended to 120 mm SL in the Southern Zone
1988	Quota introduced to the SZ
	Blacklip minimum legal length amended to 125 mm SL in the Southern Zone
1993	Abolition of owner-operator regulation
1994	Four ‘fish-down’ areas defined in the Southern Zone
1997	Management Plan implemented
2003	SZ separated into ‘fish-down’ and non-‘fish-down’ areas with separate TACC
2004	Management Plan Revised
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
2011	Blacklip TACC in non-FDAs increased from 99 to 105 t
2012	New Management Plan including harvest strategy
2012	Blacklip TACC in FDAs increased from 45 t to 46.5 t
2013	Amalgamation of mapcodes into 13 SAU individual MLLs, catch targets and catch limits

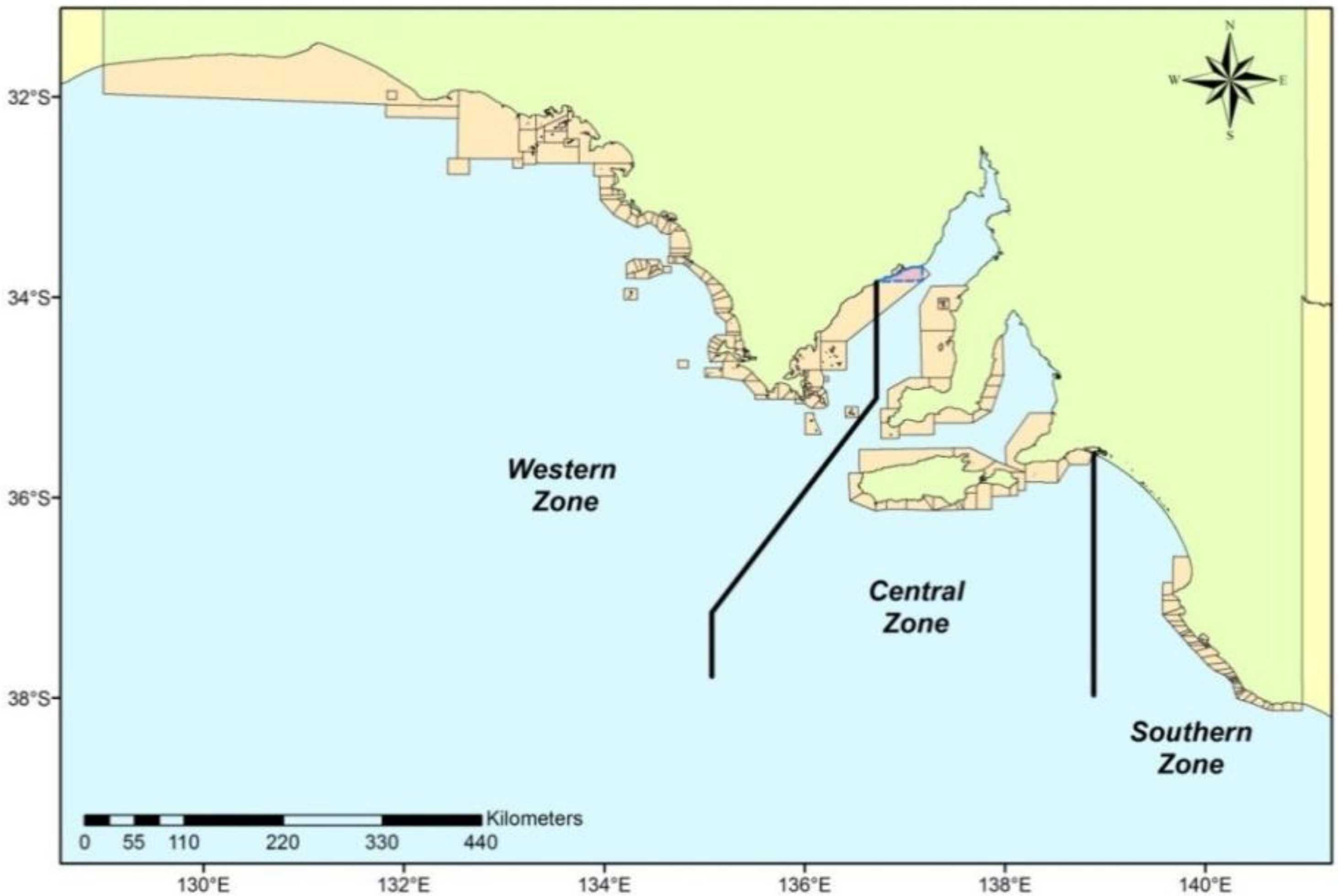

Figure 1-1. Fishing zones and mapcodes of the South Australian Abalone Fishery.

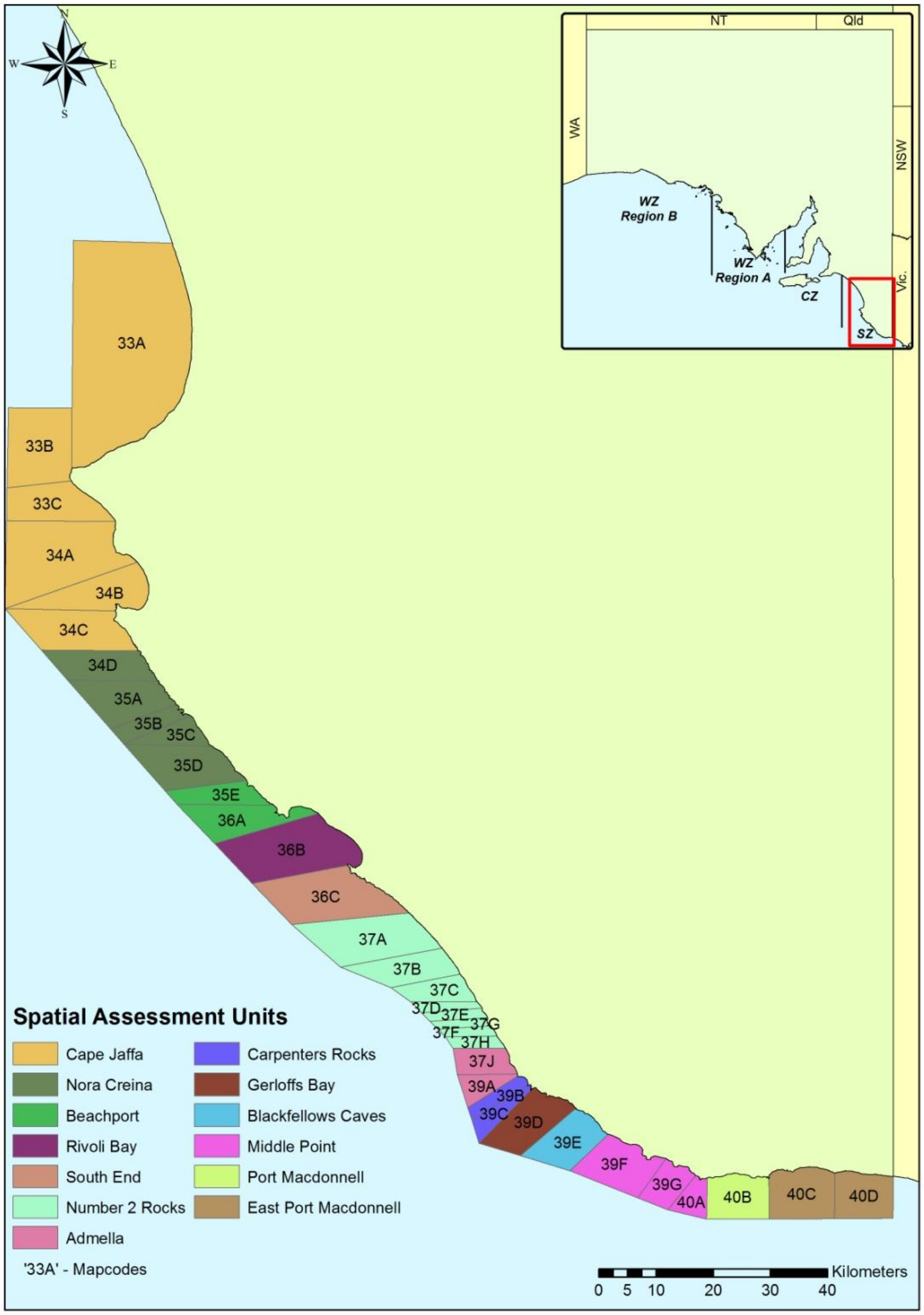

Figure 1-2. Spatial assessment units and mapcodes in the Southern Zone Abalone Fishery.

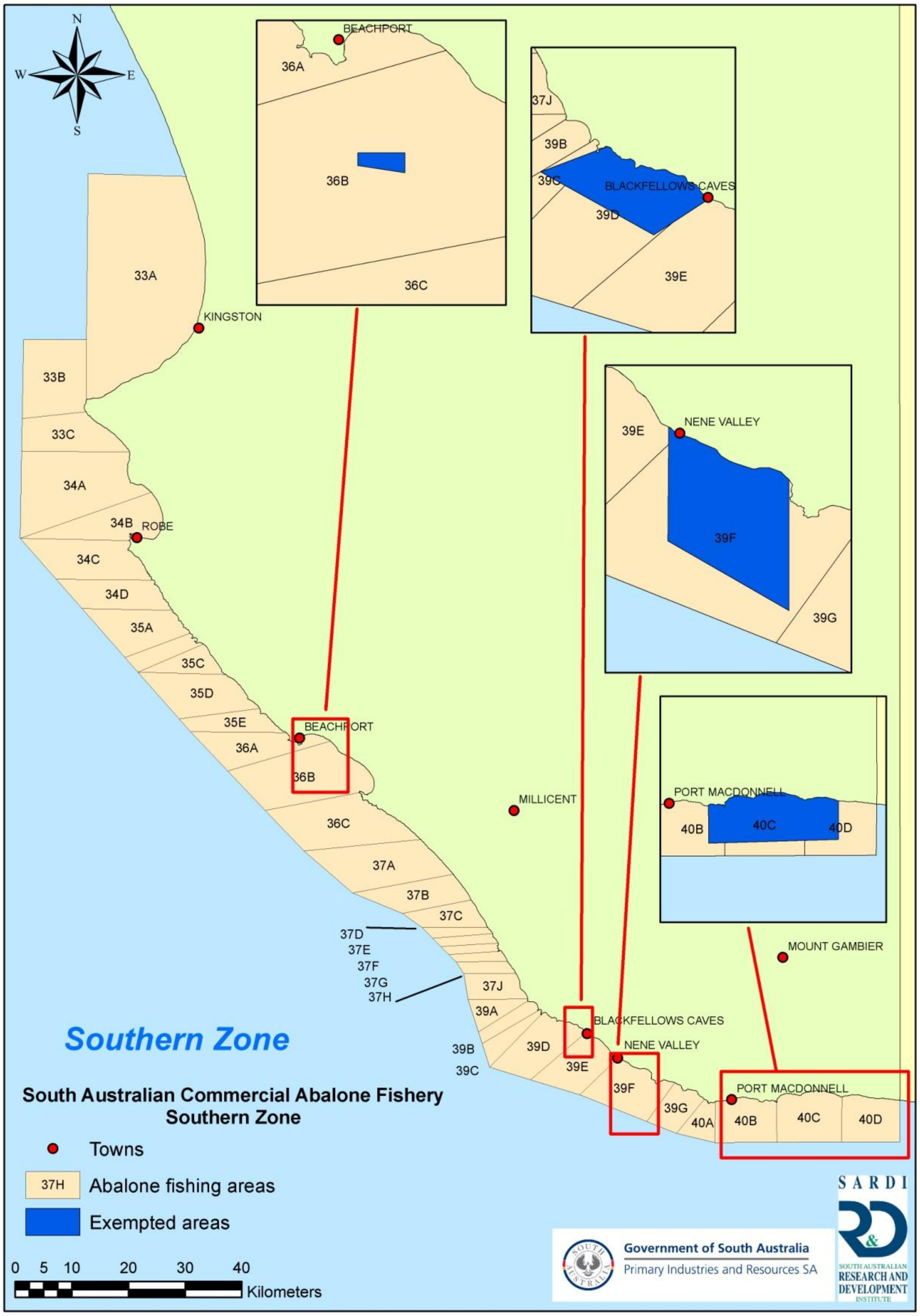

Figure 1-3. Mapcodes and 'fish-down' areas in the Southern Zone Abalone Fishery.

Table 1-4. Total allowable commercial catches (tonnes, shell weight) for the Southern Zone of the South Australian Abalone Fishery for three periods with different management arrangements for blacklip and greenlip (a) from 1988/89 to 2002/03, Southern Zone TACC with catch caps for each of two size classes; (b) from 2003/04 to 2012/13, Southern Zone TACC with catch caps for FDAs and non-FDAs each with corresponding MLLs; and (c) Southern Zone TACC with catch caps/MLLs for Spatial Assessment Units (see also Table 1-2).

Fishing season	Greenlip	Blacklip	Blacklip	Blacklip
(a)	SZ (SL >130 mm)	SZ (SL >125 mm)	SZ (110 mm <SL <125 mm)	SZ (all sizes)
1988/89-1991/92	3	108	-	108
1992/93-1993/94	6	108	-	108
1993/94	6	108	-	108
1994/95	6	108	36	144
1995/96	6	84	60	144
1996/97	6	96	48	144
1997/98-1999/00	6	108	36	144
2000/01-2002/03	3	108	39	147
(b)	SZ (SL >130 mm)	Non-FDAs (>125 mm)	FDAs (>110 mm)	SZ (all sizes)
2003/04-2004/05	3	96	51	147
2005/06-2009/10	6	99	45	144
2010/11	7.2	99	45	144
2011/12-2012/13	7.2	105	46.5	151.5
(c)	SZ (SL >130 mm)			SZ (MLLs by SAU)
2013/14	7.2			151.5

1.1.4 Economic importance

Econsearch provides an annual assessment of the economic performance of the SAAF (Paterson *et al.* 2013; Rippin *et al.* 2014). Catch value (gross value of production) in the fishery increased rapidly between 1997/98 and 2000/01, but followed a declining trend in subsequent years that was associated with a decline in the price of abalone linked to a drop in the value of the Australian dollar (Rippin *et al.* 2014). In spite of the decrease in product value, in 2012/13 the SAAF was estimated to contribute $54.6 million dollars to the South Australian economy and generate 304 full time jobs directly and indirectly (Rippin *et al.* 2014).

Major costs within the SAAF include interest, management costs and fuel. The average cost of management per licence holder has remained relatively stable since 2004/05 and, in 2012/13, was $70,007 (Rippin *et al.* 2014). In contrast, there was a large (29%) increase in fuel and interest costs between 2010/11 and 2011/12 with costs remaining relatively high in 2012/13 (Paterson *et al.* 2013; Rippin *et al.* 2014).

1.2 Management plans

1.2.1 Previous management plans

The first Management Plan for the SAAF (Zacharin 1997) identified biological, economic, environmental and social management objectives, associated strategies, performance indicators (PIs) and reference points to manage the fishery. The key PIs were (1) catch rate (catch per unit effort (CPUE) measured in kilograms per hour ($kg.hr^{-1}$)), (2) size composition of the commercial catch, and (3) the abundance of legal-sized and pre-recruit-sized abalone observed on fishery-independent surveys ($number.m^{-2}$). Reference points were percentage changes in these measures between years and across five consecutive years which, when exceeded, triggered a series of management actions. These management actions included notification to the responsible Minister, an examination of the causes of the observed changes, consultation on the need for alternative management arrangements and provision of a report on the review to the Minister within a specified time period.

Following extensive review, Zacharin (1997) was superseded in 2004 by the second Management Plan for the fishery (Nobes *et al.* 2004). Although Nobes *et al.* (2004) had similar (1) management objectives and associated strategies for the fishery and (2) management actions following triggering of PIs, this second Management Plan identified a broader suite of PIs – spanning a wide range of FD and FI data – applied to individual fishing areas within a statistical framework.

The triggering of PIs was primarily determined from statistically significant differences in PI values (1) between years and (2) across five consecutive years. This approach had two key advantages (Chick *et al.* 2009). Firstly, the suite of PIs was sufficiently broad, thereby encompassing almost all aspects of the fishery and, secondly, the complex population structures of abalone were captured by their spatial focus (Miller *et al.* 2009; Saunders and Mayfield 2008; Saunders *et al.* 2009a). However, a key disadvantage of this approach was the need to continually assess the fishery against a large number of PIs that, when triggered, seldom provided consistent inferences about stock status. Furthermore, this challenge was compounded by (1) inclusion of PIs that seldom informed stock status (e.g. mean daily effort) or were difficult to calculate (e.g. egg production); (2) the lack of target or limit reference points for PIs; and (3) not amalgamating the PIs across fishing grounds into a single index of stock status for each species in each zone, which made management decisions difficult because quotas are determined for each species in each zone. In addition, Nobes *et al.* (2004) did not provide clear decision rules to guide TACC changes among years. Chick *et al.* (2009) made several suggestions to overcome these difficulties that aided development of the new Management Plan, including (1) amalgamating the PIs for the key fishing grounds into a single index of stock status; and (2) employing the 'traffic-light' or 'thermostat' approaches suggested by Caddy (2002) and Shepherd and Rodda (2001).

