Fisheries

Western Zone Greenlip Abalone (*Haliotis laevigata*) Fishery

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

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July 2014

Fishery Stock Assessment Report to PIRSA Fisheries and Aquaculture

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EXECUTIVE SUMMARY

This report provides an assessment of the current status of Greenlip Abalone *Haliotis laevigata* (hereafter referred to as greenlip) stocks in the Western Zone (WZ) Abalone Fishery. This is the first assessment of the entire WZ following the merger of regions A and B from 1 January 2014.

This assessment was informed by the harvest strategy in the Abalone Fishery Management Plan (PIRSA 2012) and the traditional, weight-of-evidence assessment. Comparison between these continues to identify several potential improvements to the harvest strategy.

Data spanning two spatial scales were integrated in this assessment: WZ and the spatial assessment units (SAUs) defined in the harvest strategy.

Greenlip comprises 45% of the combined WZ abalone total allowable commercial catch (TACC). Total catches were relatively stable from 1989 to 2009 (average of 79 t meat weight), but 12% lower thereafter.

Catch per unit effort (CPUE) provides a key measure of relative greenlip abundance. The CPUE on greenlip for the WZ has declined from a historic high in 2003 and, in 2013, was similar to that in the 1990s, prior to a substantial increase in greenlip abundance. Fishery-independent (FI) survey densities also suggest greenlip densities at key sites are similar to those in the 1990s.

Based on this evidence, the WZ Greenlip Abalone Fishery has been classified as "**sustainable**" under the national framework for reporting stock status.

The conclusion from the weight-of-evidence approach – "**sustainable**" – differs from the outcome from application of the harvest strategy to determine the WZ zonal stock status which, in 2013, was "**under-fished**". However, the zonal stock status score of 0.56 only marginally exceeded the upper bound (0.5) of the sustainable category. Despite these classifications, there is some evidence that CPUE may decrease further across the WZ and in several SAUs.

Maintenance of the current TACC appears reliant on each SAU yielding greenlip catches of similar magnitude to current levels because there is little evidence that catch can be increased substantially from any SAUs.

Consequently, the WZ greenlip fishery will require careful monitoring, assessment and application of both the harvest strategy and weight-of-evidence methods to determine the suitability of the current and future TACCs.

The stock status classification 'sustainable' is described in Flood *et al.* (2012) as indicating biomass is sufficient to ensure that, on average, future levels of recruitment are adequate and for which fishing pressure is adequately controlled to avoid the stock becoming recruitment overfished.

1. INTRODUCTION

1.1. Overview

This fishery assessment report for the Western Zone (WZ) of the South Australian Abalone Fishery (SAAF; see Figure 1.1) updates previous fishery assessment and status reports for Region A (Chick *et al.* 2006; 2008; 2009; Stobart *et al.* 2011; 2012b) and Region B (Chick and Mayfield 2006; Chick *et al.* 2007; Stobart *et al.* 2010; 2012a) of the WZ. On 19 December 2013, His Excellency the Governor in Executive Council amended various regulations under the *Fisheries Management Act 2007* to amalgamate management of the WZ Abalone Fishery regions A and B to improve the integrity of the quota management system. These regulations were effective from 1 January 2014. The report provides an analysis of fishery-dependent (FD) and fishery-independent (FI) data for greenlip abalone (*Haliotis laevigata*), hereafter referred to as greenlip, in the WZ for the period from 1 January 1968 to 31 December 2013 and is part of the South Australian Research and Development Institute (SARDI) Aquatic Sciences' ongoing assessment program for the greenlip fishery in the WZ. It also includes a formal analysis of the fishery's performance and stock status based on the harvest strategy described in the Management Plan (PIRSA 2012), which determines: (1) the risk that stocks in the high and medium spatial assessment units (SAUs) are overfished; and (2) the zonal stock status. In the discussion, we assess the current status of the greenlip stocks in the WZ comparing the harvest strategy and traditional weight-of-evidence assessments.

The aims of the report are to: (1) document the current status of the resource; (2) identify the uncertainty associated with the assessment; (3) evaluate the new harvest strategy for the fishery; (4) detail the methodology followed to assess the fishery; (5) provide summaries of biological knowledge; (6) describe the recreational and illegal, unregulated and unreported (IUU) fisheries in this zone; and (7) identify future research needs.

The report is divided into four sections. Section one, the introduction, provides: (1) a general overview of the report; (2) the history and a description of the fishery, including the Management Plan and; (3) information on greenlip biology. Section two details the methods used in this assessment. Section three is the results and provides an assessment of FD and FI data for greenlip abalone. Where appropriate, this includes spatial and temporal analyses of catch (tonnes meat weight; t), catch-per-unit-effort (CPUE; kg.hr^{-1} meat weight), 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 greenlip fishery in the WZ. Finally, in Section four, the discussion, uncertainties in the assessment are identified, a synthesis of the information and a summary of the current status of the fishery are provided, the harvest strategy is formally evaluated, and future research needs for the fishery considered.

1.2. History and description of the fishery

1.2.1. *Commercial fishery*

The SAAF has evolved since its inception in 1964. Entrants to the fishery increased in the late 1960s, and exceeded 100 operators 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 reduced to 30 and an additional 5 licences were issued. These 35 licences remained until 2013. From 1 January 2014 removal of one licence in the WZ reduced the total licences to 34. A review of the management history is provided by Shepherd and Rodda (2001) and Mayfield *et al.* (2012), with major management milestones listed in Table 1.1. Summaries of the fishery can be found in Prince and Shepherd (1992), Keesing and Baker (1998), Zacharin (1997), Nobes *et al*. (2004) and Mayfield *et al.* (2012).

Table 1.1. Management milestones in the Western Zone of the South Australian Abalone Fishery.

Date	Milestone
1964	Fishery started
1971	Licences made non-transferable
	Fishery divided into three zones (western, central and southern)
	Minimum legal length (MLL) set at 130 mm for both species
1976	30 Licences remained; 5 additional licences issued
1978	Sub-zones and fishing blocks replaced by map numbers and codes
1980	Licences became transferable
1984	Greenlip minimum legal length amended to 145 mm in the Western Zone
1985	Western Zone divided into regions A and B
	Quota introduced to Region A in the Western Zone (97.75 t blacklip; 97.75 t greenlip)
1989	TACC in Western Zone Region A greenlip fishery reduced to 69 t
1991	Quota introduced to Region B in the Western Zone (9.2 t both species)
1993	Abolition of owner-operator regulation
	TACC in Western Zone Region B increased to 11.5 t
1994	TACC in Western Zone Region B increased to 13.8 t
1996	TACC in Western Zone Region A blacklip fishery decreased to 86 t
1997	Management Plan implemented (Zacharin 1997)
	TACC in Western Zone Region A blacklip fishery increased to 97.75 t
2004	Management Plan reviewed (Nobes *et al.* 2004)
2006	TACC in Western Zone Region A greenlip fishery increased to 75.9 t
2010	TACC in Western Zone Region A blacklip fishery decreased to 92 t
	TACC in Western Zone Region A greenlip fishery decreased to 69 t
2011	TACC in Western Zone Region B fishery decreased to 9.2 t
2012	New management plan including harvest strategy
	TACC in Western Zone Region B fishery decreased to 6.9 t
2013	TACC in Western Zone Region A blacklip fishery decreased to 87.4 t
2014	Regions A and B merged, One licence removed from WZ
	TACC in Western Zone greenlip fishery increased to 73 t, blacklip fishery decreased to 84.1 t

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 meridian of longitude 136º 30' East (Figure 1.1). This zone was further subdivided into Region A and Region B in 1985, a process that has been reversed in 2014. The fishing season extends from 1 January to 31 December each year. The only exception was a voluntary closure that took place in Region B from October to February, starting from October 2011 and remaining in place in 2012 and 2013.

To monitor catches and facilitate compliance with quota limits, fishers must complete a 'Catch and Disposal Record' 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 from 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 Fisheries and Aquaculture (hereafter referred to as PIRSA).

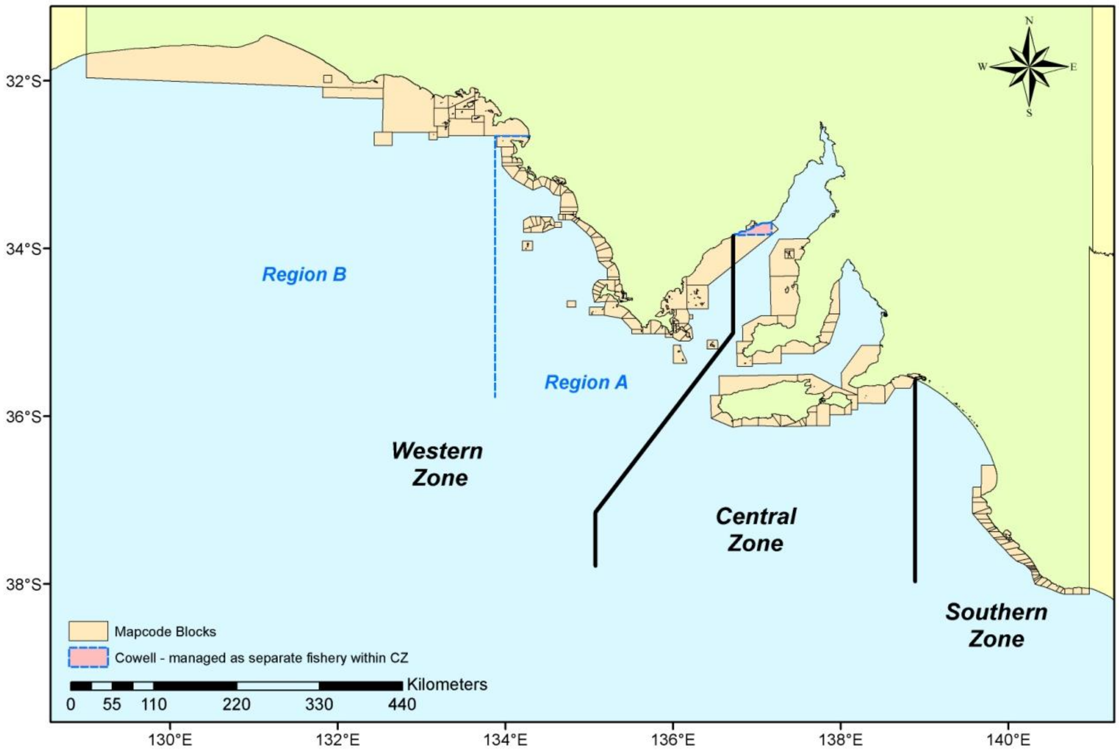

Figure 1.1. Fishing zones of the South Australian Abalone Fishery.

In Region A, annual Total Allowable Commercial Catches (TACCs) were introduced for greenlip in 1985 and amended to the calendar year fishing season from 1989 (Nobes *et al.* 2004). The TACC for greenlip in Region A was 69 t meat weight from 1989 to 2013, with the exception of a 6.9 t (10%) TACC increase from 2006 to 2009 (75.9 t) to take advantage of increased legal-sized abundance, likely a consequence of strong recruitment in the 1990s (Stobart *et al.* 2011). In Region B, both greenlip and blacklip

(*Haliotis rubra*) were included under a single annual TACC that was introduced in 1991 (Nobes *et al.* 2004). The TACC for Region B was 9.2 t (meat weight) from 1991 to 1992, 11.5 t in 1993 and 13.8 t from 1994 to 2010. The TACC was reduced by 4.6 t (33%) in 2011, and a further 2.3 t (25%) between 2011 and 2012.

Since 1997, the fishery has operated under the control of formal management plans (Zacharin 1997; Nobes *et al.* 2004; PIRSA 2012). These plans encourage management 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 greenlip in 1971 and amended to 145 mm SL in 1984, whereafter it has remained unchanged (Table 1.1).

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

Management strategy	Western Zone management arrangements
Licence holders	22
Target species	*Haliotis rubra* (blacklip) & *H. laevigata* (greenlip)
Minimum legal length	Blacklip 130 mm SL & Greenlip 145 mm SL
Quota year	1 January to 31 December
Quota transferability	Yes
Other species permitted	*H. roei*, *H. scalaris*, *H. cyclobates* when SL >130 mm
Method of capture	By hand – dive fishery
By-catch	Negligible

1.2.2. *Economic importance of the commercial fishery*

Econsearch provides an annual assessment of the economic performance of the SAAF as required by the Minister for Agriculture, Food and Fisheries to meet the obligations of Section 7 of the *Fisheries Management Act 2007* (Paterson *et al.* 2013). Catch value (gross value of production) in the fishery increased rapidly between 1997/98 and 2000/01, but fell in subsequent years associated with a decline in the price of abalone linked to a drop in the value of the Australian dollar (Paterson *et al.* 2013). In spite of the decrease in product value, in 2011/12 the SAAF was estimated to contribute $49.5 million to the South Australian economy and generated 316 full time jobs directly and indirectly.

Paid labour, which accounts for the largest share of total cash costs to the SAAF, decreased by 13% between 2010/11 and 2011/12 (Paterson *et al.* 2013). Other major costs include interest, management costs and fuel. The average annual cost of management per licence holder has remained relatively stable since 2004/05 and, in 2011/12, was $70,102. In contrast, there was a large (29%) increase in fuel and interest costs between 2010/11 and 2011/12.

1.2.3. *Recreational fishery*

The total recreational greenlip abalone catch in South Australia was estimated at 3,462 individuals for the 12 month period from November 2007 to October 2008 (Jones 2009). Of these, an estimated 49% (1,696) were caught in the WZ and equate to 237 kg meat weight (based on average weight of 140 g per abalone).

1.2.4. *Illegal, unregulated and unreported catch*

Quantifying illegal, unregulated and unreported (IUU) catch is difficult. PIRSA Fisheries and Aquaculture rely on field observations and intelligence reports to estimate a quantity of IUU catch. During 2013, PIRSA Fisheries and Aquaculture received 67 intelligence reports relevant to the Western Zone. One intelligence report, considered likely to be true, was higher than average and identified 1700 kg of illegally taken greenlip abalone. The remaining intelligence reports averaged 30 kg per report. Applying this average (30 kg.report^{-1}) to 66 intelligence reports provides an estimated 1980 kg of illegally taken abalone. It can therefore be inferred 3.68 t (meat weight) has been removed illegally from the Western Zone, which is equivalent to 2% of the TACC. It should be noted that PIRSA is not informed of all instances alleging illegally taken Abalone and, as such, the 3.68 t is a conservative estimate of the extent of IUU within the Western Zone during 2013.

1.3. Management plan

The second management plan for the SAAF (Nobes *et al.* 2004) was reviewed and replaced in 2012 (PIRSA 2012; see Table 1.1). The third management plan stipulates the management goals and objectives for the fishery that reflect current policy drivers including Section 7 of the *Fisheries Management Act 2007,* Ecologically Sustainable Development as described in the *Environmental Protection and Biodiversity Conservation (EPBC) Act 1999* and the precautionary principle.

The four management goals of this management plan are to ensure: (1) the abalone resource is sustainably harvested; (2) optimal economic utilisation and equitable distribution of the abalone resource; (3) impacts on the ecosystem are minimised; and (4) cost effective and participative management of the fishery. This report is directly relevant to the first goal, for which the objectives are to: (1) maintain the stocks above ecologically sustainable levels; and (2) ensure sufficient data and information are available to undertake the harvest strategy which underpins the management decisions.

The harvest strategy is the primary tool used to achieve the goal of sustainably harvesting the abalone resource and is well described elsewhere (King 1995; Chick and Mayfield 2012; PIRSA 2012; Stobart *et al.* 2012a; 2012b; Mayfield *et al.* 2013). Briefly, it is species-specific and spatially-explicit, with SAUs as the spatial scale at which monitoring and assessments are undertaken (Figure 1.2) and comprises two key components. First, performance indicators (PIs) are used with a series of reference points to determine the risk that the stocks in each SAU are overfished. Subsequently, the assigned risks that the stocks are overfished are catch-weighted and summed to determine the status of that stock for each zone.

These outcomes are used in the 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. The range of management decisions for each SAU is constrained by explicit decision rules based on the assigned risk-of-overfishing category. These harvest-decision rules guide determination of future catch contributions from each SAU in the fishery, that are then summed by species for each zone and used to adjust annual TACCs.

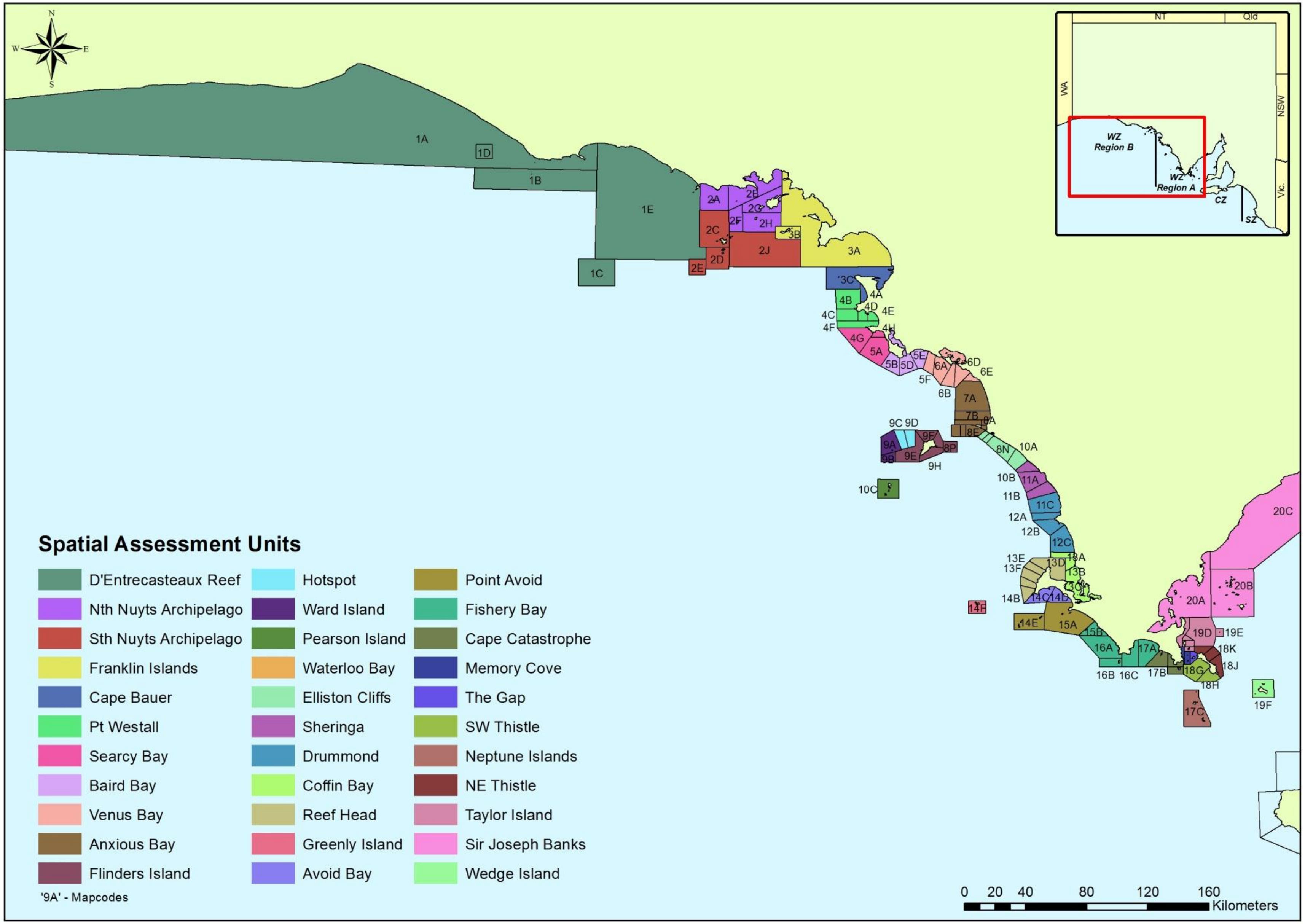

Figure 1.2. Spatial assessment units (SAUs) and map codes of the Western Zone South Australian Abalone Fishery.

1.4. Greenlip biology

Greenlip are contiguous throughout southern Australia, with their distribution ranging from Flinders Island (Tasmania) to Cape Naturaliste (Western Australia). They commonly inhabit the edge of reefs and boulders near sand or seagrass (5 to >30 m depth) and occur in clusters of local populations, separated from other similar clusters over a range of spatial scales. This pattern of disaggregated spatial distribution is reflected in the population genetics, with clusters representing putative 'metapopulations' (Shepherd and Brown 1993; Morgan and Shepherd 2006; Mayfield *et al.* 2014). Greenlip have separate sexes with size at sexual maturity varying substantially among areas. The length at which 50% of individuals are sexually mature (L_{50}) in the WZ varies between 77 mm (Anxious Bay, 2005) and 128 mm SL (Ward Island, 2006; Appendix 1, Table A1.1). The relationships between length-fecundity (Appendix 1, Table A1.2), whole weight-fecundity (Appendix 1, Table A1.3) and length-weight (Appendix 1, Table A1.4) for greenlip in the WZ are generally well established. Spawning is seasonal and synchronised to take place during summer and early autumn around the new moon (Shepherd and Laws 1974; Keesing *et al.* 1995; Rodda *et al.* 1997), with the annual spawning cycle probably driven by fluctuations in water temperature (Shepherd and Laws 1974). Fertilisation success is strongly influenced by adult density (Babcock and Keesing 1999), therefore reducing population density to a low level (termed the Allee effect) may seriously reduce fertilisation success and subsequent recruitment (Shepherd and Edgar 2013).

Duration of the larval stage typically ranges between 5 and 10 days and is predominantly determined by water temperature. Larvae are lecithotrophic and dispersal distances are strongly influenced by larval behaviour and local hydrodynamics (Prince *et al.* 1987). Recruitment may vary widely from year to year and the relationship between stock size and subsequent recruitment is uncertain (Prince *et al.* 1988; Shepherd 1990; Shepherd *et al.* 1992c). Recently settled greenlip abalone prefer encrusting coralline algae (Shepherd and Turner 1985; Shepherd and Daume 1996) that provide an important source of food, and protection from predation (Shepherd and Cannon 1988). Through their ontogeny, the diet shifts from crustose coralline algae in juveniles (individuals 5-10 mm SL) to drift algae in adults (Shepherd and Cannon 1988).

Abalone growth rates are highly variable and largely dependent on water temperature, water movement and the quantity and species of macroalgae available for consumption (Day and Fleming 1992; Zacharin 1997). Initial rates of growth of settled larvae are high and can be length-dependent (Shepherd 1988). Typically, growth rates are described by a von Bertalanffy model (Shepherd and Hearn 1983), although more complex models are being used (Haddon *et al.* 2008). Greenlip growth rates vary considerably in both time and space. Newly settled greenlip grow rapidly, at around 20-30 μm.day^{-1} (Preece *et al.* 1997; Rodda *et al.* 1997). Sub-legal growth rates in the WZ ranged between 15.3 mm and 39.6 mm.yr^{-1} at Yanerbie and Taylor Island, respectively (Appendix 1, Table A1.5). For adult greenlip (> 90 mm SL), growth is non-linear and can be represented by the parameters k (growth rate; yr^{-1}) and L_∞ (asymptotic length; mm SL) from the von Bertalanffy growth curve. Estimates of k ranged from 0.186 yr^{-1} at Sceale Bay to 0.595 yr^{-1} at Waterloo Bay, and L_∞ ranged between 119.5 mm SL (Anxious Bay, 1988) and 213.5 mm SL (Hotspot; 2003) (Appendix 1, Table A1.6).

Small abalone are preyed upon by a range of predators, including fish, crabs, lobsters, starfish and octopus. Adult greenlip reach a refuge size after which they are able to live on exposed surfaces of flat rock. Shells are frequently bored by whelks that then feed on the foot muscle. Boring polychaetes also erode the shells and spire (Shepherd 1973). Adult mortality rates (M) ranged from 0.13 yr^{-1} at Ward Island to 0.40 yr^{-1} at Waterloo Bay (Appendix 1, Table A1.7).

