Western Zone Abalone
(\textit{Haliotis laevigata} & \textit{H. rubra}) Fishery
(Region B)

B. Stobart, S. Mayfield, J. Dent and D.J. Matthews

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October 2012

Fishery Stock Assessment Report to PIRSA Fisheries and Aquaculture
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EXECUTIVE SUMMARY

This report provides a current assessment of *Haliotis laevigata* and *H. rubra* (hereafter referred to as greenlip and blacklip abalone, respectively) stocks in Region B of the Western Zone (WZ).

This assessment was informed by the harvest strategy in the new Abalone Fishery Management Plan (PIRSA 2012) and the traditional, weight-of-evidence assessment. Comparison between these has identified several potential improvements to the harvest strategy. Data spanning three spatial scales were integrated: Region B, fishing areas (FAs) and spatial assessment units (SAUs).

The total allowable commercial catch (TACC) for both species combined was 41.4 t.yr\(^{-1}\) from 1994 to 2010. In 2011 and 2012 it was 27.6 t and 20.7 t, respectively. The reduction reflected weakening stock status. Most (about 70%) of the catch has been harvested from FA 2.

The catch per unit effort (CPUE; greenlip and blacklip abalone combined) in 2011 was the lowest on record, 26% below the mean value from 1990 to 2009 (termed CPUE\(_{90-09}\)) and 10% below that in 2010. The 25% reduction in CPUE since 2008 indicates declines in the abundance of legal-sized abalone over recent years.

The temporal patterns in CPUE were consistent both across species and spatially. This suggests the harvestable biomass of greenlip and blacklip abalone has declined in most of the Region B fishing grounds.

The CPUE on greenlip abalone across Region B has been declining since 2003 and, in 2011, was 24% below CPUE\(_{90-09}\) and at the lowest level in the history of the fishery. In 2011, CPUE was at or among the lowest levels in more than 30 years in FAs 1, 2 and 3 and in the North Nuyts Archipelago and South Nuyts Archipelago SAUs.

The proportion of large (i.e. Grade 1) greenlip abalone in the catch has declined from about 60% to 40% since 2003, despite ongoing market demand for larger individuals.

The CPUE on blacklip abalone declined by 40% between 2009 and 2011 to the lowest level on record, and 40% below CPUE\(_{90-09}\). CPUE decreases were also evident in FAs 1 and 2 and the North Nuyts Archipelago SAU, the principal fishing ground.

Most available evidence suggests that the abalone stocks in Region B are in their weakest position in more than 30 years. This evidence, primarily low and declining CPUE, was apparent for both greenlip and blacklip abalone across most spatial scales. The traditional weight-of-evidence assessment was consistent with the harvest strategy which categorised Region B as over-fished.

Objective application of the harvest decision rules would reduce the TACC by >10%. This reduction would follow the 50% decrease between 2010 and 2012 and result in Region B comprising about 2.5% of the total catch across the South Australian Abalone Fishery.

The small catches and consequent low value suggest the merits of retaining Region B as a separately assessed and managed fishery should be evaluated.

However, the two options available – merge Regions A and B to create a unified WZ or retaining Regions A and B as separate fisheries – both require explicit consideration of the current status of the abalone stocks in Regions A and B.
1. **INTRODUCTION**

1.1. **Overview**

This fishery assessment report for Region B of the Western Zone (WZ) of the South Australian Abalone Fishery (hereafter referred to as Region B; see Figure 1.1) updates the previous fishery assessment and status reports for this region (Chick and Mayfield 2006; Chick *et al.* 2007; Stobart *et al.* 2010). The report covers the period from 1 January 1968 to 31 December 2011 and is part of the South Australian Research and Development Institute (SARDI) Aquatic Sciences' ongoing assessment program for the fishery.

The aims of the report are to (1) document the current status of the resource and associated management implications, including the merits of retaining Region B as a separately assessed and managed fishery; (2) identify uncertainty associated with the assessment; (3) evaluate the new harvest strategy for the fishery; (4) detail the methodology followed to assess the fishery; and (5) provide summaries of biological knowledge. This is the first report for Region B in which the harvest strategy, defined in the new Management Plan for the South Australian Abalone Fishery (PIRSA 2012), was implemented. The methodology underpinning the harvest strategy is detailed in PIRSA (2012) and Stobart *et al.* (2012).

The report is divided into four sections, including this introduction, which provides (1) a general overview of the report; (2) the history and a description of the fishery; (3) a description of management plans; and (4) information on the biology of the species harvested. Section 2 outlines the methods used in the assessment while Section 3 provides an assessment of fishery-dependent data for greenlip (*Haliotis laevigata*) and blacklip (*Haliotis rubra*) abalone (hereafter referred to as greenlip and blacklip, respectively). For each of these species, where appropriate, this includes spatial and temporal analyses of catch (tonnes shell weight; t. yr⁻¹), effort (days), catch-per-unit-effort (CPUE; kg.hr⁻¹), commercial catch size-structure and application of the harvest strategy that determines the risk that stocks within spatial assessment units (SAUs) are overfished and the status of the abalone fishery in Region B, as described in The Management Plan. Finally, in the Discussion (Section 4), uncertainties in the assessment are identified, a synthesis of the information for Region B is presented along with a summary of its current status, assessments for greenlip and blacklip are compared, management implications considered and future research needs for the fishery outlined. This section also includes a formal evaluation of the harvest strategy in the new Management Plan.
1.2. **History and description of the fishery**

The South Australian Abalone Fishery (SAAF) has evolved since its inception in 1964. Entrants to the fishery increased in the late 1960s, and exceeded 100 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 5 licences were issued. These 35 licences remain in 2012. A review of the management history is provided by Shepherd and Rodda (2001) and major management milestones listed in Table 1.1. Summaries of the fishery, including management arrangements, can be found in Prince and Shepherd (1992), Keessing *et al.* (1995), Zacharin (1997), Nobes *et al.* (2004), Mayfield *et al.* (2011a) and Stobart *et al.* (2012).