1.2.2 The current Management Plan

Coincident with a project funded by the Fisheries Research and Development Corporation (FRDC) on abalone fishery performance measures (FRDC 2007/020), the second Management Plan (Nobes *et al.* 2004) was reviewed and revised in 2010 and 2011. The aim of this review was to develop a formal, species-specific, spatially-explicit harvest strategy for the SAAF that (1) defines stock status; (2) delivers sustainability outcomes; (3) is cost effective; and (4) facilitates stakeholder engagement. The objectives underpinning this process were to (1) capture the spatial structure of abalone stocks; (2) target assessments (and research) to key fishing grounds; (3) use a broad range of PIs to measure fishery performance and determine stock status; (4) develop clear frameworks for data utilisation, integration, interpretation; and (5) provide a structured, documented process for determining TACCs using harvest-decision rules that incorporate a framework to guide integration with industry information. These aims and objectives were selected following an extensive review of the role of PIs, reference points and decision rules in fisheries management (Caddy 2002, 2004; Sainsbury 2008). This review identified that clear indicators, reference points and decision rules improve the understanding of stock status among stakeholders providing increased certainty in management decisions.

The Management Plan (PIRSA 2012) reflects the aims and objectives of the review. For example, assessments are made at spatial scales that better reflect functional biological populations, termed SAUs. Research is focused into those SAUs from which most of the catch is harvested (high importance) and as a result the risk that abalone stocks in these areas are overfished is assessed using PIs that utilise both FD and FI data. These PIs have clearly-documented data utilisation (Table 1-5) and interpretation (Figure 1-6) and were selected because they directly measure abundance and exploitation rate whilst remaining as independent as possible. In contrast, those areas from which limited catch has been harvested – low importance SAUs – are not assessed using PIs. Following the risk-of-overfishing assessment for each SAU, the assigned risks are catch-weighted and summed to determine the stock status for each species. These outcomes serve two purposes. First, the assigned risk-of-overfishing category for each SAU is linked with explicit, bounded harvest-decision rules (Table 1-6) and industry-based information to determine the catch contribution from this SAU to the

TACC in the subsequent year. Second, the stock status enables the TACC to be set for two years – concurrent with the biennial assessment program – providing that stock status does not change among years. Thus, the Management Plan (PIRSA 2012) incorporates a species-specific, spatially-explicit harvest strategy that combines (1) PIs and reference points with (2) harvest-decision rules to determine future catch contributions from each SAU. Catch contributions are then summed by species for each zone and used to adjust annual TACCs. This approach overcomes many of the deficiencies of previous plans including reduced subjectivity in interpretation of a complex array of spatially-explicit PIs and a structured process for determining TACCs.

There are two key components to the harvest strategy. These are (1) determining the risk that each SAU is over-fished and indicating the overall status (depleted, over-fished, sustainably-fished, under-fished or lightly-fished) of each species in each zone; and (2) a decision-making process which integrates information from multiple sources (*e.g.* divers, licence holders, fishery managers, compliance officers, researchers) to make management decisions for each SAU. These management decisions are constrained by harvest-decision rules that, in turn, are determined by the risk-of-overfishing in each SAU. Determining the risk-of-overfishing and zonal stock status comprises five steps. Each of these is described in detail in the Management Plan and briefly below. Note that status is different to the national stock status reporting framework (Flood *et al*. 2014).

Step 1: Identify spatial assessment units

Spatial assessment units are the spatial scale at which monitoring and assessments are undertaken (Figure 1-2; PIRSA 2012) and, while intended to reflect distinct abalone populations (Morgan and Shepherd 2006; Mayfield and Saunders 2008; Miller *et al.* 2009), these SAUs likely encompass multiple abalone stocks. To ensure known catch history, SAUs comprise single or multiple mapcodes, which is the spatial scale against which FD data have been reported since 1979. SAUs are the same for greenlip and blacklip in each zone.

Step 2: Determine relative importance of each spatial assessment unit

The importance of each SAU for each species in each zone is based on the relative contribution to total (i.e. greenlip and blacklip combined) catch over the ten-year period ending with the year being assessed (i.e. the current year). Thus, for this assessment, importance was determined using data from 2004/05 to 2013/14. Three importance categories are defined – high, medium and low – based on the percentage contribution to total catch. SAUs from which, cumulatively,

>50% of catch was harvested are deemed of high importance. Medium importance SAUs comprise those which, cumulatively, bring the total catch to >80% of the combined TACC when added to the catch from high importance SAUs. All remaining SAUs were classified as being of low importance. For the ten-year period ending 31 August 2014, there were three high (Middle Point, Gerloffs Bay and Number Two Rocks) and four medium (Rivoli Bay, Admella, Carpenters Rocks and Beachport) importance SAUs in the SZ (Figure 1-4).

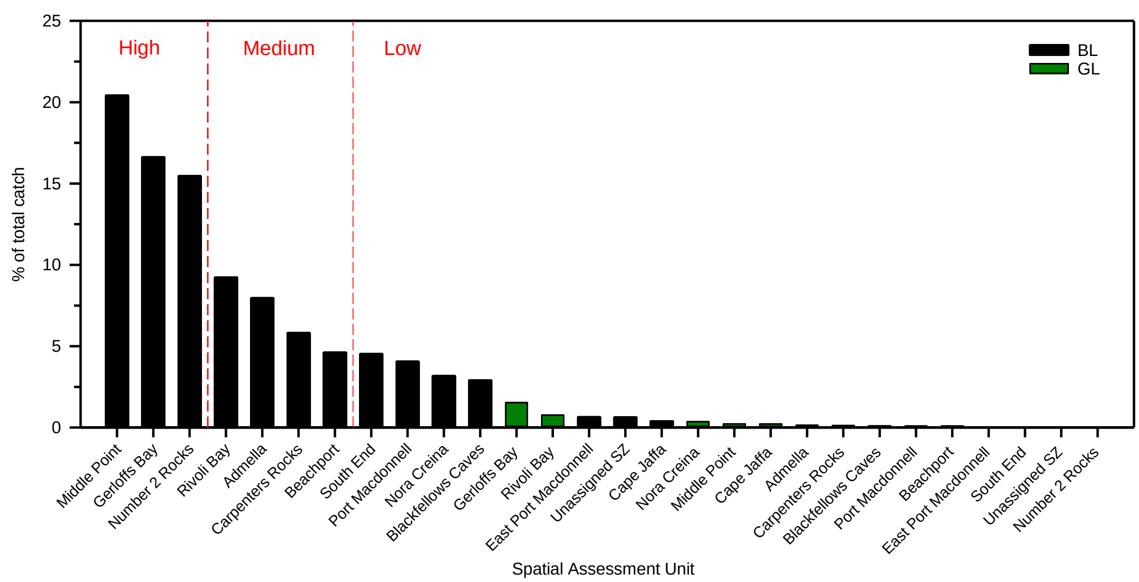

Figure 1-4. Relative importance (ten year % of total catch) of each blacklip (black bars) and greenlip (green bars) SAU. Note each SAU is ranked twice, once for blacklip and once for greenlip. Red text and dotted lines indicate SAU importance and division.

Step 3: Score performance indicators for each spatial assessment unit

Six PIs – three based on FD and three based on FI data – are used to measure fishery performance (Table 1-5). These PIs were selected because they provide direct measures of abalone abundance and/or exploitation rates and they are as independent from each other as was possible from the available datasets. All PIs are weighted equally. For those SAUs categorised as high, all six PIs are used to assess fishery performance; only the three FD PIs are used for SAUs categorised as medium importance. No scoring of the low importance SAUs is undertaken.

Where applicable, each PI for each species in each SAU is scored using a series of reference points. The reference points are derived from the 20-year time series (1990 – 2009) of data for each PI, termed the reference period. The exception is where <20 years of data are available (predominantly FI data), in which case, the most recent years (not the current year) are included in the 'reference period' until a period spanning 20 years is obtained. Four reference points are used for scoring (Figure 1-5): (1) upper limit reference point (ULRP) defined as the 3rd highest value (*i.e.* top 10%) during the reference period; (2) upper target reference point (UTRP) defined as the 6th highest value (*i.e.* top 25%) during the reference period; (3) lower target reference point (LTRP) defined as the 6th lowest value (*i.e.* bottom 25%) over the reference period; and (4) lower limit reference point (LLRP) which is defined as the 3rd lowest value (*i.e.* bottom 10%) during the reference period.

The scoring system is symmetrical with assigned scores for each year ranging from -2 to +2 (Figure 1-5). Each PI is scored on its current and recent performance. Current performance is scored on the current year value. Recent performance is scored on consecutive values of the PI above or below the UTRP-LTRP band for up to three previous years. The current and recent scores are summed to provide a single score for each PI. Thus, in combination, values of the PIs from the last four years are considered in determining the score of each PI for each species in each SAU.

Based on the example provided in Figure 1-5, the total score for that PI would be +3. This comprises +2 for current performance and +1 for recent performance (+1 for 2009). No score is assigned for 2008 as the value of the PI is inside the UTRP-LTRP band. Similarly, no score is assigned for 2007 because retrospective scoring ceases once the UTRP-LTRP band is entered or crossed. The principal exception to this scoring system is the assignment of a score of -1 for those high and medium blacklip SAUs for which commercial-catch-sampling data are not available.

Table 1-5. Summary of the PIs and the formulae and data constraints underpinning their utilisation in the harvest strategy in the Southern Zone.

Performance indicator	Description	Formulae	Data constraints
Catch	Total catch, expressed as a percentage of the TACC	$\text{Catch} = \frac{\sum \text{Species Catch (t)}}{\text{TACC}}.$	None
Proportion large	Proportion of large abalone in the commercial catch	$\text{PropLge} = \frac{\text{N Large}}{\text{Total N}},$	All measurements <125 mm SL excluded; Minimum sample size (N): 100 measurements Blacklip >150 mm SL defined as large Greenlip >150 mm SL defined as large
CPUE	Commercial catch-per-unit effort ($kg.hr^{-1}$)	$CPUE_{Wt} = \frac{\sum_{i=1}^{n} w_i \frac{C_{PSi}}{E_i}}{\sum_{i=1}^{n} w_i},$	All records where: total catch was >1200 kg; CPUE (total catch/total effort) was >150 $kg.hr^{-1}$; fishing effort was >10 hr; fishing effort was <3 hr; the reported catch of both species was zero; or the catch of the species for which CPUE was being estimated was <30% of the total catch were excluded. Minimum sample size: 10 records
Density_{legal}	Density of legal-sized abalone on surveys	$\text{Density}_{\text{Legal}} = \frac{\sum \text{Legal counted}}{\text{Total area surveyed}}$	>90% of survey completed Blacklip ≥120 mm SL defined as legal-sized
$\text{Density}_{pre\text{-}recruit}$	Density of pre-recruit (*i.e.* those that will exceed MLL within ~2 yr) abalone on surveys	$\text{Density}_{\text{Pre-recruit}} = \frac{\sum \text{Pre-recruit counted}}{\text{Total area surveyed}}$	>90% of survey completed Blacklip 80 to <120 mm SL defined as pre-recruits
Total mortality	Measure of the difference between the MLL and the mean length of legal-sized abalone. For consistency with other PIs, it is expressed as 1/total mortality	$Z = K\frac{(L_\infty - \bar{L})}{(\bar{L} - \text{MLL})},$	Minimum sample size: 100 measurements

Step 4: Determine risk of overfishing for each spatial assessment unit

Determining the risk that the stocks in each SAU are overfished comprises two steps. First, the scores for each PI are summed to provide a single numeric value for that SAU. Second, the total score is used to assign that SAU to a risk-of-overfishing, colour-coded category using a probability distribution which describes the likelihood of obtaining that total score by chance. The probability distributions (Figure 1-6) were determined in two steps: (1) the probability of obtaining each score (range: -8 to +8) for each PI was determined analytically and (2) Monte Carlo simulation (n = 1,000,000) was used to obtain probabilities of scores for multiple (*i.e.* combined) PIs. This approach relies on the assumption that all outcomes are equally likely and that the PIs are independent from each other and between years. Simulations were undertaken separately for the high (*i.e.* six PIs) and medium (*i.e.* three PIs) importance SAUs. As with the scoring of the PIs, the categories defining the risk that the stocks in a SAU are overfished are symmetrical with the boundaries between categories analogous to the reference points described in step 3 above. Importantly, the colour-coded categories are linked to explicit harvest decision rules (Table 1-6) that are applied to the mean catch over the most recent (four-year) period from each SAU during the decision-making process.

Step 5: Determine zonal status

The status of each species in each zone is derived from a combination of the (1) risk-of-overfishing category for each SAU and (2) importance of that SAU, by catch, to the zone. This is undertaken in a four-stage process. First, numeric scores are assigned to each colour-coded, risk-of-overfishing category. These scores are -2 (red), -1 (yellow), 0 (green), +1 (blue) and +2 (light blue). Second, the proportional contribution to the combined catch from each high and medium SAU is determined, with catches from low importance SAUs ignored. Third, the risk-of-overfishing score (-2 to +2) for each SAU is multiplied by its proportional contribution to the combined catch. Finally, the products of these calculations are summed to provide a catch-weighted score for zone status that ranges between -2 and +2. Zonal status scores fall into one of five categories. These are defined as depleted (score ≤ -1.5), overfished (>-1.5 score ≤-0.5), sustainably fished (>-0.5 > score ≤ 0.5), under fished (> 0.5 score ≤ 1.5) and lightly fished (score ≥ 1.5).

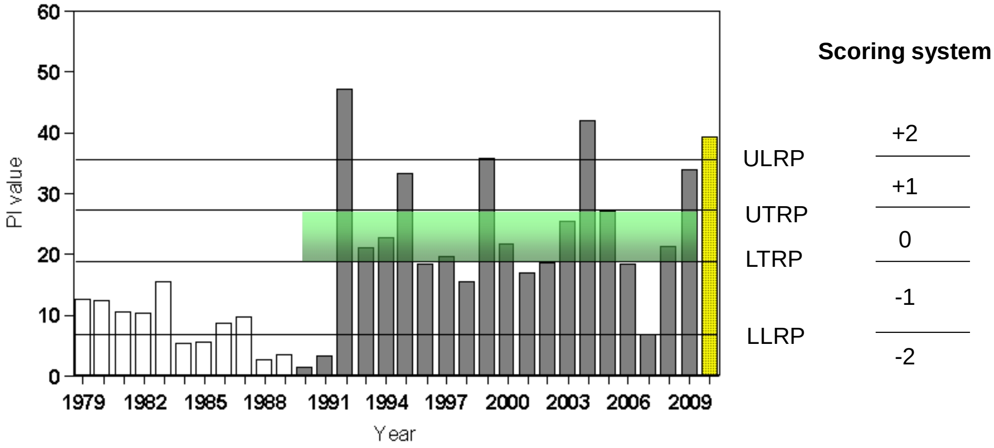

Figure 1-5. Schematic showing the reference period (grey bars), associated reference points, the year being assessed (yellow bar) and the scores applied to measure fishery performance. ULRP, UTRP, LTRP and LLRP refer to upper limit reference point upper trigger reference point, lower trigger reference point and lower limit reference point, respectively. The green shading indicates the middle 50% of values observed during the reference period.

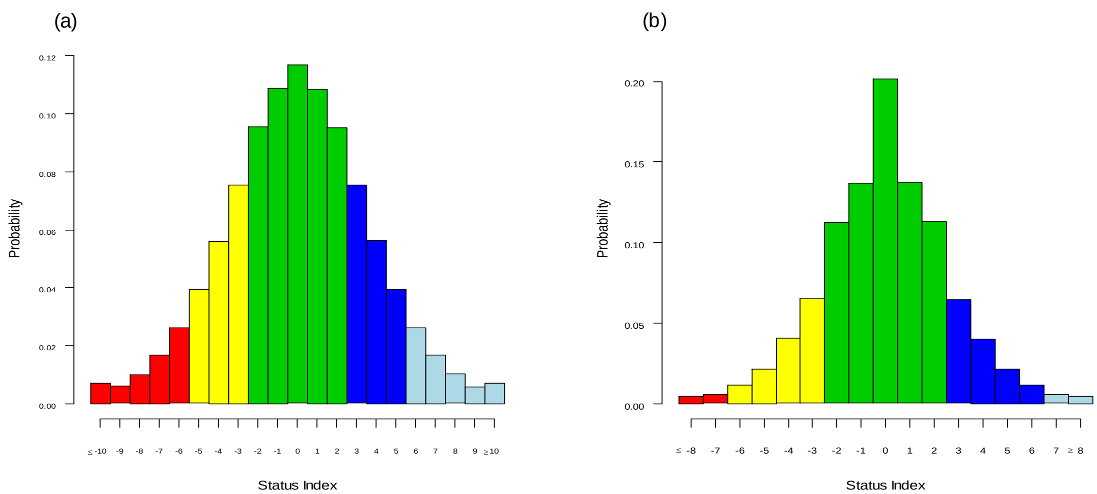

Figure 1-6. Histograms showing the probability distributions of obtaining total scores across (a) six PIs for SAUs of high importance and (b) three PIs for SAUs of medium importance. Probabilities above and below ±10 (High) and ±8 (Medium) were accumulated in these upper and lower bin classes, respectively, for each of the six and three PIs distributions.

Table 1-6. Range of harvest decision rules (% change in catch contribution) following identification of the risk of overfishing category by the harvest strategy.

