Fisheries

Western Zone Abalone (*Haliotis rubra & H. laevigata*) Fishery (Region A)

B. Stobart, S. Mayfield, J. Dent, D.J. Matthews and R.C. Chick

SARDI Publication No. F2007/000561-4
SARDI Research Report Series No. 660

SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

October 2012

Fishery Stock Assessment Report to PIRSA Fisheries and Aquaculture

Government of South Australia

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

Cover photo: Greenlip abalone (*Haliotis laevigata*), B. Stobart.

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Printed in Adelaide: October 2012

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Signed:

Date: 11 October 2012

Distribution: PIRSA Fisheries and Aquaculture, Western Zone Abalone Fishery licence holders, SAASC Library, Parliamentary Library, State Library and National Library

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Funds for this research were provided by PIRSA Fisheries and Aquaculture, obtained through licence fees. SARDI Aquatic Sciences provided substantial in-kind support. We thank the Western Zone licence holders, fishers and shellers for providing length measurements of abalone in the commercial catch, and who have contributed to our understanding of information presented in this report. We are grateful to Brian Foureur and Andrew Hogg and other SARDI past and present divers for assistance with diving and the collection and management of data. Dr Rick McGarvey provided substantial statistical support including development of a mean ratio estimator for CPUE performance indicators. We thank Dr Paul Burch for statistical support and programming. This report was formally reviewed by Dr Lianos Triantafillos (PIRSA Fisheries and Aquaculture), Drs Adrian Linnane and Daniel Gorman (SARDI Aquatic Sciences), and Prof. Gavin Begg, Research Chief (SARDI Aquatic Sciences. It was formally approved for release by Assoc. Prof. Timothy Ward, Science Leader, Fisheries, SARDI Aquatic Sciences.

EXECUTIVE SUMMARY

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

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

Data spanning three spatial scales were integrated: Region A, fishing areas (FAs) and spatial assessment units (SAUs).

BLACKLIP

Blacklip abalone comprises 57% of the combined Region A abalone total allowable commercial catch (TACC; 2011 TACC 276 t). Total catches have been relatively stable since 1989.

Blacklip abalone stocks in Region A appear to have benefitted from a zone-wide recruitment event that increased their abundance above historical levels for approximately eight years from 2001 to 2008. The current harvestable biomass may be similar to that prior to the recruitment event.

The spatial distribution of catch has changed since 2009. Catches from FA 9 have declined to the lowest level in more than 20 years, with catches from other traditional FAs (11-14) increasing. These changes were also evident among SAUs.

The increased catches from FAs 11-14 are unlikely to be sustainable because recent catch rates in these areas are low and/or declining. These areas contributed >50% of blacklip catch in 2011.

Overall, the weight-of-evidence assessment was consistent with the harvest strategy which categorised the Region A blacklip abalone fishery as sustainably-fished.

However, maintenance of the current TACC appears reliant on catches being redistributed from FAs 11-14, without overfishing blacklip stocks elsewhere.

GREENLIP

Total greenlip abalone catch has generally been stable since 1989. The exception was from 2006 to 2009 during which the TACC was higher at 227 t. The TACC in 2011 was 207 t.

Greenlip abalone stocks also appear to have benefitted from a zone-wide recruitment event prior to 2001. CPUE estimates suggest the abundance of legal-sized greenlip may be higher than that prior to the recruitment event. However, fishery-independent survey data indicate that the harvestable biomass was lower and comparable to that in the late 1990s. This suggests CPUE may be hyperstable.

The spatial distribution of catch has changed since 2009. Catches from FA 9 have declined substantially whilst those from other, less-traditional fishing grounds have increased. These changes were also evident among SAUs.

There are five SAUs (Anxious Bay, Flinders Island, Ward Island, Hotspot and Drummond) within which the abundance of legal-sized greenlip abalone is low and/or decreasing. About 30% of the greenlip catch was harvested from these SAUs in 2011 and 40% over the last 10 years (i.e. $C_{02\text{-}11}$). Catches in these SAUs may be partially offset with larger catches from SAUs with historically higher catches than currently harvested.

The traditional weight-of-evidence assessment was generally consistent with the harvest strategy which categorised the Region A greenlip fishery as sustainably fished.

1. INTRODUCTION

1.1. Overview

This fishery assessment report for Region A of the Western Zone (WZ; hereafter referred to as Region A) of the South Australian Abalone Fishery (SAAF; see Figure 1.1) updates previous fishery assessment and status reports for this region (Chick *et al.* 2006; 2008; 2009; Stobart *et al.* 2011). The report covers the period from 1 January 1968 to 31 December 2011 and is part of the South Australian Research and Development Institute (SARDI) Aquatic Sciences' ongoing assessment program for the blacklip (*Haliotis rubra*) and greenlip abalone (*H. laevigata*) fisheries (hereafter referred to as blacklip and greenlip, respectively) in this zone.

The aims of the report are to (1) document the current status of the resource; (2) identify the uncertainty associated with the assessment; (3) evaluate the new harvest strategy for the fishery; (4) detail the methodology followed to assess the fishery; (5) provide summaries of biological knowledge; (6) describe the recreational and illegal, unregulated and unreported (IUU) fisheries in this zone; and (7) identify future research needs. Furthermore, as this is the first report for Region A in which the harvest strategy, stipulated by the new Management Plan for the South Australian Abalone Fishery, was implemented (PIRSA 2012), the relevant methodology is detailed.

