Fisheries

Assessment of the Western Zone Greenlip Abalone (*Haliotis laevigata*) Fishery in 2015

B. Stobart and S. Mayfield

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SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

September 2016

Fishery Stock Assessment Report to PIRSA Fisheries and Aquaculture

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South Australian Research and Development Institute
SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024

Telephone: (08) 8207 5400
Facsimile: (08) 8207 5406
http://www.pir.sa.gov.au/research

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Author(s):	B. Stobart and S. Mayfield
Reviewer(s):	A. Linnane and A. Fowler (SARDI) and B. McGrath-Steer (PIRSA)
Approved by:	T. Ward Science leader – Marine Ecosystems
Signed:	
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EXECUTIVE SUMMARY

This report assesses the status of greenlip abalone (*Haliotis laevigata*, hereafter referred to as greenlip) stocks in the Western Zone (WZ) of the South Australian Abalone Fishery (SAAF).

The Management Plan for the SAAF (PIRSA 2012) requires annual application of the harvest strategy (HS) to determine stock status and review the total allowable commercial catch (TACC). The HS is relatively new and several limitations have been identified, including stock status classifications which are considered over-optimistic (Stobart *et al.* 2014, 2015b). The stock status outcome from the HS was compared to the weight-of-evidence analysis using the National Fishery Status Reporting Framework (NFSRF; Flood *et al.* 2014).

The assessment integrated over three spatial scales: the WZ; three regions (Port Lincoln, Elliston, Streaky Bay); and the spatial assessment units (SAUs) defined in the HS.

Greenlip comprises 47% of the combined WZ TACC. Total catches were relatively stable from 1989 to 2010 (average of 79 t meat weight), but decreased by 16.6% between 2009 (82.6 t) and 2015 (68.9 t). This included a voluntary catch reduction of 5% in 2015.

Determination of stock status was complicated by likely changes in the relationship between catch per unit effort (CPUE) and greenlip abundance during 2015 driven by: (1) a shift in fishing effort from summer to autumn, when catch rates on greenlip are generally higher; (2) a change in the spatial distribution of catch among SAUs; and (3) a higher proportion of large greenlip (PropG1) in the catch. However, as the change in the relationship between CPUE and greenlip abundance could not be quantified, this assessment assumes the relationship has not changed.

In 2014, greenlip stocks were at their weakest position in over 25 years. However, there is considerable evidence that stock status improved between 2014 and 2015. This evidence includes: (1) the largest recorded inter-annual increase in CPUE for the WZ; (2) increases in CPUE in many high and medium importance SAUs and in both summer and autumn; (3) an increase in PropG1, to the third highest value on record; (4) CPUE increasing despite the large increase in the proportion of Grade 1 greenlip harvested; (5) reduced exploitation rate following transfer of catches from summer to autumn, TACC reductions since 2009 and the voluntary catch reduction in 2015. Collectively, these data provide strong evidence that current legal-sized greenlip abundance is similar to, or higher than, that in the 1990s, which preceded the rapid increase in greenlip abundance during the 2000s, and that current exploitation rates have decreased.

There is evidence that some of the component stocks have not similarly improved over the same time period. The harvestable biomass at The Gap, the second most important greenlip SAU, has declined. Legal and sublegal densities from fishery independent surveys at Anxious Bay, the most important SAU, remain low. Historically important fishing grounds show no evidence of recovery in 2015. CPUE estimates for the Port Lincoln region were relatively low in summer and autumn 2015.

Overall, the evidence available does not indicate that (1) the WZ stock is recruitment overfished; or (2) current fishing pressure is likely to result in the stock becoming recruitment overfished. Hence, the WZ Greenlip Abalone Fishery is classified as **'sustainable'** under the NFSRF (Flood *et al.* 2014). This is an improvement from 2014 when the fishery was classified as "transitional depleting". This positive change was also reflected in the outcome from the HS – zonal stock status was 'sustainably fished' in 2014 and 'under fished' in 2015.

Key WZ greenlip statistics from 2014 are summarised in the Table below:

Key statistics for the WZ greenlip fishery from 2014 including number of licences (No. licences); total allowable commercial catch (TACC), voluntary catch limit (VCL), total commercial catch (TCC), catch per unit effort (CPUE), harvest strategy (HS) stock status and national fishery status reporting framework (NFSRF) weight of evidence (WOE) stock status. tmw = tonnes meat weight, kg.hr^{-1} = kilograms per hour, na = not applicable.

Season	No. licences	TACC (tmw)	VCL (tmw)	TCC (tmw)	CPUE (Kg.hr^{-1})	HS Stock Status (TACC)	HS Stock Status (VCL)	NFSRF WOE Stock status
2014	22	73.01	na	71.74	17.05	Sustainably Fished	na	Transitional depleting
2015	22	73.01	69.70	68.88	19.88	Under Fished	Under Fished	Sustainable

1 INTRODUCTION

1.1 Background

This fishery assessment report for greenlip abalone (*Haliotis laevigata*; hereafter referred to as greenlip) in the Western Zone (WZ) of the South Australian Abalone Fishery (SAAF; 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). Recent reports have encompassed the entire WZ following amalgamation of the two regions from 1 January 2014. 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 harvest strategy for the fishery; and (4) identify future research needs.

This report provides an analysis of fishery-dependent (FD) and fishery-independent (FI) data from 1 January 1968 to 31 December 2015 and is part of the ongoing assessment program for the greenlip fishery in the WZ. It also includes analysis of the fishery's performance and stock status based on the harvest strategy described in the Management Plan (PIRSA 2012). The report is divided into four sections.

This Introduction provides (1) a general overview of the report; (2) the history and a description of the fishery, including the Management Plan and; (3) relevant information on greenlip biology. Section 2 details the methods used in this assessment. Section 3 is the Results and provides an assessment of FD and FI data for greenlip. 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. In Section 4, 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 evaluated, and future research needs are also identified. In the Discussion, we also compare status of greenlip stocks in the WZ determined using the harvest strategy and traditional, weight-of-evidence assessments under the National Fishery Status Reporting Framework (NFSRF; Table 1.1; Flood *et al.* 2014) adopted by Primary Industries and Regions South Australia (PIRSA) Fisheries and Aquaculture for classifying fish stocks (PIRSA 2015).

Table 1.1. Terminology for the status of key Australian fish stocks reports (Flood *et al.* 2014).

Stock status	Description	Potential implications for management of the stock
Sustainable	Stock for which biomass (or biomass proxy) is at a level sufficient to ensure that, on average, future levels of recruitment are adequate (i.e. not recruitment overfished) and for which fishing pressure is adequately controlled to avoid the stock becoming recruitment overfished	Appropriate stock management is in place
↑ Transitional–recovering	Recovering stock—biomass is recruitment overfished, but management measures are in place to promote stock recovery, and recovery is occurring	Appropriate stock management is in place, and the stock biomass is recovering
↓ Transitional–depleting	Deteriorating stock—biomass is not yet recruitment overfished, but fishing pressure is too high and moving the stock in the direction of becoming recruitment overfished	Management is needed to reduce fishing pressure and ensure that the biomass does not deplete to an overfished state
Overfished	Stock is recruitment overfished, and current management is not adequate to recover the stock; or adequate management measures have been put in place but have not yet resulted in measurable improvements	Management is needed to recover this stock; if adequate management measures are already in place, more time may be required for them to take effect
Undefined	Not enough information exists to determine stock status	Data required to assess stock status

1.2 History and description of the fishery

1.2.1 Commercial fishery

A review of the management history of the SAAF since its inception in 1964 is provided by Mayfield *et al.* (2012). Major management milestones are listed in Table 1.2. Briefly, 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. By 1976, the number had fallen to 30 and an additional 5 licences were issued. These 35 licences remained until 2013. From 1 January 2014, removal of one licence – as part of the voluntary marine park buy-back scheme – reduced the total number of licences in the SAAF to 34.

In 1971, the SAAF was divided into three zones (Western (WZ), Central and Southern) (Figure 1.1). The WZ of the SAAF includes coastal waters of South Australia between the Western Australia/South Australia border and eastern Eyre Peninsula (Figure 1.1). This zone was subdivided into Region A and Region B in 1985, a process that was reversed in 2014. Quota removal from the WZ due to marine park implementation in 2014 led to a reduction in the total number of licenses to 22. The fishing season extends from 1 January to 31 December each year. The only exception was a voluntary closure of Region B from October to February, starting from October 2011 and remaining in place up to 1 January 2014.

Table 1.2. Management milestones: 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 shell length (SL) for both species
1976	30 licences remained; 5 additional licences issued
1978	Sub-zones and fishing blocks replaced by map numbers and codes
1980	Licences became transferable
1984	Greenlip minimum legal length amended to 145 mm SL 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	Total allowable commercial catch (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 97.8 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 (PIRSA 2012)
	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 amalgamated, Number of licences reduced to 22.
	TACC in Western Zone greenlip fishery increased to 73 t, blacklip fishery decreased to 84.1 t
	Ministerial exemption to harvest *Haliotis roei* with a TACC of 11 t granted from February 2014
2015	Harvest strategy review commenced

A research logbook must be completed for each fishing day and submitted to SARDI Aquatic Sciences at the end of each month. Commercial catch and effort data on this fishery have been collected since 1968. These data are used in stock assessment or status reports for each zone.

In Region A, annual Total Allowable Commercial Catches (TACCs) were introduced for blacklip in 1985 and amended to the calendar year fishing season from 1989 (Nobes *et al.* 2004). From 1989 to 2014, the TACC for greenlip in Region A was 69 t meat weight, with the exception of a 6.9 t (10%) TACC increase from 2006 to 2009 (75.9 t). The latter took advantage of increased legal-sized abundance, which was likely a consequence of strong recruitment in the 1990s (Stobart *et al.* 2011). For 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 in Region B was reduced substantially prior to 2012. Regions A and B were merged from January 2014 to improve the efficiency and cost-effectiveness of the assessment and management framework.

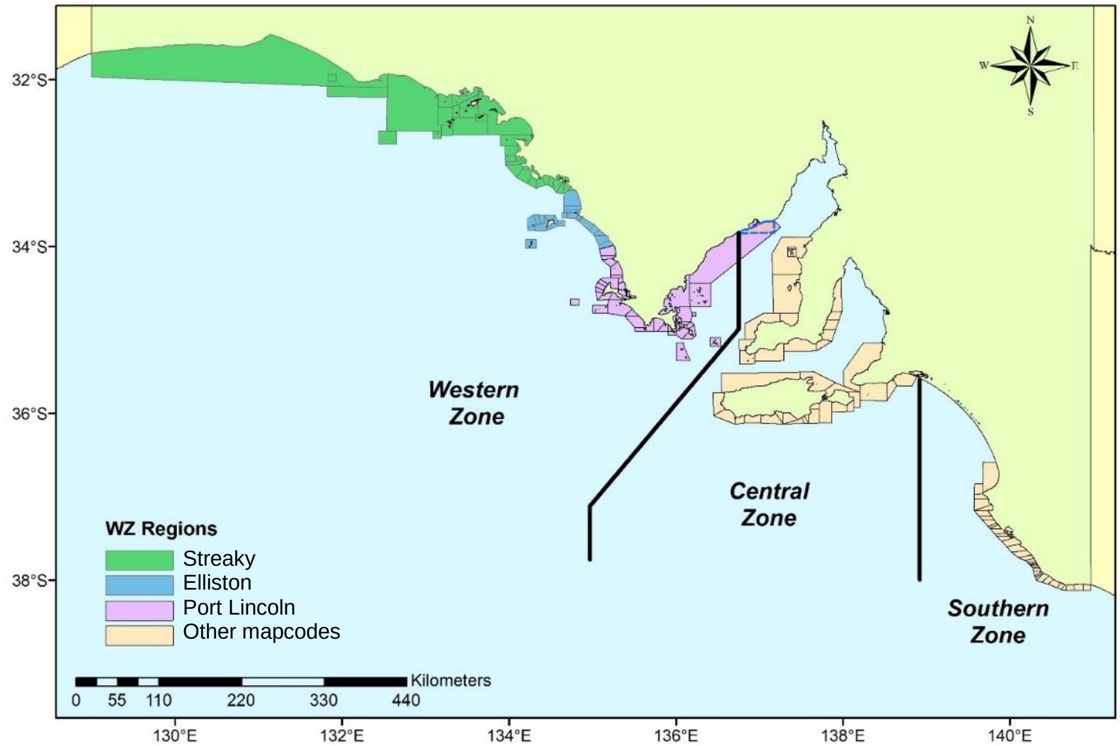

Figure 1.1. Fishing zones and mapcodes of the South Australian Abalone Fishery and regions of the WZ.

Since 1997, the fishery has operated under the control of formal management plans (Zacharin 1997; Nobes *et al.* 2004; PIRSA 2012). These plans ensure 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 Tables 1.2 and 1.3.

Table 1.3. 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), *H. roei* (roei)
Minimum legal length	Blacklip 130 mm SL, Greenlip 145 mm SL, Roei 75 mm SL
Quota year	1 January to 31 December
Quota transferability	Yes
Other species permitted	*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 (Paterson *et al.* 2013; Rippin *et al.* 2014; Fargher *et al.* 2015). Catch value (gross value of production – GVP) in the fishery increased rapidly between 1997/98 and 2000/01, but followed a declining trend in subsequent years associated with a decline in the price of abalone that was linked to an increase in the value of the Australian dollar (Rippin *et al.* 2014). Until 2013/14, GVP closely followed changes in average price because total catch had remained relatively stable. However, in 2013/14, the total catch of abalone in the SAAF dropped by 25% (principally through the Southern Zone TACC not being harvested, see Mayfield *et al.* 2015) so GVP was impacted by both changing levels of catch and changes to average price. In 2013/14 the SAAF catch was valued at AU$22.1 million dollars, directly and indirectly generating 247 full time jobs. Both are now lower than the previous assessment in 2012/13.

Paid labour, which accounts for the largest share of total cash costs to the SAAF, decreased by 16% between 2012/13 and 2013/14 (Fargher *et al.* 2015). Other major costs include interest, management fees and fuel. With the exception of interest repayments and insurance, most fixed costs were lower in 2013/14. Profitability of the fishery fell in 2013/14, with profit at full equity 36% lower than the previous year. The average cost of management per licence holder has remained relatively stable since 2004/05 and in 2013/14 was AU$73,292. However, the combination of a small increase in management costs and a decrease in value of the catch has resulted in licence fees being 11.3% of GVP in 2013/14 (Fargher *et al.* 2015).

1.2.3 Recreational fishery

The most recent recreational greenlip abalone catch estimate for South Australia was 4,395 individuals for the 12 month period from late 2013 to 2014 (Giri and Hall 2015). This equates to 1.93 t meat weight, a 14% increase since the previous survey (Jones 2009). Recreational fishing effort was estimated at 16% for the west coast during 2013/14 (Giri and Hall 2015), equating to 703 greenlip. However, with estimates of greenlip abundance highest in the Western and Central zones, it is likely that recreational greenlip harvest in the WZ is greater than 703 individuals per annum.

1.2.4 Illegal, unregulated and unreported catch

Illegal, unregulated and unreported (IUU) catch is difficult to estimate. PIRSA rely on field observations and intelligence reports that document quantities of abalone when estimating the IUU catch. During 2015, PIRSA received 75 information reports relevant to the Western Zone.

Nine reports contained estimates of illegally harvested abalone which totalled 66.3 kg (meat weight). Applying the mean weight per information report (7.37 kg/report) to the 75 provides an estimated illegal harvest equivalent to 0.55 t (meat weight) abalone or 0.3% of the TACC. This estimate excludes IUU take where a caution, expiation or brief has been compiled. It should also be noted that PIRSA would not have been advised of all illegally harvested abalone and as such, the actual extent of IUU is expected to be higher.

1.3 Management Plan

The second Management Plan for the SAAF (Nobes *et al.* 2004) was reviewed and replaced in 2012 by the current management plan (PIRSA 2012) that is undergoing review with recommendations due by June 2017. This 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 Act 1999* and the precautionary principle.

The four management goals 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 it is described elsewhere (Chick and Mayfield 2012; PIRSA 2012; Stobart *et al.* 2012a; 2012b; Mayfield *et al.* 2013). Briefly, it is species-specific, spatially-explicit 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 spatial assessment unit (SAU) (Figure 1.2) are overfished. Second, the assigned risks that the stocks are overfished are catch-weighted and summed to determine the status of that stock for each zone. The stock status enables the TACC to be set for two years – concurrent with the biennial assessment program – providing that zonal stock status does not change among years.

The outcomes from the harvest strategy 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 (PIRSA 2012). 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.

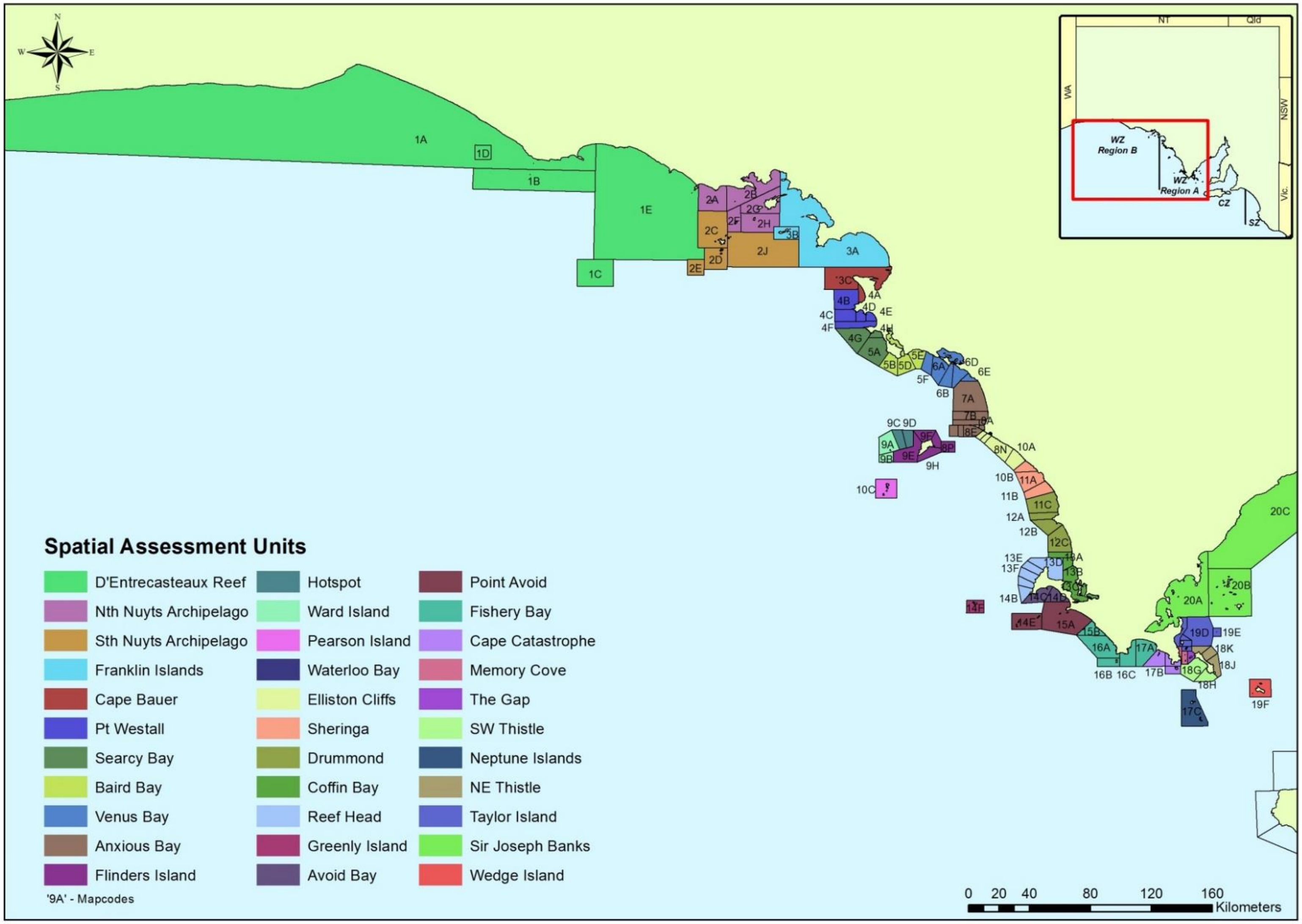

Figure 1.2. Spatial assessment units (SAUs) and map codes of the Western Zone South Australian Abalone Fishery.