Risk-of-overfishing	**Harvest decision rule**
	At least 30% reduction
	10-30% reduction
	10% reduction to 10% increase
	Up to 30% increase
	Up to 50% increase

1.3 Previous stock assessments

The first assessment of the South Australian abalone resource was published in 1984 (Lewis *et al.*1984). It was followed, in 1996, by a review of the abalone research arrangements and Management Plan. The 2001 stock assessment report provided fishery statistics for all three zones of the fishery (Mayfield *et al.* 2001) and provided the basis for more detailed stock assessments for each zone during 2002 (Mayfield *et al.* 2002a,b; Mayfield and Ward 2002). The first dedicated SZ report (Mayfield *et al.* 2002a) synthesised all data for the SZ from 1968 to 2002. That report has since been updated regularly (Mayfield *et al.* 2003, 2004, 2005, 2006, 2007), with more recent reports providing detailed analyses for both FDA and non-FDA (Mayfield *et al.* 2005, 2006, 2007, 2009, 2013; Mayfield and Hogg 2011). The report from 2013 assessed the fishery against the new harvest strategy based on SAUs and also provided an evaluation of the harvest strategy (PIRSA 2012; Mayfield *et al*. 2013).

Historically, assessments of the status of SZ stocks were heavily weighted by commercial catch and effort data (see Mayfield *et al.* 2002a, 2003, 2004, 2005, 2006). This assessment, like those undertaken since 2007 (Mayfield *et al.* 2007, 2009, 2013; Mayfield and Hogg 2011), is more robust as the assessment information is better balanced between that provided by commercial fishers (*e.g.* catch and effort and catch-sampling data) and that collected by SARDI Aquatic Sciences (*i.e.* biological and FI-survey data).

The stock assessment in 2013 concluded that blacklip stocks in the SZ were in a strong position but noted that the impact of widespread blacklip mortality in 2011/12 had not been determined and the ongoing capacity for blacklip populations to support historical catches remained unknown (Mayfield *et al.* 2013). The stock status report in 2014 reflected a decline in the estimates of CPUE for the SZ and most SAUs across the 2011/12 and 2012/13 fishing seasons although levels of CPUE remained historically high (Mayfield *et al.* 2014).

2 BLACKLIP ABALONE

2.1 Introduction

This section of the report provides an analysis of the fishery-dependent (FD) and fishery-independent (FI) data for blacklip in the SZ from 1 September 1968 to 31 August 2014, to determine the stock status of blacklip in the SZ in the 2013/14 season. It also includes a formal analysis of the fishery's performance and stock status based on the harvest strategy described in the Fishery Management Plan for the commercial Abalone Fishery (PIRSA 2012), which determines the (1) risk-of-overfishing in each high- and medium-importance SAU; and (2) the zonal stock status for blacklip. As this relatively new harvest strategy has several limitations (Stobart *et al.* 2014; Mayfield *et al.* 2014) and is being reviewed in 2015, the stock status classifications from the harvest strategy for both species were compared to the traditional, weight-of-evidence analysis using the NFSRF (Flood *et al.* 2014) as the framework for classifying fish stocks.

2.2 Methods

2.2.1 Data sources

The assessment used both FD and FI data. The FD data comprised catch (t, shell weight), effort, fishing location (mapcode, SAU), catch rate (CPUE, kg shell weight.hr^{-1}), and the proportion of large (≥150 mm SL) blacklip in the commercial catch. Fishery-independent data consisted of estimates of blacklip densities for sub-legal-sized (<120 mm SL) and legal-sized (≥120 mm SL) individuals separately and collectively (i.e. total density), and population length-frequency distribution. All data are presented as mean ± standard error (se) unless otherwise stated.

2.2.2 Fishery-dependent data

The FD data have been collected since 1968 by fishers completing a catch and effort logbook for each fishing day. Data on the length-frequency distribution of the commercial catch from September 2001 to August 2014 were obtained by SARDI observers measuring samples provided by commercial fishers. Fishery statistics are provided at three spatial scales. These are the whole of the SZ, individual SAUs and FDAs 1 and 3 (Figures 1-1, 1-2, 1-3). The latter were included because SZ divers and licence holders were concerned that the increased MLLs in mapcodes 39F and 36B have led to reduced catch rates and were unnecessary.

Catch (t, shell weight) was determined from all daily logbook returns. Effort was calculated from all daily records where blacklip catch was reported (i.e. >0 kg). Annual estimates of CPUE were calculated as the catch-weighted mean of daily CPUE (see Burch *et al.* 2011) with the percentage of blacklip in the catch for each daily record used as a weighting factor in calculating the arithmetic mean of daily CPUE records. Prior to calculation of CPUE, daily data were filtered to remove records where catch was >1.2 t, effort was <3 or >10 hours, the ratio of total catch over total hours was >150 $kg.hr^{-1}$ or blacklip was <30% of catch. The small proportion of records (<1%) where multiple daily dives were entered as separate days were ignored. Limited daily records (i.e. n<10) prevented calculation of CPUE in some years at some spatial scales. Annual CPUE estimates were determined for the SZ and each SAU. In addition, given the revised management arrangements that included the raising and lowering of MLLs in some mapcodes, the CPUE on blacklip was also estimated for those mapcodes where the (a) MLL was raised, (b) lowered, or (c) remained unchanged.

As a prelude to potential CPUE standardisation, the influence of individual divers on annual estimates of CPUE was examined by comparing six time-series of annual CPUE estimates (Figure 2-1). Each time-series comprised catch and effort data from five of the potential six licence holders (i.e. six data sets were prepared by sequentially removing one licence holder from each). There was no significant difference in annual CPUE among all time-series regardless of which of five licence holders contributed data (General Linear Model, GLM: $F_{1,5}$ = 0.242; P = 0.943). The absence of a diver effect supports the use of mean CPUE based on pooled data from all licences as the best available index of relative abundance. Consequently, that index has been used in all CPUE estimates in this report.

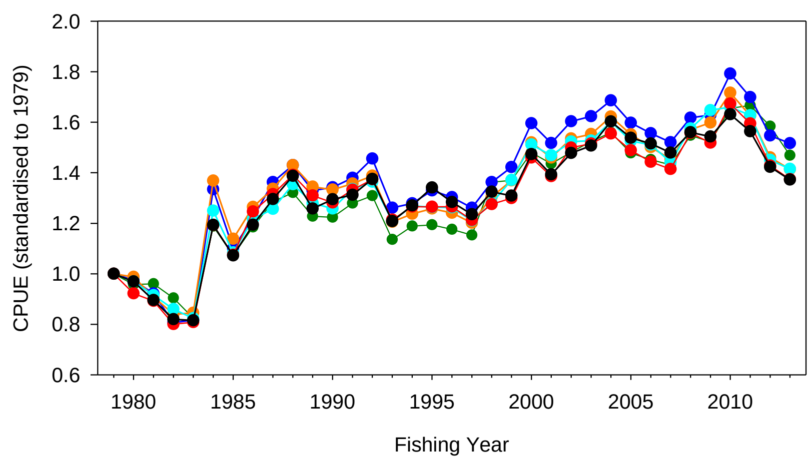

Figure 2-1. Standardised CPUE on blacklip in the Southern Zone from catch and effort data aggregated from six combinations of licence holders from 1979/80 (denoted 1979) to 2013/14.

2.2.3 Fishery-independent data

Estimates of blacklip density were obtained from FI diver surveys initiated in 2002/03 (see Mayfield *et al.* 2003) that, in more recent years, have been undertaken biennially and/or triennially as part of an overall rationalisation of the research program. Survey sites were historically located in non-fish-down areas (Douglas Bay, Middle Point, Cape Northumberland) and fish-down areas (Ringwood Reef, FDA 3; Jones Bay, FDA 2; and Gerloffs Bay, FDA 4) (Mayfield *et al.* 2009). The survey method involved counting blacklip abalone in paired (i.e. left and right) 20-m long transects distributed along ten 170-m, leaded-line transects at each survey site that are laid from the vessel using GPS co-ordinates for the start and end point (Mayfield *et al.* 2004, 2013; McGarvey 2006; McGarvey *et al.* 2008; Mayfield *et al.* 2013). Population length-frequency data were obtained by collecting and then measuring blacklip from within the surveyed area, but not from within the transects. These data were used to estimate the proportion of large blacklip observed (blacklip <60 mm SL excluded; blacklip >134 mm SL defined as large). Following a review of diving procedures, the survey method in the Middle Point and Gerloffs Bay SAUs was changed in 2014/15 from leaded-line transects to cross-drops. This change was necessary to eliminate the risk of the transect line becoming entangled in the vessels propoellor, posing a risk to vessel safety. The cross-drop method developed by Chick *et al.* (2012) is used throughout the Western Zone of the SAAF (Stobart *et al.* 2015). The leaded-line and cross-drop methods are based on the same sampling principals (McGarvey 2006; McGarvey *et al.* 2008) and yield comparable changes in blacklip density following fishing (Chick *et al.* 2012). Briefly, cross-drops involve counting blacklip abalone in 10-m long by 1-m wide transects radiating from a central point. To increase independence among samples, the inner 2-m is not sampled (i.e. transect lines are 12 m long with the first 2 m not sampled). To enable direct comparison with historical survey estimates of density, 10-m cross-drops were located using GPS to ensure sampling encompassed selected 20-m transects from the original 170-m leaded-line surveys. This required re-estimation of historical abalone densities using only those data from the leaded-line survey locations that were re-sampled in 2014/15. As before, population length-frequency data were obtained by collecting and then measuring blacklip from within the surveyed area, but not within the transects. Surveys conducted in the Rivoli Bay SAU in 2014/15 were undertaken using the original leaded-line method. However, following the same review of diving procedures, only five of the historical 10 leaded-lines were sampled. To enable direct comparison with historical survey estimates of density, historical abalone densities were re-estimated using only those data from the leaded-line survey locations that were re-sampled in 2014/15. In 2014/15, cross-drop surveys were also initiated in the Number 2 Rocks SAU.

2.3 Results

2.3.1 Southern Zone

From 1969/70 to 1993/94, which comprised the early, formative years of the SZ fishery, catches of blacklip ranged from 19 – 186 $t.yr^{-1}$ (mean: 109 $t.yr^{-1}$, Figure 2-2). From 1994/95 to 2011/12 total annual catches were relatively stable and generally higher (range: 142 – 151 $t.yr^{-1}$; mean: 144 $t.yr^{-1}$) than the preceding 25 years. The catch of 149 t in 2012/13 was similar to the contemporary maximum of 151 t in 2011/12. However, in 2013/14, only 83% of the TACC was harvested with the catch of 126 t, 17% below that in 2011/12 and the lowest since 1991.

Total annual effort was 1,997 hours (hr) in 1992/93, which was the highest on record (Figure 2-2). From 1992/93, total annual effort declined substantially (>30%) to 1,251 hr in 2010/11 which was the lowest level in 20 years. From 2010/11, effort increased to 1,524 hr in 2012/13 then declined by 13% to 1,334 hr in 2013/14.

From 1993/94 to 2010/11, the combination of stable catches and reductions in fishing effort resulted in increasing catch rates and mean annual CPUE exceeded 100 $kg.hr^{-1}$ from 2008/09 to 2011/12 (Figure 2-2 A). The CPUE of 114 $kg.hr^{-1}$ in 2010/11 was the highest in 30 years (i.e. since 1979/80). From 2010/11, CPUE declined (20%) over three consecutive seasons to 91 $kg.hr^{-1}$ in 2013/14. This was the lowest level since 2001/02.

While there was a moderate (GLM: $F_{1,2} = 3.090$; $P = 0.0497$) difference among estimates of CPUE from mapcodes where the MLL was raised, lowered or remained unchanged, in all cases the CPUE estimate in 2013/14 was lower than that in 2012/13 (Figure 2-2 B). Tukey HSD *post hoc* tests indicated that the estimates of CPUE from data for mapcodes where the MLL was raised was similar to CPUE estimated from mapcodes where the MLL was lowered ($P = 0.572$) but differed from that estimated from mapcodes where the MLL was stable ($P = 0.040$).

2.3.2 Spatial assessment units

2.3.2.1 Distribution of catch among SAUs

Since 1979/80, ~60% of the annual total blacklip catch has been harvested from the Middle Point (26%), Number 2 Rocks (20%) and Gerloffs Bay (13%) SAUs (Figure 2-3). During this period several SAUs (e.g. Rivoli Bay, Admella, South End and Carpenters Rocks) made moderate contributions (5 - 8%) to the total blacklip catch. Minimal catches were contributed by the Cape Jaffa (<1%), East Port MacDonnell (2%) and Blackfellows Caves (2%) SAUs. The distribution of catch among SAUs remained stable for an extended period from the early 1990s to 2010/11. However, from 2010/11 to 2013/14 contributions to the total catch from the Middle Point, Port MacDonnell and Carpenters Rocks SAUs increased, whilst those from the Rivoli Bay and Gerloffs Bay SAUs decreased. The contribution from the Gerloffs Bay SAU in 2013/14 was 5% of the total annual catch which was less than one quarter of the mean contribution to total catch from this SAU over the previous four seasons (i.e. 2009/10 to 2012/13). Overall, there were three high- (Middle Point, Gerloffs Bay, Number 2 Rocks) and four medium-importance (Rivoli Bay, Admella, Carpenters Rocks and Beachport) SAUs for blacklip in the SZ for the 10-year period ending 31 August 2014 (Figure 1-4).

With the exception of the Port MacDonnell SAU, the catch in 2013/14 in each SAU was below the catch cap (Figure 2-4 A). For the three high importance SAUs – Middle Point, Number 2 Rocks and Gerloffs Bay – catches were 10%, 25%, and 50% below their catch caps, respectively. Similarly, catches from 2013/14 for the medium importance SAUs (Carpenters Rocks, Rivoli Bay, Beachport, and Admella) were also substantially lower than the catch caps (range: 10% to 74%).

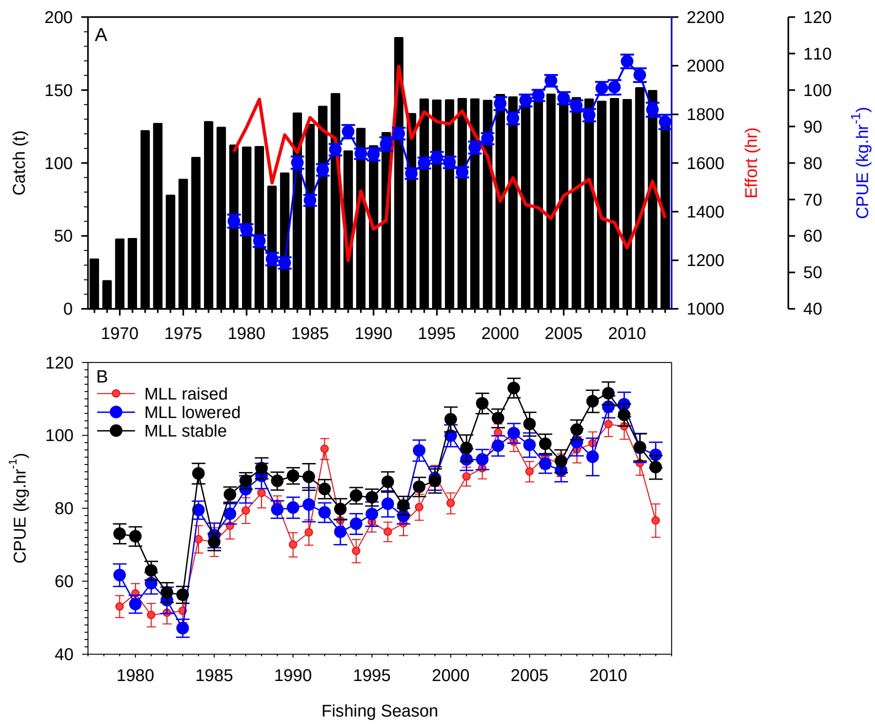

Figure 2-2. (A) Total reported catch (tonnes, black bars), effort (hours, red line) and CPUE (kg.hr^{-1}, blue line) on blacklip in the Southern Zone from 1968/69 (denoted 1968) to 2013/14. (B) CPUE on blacklip in the Southern Zone for mapcodes where the minimum legal length (MLL) was raised, lowered, or remained stable in 2013/14.

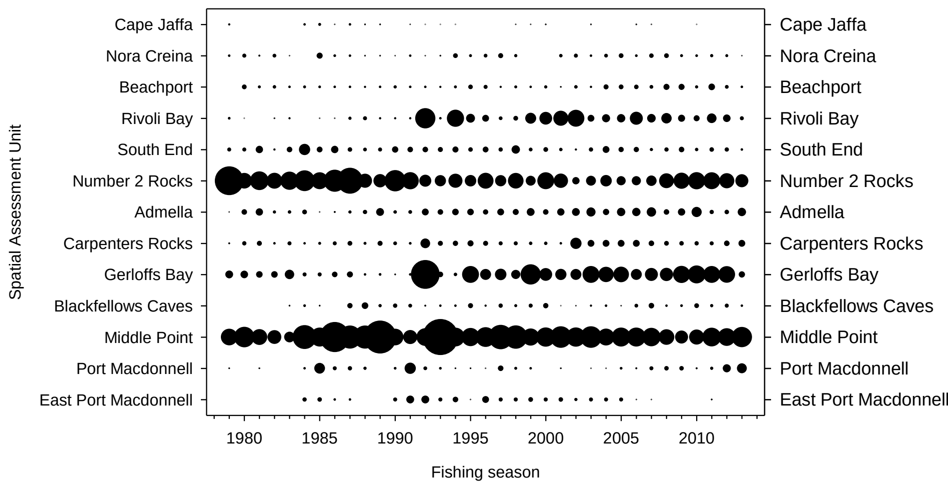

Figure 2-3. Bubble plot showing the spatial distribution of the blacklip catch (% of total catch) among each of the SAUs in the SZ from 1979/80 (denoted 1979) to 2013/14.