**Table 1.1.** Management milestones in the South Australian Abalone Fishery (SAAF).

<table>
<thead>
<tr>
<th>Date</th>
<th>Milestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>1964</td>
<td>Fishery started</td>
</tr>
<tr>
<td>1971</td>
<td>Licences made non-transferable</td>
</tr>
<tr>
<td></td>
<td>Fishery divided into three zones</td>
</tr>
<tr>
<td></td>
<td>Minimum legal length (MLL) set at 130 mm for both species</td>
</tr>
<tr>
<td>1976</td>
<td>30 Licences remained; 5 additional licences issued</td>
</tr>
<tr>
<td>1978</td>
<td>Sub Zones and fishing blocks replaced by map numbers and codes</td>
</tr>
<tr>
<td>1980</td>
<td>Licences became transferable</td>
</tr>
<tr>
<td>1984</td>
<td>Blacklip minimum legal length amended to 120 mm in the Southern Zone</td>
</tr>
<tr>
<td></td>
<td>Greenlip minimum legal length amended to 145 mm in the Western Zone</td>
</tr>
<tr>
<td>1985</td>
<td>Western Zone divided into Regions A and B</td>
</tr>
<tr>
<td></td>
<td>Quota introduced to Region A in the Western Zone (293.25 t blacklip; 293.25 t greenlip)</td>
</tr>
<tr>
<td>1989</td>
<td>Quota introduced to the Central Zone</td>
</tr>
<tr>
<td>1991</td>
<td>Quota introduced to Region B in the Western Zone (27.6 t both species)</td>
</tr>
<tr>
<td>1993</td>
<td>Abolition of owner-operator regulation</td>
</tr>
<tr>
<td>1994</td>
<td>Four ‘fish-down’ areas declared in the Southern Zone</td>
</tr>
<tr>
<td></td>
<td>TACC in Western Zone Region B increased to 41.4 t</td>
</tr>
<tr>
<td>1996</td>
<td>TACC in Western Zone Region A blacklip fishery decreased to 258 t for one year</td>
</tr>
<tr>
<td>1997</td>
<td>Management Plan implemented (Zacharin 1997)</td>
</tr>
<tr>
<td>2006</td>
<td>TACC in Western Zone Region A greenlip fishery increased to 227.7 t</td>
</tr>
<tr>
<td>2010</td>
<td>TACC in Western Zone Region A blacklip fishery decreased to 276 t</td>
</tr>
<tr>
<td></td>
<td>TACC in Western Zone Region A greenlip fishery decreased to 207 t</td>
</tr>
<tr>
<td>2011</td>
<td>TACC in Western Zone Region B decreased to 27.6 t</td>
</tr>
<tr>
<td></td>
<td>Voluntary closed season implemented from 2011</td>
</tr>
<tr>
<td>2012</td>
<td>New management plan and harvest strategy</td>
</tr>
</tbody>
</table>

In 1971, the SAAF was divided into three zones (Western (WZ), Central and Southern) to facilitate more effective management (Figure 1.1). The WZ of the SAAF includes all coastal waters of South Australia between the Western Australia/South Australia border and the eastern Eyre Peninsula (Figure 1.1). This zone was further subdivided into Region A and Region B in 1985. The fishing season extends from 1 January to 31 December each year.
To monitor catches and facilitate compliance with quota limits, fishers must complete a 'Catch and Disposal Record' (CDR) form upon landing. In addition, a research logbook must be completed for each fishing day and submitted to SARDI Aquatic Sciences at the end of each month. Commercial catch and effort data on this fishery have been collected since 1968. These data are used by SARDI to provide analyses of catch, effort and CPUE in Stock Assessment or Status Reports for each zone for Primary Industries and Regions South Australia (PIRSA) Fisheries and Aquaculture.

Since 1997, the fishery has operated under the control of a formal management plan (Zacharin 1997; Nobes et al. 2004; PIRSA 2012). This plan encourages management of the fishery through a regime of input (e.g. limited entry) and output (e.g. minimum legal lengths (MLLs) and quotas) controls. The current management arrangements in the WZ are summarised in Table 1.2. A MLL of 130 mm shell length (SL) was introduced for both species in 1971. Whilst this has remained unchanged for blacklip, the MLL for greenlip was increased to 145 mm SL in 1984 (Table 1.1).

In Region B, an annual Total Allowable Commercial Catch (TACC), including both blacklip and greenlip under a single TACC, was introduced in 1991 (Nobes et al. 2004). The TACC for Region B was 27.6 t, (shell weight) from 1991 to 1992, 34.5 t in 1993 and 41.4 t from 1994 to 2010. The TACC was reduced by 13.8 t (33%) from 2011 because evidence that the resource on which the fishery is based was weakening (Stobart et al. 2010) matched licence-holder concern for the stock. Licence holders

Figure 1.1. Fishing zones of the South Australian Abalone Fishery.
also implemented a voluntary closed season from October to February, inclusive, to limit the number of greenlip harvested (Stobart et al. in review).

**Table 1.2.** Summary of the current management arrangements for the Western Zone commercial abalone fishery.

<table>
<thead>
<tr>
<th>Management strategy</th>
<th>Western Zone management arrangements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Licence holders</td>
<td>23</td>
</tr>
<tr>
<td>Target species</td>
<td>Haliotis rubra (blacklip) &amp; H. laevigata (greenlip)</td>
</tr>
<tr>
<td>Minimum legal length</td>
<td>Blacklip 130 mm SL &amp; Greenlip 145 mm SL</td>
</tr>
<tr>
<td>Quota year</td>
<td>1 January to 31 December</td>
</tr>
<tr>
<td>Quota transferability</td>
<td>Yes</td>
</tr>
<tr>
<td>Other species permitted</td>
<td>H. roei, H. scalaris, H. cyclobates when SL &gt;130 mm</td>
</tr>
<tr>
<td>Method of capture</td>
<td>By hand – dive fishery</td>
</tr>
<tr>
<td>By-catch</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

1.3. **Management plans**

The first Management Plans for the South Australian Abalone Fishery (Zacharin 1997; Nobes et al. 2004) had similar (1) management objectives and associated strategies for the fishery and (2) management actions following triggering of performance indicators (PIs). However, the latter (Nobes et al. 2004) identified a broader suite of PIs – spanning a wide range of fishery-dependent and fishery-independent data – applied to individual fishing areas within a statistical framework for assessing fishery performance (Stobart et al. 2012). Application of these plans was complicated because the PIs were not amalgamated across fishing grounds into a single index of stock status. This made management decisions difficult because, with the exception of Region B, quotas are determined for each species in each zone. Nobes et al. (2004) was reviewed between 2009 and 2012 with the current plan (PIRSA 2012) appearing to meet most of the review objectives (Stobart et al. 2012). A key element of the review was the establishment of a framework to link stock status with explicit decision rules to set TACCs (i.e. a formal, species-specific, spatially-explicit harvest strategy for the SAAF). The decision rules are based on monitoring and assessment of SAUs, of which there are four in Region B (Figure 1.2). This harvest strategy is well described in the Management Plan (PIRSA 2012) and the most recent stock assessment report for Region A of the WZ (Stobart et al. 2012).