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) following which fishery assessment reports were produced annually between 1998 and 2000 (Rodda *et al.* 1998; 2000; Shepherd *et al.* 1999). 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.* 2003; 2004; 2005; Chick *et al.* 2006). Subsequent fishery assessment and status reports for regions A (Chick *et al.* 2008; 2009; Stobart *et al.* 2011; 2012b) and B (Chick *et al.* 2007; Stobart *et al.* 2010; 2012a) of the WZ have been provided to PIRSA in alternate years. In the most recent reports, rapid changes in greenlip CPUE (Stobart *et al.* 2011; 2012b) and mean daily catch (Stobart *et al.* 2011) over the past decade were identified and these changes were ascribed to an increased abundance of legal-sized greenlip abalone between 2000 and 2008 following elevated, zone-wide recruitment levels in the mid-late 1990s. These changes were not as apparent in Region B, although there was a period of relatively high greenlip CPUE between 1999 and 2004 (Stobart *et al.* 2012a). The 2012 assessment for Region A (Stobart *et al.* 2012b) concluded that: (1) the harvestable biomass was either higher (based on the assumption that catch rates are not hyperstable) or similar to (assuming catch rates are hyperstable) that prior to the recruitment pulse in the 1990s; and (2) catches from five SAUs (Anxious Bay, Flinders Island, Ward Island, Hotspot and Drummond), from which recent catch rates were low or declining, were unlikely to be sustainable. Cumulatively, these five SAUs contributed 40% of the catch over the previous ten years. In 2012, the harvest strategy categorised Region A greenlip as sustainably fished. In contrast, the 2012 assessment for Region B (Stobart *et al.* 2012a) identified that the CPUE across Region B was at the lowest level in the history of the fishery, and was also at, or among, the lowest levels in all SAUs and fishing areas within Region B. In 2011, the harvest strategy categorised Region B as overfished.

2. METHODS

This assessment relies on analyses of fishery-dependent and fishery-independent data for greenlip in the WZ. Fishery-dependent data consists of catch and effort data from 1 January 1968 to 31 December 2013 and weight grade data for the period 1 January 1979 to 31 December 2013 provided by Western Abalone Processors. The fishery-independent data consists of estimates of density derived from timed-swim and lead-line surveys conducted by SARDI periodically at selected SAUs from 1989 to 2013 and 2004 to 2013, respectively. During these surveys, population length-frequency distributions were also obtained at the same locations.

Data were analysed at two spatial scales: (1) the WZ; and (2) spatial assessment units (SAUs) defined in the harvest strategy. For historical reference, catch and effort data are also provided by region (Appendix 2). The importance of each greenlip SAU in the WZ is based on the relative contribution to total catch of abalone 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 to 2013. Three importance categories are defined – high, medium and low – depending on their percentage contribution to total catch. SAUs from which the cumulative catch harvested reaches 50% 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 are classified as low importance.

2.1. Catch and effort

Commercial catch and effort data are collected in the form of daily entries to commercial logbooks submitted to SARDI, allowing spatial and temporal analyses of catch (t, shell weight) and mean CPUE ± standard error (se). Multi-dimensional scaling (MDS) was used to evaluate temporal changes in the distribution of the proportion of catch among SAUs, where proximity between years indicates their similarity. MDS results were further interpreted with similarity percentage (SIMPER) analysis which calculates the percentage each SAU contributes to the difference between each year pair (i.e. which SAUs are contributing most to the differences) and hierarchical cluster analysis (CLUSTER) using complete linkage. CLUSTER aims to find “natural groupings” of years such that years within a group are more similar to each other than samples in different groups.

The mean CPUE was computed by year and season (summer: January-March; autumn: April-June) using the catch-weighted mean of daily CPUE (Burch *et al.* 2011).

Prior to calculation of CPUE, daily data were filtered to remove records likely to be erroneous where either catch was >300 kg, effort was <3 and >8 hours, or the catch rate was >50 $kg.hr^{-1}$. In addition, data where greenlip comprised <30% of catch were also removed. The minimum sample size was 10 fishing records; therefore the absence of data for this measure in any one year indicates fewer records were available.

For historical comparison, mean values of key measures of fishery performance are provided both in text and as dashed lines on graphs. These are: (1) the proportion of the greenlip TACC harvested from each SAU for the 10-yr period between 2004 and 2013 (C_{04-13}); and (2) the mean annual CPUE for the 20-yr period between 1990 and 2009 ($CPUE_{90-09}$). CPUE values whose standard error bars overlap $CPUE_{90-09}$ are considered equivalent to $CPUE_{90-09}$. Ranking and percent of total catch in SAU titles refer first to the ten-year period (C_{04-13}), followed by the value in 2013 separated by a hyphen (e.g. Rank 1-5; 10.1-13.5% had rank 1 and represented 10.1% of the total catch over the 10-yr period and rank 5 representing 13.5% of the total catch in 2013).

2.2. Commercial catch sampling

Weight grade data were used as a proxy for length-structure information, as the proportion of Grade 1 greenlip in the catch (i.e. meat weight ≥230 g; PropG1) is a suitable measure of size to aid the greenlip stock assessment (Mayfield 2010). PropG1 is the sum of Grade 1 weights divided by the remaining catch weight. Prior to calculation of PropG1, all records where the total catch was >1% different from the sum of the three weight-grade categories were excluded, as well as records with zero catch. The minimum sample size for this measure was 10 fishing records, the absence of data for PropG1 indicates this condition was not achieved. For historical comparison, mean values of PropG1 for the 20-yr period between 1990 and 2009 are provided as dashed lines on graphs ($PropG1_{90-09}$).

2.3. Fishery-independent surveys

Greenlip abundance and population size structure were obtained from SARDI fishery-independent (FI) surveys which, in recent years, have been undertaken bienially as part of an overall rationalisation of the research program. The FI information provided includes length-frequency distributions and mean density ± se of legal and sub-legal-sized greenlip. These are primarily obtained from high importance SAUs. In 2014, data were available for the three high importance SAUs. Density was estimated using timed swims (Shepherd 1985) and lead lines (McGarvey *et al.* 2008).

In order to aid the interpretation of the length-frequency distributions, the percentage of large greenlip (LARGE) from FI length-frequency distributions was defined as the ratio of 'large' greenlip (≥ 165 mm SL) to all legal sized (i.e. ≥ 145 mm SL) animals. The percentage of small (SMALL) greenlip was defined as the ratio of 'small' greenlip (< 110 mm SL) to all sub-legal-sized greenlip (i.e ≥ 110 mm to 145 mm SL).

2.4. Harvest strategy

The harvest strategy integrates catch and effort, commercial catch sampling and FI data to determine the risk that individual SAUs are overfished and a zonal stock status. The methodology used to calculate, score and interpret high and medium importance SAU PIs for the harvest strategy is detailed in Stobart *et al.* (2012b) and the Management Plan (PIRSA 2012). In order to carry out WZ calculations for the proportion TACC PI, there was a need to allocate species-specific TACC from Region B. This was done by apportioning catch to greenlip from Region B using the average greenlip to blacklip catch ratio for the ten-year period between 2004 and 2013. While this split was chosen to reflect the recent history of fishing in Region B, alternative split options were also considered. These included: (1) apportioning the TACC to greenlip and blacklip using the 2013 ratio alone; and (2) the ratio for each year. In addition, the harvest strategy was also run using the catch by species for both Region A and Region B, instead of the TACC. While there were some subtle differences between these methods, risk-of-overfishing categories across SAUs and the zonal stock status remained the same in all cases.

2.5. Quality Assurance

Quality assurance systems form an integral part of stock assessments undertaken by SARDI. These systems are designed to ensure high quality project planning, data collection and storage, analyses, interpretation of results and report writing.

2.5.1. *Research planning*

The requirements of PIRSA were discussed in December 2012 and subsequently provided to representatives of the WZ abalone fishery to confirm their understanding of proposed deliverables. This ensures that the research undertaken and deliverables provided are consistent with the needs of PIRSA to meet their obligations under the *Fisheries Management Act 2007.*

2.5.2. *Data collection*

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

2.5.3. *Data entry, validation, storage and security*

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

2.5.4. *Data and statistical analyses*

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

2.5.5. *Data interpretation and report writing*

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

3. RESULTS

3.1. Western Zone

Total catches were relatively stable between 1989, when the Region A TACC was reduced to 69 t, and 2009. Within this period, fluctuations in catch were attributed to the introduction of quota to Region B in 1991 (9.2 t), increases to the Region B TACC in 1993 (11.5 t) and 1994 (13.8 t), fluctuation in the proportion of greenlip caught in Region B and an increase to the Region A TACC that lasted from 2006 to 2009 (75.7 t; Figure 3.1). Subsequently, catch from the WZ decreased by 12.4% between 2009 (82.6 t) and 2013 (72.4 t) following reductions to the Region A TACC in 2010 (69 t) and Region B in 2011 (9.2 t) and 2013 (6.9 t). CPUE generally decreased from 1979 to a historic low in 1985 (15.8 kg.hr^{-1}), after which it remained relatively stable (mean 17.8 kg.hr^{-1}) between 1986 and 1998. From 1998 to 2003, CPUE increased rapidly (32%) to the highest level on record (24.4 kg.hr^{-1}). CPUE declined between 2003 and 2009, remained stable from 2009 to 2012 and declined further between 2012 and 2013. In 2013, CPUE was 18.6 kg.hr^{-1}, 9% below $CPUE_{90\text{-}09}$. The proportion of Grade 1 greenlip in the commercial catch has been above $PropG1_{90\text{-}09}$ since 1997 (Figure 3.1).

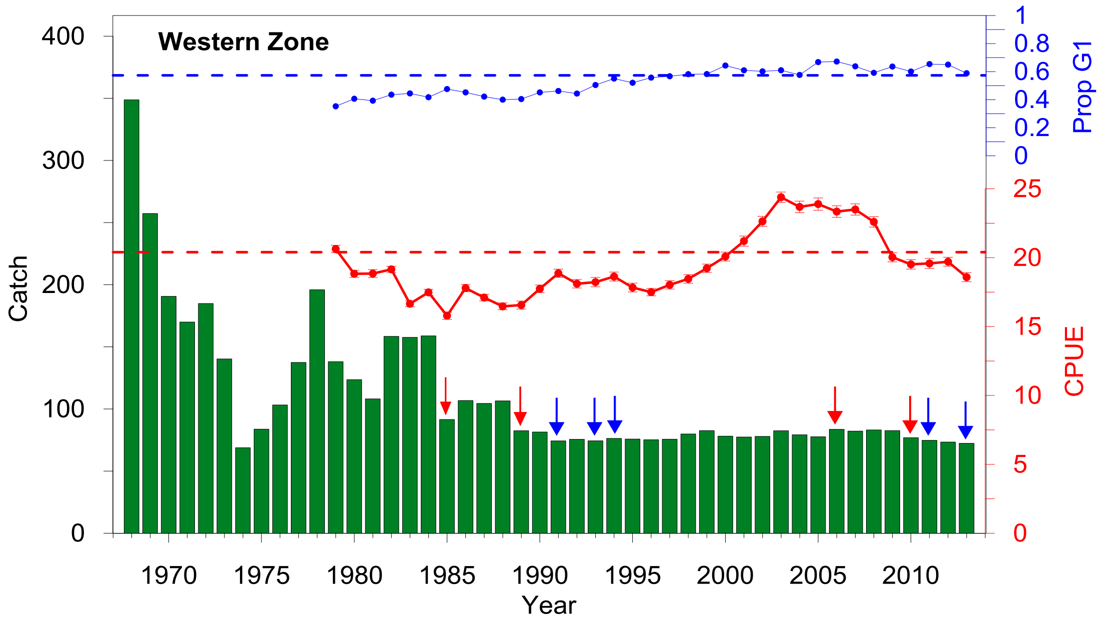

Figure 3.1. Catch (t, meat weight; green bars) of greenlip from the Western Zone from 1968 to 2013. CPUE ± se (kg.hr^{-1}) and PropG1 are shown as red and blue lines, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively. Red arrows indicate implementation (1985) and amendment (1989, 2006 and 2010) of the TACC in Region A. Blue arrows indicate implementation (1991) and amendment (1993, 1994, 2011 and 2013) of the TACC in Region B.

3.1.1. *Within-season distribution of catch and CPUE*

Since 1979, most of the catch has been harvested in summer or autumn (Figure 3.2a). From 1987 to 2004, the percentage of the catch caught in summer increased substantially, with a peak of 66% in 2004. With the exception of a brief increase in 1988

(40%), the percentage of the total catch caught in autumn generally decreased as summer catch increased. More recently, the percentage of catch caught in summer has decreased from 65% in 2006 to 49% in 2013, while autumn catch has increased from 16% in 2007 to 37% in 2013 (Figure 3.2a).

The annual estimates of summer CPUE were generally lower than the estimates for autumn CPUE (Figure 3.2b). This was evident for both the Western Zone (63% of years) and the combined three high importance SAUs (77% of years).

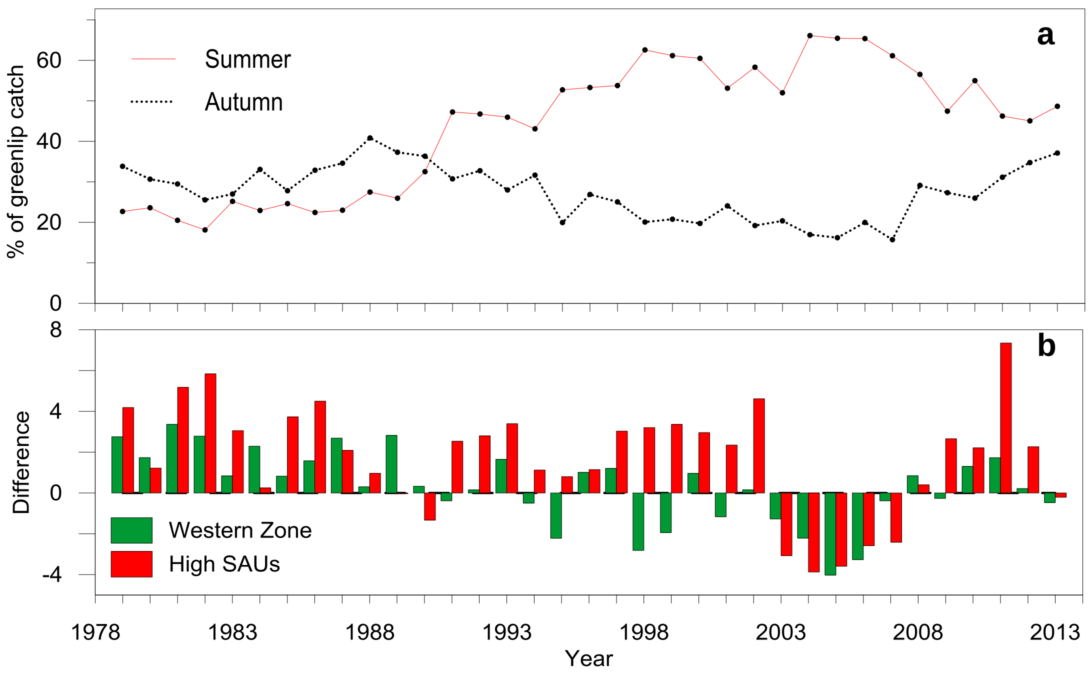

Figure 3.2. a) Within season distribution of greenlip catch (% of total greenlip catch) from the Western Zone from 1979 to 2013; b) Difference between CPUE (autumn CPUE – summer CPUE). Legends indicate a) season and b) spatial scale of CPUE estimate.

3.1.2. *Spatial assessment units*

For the ten year period ending 31 December 2013, there were 11 high and 16 medium importance SAUs in the WZ (Figure 3.3). Of these, 3 high (Anxious Bay, The Gap and Avoid Bay) and 11 medium (Flinders Island, Hotspot, Ward Island, South Nuyts Archipelago, Taylor Island, Point Avoid, Baird Bay, Drummond, Reef Head, Point Westall and Memory Cove) were greenlip SAUs. The only change in importance rating between 2012 and 2013 was for Reef Head and Drummond, for which relatively high catches over recent years have led to a change in their status from low importance in 2012 (Stobart *et al.* 2013a) to medium importance in 2013.

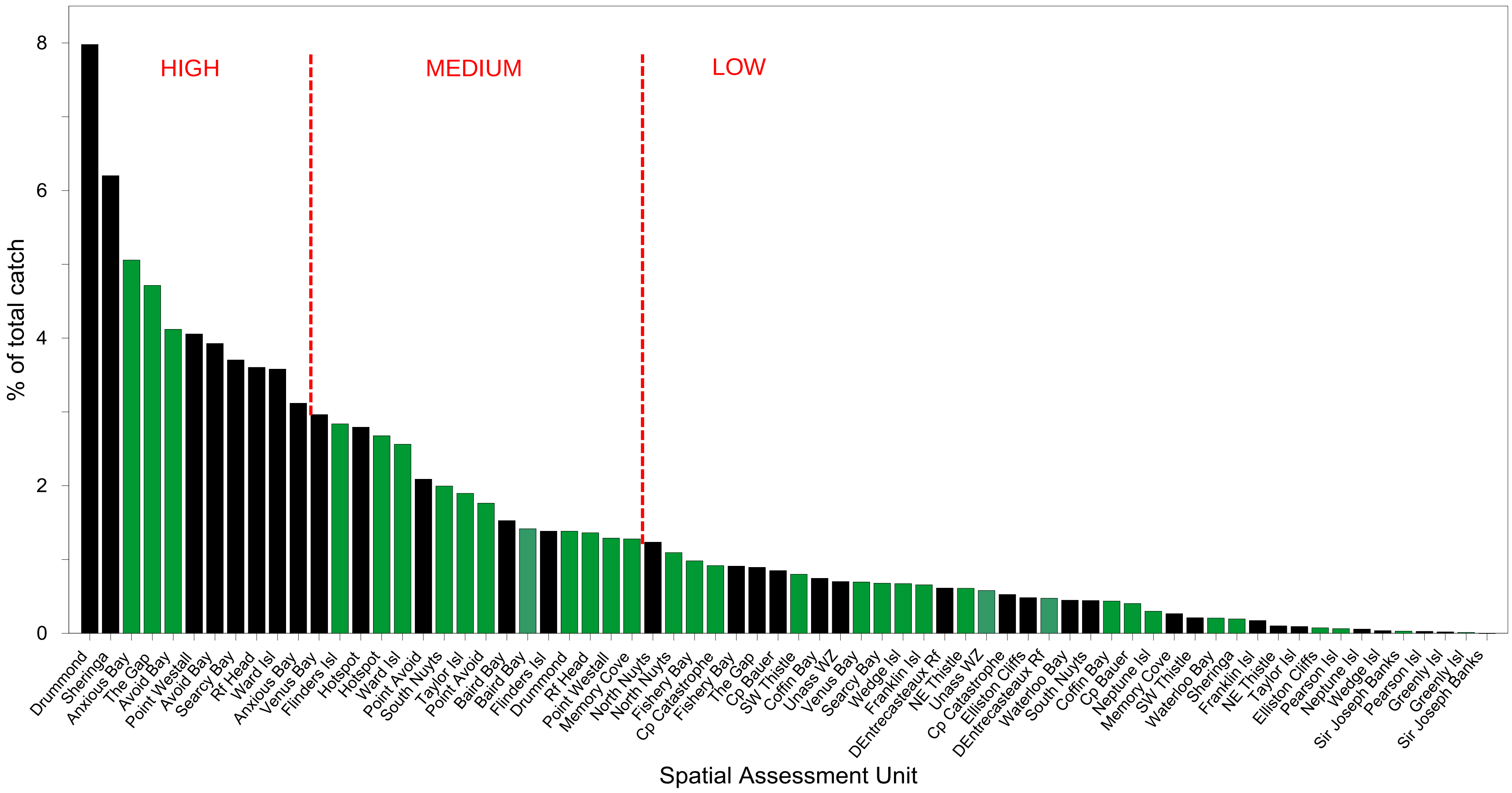

Figure 3.3. Relative importance (ten year % of catch) of each blacklip (black bars) and greenlip (green bars) SAU. Note each SAU is ranked twice, once for blacklip and once for greenlip. Red text and dotted lines indicate SAU importance category and division. Note abbreviations for Cape (Cp), island (Isl), reef (Rf) and unassigned (Unass).

3.1.3. *Distribution of catch among spatial assessment units*

In 2013, SAUs from which more than 5% of the total greenlip catch for the WZ was harvested were Anxious Bay (10.8%), The Gap (10.6%), Reef Head (7.3%), Avoid Bay (6.2%), Drummond (6.0%), Ward Island (5.7%) and Point Avoid (5.4%). Cumulatively, these SAUs represent 52% of the catch. The same SAUs were used to harvest 57% of the catch in 2012, but significant contributions (>5%) from Taylor Island and Flinders Island in 2012 were replaced by Reef Head and Ward Island in 2013. The distribution of catch among SAUs also remained similar between 2012 and 2013, although there were considerable increases at Reef Head (2.6 t; 3.5% to 5.3 t; 7.3%) and decreases at Avoid Bay (6.4 t; 8.7% to 4.5 t; 6.2%), Drummond (6.2 t; 8.4% to 4.3 t; 6.0%) and Taylor Island (6.8 t; 9.3% to 2.3 t; 3.2%).

The MDS plot shows three periods when the distribution of catches among SAUs was similar (*i.e.* 75% similarity; Figure 3.4). The longest period of similarity lasted 20 years from 1990 to 2009. During this period a large proportion of the catch was harvested from the Hotspot and Flinders Island SAUs, and generally changed less abruptly between years (Figure 3.5). Between 2010 and 2013, the distribution of catch among years has been more similar to that obtained between 1986 and 1989, with the spatial distribution of catch in 2013 being most similar to that from 2012 (Figure 3.4). Within the last five years the shift between clusters 2 in 2009 to 3 in 2010 was most strongly influenced by increases in catch from Reef Head, Waterloo Bay, Point Avoid and Anxious Bay, plus decreases in catch from Baird Bay and Ward Island. The small difference between 2012 and 2013 was primarily attributed to increased catch from Reef Head, Neptune Islands and Point Westall, along with decreases from Taylor Island, Avoid Bay and Drummond.

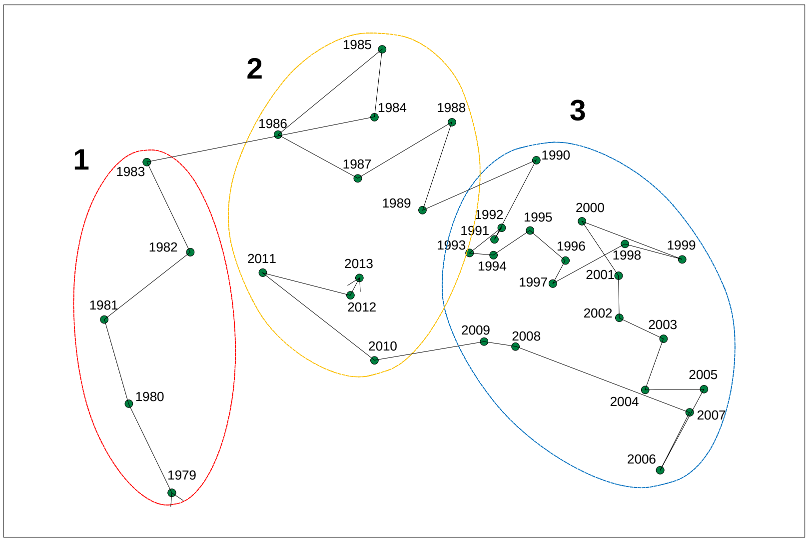

Figure 3.4. Multi-dimensional scaling (MDS) plot for SAUs showing similarity among years based on greenlip catch from the Western Zone from 1979 to 2013. 2D stress = 0.12. Red, orange and blue lines indicate numbered clusters with 75% similarity, labelled 1 to 3.