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 >50 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; Miller *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 shell length (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), hence reducing population density to a low level (termed the Allee effect) may substantially 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 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 in space and time, and largely dependent on water temperature, water movement and the quantity and species of macro algae 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 have been used (Haddon *et al.* 2008). Newly settled greenlip grow rapidly, at around 20-30 $\mu m.day^{-1}$ (Preece *et al.* 1997; Rodda *et al.* 1997). Sublegal 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 can 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 reports were produced annually between 1998 and 2000 (Rodda *et al.* 1998; 2000; Shepherd *et al.* 1999). The 2001 stock assessment report provided the first 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 were provided to PIRSA in alternate years. From 2014, following the amalgamation of regions A and B, dedicated greenlip assessments have been provided for the WZ (Stobart *et al.* 2014, 2015b).

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 ascribed to an increased abundance of legal-sized greenlip between 2000 and 2008 following elevated, zone-wide recruitment levels in the mid-late 1990s. These changes were followed by a decline, including a sharp reduction between 2008 and 2009. This pattern was not as apparent in Region B, although there was a period of relatively high greenlip CPUE between 1999 and 2004 (Stobart *et al.* 2012a). Following this period of increased abundance, assessments focused on understanding current abundance in relation to the historical abundance (i.e. in the 1990's, prior to the TACC increase). In 2013, the CPUE was similar to that in the 1990s, but there was no evidence that the decrease in CPUE had abated (Stobart *et al.* 2014). The similarity between the estimates of CPUE and survey density estimates in the 1990s and 2013 were the primary drivers for the fishery being classified as 'sustainable'. Maintenance of the TACC being reliant on each SAU yielding greenlip catches of similar levels to those harvested in 2013 and the absence of evidence that catch could be increased substantially from any SAUs were noted as early indicators of potential future stock status (Stobart *et al.* 2014). This was in contrast to the outcome from the harvest strategy which determined WZ zonal stock status in 2013 as 'under-fished'.

The decline in greenlip stocks continued in 2014 and was reflected in the zonal stock status, derived from the harvest strategy, which changed from 'under-fished' in 2013 to 'sustainably-fished' in 2014 (Stobart *et al.* 2015b). In contrast, based on the weight-of-evidence, the fishery was classified as 'transitional depleting' in 2014. This was because data for the fishery suggested greenlip stocks were at their weakest position in over 25 years.

2 METHODS

This assessment relies on analyses of fishery-dependent and fishery-independent data. Fishery-dependent data consisted of catch and effort data for the 47-year period from 1 January 1968 to 31 December 2015, and weight grade data from 1 January 1979 to 31 December 2015 provided by fish processors. The fishery-independent data consisted of estimates of density derived from timed-swim and leaded-line surveys periodically conducted in selected SAUs from 1989 to 2013 and 2004 to 2016, respectively. During these surveys, population length-frequency distributions were also obtained at the same locations.

Data were analysed at three spatial scales: (1) WZ; (2) regions of the WZ (i.e. Port Lincoln, Elliston and Streaky Bay); and (3) SAUs defined in the harvest strategy. The regions of Port Lincoln, Elliston and Streaky Bay comprised those SAUs typically accessed from these regional centres (see Figure 1.1). Data were also analysed at multiple temporal scales. These were (1) complete years; and (2) summer (January – February) and autumn (March – June) seasons.

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 contribute 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 and proportion of Grade 1 greenlip (PropG1) were computed by year and season for the WZ, SAUs and WZ regions. CPUE was estimated 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 catch was >300 kg, effort was <3 and >8 hours, or the ratio of total catch over total hours was >50 kg.hr^{-1}. In addition, data where greenlip comprised <30% of catch were also removed. To account for changes in temporal fishing patterns (see Section 3.1), we undertook a preliminary standardisation of the CPUE time series for the WZ using the seasonal relationships between SL and bled meat weight after Stobart *et al.* (2013). This was achieved by normalising greenlip catch values in each month to January to obtain a normalised CPUE.

For PropG1, all records where the total catch was >1% different from the sum of all three weight-grade categories were excluded, as were all records with zero catch. The minimum sample size for both these measures 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 2006 and 2015 ($C_{06\text{-}15}$); and (2) the mean annual CPUE for the 20-yr period between 1990 and 2009 ($CPUE_{90\text{-}09}$). CPUE values whose standard error bars overlap $CPUE_{90\text{-}09}$ are considered equivalent-to $CPUE_{90\text{-}09}$. Ranking and percent of total catch in SAU titles refer first to the ten-year period ($C_{06\text{-}15}$), followed by the value in 2015 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 2015).

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 total 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; consequently, 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 ($PropG1_{90\text{-}09}$).

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 biennially 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 sublegal-sized greenlip. These are primarily obtained from high importance SAUs, but historically were also conducted in other SAUs (see Appendix A3). In 2015, data were available for the three high importance SAUs. Density was estimated using timed-swims (Shepherd 1985) and leaded-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 sublegal-sized greenlip (i.e. ≥ 110 mm SL to 144 mm SL). Greenlip density estimates from timed-swims in 2016, required for application of the harvest strategy to The Gap SAU, were obtained by applying the percentage change in density from the leaded-lines between 2013 and 2016, to the 2013 timed-swim estimates.

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).

There was a key difference between application of the harvest strategy in this report compared with previous status and assessment reports. This is because two outcomes are provided based on differing values from the scoring of the “proportion of TACC” PI. Thus, application of the harvest strategy to determine the zonal stock status was carried out using both the legislated TACC (73.0 t) and voluntary (69.7 t) catch limit. This reflects the commercial sector unanimously agreeing to voluntarily under-catch the TACC by 5% in 2015.

The shift to biennial fishery-independent surveys has required adjustment of the time period over which these FI data contribute to the harvest strategy. To prevent aged survey data being used, only survey data obtained in the last four years (i.e. 2013-2016) were used in this assessment. This results in fewer survey data being used (typically 2 years) when compared to fishery-dependent data (all four years). Whilst this effectively ‘down weights’ the survey data, this approach is used because it maintains the use of most recent data in line with the design of the harvest strategy.

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. Details on the five individual components are provided in Appendix 2.

3 RESULTS

3.1 Western Zone

Total catches were relatively stable between 1989 and 2009, when the Region A TACC was reduced to 69 t (Figure 3.1). Within this period, fluctuations in catch were attributed to: (1) the introduction of quota to Region B in 1991 (9.2 t); (2) increases to the Region B TACC in 1993 (11.5 t) and 1994 (13.8 t); (3) fluctuation in the proportion of greenlip caught in Region B; and (4) an increase to the Region A TACC from 2006 to 2009 (75.7 t). Subsequently, catch from the WZ decreased by 16.6% between 2009 (82.6 t) and 2015 (68.9 t) after reductions to the Region A TACC in 2010 (69 t), Region B in 2011 (9.2 t) and 2013 (6.9 t), the removal of a licence during the process of merging regions A and B in 2014 and a 5% voluntary under-catch of the TACC in 2015.

Nominal CPUE (hereafter referred to as 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 (Figure 3.1). From 1998 to 2003, CPUE increased 30% to the highest level on record (23.8 kg.hr^{-1}). With few exceptions, CPUE declined between 2003 and 2014, whereafter it increased substantially (17%). In 2015, CPUE was 19.9 kg.hr^{-1} and equivalent to CPUE$_{90\text{-}09}$. The trend in normalised CPUE between 1979 and 2015 closely resembled CPUE. However, between 2014 and 2015, normalised CPUE increased 13%, three quarters that observed for CPUE.

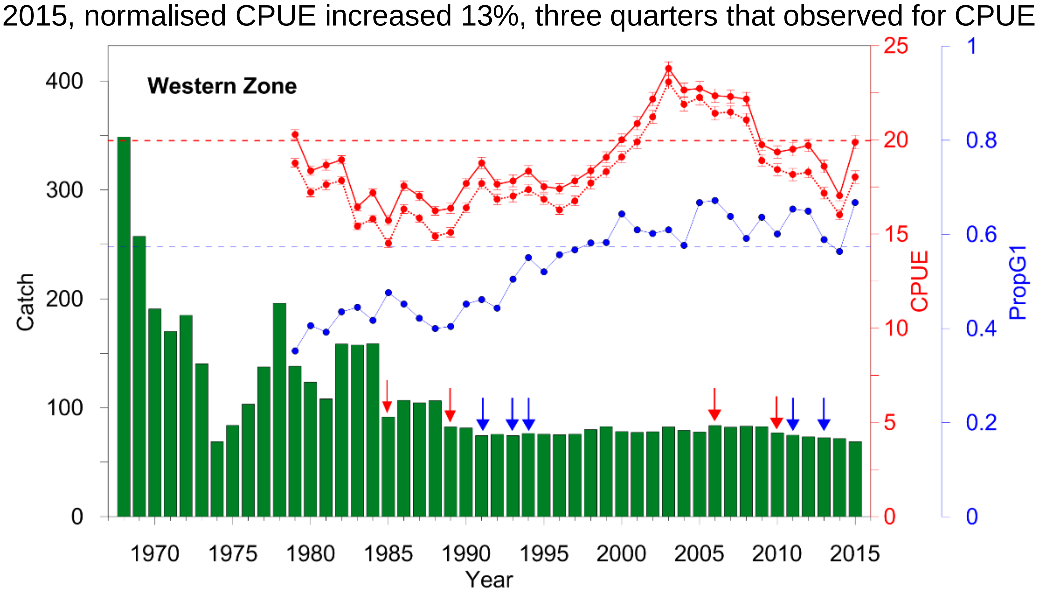

Figure 3.1. Catch (t, meat weight; green bars) of greenlip from the Western Zone from 1968 to 2015. CPUE and normalised CPUE ± se (kg.hr^{-1}) are shown as red lines and dashed lines respectively. PropG1 are shown as blue lines. Red and blue dashed horizontal reference lines show CPUE$_{90\text{-}09}$ 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.

Proportion of Grade 1 greenlip in the commercial catch has been above, or equivalent-to, $PropG1_{90\text{-}09}$ since 1997 and, from 2014 to 2015, increased by 19% to the third highest value on record (Figure 3.1). Both changes in CPUE and PropG1 observed between 2014 and 2015 were the highest inter-annual changes on record.

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. More recently, the percentage of catch caught in summer has decreased from 66% in 2004 to 28% in 2015, while autumn catch has increased from 16% in 2007 to 45% in 2015 (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 WZ (62% of years) and the combined three high importance SAUs (78% of years).

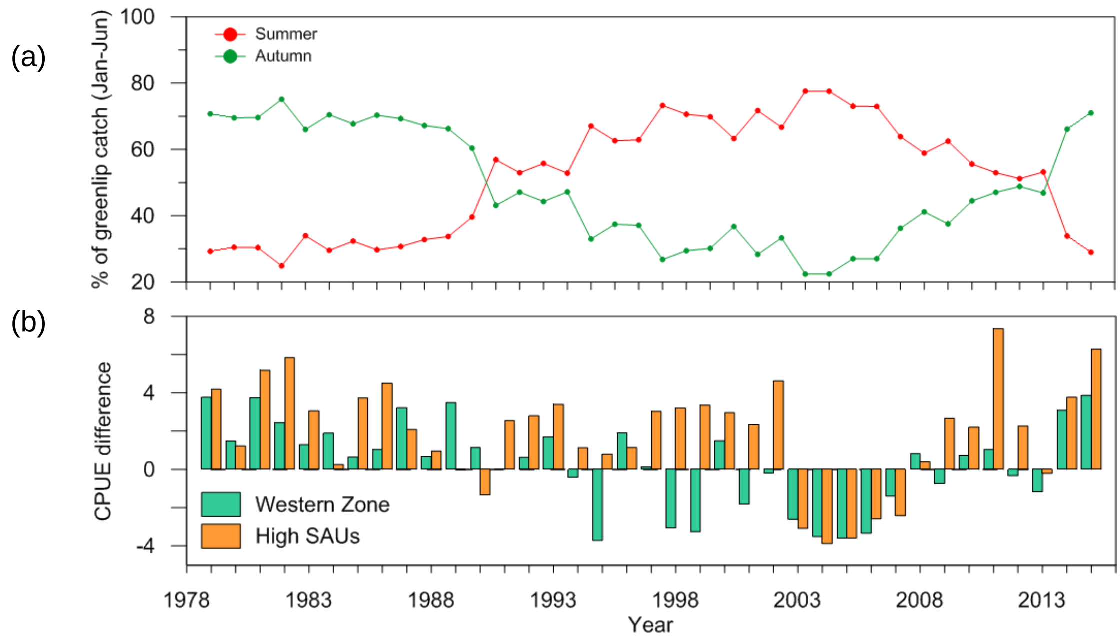

Figure 3.2. a) Within season distribution of greenlip catch (% of total greenlip catch) from the Western Zone from 1979 to 2015 where Summer = Jan-Feb and Autumn = Mar-Jun; b) Difference between CPUE (kg.hr^{-1}; Autumn CPUE – summer CPUE). Legends indicate a) season and b) spatial scale of CPUE estimate.

The increase in zonal CPUE observed between 2014 and 2015 was apparent both for CPUE estimated for summer (7. 6% increase) and autumn (13.3% increase; Figure 3.3a). During the same period, the proportion of Grade 1 greenlip also increased 15.8% in summer and 21% for autumn (Figure 3.3b). The 2015 CPUE values for the three regions, relative to historic, differed both in summer and autumn (Figure 3.4). The 2015 summer CPUE for Port Lincoln was the fourth lowest on record, Elliston was relatively low (within the lower third of records) and Streaky Bay was relatively high. Similarly, the Port Lincoln autumn CPUE estimate for 2015 was relatively low, Elliston close to the long-term average and Streaky Bay the second highest on record. The increase in zonal CPUE between 2014 and 2015 during summer was primarily due to an increase in CPUE from Elliston, with Streaky Bay and Port Lincoln recording small increases and decreases, respectively (Figure 3.4). This was in contrast to autumn CPUE that increased considerably in all three regions. PropG1 increased during summer throughout the WZ but was relatively small for the Streaky Bay region (Figure 3.5). In contrast, the increase was large for all regions in autumn.

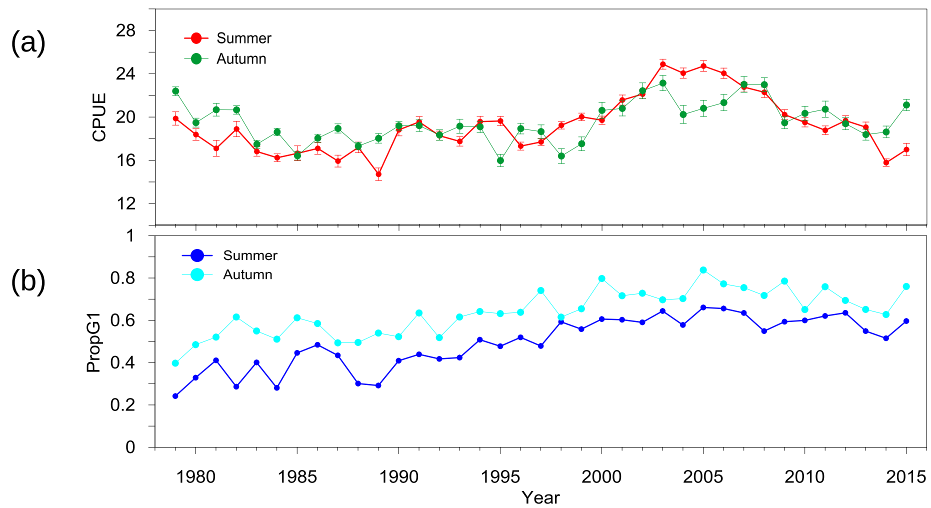

Figure 3.4. a) Seasonal difference between CPUE(kg.hr^{-1}) from 1979 to 2015; and b) proportion Grade 1 greenlip as shown in legends where Summer = Jan-Feb and Autumn = Mar-Jun.

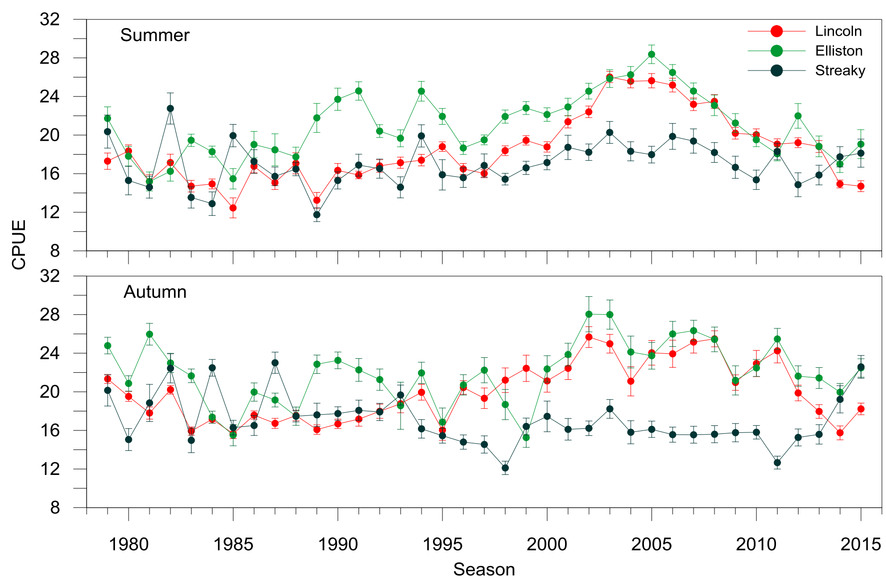

Figure 3.3. Difference between CPUE at SAUs located near Port Lincoln, Elliston and Streaky Bay (see legend) during Summer (Jan-Feb) and Autumn (Mar-Jun) from 1979 to 2015.

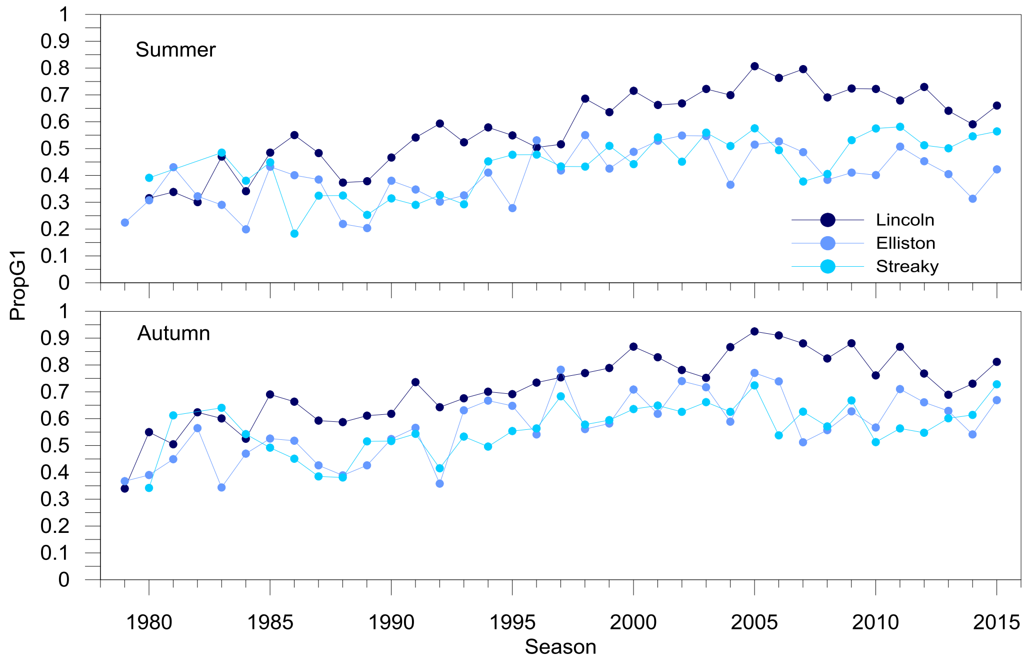

Figure 3.5. Difference between PropG1 at SAUs located near Port Lincoln, Elliston and Streaky Bay (see legend) during summer (Jan-Feb) and autumn (Mar-Jun) from 1979 to 2015.