There was a linear relationship between the catch from each SAU in 2013/14 and the mean catch from these SAUs over the previous 10 fishing seasons (i.e. 2003/04 to 2012/13; Linear Regression (LR): $r^2 = 0.80$, $F_{1,11} = 43.053$, $P = 0.000$; Figure 2-4 B). However, there were some notable exceptions. First, catches from the Rivoli Bay and Gerloffs Bay SAUs in 2013/14 were approximately 60% lower than would have been expected based on previous catch history. In contrast, the Port MacDonnell and Middle Point SAUs yielded catches in 2013/14 that were greater than the mean over the previous 10 seasons. The increased catches at the latter two SAUs likely reflect the reduced MLL in mapcodes 39G, 40A and 40B between 2012/13 and 2013/14.

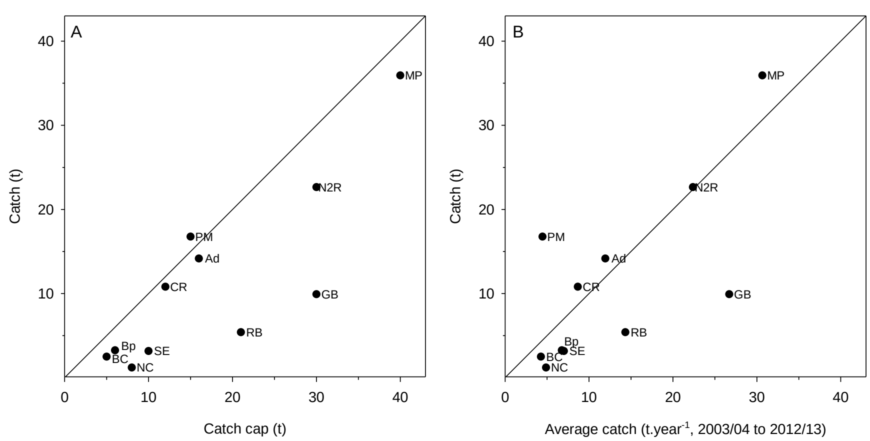

Figure 2-4. The relationship between annual catch and (A) the catch cap (t) and (B) ten-year average catch (t, 2003/04 to 2012/13) for each SAU in the SZ in 2013/14. (Ad, Admella; Bp, Beachport; BC, Blackfellows Caves; CJ, Cape Jaffa; CR, Carpenters Rocks; EPM, East Port MacDonnell; GB, Gerloffs Bay; MP, Middle Point; NC, Nora Creina; N2R, Number 2 Rocks; PM, Port MacDonnell; RB, Rivoli Bay; SE, Southend).

2.3.2.2 Temporal patterns in SAUs of high importance.

Middle Point

Since 1979/80, ~26% of the blacklip catch harvested from the SZ has been obtained from the Middle Point SAU (range: 16 – 48%; Figure 2-3). Annual catches increased steadily between 1979/80 and the maximum catch of 65 t in 1993/94, although catches were variable among years (Figure 2-5). Since 1994/95, the catch harvested from this SAU has been more stable (range: 23 – 44 t), with that in 2013/14 (36 t) slightly higher than the mean catch since 1979/80 (35 $t.yr^{-1}$). The estimated CPUE on blacklip in the Middle Point SAU increased significantly through time (LR: $r^2 = 0.84$, $F_{1,33} = 175.78$; $P < 0.01$; Figure 2-5) and the CPUE of 111 $kg.hr^{-1}$ in 2011/12 was the highest level on record. From 2011/12, CPUE declined over two consecutive years to 102 $kg.hr^{-1}$ in 2013/14. Whilst this index remained at a historically high level, the decline from 2012/13 to 2013/14 coincided with a decrease in the MLL from 125 to 120 mm SL in mapcodes 39G and 40A. The time series of CPUE estimates for FDA 1 show a similar overall trend to that evident for the Middle Point SAU. However, there were several seasons where (1) the CPUE from FDA 1 was substantially greater (e.g. 1989/90 and 1993/94), due to the initial unlimited fishing at a lower MLL at that time; and (2) the CPUE in FDA 1 could not be estimated due to limited data.

With the exception of 2007, there was a lower percentage of large blacklip in commercial catches from 2003/04 to 2012/13, compared to the period from 2001/02 to 2003/04 (Figure 2-6). In 2013/14, the percentage of large blacklip in the commercial catch was <1% which was the lowest recorded (Figure 2-6). This was supported by the poor representation of blacklip >140 mm in the size-frequency distribution from 2013/14 compared to other years and a reduction in the dominant size class in 2013/14 (125 mm upper size class limit) compared to that from previous years (130 to 135 mm upper size class limit). Annual estimates of the percentage of large blacklip in the catch from FDA 1 varied among years with no long-term trend evident. Notably, in several seasons, the percentage of large blacklip in the catch from FDA 1 exceeded that from the Middle Point SAU.

There were no long-term trends in the densities of blacklip obtained from FI surveys in the Middle Point SAU (Figure 2-7). However, densities of both legal-sized and sub-legal-sized blacklip were lower in 2014/15 (20% and 12%, respectively), when compared to estimates in 2011/12, but remained about 30% above minimum observed values. The percentage of large blacklip observed on surveys varied among seasons, but no overall temporal trend was apparent.

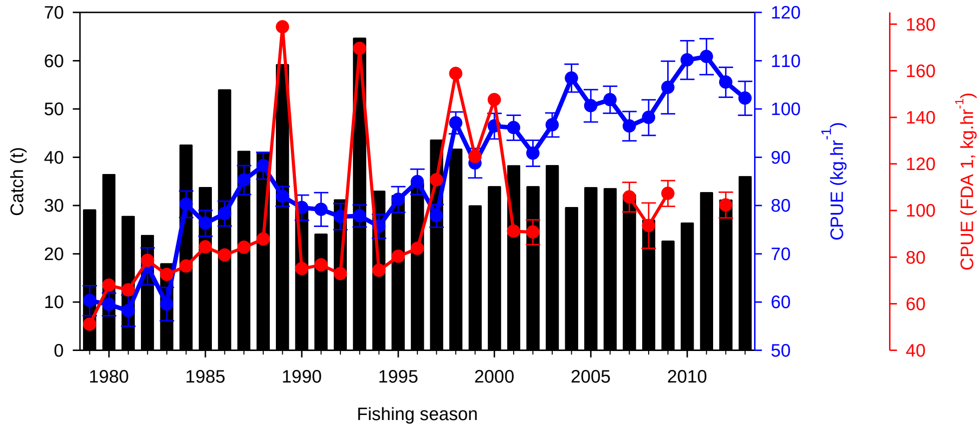

Figure 2-5. Reported catch (tonnes, black bars) and CPUE (kg.hr^{-1}, blue line) on blacklip in Middle Point from 1979/80 (denoted 1979) to 2013/14. Also shown is CPUE for FDA 1 (kg.hr^{-1}, red circles) for years when data were available.

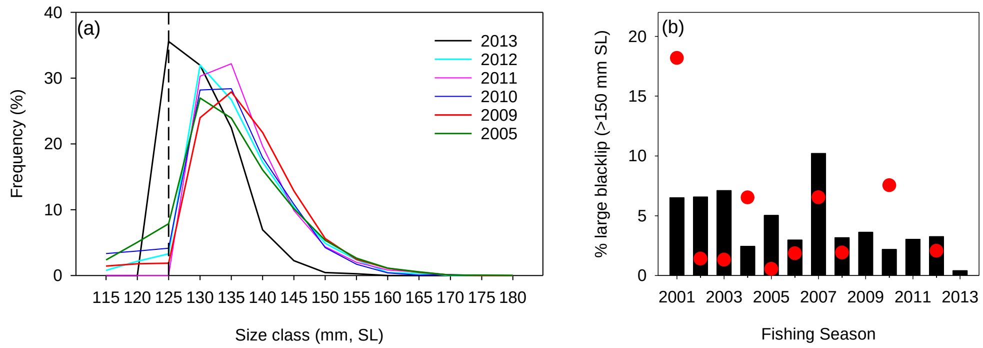

Figure 2-6. (a) Frequency distributions of shell lengths in selected years and (b) percentage of large (>150 mm SL; black bars) blacklip in the commercial catch from Middle Point from 2001/02 (denoted 2001) to 2013/14. Also shown on (b) are estimates of percentage large for blacklip from FDA 1 (red dots). X-axis labels in (a) show upper limit of each size class. Dashed vertical line in (a) shows MLL in place since September 2013.

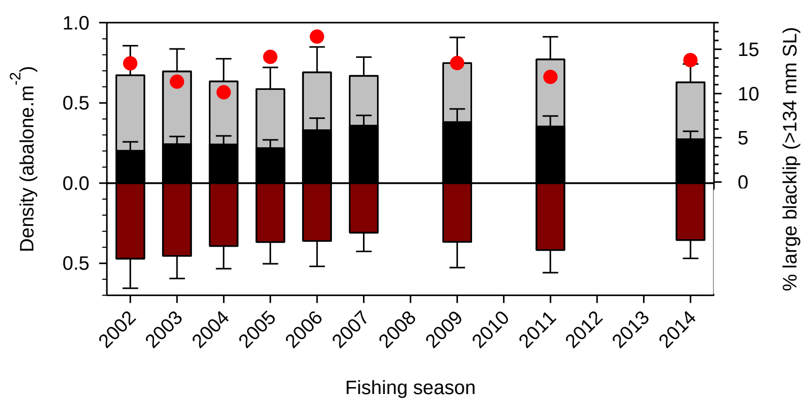

Figure 2-7 Density of blacklip (abalone.m^{-2}; ± se) counted in transects during fishery-independent surveys at sites across Middle Point from 2002/03 (denoted 2002) to 2014/15. Surveys were not conducted in 2008/09, 2010/11, 2012/13 or 2013/14. Grey bars show total blacklip. Red and black bars show blacklip <120 and ≥120 mm SL, respectively. Red dots represent the percentage of large blacklip.

Gerloffs Bay

Since 1979/80, ~13% of the total SZ harvest of blacklip abalone has been obtained from the Gerloffs Bay SAU, with that percentage gradually increasing over time (range 1 - 28%; Figure 2-3). Total annual catches from this SAU increased gradually from the early 1980s (Figure 2-8) and the largest catch of 51 t was obtained in 1992/93 (during unrestricted fishing in the previous FDA 4 at a lower MLL). Recent catches, from 2009/10 to 2012/13 (range 29 - 31 t), were among the largest on record. However, in 2013/14, the catch declined to 10 t, a reduction of 66% from the previous year and the lowest since 1994/95. Catch rates increased from 1994/95 to a peak of 104 $kg.hr^{-1}$ in 2010/11. Following a small reduction to 102 $kg.hr^{-1}$ in 2011/12 catch rates declined to 85 $kg.hr^{-1}$ in 2012/13 and 63 $kg.hr^{-1}$ in 2013/14 (Figure 2-8), the lowest value since 1994/95. Thus, the decrease in CPUE over three fishing seasons was approximately 40%. This low CPUE in 2013/14 was coincident with the lowest catch in 20 years.

The percentage of large shells in the commercial catch has varied among years (range: 2 – 11%; Figure 2-9). From 2009/10 to 2011/12, the percentage of large blacklip in annual commercial catches were among the highest recorded whilst those in 2012/13 and 2013/14 were amongst the lowest (Figure 2-9). This was supported by a contraction in the size frequency distribution from 2013/14 due to a reduction in the dominant size class (125 mm upper size class limit) compared to previous years (130 – 135 mm upper size class limit).

For all size classes (i.e. total, legal-sized and sub-legal-sized), there has been a gradual reduction in the densities obtained from FI surveys in Gerloffs Bay (Figure 2-10). For each of these, the estimate from 2014/15 was the lowest on record. The percentage of large blacklip observed on surveys varied among seasons, but no overall temporal trend was apparent. However, values estimated for 2011/12 and 2014/15 were relatively low.

Number 2 Rocks

Approximately 20% of the blacklip catch harvested from the SZ since 1979/80 has been obtained from the Number 2 Rocks SAU (range: 8 – 46%; Figure 2-3). Total annual catch was greatest in 1979/80 (51 t; Figure 2-11), where after catches varied among years, whilst gradually decreasing to the lowest recorded catch of 12 t in 2002/03. From 2002/03, annual catches gradually increased to 30 t in 2010/11 before declining to 23 t (23%) in 2013/14.

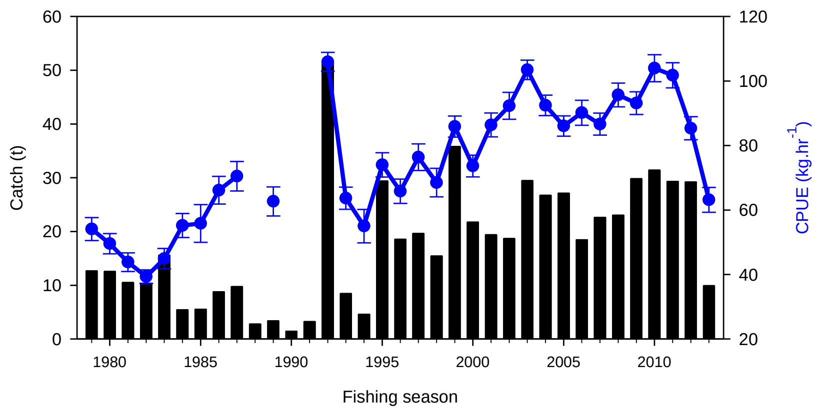

Figure 2-8. Reported catch (tonnes, black bars) and CPUE (kg.hr^{-1}, blue line) on blacklip in Gerloffs Bay between 1979/80 (denoted 1979) and 2013/14.

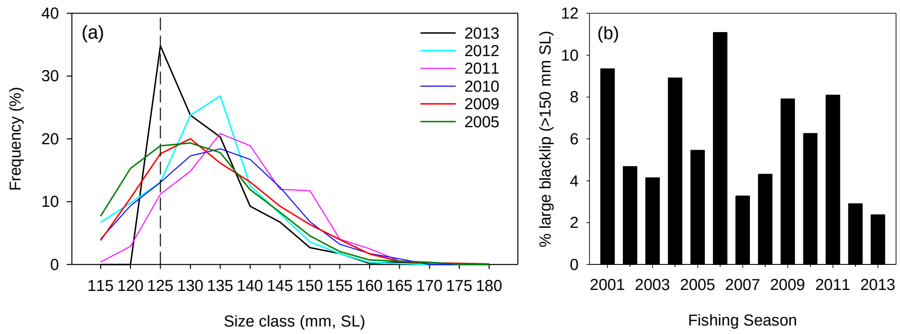

Figure 2-9. Frequency distributions of shell lengths in selected years (a) and percentage of large (>150 mm SL) blacklip (b) in the commercial catch from Gerloffs Bay between 2001/02 (denoted 2001) and 2011/12. X-axis labels in (a) show upper limit of each size class. Dashed vertical line in (a) shows MLL in place since September 2013.

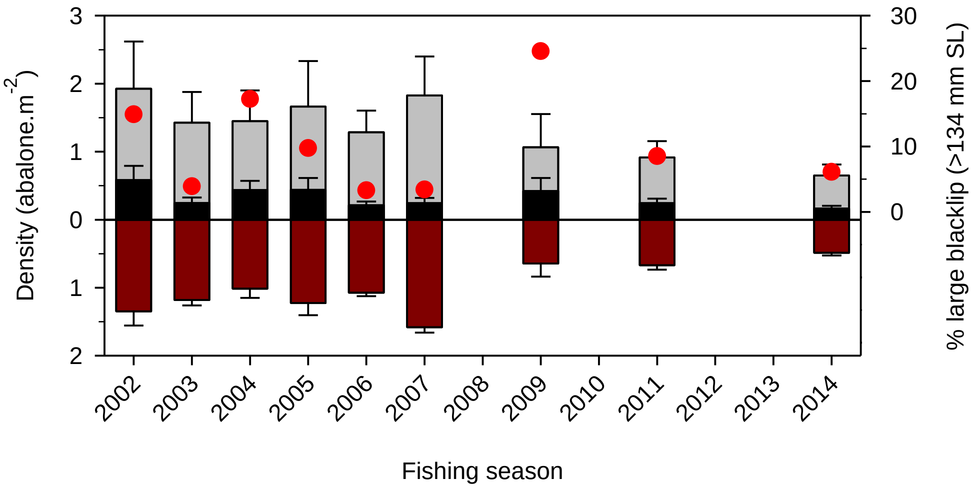

Figure 2-10. Density of blacklip (abalone.m^{-2}; ± se) counted in transects during fishery-independent surveys at sites across Gerloffs Bay from 2002/03 (denoted 2002) to 2014/15. Surveys were not conducted in 2008/09, 2010/11, 2012/13, and 2013/14. Grey bars show total blacklip. Red and black bars show blacklip <120 and ≥120 mm SL, respectively. Red dots represent the percentage of large blacklip.