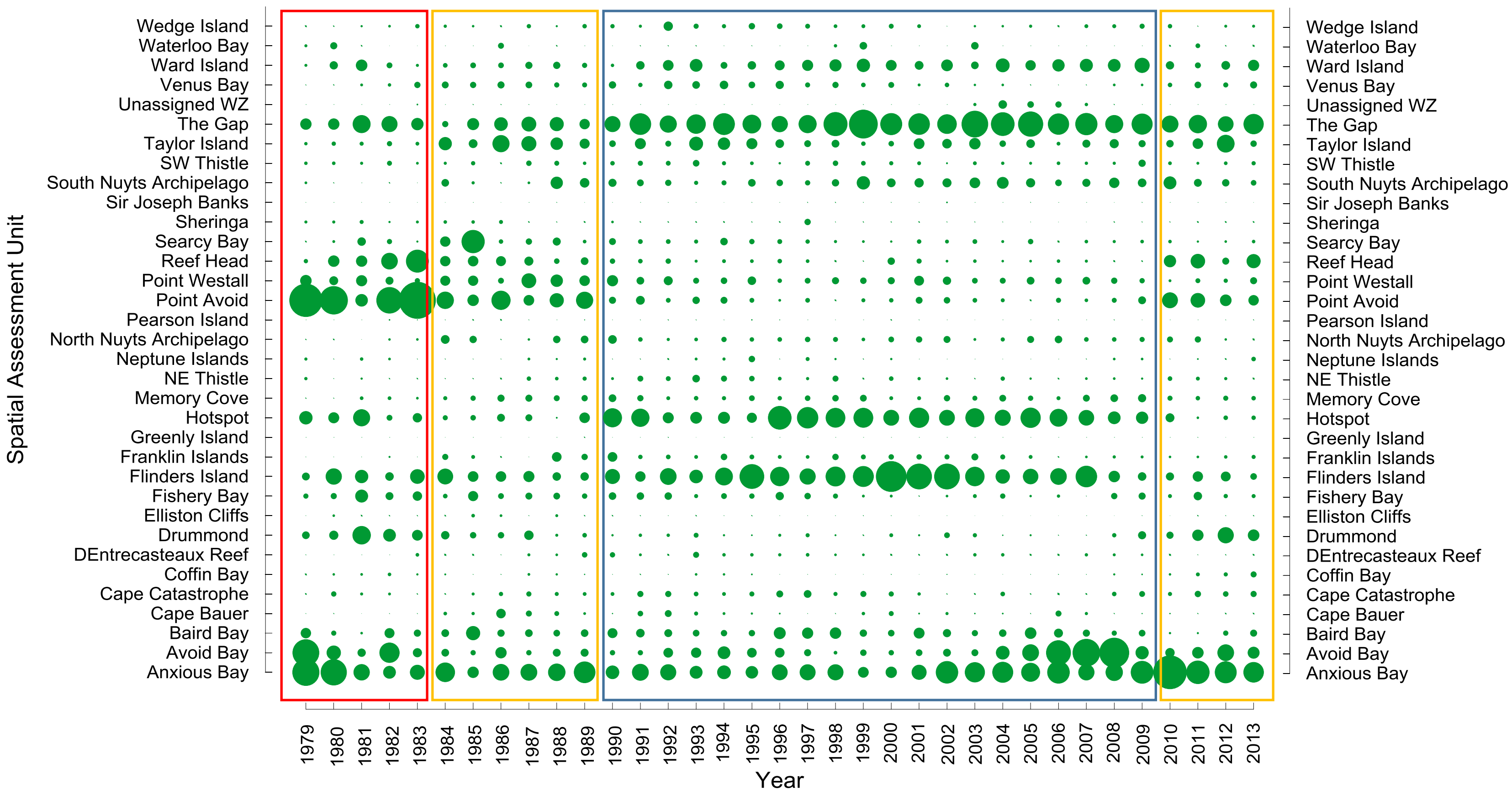

Figure 3.5. Bubble plot showing the spatial distribution of the greenlip catch (% of total catch) among the SAUs in the WZ from 1979 to 2013. Coloured boxes are clusters 1 (red), 2 (orange) and 3 (blue) from the MDS in Figure 3.4.

3.1.4. *Temporal patterns in high importance spatial assessment units*

Anxious Bay (Rank 1-1; 11.4-10.8%)

Anxious Bay has been the most important greenlip SAU in the WZ for the past ten years. With the exception of high catches in 1979 (20 t), 1980 (17 t), 1984 (16 t) and 2010 (14 t), catch has generally ranged from 5 to 10 $t.yr^{-1}$ (Figure 3.6). In 2013, catch was 7.8 t. CPUE increased substantially from 1996 with maxima observed in 2004 and 2008 (~28 $kg.hr^{-1}$). However, CPUE subsequently decreased between 2008 and 2010 (20.7 $kg.hr^{-1}$), to the lowest level in over ten years, 13% below $CPUE_{90\text{-}09}$. CPUE remained low from 2010 to 2013, ranging between 7% and 13% below $CPUE_{90\text{-}09}$. In contrast the PropG1 has exceeded $PropG1_{90\text{-}09}$ since 2005 and, in 2012 and 2013 was the highest and third-highest on record, respectively.

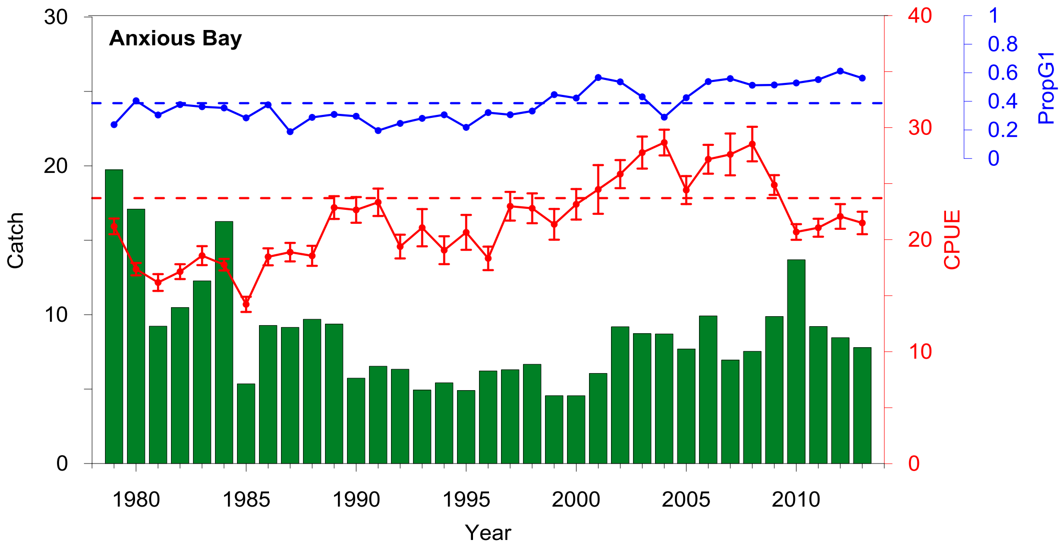

Figure 3.6. Catch (t, meat weight; green bars) of greenlip from Anxious Bay from 1979 to 2013. CPUE ± se ($kg.hr^{-1}$) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

FI surveys at Anxious Bay indicated that the percentage of LARGE greenlip varied between years (range: 22-54%), with the highest percentage recorded in 2013 (Figure 3.7). The percentage of SMALL greenlip was the lowest on record in 2013 (8%) and highest in 2005 (22%) and 2006 (26%). Density of legal-size greenlip halved between 2007 and 2008 and has remained low in 2010, 2012 and 2013, with 2013 the lowest level on record (Figure 3.8). Similarly, the density of sub-legal-sized greenlip decreased consistently between 2004 and 2012, the lowest level on record, remaining at a similar low-level in 2013.

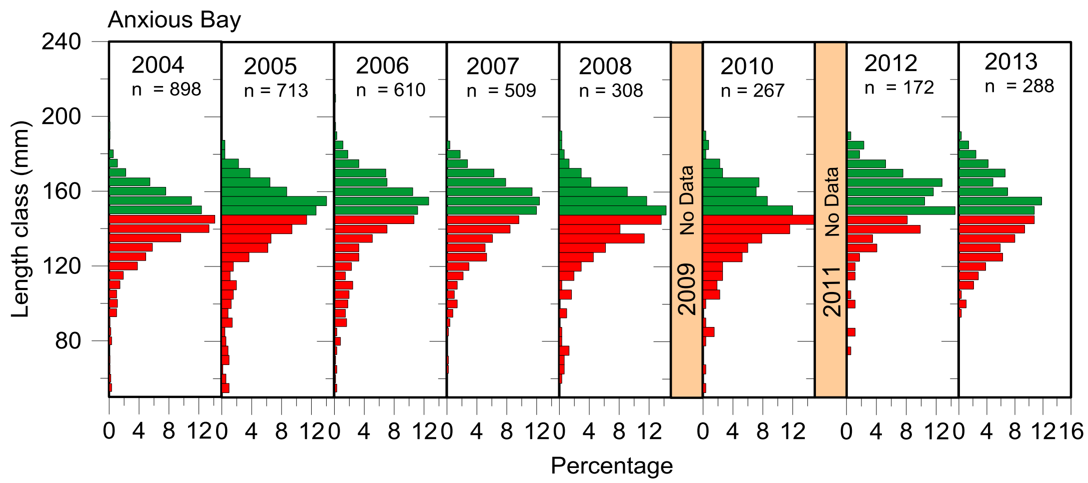

Figure 3.7. Length-frequency distributions of legal-sized (green bars) and sub-legal-sized (red bars) greenlip at Anxious Bay (map-code 8A) observed on fishery-independent surveys from 2004 to 2013. Length classes represent the upper length of each 5 mm bin. n = number of greenlip measured. Bin classes < 50 mm pooled.

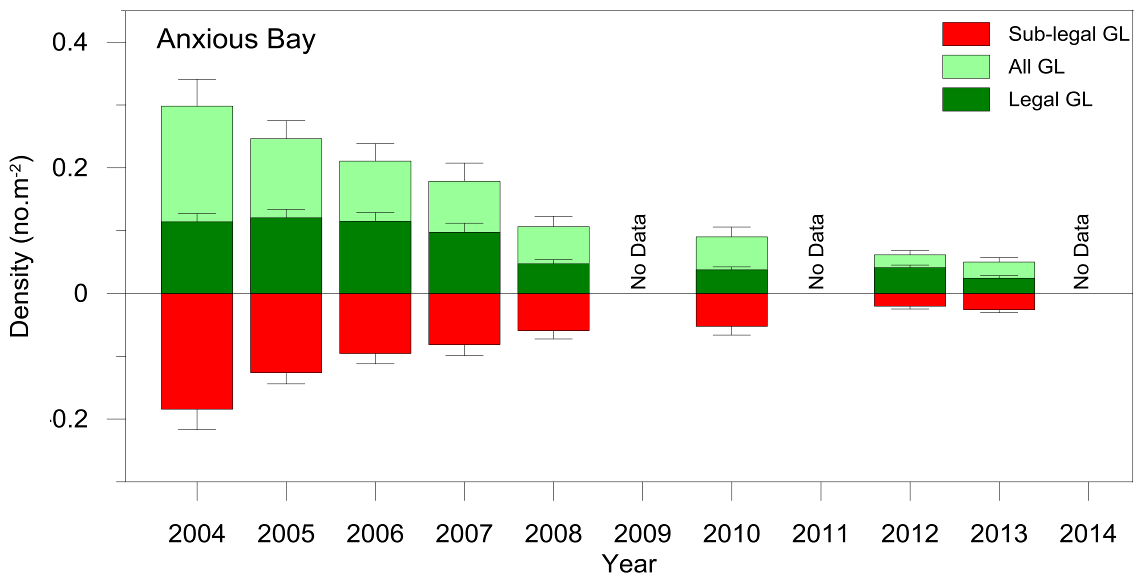

Figure 3.8. Mean density ± se (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) greenlip at Anxious Bay (lead lines; map-code 8A) from 2004 to 2014.

The Gap (Rank 2-2; 10.7-10.6%)

Annual catches from The Gap have gradually declined since the high catches in 1999 (12.6 t) and 2003 (11.6 t; Figure 3.9). However, the catch from this SAU in 2013 (7.7 t) was the highest since 2009 (9.1 t). CPUE was relatively stable between 1979 and 1997 (about 17 kg.hr^{-1}), whereafter it increased to a historic peak in 2005 (26.5 kg.hr^{-1}). Between 2005 and 2010, CPUE declined consistently to the lowest level since 1997 and, from 2010 to 2013, has fluctuated among years. In 2013, CPUE was equivalent to $CPUE_{90\text{-}09}$. The PropG1 in the commercial catch has remained stable and, in 2013 was equivalent to $PropG1_{90\text{-}09}$.

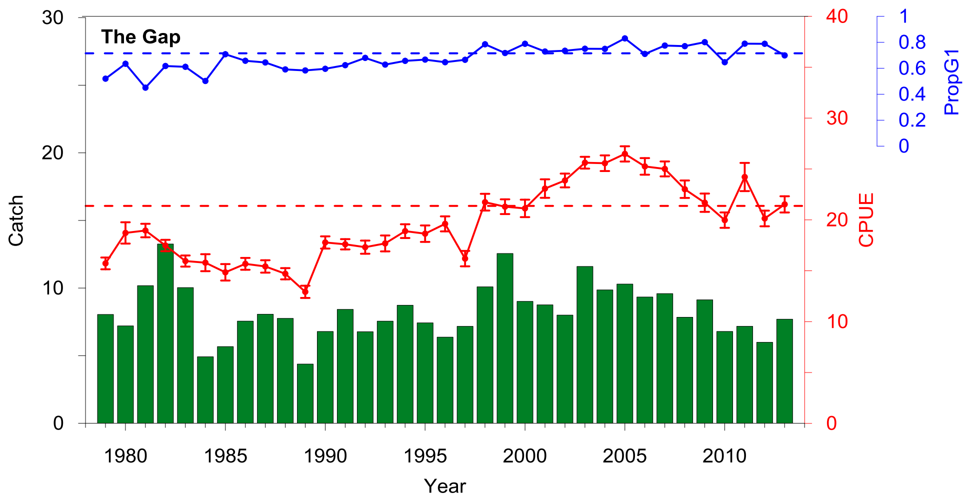

Figure 3.9. Catch (t, meat weight; green bars) of greenlip from The Gap from 1979 to 2013. CPUE ± se (kg.hr^{-1}) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

FI surveys at The Gap indicate that the percentage of LARGE greenlip generally decreased between 2001 (45%) and 2013 (39%), with the highest percentage in 2005 (48%; Figure 3.10). The percentage of SMALL greenlip was variable between years (range 15 to 26%). Densities of legal-sized greenlip were the lowest on record in the early 1990s, increased to the mid-2000s and subsequently declined to an intermediate value by 2009, whereafter density has been stable (Figure 3.11). The density of sub-legal sized greenlip had high but variable values between 1989 and 2007 but has been relatively low during recent surveys in 2009, 2011 and 2013 (Figure 3.11).

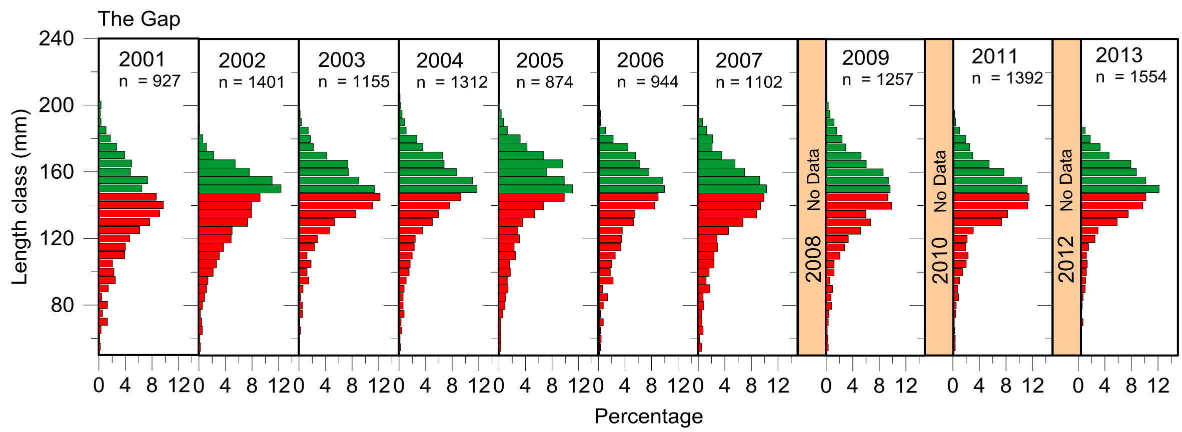

Figure 3.10. Length-frequency distributions of legal-sized (green bars) and sub-legal-sized (red bars) greenlip at The Gap (map-code 18F) observed on fishery-independent surveys from 2001 to 2013. Length classes represent the upper length of each 5 mm bin. n = number of greenlip measured. Bin classes < 50 mm SL pooled.

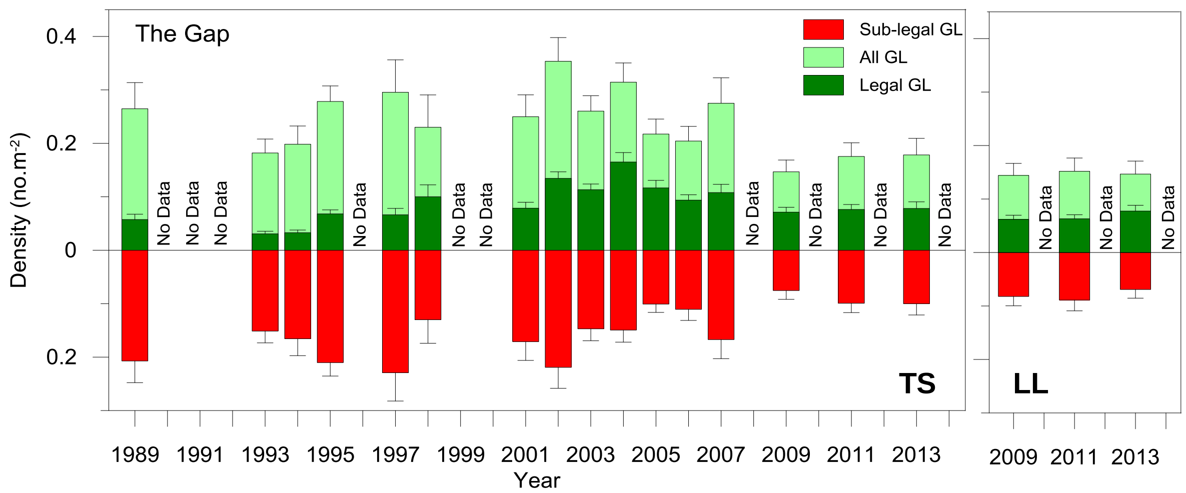

Figure 3.11. Mean density ± se (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) greeenlip at The Gap (timed swims and lead lines; map-code 18F). TS = timed swims from 1989 to 2014, LL = lead lines from 2009 to 2014.

Avoid Bay (Rank 3-4; 9.3-6.2%)

Initial high catches at Avoid Bay in 1979 and 1982 were followed by a sharp decrease to 2.4 t in 1985, whereafter catch was stable at about 3 t.yr^{-1} until 2003 (Figure 3.12). Catches increased fourfold between 2003 (3 t) and 2008 (13 t), subsequently declining but remaining above historic mean levels from 2009 (5.7 t) to 2013 (4.5 t). CPUE has varied considerably among years, but has recently declined from high levels through the mid-2000s to a level similar to $CPUE_{90-09}$ from 2011 to 2013. The PropG1 in the commercial catch has been above $PropG1_{90-09}$ since 2004. However, from 2012 to 2013 PropG1 decreased by 18% and, in 2013 was the lowest in ten years.

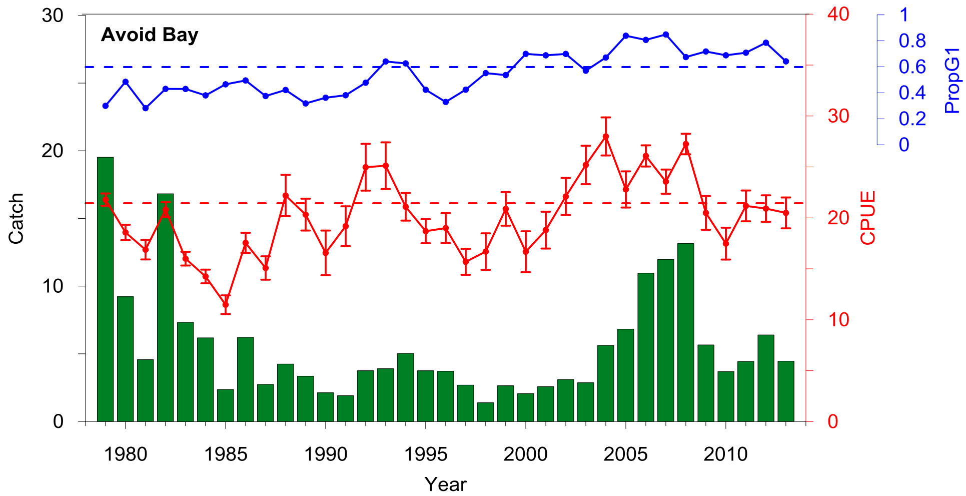

Figure 3.12. Catch (t, meat weight; green bars) of greenlip from Avoid Bay from 1979 to 2013. CPUE ± se (kg.hr^{-1}) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90-09}$ and $PropG1_{90-09}$, respectively.

FI surveys at Avoid Bay began in 2008 and the percentage of LARGE greenlip has remained relatively stable (range: 30-38%; Figure 3.13). In contrast, the percentage of SMALL greenlip has decreased consistently between years from 38% in 2008 to 19% in 2014. Density estimates suggest that the abundance of legal-sized greenlip almost halved between 2008 and 2010, remained low in 2012, and were the lowest level on record in 2014 (Figure 3.14). The density of sub-legal-sized greenlip also reduced between 2008 and 2010, remaining stable thereafter (Figure 3.14).

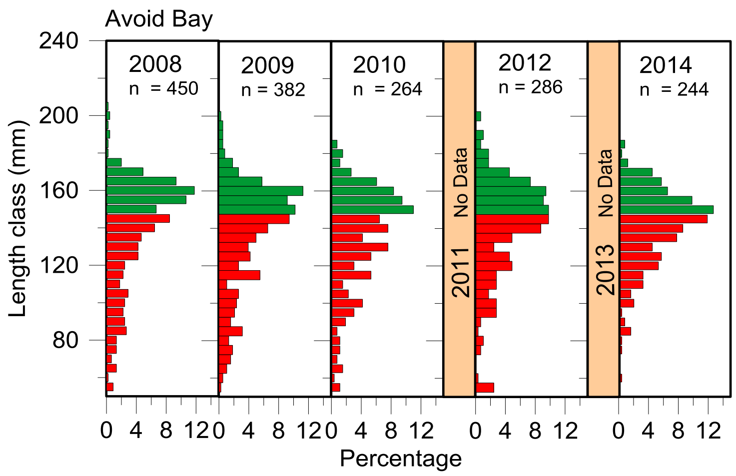

Figure 3.13. Length-frequency distributions of legal-sized (green bars) and sub-legal-sized (red bars) greenlip at Avoid Bay (map-code 14D) observed on fishery-independent surveys from 2008 to 2014. Length classes represent the upper length of each 5 mm bin. n = number of greenlip measured. Bin classes < 50 mm SL pooled.

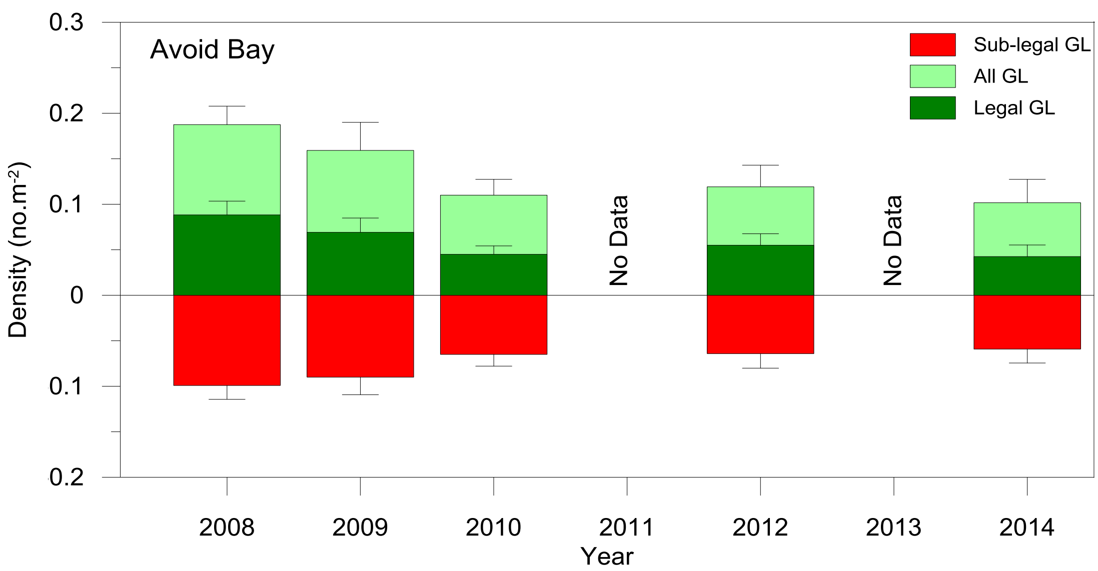

Figure 3.14. Mean density ± se (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) greenlip at Avoid Bay (lead lines; Black Rocks, map-code 14D) from 2008 to 2014.