Spatial assessment units (SAUs)

For the ten year period ending 31 December 2015, there were 11 high and 16 medium importance SAUs in the WZ (Figure 3.6). Of these, 3 high (Anxious Bay, The Gap and Avoid Bay) and 12 medium (Flinders Island, Ward Island, Point Avoid, Hotspot, Drummond, Taylor Island, Reef Head, South Nuyts Archipelago, Baird Bay, Point Westall, Memory Cove and Fishery Bay) SAUs were for greenlip. The only changes in importance rating between 2014 and 2015 were for Memory Cove and Fishery Bay SAUs, for which relatively high catches in 2015 led to them changing status from low importance in 2014 (Stobart *et al.* 2015a) to medium importance in 2015.

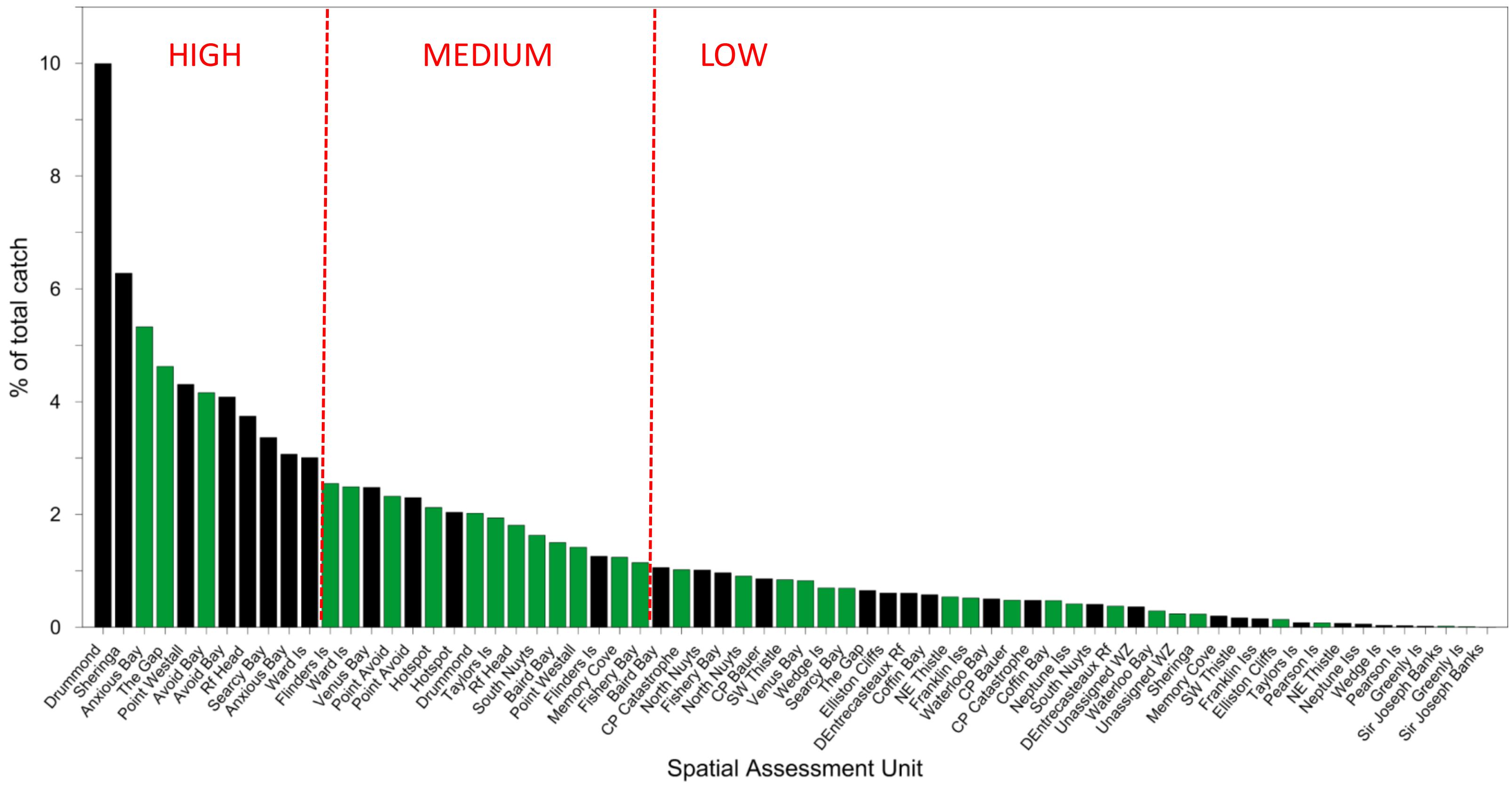

Figure 3.6. Relative importance (% of total catch) of each greenlip (green bars) and blacklip (black bars) SAUs. Note each SAU is ranked twice, once for greenlip and once for blacklip. Red text and dotted lines indicate SAU importance category and division. Note abbreviations for Cape (Cp), island (Is), reef (Rf), North East (NE) and South West (SW).

3.1.2 Distribution of catch among spatial assessment units

In 2015, there were eight SAUs from which more than 5% of the total greenlip catch for the WZ was harvested. These were Anxious Bay (13.5%), The Gap (9.3%), Point Avoid (9.2%), Avoid Bay (9.2%), Reef Head (7.0%), Drummond (6.6%), Baird Bay (6.5%) and Ward Island (5.5%). Cumulatively, these SAUs represented 67% of the catch. The same SAUs contributed less to the catch in 2014 (54%) as the distribution of catch among SAUs changed between years, with considerable increases at Avoid Bay (3.9 t; 5.5% to 6.3 t; 9.2%) and Point Avoid (4.2 t; 5.8% to 6.3 t; 9.2%), and a decrease at The Gap (8.9 t; 12.4% to 6.4 t; 9.3%).

The MDS plot shows three periods when the distribution of catches among SAUs was similar (i.e. 75% similarity; Figure 3.7). During the longest period of similarity (1990 to 2009) a large proportion of the catch was harvested from Hotspot and Flinders Island SAUs, generally changing less abruptly between years (Figure 3.8). The period between 2010 and 2013 was marked by a redistribution of catch into non-traditional greenlip fishing grounds (e.g. Drummond SAU) from more traditional fishing grounds such as the Flinders Island, Hotspot and Ward Island SAUs, spreading catch more evenly across the fishery. There was further change between 2013 and 2014, when the distribution of catch became more similar to that of the early years of the fishery (1979 to 1983) when fishing was less evenly spread across SAUs (Figure 3.8). The spatial distribution of catch in 2015 was most similar to that of 1981, with a higher proportion obtained from Anxious Bay, Avoid Bay and Point Avoid SAUs. Within the last three years, the shift between clusters (2 in 2013 to 1 in 2014 – see Figure 3.7) was most strongly influenced by increases in catch from Fishery Bay and decreases in catch from Coffin Bay, D'Entrecasteaux Reef, North Nuyts Archipelago and South Nuyts Archipelago SAUs. In 2015 there was further change primarily attributed to increased catch from Avoid Bay and Point Avoid, along with decreases from South Nuyts Archipelago, Franklin Islands, Point Westall and Flinders Island SAUs.

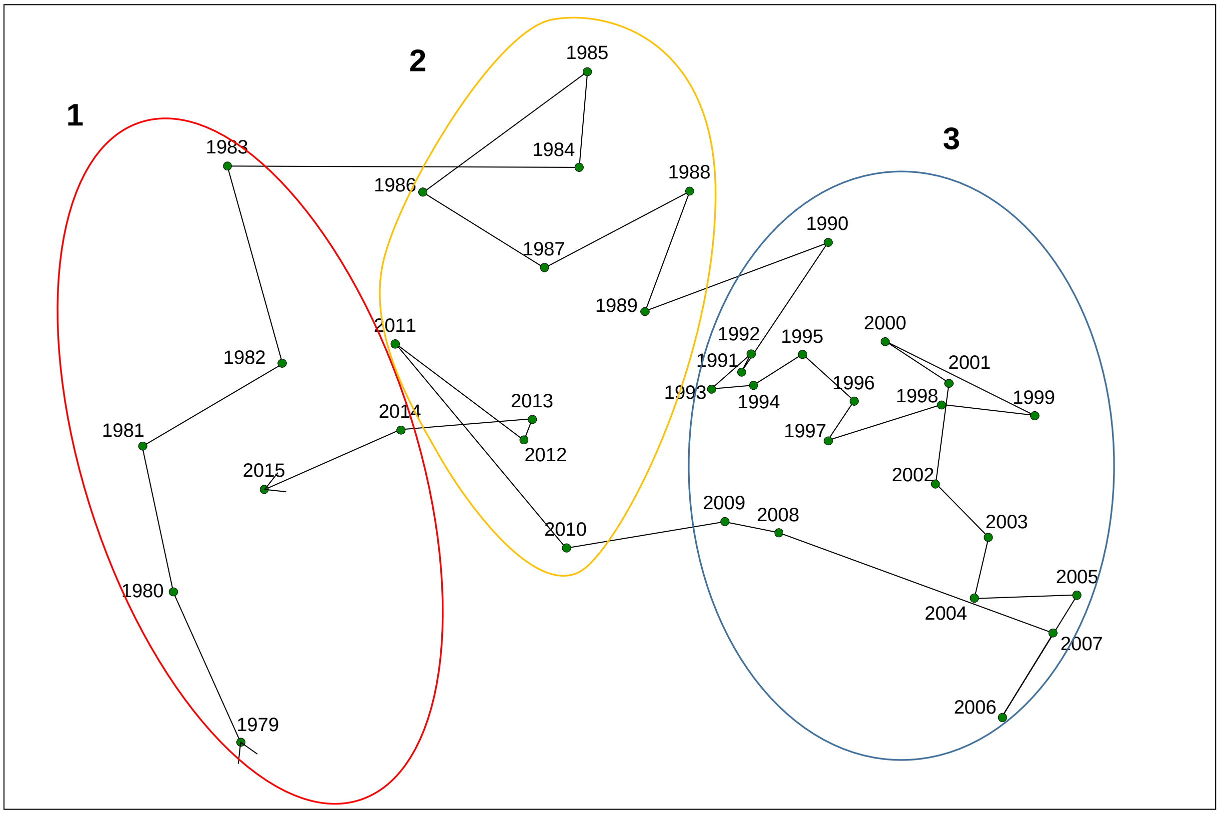

Figure 3.7. Multi-dimensional scaling (MDS) plot for SAUs showing similarity among years based on the spatial distribution of greenlip catch from the Western Zone from 1979 to 2015. 2D stress = 0.13. Red, orange and blue lines indicate numbered clusters with 75% similarity, labelled 1 to 3.

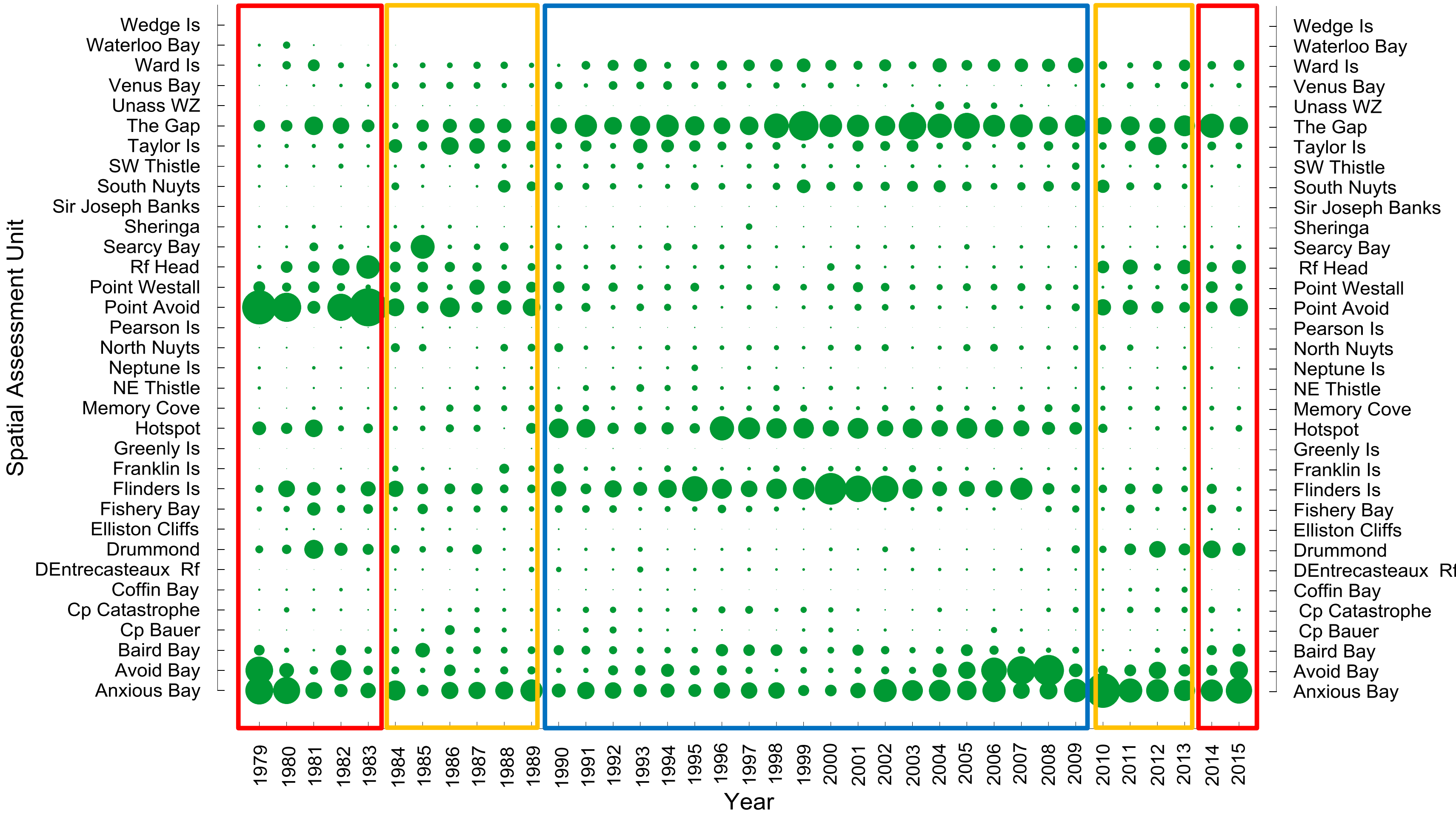

Figure 3.8. Bubble plot showing the spatial distribution of the greenlip catch (% of total catch) among the SAUs in the WZ from 1979 to 2015. Coloured boxes are clusters 1 (red), 2 (orange) and 3 (blue) from the MDS in Figure 3.7. Note abbreviations for Cape (Cp), island (Is), reef (Rf), north east (NE) and south west (SW).

3.1.3 Temporal patterns in high importance spatial assessment units

Anxious Bay (Rank 1-1; 11.8-13.5%)

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 3.9). In 2015, catch was 9.3 t. CPUE increased from 1996 with maxima in 2004 and 2008 (~28 $kg.hr^{-1}$). However, CPUE decreased between 2008 and 2014 (19.5 $kg.hr^{-1}$), to the lowest level since 1996. Between 2014 and 2015, CPUE increased by 22% and, in 2015, was equivalent to $CPUE_{90\text{-}09}$. The PropG1 has exceeded $PropG1_{90\text{-}09}$ since 2005 and, in 2015 was 41% above $PropG1_{90\text{-}09}$.

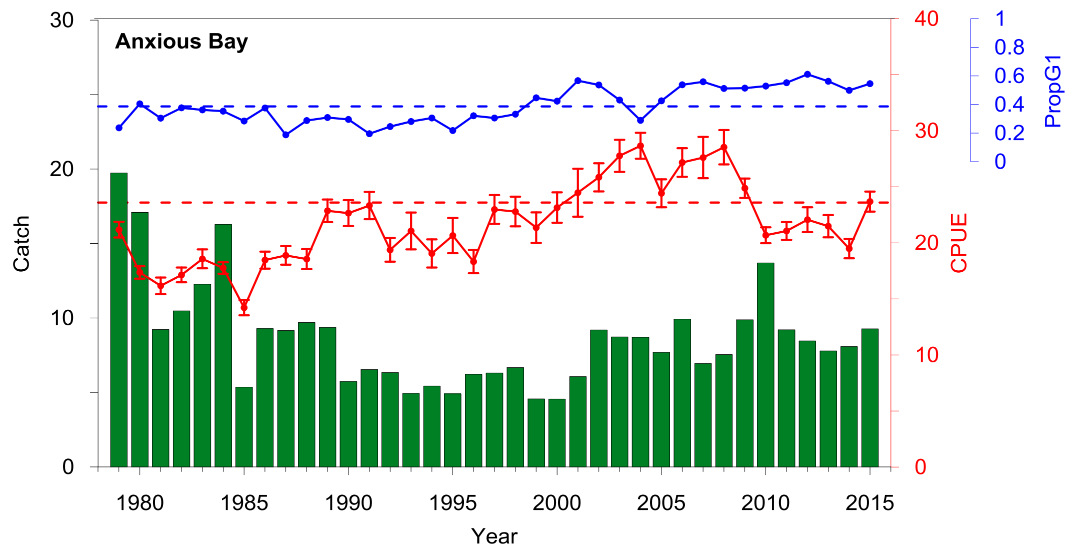

Figure 3.9. Catch (t, meat weight; green bars) of greenlip from Anxious Bay from 1979 to 2015. CPUE ± se ($kg.hr^{-1}$) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

FI surveys at Anxious Bay indicated that the percentage of LARGE greenlip varied between years (range: 22-82%), with the highest percentage recorded in 2016 (Figure 3.10). The percentage of SMALL greenlip was the lowest on record in 2013 (8%) and highest in 2016 (23%) and 2006 (26%). The density of legal-sized greenlip halved between 2007 and 2008 and remained low in 2010, 2012, 2013 and 2016, although 2016 was the highest since 2007 (Figure 3.11). The density of sub-legal-sized greenlip decreased consistently between 2004 and 2012, remaining at similarly low levels in 2013 and 2016.

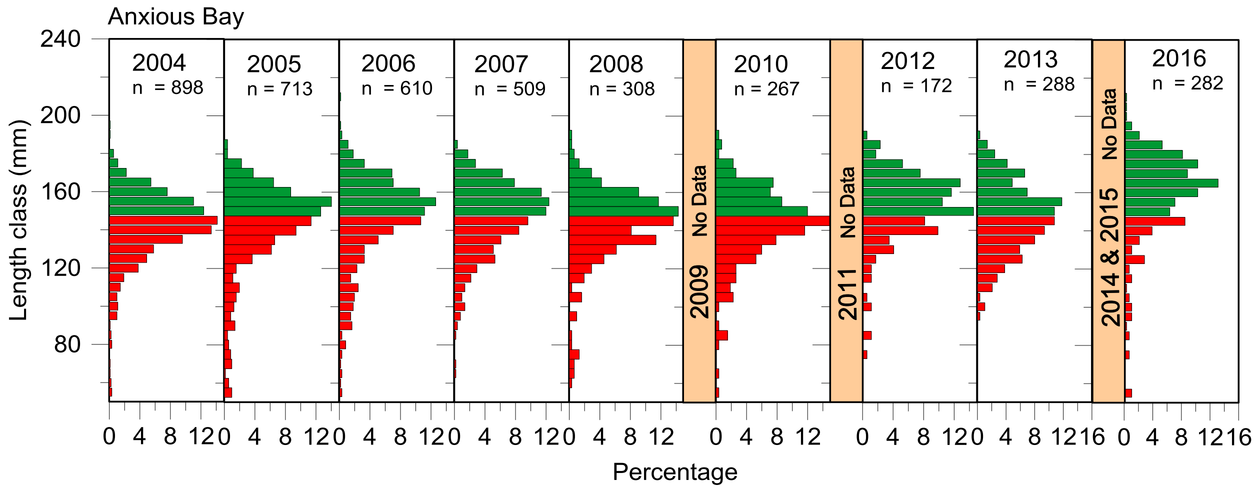

Figure 3.10. Length-frequency distributions of legal-sized (green bars) and sublegal-sized (red bars) greenlip at Anxious Bay (mapcode 8A) observed on fishery-independent surveys from 2004 to 2016. Length classes represent the upper length of each 5 mm bin. n = number of greenlip measured. Bin classes < 50 mm SL pooled.