The report is divided into four sections, including this introduction, which provides (1) a general overview of the report; (2) the history and a description of the fishery, including the management plans and; (3) information on the biology of each species harvested. Sections 2 and 3 provide an assessment of fishery-dependent (FD) and fishery-independent (FI) data for blacklip and greenlip abalone. For each of these species, where appropriate, this includes spatial and temporal analyses of catch (tonnes shell weight; t), effort (days), catch-per-unit-effort (CPUE; $kg.hr^{-1}$), commercial catch size-structure, FI survey data and application of the harvest strategy that determines (1) the risk that stocks within SAUs are overfished and (2) the status of the abalone fishery in Region A. Each of these two sections is concluded by a discussion providing a synthesis of the information presented and a summary of the current status of the fishery. Finally, in the General Discussion (Section 4), uncertainties in the assessment are identified, the assessments for greenlip and blacklip compared, the harvest strategy formally evaluated, and future research needs for the fishery considered.

1.2. History and description of the fishery

1.2.1. Commercial fishery

The SAAF has evolved since its inception in 1964. Entrants to the fishery increased in the late 1960s, and exceeded 100 entrants by 1970. Licences were made non-transferable in 1971 to reduce the number of operators in the fishery. By 1976, the number of operators had reduced to 30 and an additional 5 licences were issued. These 35 licences remain in 2012. A review of the management history is provided by Shepherd and Rodda (2001) and major management milestones are listed in Table 1.1. Summaries of the fishery can be found in Prince and Shepherd (1992), Keesing *et al.* (1995), Zacharin (1997), Nobes *et al.* (2004) and Mayfield *et al.* (2011).

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

Date	Milestone
1964	Fishery started
1971	Licences made non-transferable
	Fishery divided into three zones
	Minimum legal length (MLL) set at 130 mm for both species
1976	30 Licences remained; 5 additional licences issued
1978	Sub-zones and fishing blocks replaced by map numbers and codes
1980	Licences became transferable
1984	Blacklip minimum legal length amended to 120 mm in the Southern Zone
	Greenlip minimum legal length amended to 145 mm in the Western Zone
1985	Western Zone divided into Regions A and B
	Quota introduced to Region A in the Western Zone (293.25 t blacklip; 293.25 t greenlip)
1989	Quota introduced to the Central Zone
	TACC in Western Zone Region A greenlip fishery reduced to 207 t
1991	Quota introduced to Region B in the Western Zone (27.6 t both species)
1993	Abolition of owner-operator regulation
	TACC in Western Zone Region B increased to 34.5 t
1994	Four ‘fish-down’ areas declared in the Southern Zone
	TACC in Western Zone Region B increased to 41.4 t
1996	TACC in Western Zone Region A blacklip fishery decreased to 258 t
1997	Management Plan implemented (Zacharin 1997)
	TACC in Western Zone Region A blacklip fishery increased to 293.25 t
2004	Management Plan reviewed (Nobes *et al.* 2004)
2006	TACC in Western Zone Region A greenlip fishery increased to 227.7 t
2010	TACC in Western Zone Region A blacklip fishery decreased to 276 t
	TACC in Western Zone Region A greenlip fishery decreased to 207 t
2012	New management plan including harvest strategy

In 1971, the SAAF was divided into three zones (Western (WZ), Central and Southern) to facilitate more effective management (Figure 1.1). The WZ of the SAAF includes all coastal waters of South Australia between the Western Australia/South Australia border and the eastern Eyre Peninsula (Figure 1.1). This zone was further subdivided into Region A and Region B in 1985. The fishing season extends from 1 January to 31 December each year.

To monitor catches and facilitate compliance with quota limits, fishers must complete a 'Catch and Disposal Record' (CDR) form upon landing. In addition, a research logbook must be completed for each fishing day and submitted to SARDI Aquatic Sciences at the end of each month. Commercial catch and effort data on this fishery have been collected since 1968. These data are used by SARDI to provide analyses of catch, effort and CPUE in Stock Assessment or Status Reports for each zone for Primary Industries and Regions South Australia (PIRSA) Fisheries and Aquaculture.