1.4. **Biology of abalone in Region B**

Data on the biology of abalone in Region B are limited to two sites at St Francis Island sampled in 2008, and are summarised in Table 1.3. More comprehensive, spatially-representative biological data for greenlip and blacklip are provided in the stock assessment report for Region A (Stobart et al. 2012).
Table 1.3. Relationships between shell length (SL, mm) and total weight (TW, g), meat weight (MW, g), bled meat weight (BW, g) and fecundity (F, millions of eggs), and between total weight and fecundity, for greenlip and blacklip abalone from St Francis Island. The equations are in the form TW/MW/BW = aSL^b and SL/TW = aF x b. All samples are from 2008. SARDI unpublished data.

<table>
<thead>
<tr>
<th>Site</th>
<th>Species</th>
<th>Comparison</th>
<th>a</th>
<th>b</th>
<th>r²</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>St Francis East BL</td>
<td>SL x TW</td>
<td>2 x 10^4</td>
<td>2.94</td>
<td>0.94</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>St Francis East BL</td>
<td>SL x MW</td>
<td>6 x 10^5</td>
<td>3</td>
<td>0.88</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>St Francis East BL</td>
<td>SL x BW</td>
<td>1 x 10^4</td>
<td>2.76</td>
<td>0.86</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>St Francis West BL</td>
<td>SL x TW</td>
<td>1 x 10^4</td>
<td>3.06</td>
<td>0.97</td>
<td>202</td>
<td></td>
</tr>
<tr>
<td>St Francis West BL</td>
<td>SL x MW</td>
<td>5 x 10^5</td>
<td>3.09</td>
<td>0.95</td>
<td>122</td>
<td></td>
</tr>
<tr>
<td>St Francis West BL</td>
<td>SL x BW</td>
<td>4 x 10^5</td>
<td>3.05</td>
<td>0.96</td>
<td>122</td>
<td></td>
</tr>
<tr>
<td>St Francis East GL</td>
<td>SL x TW</td>
<td>3 x 10^5</td>
<td>3.35</td>
<td>0.96</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>St Francis East GL</td>
<td>SL x MW</td>
<td>9 x 10^6</td>
<td>3.4</td>
<td>0.94</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>St Francis East GL</td>
<td>SL x BW</td>
<td>1 x 10^5</td>
<td>3.3</td>
<td>0.88</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>St Francis West GL</td>
<td>SL x TW</td>
<td>3 x 10^5</td>
<td>3.35</td>
<td>0.99</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>St Francis West GL</td>
<td>SL x MW</td>
<td>8 x 10^6</td>
<td>3.42</td>
<td>0.98</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>St Francis West GL</td>
<td>SL x BW</td>
<td>1 x 10^5</td>
<td>3.3</td>
<td>0.96</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>St Francis BL</td>
<td>SL x F</td>
<td>0.026</td>
<td>-1.67</td>
<td>0.4</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>St Francis BL</td>
<td>TW x F</td>
<td>0.003</td>
<td>0.35</td>
<td>0.36</td>
<td>36</td>
<td></td>
</tr>
</tbody>
</table>

1.5. Previous stock assessments

The first assessment of the South Australian abalone resource was published by the South Australian Department of Fisheries in 1984 (Lewis et al. 1984). In 1996, the abalone research arrangements were comprehensively reviewed (Andrew 1996). Fishery assessment reports were produced annually between 1998 and 2000 (Rodda et al. 1998; Shepherd et al. 1999; Rodda et al. 2000). The 2001 stock assessment report provided fishery statistics for all three zones of the SAAF (Mayfield et al. 2001). The first dedicated WZ report (Mayfield et al. 2002) synthesised relevant fisheries data from 1968 to 2001. Stock assessment reports were updated annually to 2006 (Mayfield et al. 2005; Chick et al. 2006). Subsequent fishery assessment and status reports for Regions A and B of the WZ have been provided to PIRSA in alternate years (Chick et al. 2007, 2008; Stobart et al. 2010; Stobart et al. 2011). The most recent Region B report, Stobart et al. (2010), identified an increase in total effort from 2006 to 2009 with a decrease in catch and CPUE between 2008 and 2009, suggesting that the abundance of legal-sized abalone in Region B had declined. For greenlip, the assessment concluded that stocks had weakened over recent years. This was based on a decline in greenlip catch, despite the beach price of greenlip exceeding that for blacklip, reductions in the proportion of Grade 1 greenlip in the catch and decreasing CPUE. In contrast, blacklip catch increased during the same period while CPUE remained stable, suggesting that the abundance of legal-sized blacklip had remained relatively unchanged. This information, in combination with provisional 2011 data, led to a 33% decrease in the TACC in 2011 and a voluntary closed season implemented from October to February.
Figure 1.2. Spatial assessment units and map codes in Region B of the South Australian, Western Zone Abalone Fishery.
2. METHODS

Commercial catch and effort data have been collected since 1968 as daily entries to commercial logbooks submitted to SARDI, allowing spatial and temporal analyses of catch, effort, and CPUE on both species and the proportion of large abalone (i.e. Grade 1) in the commercial greenlip catch. Data on the length-frequency distribution of the blacklip commercial catch were obtained by measuring samples provided to SARDI by commercial fishers (1 January 2004 – 30 June 2005) and data provided by the Abalone Industry Association of South Australia (1 July 2005 to 31 December 2008).

Fishery statistics are provided at three spatial scales: (1) the whole of Region B; (2) fishing areas (FAs); and (3) spatial assessment units (SAUs). Statistics provided are catch (t, shell weight), total effort (days), species-specific CPUE computed using the catch-weighted mean of daily CPUE (Burch et al. 2011), the CPUE on both species combined estimated using the extended ratio estimator (Burch et al. 2011) and the proportion of large blacklip (PropLge) or the proportion of Grade 1 greenlip (PropG1) in the commercial catch. Error bars show the standard error (se) of the mean.

Catch was determined from all daily records and included all catches from mapcode 3A. This was done because (1) mapcode 3A covers fishing grounds in both Regions A and B; (2) catches from mapcode 3A cannot be partitioned into Region A or B; and (3) most of the catch harvested from mapcode 3A is harvested from Region B (Jonas Woolford, Abalone Industry Association of SA, personal communication). Prior to calculation of CPUE, daily data were filtered to remove records where catch was >900 kg, effort was <3 and >8 hours or the ratio of total catch over total hours was >150 kg.hr⁻¹. This removed approximately 10% of daily records (Burch et al. 2011). Additionally, when calculating species-specific, catch-weighted mean daily CPUE, records where the species for which CPUE was being estimated comprised <30% of total daily catch were also removed. This approach was consistent with that used in Region A (Stobart et al. 2012). For PropG1, all records where the total catch was >1% different from the sum of the three weight-grade categories were excluded, as were records with zero catch. As the minimum sample size was 10 fishing records, the absence of data for these measures indicates that this condition was not achieved.