3.1.5. *Temporal patterns in medium importance spatial assessment units*

Flinders Island (Rank 4-11; 6.4-3.3%)

Catch from Flinders Island has been variable throughout its history, with highest catches in the early 1980s and 2000s (Figure 3.15). With the exception of higher catches in 2007 (9.3 t), catch has generally declined from the second highest recorded catch in 2000 (12.7 t) to the lowest catch on record in 2013 (2.4 t). CPUE declined in the early 1980s to the second lowest value on record in 1985, whereafter it increased to the maximum recorded value of 29.1 $kg.hr^{-1}$ in 2005. From 2005, CPUE has declined and, in 2013, was at the lowest level on record (15.8 $kg.hr^{-1}$). The PropG1 in the commercial catch has varied among years, while remaining stable around $PropG1_{90\text{-}09}$. In 2013, PropG1 was equivalent to $PropG1_{90\text{-}09}$.

Hotspot (Rank 5-18; 6.1-2.1%)

The catch at Hotspot varied among years between 1979 and 1995 and was stable between 1996 to 2006, whereafter it has decreased consistently from 7.8 t in 2006 to the second lowest on record (0.9 t) in 2011, remaining low in 2012 and 2013 (~1.6 t; Figure 3.15). CPUE was mostly high, but variable, between 1979 and 1994 following which, between 1994 and 2010, it was more stable and similar to $CPUE_{90\text{-}09}$ (22.6 $kg.hr^{-1}$). CPUE was relatively high in 2012 (25.7 $kg.hr^{-1}$) and not estimable in 2011 and 2013 due to limited data. The PropG1 of greenlip in the commercial catch declined consistently from 2005 and, in 2012, was 45% below $PropG1_{90\text{-}09}$. PropG1 could not be estimated in 2011 and 2013 due to limited data.

Ward Island (Rank 6-6; 5.8-5.7%)

The annual catch from Ward Island has oscillated on a 5 - 6 year scale ranging from approximately 1 $t.yr^{-1}$ to 6 $t.yr^{-1}$ (Figure 3.15). In 2013, catch was 4 t, equivalent to the historical average. CPUE has fluctuated among years and, in 2013, was 23.4 $kg.hr^{-1}$. This was the highest level since 2005 and 9% above $CPUE_{90\text{-}09}$. However, the PropG1 of greenlip has reduced consistently since 2006 and, in 2013, was 25% below $PropG1_{90\text{-}09}$.

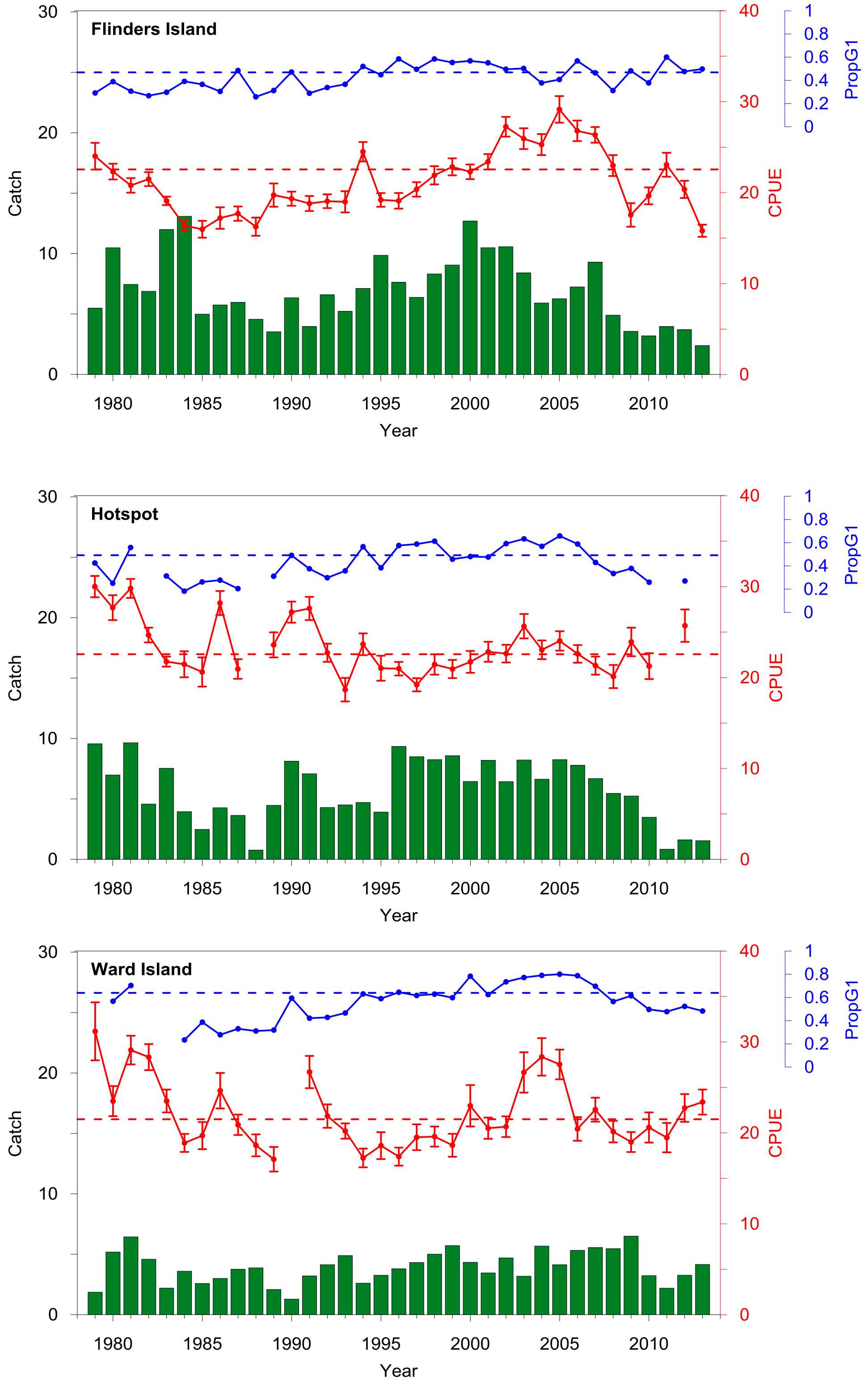

Figure 3.15. Catch (t, meat weight; green bars) of greenlip from SAUs Flinders Island, Hotspot and Ward Island from 1979 to 2013. CPUE ± se (kg.hr^{-1}) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

South Nuyts Archipelago (Rank 7-15; 4.5-2.8%)

Catch has been variable throughout the history of the South Nuyts Archipelago, with highest catches in 1984, 1988, 1999 and 2010 (>5 t; Figure 3.16). The catch harvested from this SAU in 2013 (2 t) was the lowest since 1997. CPUE has varied among years and, in 2013 (18.1 $kg.hr^{-1}$) was 13% above $CPUE_{90\text{-}09}$. The proportion of Grade 1 greenlip in the commercial catch has decreased since 2003 and, in 2013, was 13% below $PropG1_{90\text{-}09}$.

Taylor Island (Rank 8-12; 4.3-3.2%)

With the exception of a period of high catches in the mid to late 1980s and in 2012 (6.8 t), annual catch from Taylor Island has remained relatively stable at about 3.5 t (Figure 3.16). However, catch from this SAU in 2013 (2.3 t) was amongst the lowest on record. CPUE was relatively low between 1979 and 1998, whereafter it increased to a historic high in 2003 (26.2 $kg.hr^{-1}$). Between 2003 and 2012, CPUE has varied considerably while remaining relatively high (Figure 3.16). However, between 2012 and 2013, CPUE decreased by 34% and, in 2013 (15.4 $kg.hr^{-1}$), was the lowest since 1994 and 22% below $CPUE_{90\text{-}09}$. The proportion of Grade 1 greenlip in the commercial catch has fluctuated over the past decade and, in 2013, was 7% below $PropG1_{90\text{-}09}$.

Point Avoid (Rank 9-7; 4.0-5.6%)

Following high catches from Point Avoid in the 1980s, catch was stable at 2 $t.yr^{-1}$ between 1990 and 2009 (Figure 3.16). Between 2009 and 2010 catch almost doubled to 6.4 t, the highest level since 1989, following which it has decreased consistently and, in 2013 was 3.9 t. CPUE has fluctuated among years, with a historic high in 2003 and, in 2013, was equivalent to $CPUE_{90\text{-}09}$. Since 2007, the proportion of Grade 1 greenlip in the commercial catch has declined, but remained above $PropG1_{90\text{-}09}$ and high in relation to previous years (Figure 3.16).

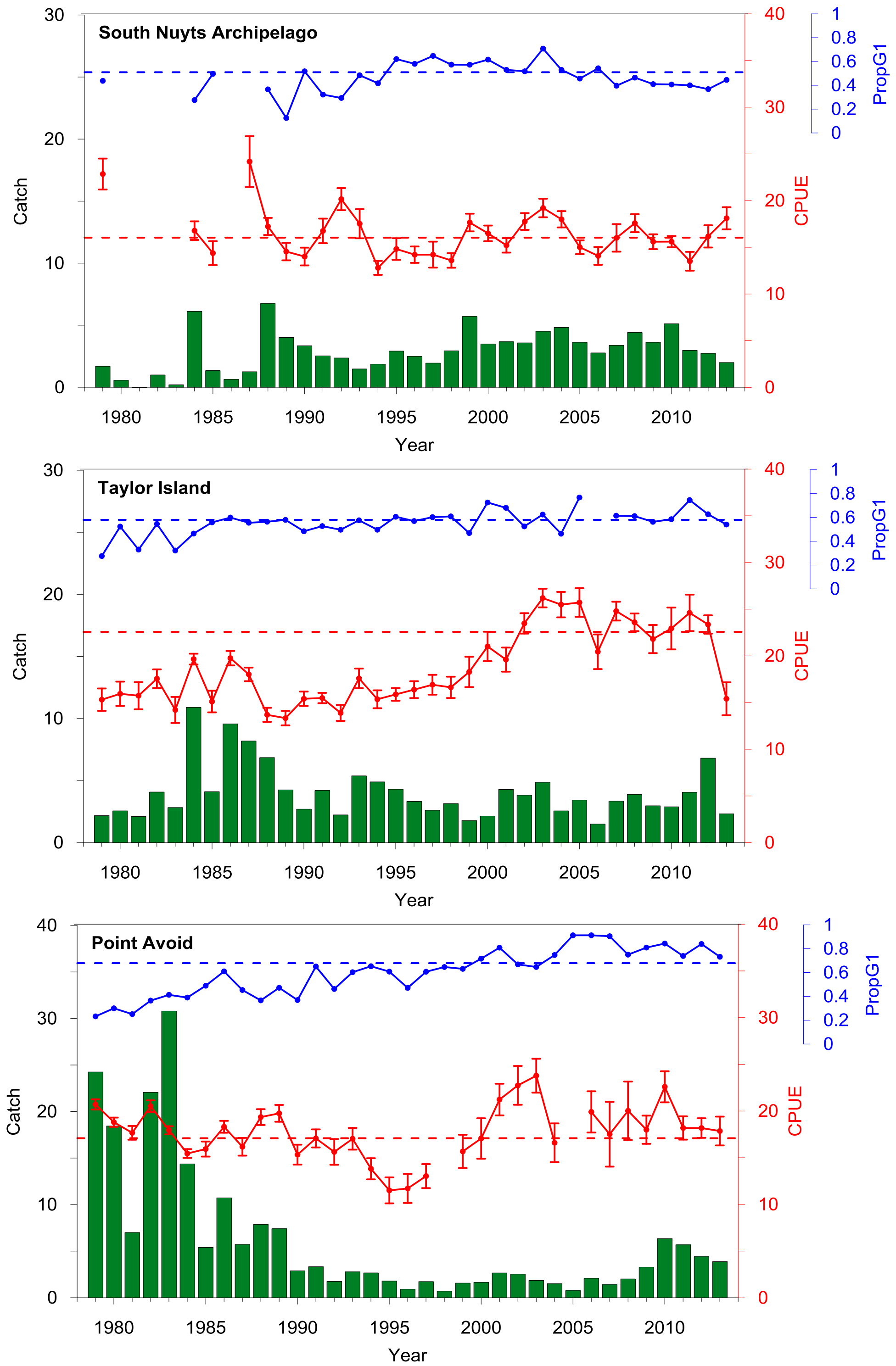

Figure 3.16. Catch (t, meat weight;green bars) of greenlip from SAUs South Nuyts Archipelago, Taylor Island and Point Avoid from 1979 to 2013. CPUE ± se ($kg.hr^{-1}$) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

Baird Bay (Rank 10-9; 3.2-3.5%)

For over 20 years, annual catches from Baird Bay were relatively stable at approximately 3.6 t. However, in 2010 and 2011, the catch harvested from this SAU was substantially smaller and, although increasing, has remained relatively low in 2012 and 2013 (Figure 3.17). CPUE was more variable among years in the 1980s and early 1990s than during subsequent years where it has increased steadily and, in 2013, was amongst the highest on record and 17% above $CPUE_{90-09}$. The proportion of Grade 1 greenlip in the commercial catch has fluctuated among years and, in 2013, was equivalent to $PropG1_{90-09}$.

Drummond (Rank 11-5; 3.1-6.0%)

Initial catches at Drummond were higher from 1979 to 1987, whereafter catch was stable at about 1 $t.yr^{-1}$ until 2008 (Figure 3.17). Catches increased substantially between 2008 and 2012 (6.2 t; the highest level since 1987), and remained high in 2013 (4.3 t). CPUE was relatively low between 1979 and 1989 (about 12 $kg.hr^{-1}$), whereafter the years for which CPUE was estimable suggest it increased to a historic peak in 2009 (22 $kg.hr^{-1}$). CPUE declined between 2009 and 2011, but has since increased and, in 2013, was equivalent to $CPUE_{90-09}$. The proportion of Grade 1 greenlip in the commercial catch remained above $PropG1_{90-09}$ from 2000 to 2010, following which it has declined consistently among years and, in 2013, was 16% below $PropG1_{90-09}$.

Reef Head (Rank 12-3; 3.1-7.3%)

Following relatively high catches from Reef Head throughout the 1980s, along with very high catches in 1982 (14 t) and 1983 (19 t), catch was stable at less than 3 $t.yr^{-1}$ between 1990 and 2009 (Figure 3.17). Catches increased to 5 t or more in 2010, 2011 and 2013. CPUE has varied among years and, in 2013, was 37% above $CPUE_{90-09}$. The proportion of Grade 1 greenlip in the commercial catch was relatively low between 1979 and 1993, wheareafter it increased to a historic high in 2007. PropG1 has reduced since 2007 but, in 2013, remained above $PropG1_{90-09}$ (15%).

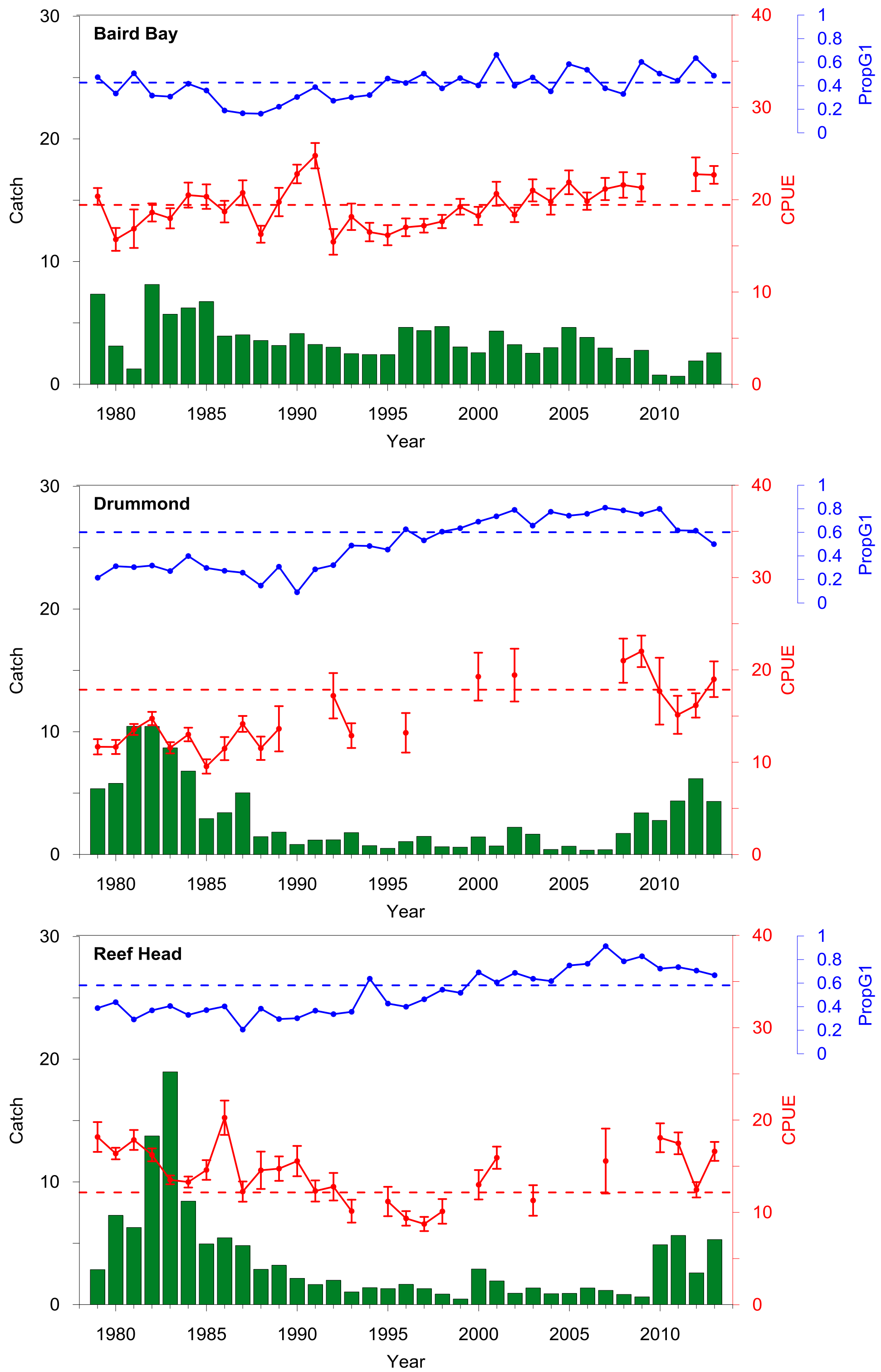

Figure 3.17. Catch (t, meat weight; green bars) of greenlip from SAUs Baird Bay, Drummond and Reef head from 1979 to 2013. CPUE ± se (kg.hr^{-1}) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90-09}$ and $PropG1_{90-09}$, respectively.

Point Westall (Rank 13-10; 2.9-3.5%)

Annual catches at Point Westall were initially high, but more than halved between 1987 and 1991, whereafter they remained relatively stable at about 2.7 t for almost 20 years (Figure 3.18). In 2010, the catch from this SAU was the lowest on record (1.0 t) and remained low in 2011 and 2012, but increased to 2.6 t in 2013. CPUE was variable in the 1980s, followed by a period of relative stability at low levels in the early to mid-1990s. From 1996, CPUE increased, reaching the maximum observed value in 2003 (22.6 $kg.hr^{-1}$). Between 2003 and 2012 CPUE declined but has since increased and, in 2013, was equivalent to $CPUE_{90-09}$. The proportion of Grade 1 greenlip in the commercial catch has oscillated among years and, in 2013 was the second-highest on record and 44% above $PropG1_{90-09}$.

Memory Cove (Rank 14-17; 2.9-2.2%)

Annual catches at Memory Cove have been relatively stable since 1981, ranging between approximately 1 and 4 $t.yr^{-1}$ (Figure 3.18). CPUE increased substantially from a relatively low level between 1981 and 1994 to a historic high in 2007 (27.6 $kg.hr^{-1}$). CPUE has fluctuated but generally declined between 2007 and 2013 and, in 2013, was 16% below $CPUE_{90-09}$. The proportion of Grade 1 greenlip in the commercial catch has been greater than $PropG1_{90-09}$ from 2008, reaching the second highest observed value in 2010. However, between 2010 and 2013 PropG1 has decreased and, in 2013, was equivalent to $PropG1_{90-09}$ (Figure 3.18).

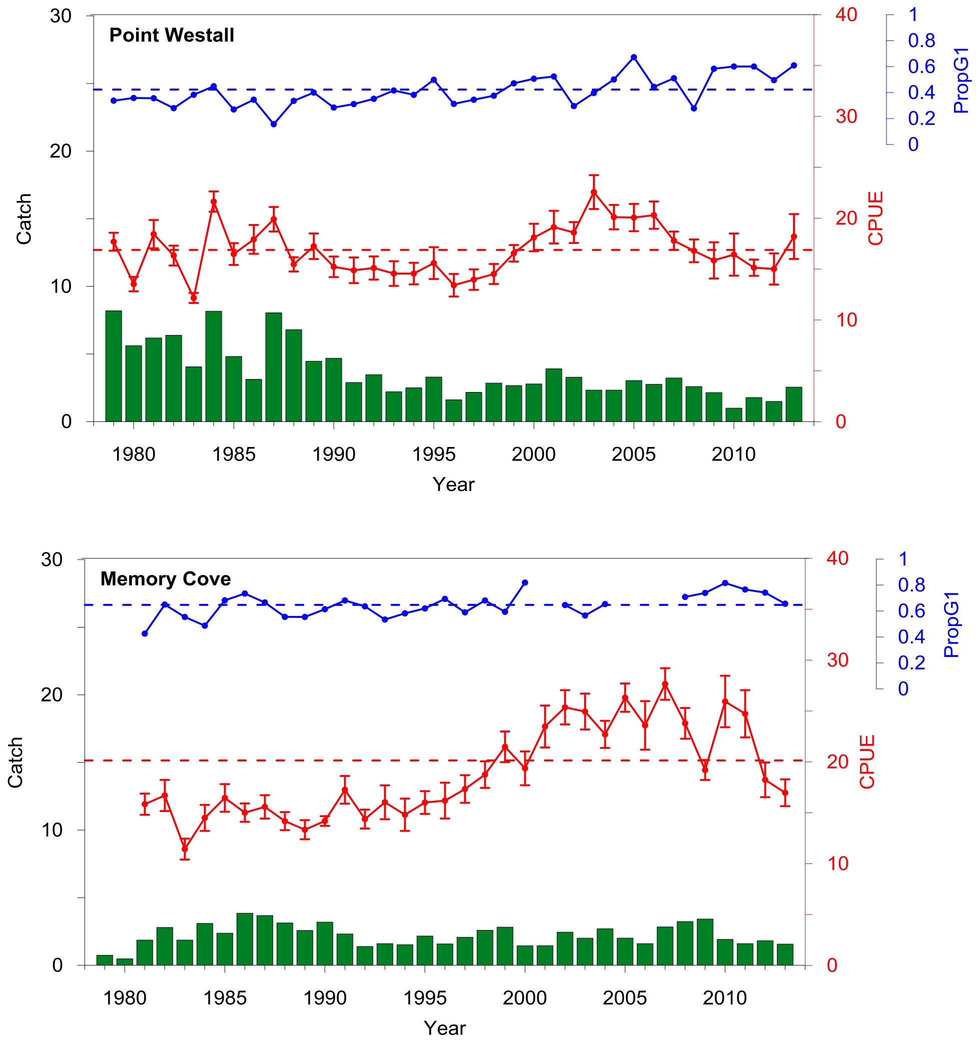

Figure 3.18. Catch (t, meat weight; green bars) of greenlip from SAUs Point Westall and Memory Cove from 1979 to 2013. CPUE ± se ($kg.hr^{-1}$) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

3.2. Risk-of-overfishing in SAUs and zonal stock status

There were three high and eleven medium importance SAUs for greenlip in the WZ in 2013, with all remaining SAUs being of low importance (Table 3.1, Appendix A4). It was possible to determine the risk of being overfished for 13 (93%) of these 14 SAUs. The inability to estimate CPUE on greenlip in one medium importance SAU in 2013 (Hotspot), due to insufficient data, resulted in the greenlip stocks in this SAU being categorised as uncertain (Table 3.1; Appendix A4.4).