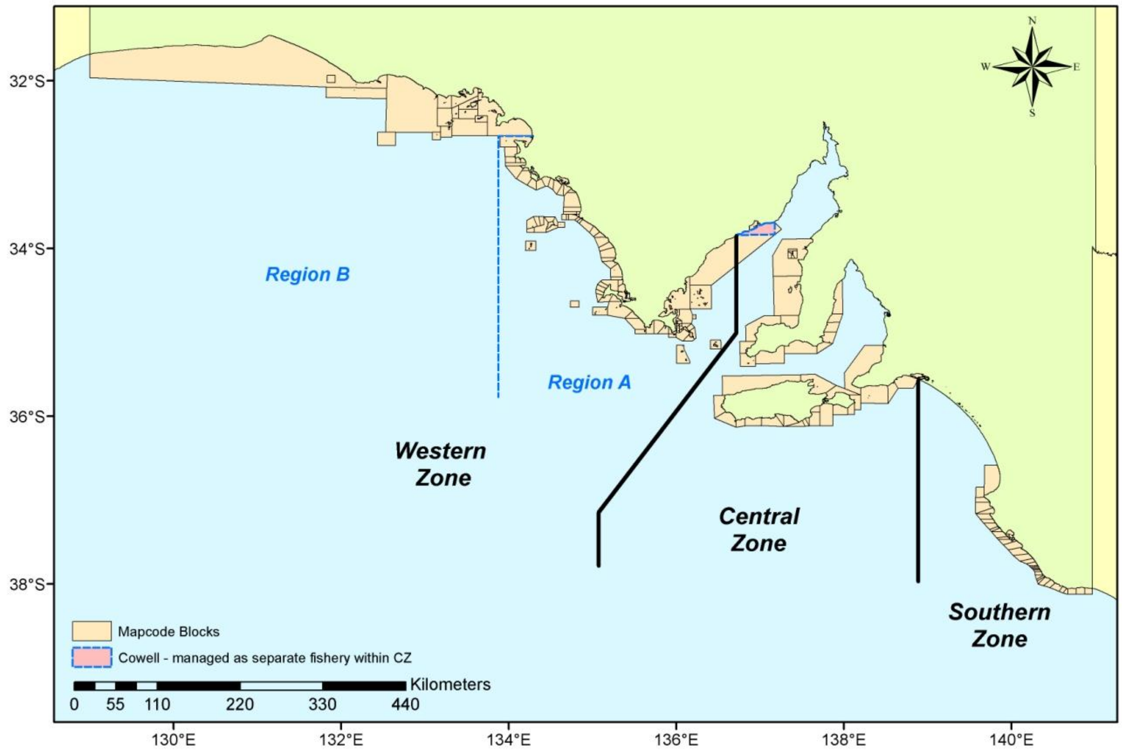

Figure 1.1. Fishing zones of the South Australian Abalone Fishery.

In Region A, annual Total Allowable Commercial Catches (TACCs) were introduced for blacklip and greenlip in 1985 and amended to the calendar year fishing season from 1989 (Nobes *et al.* 2004). The TACC for blacklip in Region A was 293.25 t shell weight from 1989 to 2009, with the exception of a 35.25 t (12%) reduction in 1996 (258 t) due to infection of blacklip with *Perkinsus* sp. in Thorny Passage (Nobes *et al.* 2004) and a reduction of 17.25 t (6%) from 2010 (276 t) driven by licence holders concern for the stock. The TACC for greenlip in Region A was 207 t shell weight between 1989 and 2011, with the exception of a 20.7 t (10%) TACC increase from 2006 to 2009 (227.7 t) to take advantage of increased legal-sized abundance, likely a consequence of strong recruitment during the 1990s (Stobart *et al.* 2011).

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

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

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

1.2.2. **Recreational fishery**

The total recreational abalone catch in South Australia was estimated at 1,685 blacklip and 3,462 greenlip abalone for the 12 month period from November 2007 to October 2008 (Jones 2009). Of these, an estimated 10% blacklip (168) and 49% greenlip (1,696) were caught in the WZ. Based on the previous recreational survey by Henry and Lyle (2003), this estimate is 64% lower than the 5,210 abalone recreationally harvested from the WZ for the period May 2000 to April 2001 (Chick *et al.* 2009). The recreational catch of 1,864 individuals equates to 261 kg meat weight (based on average weight of 140 g per abalone).

1.2.3. **Illegal, unregulated and unreported catch**

Accurate estimation of illegal, unregulated and unreported (IUU) catch is difficult, as many information reports cannot be validated. During 2010/2011, PIRSA received 92 information reports relevant to Western Zone. PIRSA identified that, through 13 of these reports, at least 1,650 kg (meat weight) and 656 whole abalone were taken illegally. By attributing an estimated average weight of 140 g per abalone, the weight of whole abalone would be 91.8 kg, and thus the total meat weight for the 13 information reports was estimated at 1741.8 kg (mean: 134 kg.report^{-1}). Applying this value to the 92 information reports received, the estimated illegal catch of abalone in the WZ equates to about 12 t (meat weight), which equates to 7.5% of the TACC. This estimate excludes IUU take where a caution, expiation or brief has been compiled (PIRSA

Fisheries and Aquaculture). It would be expected that PIRSA would not have been notified of all reports alleging that abalone theft had occurred within the WZ during 2011, so the actual extent of IUU take of abalone is likely to have been higher.

1.3. **Management plans**

1.3.1. **Previous management plans**

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

Following extensive review, Zacharin (1997) was superseded by Nobes *et al*. (2004). Although this second Management Plan had similar (1) management objectives and associated strategies for the fishery and (2) management actions following any triggering of PIs, this second Management Plan identified a broader suite of PIs – spanning a wide range of fishery-dependent and fishery-independent data – applied to individual fishing areas within a statistical framework. The triggering of PIs was primarily determined from statistically significant differences in PI values (1) between years and (2) across five consecutive years. This approach had two key advantages (Chick *et al.* 2009). Firstly, the suite of PIs was sufficiently broad, thereby encompassing almost all aspects of the fishery and, secondly, the complex population structures of abalone were better captured by their spatial focus (Saunders and Mayfield 2008; Miller *et al.* 2009; Saunders *et al.* 2009a; 2009b). However, a key disadvantage of this approach was the need to continually assess the fishery against a large number of PIs that, when triggered, seldom provided consistent inferences about stock status. Furthermore, this challenge was compounded by (1) inclusion of PIs that seldom informed stock status (e.g. mean daily effort) or were difficult to calculate (e.g. egg production); (2) the lack of target or limit reference points for PIs; and (3) not amalgamating the PIs across fishing grounds into a single index of stock status for each species in each zone, which made management decisions difficult because quotas are determined for each species in each zone. In addition, Nobes *et al.* (2004)