PropLge was the ratio of “large” blacklip shells (>165 mm SL) to all commercial SL measurements (minimum sample size = 100); SL measurements >5 mm SL below the MLL (130 mm SL) were excluded. Whilst these PropLge data were provided for completeness, the limited information between 2004 and 2008 and lack of information thereafter impedes their interpretation and thus they were excluded from analyses of stock status.
For historical comparison, mean values of key measures of fishery performance are provided in text and/or as dashed lines on graphs. These are the proportion of the greenlip or blacklip TACC harvested from each SAU for the 10-yr period between 2002 and 2011 ($C_{02-11}$) and the mean annual CPUE and PropG1 for the 20-yr period between 1990 and 2009 (CPUE$_{90-09}$ and PropG1$_{90-09}$, respectively). Rankings of SAUs refer first to the rank within the ten-year period ($C_{02-11}$), followed by the rank in 2011 separated by a hyphen (e.g. 1-5 had rank 1 over the ten-year period and rank 5 in 2011).

The methodology used to calculate, score and interpret PIs for the new harvest strategy is detailed in Stobart et al. (2012) and the Management Plan for the SAAF (PIRSA 2012).
3. **RESULTS**

3.1. **Region B**

Total catches have closely reflected the TACC that was increased from 27.6 t (1991 and 1992) to 34.5 t (1993) and 41.4 t (1994-2010, Figure 3.1). The exception was 2009 when the total reported catch for both species was 38.7 t, representing 93.5% of the TACC. In 2011, the TACC was set at 27.6 t, 33% below that in 2010, and catch consequently decreased. Total effort has closely reflected the pattern of catch since 1968, with a period of stability between 1995 and 2006 following the introduction of a TACC in 1991 and the subsequent amendments. However, between 2006 and 2010 total effort increased from 672 to 860 hrs (28%), to the highest value since 1990, with most of the change occurring between 2009 and 2010. Similarly, CPUE was relatively stable between 1999 and 2008, but then decreased sharply between 2008 and 2011. In 2011, CPUE was 45 kg.hr⁻¹, 26% below CPUE_{90-09} and at the lowest level in the history of the fishery (Figure 3.1).

![Figure 3.1. Catch (t, shell weight) of greenlip (green bars) and blacklip (black bars) from Region B from 1968 to 2011. Total effort (hrs; 10³) and mean CPUE ± se (kg.hr⁻¹) are shown in black and red, respectively. Red dashed line is CPUE_{90-09}. Red arrows indicate implementation (1991) and amendment (1993, 1994 and 2011) of TACC.](image)

Greenlip comprised >90% of the total catch in Region B between 1968 and 1984, with the single exception of 1973 (70%; Figure 3.2). The proportion of greenlip in the catch then declined from 1981 until 1989, whereafter it has ranged between approximately 50% and 70% and was variable among years. The proportion of greenlip in the catch was highest in FAs 2 and 3, while the proportion of blacklip in the catch was highest in FA 1 (Figure 3.2). Within FA 2, greenlip have formed the highest proportion of the catch.
from the South Nuyts Archipelago SAU since 1979. This contrasts with the North Nuyts Archipelago SAU where catches are more evenly distributed between greenlip and blacklip (Figure 3.3).

**Figure 3.2.** Percentage of greenlip (green fill) and blacklip (black fill) in total catch from Region B (top) from 1968 to 2011, and for fishing areas (FA) 1, 2 and 3 separately from 1979 to 2011. White arrows indicate implementation and subsequent changes to TACC.
Figure 3.3. Percentage of greenlip (green fill) and blacklip (black fill) in total catch from SAUs North Nuyts Archipelago, South Nuyts Archipelago, D'Entrecasteaux Reef, and Franklin Islands, from 1979 to 2011. White arrows indicate implementation and subsequent changes to TACC.
3.2. **Greenlip**

Total catches varied considerably between 1968 and 1990, whereafter they have been relatively stable ranging between approximately 18 and 31 t yr\(^{-1}\) (Figure 3.4). In 2011, after the reduction in quota, catch decreased to 19 t, the lowest level since 1993. Following high catch rates in 1979, 1980 and 1982, CPUE has been more variable among years (Figure 3.4). However, CPUE has declined substantially over recent years from a local maximum in 2003 and, in 2011, was at the lowest level on record, 24% below CPUE\(_{90-09}\). Similarly, the proportion of Grade 1 greenlip in the commercial catch has decreased substantially from the highest recorded value of 60% in 2003 to 40% in 2007, whereafter it has remained relatively stable (Figure 3.4).

![Figure 3.4](image-url) Catch (t, shell weight; green bars) of greenlip from Region B from 1968 to 2011. Mean CPUE ± se (kg.hr\(^{-1}\)) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show CPUE\(_{90-09}\) and PropG1\(_{90-09}\), respectively.

### 3.2.1. Distribution of catch and temporal patterns in fishing areas

With few exceptions, for over 30 years most of the greenlip catch in Region B has been harvested from FA 2 (Figure 3.5). The proportion of the greenlip catch harvested from this FA has increased steadily since 1993 and, in 2011, was amongst the highest levels on record (83%). The proportions harvested from FA 1 and FA 3 have been similar over time but decreased in recent years in response to the increased harvest from FA 2.

Catches from FA 1 were variable from 1979 to 1993, whereafter they were stable (Figure 3.6). For FAs 2 and 3, catches were variable from 1979 to 1998 and relatively stable between 1999 and 2010, with the exception of about a 50% decrease in catch from FA 3 in 2006. CPUE has varied among years in all three FAs. However, in all FAs, CPUE has declined from the early 2000s: CPUE declined from 2003 to 2010 in FA 1 and, in 2010,
was 26% below CPUE$_{90-09}$; in FA 2, CPUE declined from 2008 to 2011 and, in 2011, was 21% below CPUE$_{90-09}$; in FA 3, CPUE declined over a longer period from 2001 to 2009, whereafter it has remained stable at about 32% below CPUE$_{90-09}$. The proportion of Grade 1 greenlip harvested from FAs 1 and 2 were historically high in 2003 (0.72 and 0.65, respectively), but decreased from 2003 to 2007, whereafter it has remained at about 0.44 and similar to PropG1$_{90-09}$. This contrasts with FA 3 where, during the same time period, the proportion of Grade 1 has been more variable among years.