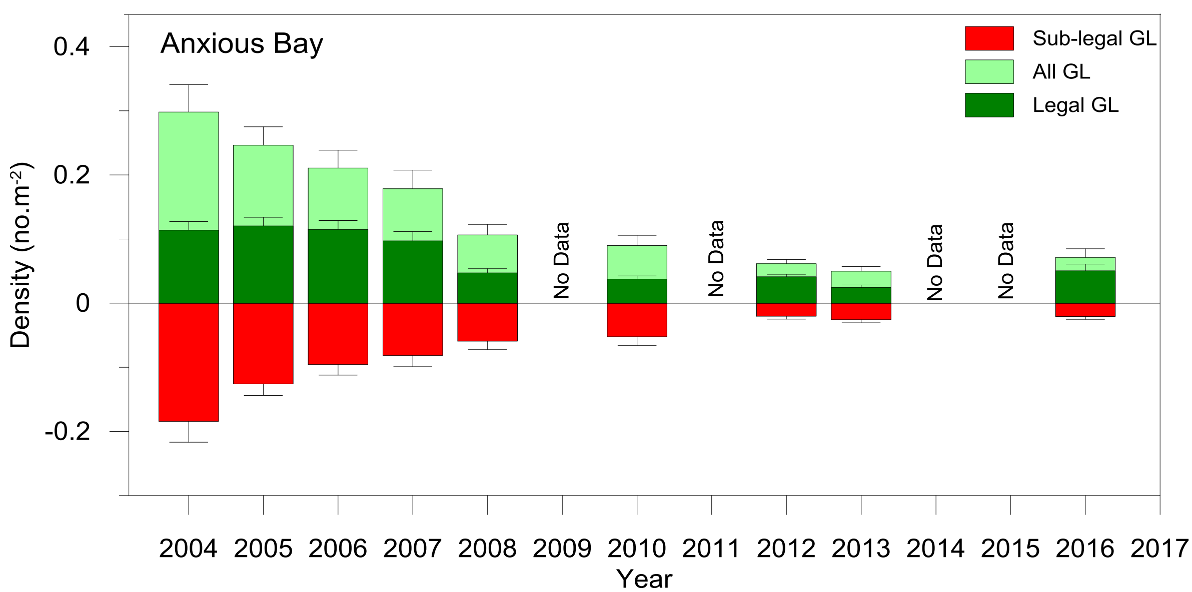

Figure 3.11. Mean density ± se (abalone.m^{-2}) of all, legal-sized and sublegal sized (see legend) greenlip (GL) at Anxious Bay (leaded-lines; mapcode 8A) from 2004 to 2016.

The Gap (Rank 2-2; 9.3-10.3%)

Annual catches from The Gap have gradually declined since the high catches in 1999 (12.6 t) and 2003 (11.6 t; Figure 3.12) to 6.4 t in 2015, which was the 6th lowest catch on record. 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 2015 (17.8 kg.hr^{-1}), CPUE declined 33% and, in 2015, was 15% below $CPUE_{90\text{-}09}$. PropG1 has remained stable and, in 2015 was equivalent to $PropG1_{90\text{-}09}$.

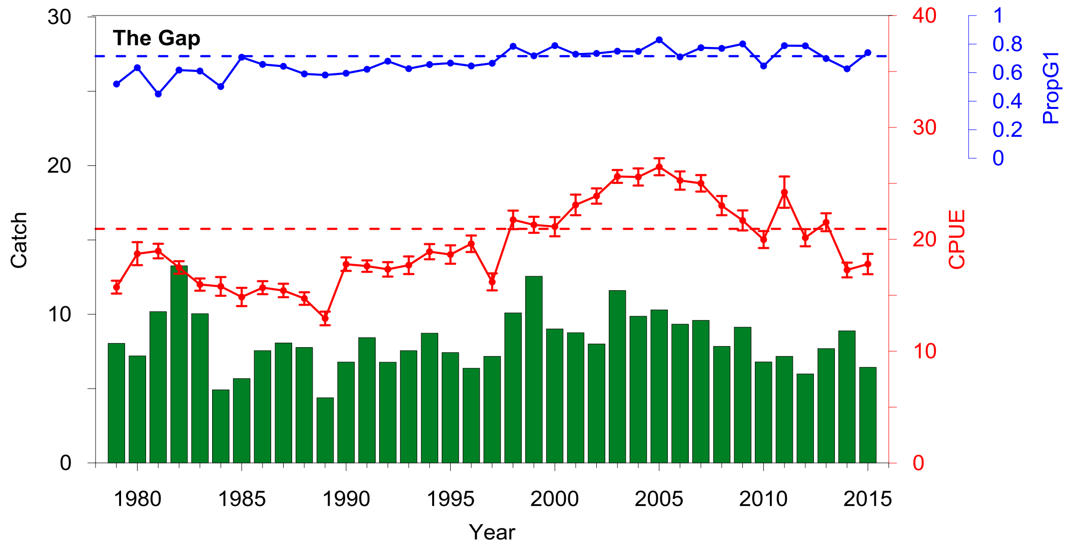

Figure 3.12. Catch (t, meat weight; green bars) of greenlip from The Gap from 1979 to 2015. CPUE ± se (kg.hr^{-1}) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

FI surveys at The Gap indicate that the percentage of LARGE greenlip was variable between years, ranging between 33% in 2011 to 48% in 2005 (Figure 3.13). The percentage of SMALL greenlip also varied between years (range 15 in 2003 to 26% in 2006). Densities of legal-sized greenlip from timed-swims were lowest in the early 1990s, increased to the mid-2000s and subsequently declined to an intermediate value by 2009, whereafter density has been stable at a level similar to that of the early to mid-1990s (Figure 3.14). The density of sublegal sized greenlip from timed-swims had high but variable values between 1989 and 2007. However, these densities were relatively low during recent surveys in 2009, 2011, 2013 and 2016, with 2016 the lowest density on record (Figure 3.14).

Density data from leaded-lines were available from 2009 to 2016. These data show relatively stable densities of legal-sized greenlip, but a lower estimate of sublegal-sized greenlip in 2016.

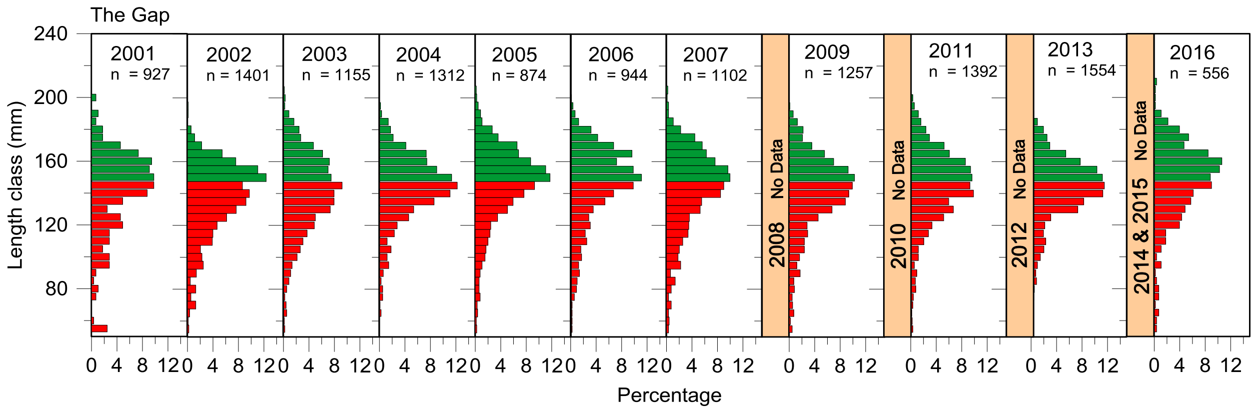

Figure 3.13. Length-frequency distributions of legal-sized (green bars) and sublegal-sized (red bars) greenlip at The Gap (mapcode 18F) observed on fishery-independent surveys from 2001 to 2016. Length classes represent the upper length of each 5 mm bin. n = number of greenlip measured. Bin classes < 50 mm SL pooled. Data for 2001-2007 were from timed-swims, in 2016 were from leaded-lines and values from 2009-2013 utilised data from both methods.

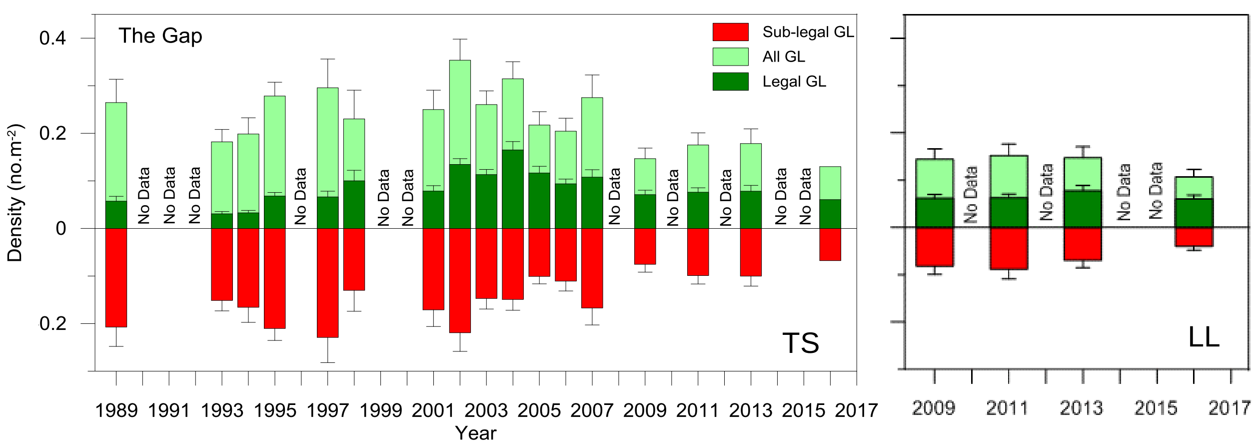

Figure 3.14. Mean density ± se (abalone.m^{-2}) of all, legal-sized and sublegal sized (see legend) greenlip (GL) at The Gap (timed swims and leaded-lines; mapcode 18F). TS = timed swims from 1989 to 2014, LL = leaded-lines from 2009 to 2016. Note TS value for 2016 is generated from LL data and therefore has not error bars.

Avoid Bay (Rank 3-4; 9.2-9.2%)

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 3.15). Catches increased fourfold between 2003 (3 t) and 2008 (13 t), subsequently declining, but remaining above historic levels from 2009 (5.7 t) to 2015 (6.3 t). CPUE has varied among years, but has recently declined from high levels through the mid-2000s to values similar to $CPUE_{90\text{-}09}$ (2011-2013), or lower (2010, 2014 and 2015). Between 2014 and 2015, CPUE increased by 20% and, in 2015, was 7% below $CPUE_{90\text{-}09}$. The PropG1 in the commercial catch has been above $PropG1_{90\text{-}09}$ since 2004 and, in 2015, was 24% higher than in 2014.

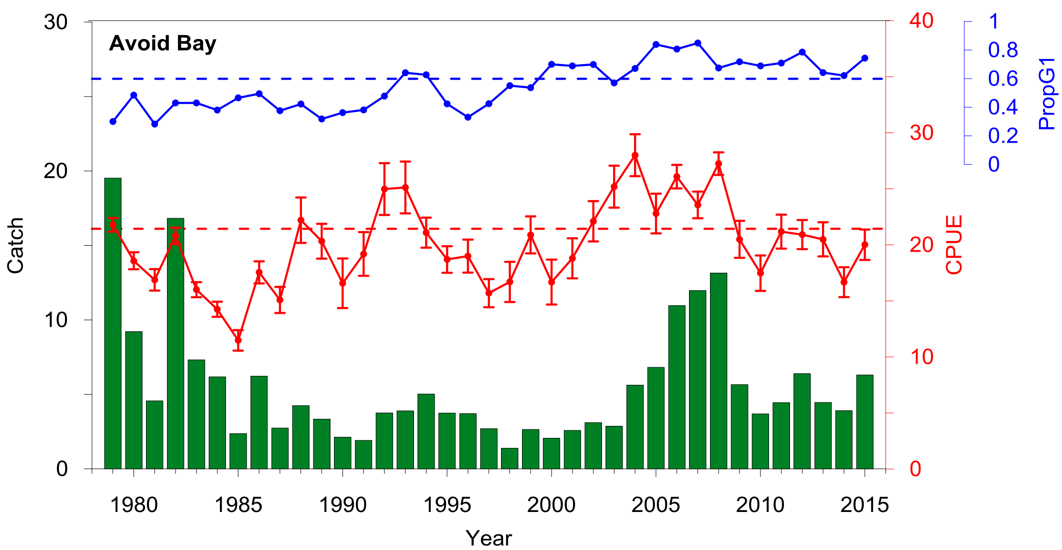

Figure 3.15. Catch (t, meat weight; green bars) of greenlip from Avoid Bay from 1979 to 2015. CPUE ± se ($kg.hr^{-1}$) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

FI surveys at Avoid Bay began in 2008 and the percentage of LARGE greenlip has remained relatively stable (range: 30-42%; Figure 3.16). In contrast, the percentage of SMALL greenlip has decreased consistently between years from 38% in 2008 to 11% in 2016. Density estimates suggest that the abundance of legal-sized greenlip almost halved between 2008 and 2010, remained at a similarly low level between 2010 and 2014, buy then increased to the second highest level on record in 2015 (Figure 3.17). The density of sublegal-sized greenlip also fell between 2008 and 2010, remained stable between 2010 and 2014, and then decreased to the lowest on record in 2016 (Figure 3.17).

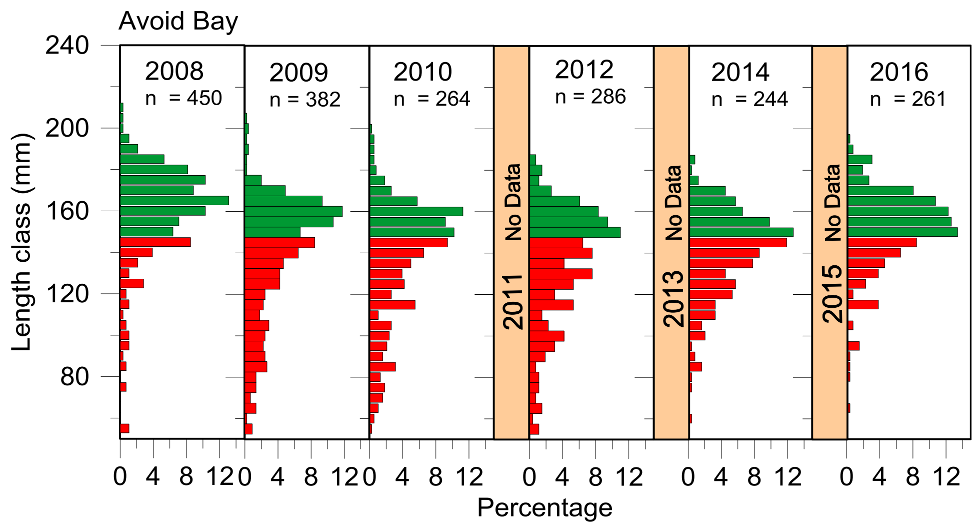

Figure 3.16. Length-frequency distributions of legal-sized (green bars) and sublegal-sized (red bars) greenlip at Avoid Bay (mapcode 14D) observed on fishery-independent surveys from 2008 to 2016. Length classes represent the upper length of each 5 mm bin. n = number of greenlip measured. Bin classes < 50 mm SL pooled.

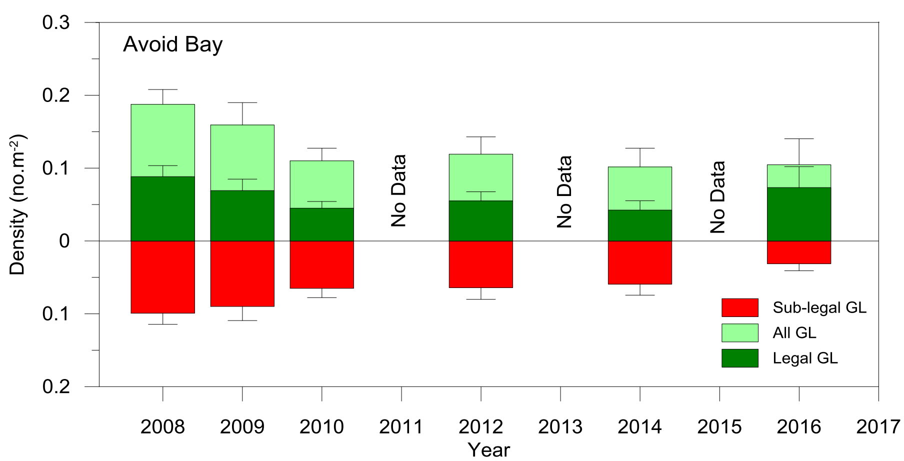

Figure 3.17. Mean density ± se (abalone.m^{-2}) of all, legal-sized and sublegal sized (see legend) greenlip at Avoid Bay (leaded-lines; Black Rocks, mapcode 14D) from 2008 to 2016.

3.1.4 Temporal patterns in medium importance spatial assessment units

Flinders Island (Rank 4-15; 5.7-2.3%)

Catch from Flinders Island has been variable, with the highest catches recorded in the early 1980s and 2000s (Figure 3.18). With the exception of 2007 (9.3 t), catch has generally declined from the second highest in 2000 (12.7 t) to the lowest in 2015 (1.6 t). CPUE declined in the early 1980s to the second in 1985, but then it increased to the maximum 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 $kg.hr^{-1}$), remaining at similar low levels in 2014 and 2015. The PropG1 was relatively low from 1979 to 1994, whereafter it has varied around $PropG1_{90\text{-}09}$.

Ward Island (Rank 5-8; 5.5-5.5%)

The annual catch from Ward Island has oscillated on a 5-6 year scale from approximately 1 $t.yr^{-1}$ to 6 $t.yr^{-1}$ (Figure 3.18). In 2015, catch was 3.8 t, equivalent to the historical average. CPUE has fluctuated among years and was generally high in the late 1970s to early 1980s and again in the mid-2000s. Between 2014 and 2015, CPUE increased by 54% to the second highest on record (29.1 $kg.hr^{-1}$), 36% above $CPUE_{90\text{-}09}$. PropG1 fell consistently between 2006 and 2014, but then increased by 75% in 2015, and was 24% above $PropG1_{90\ 09}$.

Point Avoid (Rank 6-3; 5.1-9.2%)

Following high catches from Point Avoid in the 1980s, catch was relatively stable around 2 $t.yr^{-1}$ between 1990 and 2009 (Figure 3.18). in 2010 it doubled to 6.4 t, the highest since 1989, following which it has remained relatively high and in 2015 was 6.4 t. CPUE has fluctuated among years, with a historic high in 2003. Following the third lowest CPUE in 2014 (17.9 $kg.hr^{-1}$), it increased 32% and in 2015 was the fourth highest on record (21.3 $kg.hr^{-1}$), and 24% above $CPUE_{90\text{-}09}$. Since 2007, the proportion of Grade 1 greenlip in the commercial catch has declined and, in 2015, was equivalent to $PropG1_{90\text{-}09}$ (Figure 3.18).