did not provide clear decision rules to guide TACC changes among years. Chick *et al*. (2009) made several suggestions to overcome this difficulty, including (1) employing the 'traffic-light' or 'thermostat' approaches suggested by Caddy (2002) and Shepherd and Rodda (2001), and (2) amalgamating the PIs for the key fishing grounds into a single index of stock status.

1.3.2. **The New Management Plan**

Coincident with an FRDC-funded project focussed on abalone fishery performance measures (FRDC 2007/020), Nobes *et al.* (2004) was reviewed. As the management objectives and strategies for the fishery are well established, the key focus of this review was the development of a framework to link stock status with explicit decision rules to set TACCs. The aim was to develop a formal, species-specific, spatially-explicit harvest strategy for the SAAF that (1) defines stock status; (2) delivers sustainability outcomes; (3) is cost-effective; and (4) facilitates stakeholder engagement. The objectives underpinning this process were to (1) capture the spatial structure of abalone stocks; (2) target assessments (and research) to key fishing grounds; (3) use a representative range of PIs to measure fishery performance and determine stock status; (4) develop clear frameworks for data utilisation, integration, interpretation; and (5) provide a structured, documented process for determining TACCs using harvest-decision rules that incorporated a framework to guide integration with industry information. This aim and these objectives were selected because, following extensive review of the use of indicators, reference points and decision rules in fisheries management (Caddy 2002, 2004; Sainsbury 2008; and references therein), these systems have a demonstrated record of improving the understanding of stock status among stakeholders and providing increased certainty in management decisions.

The current plan (PIRSA 2012) appears to meet most of these objectives. For example, assessments are made at scales that better reflect functional biological populations, termed spatial assessment units (SAUs). Research is focussed into those SAUs from which most of the catch is harvested (high importance) because the risk that abalone stocks in these areas are overfished is assessed using six PIs. These six PIs are based on FD and FI data, have clearly-documented data utilisation (Table 1.3) and interpretation (Table 1.4) and were selected because they directly measure abundance and exploitation rate whilst remaining as independent as possible. Areas from which intermediate catch is harvested (medium importance) are assessed using the three fishery-dependent PIs while, in contrast, those areas from which limited catch has been harvested – low importance SAUs – are not assessed using PIs.

Following risk-of-overfishing assessment for each SAU, the assigned risks are catch-weighted and summed to determine the stock status for each species. These outcomes serve two purposes. First, the assigned risk-of-overfishing category for each SAU is linked with explicit, bounded decision rules (Table 1.4) and industry-based information to determine the catch contribution from this SAU to the TACC in the subsequent year. Second, the stock status enables the TACC to be set for two years – concurrent with the biennial assessment program – provided that index does not change among years. Thus, the current management plan for the fishery (PIRSA 2012) incorporates a species-specific, spatially-explicit harvest strategy that combines (1) PIs and reference points with (2) harvest-decision rules to determine future catch contributions from the component stocks (SAUs) in the fishery. Catch contributions are then summed by species for each zone and used to adjust annual TACCs. This approach overcomes many of the deficiencies of previous plans including reduced subjectivity in interpretation of a complex array of spatially-explicit PIs and a structured process for determining TACCs.

There are two key components to the harvest strategy. These are (1) determining the risk that each SAU is overfished and the overall status (depleted, overfished, sustainably fished, under fished or lightly fished) of each species in each zone of the SAAF; and (2) 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. These management decisions are constrained by harvest decision rules that, in turn, are determined by the risk-of-overfishing in each SAU. Determining the risk-of-overfishing and zonal stock status comprises five steps. Each step is described in detail in the Management Plan (PIRSA 2012) and briefly below.

Step 1: Identify spatial assessment units

Spatial assessment units (SAUs) are the spatial scale at which monitoring and assessments are undertaken. Whilst they are intended to reflect distinct abalone populations (Morgan and Shepherd 2006; Mayfield and Saunders 2008; Miller *et al.* 2009), data limitations have required some SAUs to be larger than biologically desirable (e.g. WZ Region B) to allow minimum data requirements for their assessment. These SAUs are likely to encompass multiple abalone populations. To ensure known catch history, SAUs comprise single or multiple map codes, which is the spatial scale against which fishery-dependent data have been reported since 1979. SAUs are the same for greenlip and blacklip abalone in each zone. There are 30 SAUs identified for Region A of the WZ (Figure 1.2). Four SAUs are also defined for Region B (PIRSA 2012).

Step 2: Determine relative importance of each SAU

The importance of each SAU for each species in each zone is based on the relative contribution to total (i.e. combined greenlip and blacklip and combined Regions A and B) catch over the ten-year period ending with the year being assessed (i.e. the current year). Thus, for this assessment, importance was determined using data from 2002 to 2011. Three importance categories are defined – high, medium and low – based on the percentage contribution to total catch. SAUs from which, cumulatively, >50% of catch was harvested are deemed of high importance. Medium importance SAUs comprise those from which, cumulatively, the next 30% of catch was harvested. Thus, the total catch from those SAUs categorised as either high or medium will be >80% of the combined TACC. All remaining SAUs are classified as being of low importance.