**Figure 3.5.** Percent of greenlip catch in each FA (see legend) in Region B from 1979 to 2011. FAs ranked by catch.
3.2.2. Distribution of catch and temporal patterns in spatial assessment units

The South Nuyts Archipelago is the only medium importance greenlip SAU in Region B, with the remaining SAUs - North Nuyts Archipelago, D’Entrecasteaux Reef and Franklin Islands - being of low importance. Both the South Nuyts Archipelago and North Nuyts Archipelago SAUs are located within FA 2 where the increase in catch from 1993, described above, was primarily driven by increases in catch from the South Nuyts Archipelago SAU (Figure 3.7). As the D’Entrecasteaux and Franklin Islands SAUs comprise all of FAs 1 and 3, respectively, temporal patterns in these SAUs are equivalent to those from these FAs provided in Section 3.2.1.

Figure 3.6. Catch (t, shell weight; green bars) of greenlip from FAs 1, 2 and 3 from 1979 to 2011. Mean CPUE ± se (kg.hr⁻¹) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show CPUE₉₀₋₀₉ and PropG₁₉₀₋₀₉, respectively.
3.2.2.1. **South Nuyts Archipelago (Rank 1-1; 45%C_{02-11})**

Catch has been variable throughout the history of the South Nuyts Archipelago, with periods of highly variable catches throughout the 1980s, and less variable catches thereafter (Figure 3.8). The catch harvested from this SAU decreased from 15.3 to 8.9 t (42%) between 2010 and 2011 to the second lowest level since 1999. CPUE has varied among years, but declined from a recent maximum in 2008 and, in 2011, was at the lowest level since 1997, 16% below CPUE_{90-09}. The percentage of Grade 1 greenlip in the commercial catch has also decreased since 2003. In 2011, PropG1 was at the lowest level since 1992, 18% below PropG1_{90-09}.

3.2.2.2. **North Nuyts Archipelago (Rank 2-2; 25%C_{02-11})**

Annual catches from the North Nuyts Archipelago varied considerably between 1979 and 1990, whereafter they have been relatively stable, ranging between about 3 and 10 t.yr^{-1} (Figure 3.8). CPUE has decreased, from a recent maximum in 2005 and, in 2011, was at the second lowest level on record, 25% below CPUE_{90-09}. In contrast, the proportion of Grade 1 greenlip has increased steadily since 2006 reaching 14% above PropG1_{90-09} in 2011.

3.2.2.3. **Franklin Islands (Rank 3-3; 16%C_{02-11})**

Catch from the Franklin Islands varied considerably between 1979 and 1990, followed by a period of relatively stable catches among years from 1991 to 2005, and lower stable catches from 2006 to 2011 (Figure 3.8). CPUE declined steadily from a recent maximum in 2001 to the lowest level on record in 2009, whereafter it has remained stable and, in
2011, was 33% below CPUE\textsubscript{90-09}. The proportion of Grade 1 greenlip in the commercial catch was variable among years with no long-term trend evident.

3.2.2.4. **D’Entrecasteaux Reef (Rank 4-4; 11\%C\textsubscript{02-11})**

Annual catch from D’Entrecasteaux Reef was relatively stable between 1994 and 2010. However, catch declined in 2011 to the lowest level in over 25 years (Figure 3.8). CPUE and PropG1 could not be estimated in most years due to limited data.

**Figure 3.8.** Catch (t, shell weight; green bars) of greenlip from the South Nuyts Archipelago, North Nuyts Archipelago, Franklin Islands and D’Entrecasteaux Reef SAUs from 1979 to 2011. Mean CPUE ± se (kg.hr\(^{-1}\)) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show CPUE\textsubscript{90-09} and PropG1\textsubscript{90-09}, respectively.
3.3. **Blacklip**

Following low catches from 1968 to 1984, blacklip catches from Region B increased to a historic peak in 1989 (46 t; Figure 3.9). Subsequently, for the period 1993 to 2010, catch has ranged between 12 and 20 t yr⁻¹. In 2011, following the reduction in quota, catch decreased to 8 t, the lowest level since 1991. With the exception of a peak in 1994, CPUE was relatively stable between 1989 and 2009. However, CPUE declined sharply from 2009 and, in 2011, was at the lowest level on record, 40% below CPUE₀₀-₀₉.

![Figure 3.9](image.png)

**Figure 3.9.** Catch (t, shell weight; black bars) of blacklip from Region B from 1968 to 2011. Mean CPUE ± se (kg hr⁻¹) and PropLge are shown in red and blue, respectively. Red dashed line shows CPUE₀₀-₀₉.

### 3.3.1. **Distribution of catch and temporal patterns in fishing areas**

From 1984 onwards, most of the blacklip catch from Region B was harvested from FA 2, with the exception of 1993 when most of the catch was harvested from FA 1. The proportion of blacklip harvested from FA 2 increased steadily from 1993 and, in 2005, reached the highest level on record (85%; Figure 3.10). High catches from FA 2 have occurred at about 5-year intervals since 1991, with periods of low catch from this FA primarily offset by increased catches from FA 1.

Following relatively high catches from 1988 to 1990, catches from all FAs have varied among years (Figure 3.11). CPUE has varied among years in all three FAs. However, since 2009 there has been a substantial decline in CPUE in FA 2 and, in 2011, CPUE in this FA was 47% below CPUE₀₀-₀₉. In 2011, the mean CPUE in FAs 1 and 3 were among the lowest on record.
Figure 3.10. Percent of blacklip catch in each FA (see legend) in Region B from 1979 to 2011. FAs ranked by catch.

Figure 3.11. Catch (t, shell weight; black bars) of blacklip from FAs 1, 2 and 3 from 1979 to 2011. Mean CPUE ± se (kg.hr$^{-1}$) and PropLge are shown in red and blue, respectively. Red line shows CPUE$_{90-09}$. 
3.3.2. **Distribution of catch and temporal patterns in spatial assessment units**

The North Nuyts Archipelago is the only medium importance blacklip SAU in Region B, with remaining SAUs - South Nuyts Archipelago, D'Entrecasteaux Reef and Franklin Islands - being of low importance. Both the North Nuyts Archipelago and South Nuyts Archipelago SAUs are located within FA 2, with the increase in catch from 1993 described above primarily due to increases in catch from the North Nuyts Archipelago (Figure 3.12). Periodic decreases in catch from the North Nuyts Archipelago were replaced with increases in catch from D'Entrecasteaux Reef. With a few exceptions, the proportion of catch harvested from the South Nuyts Archipelago and Franklin Islands has remained relatively stable over time.