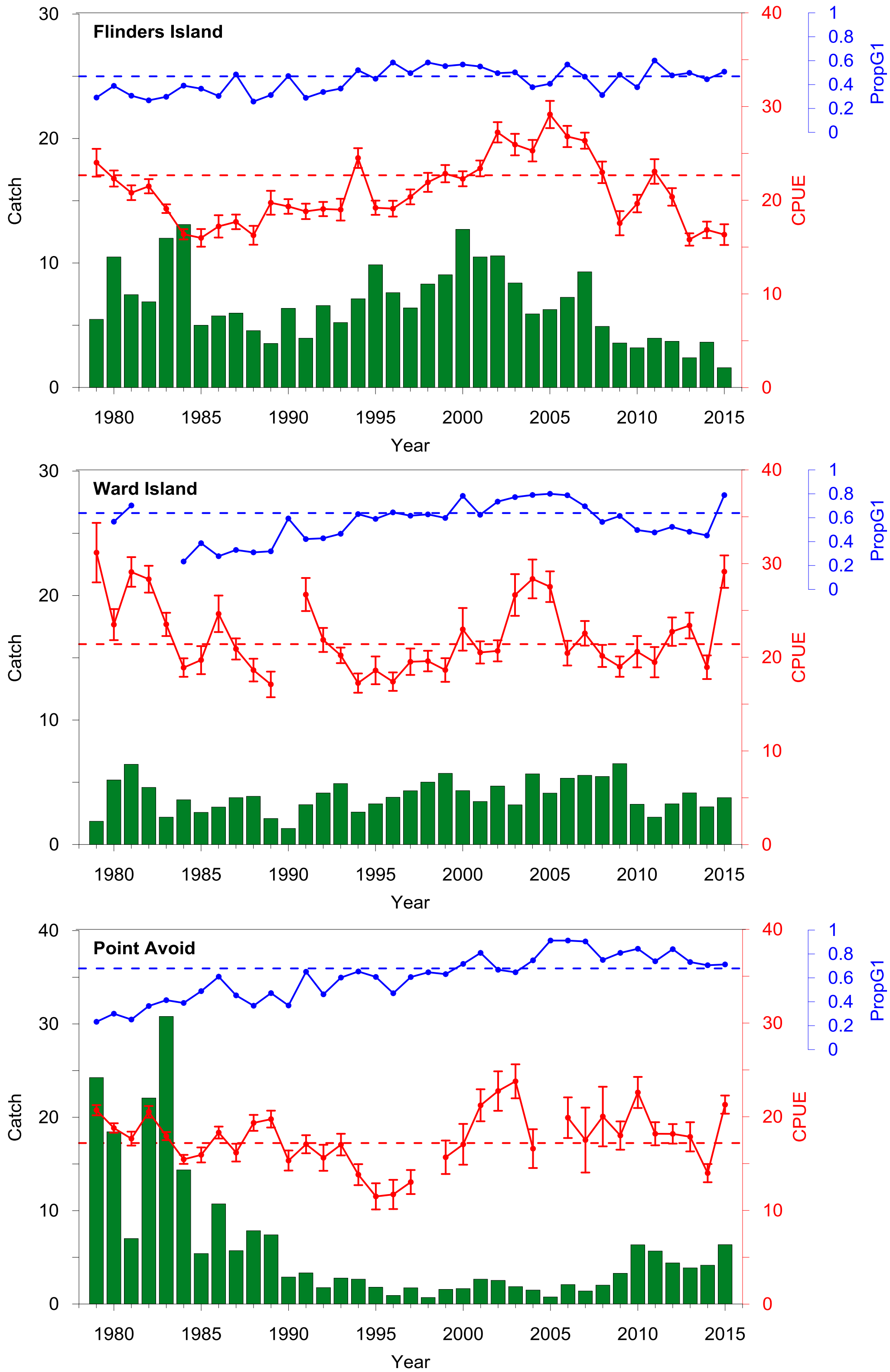

Figure 3.18. Catch (t, meat weight; green bars) of greenlip from SAUs Flinders Island, Ward Island and Point Avoid from 1979 to 2015. CPUE ± se (kg.hr^{-1}) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

Hotspot (Rank 7-10; 4.7-3.3%)

The catch at Hotspot varied among years between 1979 and 1995, was stable between 1996 to 2006, whereafter it decreased consistently from 7.8 t in 2006 to the second lowest (0.9 t) in 2011, remaining low between 2012 and 2015 (~1.7 t; Figure 3.19). CPUE was mostly high, but variable, between 1979 and 1994 following which it was more stable and, with the exceptions of 2011 and 2013 when CPUE was not estimable due to limited data, similar to $CPUE_{90\text{-}09}$ (22.6 $kg.hr^{-1}$). In 2015, CPUE was equivalent to $CPUE_{90\text{-}09}$. PropG1 declined consistently from 2005 to 2014 when it was 62% below $PropG1_{90\text{-}09}$, but increased substantially (128%) between 2014 and 2015, when it remained 12% below $PropG1_{90\text{-}09}$.

Drummond (Rank 8-6; 3.1-6.6%)

Initial catches at Drummond were high from 1979 to 1987, whereafter they were stable at about 1 $t.yr^{-1}$ until 2008 (Figure 3.19). Catches increased substantially between 2008 and 2012 to 6.2 $t.yr^{-1}$, which was the highest since 1987, and remained relatively high thereafter. CPUE was relatively low between 1979 and 1989 (about 12 $kg.hr^{-1}$), whereafter for those years for which it was estimable, it increased to a historic peak of 22 $kg.hr^{-1}$ in 2009. CPUE has subsequently declined and, in 2015 (16.2 $kg.hr^{-1}$), was equivalent to $CPUE_{90\text{-}09}$. The proportion of Grade 1 greenlip in the commercial catch remained above $PropG1_{90\text{-}09}$ from 2000 to 2010, then declined to the lowest level since 1995 by 2013. It has subsequently increased to 19% above $PropG1_{90\text{-}09}$ in 2015.

Taylor Island (Rank 9-11; 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 $t.yr^{-1}$ (Figure 3.19). However, in 2015, the catch of 2.2 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 3.19). In 2013, CPUE decreased by 34% to 15.4 $kg.hr^{-1}$ and has remained at a similar level in 2014 and 2015. The proportion of Grade 1 greenlip in the commercial catch has fluctuated over the past decade and in 2015 was 9% above $PropG1_{90\text{-}09}$.

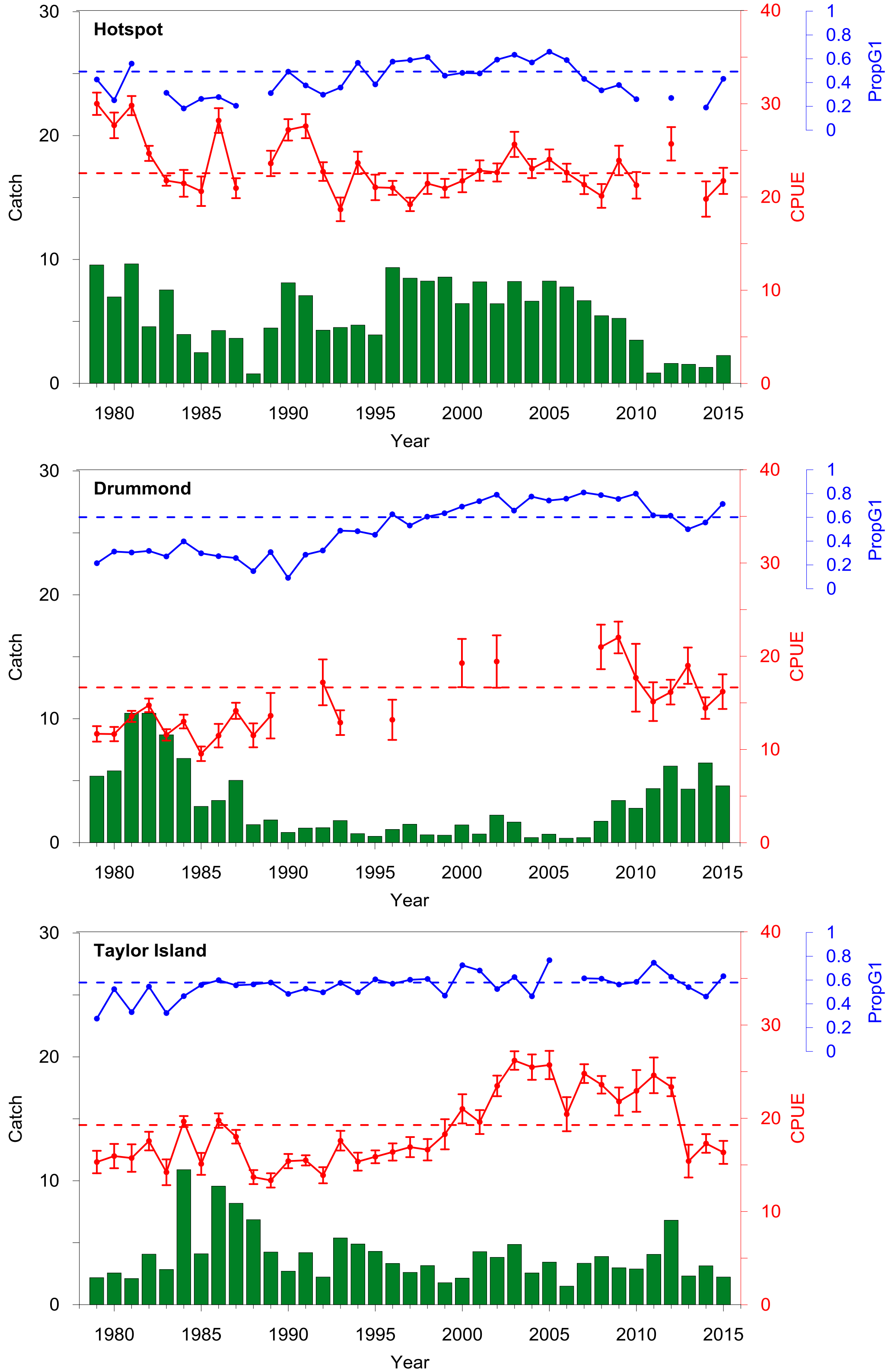

Figure 3.19. Catch (t, meat weight; green bars) of greenlip from SAUs Hotspot, Drummond and Taylor Island from 1979 to 2015. CPUE ± se (kg.hr^{-1}) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

Reef Head (Rank 10-5; 4.0-7.0%)

Following relatively high catches from Reef Head throughout the 1980s, including very high catches in 1982 (14 t) and 1983 (19 t), catch was stable at less than 1.5 $t.yr^{-1}$ between 1990 and 2009 (Figure 3.20). Catch more than doubled in 2010 and, since then, has remained high ranging from 2.6 t in 2012 to 5.6 t in 2011. CPUE varied among years and, in 2015, was 16% above $CPUE_{90-09}$. The proportion of Grade 1 greenlip in the commercial catch was relatively low between 1979 and 1993, whereafter it increased to a historic high in 2007. PropG1 decreased from 2007 and, in 2015, was similar to $PropG1_{90-09}$.

South Nuyts Archipelago (Rank 11-30; 3.6- 0.0%)

Catch has been variable from the South Nuyts Archipelago, with higher catches in 1984, 1988, 1999 and 2010 (>5 $t.yr^{-1}$; Figure 3.20). Catch decreased steadily from the high in 2010 to no catch in 2015, likely due to many of the fishing grounds are now located in a marine park sanctuary zone. CPUE has varied among years and was relatively high in 2013 (18.1 $kg.hr^{-1}$) but not estimable in 2014 or 2015 due to limited data. The proportion of Grade 1 greenlip in the commercial catch has decreased since 2003, was 13% below $PropG1_{90-09}$ in 2013, and was not estimable in 2014 or 2015.

Baird Bay (Rank 12-7; 3.3-6.5%)

For over 20 years, annual catches from Baird Bay have been relatively stable at approximately 3.6 $t.yr^{-1}$. Exceptions were periods of higher catches in the late 1970s and early 1980s, along with lower catches in 1981, 2010 and 2011 (Figure 3.20). In 2015, catch was relatively high at 4.5 t. CPUE was more variable among years in the 1980s and increased steadily from 1992 to 2013 before increasing substantially in 2014 and 2015. In 2015, CPUE was the highest on record and (30.3 $kg.hr^{-1}$) and 57% above $CPUE_{90-09}$. The proportion of Grade 1 greenlip in the commercial catch has fluctuated among years and, in 2015, was 51% above $PropG1_{90-09}$.

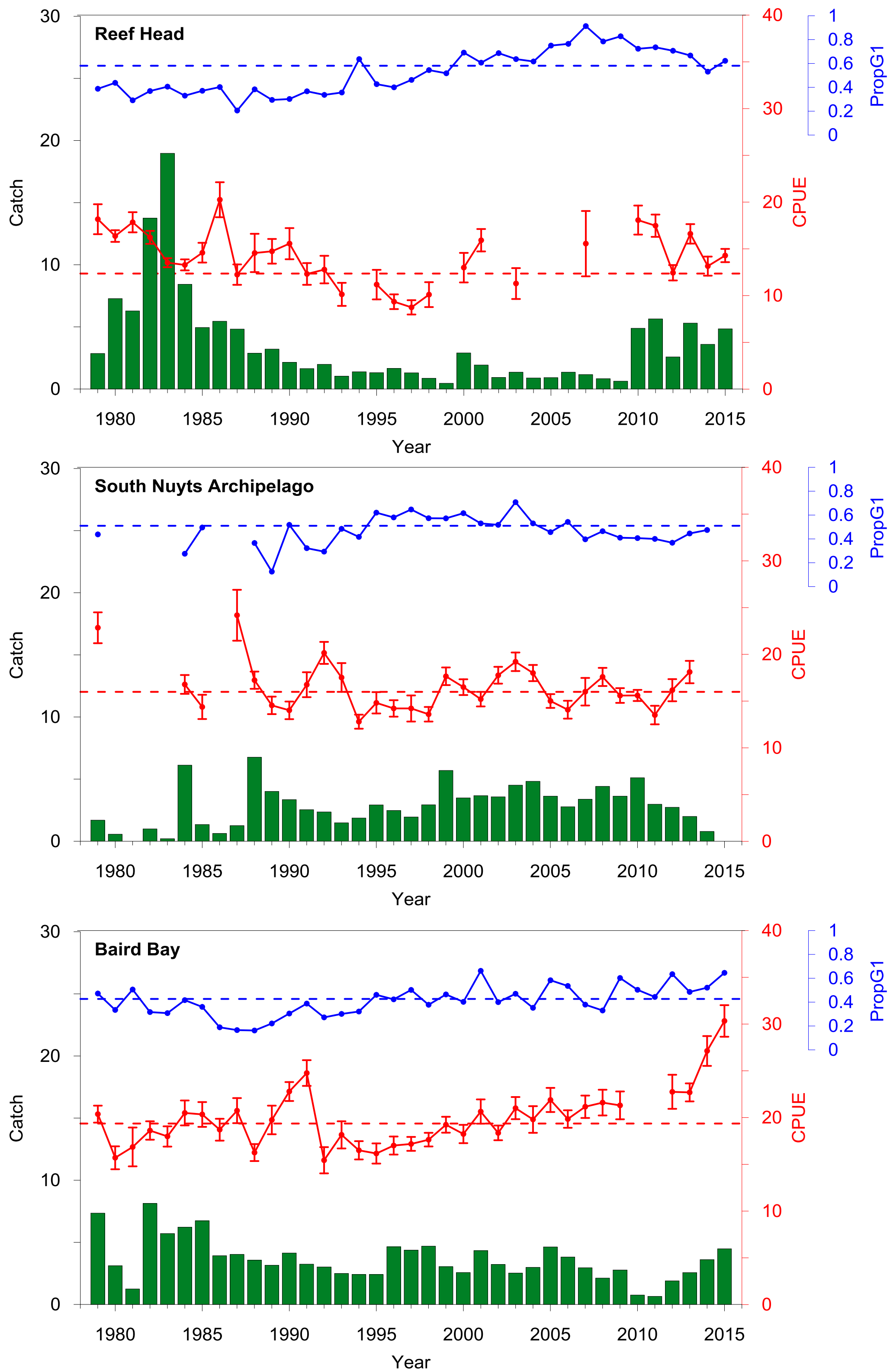

Figure 3.20. Catch (t, meat weight; green bars) of greenlip from SAUs Reef Head, South Nuyts Archipelago and Baird Bay from 1979 to 2015. CPUE ± se ($kg.hr^{-1}$) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

Point Westall (Rank 13-9; 3.1-3.6%)

Annual catches at Point Westall were initially high, but more than halved between 1987 and 1991, whereafter they remained relatively stable at about 2.6 $t.yr^{-1}$ for 25 years, ranging between 1.0 t in 2010 and 4.7 t in 1998 (Figure 3.21). CPUE was variable in the 1980s, followed by a period of relative stability at low levels in the early to mid-1990s. From 1996, it increased to a maximum of 22.6 $kg.hr^{-1}$ in 2003. Between 2003 and 2012, CPUE declined but has since increased and, in 2015, was 14% above $CPUE_{90\text{-}09}$. The proportion of Grade 1 greenlip in the commercial catch has oscillated among years but, from 2009 to 2015, was relatively stable and above $PropG1_{90\text{-}09}$. In 2015 it was amongst the highest on record and 38% above $PropG1_{90\text{-}09}$.

Memory Cove (Rank 14-16; 2.8-2.1%)

Annual catches at Memory Cove have been relatively stable since 1981, ranging between approximately 1 and 4 $t.yr^{-1}$ (Figure 3.21). CPUE increased substantially from a relatively low level between 1981 and 1994, to a historic high in 2007 (27.6 $kg.hr^{-1}$). CPUE fluctuated between 2007 and 2010, whereafter it has declined consistently. In 2015, CPUE was the second lowest on record, 36% below $CPUE_{90\text{-}09}$. The proportion of Grade 1 greenlip in the commercial catch has been greater than $PropG1_{90\text{-}09}$ since 2008, reaching the second highest value in 2010. In 2015, it was 12% above $PropG1_{90\text{-}09}$ (Figure 3.21).

Fishery Bay (Rank 15-12; 2.5-2.6%)

With the exception of relatively high catches from Fishery Bay between 1981 and 1983, and low catches in 2001 and 2007, catch ranged between 0.2 t in 2007 and 3.1 t in 2014 (Figure 3.21). CPUE has varied among years and, in 2015, was equivalent to $CPUE_{90\text{-}09}$. The proportion of Grade 1 greenlip in the commercial catch increased between 1979 and 2004, whereafter it has remained relatively high. In 2015, PropG1 was 8% above $PropG1_{90\text{-}09}$.