Summed PI scores ranged from -10 (Flinders Island) and +10 (Reef Head) with the three high-importance SAUs assigned to a pale blue (Anxious Bay) and yellow (The Gap, Avoid Bay) risk-of-overfishing category (Table 3.1; Appendix A.4). Of the ten assessable medium importance SAUs, four were assigned to a pale blue (Point Avoid, Baird Bay, Drummond and Reef Head), four to a green (Ward Island, Taylor Island, Point Westall and Memory Cove), one to a yellow (South Nuyts Archipelago) and one to a red (Flinders Island) risk-of-overfishing category. Low importance SAUs were not assessed against the PIs. The catch-weighted, zonal score was 0.56, defining a zonal stock status for WZ greenlip of underfished (Table 3.1).

Table 3.1. Outcome from application of the harvest strategy described in the Management Plan for the SAAF against the greenlip fishery in the Western Zone. Grey shading identifies the performance indicators and their respective scores. ND indicates no data**.**

Spatial assessment unit	% contribution to mean total catch (WZ) over the last 10 years (04-13)	Importance	% contribution to catch from high & medium SAU in 2013	CPUE	%TACC	PropG1	Pre-recruit Density	Legal Density	Mortality	Combined PI score	Risk of overfishing	Catch-weighted contribution to zonal score
Anxious Bay	5.1	High	15.28	0	6	7	-3	-4	2	8	2	0.31
The Gap	4.7	High	15.10	0	0	0	-5	0	0	-5	-1	-0.15
Avoid Bay	4.1	High	8.74	0	0	0	0	-1	-2	-3	-1	-0.09
Flinders Island	2.8	Medium	4.69	-2	-8	0	-	-	-	-10	-2	-0.09
Hotspot	2.7	Medium	-	ND	-8	0	-	-	-	Uncertain	Not assigned	-
Ward Island	2.6	Medium	8.15	2	0	-4	-	-	-	-2	0	0.00
South Nuyts Archipelago	2.0	Medium	3.92	2	-1	-5	-	-	-	-4	-1	-0.04
Taylor Island	1.9	Medium	4.53	-1	-1	0	-	-	-	-2	0	0.00
Point Avoid	1.8	Medium	7.60	0	8	0	-	-	-	8	2	0.15
Baird Bay	1.4	Medium	5.02	4	0	3	-	-	-	7	2	0.10
Drummond	1.4	Medium	8.48	0	8	0	-	-	-	8	2	0.17
Reef Head	1.4	Medium	10.40	2	8	0	-	-	-	10	2	0.21
Point Westall	1.3	Medium	5.00	0	0	2	-	-	-	2	0	0.00
Memory Cove	1.3	Medium	3.08	0	0	0	-	-	-	0	0	0.00
North Nuyts Archipelago	1.1	Low		-	-	-	-	-	-	-	Not assessed	
Fishery Bay	1.0	Low		-	-	-	-	-	-	-	Not assessed	
Cape Catastrophe	0.9	Low		-	-	-	-	-	-	-	Not assessed	
SW Thistle	0.8	Low		-	-	-	-	-	-	-	Not assessed	
Venus Bay	0.7	Low		-	-	-	-	-	-	-	Not assessed	
Searcy Bay	0.7	Low		-	-	-	-	-	-	-	Not assessed	
Wedge Island	0.7	Low		-	-	-	-	-	-	-	Not assessed	
Franklin Islands	0.7	Low		-	-	-	-	-	-	-	Not assessed	
NE Thistle	0.6	Low		-	-	-	-	-	-	-	Not assessed	
Unass WZ RG A	0.5	Low		-	-	-	-	-	-	-	Not assessed	
D'Entrecasteaux Reef	0.5	Low		-	-	-	-	-	-	-	Not assessed	
Coffin Bay	0.4	Low		-	-	-	-	-	-	-	Not assessed	
Cape Bauer	0.4	Low		-	-	-	-	-	-	-	Not assessed	
Neptune Islands	0.3	Low		-	-	-	-	-	-	-	Not assessed	
Waterloo Bay	0.2	Low		-	-	-	-	-	-	-	Not assessed	
Sheringa	0.2	Low		-	-	-	-	-	-	-	Not assessed	
Elliston Cliffs	0.1	Low		-	-	-	-	-	-	-	Not assessed	
Pearson Island	0.1	Low		-	-	-	-	-	-	-	Not assessed	
Unass WZ RG B	0.1	Low		-	-	-	-	-	-	-	Not assessed	
Sir Joseph Banks	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Greenly Island	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Sum	**44.2**		**100.0**									
											Zonal Stock Status	**0.56**

4. DISCUSSION

4.1. Information, data gaps and uncertainty in the assessment

Substantial information was available to assess the greenlip stocks in the WZ including: (1) a well-documented history of the management of the fishery; (2) fine-scale, fishery-dependent, catch and effort data, including detailed information on grades; (3) fishery-independent survey data for greenlip population density and size-frequency at eight sites; and (4) biological data. Limited information was also available on recreational and IUU catch. In addition, this fishery assessment report for the WZ provides a quantitative measure of fishery status via the harvest strategy, based on an integrated suite of performance indicators within a risk analysis framework, in accordance with the Management Plan (PIRSA 2012). In 2013, application of the harvest strategy to determine stock status for the WZ was based on 14 SAUs distributed throughout the fishery, thus better representing the fished stocks when compared with other zones that rely on fewer SAUs for the assessment (e.g. greenlip in the Central Zone abalone fishery; Chick and Mayfield 2012).

There were, however, several limitations to this assessment. First, decision rules are applied to the data, designed to exclude outliers from analyses and ensure minimum data standards are applied. In the case of CPUE, decision rules are also used to enable its estimation from data which do not distinguish between effort apportioned to the harvest of blacklip and greenlip within a fishing day. Different methods of estimating CPUE have been examined by Burch *et al.* (2011) who showed that temporal trends in CPUE obtained across methods were highly correlated. Burch *et al.* (2011) recommended that a catch-weighted mean of daily CPUE would be more appropriate to estimate CPUE as it: (1) weights the contribution of each daily catch and effort record to the CPUE estimate on the basis of catch; and (2) can be applied consistently to greenlip and blacklip abalone at multiple spatial scales across the fishery. As a result of these recommendations, catch-weighted mean daily CPUE has been adopted as the standard method for estimation of this statistic since 2012 (Stobart *et al.* 2012b).

Second, while analyses of the catch and effort data provide useful information on the spatial and temporal distribution of catch within individual fishing areas (Chick *et al.* 2006; 2008; Mayfield and Saunders 2008; Mayfield *et al.* 2009), interpreting these patterns is complicated because fishers may move among areas to maintain, or increase, their expected levels of catch for a range of plausible reasons. These could include technological changes in the fishing fleet (e.g. trends to larger or smaller vessels, increased use of motorised dive cages) that may restrict or increase the number of access points along the coast, increasing fishing efficiency (effort creep), market demands for particular product types (e.g. smaller or larger size abalone), changes in diver demographics, diver preference and habit, convenience, rotation of fishing grounds by divers and changes in abalone abundance. Therefore, while we use CPUE to assess stock status, based on the assumption that changes in this measure reflect changes in the relative abundance of the fishable stock (Tarbath *et al.* 2005), we note CPUE can be strongly influenced by numerous factors that may be unrelated to, or lag, changes in abundance (see Stobart *et al.* 2013). Briefly, while this measure is often viewed as a biased index of relative abundance (Harrison 1983; Breen 1992; Prince and Shepherd 1992; Gorfine *et al.* 2002) because catch rates in dive fisheries can be hyperstable (Shepherd and Rodda 2001; Dowling *et al.* 2004), decreases in CPUE in abalone fisheries are generally considered to be a reliable indicator of declines in abalone abundance, particularly where effort is consistently applied (Tarbath *et al.* 2005).

Third, inter-annual differences in the timing of fishing may influence CPUE as daily catch rates on greenlip are generally higher in autumn when individual abalone weigh more and “bleed” less (Stobart *et al.* 2013b; Figure 3.2). However, interpretation of seasonal effects on annual CPUE require further evaluation because of the potential strong influences of: (1) small sample sizes in some years; (2) changes in SAUs fished; and (3) changes in spatial and temporal fishing patterns of individual licence holders.

Finally, the accuracy and precision of estimates of IUU catches are unknown, difficult to estimate and may change over time if the level of fisheries enforcement is not constant. This prevents reliable estimates of the total catch and, hence, impedes this assessment. Development of alternative methods for estimation of IUU extractions may reduce this uncertainty. Similarly, current recreational catch is unknown, though it is considered to be very low in the WZ (Section 1.2.2).

4.2. Status of greenlip in the WZ

Greenlip comprises 45% (73 $t.yr^{-1}$) of the combined abalone TACC (i.e. blacklip and greenlip) in the WZ. Total annual catch was relatively stable from 1989 to 2010, despite small inter-annual TACC changes in regions A and B. Since 2010, the WZ TACC has decreased due to a 10% reduction to the Region A greenlip TACC in 2010 and, 33% and 25% reductions to the Region B TACC (both species) in 2011 and 2012, respectively. Overall, these represent a 12.4% decrease in the WZ greenlip catch.

Previous reports used changes in CPUE, the principal relative index of greenlip abundance, as evidence that the abundance of legal-sized greenlip in Region A increased rapidly between the late 1990s and early 2000s, peaked in 2003 (Chick *et al.*

2008; 2009) and then declined, including a sharp decrease from 2008 to 2009 (Stobart *et al.* 2012b). While the pattern was not as strong for Region B, CPUE was also relatively high during the ten-year period from 1999 to 2009, and subsequently declined rapidly (Stobart *et al.* 2012a). The combined WZ CPUE estimates show the same trend. These recent, spatially-consistent, rapid increases and decreases in CPUE between the early 2000s and the present are most likely the result of a widespread, strong recruitment pulse in the mid-1990s that elevated the abundance of legal-sized greenlip 6-10 years later (Stobart *et al.* 2011; 2012b). Similar trends were also evident during the same period for blacklip in the WZ (Stobart *et al.* 2012b) and the Central Zone of the SAAF (Mayfield *et al.* 2010), with long-term FI data for greenlip providing some evidence of elevated recruitment in the mid-late 1990s (Stobart *et al.* 2012b).

It is likely that the rate of reduction in greenlip abundance between 2003 and 2009 abated because the ensuing WZ CPUEs (i.e. 2009 to 2012) were similar. This was important as it suggested abundance had stabilised over the four-year period at a level similar to that in the late 1990s, prior to the period of relatively high abundance. However, between 2012 and 2013 there was a further 6% decline in CPUE, to the lowest level since 1998, indicating a more recent decrease in harvestable biomass. This trend reflected abundance changes in fishing grounds comprising Region A (7% reduction in CPUE between years), rather than those in Region B (10% increase in CPUE between years; Appendix 2). Although the WZ CPUE in 2013 was low in a recent historical context, it remained higher than in the 1980s and was equivalent to the average CPUE for the 10-year period between 1990 and 1999. This suggests greenlip abundance in 2013 was similar to that prior to the likely recruitment event. However, CPUE should be monitored carefully for signs of further decline in future assessments because: (1) the catch rates on greenlip abalone typically exhibit hyperstability in the Western (Shepherd and Rodda 2001; Dowling *et al.* 2004; Stobart *et al.* 2012b) and Central (Chick and Mayfield 2012) zones of the SAAF; and (2) may be positively biased from 2010 as fishing has shifted from summer to autumn, when catch rates on greenlip are generally higher. Notably, the proportion of the greenlip catch harvested during autumn 2013 was the highest since 1988, but was insufficient to prevent the CPUE decreasing from that in 2012. Fishery-independent surveys at Anxious Bay, The Gap and Avoid Bay also show a decline in abundance from the mid-2000s that abated from 2009-2010 onwards. In addition, the most recent density estimates for Anxious Bay in 2013 and Avoid Bay in 2014 indicate there was a further decline in density between years. These changes in density are in agreement with CPUE estimates that suggest the harvestable biomass of greenlip stabilised from 2009 to 2012 but decreased further between 2012 and 2013.

While these recent estimates were the lowest on record, there are no FI data from these sites prior to the high greenlip densities observed across the WZ in the 2000s. The FI data also suggest that the most recent estimates of legal-sized greenlip density, compared with the mean density through the 1990s, were lower at Flinders Island, similar at Hotspot and higher at Ward Island, Point Avoid and The Gap (see Appendix 3; FI survey results from medium importance SAUs). Consistent with the CPUE data, this suggests the harvestable biomass of legal-sized greenlip in 2013 was likely to be similar to that in the 1990s.

Collectively, the spatially-consistent CPUE and FI survey densities provide strong evidence that current legal-sized greenlip abundance is similar to that in the 1990s, that preceded the rapid increase in greenlip abundance during the 2000s. On this basis the WZ Greenlip Abalone Fishery has been classified as "**sustainable**"[1] under the national framework for reporting stock status (Flood *et al.* 2012). However, there is some evidence to indicate a different classification will transpire because in some SAUs: (1) CPUE is either currently low relative to $CPUE_{90\text{-}09}$ and/or declining; (2) PropG1 is low and/or declining (despite ongoing market demand for large greenlip); (3) two of the three high-importance SAUs were allocated a 'yellow' risk-of-overfishing category based primarily on FI data; and (4) there has been wide-spread redistribution of catch from several traditional greenlip fishing grounds (e.g. Hotspot, Flinders Island and Ward Island) to more traditional blacklip fishing grounds (e.g. Drummond, Reef Head and Avoid Bay) over recent years (Stobart *et al.* 2012b) which may not be sustained.

The conclusion from the weight-of-evidence approach – "**sustainable**" – was different to the outcome from application of the harvest strategy to determine zonal stock status, which was "**underfished**" in 2013 for the WZ (Table 3.1), Region A and Region B (Appendix 5). However, the zonal stock status score of 0.56 only marginally exceeded the upper bound of the "**sustainable**" category (i.e. 0.5). The zonal stock status for the WZ did not change between 2012 and 2013 (Appendix 6). The allocation of high positive scores for relatively large catches from SAUs is one of the primary reasons for the different conclusions between these two approaches. For example, the high importance SAU Anxious Bay, that has been the most important SAU for greenlip since 2002, was allocated a 'pale blue' risk-of-overfishing category by the harvest strategy. This outcome was strongly influenced by the PI value for catch, which reflects the higher catches obtained from this SAU during recent years, despite the low CPUE from 2010 to 2013. Similarly, for several medium-importance SAUs (Point Avoid, Drummond and Reef

[1] The stock status classification 'sustainable' is described in Flood *et al.* (2012) as indicating biomass is sufficient to ensure that, on average, future levels of recruitment are adequate and for which fishing pressure is adequately controlled to avoid the stock becoming recruitment overfished.

Head), recent substantial catch increases over the last 4-5 years have also resulted in allocation to a ‘pale blue’ risk-of-overfishing category. Application of the harvest-decision rules to a 'pale blue' risk-of-overfishing category allows up to a 50% increase in the catch contribution from these SAUs to the TACC, based on mean catch over the last four years (i.e. 2010-2013). For Anxious Bay, given that: (1) current catches are relatively high; (2) CPUE is 9% below $CPUE_{90\text{-}09}$; and (3) the density of legal-sized greenlip halved between 2007 and 2009 and has remained low since, an increased catch contribution to the TACC from this SAU would be difficult to support. This is also the case for the Point Avoid (current CPUE equivalent to $CPUE_{90\text{-}09}$), Drummond (current CPUE equivalent to $CPUE_{90\text{-}09}$; PropG1 decreasing) and Reef Head (PropG1 decreasing) SAUs.

In summary, there is strong evidence that the harvestable biomass of greenlip in the WZ has declined substantially over recent years following a zone-wide recruitment event that increased greenlip abundance above historical levels for approximately seven years from 2002 to 2008. Most of the evidence indicates that the current legal-sized greenlip abundance is likely to be equivalent to that observed in the late 1990s, prior to the extended period of elevated abundance. There have also been substantial changes to the spatial distribution of catch among SAUs over recent years due to re-distribution of catch into non-traditional fishing grounds from some traditional fishing SAUs such as Flinders Island, Hotspot and Ward Island. As there is no evidence that catches from these three SAUs can be increased, maintenance of the current TACC appears reliant on the three high-importance SAUs (for which two were assigned a yellow risk of overfishing category) and the less-traditional greenlip fishing grounds of Drummond, Reef Head and Point Avoid which, in 2013, collectively yielded 46% of the total greenlip catch in the WZ. Catches from remaining medium and low importance SAUs will also need to remain at similar levels as there is little evidence that catch from remaining SAUs can be increased substantially. Consequently, the WZ greenlip fishery will require careful monitoring, assessment and application of both the harvest strategy and weight-of-evidence methods to determine the suitability of the current and future TACCs.

4.3. Harvest strategy for the WZ abalone fishery

Previous WZ stock assessment reports identified several challenges facing the implementation of the new harvest strategy for the fishery (Stobart *et al.* 2011; 2013a), with similar issues identified in the Central (Chick and Mayfield 2012) and Southern zones (Mayfield *et al.* 2013). Whilst there were fewer problems with applying the harvest strategy to greenlip in this assessment when compared with the latest blacklip assessment (Stobart *et al.* 2013a), three key issues recurred which should be considered when the harvest strategy is reviewed in 2015.

First, 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 were allocated positive scores which can substantially influence the total score for that SAU. For example, in this assessment the score of 6 assigned for the catch PI for greenlip in the Anxious Bay SAU contributed a high proportion of the total score of 8 and ‘pale blue’ risk-of-overfishing category. This was a more optimistic interpretation of stock status in this SAU than was derived through the weight-of-evidence assessment. The same problems were also evident for greenlip in the Point Avoid, Drummond and Reef Head SAUs. There are several possible solutions to this issue including: (1) weighting the PIs, with higher weighting allocated to CPUE and FI survey abundance; (2) allocating negative scores when the proportion of the TACC harvested from an SAU exceeds the upper target reference point or upper limit reference point; (3) using supplementary decision rules that prevent an increase in catch contribution to future TACCs when the score for CPUE is negative; and (4) scoring the catch PI 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 (i.e. PI for catch) would similarly receive positive scores (Stobart *et al.* 2012b).

Secondly, the proportion of grade 1 greenlip PI may be subject to influences other than stock status. For example, a change in the current market demand for large greenlip would result in changes to the value of this PI and may also influence CPUE. One option to resolve this issue is the use of convincing, *a priori*, information from other sources (e.g. divers, processors) to aid interpretation of the PI scores.

As a direct result of these two issues, application of the harvest strategy to greenlip provided a slightly more optimistic interpretation of current stock status than that obtained from the weight-of-evidence assessment used in this assessment of stock status.

Finally, the Management Plan (PIRSA 2012) does not identify a performance indicator and reference point below which the fishery would be defined as transitional or overfished. Consequently, when the Management Plan is reviewed consideration should also be given to identifying a PI and associated target and limit reference points to enable the status of the fishery to be defined against the national guidelines (Flood et al. 2012). Under this approach, the PI values can be directly linked to stock status classification (e.g. sustainable: PI value exceeds target reference point; transitional: PI value between target and limit reference points; and overfished: PI value below limit reference point). Given the limited spatial coverage of fishery-independent surveys in the WZ, the most obvious PI to use would be CPUE. If this approach was adopted, there would be a need to determine both appropriate spatial scales for application (e.g. WZ; high-importance SAUs; combined high and medium importance SAUs) and reference points.

4.4. Future research needs

The most pressing need for this fishery is to evaluate the effectiveness of the new harvest strategy. This should include identifying limitations and potential improvements to inform the pending review of the Management Plan (including the location, frequency and distribution of FI surveys, formal incorporation of diver-based information, and consideration of the potential for increased industry-based data), ongoing comparison between the weight-of-evidence approach and harvest strategy outputs and testing the harvest strategy performance using a management strategy evaluation procedure. The formal review should also be used to link the harvest strategy more closely with the national fishery status reporting framework (Flood *et al.* 2012).

Identification and testing of a process to formally include industry information into the application of the harvest decision rules for determining TACCs is needed 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.

The FI survey program for greenlip (and blacklip) in the WZ should also be reviewed. This review should include: (1) quantifying their benefit to the harvest strategy and weight of evidence assessments; (2) survey continuity; and (3) a cost-benefit analysis. Amongst others, this could be achieved by re-evaluating the criteria for identifying survey sites and optimising the number of sites to maximise survey reliability. For example, consideration should be given to continuing FI surveys in medium-importance SAUs with a long series of survey data such as Flinders Island, Hotspot and Ward Island, as cessation of surveys diminishes the value of invested effort in these SAUs. Surveys at these sites could be re-initiated if the extent of SAUs were reviewed, as the magnitude of catch in each SAU determines their importance and thus whether or not they require FI surveys. SAUs comprise single or multiple mapcodes that are intended to reflect abalone metapopulations or, in some cases, limited data require the amalgamation of additional mapcodes (PIRSA 2012). As recent research suggests that greenlip metapopulations may be more extensive than previously considered (Mayfield *et al.* 2014), it may be appropriate to consider Flinders Island, Hotspot and Ward Island as a single SAU whose combined catch will likely be equivalent to that of a high importance SAU that would require FI surveys. The outcomes from the review could be incorporated in the revised management plan for the fishery.

Assessment of abalone in the WZ would also benefit from: (1) analysing external influences (e.g. diver, dive location, month, and loss of access) on CPUE through standardisation; (2) improved estimates of the magnitude and trends in IUU catch; (3) assessment of direct and indirect effects of commercial harvest on the ecosystem; and (4) obtaining information on abalone population age structures. Supplementing current data for assessment of stock status with population age structures would enhance interpretation of the patterns in the length-frequency distributions of the commercial catches. While these data can be obtained from stable oxygen isotope analyses (Gurney *et al.* 2005), research effort should be directed towards exploring the relationships between telomere length and age as this is a considerably cheaper analytical technique (Dr Craig Mundy, University of Tasmania, personal communication).

5. REFERENCES

Andrew, N. L. (1996). Review of the South Australian Abalone Research and Management Plan. Report to PIRSA. 35pp**.**

Babcock, R. C. and Keesing, J. K. (1999). Fertilization biology of the abalone *Haliotis laevigata*: laboratory and field studies. *Canadian Journal of Fisheries and Aquatic Sciences*. 56: 1668-1678.

Breen, P. A. (1992). A review of models used for stock assessment in abalone fisheries. Abalone of the World: Biology, Fisheries and Culture. S. A. Shepherd, M. J. Tegner and S. A. Guzmán Del Próo. Oxford, Blackwell**:** 253-275.

Burch, P., Mayfield, S., Stobart, B., Chick, R. C. and McGarvey, R. (2011). Estimating species-specific catch rates in a mixed-species dive fishery. *Journal of Shellfish Research*. 30(2): 425-436.

Chick, R. C. and Mayfield, S. (2006). Western Zone Abalone (*Haliotis laevigata* & *H. rubra*) Fishery 2. Region B. Fisheries assessment report to PIRSA Fisheries. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. RD05/017-4. Research Report Series No. 161. 36pp**.**

Chick, R. C. and Mayfield, S. (2012). Central Zone Abalone (*Haliotis laevigata & H. rubra)* Fishery. Fishery Assessment report for PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), SARDI Publication No.F2007/000611-4 SARDI Research Report Series No. 654. 67pp**.**

Chick, R. C., Mayfield, S., Turich, N. and Foureur, B. (2006). Western Zone Abalone (*Haliotis laevigata* & *H. rubra*) Fishery 1. Region A. Fishery Assessment Report to PIRSA. Adelaide. South Australian Research and Development Institute (Aquatic Sciences), SARDI Publication No. RD05/0017-3. SARDI Research Report Series No. 167. 103pp**.**

Chick, R. C., Turich, N. and Mayfield, S. (2007). Western Zone Abalone (*Haliotis laevigata* and *H. rubra*) Fishery Region B. Fishery Status Report to PIRSA. Adelaide. South Australian Research and Development Institute (Aquatic Sciences), SARDI Publication No. F2007/000563-1. SARDI Research Report Series No. 240. 14pp.