The CPUE on blacklip in this SAU increased significantly through time (LR: r^2 = 0.68, $F_{1,32}$ = 68.89; P <0.01; Figure 2-11), reaching a historic peak of 125 $kg.hr^{-1}$ in 2011/12. From 2011/12, CPUE has declined by 18% to 103 $kg.hr^{-1}$ in 2013/14, the lowest value since 1997/98.

There were no obvious trends in the size-frequency distributions from the commercial catch (Figure 2-12). The percentage of large, legal-sized blacklip increased from 2001/02 to the highest on record in 2007/08, where after it declined to 4% in 2013/14, the lowest on record (Figure 2-12). There is currently no time-series of FI estimates of abalone density available for this high importance SAU.

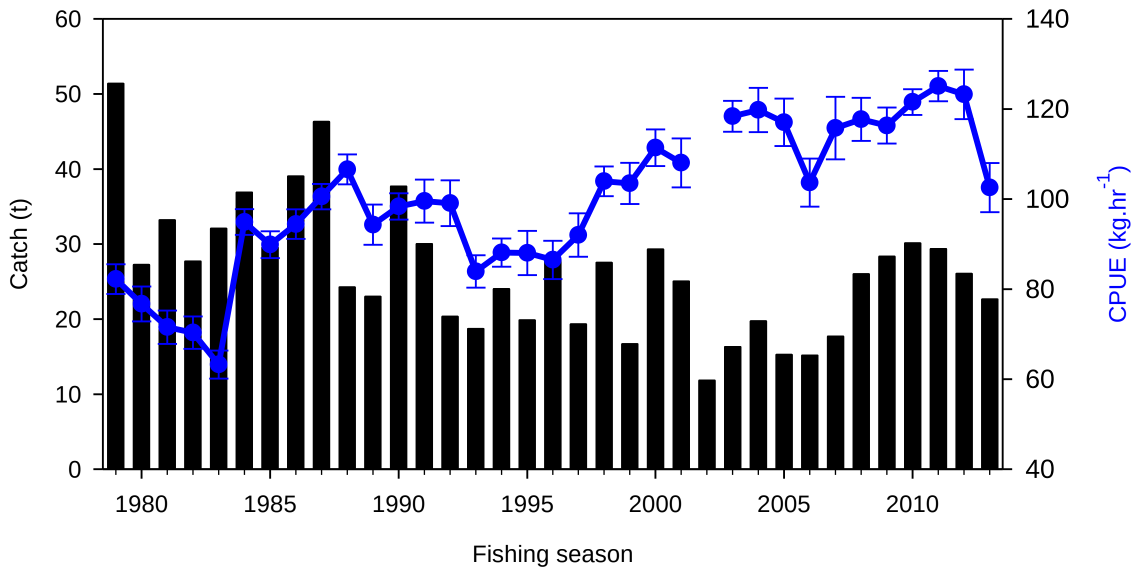

Figure 2-11. Reported catch (tonnes, black bars) and CPUE ($kg.hr^{-1}$, blue line) on blacklip in Number 2 Rocks between 1979/80 (denoted 1979) and 2013/14.

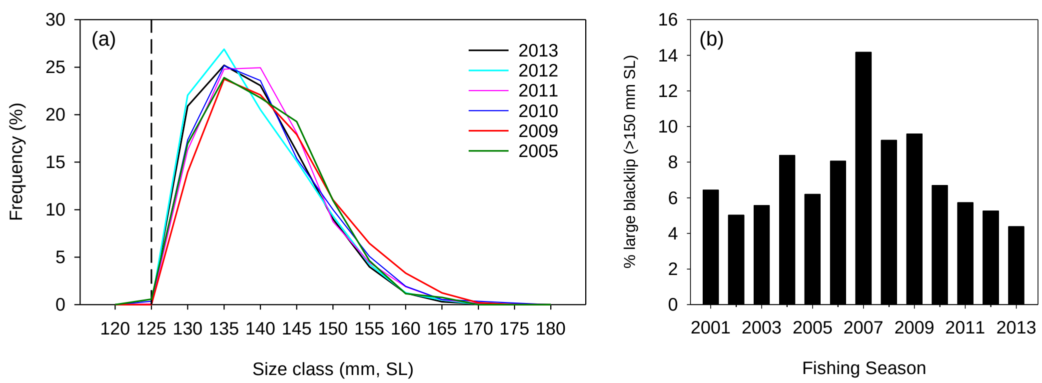

Figure 2-12. Frequency distributions of shell lengths in selected years (a) and percentage of large (>150 mm SL) blacklip (b) in the commercial catch from Number 2 Rocks between 2001/02 (denoted 2001) and 2013/14. X-axis labels in (a) show upper limit of each size class. Dashed vertical line in (a) shows MLL in place since September 2013.

2.3.2.3 Temporal patterns in SAUs of medium importance

Rivoli Bay

Total annual catches of blackip from the Rivoli Bay SAU were small (~5 t.yr^{-1}) prior to 1992/93 when 36 t was harvested (unrestricted fishing at a lower MLL in FDA 3; Figure 2-13). Since then, catches have been variable among years (range 3 - 30 t). The mean catch over the 10 seasons from 2004/05 (mean 14 t.yr^{-1}, range 5 – 23 t) was higher than the long-term mean from 1979/80 (11 t.yr^{-1}). However, from a minor peak of 16 t in 2011/12, catches declined to 5 t in 2013/14, which was 64% below the recent ten year mean catch. CPUE was relatively stable (range 88 – 109 kg.hr^{-1}) over 12 seasons from 1999/00 to 2011/12 when it was approximately 102 kg.hr^{-1}, where after it declined by 15% to 86 kg.hr^{-1} in 2012/13 (Figure 2-13). There were insufficient data to calculate CPUE in 2013/14, and thus to determine whether this downward trend had continued. The time series of CPUE estimates for FDA 3 show a similar overall trend to that evident for the Rivoli Bay SAU, with a parallel reduction in CPUE from 2010/11 to 2012/13.

The percentage of large blacklip in the commercial catch was relatively high in 4 of 5 years from 2006/07 to 2011/12. However, from 2009/10, the percentage of large blacklip in the catch declined consistently to 2013/14 (Figure 2-13). This was supported by the trend in length frequency distributions with a smaller size class dominating the distribution from 2013/14. The trend in percentage of large blacklip from FDA 3 differed to that of the Rivoli Bay SAU. The percentage of large blacklip from FDA 3 increased from a low level in 2003/04 to a peak in 2007/08 then declined to a low level in 2008/09 before increasing to a second peak in 2012/3.

Total densities of blacklip obtained from FI surveys in Rivoli Bay were relatively stable from 2002/03 to 2011/12 (Figure 2-15), but high in 2006/07. Densities of both legal-sized and sub-legal-sized blacklip were substantially lower in 2012/13, immediately following a reported summer mortality (Mayfield *et al*., 2013, 2014). Subsequently, the density of sub-legal-sized blacklip has increased markedly, while that for legal-sized blacklip continued to decline. The density of legal-sized blacklip observed on FI surveys in Rivoli Bay in 2014/15 was the lowest on record, and 70% below the previous minimum observed in 2012/13. The percentage of large blacklip estimated from FI surveys ranged from 10% in 2002/03 to a peak of 13% in 2007/08. The percentage of large blacklip observed subsequently declined to 7% in 2012 and to <1% in 2014/15.

Admella

Catches from the Admella SAU have varied among years since 1979/80, but gradually increased through time (Figure 2-13). The highest recorded catch of 17 t occurred in 2010/11 with catches declining to 6 t and 7 t in 2011/12 and 2012/13 respectively. From 2012/13, catches increased to 14 t in 2013/14. The CPUE on blacklip in this SAU was stable at about 95 $kg.hr^{-1}$ from 2002/03 to 2011/12 then declined to 82 $kg.hr^{-1}$ in 2012/13 and 2013/14, the lowest since 2006/07 (Figure 2-13).

The percentage of large blacklip in the commercial catch declined from the highest recorded in 2009/10 (~18%) to 1% and 3% in 2011/12 and 2012/13 respectively, which were amongst the lowest values recorded (Figure 2-14). This was supported by size frequency distributions in which larger size classes (upper size class limits 145 to 160 mm SL) were poorly represented compared to previous years. There were insufficient commercial catch length frequency data for this SAU in 2013/14 to estimate the percentage of large blacklip.

Carpenters Rocks

Substantial catches were obtained from the Carpenters Rocks SAU in 1992/93 (16 t) and 2002/03 (19 t), with catches in remaining years considerably smaller (range: 2 – 11 t; Figure 2-13). Catches in 2012/13 (9 t) and 2013/14 (11 t) were higher than the mean annual catch since 1979/80 (7 t). The CPUE in 2009/10 (103 $kg.hr^{-1}$) was among the highest on record. Whilst CPUE was slightly lower in 2012/13 (92 $kg.hr^{-1}$) and 2013/14 (84 $kg.hr^{-1}$) it remained among historically high levels.

The percentage of large blacklip in the catch was ~20% in 2008/09, which was the highest recorded level (Figure 2-14). Although the percentage of large blacklip in the commercial catch was lower in 2012/13 (8%) and 2013/14 (4%), these values were higher than those observed in 2001/02 and 2004/05.

Beachport

Catches from the Beachport SAU have gradually increased through time, with that harvested in 2011/12 (10 t) the highest on record (Figure 2-13). Relatively high catches (9 t) were also obtained from this SAU in 2008/09 and 2009/10. Smaller catches of 5 t and 3 t were taken in 2012/13 and 2013/14, respectively. There were insufficient data to estimate the CPUE on blacklip in the Beachport SAU in most years (Figure 2-13). The estimates of CPUE in 2011/12 and 2012/13 were 97 $kg.hr^{-1}$ and 78 $kg.hr^{-1}$, respectively, reflecting the same decreasing trend in

CPUE observed in other SAUs. Since 2001/02, the percentage of large blacklip in the catch has declined substantially, with estimates in 2010/11 and 2011/12 the lowest recorded for this SAU (Figure 2-14). This was supported by decreasing contributions of larger size classes to size frequency distributions of the commercial catch. There were no data available for 2012/13 or 2013/14.

2.3.2.4 Temporal patterns in SAUs of low importance

Three temporal patterns in catch were evident in the low importance SAUs (Figure 2-16). First, annual catches from the South End, Nora Creina, and Blackfellows Caves SAUs have varied substantially among years, but show no evidence of any long-term trend. Second, recent catches from two SAUs – East Port MacDonnell and Cape Jaffa – are low relative to those in the earlier years of the fishery. Third, large catches have been obtained periodically, as evident for the Port MacDonnell SAU (approximately every five years).

Insufficient data prevented estimation of CPUE in most years in many of the low importance SAUs (Figure 2-16). Recent estimates of CPUE in the Port MacDonnell and Blackfellows Caves SAUs were generally high relative to estimates from previous years, whereas the CPUE in the South End SAU exhibits the declining trend observed in many other SAUs.

2.3.2.5 Risk-of-overfishing in SAUs and zonal stock status

There were three high and four medium importance SAUs for blacklip in 2013 (Figure 1-4; Table 2-1). It was possible to determine the risk of overfishing for five of these seven SAUs. The inability to estimate CPUE in the Beachport and Rivoli Bay SAUs in 2013/14, due to insufficient data, prevented categorisation of the risk of overfishing for stocks in these SAUs (Figure 2-13; Appendix 1). In addition, for the Number 2 Rocks SAU, the short time-series of FI data meant that this high importance SAU could only be assessed with FD PIs (i.e. three of a potential six PIs; Table 2-1). Summed PI scores ranged between -11 (Gerloffs Bay) and +10 (Middle Point; Table 1). Gerloffs Bay was assigned to a 'red' (highest risk), Number 2 Rocks to a ‘yellow’ (medium risk), Middle Point to a 'light blue' (lowest risk) and Admella and Carpenters Rocks were assigned a 'green' risk-of-overfishing category (Table 2-1). The catch-weighted zonal score was -0.12. Under the harvest strategy, this score defines the status of the blacklip fishery in the SZ as ‘**sustainably fished**’ (Table 2-1).

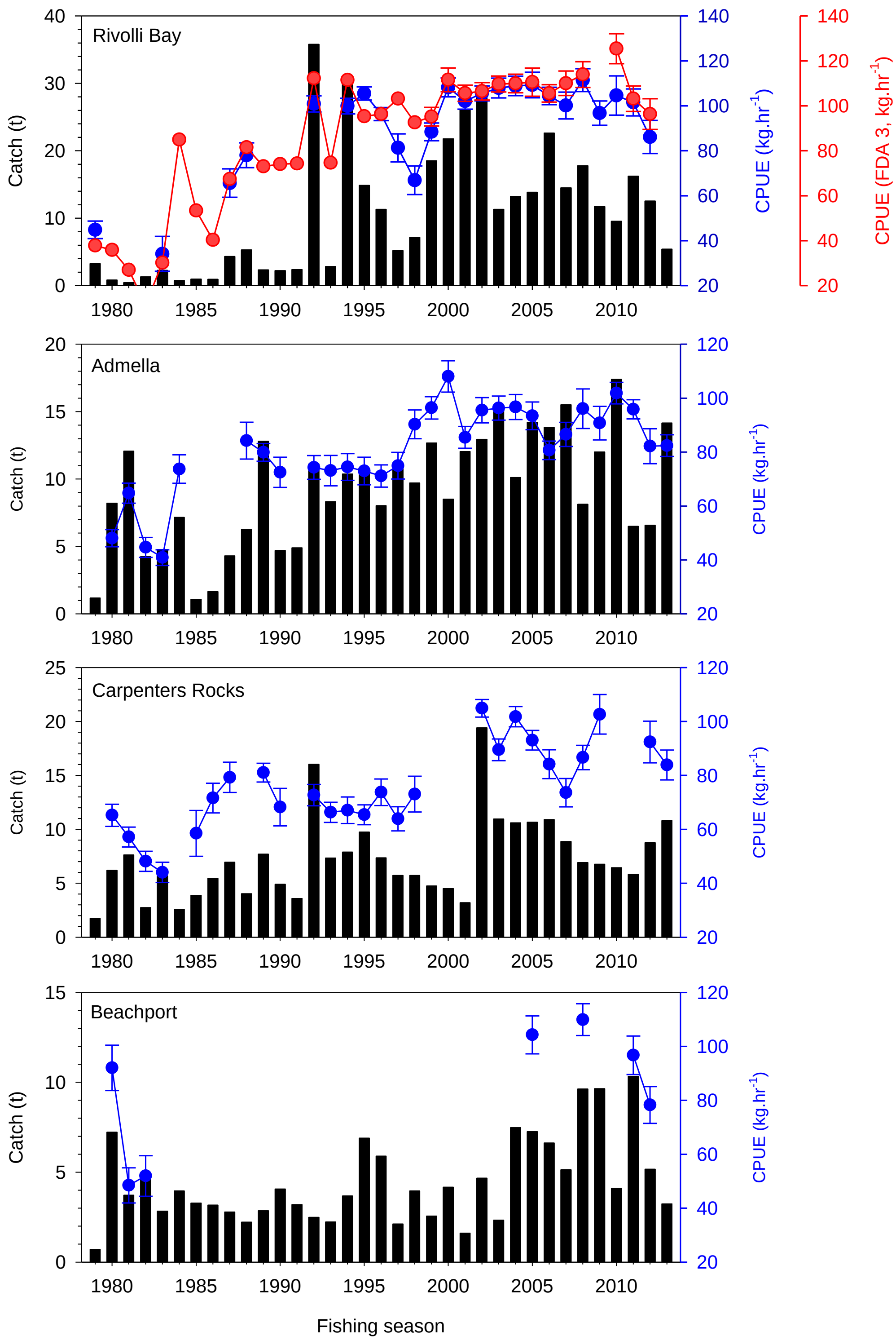

Figure 2-13. Reported catch (tonnes, black bars) and CPUE (kg.hr^{-1}, blue line) on blacklip in the Rivoli Bay, Admella, Carpenters Rocks and Beachport SAUs between 1979/80 (denoted 1979) and 2013/14. Included in Rivoli Bay SAU is CPUE for FDA 3 (kg.hr^{-1}, red line) for years when data were available. Note scales on Y-axes vary among SAUs.