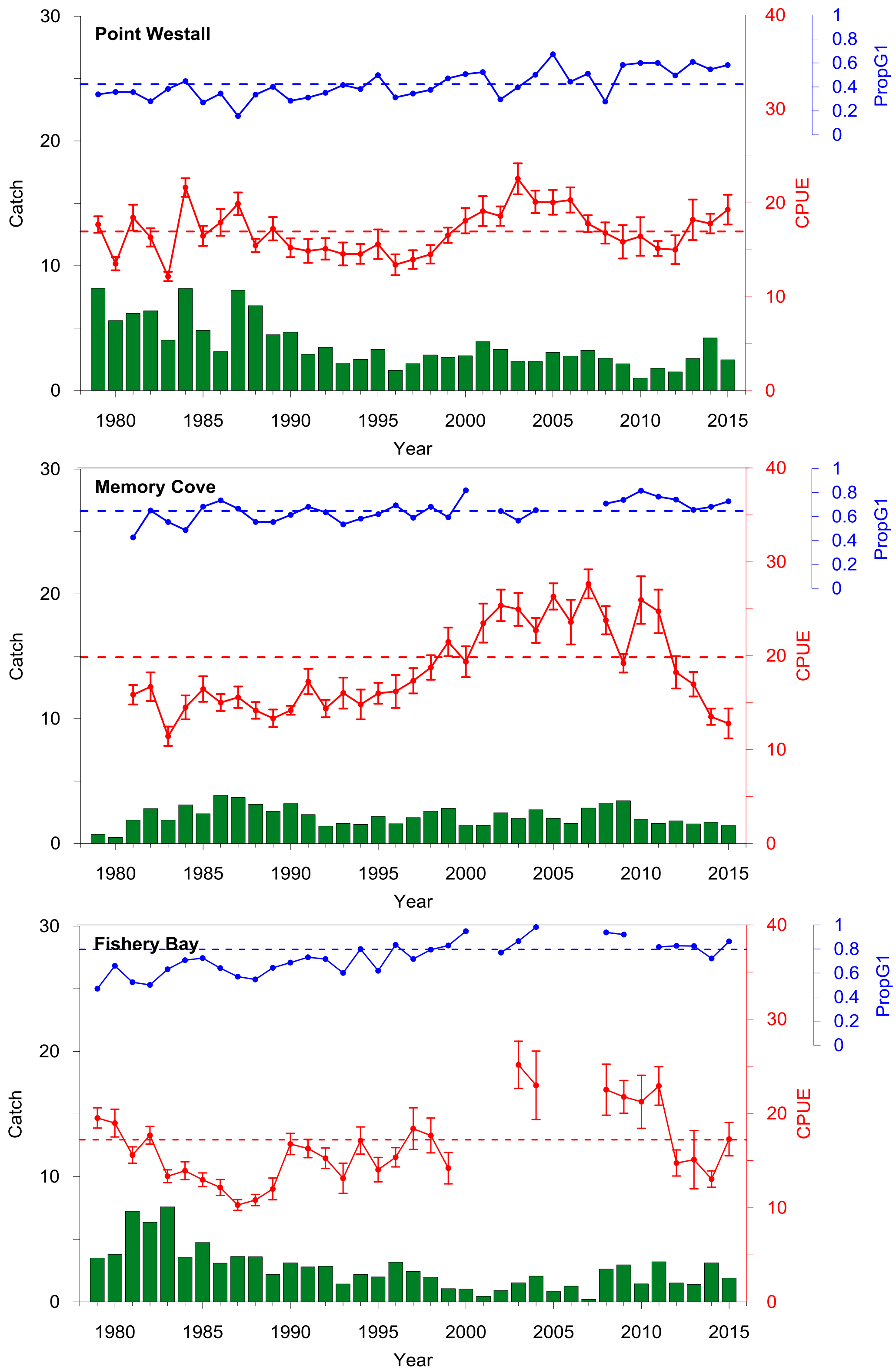

Figure 3.21. Catch (t, meat weight; green bars) of greenlip from SAUs Point Westall, Memory Cove and Fishery Bay from 1979 to 2015. CPUE ± se ($kg.hr^{-1}$) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

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

There were three high and twelve medium importance SAUs for greenlip in the WZ in 2015, with all other SAUs being of low importance (Tables 3.1 – 3.2,5. It was possible to determine the risk of being overfished for 13 (93%) of these 15 SAUs. The inability to estimate CPUE in one medium importance SAU in 2015 (South Nuyts Archipelago), due to insufficient data, resulted in the greenlip stocks in this SAU being categorised as uncertain (Tables 3.1 – 3.2; Appendix A5).

Use of the two alternate TACC values for scoring the “proportion of TACC” PI yielded two differences: the “proportion of TACC” PI score for The Gap was -2 and -1 and for Memory Cove it was -1 and 0 when the legislated and voluntary TACCs were used, respectively (Tables 3.1 – 3.2). This did not change the red risk-of-overfishing category for The Gap, but did for Memory Cove (yellow using the legislated TACC, green using the voluntary TACC). Summed PI scores ranged from -14 (Flinders Island) to +17 (Baird Bay) with the three high-importance SAUs assigned to a pale blue (Anxious Bay), red (The Gap) and green (Avoid Bay) risk-of-overfishing categories (Table 3.1; Appendix A.4). Of the 11 assessable medium importance SAUs, four were assigned to pale blue (Point Avoid, Reef Head, Baird Bay and Point Westall), two to dark blue (Ward Island and Drummond), two to green (Taylor Island and Fishery Bay), one to yellow (Memory Cove – but note it was a green when using the voluntary TACC) and two to red (Flinders Island and Hotspot) risk-of-overfishing categories. Low importance SAUs were not assessed or categorised. The catch-weighted zonal score was 0.71 and 0.74 when using the legislated (Table 3.1) and voluntary (Table 3.2) TACCs, respectively, in both cases defining a zonal stock status for WZ greenlip of ‘under fished’.

Table 3.1. Outcome from application of the harvest strategy described in the Management Plan for the South Australian Abalone Fishery against the greenlip fishery in the Western Zone. Scoring of the "proportion of TACC" PI was against the legislated TACC. 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 (06-15)	Importance	% contribution to catch from high & medium SAU in 2015	CPUE	Proportion TACC	PropG1	Pre-recruit Density	Legal Density	Mortality	Combined PI score	Risk of overfishing	Catch-weighted contribution to zonal score
Anxious Bay	5.3	High	16.02	0	5	2	-5	0	5	7	2	0.32
The Gap	4.6	High	11.10	-3	-2	0	-5	-1	1	-10	-2	-0.22
Avoid Bay	4.2	High	10.89	0	1	1	-2	0	2	2	0	0.00
Flinders Island	2.6	Medium	2.75	-6	-8	0				-14	-2	-0.06
Ward Island	2.5	Medium	6.50	2	0	2				4	1	0.07
Point Avoid	2.3	Medium	10.97	2	8	0				10	2	0.22
Hotspot	2.1	Medium	3.90	0	-8	0				-8	-2	-0.08
Drummond	2.0	Medium	7.90	-2	8	0				6	1	0.08
Taylor Island	1.9	Medium	3.85	-1	-1	1				-1	0	0.00
Reef Head	1.8	Medium	8.37	4	8	0				12	2	0.17
South Nuyts Archipelago	1.6	Medium	-	ND	-5	0				Uncertain	Not assigned	-
Baird Bay	1.5	Medium	7.73	8	3	6				17	2	0.15
Point Westall	1.4	Medium	4.25	1	0	6				7	2	0.08
Memory Cove	1.2	Medium	2.49	-4	-1	2				-3	-1	-0.02
Fishery Bay	1.1	Medium	3.28	0	0	0				0.0	0	0.00
Cape Catastrophe	1.0	Low		-	-	-	-	-	-	-	Not assessed	
North Nuyts Archipelago	0.9	Low		-	-	-	-	-	-	-	Not assessed	
SW Thistle	0.8	Low		-	-	-	-	-	-	-	Not assessed	
Venus Bay	0.8	Low		-	-	-	-	-	-	-	Not assessed	
Wedge Island	0.7	Low		-	-	-	-	-	-	-	Not assessed	
Searcy Bay	0.7	Low		-	-	-	-	-	-	-	Not assessed	
NE Thistle	0.5	Low		-	-	-	-	-	-	-	Not assessed	
Franklin Islands	0.5	Low		-	-	-	-	-	-	-	Not assessed	
Cape Bauer	0.5	Low		-	-	-	-	-	-	-	Not assessed	
Coffin Bay	0.5	Low		-	-	-	-	-	-	-	Not assessed	
Neptune Islands	0.4	Low		-	-	-	-	-	-	-	Not assessed	
DEntrecasteaux Reef	0.4	Low		-	-	-	-	-	-	-	Not assessed	
Waterloo Bay	0.3	Low		-	-	-	-	-	-	-	Not assessed	
Unassigned WZ RG A	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	
Unassigned WZ RG B	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Greenly Island	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Sum	**45.2**		**100.0**									
										Zonal Stock Status		**0.71**

Table 3.2. Outcome from application of the harvest strategy described in the Management Plan for the South Australian Abalone Fishery against the greenlip fishery in the Western Zone. Scoring of the "proportion of TACC" PI was against the voluntary catch limit (i.e. 5% below the TACC). 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 (06-15)	Importance	% contribution to catch from high & medium SAU in 2015	CPUE	Proportion TACC	PropG1	Pre-recruit Density	Legal Density	Mortality	Combined PI score	Risk of overfishing	Catch-weighted contribution to zonal score
Anxious Bay	5.3	High	16.02	0	5	2	-5	0	5	7	2	0.32
The Gap	4.6	High	11.10	-3	-1	0	-5	-1	1	-9	-2	-0.22
Avoid Bay	4.2	High	10.89	0	1	1	-2	0	2	2	0	0.00
Flinders Island	2.6	Medium	2.75	-6	-8	0				-14	-2	-0.06
Ward Island	2.5	Medium	6.50	2	0	2				4	1	0.07
Point Avoid	2.3	Medium	10.97	2	8	0				10	2	0.22
Hotspot	2.1	Medium	3.90	0	-8	0				-8	-2	-0.08
Drummond	2.0	Medium	7.90	-2	8	0				6	1	0.08
Taylor Island	1.9	Medium	3.85	-1	-1	1				-1	0	0.00
Reef Head	1.8	Medium	8.37	4	8	0				12	2	0.17
South Nuyts Archipelago	1.6	Medium	-	ND	-5	0				Uncertain	Not assigned	-
Baird Bay	1.5	Medium	7.73	8	3	6				17	2	0.15
Point Westall	1.4	Medium	4.25	1	0	6				7	2	0.08
Memory Cove	1.2	Medium	2.49	-4	0	2				-2	0	0.00
Fishery Bay	1.1	Medium	3.28	0	0	0				0	0	0.00
Cape Catastrophe	1.0	Low		-	-	-	-	-	-	-	Not assessed	
North Nuyts Archipelago	0.9	Low		-	-	-	-	-	-	-	Not assessed	
SW Thistle	0.8	Low		-	-	-	-	-	-	-	Not assessed	
Venus Bay	0.8	Low		-	-	-	-	-	-	-	Not assessed	
Wedge Island	0.7	Low		-	-	-	-	-	-	-	Not assessed	
Searcy Bay	0.7	Low		-	-	-	-	-	-	-	Not assessed	
NE Thistle	0.5	Low		-	-	-	-	-	-	-	Not assessed	
Franklin Islands	0.5	Low		-	-	-	-	-	-	-	Not assessed	
Cape Bauer	0.5	Low		-	-	-	-	-	-	-	Not assessed	
Coffin Bay	0.5	Low		-	-	-	-	-	-	-	Not assessed	
Neptune Islands	0.4	Low		-	-	-	-	-	-	-	Not assessed	
DEntrecasteaux Reef	0.4	Low		-	-	-	-	-	-	-	Not assessed	
Waterloo Bay	0.3	Low		-	-	-	-	-	-	-	Not assessed	
Unassigned WZ RG A	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	
Unassigned WZ RG B	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Greenly Island	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Sum	**45.2**		**100.0**									
											Zonal Stock Status	**0.74**

4 DISCUSSION

4.1 Information, data gaps and uncertainty in the assessment

Assessment of the greenlip stocks in the WZ is supported by: (1) fine-scale catch, effort and weight-grade data; (2) fishery-independent survey data on greenlip population density and size-frequency at three sites; and (3) the harvest strategy in the Management Plan (PIRSA 2012). However, this relatively new harvest strategy has several limitations including stock status classifications which are considered over-optimistic (e.g. Stobart *et al.* 2014) and the absence of an agreed limit reference point for determining when the stocks are recruitment overfished that would link the harvest strategy to the National Fishery Status Reporting Framework (NFSRF; Flood *et al.* 2014). The harvest strategy is currently being reviewed.

The determination of stock status was complicated because, in 2015, numerous factors had the potential to affect estimates of CPUE, the primary indicator of relative stock abundance. First, from 2010, fishing effort has shifted from summer to autumn when catch rates on greenlip are generally higher (Stobart *et al.* 2013a). Much of this recent change occurred between 2014 and 2015 and is therefore likely to positively bias CPUE estimates in 2015. Second, there have likely been changes in fishing efficiency through time, both positive (i.e. effort creep; e.g. caused by technological change such as increased use of motorised dive cages or GPS) and negative such as changes in diver demographics (J Woolford, personal communication) and diver preference including choosing to harvest abalone closer to home to reduce costs. These have not been accounted for.

Third, the distribution of catch has changed between 2014 and 2015. While these data usually 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), their interpretation becomes difficult when fishers move among areas to maintain, or increase, their expected levels of catch for a range of plausible reasons. These reasons include changes in the fishing fleet (e.g. trends to larger or smaller vessels) that may impact access, market demands for particular product types (e.g. smaller or larger sized abalone), the aforementioned changes in diver demographics and behaviour, and changes in abalone abundance. The main change observed in recent years, and particularly in 2015, was a contraction of the fishery into fewer SAUs, many of which are closer to Port Lincoln.

Fourth, widespread increases in PropG1 observed across most SAUs in 2015, suggest that greenlip meat weights in 2015 were higher than usual. This was supported by anecdotal evidence from commercial divers. The observed change in PropG1 is likely the result of inter-annual differences in conditions that affect animal growth such as temperature, food availability and oceanographic conditions.

All of these factors may have affected the relationship between CPUE and abundance, relative to historical values. CPUE plays a key role in this assessment, based on the assumption that it relates to changes in the relative abundance of the fishable stock (Tarbath *et al.* 2005). However, CPUE can be strongly influenced by numerous factors that may be unrelated to, or lag, changes in abundance (see Stobart *et al.* 2013a), including those described above. Therefore, this measure is often viewed as a biased index of relative abundance (Harrison 1983; Breen 1992; Prince and Shepherd 1992; Gorfine *et al.* 2002).

Consequently, in this assessment, some of the potential impacts on catch rate (CPUE) from the changed spatial and temporal fishing patterns were evaluated to aid the interpretation of the relationships between CPUE and greenlip abundance. Two key analyses were undertaken. First, CPUE was normalised to account for the known seasonal variation in bled-meat-weight. This analysis estimated that the seasonal change in fishing accounted for approximately a quarter of the increase in CPUE between 2014 and 2015. Thus, other factors, including changes in abundance and fishing location, have collectively accounted for the remaining three quarters of the CPUE increase between 2014 and 2015. Second, estimates of CPUE and PropG1 were calculated for two time periods (summer, autumn) and three regions of the WZ (Port Lincoln, Elliston, Streaky Bay). These analyses showed that (1) the increase in PropG1 and CPUE between 2014 and 2015 were consistent across season, but magnified for autumn; and (2) there were strong regional differences in fishery performance. Notably, the magnitude of the increases in CPUE and PropG1 between 2014 and 2015 were depressed in the two southern regions.

A further limitation to this assessment included the continued use of decision rules applied to the data, designed to exclude outliers from analyses and ensure minimum data standards (see Burch *et al.* 2011; Stobart *et al.* 2012b). However, we note subsequent assessment of the validity of the CPUE data decision rules and consideration of running mean estimates that have now been tested in the Central Zone abalone fishery (Burnell *et al*. 2016), and suggest that a review of these rules and this approach for the WZ may be required.

The annual TACC for the greenlip fishery is determined based on evaluation of the status of stocks across all fishing grounds. The current interpretation of stock status is complex as many of the changes in 2015 increase the likelihood that the relationship between CPUE and abundance has changed. This increases the risk that estimates of stocks across SAUs are based on CPUE estimates that are positively biased and/or hyperstable and mask a continued decline in abundance. If this is the case, the assessment of stock status would be over-optimistic. However, in the absence of data to fully quantify the extent to which the relationship between CPUE and greenlip abundance may have changed – noting our preliminary assessment that the change in fishing season may account for one quarter of the increase in CPUE between 2014 and 2015 – this assessment is made on the assumption that the relationship remains unchanged.

4.2 Status of greenlip in the WZ

In 2015, greenlip comprised 47% (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 2009, but since then the WZ greenlip catch has been decreased through reductions to the TACCs (see Table 1.1), the removal of one licence during the implementation of marine park sanctuary zones and a 5% voluntary under-catch in 2015. Overall, these represent a 16.6% decrease in the WZ greenlip catch over 7 years.

Stock status determination using the NFSRF changed from sustainable in 2013 (Stobart *et al.* 2014) to transitional depleting in 2014 (Stobart *et al.* 2015b), reflective of declining harvestable biomass. In 2014, greenlip stocks were at their weakest position in over 25 years (Stobart *et al.* 2015b). However, there is considerable evidence that there has been an improvement in the stocks between 2014 and 2015.

Firstly, there was a large increase in CPUE (17%) to a value equivalent to the 20-year average (1990-2009), and that was also 10% higher than the average CPUE for the 10-year period between 1990 and 1999. This was the largest inter-annual change in CPUE in the history of the fishery and CPUE in 2015 was among the top 30% of records. Second, the increases in CPUE were spatially consistent with large increases at 36% of high and medium importance SAUs, and small increases at a further 36% of SAUs. Third, there was an unprecedented increase in PropG1 that, with the exception of Venus Bay, occurred in all SAUs for which there were data. This was the largest inter-annual increase in zonal PropG1 that, in 2015, was at the third highest level on record. Notably, the CPUE increases occurred despite this large increase in the proportion of Grade 1 greenlip harvested, suggesting large greenlip were readily available in the fishery. Fourth, the increases in CPUE occurred in both summer and autumn, suggesting they were, at least in part, unrelated to changes in fishing practices. Fifth, the transfer of catches from summer to autumn will have reduced the exploitation rate on greenlip because the recovered meat weights are higher, per unit shell length, in autumn (Stobart *et al.* 2013b). Harvesting fewer greenlip from this change for the same total catch when compared with previous years (2005-2009) – estimated at 4.3% (Stobart *et al.* 2013b) – in combination with the TACC reductions (11.5%) since 2009 and voluntary catch reduction of 5% in 2015, will have reduced the risk of overfishing. Finally, the outcome from application of the harvest strategy to determine zonal stock status was 'under fished' in 2015 for the WZ (Table 3.1). This was an improvement from the previous zonal stock status that was classified as 'sustainable' in 2014. Collectively, this evidence provides a strong indication that current legal-sized greenlip abundance is similar to, or higher than, that in the 1990s and that exploitation rates have decreased. Despite this accumulated positive evidence, the current legal-sized greenlip abundance is difficult to infer due to the complicating factors outlined in Section 4.1. Consequently, survey density estimates, CPUE and PropG1 should be monitored carefully in future assessments.

There is evidence that some of the component stocks have not similarly improved over the same time period. First, data show the harvestable biomass at The Gap, the second most important greenlip SAU, has decreased. In 2015, catch was relatively low, CPUE was 15% below $CPUE_{90-09}$, legal density was amongst the lowest on record and sublegal density was the lowest recorded. Second, FI survey density at Anxious Bay, the most important greenlip SAU, declined from 2004 to 2010 and then stabilised at a low level. Sublegal density declined from 2004 to 2012 and again stabilised at a low level. Third, there have been recent large decreases in catch from traditional greenlip sites, including Flinders Island and Hotspot, both showing no evidence of recovery (e.g. through increased catch rates) in 2015. Fourth, the medium importance SAUs of Taylor Island and Memory Cove had 2015 CPUE values 15% and 36% below $CPUE_{90-09}$, respectively. Finally, CPUE estimates in 2015 for the Port Lincoln and Elliston regions were low in summer, and for Port Lincoln also low in autumn.

In summary, there is strong evidence that, in 2014, the WZ greenlip stocks were at their weakest position in over 25 years. Subsequently, between 2014 and 2015, there is widespread evidence of a substantial improvement in stock status, including unprecedented increases in zonal CPUE and PropG1. The likely causes of these recent increases are complex and include an increase in fishing during autumn months, changes to the distribution of catch and a higher prevalence of Grade 1 greenlip during 2015. All of these factors may positively bias CPUE estimates. The improvement in stock status was not ubiquitous. However, current CPUEs suggest that the abundance of legal-sized greenlip is at least equivalent to that observed in the late 1990s and that the risk of overfishing has recently been reduced by a combination of lower catch and fewer greenlip being harvested.

In the absence of evidence to indicate that the overall WZ stock (1) is recruitment overfished; or (2) has a current fishing pressure likely to result in the stock becoming recruitment overfished, the WZ Greenlip Abalone Fishery is classified as **'sustainable'** under the NFSRF (Flood *et al.* 2014). This was an improvement from 2014 when the fishery was classified as "transitional depleting" using the same criteria.