Chick, R. C., Turich, N. and Mayfield, S. (2008). Western Zone Abalone (*Haliotis laevigata* and *H. rubra*) Fishery (Region A). Fishery Status Report to PIRSA. Adelaide. South Australian Research and Development Institute (Aquatic Sciences), SARDI Publication No. RD05/0017-3. pdf SARDI Research Report Series No. 240. 40pp**.**

Chick, R. C., Turich, N., Mayfield, S. and Dent, J. (2009). Western Zone Abalone (*Haliotis rubra* and *H. laevigata*) Fishery (Region A). Fishery Assessment Report for PIRSA. Adelaide. South Australian Research and Development Institute (Aquatic Sciences), SARDI Publication No. F2007/000561-3. SARDI Research Report Series No. 376. 90pp.

Day, R. W. and Fleming, A. E. (1992). The determinants and measurement of abalone growth. Abalone of the World: Biology, Fisheries and Culture. S. A. Shepherd, M. J. Tegner and S. A. Guzman del Proo. Oxford, UK, Blackwell Scientific Publications Ltd**:** 141-168.

Dowling, N. A., Hall, S. J. and McGarvey, R. (2004). Assessing population sustainability and response to fishing in terms of aggregation structure for greenlip abalone (*Haliotis laevigata*) fishery management. *Canadian Journal of Fisheries and Aquatic Sciences*. 61(2): 247-259.

Flood, M., Stobutzki, I., Andrews, J., Begg, G., Fletcher, W., Gardner, C., Kemp, J., Moore, A., O'Brien, A., Quinn, R., Roach, J., Rowling, K., Sainsbury, K., Saunders, T., Ward, T. and Winning,

M. (2012). Status of key Australian fish stocks reports 2012. Canberra. Fisheries Research an Development Corporation.

Geibel, J. J., Demartini, J. D., Haaker, P. L. and Karpov, K. (2010). Growth of red abalone, *Haliotis rufescens* (Swainson), along the north coast of California. *Journal of Shellfish Research*. 29(2): 441-448.

Gorfine, H. K., Taylor, B. T. and Smith, D. C. (2002). Abalone- 2001. Fisheries Victoria Assessment Report No. 43 (MAFRI, Queenscliff).

Gurney, L. J., Mundy, C. and Porteus, M. C. (2005). Determining age and growth of abalone using stable oxygen isotopes: a tool for fisheries management. *Fisheries Research*. 72: 353-360.

Haddon, M., Mundy, C. and Tarbath, D. (2008). Using an inverse-logistic model to describe growth increments of blacklip abalone (*Haliotis rubra*) in Tasmania. *Fishery Bulletin*. 106(1): 58-71.

Harrison, A. J. (1983). The Tasmanian abalone fishery. *Tasmanian Fisheries Research*. 26: 1-42.

Jones, K. (2009). South Australian Recreational Fishing Surey. Adelaide. PIRSA. No. 55

Keesing, J. K. and Baker, J. L. (1998). The benefits of catch and effort data at a fine spatial scale in the South Australian abalone (*Haliotis laevigata* and *H. rubra*) fishery. *Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management*. 125: 179-186.

Keesing, J. K., Grove Jones, R. and Tagg, P. (1995). Measuring settlement intensity of abalone: Results of a pilot study. *Marine and Freshwater Research*. 46(3): 539-543.

King, M. (1995). Fisheries Biology, Assessment and Management. Fishing News Books**:** 342pp.

Lewis, R. K., Shepherd, S. A., Sluczanowski, P. and Rohan, G. (1984). An assessment of the South Australian abalone resource. South Australian Department of Fisheries. 59**.**

Mayfield, S. (2010). Enhancing fishery assessments for an Australian abalone fishery using commercial weight-grade data. *Fisheries Research*. 105(1): 28-37.

Mayfield, S., Carlson, I. J. and Chick, R. (2010). Central Zone Abalone Fishery *(Haliotis laevigata* and *H. rubra)*. South Australian Research and Development Institute (Aquatic Sciences), Publication No. F2009/000616-1. SARDI Research Report Series No. 399.

Mayfield, S., Chick, R. C., Carlson, I. J., Turich, N., Foureur, B. L. and Ward, T. M. (2005). Western Zone Abalone (*Haliotis laevigata* and *H. rubra*) Fishery 1. Region A. Fishery assessment report to PIRSA. Adelaide. South Australian Research and Development Institute (Aquatic Sciences), Fisheries Assessment Series. Publication No. RD05/0017-1 pdf SARDI Research Report Series No. 104. 106pp**.**

Mayfield, S., Foureur, B. L., Rodda, K. R., Preece, P. A. and Ward, T. M. (2003). Western Zone Abalone (*Haliotis laevigata* and *H. rubra*) Fishery 1. Region A. Fishery Assessment report to PIRSA Fisheries. South Australian Fisheries Assessment Series. Publication No. RD03/0193. 1-98. pdf

Mayfield, S., Foureur, B. L. and Ward, T. M. (2004). Western Zone Abalone (*Haliotis laevigata* and *H. rubra*) Fishery 1. Region A. Fishery assessment report to PIRSA. Adelaide. South Australian Fisheries Assessment Series. Publication No. RD04/0157. pdf 97pp**.**

Mayfield, S., Hogg, A. and Burch, P. (2013). 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. F2007/000552-4. SARDI Research Report Series No. 694. 54pp.

Mayfield, S., Hogg, A., Saunders, T. and Burch, P. (2009). Southern Zone Abalone Fishery (*Haliotis rubra* and *H. laevigata*). Fishery assessment report for PIRSA. Adelaide. South Australian Research and Development Institute (Aquatic Sciences), Publication No. F2007/000552-2. pdf SARDI Research Report Series No. 350. 51pp**.**

Mayfield, S., Milller, K. J. and Mundy, C. N. (2014). Towards understanding greenlip abalone population structure. Final report for the Fisheries Research and Development Corporation. Prepared by the South Australian Research and Development Insitute (Aquatic Sciences). Adelaide. FRDC Project number 2010/013. 31pp**.**

Mayfield, S., Mundy, C., Gorfine, H., Hart, A. and Worthington, D. (2012). Fifty years of sustained production in Australia's abalone fisheries. *Reviews in Fisheries Science*.

Mayfield, S., Rodda, K. R., Preece, P. A. G., Foureur, B. L. and Ward, T. M. (2001). Abalone fishery assessment report to PIRSA Fisheries Policy Group. South Australian Assessment Series 01/02. Adelaide. South Australian Research and Development Institute (Aquatic Sciences). 73pp**.**

Mayfield, S., Rodda, K. R. and Ward, T. M. (2002). Abalone (Western Zone). Fishery assessment report to PIRSA Fisheries Policy Group. South Australian Fisheries Assessment Series 02/02c. 112pp**.**

Mayfield, S. and Saunders, T. (2008). Towards optimising the spatial scale of abalone fishery management. Final report to the Fisheries Research and Development Corporation, Project Number 2004/019. SARDI Aquatic Sciences Publication No. F2008/000082-1. . SARDI Research Report Series No. 273. 148pp**.**

McGarvey, R., Mayfield, S., Byth, K., Saunders, T., Chick, R., Foureur, B., Feenstra, J. E., Preece, P. and Jones, A. (2008). A diver survey design to estimate absolute density, biomass, and spatial distribution of abalone. *Canadian Journal of Fisheries and Aquatic Sciences*. 65(9): 1931-1944.

Morgan, L. and Shepherd, S. A. (2006). Population and spatial structure of two common temperate reef herbivores: abalone and sea-urchins. Marine Metapopulations. J. P. Kritzer and P. F. Sale. Burlington, Elsevier Academic Press**:** 205-246.

Nobes, M., Casement, D. and Mayfield, S. (2004). Management Plan for the South Australian Abalone Fishery. South Australian Fisheries Management Series No. 42. Adelaide. Primary Industries and Resources South Australia. 47pp**.**

Paterson, S., Rippin, L. and Morison, J. (2013). Economic Indicators for the South Australian Abalone Fishery 2011/12. Adelaide. Econsearch. 1209, 68pp**.**

PIRSA (2012). Management Plan for the South Australian commercial Abalone Fishery. Adelaide. Primary industries and Regions South Australia Fisheries and Aquaculture. http://www.pir.sa.gov.au/__data/assets/pdf_file/0004/12982/Abalone_Fishery_Management_Plan_-_September_2012_.pdf 85pp.

Preece, P. A., Shepherd, S. A., Clarke, S. M. and Keesing, J. K. (1997). Abalone stock enhancement by larval seeding: effect of larval density on settlement and survival. *Molluscan Research*. 18: 265-273.

Prince, J. D., Sellers, T. L., Ford, W. B. and Talbot, S. R. (1987). Experimental evidence for limited dispersal of haliotid larvae (genus *Haliotis*: Mollusca: Gastropoda). *Journal of Experimental Marine Biology and Ecology*. 106: 243-263.

Prince, J. D., Sellers, T. L., Ford, W. B. and Talbot, S. R. (1988). Confirmation of a relationship between the localized abundance of breeding stock and recruitment for *Haliotis rubra* (Leach) (Mollusca: Gastropoda). *Journal of Experimental Marine Biology and Ecology*. 122: 91-104.

Prince, J. D. and Shepherd, S. A. (1992). Australian abalone fisheries and their management. Abalone of the World: Biology, Fisheries and Culture. S. A. Shepherd, M. J. Tegner and S. A. Guzmán Del Próo**:** 407-427.

Rodda, K. R., Casement, D. and Williams, H. (2000). Abalone. Fishery assessment report to PIRSA fisheries Policy Group. South Australian Fisheries Assessment Series 00/02. 13pp**.**

Rodda, K. R., Keesing, J. K. and Foureur, B. L. (1997). Variability in larval settlement of abalone on artificial collectors. *Molluscan Research*. 18(2): 253-264pp.

Rodda, K. R., Styan, C., Shepherd, S. A. and McShane, P. (1998). Abalone. Fishery assessment report to PIRSA Fisheries Policy Group. South Australian Fisheries Assessment Series 98/02. 49pp**.**

Shepherd, S. A. (1973). Studies on southern Australian abalone (genus *Haliotis*). I. Ecology of five sympatric species *Australian Journal of Marine and Freshwater Research*. 24(3): 217-258.

Shepherd, S. A. (1985). Power and efficiency of a research diver, with a description of a rapid underwater measuring gauge: Their use in measuring recruitment and density of an abalone population. Department of Fisheries. 263-272**.**

Shepherd, S. A. (1988). Studies on Southern Australian abalone (genus *Haliotis*). VIII. Growth of juvenile *H. laevigata*. *Australian Journal of Marine and Freshwater Research*. 39: 177-183.

Shepherd, S. A. (1990). Studies on Southern Australian abalone (Genus *Haliotis*) XII. Long-term recruitment and mortality dynamics of an unfished population. *Australian Journal of Marine and Freshwater Research*. 41(4): 475-492.

Shepherd, S. A. and Baker, J. L. (1998). Biological reference points in an abalone (*Haliotis laevigata*) fishery. *Canadian Journal of Fisheries and Aquatic Sciences*. 125: 235-245.

Shepherd, S. A. and Breen, P. A. (1992). Mortality in abalone: its estimation, variability and causes. Abalone of the World: Biology, Fisheries and Culture. S. A. Shepherd, M. J. Tegner and S. A. Guzman del Proo. Oxford, UK, Blackwell Scientific Publications Ltd**:** 276-304.

Shepherd, S. A. and Brown, L. D. (1993). What is an abalone stock- implications for the role of refugia in conservation. *Canadian Journal of Fisheries and Aquatic Sciences*. 50(9): 2001-2009.

Shepherd, S. A. and Cannon, J. (1988). Studies on Southern Australian abalone (genus *Haliotis*). X. Food and feeding of juveniles. *Journal of the Malacological Society of Australia*. 9: 21-26.

Shepherd, S. A., Clarke, S. M. and Dalgetty, A. (1992a). Studies on Southern Australian abalone (genus *Haliotis*). XIV. Growth of *H. laevigata* on Eyre Peninsula. *Journal of the Malacological Society of Australia*. 13: 99-113.

Shepherd, S. A. and Daume, S. (1996). Ecology and Survival of Juvenile Abalone in a Crustose Coralline Habitat in South Australia. Survival Strategies in Early Life Stages of Marine Resources. Y. Watanabe, Y. Yamashita and Y. Oozeki. Roterdam, A.A. Balkema**:** 297-313.

Shepherd, S. A. and Edgar, G. J. (2013). Ecology of Australian Temperate Reefs. Collingswood, Victoria, CSIRO Publishing.

Shepherd, S. A., Godoy, C. and Clarke, S. M. (1992b). Studies on Southern Australian abalone (genus *Haliotis*). XV. Fecundity of *H. laevigata. Journal of the Malacological Society of Australia*. 13: 115-121.

Shepherd, S. A. and Hearn, W. S. (1983). Studies on Southern Australian abalone (Genus *Haliotis*). IV. Growth of *H. laevigata* and *H. ruber*. *Australian Journal of Marine and Freshwater Research*. 34: 461-475.

Shepherd, S. A. and Laws, H. M. (1974). Studies on southern Australian abalone (genus *Haliotis*). II. Reproduction of five species. *Australian Journal of Marine and Freshwater Research*. 25: 49-62.

Shepherd, S. A., Lowe, D. and Partington, D. (1992c). Studies on Southern Australian abalone (genus *Haliotis*). XIII: Larval dispersal and recruitment. *Journal of Experimental Marine Biology and Ecology*. 164(2): 247-260.

Shepherd, S. A. and Rodda, K. R. (2001). Sustainability demands vigilance: evidence for serial decline of the greenlip abalone fishery and a review of management. *Journal of Shellfish Research*. 20(2): 829-841.

Shepherd, S. A., Rodda, K. R., Karlov, T., Preece, P. A. and Williams, H. (1999). Abalone. Fishery assessment report to PIRSA Fisheries Policy Group. South Australian Fisheries Assessment Series 99/02. 21pp**.**

Shepherd, S. A. and Triantafillos, L. (1997). Studies on Southern Australian abalone (genus *Haliotis*). XVII. A chronology of *H. laevigata*. *Molluscan Research*. 18(2): 233-245pp.

Shepherd, S. A. and Turner, J. A. (1985). Studies on southern Australian abalone (genus *Haliotis*) VI. Habitat preference, abundance and predators of juveniles. *Journal of Experimental Marine Biology and Ecology*. 93: 285-298.

Stobart, B., Dent, J., Matthews, D., Chick, R. C. and Mayfield, S. (2011). Western Zone Abalone (*Haliotis rubra* and *H. laevigata*) Fishery (Region A). Fishery Status Report for PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences). Adelaide. SARDI Publication No. F2011/000290-1. Research Report Series No. 565. 46pp.

Stobart, B., Dent, J. J., Matthews, D., Chick, R. C. and Mayfield, S. (2010). Western Zone Abalone (*Haliotis laevigata* & *H. rubra*) Fishery (Region B). Fishery Assessment Report for PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences). Adelaide. SARDI Publication No. F2010/000389-1. Research Report Series No. 485. 23pp.

Stobart, B., Mayfield, S., Dent, J. and Matthews, D. J. (2012a). Western Zone Abalone *(Haliotis laevigata and H. rubra)* Fishery (Region B). Fishery Stock Assessment Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences). Adelaide. SARDI Publication No. F2010/000389-2. SARDI Research Report Series No. 661. 32pp.

Stobart, B., Mayfield, S., Dent, J. and Matthews, D. J. (2013a). Western Zone Blacklip Abalone Fishery (*Haliotis rubra*) Fishery (Region A). Fishery Stock Assessment Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences). Adelaide. SARDI Publication No. F2007/000561-5. SARDI Research Report Series No. 738. 71pp.

Stobart, B., Mayfield, S., Dent, J., Matthews, D. J. and Chick, R. C. (2012b). Western Zone Abalone (*Haliotis rubra* and *H. laevigata*) Fishery (Region A). Fishery Stock Assessment Report to PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences). Adelaide. SARDI Publication No. F2007/000561-4. SARDI Research Report Series No. 660. 118pp.

Stobart, B., Mayfield, S. and McGarvey, R. (2013b). Maximum yield or minimum risk: Using biological data to optimize harvest strategies in a southern Australian molluscan fishery. *Journal of Shellfish Research*. 32(3): 899-909.

Tarbath, D., Mundy, C. and Haddon, M. (2005). Tasmanian Abalone Fishery 2004. Fishery Assessment Report. Tasmanian Aquaculture and Fisheries Institute. 131**.**

Zacharin, W. (1997). Management plan for the South Australian Abalone Fishery. Internal document. PIRSA Fisheries. 33pp.

APPENDIX

A.1. Greenlip biology

Table A1.1. Size at L_{50} (mm, shell length) for greenlip at different sites in the Western Zone. Parameters (a and b) describe the proportion of mature greenlip mature. The equation is of the form (f(x) = a/(1+exp(-((x-L50)/b)). N = total number sampled, *n* = number of abalone sampled within period of maturity transition.

Site	Year	Month	a	b	L_{50}	*N*	n	Reference
Anxious Bay	2005	11	0.983	7.312	76.6	119	32	SARDI unpublished
Hotspot	2006	11	1.005	3.637	111.6	109	36	SARDI unpublished
Hotspot	2010	8	1.011	6.812	120.8	144	52	SARDI unpublished
The Gap	2003	9	1.018	4.441	94.0	96	54	SARDI unpublished
The Gap	2004	9	0.984	1.952	93.8	124	62	SARDI unpublished
The Gap	2010	9	1.010	4.170	100.6	160	18	SARDI unpublished
Waterloo Bay	1974	-	-	-	102.0	-	34	(Shepherd & Laws 1974)
Ward Island	2006	11	1.033	11.548	127.7	90	62	SARDI unpublished

Table A1.2. Relationships between shell length (SL, mm) and fecundity (F, millions of eggs) for legal sized (145 mm) greenlip at different sites in the Western Zone. The equation is of the form $F = aSL^{b}$.

Site	Year	a	b	r	n	SL	F	Reference
Anxious Bay	1987	2.94E-02	3.70	0.74	15	145	2.9E+06	(Shepherd *et al.* 1992b)
Flinders Bay	2010	2.50E-03	4.07	0.46	10	145	1.6E+06	SARDI unpublished
Hotspot	2010	3.90E-08	6.33	0.85	17	145	1.9E+06	SARDI unpublished
Maclaren Point	1987	1.93E-06	5.61	0.97	14	145	2.6E+06	(Shepherd *et al.* 1992b)
Sceale Bay	1987	6.19E-10	7.24	0.90	17	145	2.8E+06	(Shepherd *et al.* 1992b)
Taylor Island	1987	7.55E-06	5.33	0.94	15	145	2.5E+06	(Shepherd *et al.* 1992b)
The Gap	2011	8.20E-03	4.18	0.75	26	145	8.9E+06	SARDI unpublished
Waterloo Bay	1987	6.40E-03	3.85	0.76	15	145	1.3E+06	(Shepherd *et al.* 1992b)
Yanerbie	1987	1.11E-02	3.87	0.87	14	145	2.6E+06	(Shepherd *et al.* 1992b)

Table A1.3. Relationships between fecundity (F, millions of eggs) and whole weight (W, g) for greenlip at different sites in the Western Zone. The equation is of the form F = c + dW.

Site	c	d	Reference
Sceale Bay	-1.13	0.011	(Shepherd & Baker 1998)
Thorny Passage	-1.57	0.014	(Shepherd & Baker 1998)
Waterloo Bay	-0.36	0.004	(Shepherd & Baker 1998)
Ward Island	-1.87	0.008	(Shepherd & Baker 1998)

Table A1.4. Relationships between shell length (SL, mm) and total weight (TW, g) greenlip abalone at various sites in the Western Zone. TW is calculated total weight for 145 mm legal-sized greenlip. The equation is of the form $TW = aSL^b$.

Site	Year	a	b	TW	r	n	Reference
Anxious Bay	1987	1.0E-04	3.07	432	0.99	46	(Shepherd *et al.* 1992b)
Anxious Bay	2004	4.0E-04	2.79	422	0.97	52	SARDI unpublished
Anxious Bay	2005	2.9E-05	3.30	407	0.99	110	SARDI unpublished
Flinders Island	1998	3.0E-04	2.90	551	0.94	69	SARDI unpublished
Flinders Island	1999	7.2E-04	2.69	469	0.68	47	SARDI unpublished
Flinders Bay	2004	2.4E-05	3.34	404	0.98	53	SARDI unpublished
Hotspot	1998	2.8E-05	3.33	439	0.94	80	SARDI unpublished
Hotspot	1999	3.5E-05	3.29	441	0.90	35	SARDI unpublished
Hotspot	2004	4.0E-04	2.81	479	0.93	53	SARDI unpublished
Hotspot	2006	6.1E-05	3.18	453	0.98	109	SARDI unpublished
Hotspot	2010	1.8E-05	3.41	404	0.98	144	SARDI unpublished
Maclaren Point	1987	5.8E-05	3.12	321	0.99	47	(Shepherd *et al.* 1992b)
Price Island	1997	5.0E-05	3.20	417	0.97	47	SARDI unpublished
Price Island	1999	2.0E-04	2.89	361	0.90	43	SARDI unpublished
Rowly Bay	1991	1.0E-04	3.04	363	0.93	65	SARDI unpublished
Searcy Bay	1999	7.0E-04	2.68	437	0.94	127	SARDI unpublished
Taylor Island	1987	4.7E-05	3.16	318	0.99	45	(Shepherd *et al.* 1992b)
The Gap	1998	2.0E-04	2.99	578	0.96	88	SARDI unpublished
The Gap	2000	1.5E-03	2.51	390	0.77	43	SARDI unpublished
The Gap	2003	4.8E-05	3.22	442	0.98	27	SARDI unpublished
The Gap	2004	6.1E-05	3.15	392	0.95	87	SARDI unpublished
The Gap	2010	4.7E-05	3.20	394	0.98	160	SARDI unpublished
Ward Island	1998	6.7E-05	3.15	425	0.94	75	SARDI unpublished
Ward Island	2004	1.0E-04	3.05	396	0.97	72	SARDI unpublished
Waterloo Bay	1987	2.0E-04	2.92	409	0.99	57	(Shepherd *et al.* 1992b)
Waterloo Bay	1999	6.0E-04	2.72	445	0.74	152	SARDI unpublished
Waterloo Bay	2005	2.8E-05	3.33	428	0.97	150	SARDI unpublished
Yanerbie	1987	4.6E-05	3.20	379	0.98	53	(Shepherd *et al.* 1992b)

Table A1.5. Growth rate (mm yr^{-1}) (± se) of sub-legal greenlip at different sites in the Western Zone.

Site	Size range (mm)	Growth rate (mm.yr^{-1}± S.E.)	Reference
Anxious Bay	25-95	20.4 ± 1.5	(Shepherd & Breen 1992)
Avoid Bay	45-115	19.7 ± 2.4	(Shepherd & Triantafillos 1997)
Maclaren Point	20-140	20.3 ± 0.4	(Shepherd *et al.* 1992a)
Sceale Bay	45-110	20.4 ± 1.8	(Shepherd *et al.* 1992a)
Taylor Island	15-145	39.6 ± 0.9	(Shepherd *et al.* 1992a)
Ward Island	60-125	25.7 ± 1.5	(Shepherd *et al.* 1992a)
Yanerbie	15-110	15.3 ± 0.9	(Shepherd *et al.* 1992a)

Table A1.6. Growth rate, k ($yr.^{-1}$) and L_∞ (mm SL) for greenlip tagged and recaptured at different sites in the Western Zone. Errors are standard errors. Size ranges are shell length at time of tagging for recaptured abalone (mm). n is the number of recaptures. For 'year tagged' * indicates uncertainty over aspects of the data including the year of tagging, time period at liberty may not adhere to criteria used for SARDI data (Geibel *et al.* 2010) while for 'size range'*indicates size ranges estimated from published graphs.