![Figure 3.12. Percent of blacklip catch in each SAU (see legend) in Region B from 1979 to 2011. SAUs ranked by catch.](image)

3.3.2.1. **North Nuyts Archipelago (Rank 1-1; 47%C_{02-11})**

Catch from the North Nuyts Archipelago has been variable throughout its history, with peaks in catch in 1990, 1996 and 2006 (Figure 3.13). Catch and CPUE declined from the recent maxima in 2006 and, in 2011, CPUE was the lowest on record and 49% below CPUE_{90-09}.

3.3.2.2. **D’Entrecasteaux Reef (Rank 2-3; 26%C_{02-11})**

Following high catches in 1989 (22 t), the catch from D’Entrecasteaux Reef has varied among years, ranging from about 1 to 11 t.yr^{-1} (Figure 3.13). CPUE could not be estimated for several years, including 2010 and 2011, due to limited data.
3.3.2.3. **South Nuyts Archipelago (Rank 3-2; 18%C\textsubscript{02-11})**

Following a relatively high catch in 1988, catch from the South Nuyts Archipelago has remained relatively stable at about 2.5 t.yr\textsuperscript{-1} (Figure 3.13). CPUE was not estimable for most years due to limited data.

3.3.2.4. **Franklin Islands (Rank 4-4; 9%C\textsubscript{02-11})**

Following relatively high catches in 1988 (5 t), 1989 (9 t) and 1990 (8 t), catch at the Franklin Islands was relatively stable at about 1.5 t.yr\textsuperscript{-1} (Figure 3.13). CPUE was not estimable for most years due to limited data.

![Figure 3.13. Catch (t, shell weight; black bars) of blacklip from the North Nuyts Archipelago, D’Entrecasteaux Reef, South Nuyts Archipelago and Franklin Islands SAUs from 1979 to 2011. Mean CPUE ± se (kg.hr\textsuperscript{-1}) and PropLge are shown in red and blue, respectively. Red dashed line shows CPUE\textsubscript{90-09}](image-url)
3.4. Risk of overfishing and stock status of Region B

There were two medium-importance SAUs for Region B. These were the South Nuyts Archipelago for greenlip and the North Nuyts Archipelago for blacklip. All remaining SAUs were of low importance. It was possible to determine the risk of being overfished for both of these medium-importance SAUs.

Summed PI scores were 0 for greenlip at South Nuyts Archipelago and -7 for blacklip at North Nuyts Archipelago. These SAUs were assigned to a 'green' and 'red' risk-of-overfishing, colour-coded category, respectively (Table 3.1; Appendix 1). The catch-weighted, zonal score was -0.662, defining a zonal stock status for Region B of overfished (Table 3.1).

Table 3.1. Outcome from application of the harvest strategy described in the Management Plan against the WZ Region B abalone fishery. Grey shading identifies the performance indicators and their respective scores. % ContWZ = % Contribution to mean total catch (WZ) over last 10 years (2002-2011); % ContSAU = % Contribution to catch from high and medium SAUs in 2011.

<table>
<thead>
<tr>
<th>Spatial assessment unit (SAU)</th>
<th>Species</th>
<th>% ContWZ</th>
<th>Importance</th>
<th>% ContSAU</th>
<th>CPUE</th>
<th>% TACC</th>
<th>% Grade</th>
<th>Combined PI score</th>
<th>Risk of overfishing</th>
<th>Catch-weighted contribution to zonal score</th>
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</table>

% ContWZ = % Contribution to mean total catch (WZ) over last 10 years (2002-2011); % ContSAU = % Contribution to catch from high and medium SAUs in 2011.
4. DISCUSSION

4.1. Information, data gaps and uncertainty in the assessment

Assessment of abalone stocks in Region B was limited to the interpretation of commercial catch, effort and catch length-frequency data. This was consistent with the harvest strategy which rationalises resources to ensure they are distributed into assessments of the most important SAUs, by catch, in the WZ of the SAAF (PIRSA 2012; Stobart et al. 2012). Consequently, application of the harvest strategy to determine the risk that greenlip and blacklip stocks are over-fished, and overall stock status, was based on one SAU of medium importance per species (South Nuyts Archipelago and North Nuyts Archipelago, respectively).

Several factors impede assessment of abalone stocks in Region B and, consequently, increase uncertainty around stock status. Firstly, Region B is unique within Australian abalone fisheries in that the TACC is not differentiated between species, thus permitting a harvest choice for fishers. Lack of species-specific TACCs complicates interpreting fishery-dependent measures such as the total catch of each species, the distribution of catch among fishing grounds and CPUE. This is because these measures can be strongly influenced by factors other than the abundance of the individual species (e.g. market preferences).

Secondly, data on the length structure of blacklip in the commercial catch, which can provide critical information to aid stock assessment (Burch et al. 2011), were limited. This directly influenced the scoring of one of the key PIs for this fishery (i.e. proportion of large for blacklip) and increases the uncertainty in the assessment of stock status (Burch et al. 2010). This difficulty could be overcome by representative sampling of blacklip shell lengths from the commercial catch in SAUs of designated high and medium importance and be most easily achieved by fishers measuring five abalone from each catch bag on more than 70% of fishing days (Burch et al. 2010).

Thirdly, we use CPUE to assess stock status, based on the assumption that changes in CPUE reflect changes in the abundance of the fishable stock (Tarbath et al. 2005). We note CPUE can be strongly influenced by numerous factors, in addition to changes in abalone abundance, such as changing diver behaviour and increasing fishing efficiency, resulting in CPUE often being viewed as a biased index of abalone abundance (Harrison 1983; Breen 1992; Prince and Shepherd 1992; Gorfine et al. 2002). For example, catch rates may remain high as a result of re-aggregation of abalone or improved knowledge of fishing areas by fishers, thereby masking fluctuations in population size arising from local depletion (Officer et al. 2001). However, decreases in CPUE in abalone fisheries can be
considered a reliable indicator of declines in abalone abundance, particularly where effort is consistently applied (Tarbath et al. 2005).

Fourthly, both blacklip and greenlip can be harvested, but effort is not required to be apportioned between the species within a fishing day thus impeding direct estimation of species-specific CPUE. In this assessment, we used the catch-weighted mean of daily CPUE to estimate species-specific CPUE (Burch et al. 2011). This method is considered the most appropriate as it (1) weights each daily catch and effort objectively; (2) removes the need to “subset” the data subjectively; and (3) can be applied consistently to greenlip and blacklip abalone at multiple spatial scales across the fishery.