For the ten-year period ending 31 December 2011, there were 12 high and 14 medium importance SAUs in the WZ (Figure 1.3). Of these, 12 high (100%) and 12 medium (86%) importance SAUs were in Region A and are assessed in this report.

Step 3: Score performance indicators for each SAU

Six PIs – three based on fishery-dependent and three based on fishery-independent data – are used to measure fishery performance (Table 1.3). These PIs were selected because they provide direct measures of abalone abundance and/or exploitation rates and they are as independent from each other as was possible. All PIs are weighted equally. For those SAUs categorised as high, all six PIs are used to assess fishery performance; only the three fishery-dependent PIs are used for SAUs categorised as medium importance. No assessment of the low importance SAUs is undertaken.

Where applicable, each PI for each species in each SAU is scored using a series of reference points. The reference points are derived from the 20-year time series (1990-2009) of data for each PI, termed the reference period. The exception is where <20 years of data are available (predominantly fishery-independent data). In which case the most recent years (not the current year) are included in the reference period until a period spanning 20 years is obtained. Four reference points are used for scoring (Figure 1.4): (1) upper limit reference point (ULRP) defined as the 3rd highest value (i.e. top 10%) during the reference period; (2) upper target reference point (UTRP) defined as the 6th highest value (i.e. top 25%) during the reference period; (3) lower target reference point (LTRP) defined as the 6th lowest value (i.e. bottom 25%) over the reference period; and (4) lower limit reference point (LLRP) which is defined as the 3rd lowest value (i.e. bottom 10%) during the reference period.

The scoring system is symmetrical with assigned scores ranging from -2 to +2 (Figure 1.4). Each PI is scored on its current and recent performance. Current performance is scored on the current year value. Recent performance is scored on consecutive values of the PI above or below the UTRP-LTRP band for up to three previous years. The current and recent scores are summed to provide a single score for each PI. Thus, in combination, values of the PIs from the last four years are considered in determining the score of each PI for each species in each SAU. Based on the example provided in Figure 1.4, the total score for that PI would be +3. This comprises +2 for current performance and +1 for recent performance (+1 for 2009). No score is assigned for 2008 as the value of the PI is inside the UTRP-LTRP band. Similarly, no score is assigned for 2007 because retrospective scoring ceases once the UTRP-LTRP band is entered or crossed.

The principal exception to this scoring system is the assignment of a score of -1 for those high and medium blacklip SAUs for which commercial catch sampling data are not representative of the fishery. However, as the harvest strategy is new, this penalty score applies to assessments from 2013 onwards; absence of these data for this PI in this assessment was scored a zero.