Site	Tag period	r^2	k (± se)	L_∞ (± se) (mm)	Size range	n	Reference
Anxious Bay	1988*	0.744	0.385(0.07)	119.5(5.3)	43-102*	26	(Shepherd *et al.* 1992a)
Anxious Bay	1999-2000	0.302	0.343	157.0	110-156	40	SARDI unpublished
Flinders Is	2004-2005	0.692	0.365	162.8	64-177	153	SARDI unpublished
Hotspot	2002-2003	0.477	0.256	213.5	63-158	120	SARDI unpublished
Hotspot	2002-2004	0.659	0.306	181.7	63-131	53	SARDI unpublished
Maclaren Pt.	1988*	0.534	0.368(0.10)	178.3(7.7)	31-163*	35	(Shepherd *et al.* 1992a)
Sceale Bay	1988*	0.856	0.186(0.04)	186.3(28.2)	79-148*	9	(Shepherd *et al.* 1992a)
Taylor Island	1988*	0.713	0.552(0.08)	180.4 (10.3)	32-158*	41	(Shepherd *et al.* 1992a)
Taylor Island	1996	0.658	0.271	195.0	68-115	23	SARDI unpublished
The Gap	2002-2003	0.658	0.278	152.8	45-159	77	SARDI unpublished
The Gap	2002-2004	0.731	0.263	155.0	44-165	108	SARDI unpublished
The Gap	2009-2010	0.686	0.344	139.3	42-167	82	SARDI unpublished
Ward Island	1988*	0.81	0.413(0.053)	167.2(5.2)	76-167*	36	(Shepherd *et al.* 1992a)
Waterloo Bay	1969*	0.921	0.595(0.036)	147.8(1.8)	52-169	126	(Shepherd & Hearn 1983)
Yanerbie	1988*	0.642	0.268(0.076)	140.4(8.6)	62-135*	19	(Shepherd *et al.* 1992a)

Table A1.7. Natural mortality rates (yr^{-1}) for adult (emergent) greenlip at different sites in the Western Zone.

Site	M (yr^{-1})	Reference
Sceale Bay	0.25	(Shepherd & Baker 1998)
Thorny Passage	0.25	(Shepherd & Baker 1998)
Waterloo Bay	0.40	(Shepherd & Baker 1998)
Ward Island	0.13	(Shepherd & Baker 1998)

A.2. Catch, CPUE and PropG1 in Regions A and B

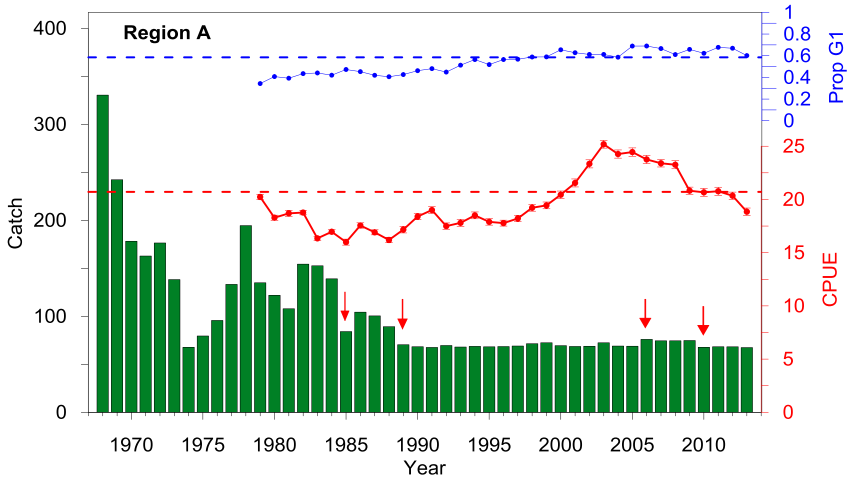

Figure A2.1. Catch (t, meat weight; green bars) of greenlip from Region A from 1968 to 2013. CPUE ± se ($kg.hr^{-1}$) and PropG1 are shown in red and blue lines, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively. Red arrows indicate implementation (1985) and amendment (1989, 2006 and 2010) of the TACC in Region A.

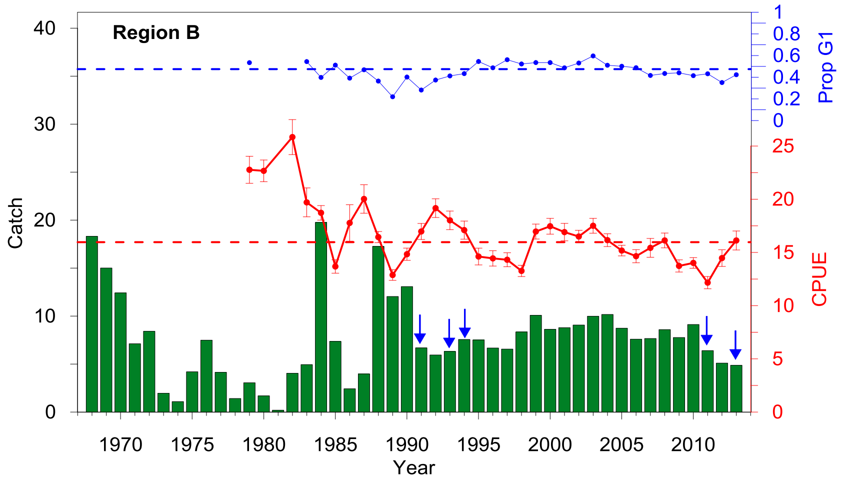

Figure A2.2. Catch (t, meat weight; green bars) of greenlip from Region B from 1968 to 2013. CPUE ± se ($kg.hr^{-1}$) and PropG1 are shown in red and blue lines, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively. Blue arrows indicate implementation (1991) and amendment (1993, 1994, 2011 and 2013) of the TACC in Region B.

A.3. Historic medium importance SAU FI surveys

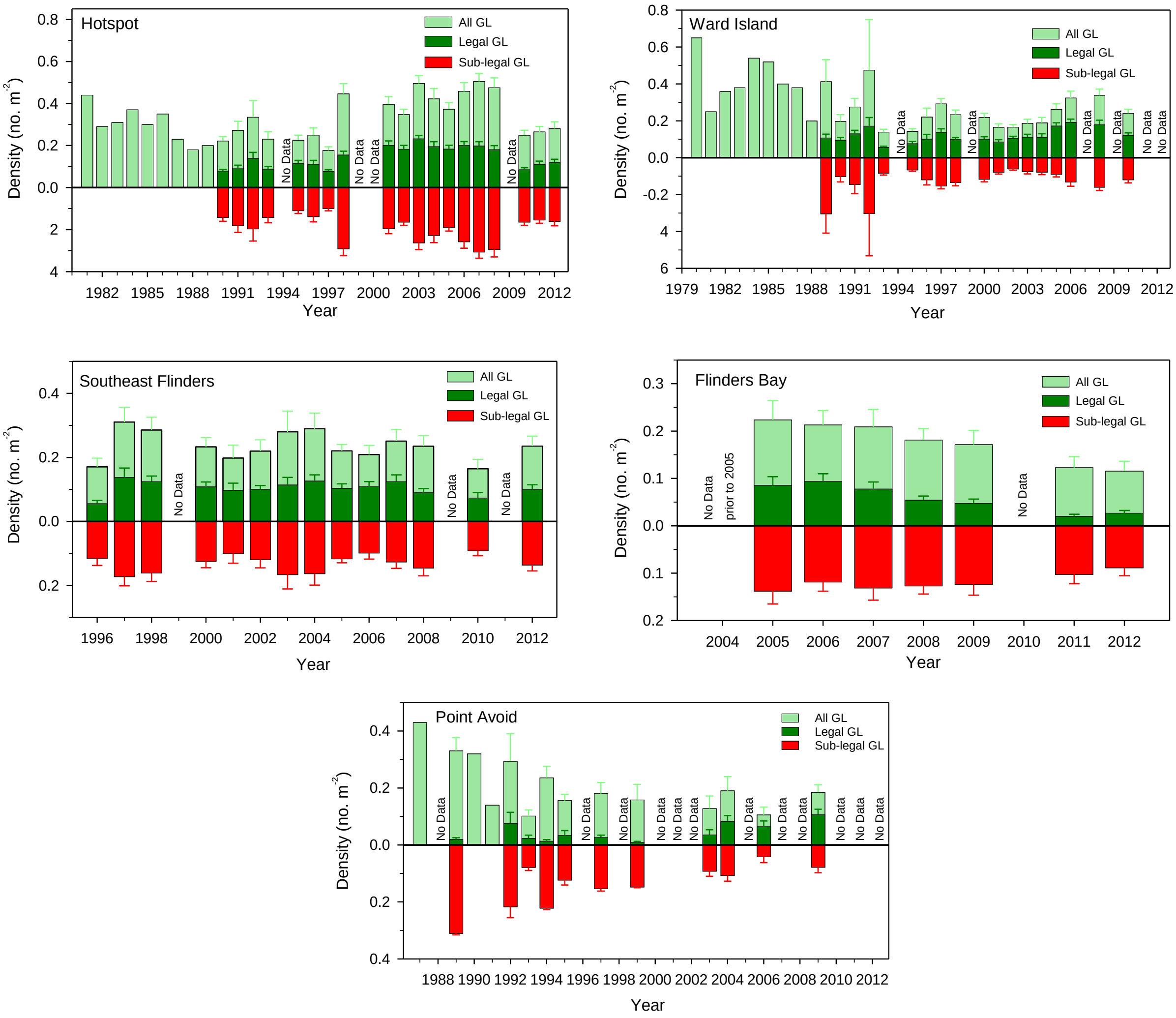

Figure A3.1. Mean ± se density (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) greenlip abalone at Hotspot (timed swims; map-code 9D), Ward Island (timed swims; map-code 9A), Southeast Flinders (timed swims; map-codes 9G & 9H), Flinders Bay (lead lines; map-code 9F) and Point Avoid (timed swims; map-code 15A) fishery independent survey sites.

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A.4. Greenlip performance indicators

Table A4.1. Summary of the PIs and the formulae and data constraints underpinning their utilisation in the harvest strategy.

Performance indicator	Description	Formulae	Data constraints
Catch	Total catch, expressed as a percentage of the combined TACC	$\text{Catch} = \frac{\sum \text{Species Catch (t)}}{\text{TACC}}.$	None
Proportion large (blacklip) or Proportion Grade 1 (greenlip)	Proportion of large (or Grade 1) abalone in the commercial catch	$\text{PropLge} = \frac{\text{N Large}}{\text{Total N}},$ or $\text{PropG1} = \frac{\sum \text{Grade 1 Meats (kg)}}{\sum \text{Meats (kg)}}.$	All measurements >5 mm SL below the MLL excluded; Minimum sample size (N): 100 measurements Blacklip >165 mm SL defined as large or All records where the total catch was >1% different from the sum of the three weight-grade categories were excluded; Records with zero catch were excluded. Minimum sample size: 10 records
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 >300 kg; CPUE (total catch/total effort) was >50 kg.hr^{-1}; fishing effort was >8 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 ≥130 mm SL defined as legal-sized Greenlip ≥145 mm SL defined as legal-sized
Density$_{pre\text{-}recruit}$	Density of pre-recruit (i.e. those that will exceed MLL within ~2 yrs.) abalone on surveys	$\text{Density}_{\text{Pre-recruit}} = \frac{\sum \text{Pre-recruit counted}}{\text{Total area surveyed}}$	>90% of survey completed Blacklip 90 to <130 mm SL defined as pre-recruits Greenlip 105 to <145 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

High importance SAUs

Anxious Bay

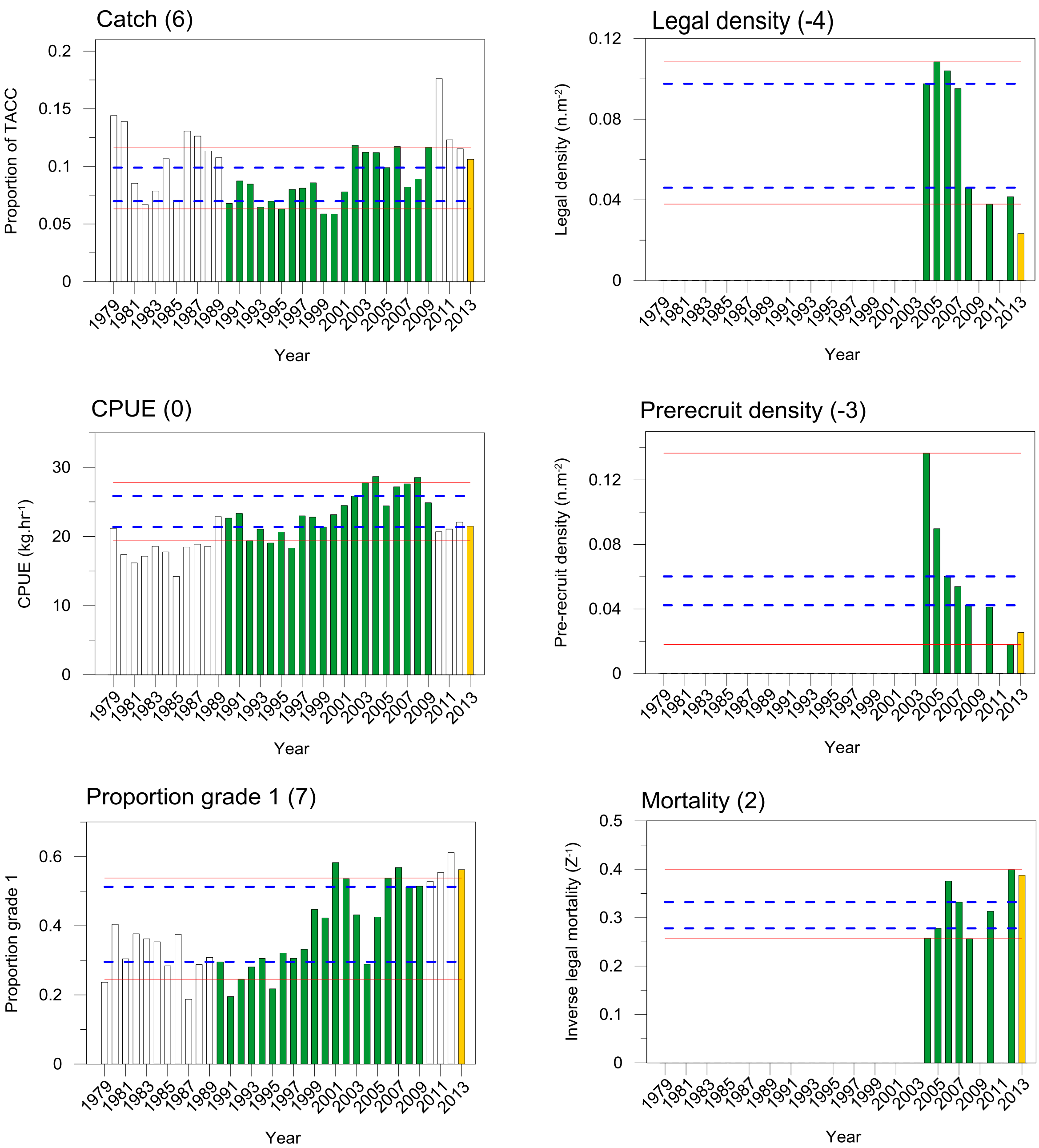

Figure A4.1. Anxious Bay (high importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropG1, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. 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.

The Gap

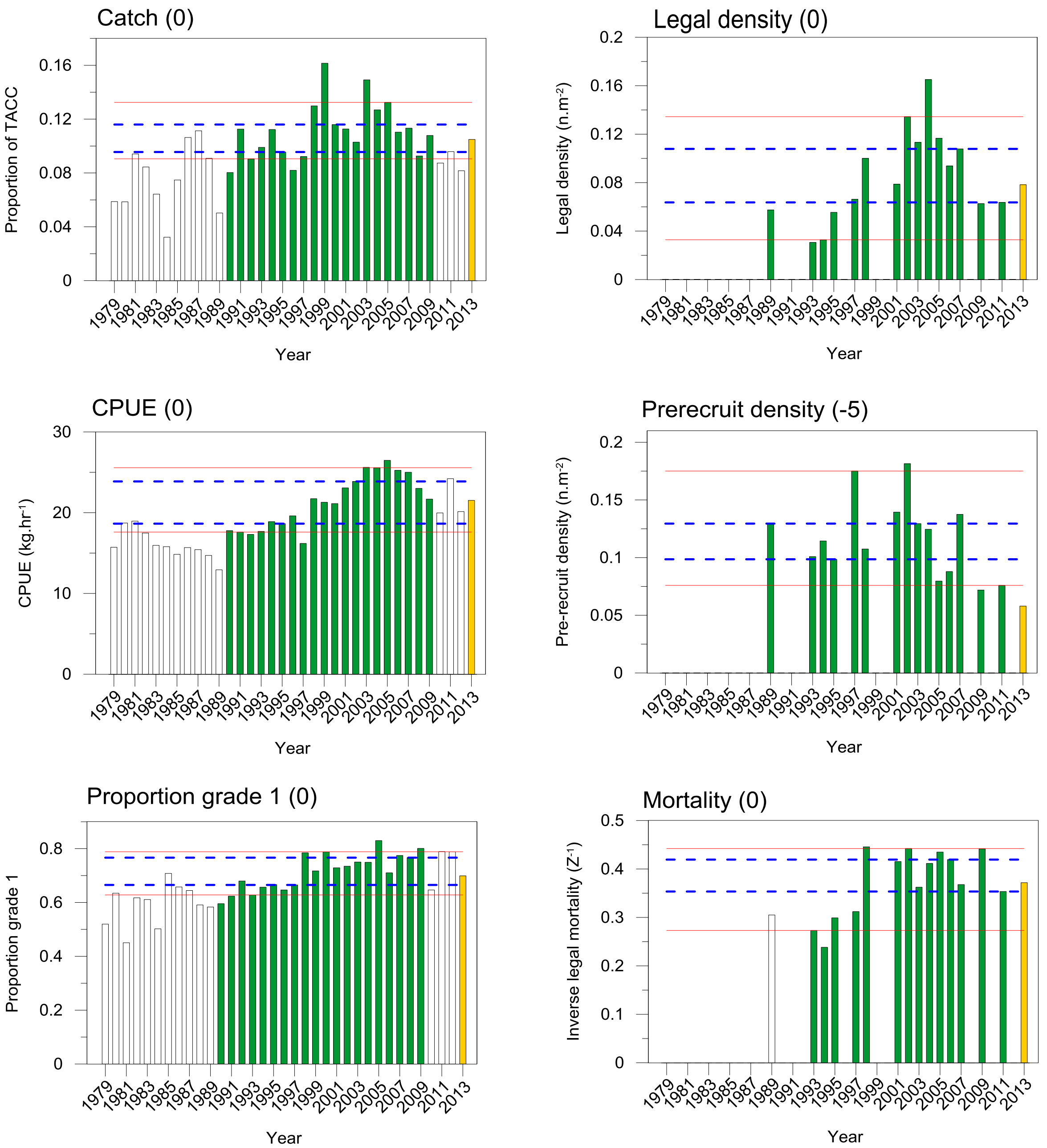

Figure A4.2. The Gap (high importance). Performance indicators catch (Proportion of TACC), CPUE ($kg.hr^{-1}$), PropG1, legal density ($n.m^{-2}$), pre-recruit density ($n.m^{-2}$), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. 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.

Avoid Bay

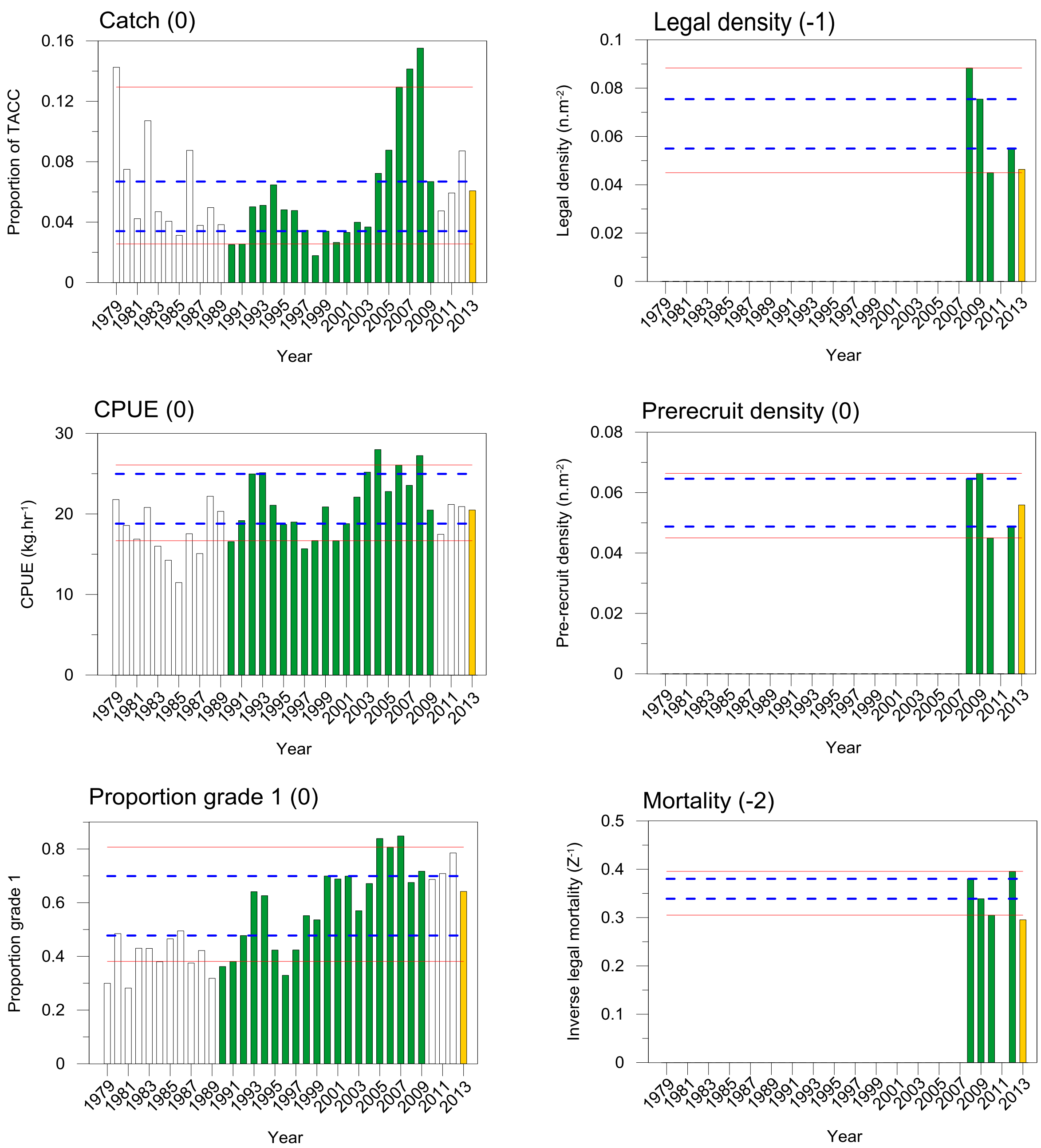

Figure A4.3. Avoid Bay (high importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropG1, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. 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.