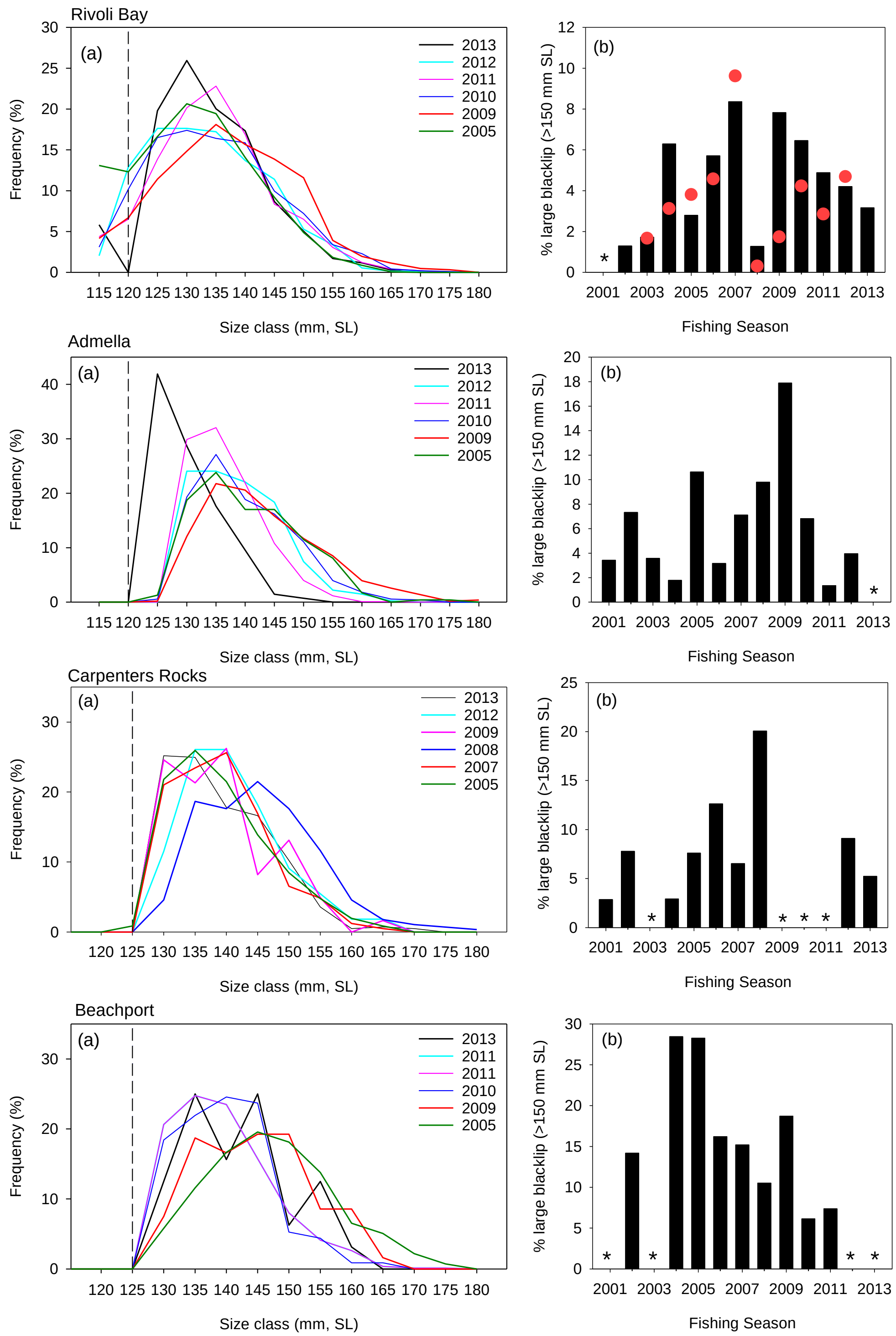

Figure 2-14. (a) Frequency distributions of shell lengths in selected years and (b) percentage of large (>150 mm SL; black bars) blacklip in the commercial catch from the Rivoli Bay, Admella, Carpenters Rocks and Beachport SAUs between 2001/02 (denoted 2001) and 2013/14. Also shown for Rivoli Bay is the proportion large from FDA 3 (red dots). X-axis labels in (a) show upper limit of each size class. Dashed vertical line in (a) shows MLL in place since September 2013 (note that historical MLL for Beachport was also 125 mm). Note scales on Y-axes vary among SAUs.* indicates insufficient data.

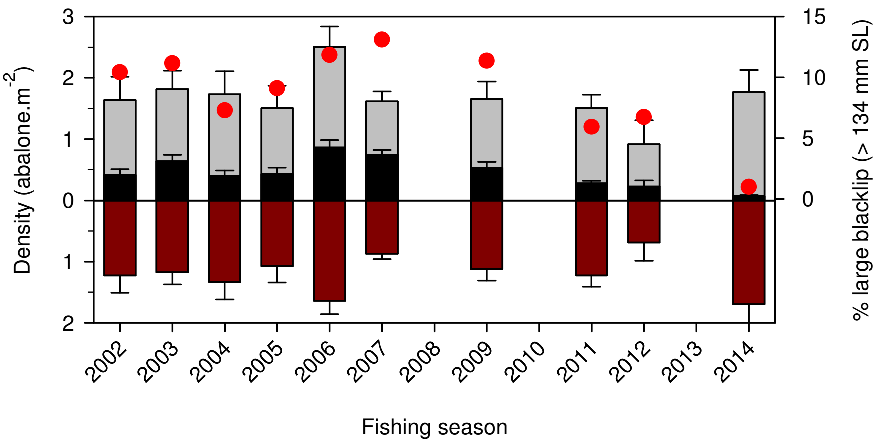

Figure 2-15. Density of blacklip (abalone.m^{-2}; ± se) counted in transects during fishery-independent surveys at sites across Rivoli Bay from 2002/03 (denoted 2002) to 2014/15. Surveys were not conducted in 2008/09, 2010/11, and 2013/14. Grey bars show total blacklip. Red and black bars show blacklip <120 and ≥120 mm SL, respectively. Red dots represent the percentage of large blacklip.

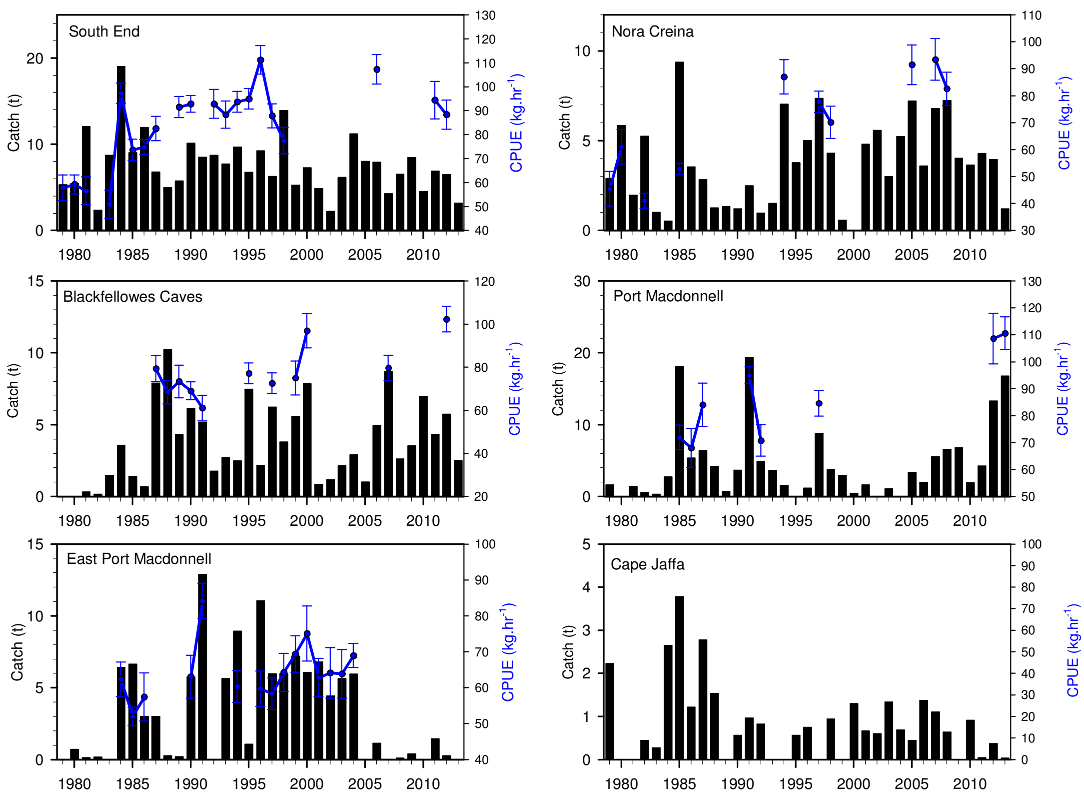

Figure 2-16. Reported catch (tonnes, black bars) and CPUE (kg.hr^{-1}, blue line) on blacklip in the Southend, Nora Creina, Blackfellows Caves, Port MacDonnell, East Port MacDonnell and Cape Jaffa SAUs between 1979/80 (denoted 1979) and 2013/14.

Table 2-1. Outcome from application of the harvest strategy described in the Management Plan against the blacklip fishery in the SZ. Grey shading identifies the performance indicators and their respective scores.

Spatial assessment unit	%Contribution to mean total catch (SZ) over last 10 years (04/05-13/14)	Importance	%Contribution to catch from high & medium SAU in 2013/14	CPUE	%TACC	%Large	Pre-recruit density	Legal density	Mortality	Combined PI score	Risk of overfishing	Catch-weighted contribution to zonal score
Middle Point	20.4	High	30.8	8	0	-2	4	0	0	10	2	0.62
Gerloffs Bay	16.6	High	25.1	-2	-1	-4	-2	-2	0	-11	-2	-0.50
Number 2 Rocks	15.4	High	23.3	0	0	-3	-	-	-	-3	-1	-0.23
Rivoli Bay	9.2	Medium	-	ND	-1	-1	-	-	-	Uncertain	Not assigned	-
Admella	7.9	Medium	12.0	0	1	-1	-	-	-	0	0	0.00
Carpenters Rocks	5.8	Medium	8.8	0	0	-1	-	-	-	-1	0	0.00
Beachport	4.6	Medium	-	ND	0	-1	-	-	-	Uncertain	Not assigned	-
South End	4.5	Low	-	-	-	-	-	-	-	Not assessed	-	-
Port Macdonnell	4.0	Low	-	-	-	-	-	-	-	Not assessed	-	-
Nora Creina	3.2	Low	-	-	-	-	-	-	-	Not assessed	-	-
Blackfellows Caves	2.9	Low	-	-	-	-	-	-	-	Not assessed	-	-
East Port Macdonnell	0.6	Low	-	-	-	-	-	-	-	Not assessed	-	-
Cape Jaffa	0.4	Low	-	-	-	-	-	-	-	Not assessed	-	-
Unassigned SZ	0.6	Low	-	-	-	-	-	-	-	Not assessed	-	-
Sum	**96.2**		**100.0**									
											Zonal stock status	-0.12

2.4 Discussion

Blacklip comprises 95% of the abalone TACC (158.7 t, i.e. blacklip and greenlip) in the SZ of the SAAF, which demonstrates the importance of blacklip to the SZ abalone fishery. The importance of this species in the SZ requires both FD and FI data for assessment of stock status. As the current harvest strategy (PIRSA 2012) rationalises resources to ensure they are distributed into assessments of the most important SAUs, by catch, FI surveys are restricted to the high-importance SAUs, which are Middle Point, Number 2 Rocks and Gerloffs Bay. However, over recent years, FI surveys have also been conducted at Ringwood Reef in Rivoli Bay because the blacklip stocks on this important fishing ground were reportedly impacted by anomalously warm water conditions in summer 2012 (Mayfield *et al*. 2013, 2014).

There were, however, some limitations to undertaking this assessment. Firstly, there were only FI survey data from Number 2 Rocks for 2014/15. This problem will be overcome in future years following the repeat of the FI survey sites in this SAU from 2015/16. These survey sites have been located using the fleet’s Vessel Monitoring System (VMS) data to ensure they are representative of the principal fishing grounds. Second, it was not possible to estimate the CPUE on blacklip in two medium-importance SAUs in 2013/14 due to a lack of data. Thus, it was not possible to assign the Beachport and Rivoli Bay SAUs to a category defining the risk-of-overfishing. Consequently, these SAUs made no contribution to the zonal stock status classification.

Third, this assessment relied heavily on commercial CPUE data and the assumption that changes in CPUE reflect changes in the abundance of the fishable stock. We note that CPUE can be influenced by numerous factors unrelated to abalone abundance including market demands for particular product types (e.g. larger or smaller abalone – though this has not yet been documented for the SZ), changes in diver behaviour, increasing fishing efficiency and the ability/inability to access ‘traditional’ fishing grounds due to variable weather conditions (e.g. wind, swell, underwater visibility). Notably, increases in effective fishing effort over the past five years through a change to ‘fishing live’ from ‘fishing anchored’ were not taken into account, indicating current CPUE values are likely to be positively biased. Preliminary evaluations of the potential impact of the less favourable weather conditions in 2013/14 indicate that while weather is a factor influencing accessibility of the fishing grounds, there was no evidence to suggest it was a key driver of recent depressed CPUE (SARDI unpublished data). Consequently, the recent decreases in CPUE are a reliable indicator of declines in abalone abundance, but the rate and degree of decline are likely underestimated (Tarbath and Gardner 2011). Moreover, these extrinsic factors are also not relevant to interpreting the FI survey data, where reductions in density mirror those in commercial CPUE.

Fourth, several decision rules were used to sub-sample the FD data prior to estimating effort, CPUE and the percentage of large blacklip in the commercial catch. For example, annual estimates of CPUE (Burch *et al.* 2011) excluded daily records where (1) the percentage of blacklip in the catch was <30%; (2) effort was <3 hr and >10 hr; (3) total catch exceeded 1.2 t; and (4) total catch/total effort was >150 kg.hr^{-1}. This approach was adopted because both blacklip and greenlip can be harvested, but effort within a fishing day is not required to be apportioned among the species. Adoption of this method followed a comprehensive comparison of the current, previous and a range of alternate decision rules to generate CPUE and a demonstration that temporal trends in CPUE obtained across methods were highly correlated (Burch *et al.* 2011). Annual estimates of the percentage of large blacklip in the catch excluded all shell lengths less than 125 mm SL, rather than the previous approach of discarding all measurements more than 5 mm SL below the MLL. This change was necessary to ensure temporal and spatial consistency following the numerous mapcodes where MLLs were changed from 2013/14 following implementation of the spatial management arrangements for the fishery.

Finally, several limitations of the relatively new harvest strategy have been identified (Stobart *et al.* 2014; Mayfield *et al.* 2014). Consequently, the stock status classification from the harvest strategy was compared to the traditional, weight-of-evidence analysis. This will aid the review of the harvest strategy scheduled for 2015. In addition, the current harvest strategy lacks a definition for determining when the resource is considered to be 'recruitment overfished', to link the harvest strategy with the national fishery status reporting framework (NFSRF; Flood *et al.* 2014). In the absence of such a definition, we use a CPUE value below the lower limit reference point that would be obtained from the 20-year reference period (*i.e*. 1990 to 2009) used in the harvest strategy for scoring this PI for each SAU as a proxy for defining 'recruitment overfished' for this stock. The suitability of this reference point will need to be considered through the current review of the harvest strategy for the fishery.

From 1979/80 to about 2011/12, the fishery for blacklip was characterised by (1) long-term, large, stable total catches; (2) declining total fishing effort; (3) increasing CPUE, the primary index of abalone abundance; (4) little variation in the distribution of catch among SAUs and years; (5) generally stable length-frequency distributions from commercial catches; and (6) consistent survey estimates of sub-legal-sized and legal-sized blacklip density. These patterns were reflected in the zonal stock status scores and stock status classifications for

2011/12 (1.6; 'lightly fished') and 2012/13 (0.52; 'underfished'). During this period, the SZ blacklip fishery was also categorised as 'sustainable' under the NFSRF (Flood *et al.* 2014).

Over more recent fishing seasons, there have been some considerable changes evident in the SZ abalone fishery. These changes, which include declining catch rates, re-distribution of catches among SAUs, lower percentagees of large blacklip in the commercial catch samples and observed on FI surveys, and reductions in the densities of legal-sized (Gerloffs Bay and Ringwood Reef) and sub-legal-sized (Gerloffs Bay) blacklip estimated from surveys, suggest that overfishing on the SZ blacklip stocks is most likely occurring. Specifically: (1) the TACC was not harvested in 2013/14. The total catch was 126 t, 25 t (17%) below the TACC, and reflected a revenue loss of approximately $700,000; (2) the CPUE on blacklip across the SZ has declined steadily since 2010/11. In 2013/14, the CPUE was at the lowest level since 2001/02; (3) recent decreases in CPUE were evident in nearly all SAUs and in the aggregated mapcodes reflecting categories where the MLL was stable, increased or decreased between 2012/13 and 2013/14. Across the three high-importance SAUs, CPUE has declined between 8% (Middle Point) and 38% (Gerloffs Bay) since 2011/12. Decreases in CPUE over the last few years were also evident for all combinations of divers examined; (4) the catch from Gerloffs Bay in 2013/14 was the lowest in almost 20 years and more than 60% below the mean catch over the previous 10 fishing seasons; (5) percentages of large blacklip in the commercial catch were at low levels in 2013/14, relative to historical values. In combination with generally decreasing modal length classes of the commercial catch, this suggests exploitation rates are high; (6) survey estimates of legal-sized blacklip and the percentages of large blacklip observed were low in Gerloffs Bay and Rivoli Bay, in comparison to previous estimates. This pattern was evident for the Middle Point SAU also, but not to the same extent.

Collectively, this evidence suggests that the blacklip harvestable biomass has declined and that overfishing has most likely occurred. However, the stocks are not yet recruitment overfished because the zonal CPUE in 2013/14 remained above a suitable proxy for defining recruitment overfished in the SZ blacklip fishery. Consequently, the SZ blacklip stocks are classified as '**transitional depleting**' under the NFSRF. This was different to the stock status classification for this fishery in 2012/13 ('sustainable'; Mayfield *et al.* 2014).