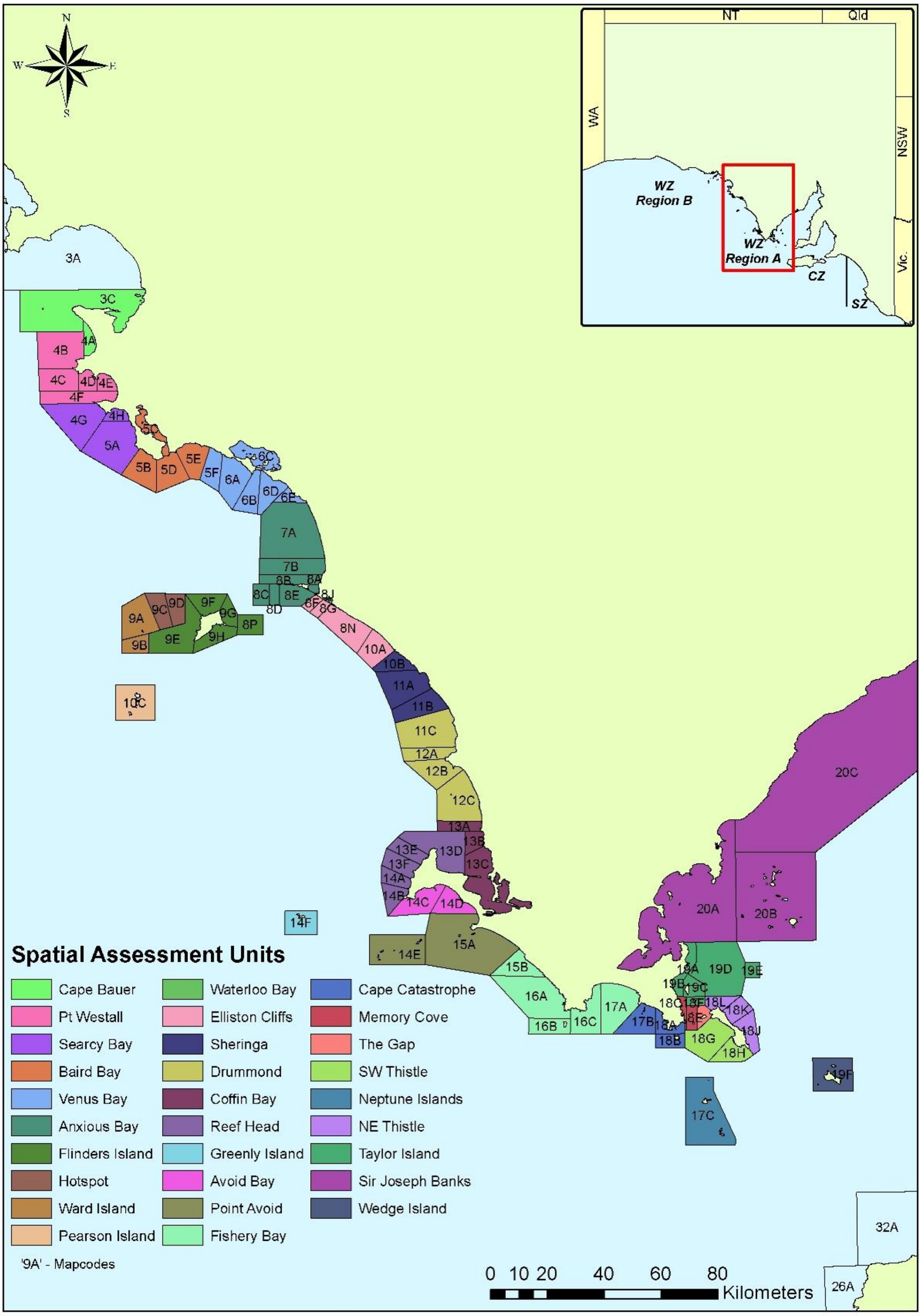

Figure 1.2. Spatial assessment units and map codes in Region A of the Western Zone South Australian Abalone Fishery.

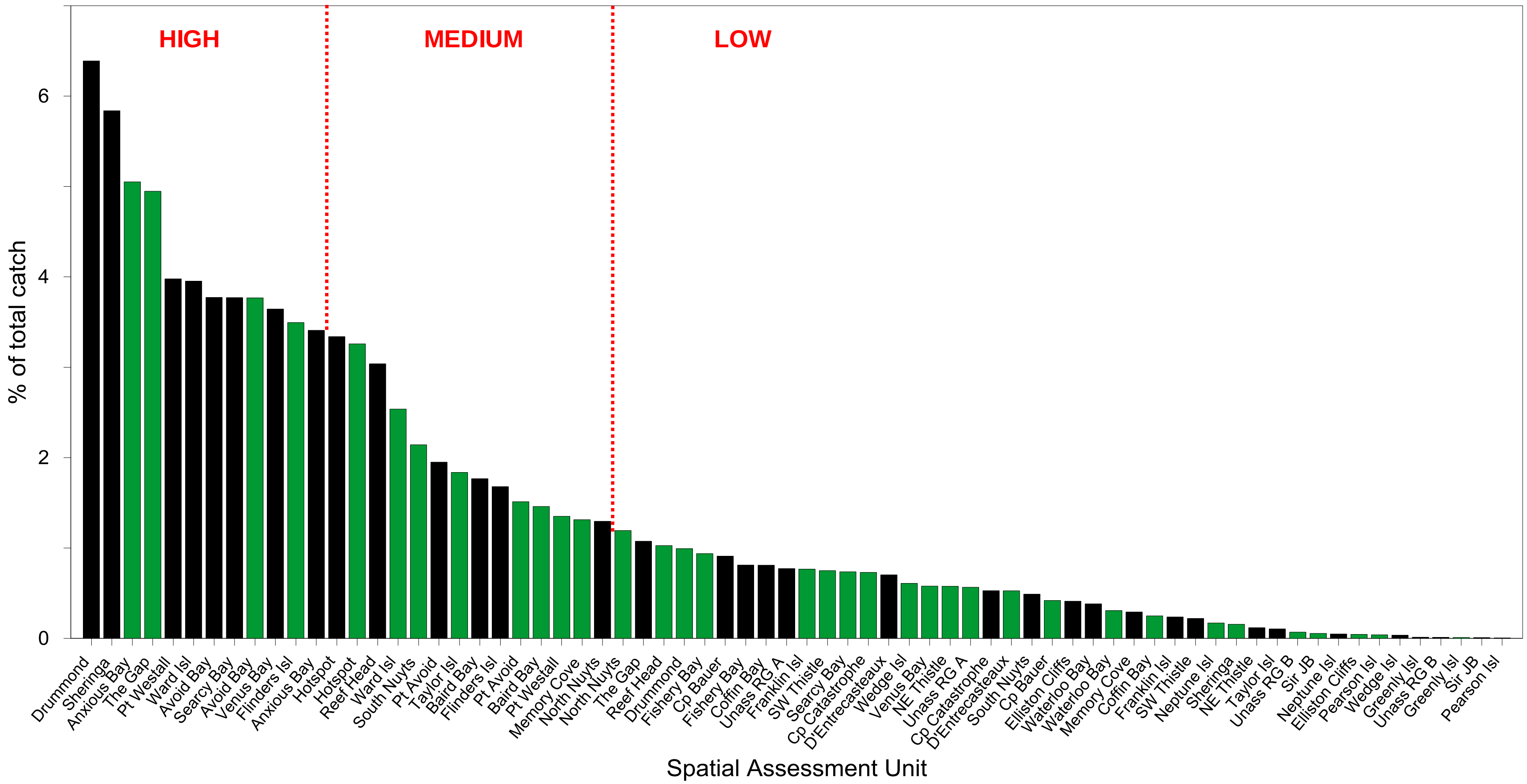

Figure 1.3. Relative importance (% of catch) of each blacklip (black bars) and greenlip (green bars) SAU. Note each SAU is ranked twice, once for blacklip and once for greenlip. Red text and dotted lines indicate SAU importance and division. Note abbreviations for cape (Cp), island (Isl), Joseph Banks (JB) and Unass RG A or Unass RG B (unassigned Region A or Region B, respectively).