Medium importance SAUs

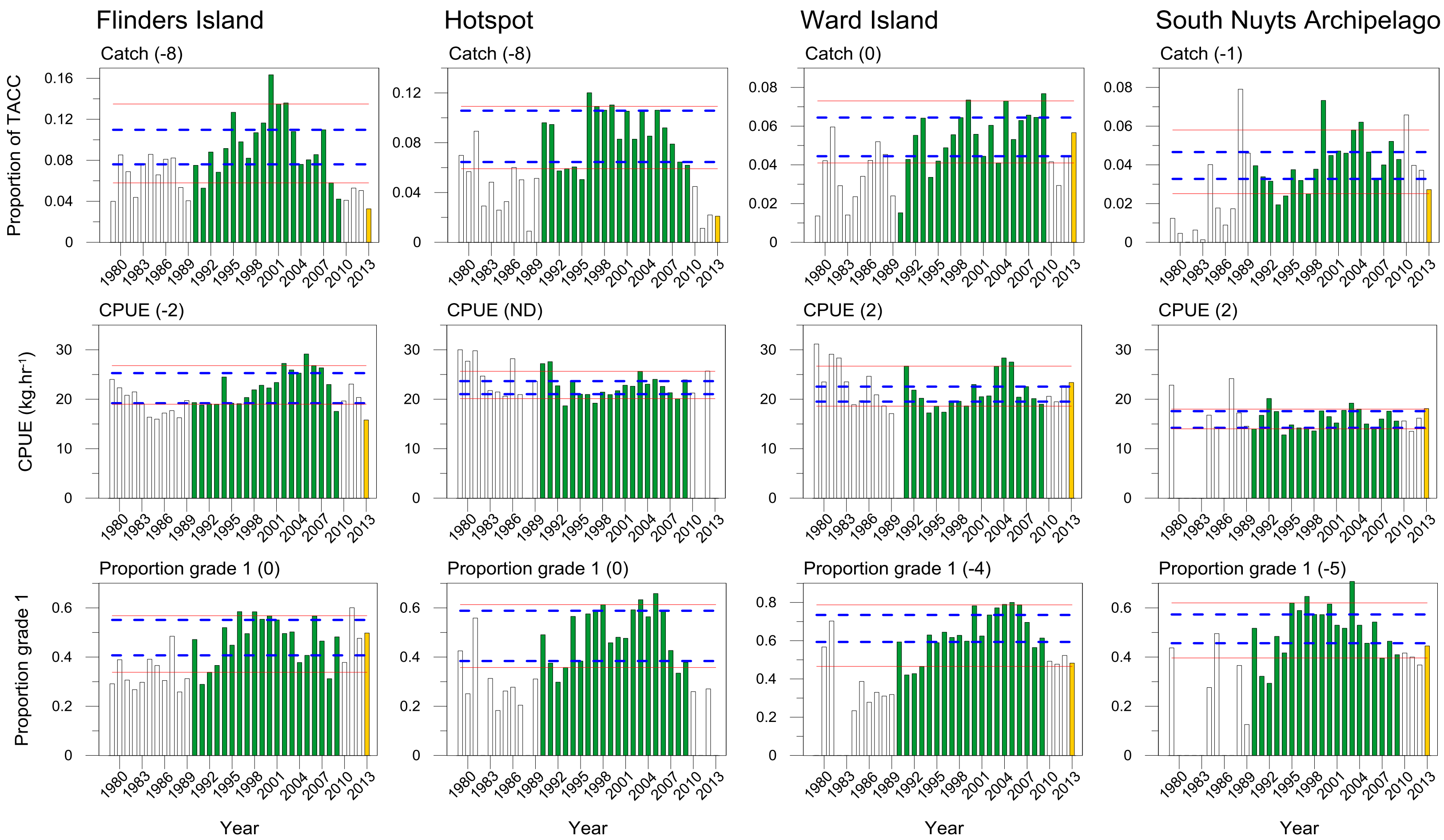

Figure A4.4. Flinders Island, Hotspot, Ward Island and South Nuyts Archipelago SAUs (medium importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropG1 and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. 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.

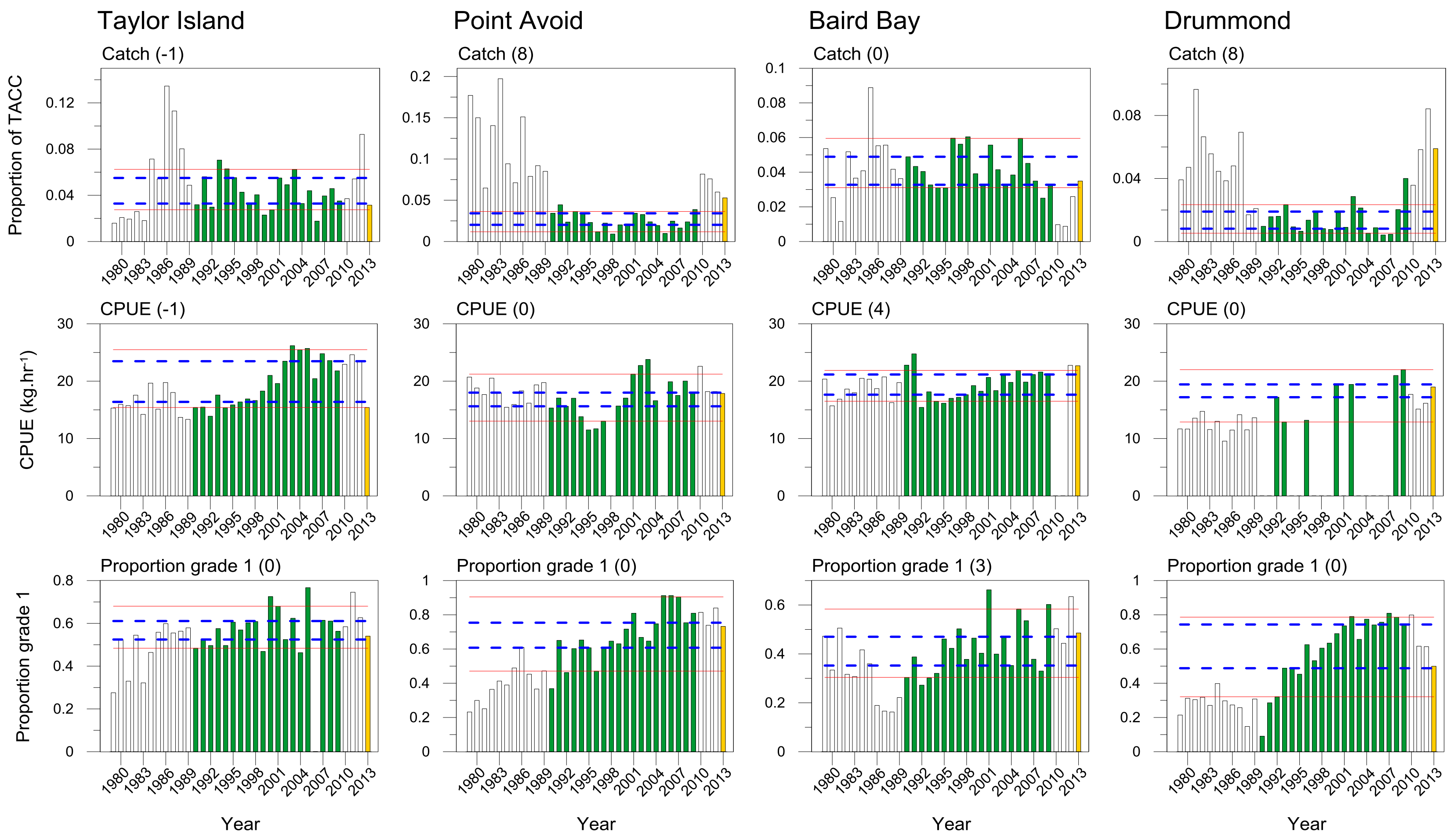

Figure A4.5. Taylor Island, Point Avoid, Baird Bay and Drummond SAUs (medium importance). Performance indicators catch (Proportion of TACC), CPUE ($kg.hr^{-1}$), PropG1 and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Green 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.

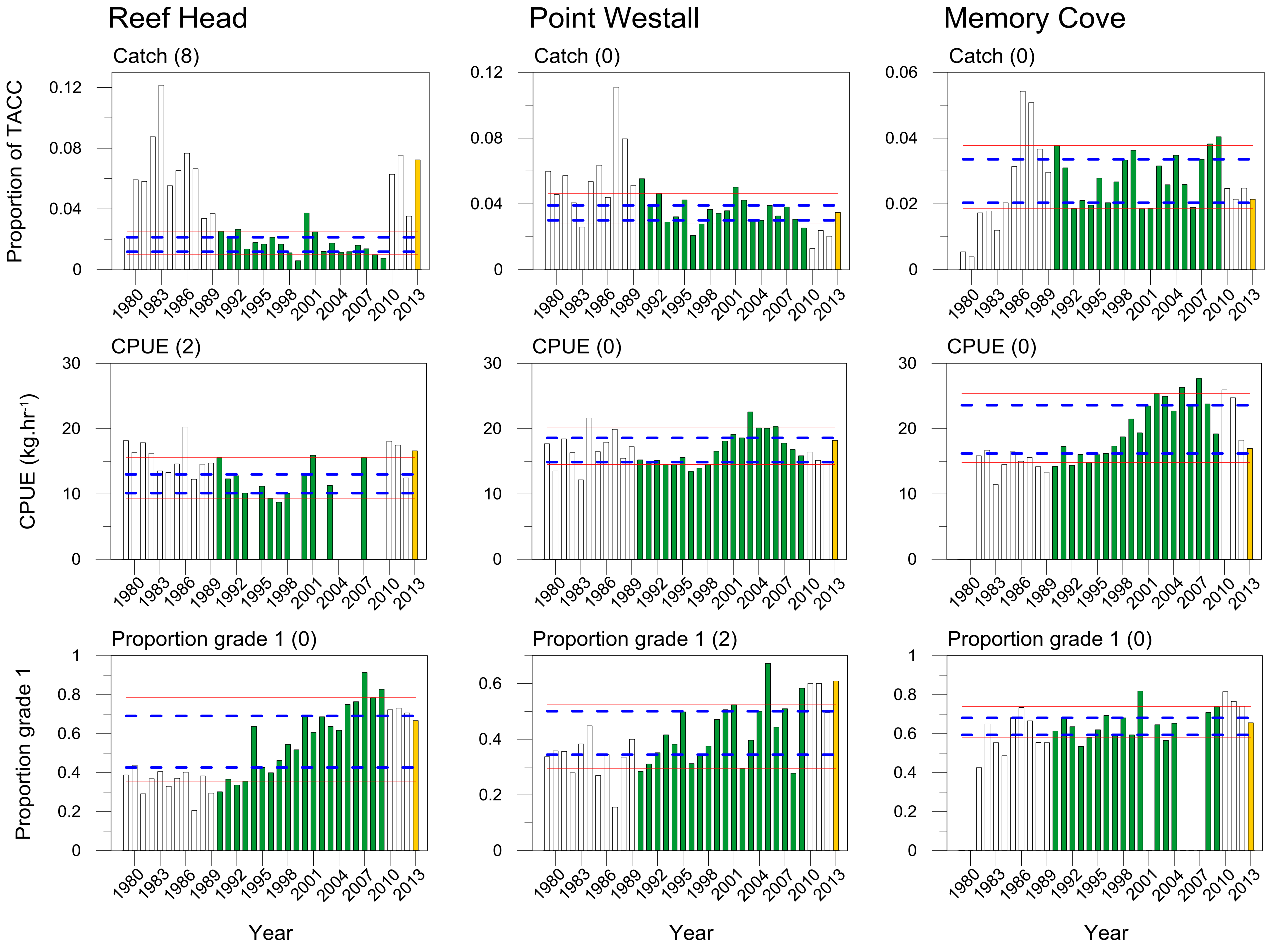

Figure A4.6. Reef Head, Point Westall and Memory Cove SAUs (medium importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropG1 and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Green bars describe 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.

Low importance SAUs

Figure A4.7. Catch (t, meat weight; green bars) of greenlip from low importance SAUs Cape Bauer, Cape Catastrophe, Coffin Bay, D'Entrecasteaux Reef, Elliston Cliffs, Fishery Bay, Franklin Islands, Greenly Island, NE Thistle, Neptune Islands, North Nuyts Archipelago and Pearson Island. CPUE ± se (kg.hr^{-1}) is shown in red. Red dashed lines show $CPUE_{90\text{-}09}$ where applicable. Note catch scales vary among graphs.

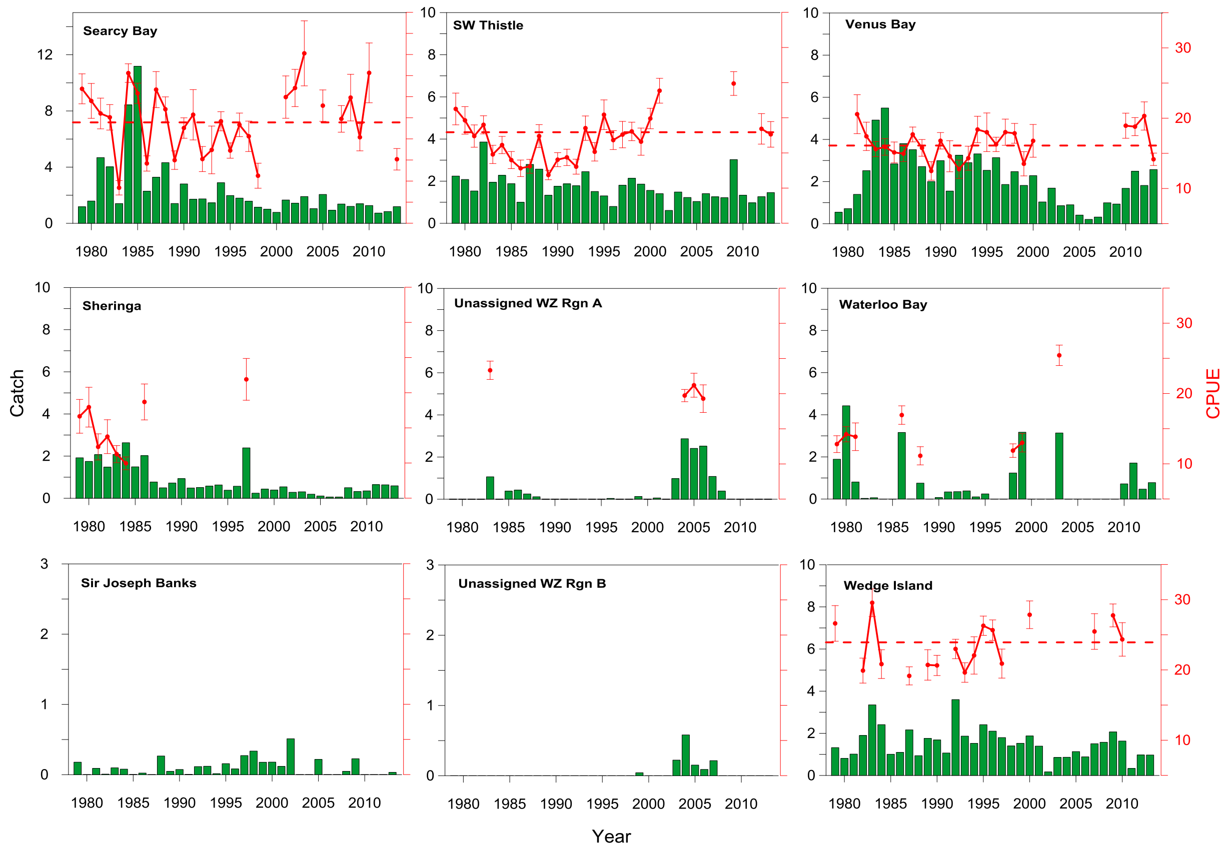

Figure A4.8. Catch (t, meat weight; green bars) of greenlip from low importance SAUs Searcy Bay, Sheringa, Sir Joseph Banks, SW Thistle, Unassigned WZ Region A, Unassigned WZ Region B, Venus Bay, Waterloo Bay and Wedge Island. CPUE ± se (kg.hr^{-1}) is shown in red. Red dashed lines show $CPUE_{90\text{-}09}$ where applicable. Note catch scales vary among graphs.

A.5. Risk-of-overfishing in SAUs and zonal stock status: regions A and B

In 2013, there were three high and ten medium importance SAUs for greenlip in Region A, and one medium importance SAU in Region B, with all remaining SAUs being of low importance (Table A5.1, Table A5.2). It was possible to determine the risk of being overfished for 12 (92%) of the 13 SAUs in Region A, and the single SAU in Region B (100%). The inability to estimate CPUE on greenlip in one medium importance SAU from Region A in 2013 (Hotspot), due to insufficient data, resulted in the greenlip stocks in this SAU being categorised as “uncertain” (Table A5.1).

With only one exception, summed PI scores for greenlip in Region A were identical to those calculated for the WZ (section 3.2). The exception was Memory Cove that had a combined PI score of -1 in Region A and 0 in the WZ. The risk-of-overfishing categories remained identical (Tables 3.1 & A5.1). The catch-weighted zonal score was 0.63, defining a zonal stock status for Region A of “underfished” (Table A5.1).

For Region B, was there was only one medium importance SAU, the South Nuyts Archipelago that had a combined PI score of 3 and was equivalent to a dark blue risk-of-overfishing category (Table A5.2). This contrasted with the WZ where the South Nuyts Archipelago had a combined PI score of -4 and a yellow risk-of-overfishing category (Table 3.1). Low importance SAUs were not assessed against the PIs. The catch-weighted zonal score for Region B was 1.0, defining a zonal stock status for greenlip of “underfished” (Table A5.2)

Table A5.1. Outcome from application of the harvest strategy described in the Management Plan for the SAAF against the greenlip fishery in Region A of the Western Zone. Grey shading identifies the performance indicators and their respective scores. ND indicates no data.

Spatial assessment unit	% contribution to mean total catch (WZ) over the last 10 years (04-13)	Importance	% contribution to catch from high & medium SAU in 2013	CPUE	%TACC	PropG1	Pre-recruit Density	Legal Density	Mortality	Combined PI score	Risk of overfishing	Catch-weighted contribution to zonal score
Anxious Bay	5.1	High	15.90	0	6	7	-3	-4	2	8	2	0.32
The Gap	4.7	High	15.71	0	0	0	-5	0	0	-5	-1	-0.16
Avoid Bay	4.1	High	9.10	0	0	0	0	-1	-2	-3	-1	-0.09
Flinders Island	2.8	Medium	4.88	-2	-8	0	-	-	-	-10	-2	-0.10
Hotspot	2.7	Medium	-	ND	-8	0	-	-	-	Uncertain	Not assigned	-
Ward Island	2.6	Medium	8.48	2	0	-4	-	-	-	-2	0	0.00
Taylor Island	1.9	Medium	4.72	-1	-1	0	-	-	-	-2	0	0.00
Point Avoid	1.8	Medium	7.91	0	8	0	-	-	-	8	2	0.16
Baird Bay	1.4	Medium	5.23	4	0	3	-	-	-	7	2	0.10
Drummond	1.4	Medium	8.83	0	8	0	-	-	-	8	2	0.18
Reef Head	1.4	Medium	10.83	2	8	0	-	-	-	10	2	0.22
Point Westall	1.3	Medium	5.21	0	0	2	-	-	-	2	0	0.00
Memory Cove	1.3	Medium	3.20	0	-1	0	-	-	-	-1	0	0.00
Fishery Bay	1.0	Low		-	-	-	-	-	-	-	Not assessed	
Cape Catastrophe	0.9	Low		-	-	-	-	-	-	-	Not assessed	
SW Thistle	0.8	Low		-	-	-	-	-	-	-	Not assessed	
Venus Bay	0.7	Low		-	-	-	-	-	-	-	Not assessed	
Searcy Bay	0.7	Low		-	-	-	-	-	-	-	Not assessed	
Wedge Island	0.7	Low		-	-	-	-	-	-	-	Not assessed	
NE Thistle	0.6	Low		-	-	-	-	-	-	-	Not assessed	
Unass WZ RG A	0.5	Low		-	-	-	-	-	-	-	Not assessed	
Coffin Bay	0.4	Low		-	-	-	-	-	-	-	Not assessed	
Cape Bauer	0.4	Low		-	-	-	-	-	-	-	Not assessed	
Neptune Islands	0.3	Low		-	-	-	-	-	-	-	Not assessed	
Waterloo Bay	0.2	Low		-	-	-	-	-	-	-	Not assessed	
Sheringa	0.2	Low		-	-	-	-	-	-	-	Not assessed	
Elliston Cliffs	0.1	Low		-	-	-	-	-	-	-	Not assessed	
Pearson Island	0.1	Low		-	-	-	-	-	-	-	Not assessed	
Sir Joseph Banks	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Greenly Island	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Sum	**40.0**		**100.0**									
										Zonal Stock Status		**0.63**

Table A5.2. Outcome from application of the harvest strategy described in the Management Plan for the SAAF against the greenlip fishery in Region B of the Western Zone. Grey shading identifies the performance indicators and their respective scores. ND indicates no data**.**

Spatial assessment unit	Species	% contribution to mean total catch (WZ) over the last 10 years (04-13)	Importance	% contribution to catch from high & medium SAU in 2013	CPUE	%TACC	PropLge	Pre-recruit Density	Legal Density	Mortality	Combined PI score	Risk of overfishing	Catch-weighted contribution to zonal score
South Nuyts Archipelago	GL	2.0	Medium	100.00	2	6	-5	-	-	-	3	1	1.00
North Nuyts Archipelago	BL	1.2	Low		-	-	-	-	-	-	0	Not assessed	
North Nuyts Archipelago	GL	1.1	Low		-	-	-	-	-	-	0	Not assessed	
Franklin Islands	GL	0.7	Low		-	-	-	-	-	-	0	Not assessed	
D'Entrecasteaux Reef	BL	0.6	Low		-	-	-	-	-	-	0	Not assessed	
D'Entrecasteaux Reef	GL	0.5	Low		-	-	-	-	-	-	0	Not assessed	
South Nuyts Archipelago	BL	0.4	Low		-	-	-	-	-	-	0	Not assessed	
Franklin Islands	BL	0.2	Low		-	-	-	-	-	-	0	Not assessed	
Unass WZ RG B	GL	0.1	Low		-	-	-	-	-	-	0	Not assessed	
Unass WZ RG B	BL	0.0	Low		-	-	-	-	-	-	0	Not assessed	
Sum		**6.8**		**100.0**									
											Zonal Stock Status		**1.00**

A.6. Risk-of-overfishing in SAUs and zonal stock status: the WZ in 2012

Table A6.1. Outcome from application of the harvest strategy described in the Management Plan for the SAAF against the greenlip fishery in the Western Zone for 2012. Grey shading identifies the performance indicators and their respective scores. ND indicates no data.

Spatial assessment unit	% contribution to mean total catch (WZ) over the last 10 years (03-12)	Importance	% contribution to catch from high & medium SAU in 2012	CPUE	%TACC	PropG1	Pre-recruit Density	Legal Density	Mortality	Combined PI score	Risk of overfishing	Catch-weighted contribution to zonal score
Anxious_Bay	5.0	High	17.42	0	6	6	-3	-2	2	9	2	0.35
The_Gap	4.9	High	12.33	0	-2	3	-3	0	0	-2	0	0.00
Avoid_Bay	4.0	High	13.17	0	1	2	0	0	1	4	1	0.13
Flinders_Island	3.1	Medium	7.62	0	-8	0	-	-	-	-8	-2	-0.15
Hotspot	3.0	Medium	3.32	2	-7	-2	-	-	-	-7	-2	-0.07
Ward_Island	2.5	Medium	6.72	1	0	-3	-	-	-	-2	0	0.00
South Nuyts Archipelago	2.1	Medium	5.62	0	0	-5	-	-	-	-5	-1	-0.06
Taylors_Island	2.0	Medium	14.01	0	2	3	-	-	-	5	1	0.14
Point_Avoid	1.6	Medium	9.06	4	8	1	-	-	-	13	2	0.18
Baird_Bay	1.4	Medium	3.92	2	-6	2	-	-	-	-2	0	0.00
Memory_Cove	1.3	Medium	3.74	0	0	7	-	-	-	7	2	0.07
Point_Westall	1.3	Medium	3.07	0	-8	0	-	-	-	-8	-2	-0.06
Drummond	1.2	Low		-	-	-	-	-	-	-	Not assessed	
Reef_Head	1.1	Low		-	-	-	-	-	-	-	Not assessed	
North Nuyts Archipelago	1.1	Low		-	-	-	-	-	-	-	Not assessed	
Fishery_Bay	1.0	Low		-	-	-	-	-	-	-	Not assessed	
Cape_Catastrophe	0.8	Low		-	-	-	-	-	-	-	Not assessed	
SW_Thistle	0.8	Low		-	-	-	-	-	-	-	Not assessed	
Franklin_Islands	0.7	Low		-	-	-	-	-	-	-	Not assessed	
Searcy_Bay	0.7	Low		-	-	-	-	-	-	-	Not assessed	
Wedge_Island	0.7	Low		-	-	-	-	-	-	-	Not assessed	
NE_Thistle	0.6	Low		-	-	-	-	-	-	-	Not assessed	
Venus_Bay	0.6	Low		-	-	-	-	-	-	-	Not assessed	
Unassigned WZ RG A	0.6	Low		-	-	-	-	-	-	-	Not assessed	
D'Entrecasteaux_Reef	0.5	Low		-	-	-	-	-	-	-	Not assessed	
Cape_Bauer	0.4	Low		-	-	-	-	-	-	-	Not assessed	
Waterloo_Bay	0.3	Low		-	-	-	-	-	-	-	Not assessed	
Coffin_Bay	0.3	Low		-	-	-	-	-	-	-	Not assessed	
Neptune_Islands	0.2	Low		-	-	-	-	-	-	-	Not assessed	
Sheringa	0.2	Low		-	-	-	-	-	-	-	Not assessed	
Unassigned WZ RG B	0.1	Low		-	-	-	-	-	-	-	Not assessed	
Elliston_Cliffs	0.1	Low		-	-	-	-	-	-	-	Not assessed	
Pearson_Island	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Sir_Joseph_Banks	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Greenly_Island	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Sum	**44.2**		**100.0**									
										Zonal Stock Status		**0.54**