4.3 Harvest strategy for the WZ abalone fishery

Previous WZ stock assessment reports identified several difficulties with the implementation of the new harvest strategy for the fishery (Stobart *et al.* 2011, 2013a, 2015a), with similar issues identified for 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 when compared with blacklip (Stobart *et al.* 2014), three key issues recurred and are currently being considered in the harvest strategy review due to be completed in December 2016.

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 (Stobart *et al.* 2014). Several possible solutions to this problem proposed by Stobart *et al.* (2014) are currently under review.

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 problem is the use of, *a priori*, information from other sources (e.g. divers, processors) to aid interpretation of the PI scores.

Finally, the Management Plan (PIRSA 2012) does not identify a PI and reference point below which the fishery would be defined as overfished. This issue is being addressed in the current review of the harvest strategy that includes the development of stock status triggers and/or reference points to ensure the harvest strategy is consistent with the South Australia Harvest

Strategy Policy (PIRSA 2015). This will also enable the status of the fishery to be defined against the national guidelines (Flood *et al.* 2014).

4.4 Future research needs

The most pressing research needs for the WZ abalone fishery are to: (1) undertake analyses to inform the change and improvement to the harvest strategy; (2) re-evaluate the appropriateness of the CPUE estimation methods for greenlip and blacklip given ongoing changes in diver behaviour and fishing patterns; (3) identification and testing of a process to formally include industry information into the assessment process; and (4) establish and validate an index of recruitment (e.g. FRDC project 2014/010).

The most pressing research need for this fishery is to continue changing, improving and testing a revised harvest strategy. This is currently underway and includes evaluation of the inclusion of year-to-date data in the harvest strategy (Dent *et al.* 2016), SAU mapcode compositions, the robustness and value of the PIs used in the harvest strategy and the inclusion of diver assessments and economic indicators in the assessment process. This formal review is also being used to link the harvest strategy more closely with the national fishery status reporting framework (Flood *et al.* 2014) and to align the harvest strategy with the South Australian harvest strategy guidelines (PIRSA 2015).

Periodic revision of the appropriateness of the CPUE estimation methods used in the WZ assessments is necessary to ensure changes in the fishery are not leading to biased estimates of CPUE. For example, it is important to ensure that data constraints and decision rules used to estimate CPUE remain relevant for the assessment of WZ stocks as the fishery changes. In addition, analysing catch rate data to account for external influences (e.g. diver, dive location, month, loss of access, technological advance) should also be considered and could be accounted for through standardisation.

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.

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Appendix

A1. 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. 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 sublegal 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)

A2. Quality assurance

5.1.1 Research planning

The requirements of PIRSA were discussed in December 2014 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.

5.1.2 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).

5.1.3 Data entry, validation, storage and security

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

5.1.4 Data and statistical analyses

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

5.1.5 Data interpretation and report writing

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

A3. Historic medium importance SAU FI surveys

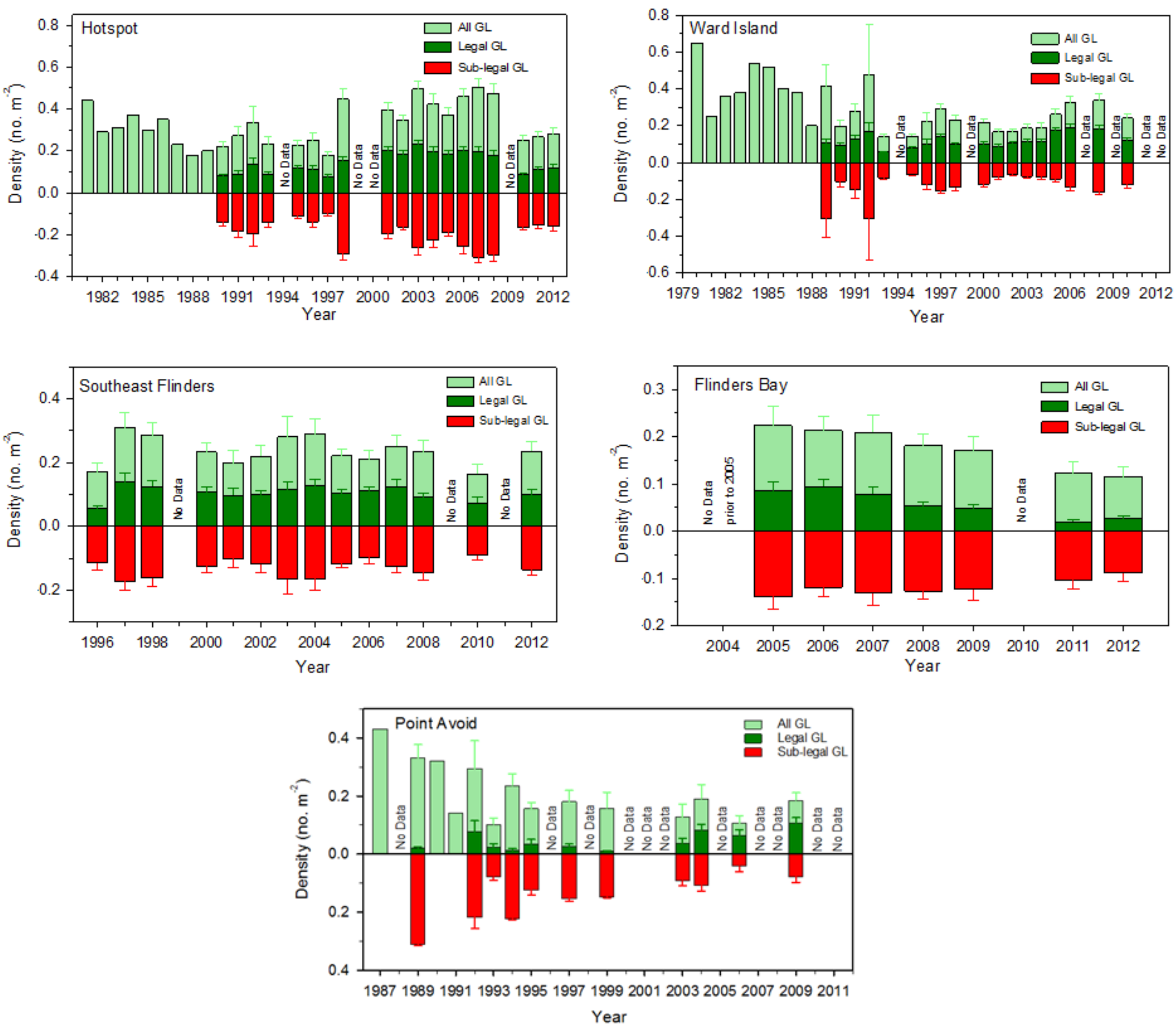

Figure A3. 1. Mean ± se density (abalone.m^{-2}) of all, legal-sized and sublegal sized (see legend) greenlip (GL) abalone at Hotspot (timed swims; map-code 9D), Ward Island (timed swims; map-code 9A), Southeast Flinders (timed swims; mapcodes 9G & 9H), Flinders Bay (leaded-lines; map-code 9F) and Point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

A4. 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
$\text{Density}_{\text{legal}}$	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
$\text{Density}_{\text{pre-recruit}}$	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

A5. Spatial assessment units

High Importance SAUs

Anxious Bay

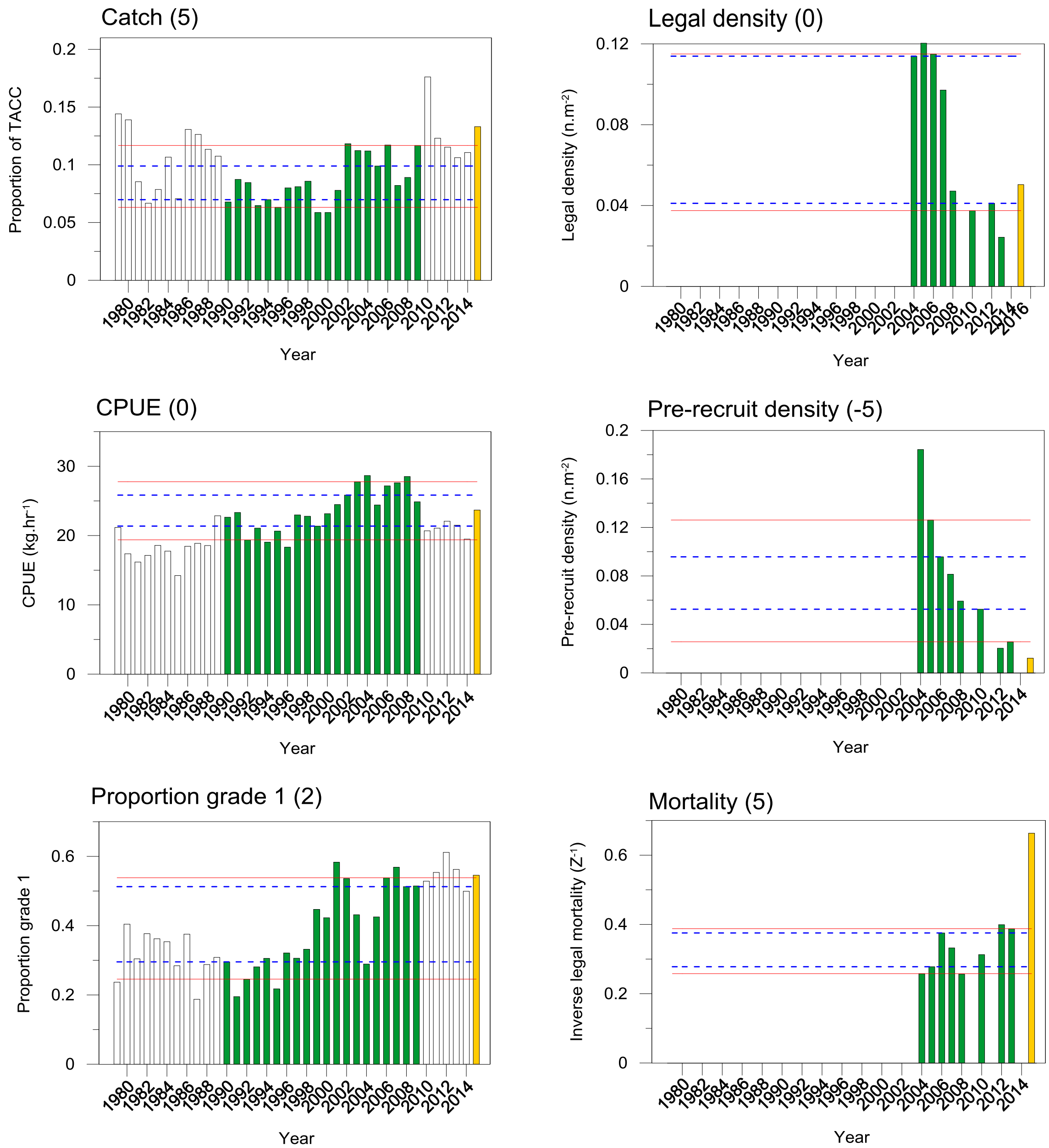

Figure A5. 1. Anxious Bay (high importance). Performance indicators catch (Proportion of legislated TACC), CPUE (kg.hr^{-1}), PropG1, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy in brackets. Red and blue lines are upper and lower limit 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

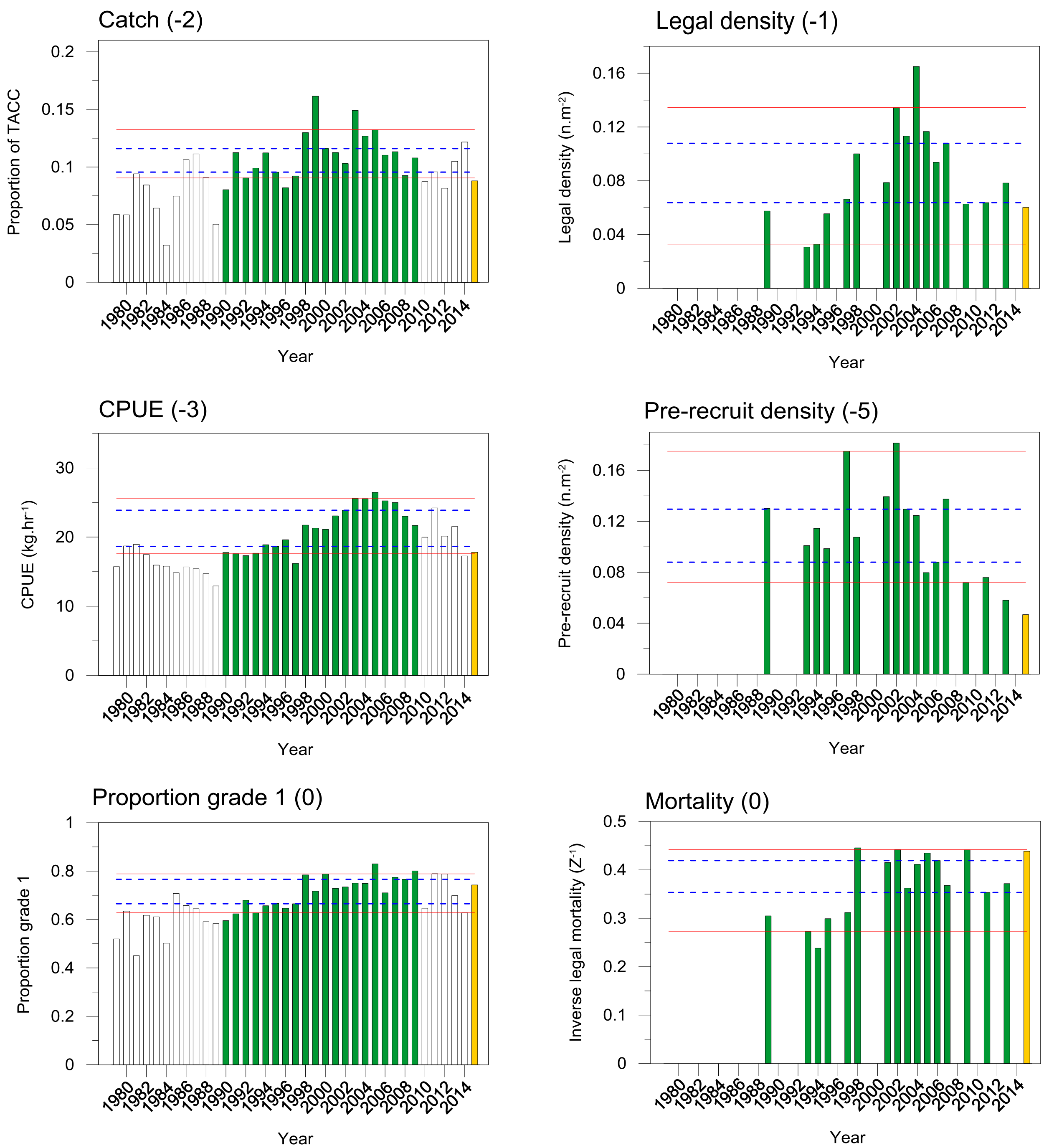

Figure A5. 2. The Gap (high importance). Performance indicators catch (Proportion of legislated TACC), CPUE (kg.hr^{-1}), PropG1, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy in brackets. Red and blue lines are upper and lower limit and 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

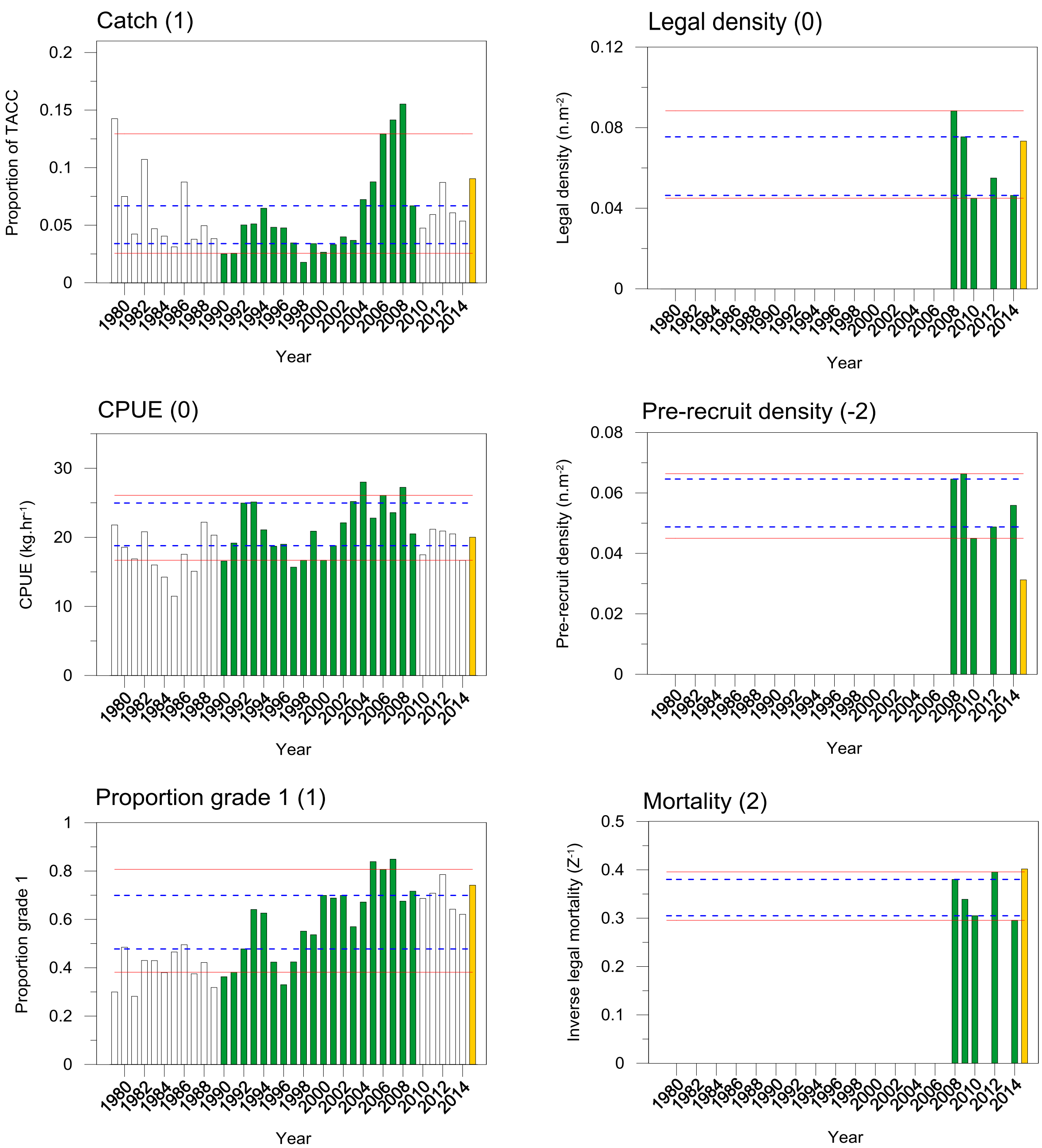

Figure A5. 3. Avoid Bay (high importance). Performance indicators catch (Proportion of legislated TACC), CPUE (kg.hr^{-1}), PropG1, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy in brackets. Red and blue lines are upper and lower limit and 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