Table 1.3. 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	$\text{Catch} = \dfrac{\sum \text{Species Catch (t)}}{\text{TACC}}$	None
Proportion large (blacklip) or Proportion Grade 1 (greenlip)	Proportion of large (or Grade 1) abalone in the commercial catch	$\text{PropLge} = \dfrac{\text{N Large}}{\text{Total N}}$ or $\text{PropG1} = \dfrac{\sum \text{Grade 1 Meats (kg)}}{\sum \text{Meats (kg)}}$	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})	$CPUE_{Wt} = \dfrac{\sum_{i=1}^{n} w_i \dfrac{C_{PSi}}{E_i}}{\sum_{i=1}^{n} w_i}$	All records where: total catch was >900 kg; CPUE (total catch/total effort) was >150 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	$\text{Density}_{\text{Legal}} = \dfrac{\sum \text{Legal counted}}{\text{Total area surveyed}}$	>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 yr) abalone on surveys	$\text{Density}_{\text{Pre-recruit}} = \dfrac{\sum \text{Pre-recruit counted}}{\text{Total area surveyed}}$	>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	$Z = K \dfrac{(L_\infty - \bar{L})}{(\bar{L} - \text{MLL})}$	Minimum sample size: 100 measurements

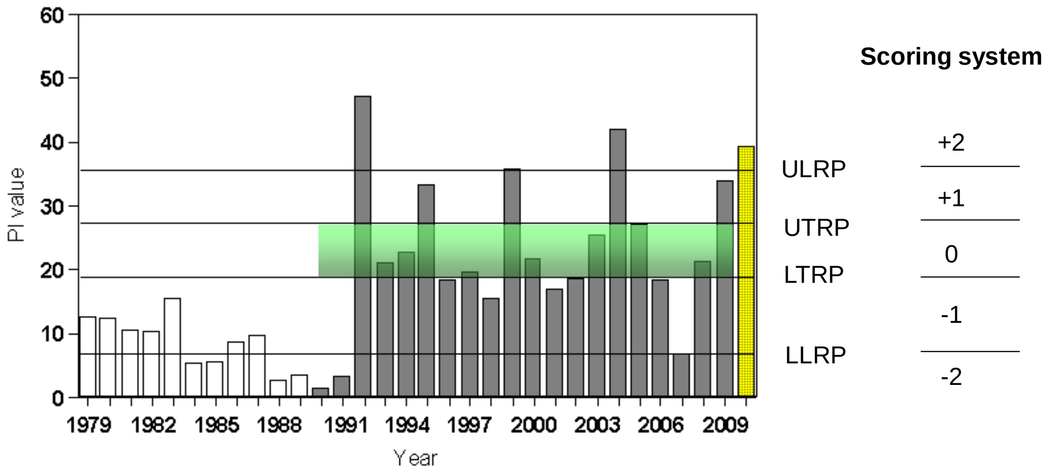

Figure 1.4. Schematic showing the reference period (grey bars), associated reference points, the year being assessed (yellow bar) and the scores applied to measure fishery performance. ULRP, UTRP, LTRP and LLRP refer to upper limit reference point upper trigger reference point, lower trigger reference point and lower limit reference point, respectively. The green shading indicates the middle 50% of values observed during the reference period.

Step 4: Determine risk of overfishing for each SAU

Determining the risk that the stocks in each SAU are overfished comprises two steps. First, the scores for each PI are summed to provide a single numeric value for that SAU. Second, the total score is used to assign that SAU to a risk-of-overfishing, colour-coded category using a probability distribution which describes the likelihood of obtaining that total score by chance. The probability distributions (Figure 1.5) were determined in two steps: (1) the probability of obtaining each score (range: -8 to +8) for each PI was determined analytically and (2) Monte Carlo simulation (n = 5000) was used to obtain probabilities of scores for multiple (i.e. combined) PIs. This approach relies on the assumption that all outcomes are equally likely and that the PIs are independent from each other and between years. Simulations were undertaken separately for the high (i.e. six PIs) and medium (i.e. three PIs) importance SAUs. As with the scoring of the PIs, the categories defining the risk that the stocks in a SAU are overfished are symmetrical with the boundaries between categories analogous to the reference points described in step 3 above. Importantly, the colour-coded categories are linked to explicit harvest decision rules (Table 1.4) that are applied to the mean catch over the most recent (four-year) period from each SAU during the decision-making process.