The reduction in stock status was also evident from the different classifications obtained from the application of the harvest strategy in the Management Plan for the South Australian Commercial Abalone Fishery (PIRSA 2012) between years. The zonal stock status score in 2013/14 was -0.12, a reduction of 0.64 from the value of 0.52 for 2012/13. This also resulted in a change in zonal stock status classification from 'underfished' in 2012/13 to 'sustainably fished' in 2013/14. Unlike the Central (Mayfield *et al.* 2014) and Western (Stobart *et al.* 2014, 2015) zones of the SAAF, where the positive scoring of the PI 'proportion of the TACC' for relatively high catches leads to a more optimistic interpretation of current stock status than that obtained from the weight-of-evidence assessment, the reasons for the discrepancy between the weight-of-evidence assessment of stock status under the NFSRF and the harvest strategy in the Management Plan for the fishery are less clear for the SZ. Consequently, these should be examined when the harvest strategy is reviewed in 2015.

Divers and licence holders in the SZ have recently suggested the need for the MLL in mapcode 39F and on Ringwood Reef to be lowered to 115 mm SL from the 120 mm SL established in these areas from 2013/14. They suggest that the increased MLL has severely impacted catch rates. As there has only been one year of spatial management, there are few data available to assess this request. We note that while CPUE has declined sharply in those mapcodes where the MLL was raised, it has also declined in those mapcodes where the MLL was either reduced or remained unchanged. Thus, it is likely that the reduced catch rates in mapcode 39F and on Ringwood Reef reflect both a reduction in stock abundance and the raised MLL. For Ringwood Reef where (1) CPUE had declined substantially prior to the MLL increase; and (2) survey estimates of legal-sized blacklip density and percentage of large blacklip in 2014/15 were at the lowest levels on record, the reduced catch rates likely reflect lower blacklip abundance rather than the increased MLL. In addition, a reduction in MLL would severely limit the capacity of the currently high abundance of pre-recruit blacklip to support stock recovery. For mapcode 39F, the data were less clear. However, the near-absence of large blacklip in the commercial catch in 2013/14, when compared with previous seasons, suggests the low abundance of these has contributed substantially to the reduced CPUE. In addition, historic catches from FDA 1 at a MLL of 110 mm SL were small (<10 $t.yr^{-1}$; Mayfield *et al*. 2013), suggesting there would be little overall benefit to the fishery from reducing the MLL in this mapcode. Thus, overall, no evidence was identified to support a reduction in MLL in mapcode 39F or on Ringwood Reef.

In conclusion, the recent reduced catches, declining catch rates and lower survey density estimates provide strong evidence that the abundance of blacklip in the SZ has declined. As recent changes in effective effort are not taken into account, the rate and extent of the decline in abundance is likely under-estimated. The most likely cause of the reduced availability of legal-sized blacklip is the documented, but unquantified, impact of the blacklip mortality associated with anomalously high water temperatures from January to May in 2013 (Vilchis *et al.* 2005;

Mayfield *et al.* 2011; Government of South Australia 2013). During this period, there were widespread (Robe to Port MacDonnell) reports of mortality with variable levels of impact up to 50% of the stock.

3 GREENLIP ABALONE

3.1 Introduction

This section of the report provides analyses of the fishery-dependent (FD) and fishery-independent (FI) data for greenlip in the SZ from 1 September 1968 to 31 August 2014. Unlike blacklip, it does not include a formal analysis of the fishery's performance and stock status based on the harvest strategy described in the Fishery Management Plan for the commercial Abalone Fishery (PIRSA 2012). This is because greenlip comprise <5% of the total abalone catch in the SZ (Table 1-3) and, consequently, there are no high- or medium-importance SAUs for this species in this zone. Thus, in the Discussion we provide a traditional, weight-of-evidence assessment of the current status of the greenlip stocks in the SZ using the NFSRF as the framework for classifying fish stocks (Flood *et al*. 2014).

3.2 Methods

The assessment used both FD and FI data. Fishery-dependent data comprised catch (t, shell weight), effort, fishing location (mapcode, SAU), and the proportion of large (≥150 mm SL) greenlip in the commercial catch. Fishery-independent data consisted of estimates of total greenlip densities (i.e combined sub-legal sized and legal sized individuals). All data are presented as mean ± standard error (se) unless otherwise stated.

3.2.1 Fishery-dependent data

Commercial catch and effort data have been collected since 1968 by fishers completing a research logbook for each fishing day. Data on the length-frequency distribution of the commercial catch from September 2001 to August 2014 were obtained by SARDI measuring samples provided by commercial fishers. Fishery statistics are provided at two spatial scales. These are the whole of the SZ and individual SAUs (Figure 1-1; 1-2). Catch (t, shell weight) was determined from all daily logbook returns. Effort and catch rate (CPUE, $kg.hr^{-1}$ shell weight) were not calculated due to the limited data available.

3.2.2 Fishery-independent data

Estimates of greenlip density were obtained from FI diver surveys initiated in 2002/03 (see Mayfield *et al.* 2003) that, in more recent years, have been undertaken biennially and/or triennially as part of an overall rationalisation of the stock assessemnt program. Greenlip were historically surveyed in the Middle Point, Rivoli Bay and Gerloffs Bay SAUs (Mayfield *et al.* 2009) However, surveys on greenlip have only continued in the Rivoli Bay SAU because densities in remaining areas are too low for reliable estimation of density. As with blacklip, the survey method involves counting greenlip abalone in paired (i.e. left and right) 20-m long transects distributed along 170 m leaded-line transects 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). Following a review of diving procedures, only five of the historical 10 leaded-lines in the Rivoli Bay SAU were sampled in 2012/13 and 2014/15. To enable direct comparison with historical survey estimates of density, historical abalone densities were re-estimated using only those data from the leaded-line survey locations that were re-sampled in these latter two surveys.

3.3 Results

After 1968/69 when almost 19 t of greenlip was landed, greenlip catches in the SZ have generally been small and did not again exceed 6 $t.yr^{-1}$ before 2010/11 (Figure 3-1). Catches were stable at >5 t from 2009/10 to 2012/13 reflecting the increase of the greenlip TACC to 7.2 $t.yr^{-1}$ from 2010/11. However, the catch in 2013/14, was 4 t, resulting in 44% of the TACC not being harvested.

Since 1979/80, >70% of the catch has been harvested from the Gerloffs Bay (40%), Rivoli Bay (14%), East Port MacDonnell (11%) and Nora Creina SAUs (9%; Figure 3-1). High catches from the East Port MacDonnell SAU during the mid-late 1990s declined to negligible levels by 2005/06. Catches from Gerloffs Bay were stable at 2 - 3 t from 2005/06 to 2012/13 but declined to 1 t in 2013/14. In contrast, the catch from Rivoli Bay increased from 1 t in 2005/06 to 3 t in 2011/12 before declining again to one t in 2013/14.

The percentage of large (>160 mm SL) greenlip in the catch has ranged between 10% and 28% since 2001/02 (Figure 3.2). Since the recent peak of 24% in 2009/10, the percentage of large greenlip harvested had declined by 13% by 2013/14. The comparatively lower estimate of percentage large in 2013/14 and recent contraction of size frequency distributions during this period suggest that exploitation rates have increased since 2010/11 when the TACC was raised from 6 to 7.2 $t.yr^{-1}$.

Estimates of total greenlip density at Ringwood Reef in the Rivoli Bay SAU generally increased with time and in 2012/13 and 2014/15 were among the highest levels recorded (Figure 3-3).

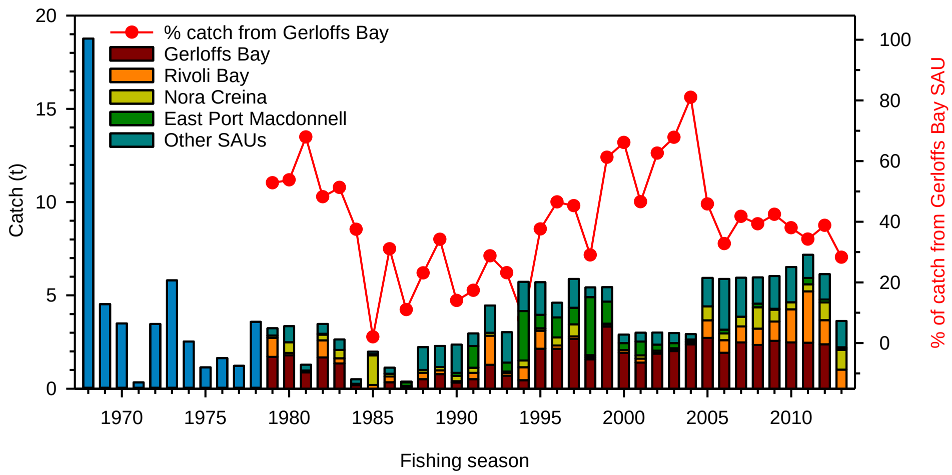

Figure 3-1. Reported catch (tonnes) of greenlip in the SZ and the Gerloffs Bay, Rivoli Bay, Nora Creina Bay and East Port MacDonnell SAUs from 1968/69 (denoted 1968) – 2013/14. The percentage of the greenlip catch harvested from the Gerloffs Bay SAU is also shown (red line).

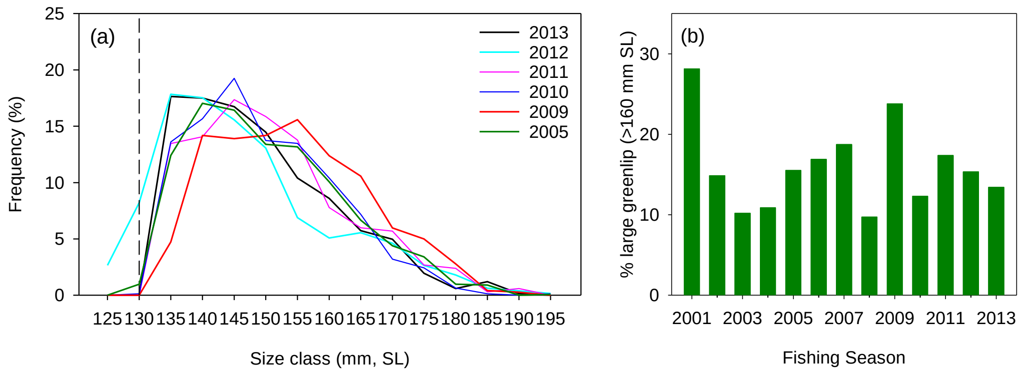

Figure 3-2. (a) Frequency distributions of shell lengths and (b) percentage of large (>160 mm SL) greenlip (b) in the commercial catch from the SZ between 2001/02 (denoted 2001) and 2013/14. X-axis labels in panel (a) show the upper limit of each size class.

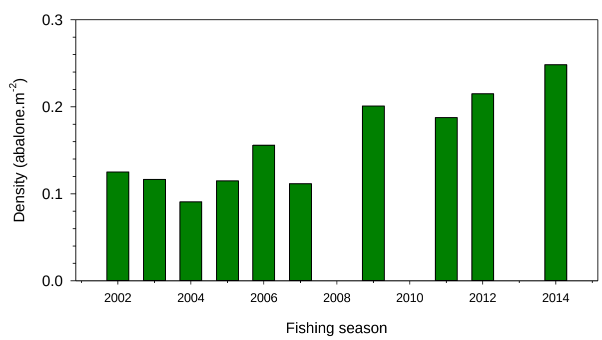

Figure 3-3. Density of greenlip (abalone.m^{-2}; all length classes combined) counted in transects during fishery-independent surveys in the Gerloffs Bay SAU from 2002/03 to 2014/15. Surveys were not conducted in 2008/09, 2010/11, 2013/14.

3.4 Discussion

Assessment of the greenlip stocks in the SZ is challenging because this species comprises <5% of the TACC and, hence, few data are available. These limited data suggest that this species occurs at a low density in the SZ and its spatial distribution is patchy. This also impedes estimation of CPUE, which is an important index of relative abalone abundance.

The recent increases in the TACC (3 t to 6 t from 2005/06 and 6 t to 7.2 t from 2010/11) coupled with its spatial management (e.g. 2.7 t ‘catch cap’ in the Gerloffs Bay SAU in 2013/14) has been effective in constraining the harvest of greenlip from Gerloffs Bay and, consequently, resulted in greenlip catches becoming more widely distributed in the SZ.

The low current and historical catch and limited data available prevents unambiguous assessment of the current status of greenlip in the SZ. Consequently, under the NFSRF (Flood *et al.* 2014), the stock status of this species in the SZ is classified as '**undefined**'. Decisions on future TACCs are likely to continue to rely heavily on input from other sources such as divers and licence holders in the fishery.

4 GENERAL DISCUSSION

4.1 Current status of blacklip and greenlip in the SZ

Substantial information was available to assess the blacklip stocks in the SZ including (1) a well-documented history of the management of the fishery; (2) fine-scale, FD, catch, effort and catch-length-frequency data; (3) long-term, FI surveys in three SAUs; and (4) extensive biological data (see Mayfield and Saunders 2008). These data facilitated both the formal analysis of the fishery's performance and stock status based on the harvest strategy described in the Fishery Management Plan for the commercial Abalone Fishery (PIRSA 2012) and the traditional, weight-of-evidence analysis under the NFSRF (Flood *et al.* 2014). In contrast, for greenlip, there were few data available reflecting the small proportion of greenlip in the SZ TACC (5%). This made assessment of greenlip difficult and precluded a formal assessment of stock status using the harvest strategy.

4.1.1 Blacklip abalone

Blacklip comprises 95% (151.5 t) of the abalone TACC in the SZ of the SAAF, demonstrating their importance to the SZ abalone fishery. Prior to 2011/12, the fishery for blacklip was characterised by long-term, large, stable catches, declining fishing effort, increasing CPUE and consistent survey estimates of sub-legal-sized and legal-sized blacklip density. These patterns were reflected in high zonal stock status scores and stock status classifications of 'lightly fished', 'underfished' and 'sustainably fished'.

However, over the past few fishing seasons, several changes have become evident in the SZ abalone fishery that include (1) widespread declining catch rates, (2) re-distribution of catches among SAUs, (3) low percentages of large blacklip in the commercial catch samples and observed on FI surveys, (4) lower blacklip densities estimated from surveys, and (5) 17% of the TACC not being harvested in 2013/14. Collectively, this evidence suggests that the blacklip harvestable biomass has declined and that overfishing has most likely occurred, but that the stocks are not yet recruitment overfished. Consequently, the SZ blacklip fishery is classified as '**transitional depleting**' under the NFSRF, which was different to the stock status classification for this fishery in 2012/13 ('sustainably fished'; Mayfield *et al.* 2014). The reduction in stock status was consistent with the different classifications obtained from the application of the harvest strategy in the Management Plan for the South Australian Commercial Abalone Fishery (PIRSA 2012) between years, from 'underfished' in 2012/13 to 'sustainably fished' in 2013/14. Thus, as observed with the Central (Mayfield *et al.* 2014) and Western (Stobart *et al.* 2014,

2015) zones of the SAAF, the harvest strategy provided a more optimistic assessment of stock status than the weight-of-evidence method.

The reason for the apparent rapid declines in the abundance of blacklip in the SZ is unclear, but likely related to the (unquantified) impact of the blacklip mortality associated with anomalously high water temperatures from January to May in 2013 (Mayfield *et al.* 2011; Government of South Australia 2013). During this period, there were widespread (Robe to Port MacDonnell) reports of mortality with variable levels of impact up to 50% of the stock.

4.1.2 Greenlip abalone

As identified above, assessment of the greenlip stocks in the SZ is challenging because few data are available and it is not possible to estimate CPUE on this species, which is the key index of relative abalone abundance. As the low current and historical catch prevents unambiguous assessment of the current status of greenlip in the SZ, under the NFSRF (Flood *et al.* 2014), the stock status of this species in the SZ is classified as '**undefined**'. Thus, decisions on future TACCs are likely to continue to rely heavily on input from other sources such as divers and licence holders in the fishery.

4.2 Future research needs

The most pressing research need in the SZ abalone fishery is continued evaluation of the recently-established harvest strategy for the SAAF to the SZ. This requires weight-of-evidence assessments to continue in conjunction with application of the harvest strategy. This will (1) enable the suitability of the revised management framework and harvest strategy to be evaluated; (2) identify limitations and potential improvements when these approaches are reviewed; and (3) continue to facilitate the management decision process. It may also be beneficial to test the performance of the harvest strategy using a management strategy evaluation approach prior to its formal review in 2017.

Identification and testing of a process to formally include industry information into the application of the harvest decision rules for determining TACCs is also a key research need. This is because (1) changes in the value of PIs through time may not be directly related to stock status and their interpretation can be informed by credible, structured information (e.g. market demand, weather patterns, changing diver demography); and (2) abalone divers directly observe abalone stocks through their harvesting process. The latter is different to nearly all other fisheries where fishers typically use fishing methods (e.g. traps, nets, lines) that do not readily facilitate direct observations on the distribution, abundance and population structure of the target species.