Finally, the accuracy and precision of estimates of illegal catch are unknown and difficult to estimate. This prevents accurate estimates of the total catch and hence impedes this assessment. Development of alternative methods for estimation of illegal, unregulated and unreported (IUU) extractions may reduce this uncertainty.

4.2. Status of the Region B abalone fishery

4.2.1. Region B

The evidence available suggests that the abalone stocks in Region B are in their weakest position in the history of the fishery. In 2011, the combined CPUE on both species was at the lowest level on record, 26% below CPUE$_{90-09}$ and 10% below that in 2010. The rapid, 25% reduction in CPUE since 2008 suggests that the abundance of legal-sized abalone in Region B has decreased substantially over recent years. Temporal patterns in CPUE were also consistent both across species and spatially – indicating declining harvestable biomass of greenlip and blacklip in most of the fishing grounds comprising Region B – and with the harvest strategy which categorised the abalone stock in Region B as over-fished. Over-fishing is especially problematic for abalone fisheries, which have a well-documented history of collapse (Prince 2004; Mayfield et al. 2011b) and subsequent limited recovery (Mayfield 2010), in part because spawning success is substantially diminished at reduced densities (Babcock and Keesing 1999). Consequently, it is likely that the exploitation rate (i.e. fishing mortality) needs to be further reduced to decrease these risks in this fishery.

4.2.2. Greenlip

There is substantial evidence that the greenlip stocks in Region B are in the weakest position in the history of the fishery. Firstly, the CPUE on greenlip across Region B has been declining since 2003 and, in 2011, was 24% below CPUE$_{90-09}$ and at the lowest level in the history of the fishery. Secondly, decreases in CPUE were spatially consistent
and, in 2011, CPUE was at or among the lowest levels in more than 30 years in FAs 1, 2 and 3 and in the two SAUs comprising FA 2 (North Nuyts Archipelago and South Nuyts Archipelago). These trends are especially problematic for FA 2 from which the majority of the greenlip catch has been harvested. Thirdly, the proportion of Grade 1 abalone in the greenlip catch has not increased in response to market demand for larger, more valuable, greenlip (Jim George, Western Abalone Processors, personal communication). Rather, at South Nuyts Archipelago, the primary greenlip fishing ground, PropG1 has declined since 2003 and in 2011 was 18% below PropG190-09. This suggests the abundance of large greenlip has probably declined. Finally, an increasing proportion of the greenlip catch has been harvested from FA 2, indicating an apparent reliance on the fishing grounds in this FA. Collectively, these four lines of evidence demonstrate that the harvestable biomass of greenlip has declined over recent years. This conclusion was consistent with those of previous reports for the fishery (Chick and Mayfield 2006; Chick et al. 2007; Stobart et al. 2010) but inconsistent with the ‘green’ risk-of-overfishing category obtained from the harvest strategy for the greenlip stocks in the North Nuyts Archipelago SAU.

4.2.3. Blacklip
Evidence that the abundance of blacklip in Region B has declined rapidly over the last two years to the weakest position in the history of the fishery, following a long period of relative stability, is also compelling. The CPUE on blacklip has declined by 40% between 2009 and 2011 to the lowest level on record, and 40% below CPUE90-09. The decreases in CPUE were also evident in FAs 1 and 2 and the North Nuyts Archipelago SAU, which are the principal fishing grounds for blacklip in Region B. Collectively, these lines of evidence suggest that the blacklip stocks in Region B have weakened over recent years – following about 20 years of apparent stability (Chick and Mayfield 2006; Chick et al. 2007; Stobart et al. 2010). This conclusion was consistent with the outcome (‘red’ risk-of-overfishing category) from applying the harvest strategy to determining the risk that the blacklip stocks in the North Nuyts Archipelago SAU are over-fished.

4.3. Management implications
Most of the available evidence suggests that the abalone stocks in Region B are in their weakest position since the initiation of detailed catch and effort information recording more than 30 years ago. This evidence, primarily current low and declining CPUE, was apparent for both greenlip and blacklip across most of the spatial scales considered and consistent with the harvest strategy which categorised the abalone stock in Region B as
over-fished. This was different to the assessment of stock status in Region B in 2010 which was sustainably-fished.

Data from two, medium-importance SAUs were used in the harvest strategy to determine the stock status of abalone in Region B. Application of the harvest decision rules specify at least a 30% reduction in the contribution from blacklip in North Nuyts Archipelago SAU to the TACC; for greenlip in the South Nuyts Archipelago SAU, the harvest decision rule range is a -10 to +10% change in catch contribution. Given the weak status of stocks in these two SAUs, reductions in catch contributions to the TACC seem appropriate. This is because in the North Nuyts Archipelago SAU the CPUE on blacklip has declined by 58% over the last 5 years while the CPUE on greenlip in the South Nuyts Archipelago SAU has declined by 23% since 2008. In both SAUs, the CPUE in 2011 was among the lowest on record. These reductions would follow recent decisions to (1) decrease the TACC in Region B by 33% between 2010 (41.4 t) and 2011 (27.6 t); (2) reduce the TACC a further 25% between 2011 and 2012 (20.7 t); and (3) close the Region B fishery from October to February (inclusive).

The TACC reductions since 2010 have resulted in catches from Region B comprising about 4% of the total catch from the WZ and 2.5% of the total catch across the SAAF. There are also several high-importance SAUs in Region A of the WZ from which catches exceed the TACC in Region B (Stobart et al. 2012). These suggest the merits of retaining Region B as a separately assessed and managed fishery should be evaluated. However, the two options available – merge Regions A and B thereby creating a unified WZ or retaining Regions A and B as separate fisheries – both require explicit consideration of the current status of the abalone stocks in Regions A and B.