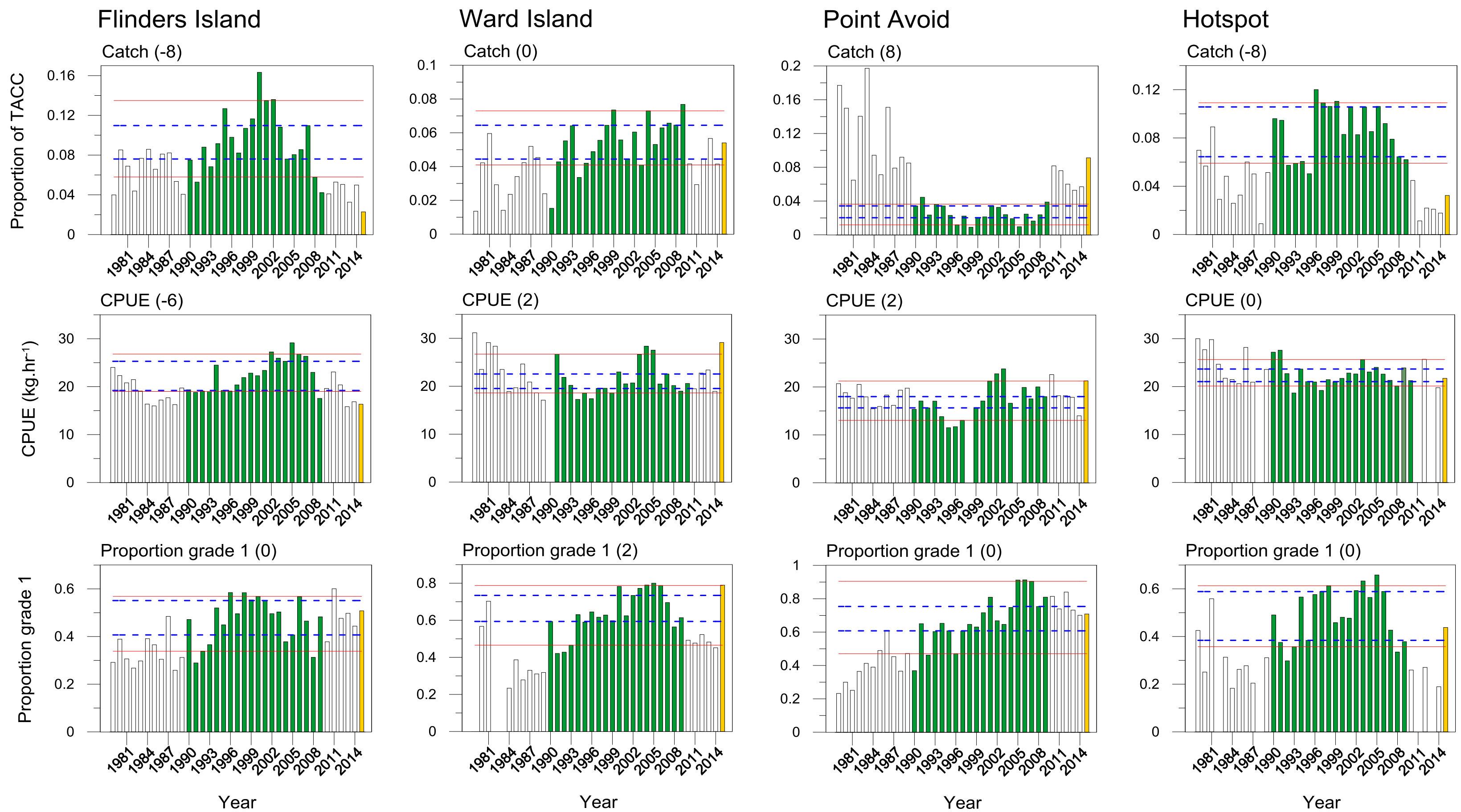

Figure A5. 4. Flinders Island, Ward Island, Point Avoid and Hotspot (medium importance). Performance indicators catch (proportion of legislated TACC), CPUE (kg.hr^{-1}), PropG1 and scores from the harvest strategy in brackets. Red and blue lines are upper and lower limit and target reference points, 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.

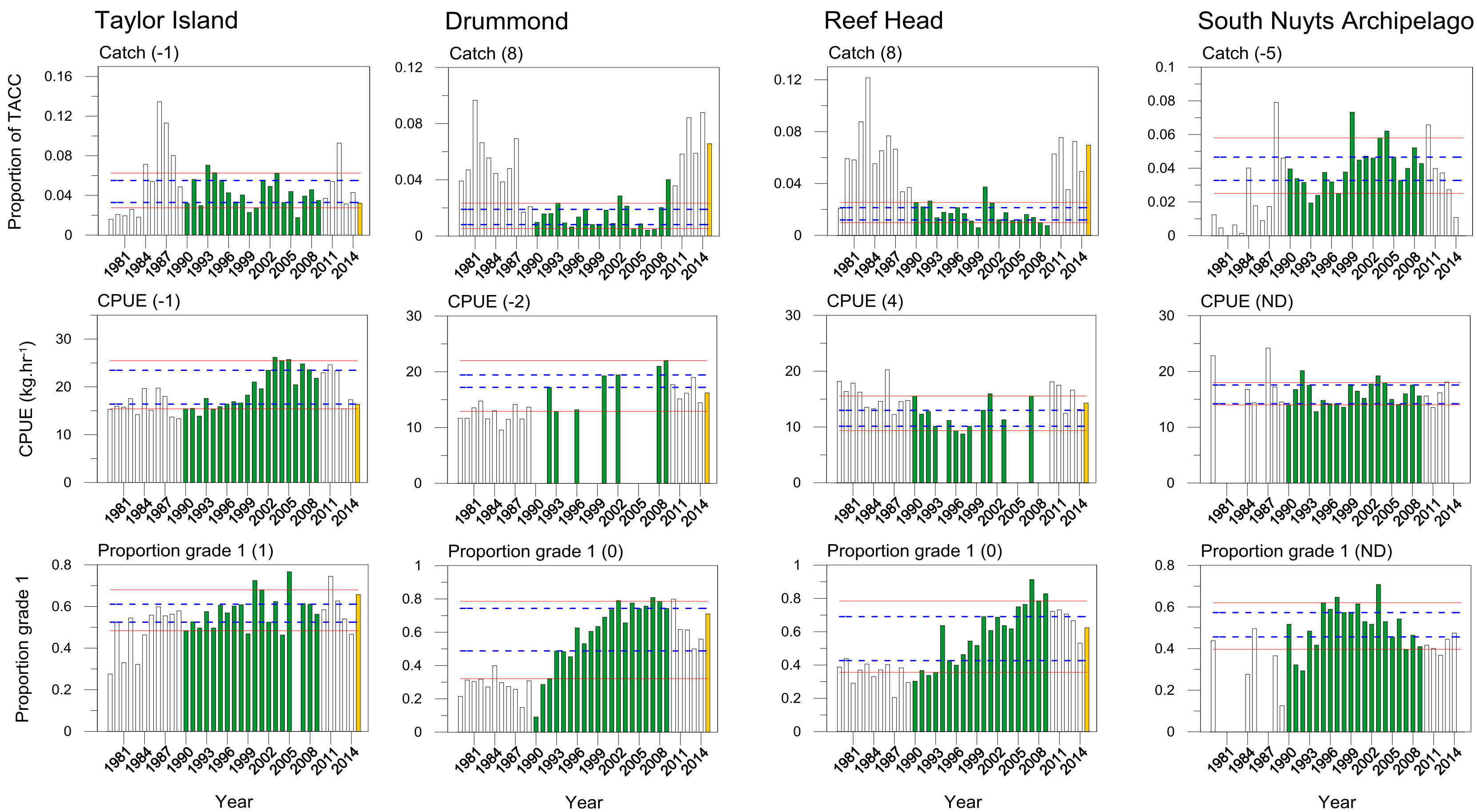

Figure A5. 5. Taylor Island, Drummond, Reef Head and South Nuyts Archipelago (medium importance). Performance indicators catch (proportion of legislated TACC), CPUE (kg.hr^{-1}), PropG1 and scores from the harvest strategy in brackets. Red and blue lines are upper and lower limit and target reference 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. ND indicates no data.

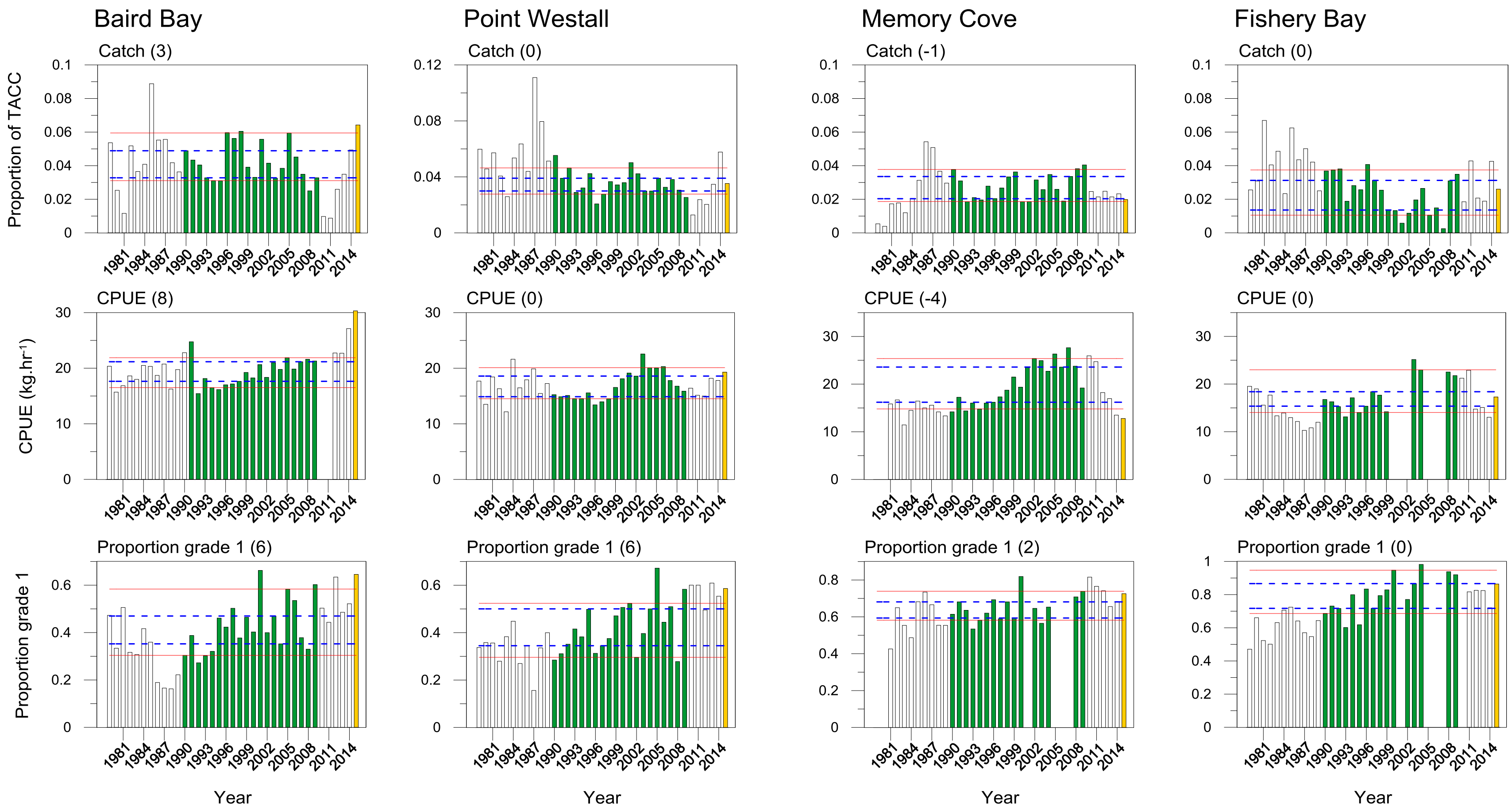

Figure A5. 6. Baird Bay, Point Westall, Memory Cove and Fishery Bay (medium importance). Performance indicators catch (proportion of legislated TACC), CPUE (kg.hr^{-1}), PropG1 and scores from the harvest strategy in brackets. Red and blue lines are upper and lower limit and target reference points, 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

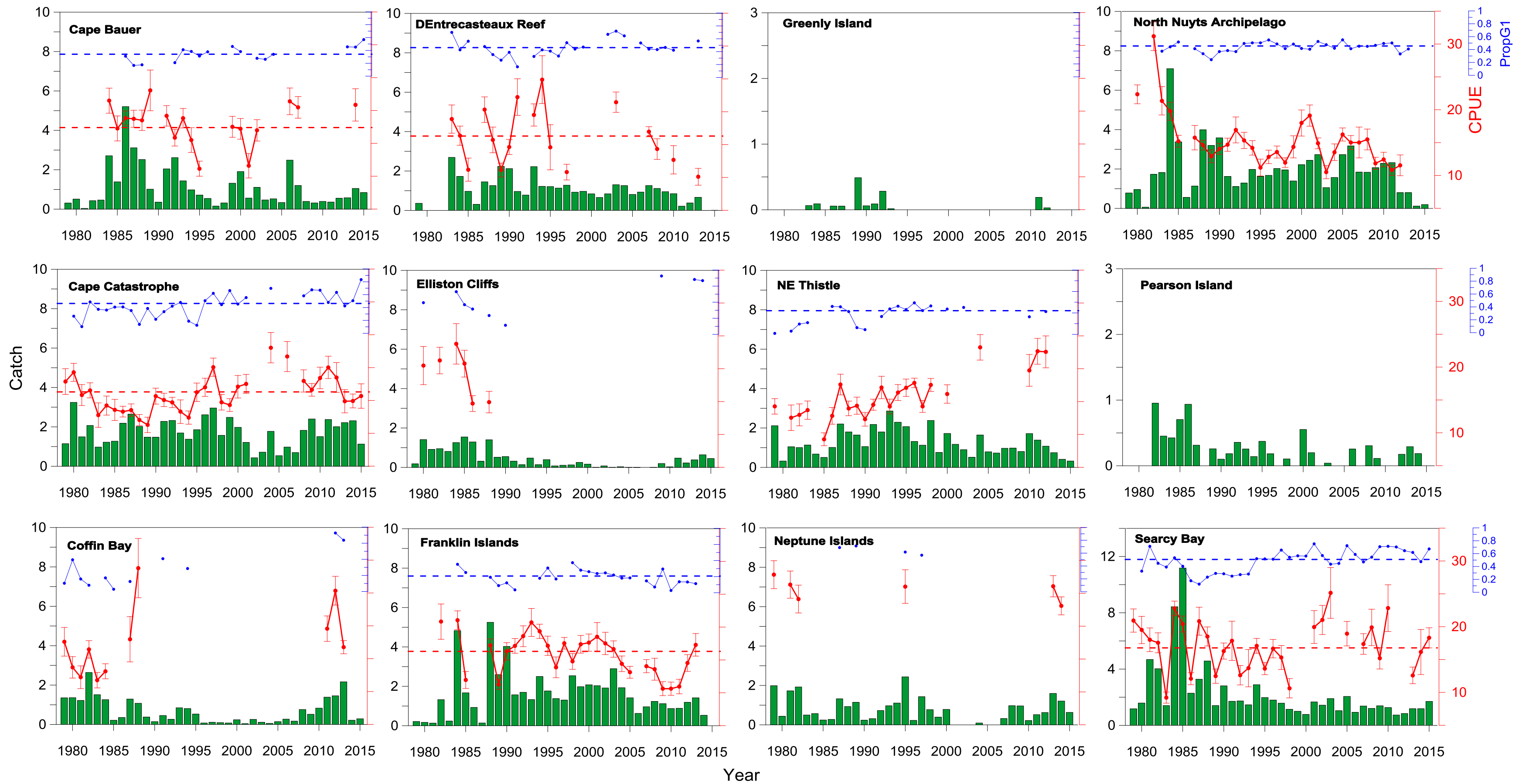

Figure A5. 7. Catch (t, meat weight; green bars) of greenlip from low importance SAUs Cape Bauer, Cape Catastrophe, Coffin Bay, D'Entrecasteaux Reef, Elliston Cliffs, Franklin Islands, Greenly Island, NE Thistle, Neptune Islands, North Nuyts Archipelago, Pearson Island and Searcy Bay. CPUE ± se (kg.hr^{-1}) is shown in red. Red dashed lines show CPUE$_{90\text{-}09}$ where applicable. Note catch scales vary among graphs.

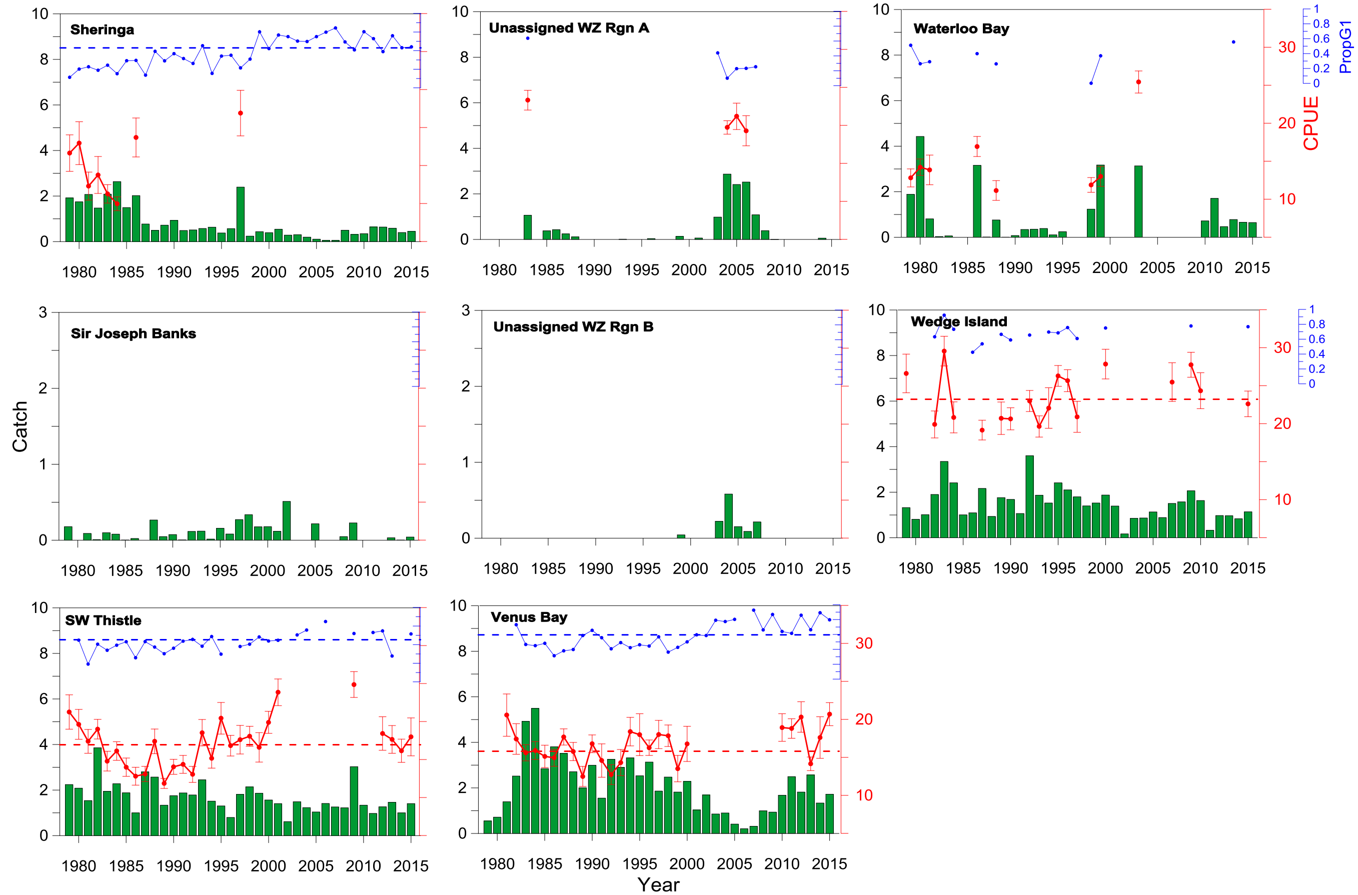

Figure A5. 8. Catch (t, meat weight; green bars) of greenlip from low importance SAUs Sheringa, Sir Joseph Banks, SW Thistle, Unassigned WZ Region A, Unassigned WZ Region B, Venus Bay, Waterloo Bay and Wedge Island. CPUE ± se (kg.hr^{-1}) is shown in red. Red dashed lines show $CPUE_{90\text{-}09}$ where applicable. Note catch scales vary among graphs.