Assessment of abalone in the SZ may also benefit from (1) determining the impacts of environmental conditions and climate change on the availability of blacklip in this zone; (2) analysing external influences (e.g. diver, dive location, month, loss of access) on CPUE through standardisation; (3) improved estimates of the magnitude and trends in IUU catch; (4) assessment of the direct and indirect effects of commercial harvest on the ecosystem; and (4) obtaining data on abalone population age structures. The latter is important because supplementing current data for assessment of stock status with more accurate population age structures would enhance interpretation of the patterns in the length-frequency distributions of the commercial catches.

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6 APPENDIX 1 – HARVEST STRATEGY PI PLOTS AND SCORES

Middle Point

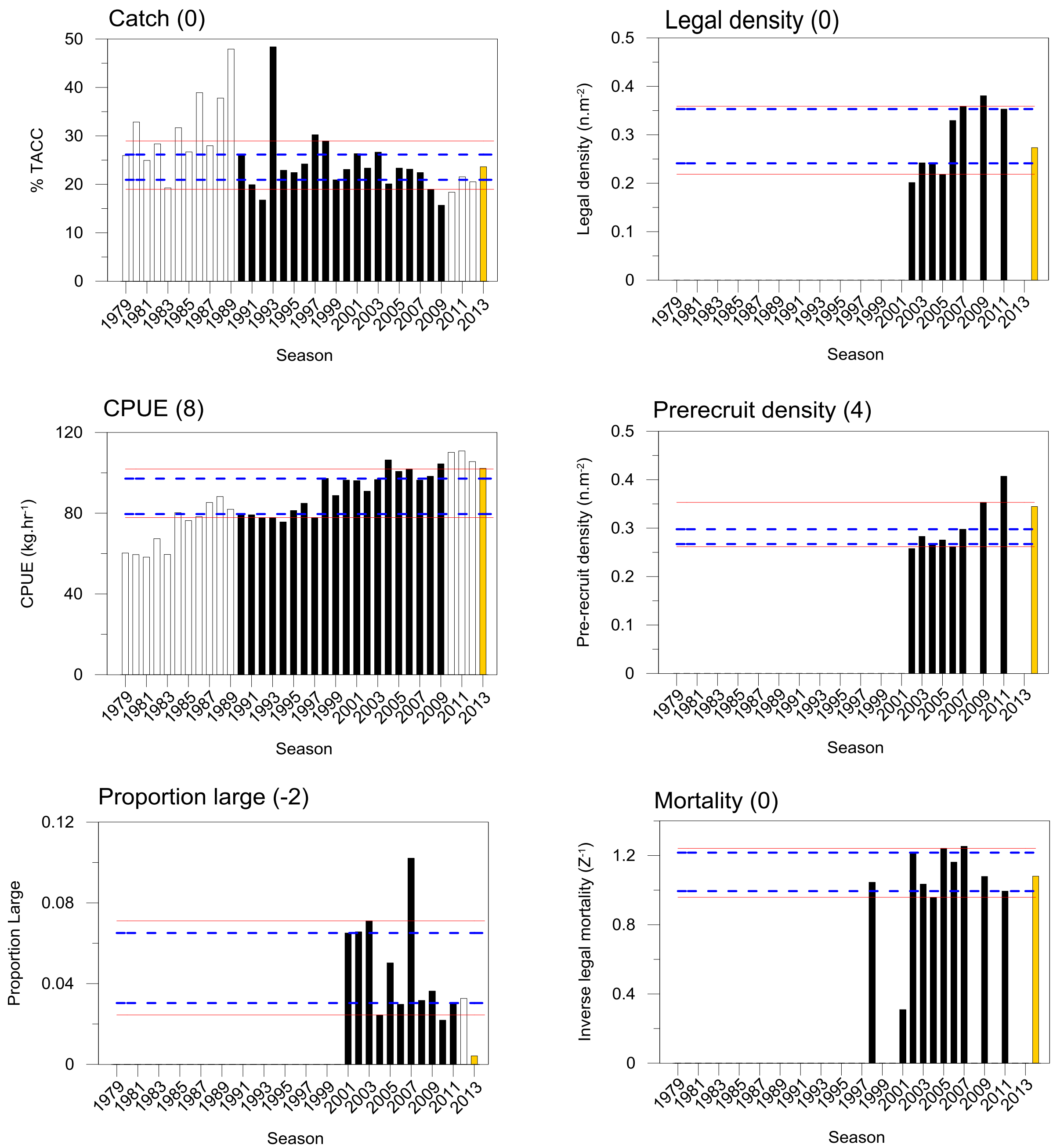

Figure A1.1 Middle Point SAU (high importance). Performance indicators (and scores from the harvest strategy to determine the risk of being overfished) and upper and lower target (blue dashed lines) and limit (red lines) reference points. Black bars show the data and time over which the reference points were calculated. Open bars describe measures of the PI outside of the reference period. Orange bars indicate the data and year subject to assessment for each PI i.e. the score-year.

Gerloff's Bay

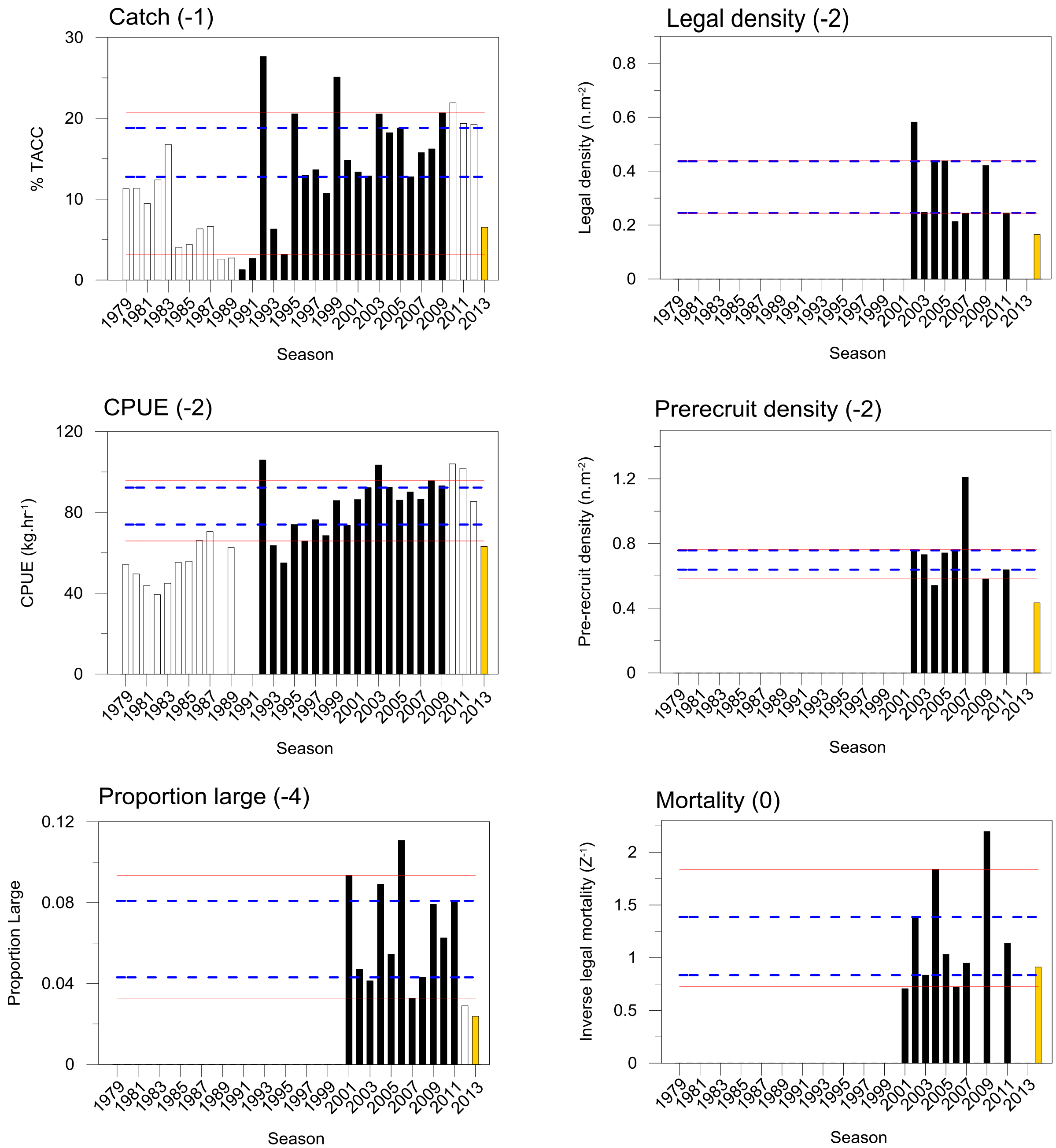

Figure A1.2: Gerloffs Bay SAU (high importance). Performance indicators (and scores from the harvest strategy to determine the risk of being overfished) and upper and lower target (blue dashed lines) and limit (red lines) reference points. Black bars show the data and time over which the reference points were calculated. Open bars describe measures of the PI outside of the reference period. Orange bars indicate the data and year subject to assessment for each PI i.e. the score-year.

Number 2 Rocks

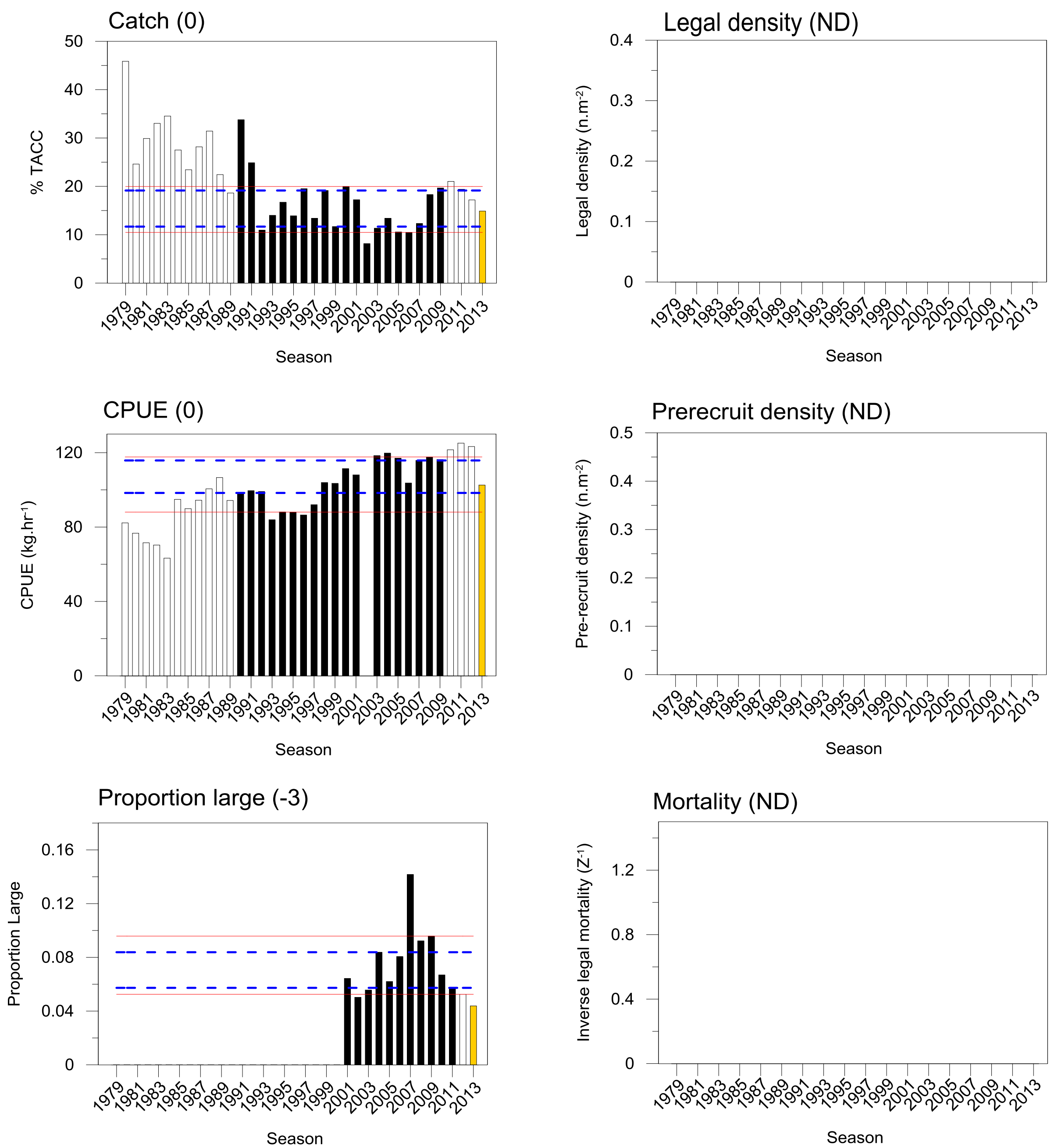

Figure A1.3: Number 2 Rocks SAU (high importance). Performance indicators (and scores from the harvest strategy to determine the risk of being overfished) and upper and lower target (blue dashed lines) and limit (red lines) reference points. Black bars show the data and time over which the reference points were calculated. Open bars describe measures of the PI outside of the reference period. Orange bars indicate the data and year subject to assessment for each PI i.e. the score-year. ND indicates no data.

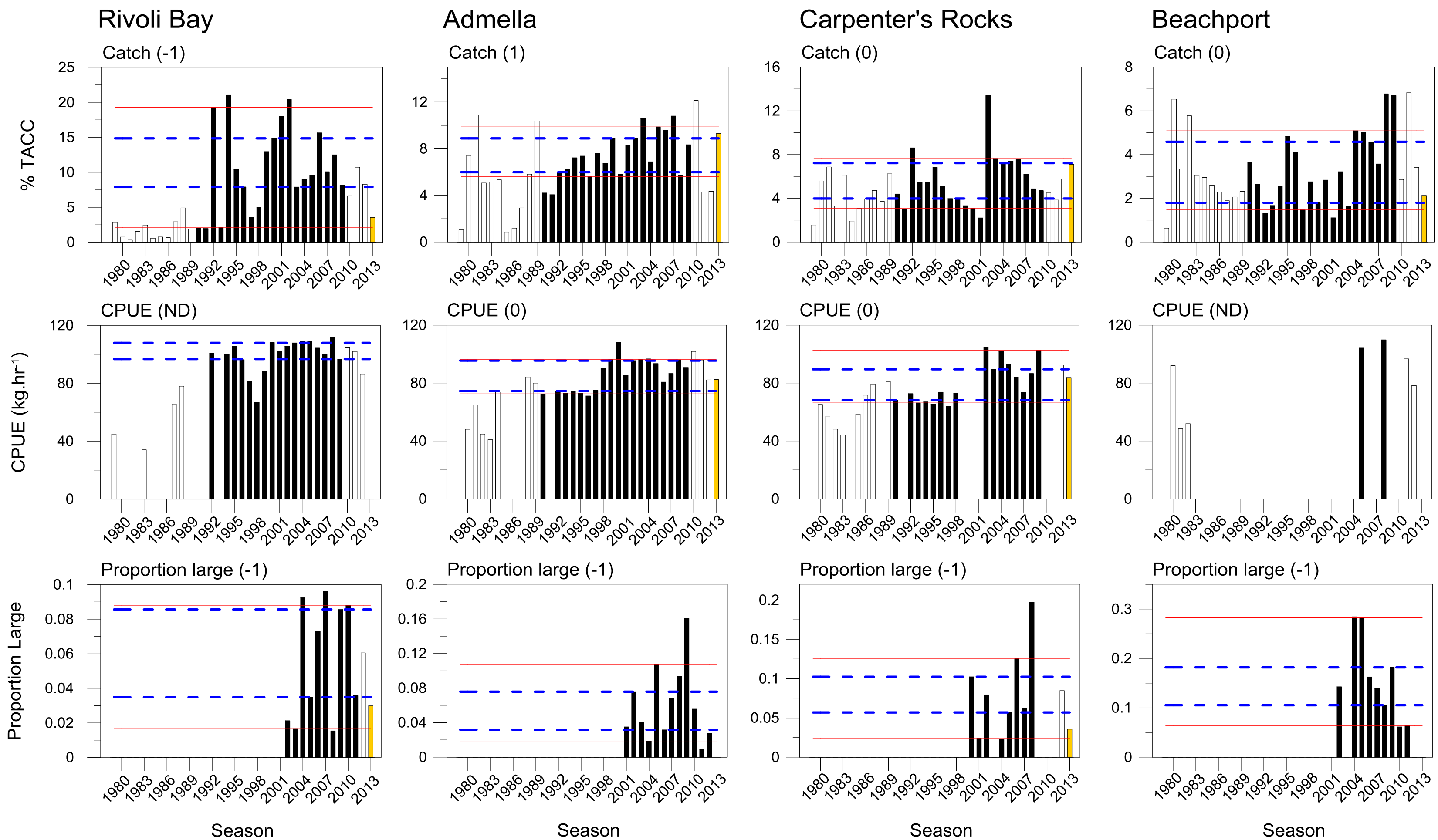

Figure A1.4: Rivoli Bay, Admella, Carpenters Rocks and South End SAUs (medium importance). Performance indicators (and scores from the harvest strategy to determine the risk of being overfished) and upper and lower target (blue dashed lines) and limit (red lines) reference points. Black bars show the data and time over which the reference points were calculated. Open bars describe measures of the PI outside of the reference period. Orange bars indicate the data and year subject to assessment for each PI i.e. the score-year.