The key advantage of merging Regions A and B is the simplification of assessment and management arrangements for the WZ. There are, however, several risks to this approach. Firstly, there would be a need to establish a TACC for each species in the unified WZ. One approach would be to apply the recently-developed harvest strategy and associated harvest-decision rules across all SAUs, by species, to objectively determine a new TACC. Alternatively, the ratio between greenlip and blacklip catches from Region B (about 62% greenlip; and 38% blacklip since 1992) could be used to apportion species-specific catches for Region B TACC that could be added to the existing greenlip and blacklip TACCs for Region A. This latter approach is more problematic given the weak status of the Region B stocks (this report) and blacklip stocks in Region A (Stobart et al. 2012). Secondly, merging Regions A and B may result in catches being displaced from SAUs in Region B to those in Region A where catch rates are higher and operating costs (e.g. fuel and accommodation) lower. Whilst this would
lead to more rapid increases in the harvestable biomass of abalone in Region B, there is little evidence that the stocks in Region A can support additional catches (Stobart et al. 2012). This is especially the case for blacklip, for which maintenance of the current TACC appears heavily reliant on the redistribution of catches away from several important SAUs, in particular Drummond, Sheringa and Reef Head (Stobart et al. 2012). Nevertheless, if catches from SAUs in Region B were shifted into those in Region A, these changes would be accounted for through subsequent application of the harvest strategy for the fishery. Thus, future WZ TACCs would be adjusted in response to the changing performance of individual SAUs.

The benefits of retaining Regions A and B as separate fisheries include the distribution of fishing effort throughout the WZ which may prevent reefs being underutilised and assist with constraining IUU fishing. However, this approach would likely require the additional cost of separate assessment and management. If separate regions are retained, there are several management options available for addressing the current weak status of the abalone stocks in Region B. These options are not mutually exclusive and include (1) retaining the TACC at 20.7 t for 2013 to enable a more thorough consideration of the effectiveness of the 50% reduction in the TACC since 2010; (2) further reducing the TACC, especially if the provisional 2012 data, available in November 2012, indicate ongoing declines in CPUE; (3) establish species-specific TACCs appropriate to recent catch history and reductions in abundance; (4) closing, or restricting catch from, the favoured mapcodes within the North and South Nuyts Archipelago SAUs to re-distribute catch into remaining mapcodes within Region B; (5) closing Region B; and (6) closing Region B but transferring all, or a portion, of the catch to Region A. Of these, options 1 to 4 have the highest levels of risk as they enable ongoing harvests from stocks exhibiting rapid declines in harvestable biomass. Options 4 and 5 are the most optimistic for recovery of the Region B stocks, though this could require up to a decade (Gorfine et al. 2009). Although the key difference between these is the potential transfer of catch to Region A, there is currently no evidence to suggest that the greenlip and blacklip stocks in Region A could support additional harvests (Stobart et al. 2012).

4.4. Harvest strategy for the Region B abalone fishery

There were several difficulties with implementation of the harvest strategy in Region B. Several of these were also relevant to Region A and are discussed in detail elsewhere (Stobart et al. 2012). First, there were no commercial catch sampling data for determining the proportion of large blacklip abalone harvested in 2011, which is one of the fishery-dependent PIs. The lack of data in 2011 prevented the use of this PI in this
assessment and the sporadic sampling from few licence holders between 2004 and 2008 influences the reliability of the reference period. These problems highlight the need for appropriate sampling – five abalone from every catch-bag, for each species – by all participants to provide adequate estimates for this PI (Burch et al. 2010). If future sampling conforms to this protocol it will (1) substantially improve the validity of the reference period and scores; and (2) eliminate the need to impose a score of -1 for this PI in future assessments where less than 70% of days are sampled. An additional problem with this PI is that values may be influenced by factors other than stock status. For example, a change in market demand towards large or small abalone would result in changes to the value of the PI measuring the proportion of large abalone in the commercial catch. As these changes could also influence CPUE, one option to resolve this problem is the use of information from other sources (e.g. divers, processors) to aid interpretation of these PI scores.

Second, there were several problems associated with the PI related to catch because, to avoid TACC changes driving positive or negative scores for catch, the PI for catch was selected as the proportion of the TACC harvested from that SAU. This means that SAUs from which recent, unusually high proportions of the TACC were harvested are allocated positive scores which can substantially influence the total score for that SAU. For example, in this assessment, a score of 3 was assigned for the catch PI for greenlip in the South Nuyts Archipelago SAU, which resulted in a total score of 0 and a ‘green’ risk-of-overfishing category. This is a more optimistic interpretation of stock status in this SAU than would be derived through a weight-of-evidence approach to interpreting these data. Application of the decision rules enables the catch contribution from this SAU to the TACC to be increased, for which there would be little justification. There are several possible solutions to this problem. Firstly, negative scores could be allocated when the proportion of the TACC harvested from a SAU exceeds the UTRP or ULRP. Secondly, supplementary decision rules could be used that prevent an increase in catch contribution to future TACCs when the score for CPUE is negative. Finally, the catch PI could be scored consistently with the CPUE PI, or on the cumulative scores of remaining PIs. Thus, where the CPUE PI is scored positively (≥ 0), high proportions of the TACC would similarly receive positive scores. Whilst this latter approach appears complicated, it probably provides the most defensible solution.

Third, stock status was determined from two medium-importance SAUs. This limitation arises because Region B comprises about 4% of the TACC in the WZ and, consequently, few SAUs in this Region attain a high or medium importance status. As was the case in the Central Zone (Chick and Mayfield 2012), this compromises the utility
of the harvest strategy for Region B. One potential solution for this would be to change the criterion by which SAUs are assigned importance to increase the number of medium-importance SAUs formally considered by the harvest strategy. This would ensure that the determination of stock status was based on data that were more representative of the fishery. However, under this model data limitations may increase the proportion of SAUs assessed as uncertain. Despite these problems, the outcome from applying the harvest strategy to determine the stock status of abalone in Region B in this report – over-fished – was generally consistent with the weight-of-evidence assessment used in previous assessments for this stock (Chick et al. 2007; Stobart et al. 2010).

4.5. **Future research needs**

As the harvest strategy for the SAAF has only recently been established its use, over time, will (1) continue evaluation of the harvest strategy’s suitability; (2) identify limitations and potential improvements for when the harvest strategy is reviewed; and (3) facilitate the management decision process. It would also be beneficial to test the performance of the harvest strategy using a management strategy evaluation approach.

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 because 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). In addition, abalone assessments in Region B may also benefit from (1) continued validation of historical greenlip grade data in the SARDI catch and effort database; (2) standardising catch rates; (3) improved estimates of the magnitude and trends in IUU catch; and (4) assessment of the direct and indirect effects of commercial harvest on the ecosystem.
5. REFERENCES


Figure A1.1. North Nuyts Archipelago (blacklip) and South Nuyts Archipelago (greenlip) SAUs (medium importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr\(^{-1}\)), PropLge, PropG1 and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Black and Green bars describe the data and time over which the reference points were calculated, open bars describe the measures of the PI outside the reference period and orange bars the data and year subject to assessment for each PI, i.e. the score-year.