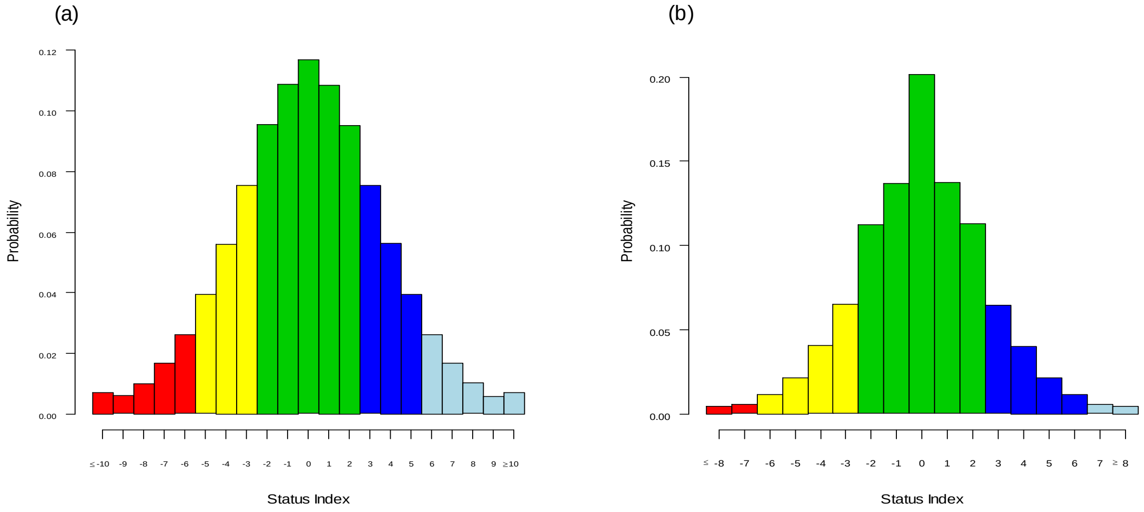

Figure 1.5. Histograms showing the probability distributions of obtaining total scores across (a) six PIs for SAUs of high importance and (b) three PIs for SAUs of medium importance. Probabilities above and below ±10 (High) and ±8 (Medium) were accummulated in these upper and lower bin classes, respectively, for each of the six and three PIs distributions.

Table 1.4. Range of harvest decision rules (% change in catch contribution) following identification of the risk of overfishing category by the harvest strategy.

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

Step 5: Determine zonal status

The status of each species in each zone is derived from a combination of the (1) risk-of-overfishing category for each SAU and (2) importance of that SAU, by catch, to the zone. This is undertaken in a four-stage process (see Table 2.1 & Table 3.1). First, numeric scores are assigned to each colour-coded, risk-of-overfishing category. These scores are -2 (red), -1 (yellow), 0 (green), +1 (blue) and +2 (light blue). Second, the proportional contribution to the combined catch from each high and medium SAU is determined, with catches from low importance SAUs ignored. Third, the risk-of-overfishing score (-2 to +2) for each SAU is multiplied by its proportional contribution to the combined catch. Finally, the products of these calculations are summed to provide a catch-weighted score for zone status that ranges between -2 and +2. Zone status scores fall into one of five categories. These are defined as depleted (score ≤ -1.5), overfished (>-1.5 score ≤ -0.5), sustainably fished (>-0.5 > score ≤ 0.5), under fished (> 0.5 score ≤ 1.5) and lightly fished (score ≥ 1.5).

1.4. Biology of greenlip and blacklip

Abalone (Family: Haliotidae; Genus: *Haliotis*) are marine gastropods inhabiting near-shore reefs (Day and Shepherd 1995) from the shallow sub-tidal zone to depths around 200 m (Geiger 2000). They have a world-wide distribution in tropical and temperate waters with the richest abalone faunas found in Australia, Japan and South Africa (Geiger 2000). Over 50 species of abalone are currently recognised (Geiger 2000).

Large genetic differences exist between the northern and southern temperate species and within the southern temperate species assemblages (Brown 1991). Even on more localised scales, genetic variation can occur (Brown and Murray 1992; Elliot *et al.* 2000; Hancock 2000; Temby *et al.* 2007; Miller *et al.* 2009) suggesting limited dispersal among 'metapopulations' (Fleming 1997; Miller *et al.* 2009).

Abalone have separate sexes, spawning is generally seasonal and synchronised with fertilisation success strongly influenced by adult density (Babcock and Keesing 1999). Duration of the larval stage typically ranges between 5 and 10 days and is predominantly influenced 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; McShane 1991; McShane and Smith 1991; Shepherd *et al.* 1992c).

Growth rates are highly variable 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 are being used (Haddon *et al.* 2008). Recently settled abalone prefer encrusting coralline algae (Shepherd and Turner 1985; Shepherd and Daume 1996) that provide an important source of food, and protection from predation (Shepherd and Cannon 1988).

Through their ontogeny the diet shifts from crustose coralline algae (individuals 5-10 mm SL) to drift algae in adults (Shepherd and Cannon 1988). In some species, including blacklip, brown algae and detritus make up a high proportion of the diet (Guest *et al.* 2008). Other abundant algae may be largely avoided, ostensibly due to non-palatability. Small abalone are preyed upon by a range of predators, including fish, crabs, starfish and octopus. Shells are frequently bored by whelks that then feed on the foot muscle. Boring polychaetes also erode the shells and spire (Shepherd 1973).

1.4.1. **Blacklip**

Blacklip are contiguous throughout southern Australia between Coffs Harbour (New South Wales) and Rottnest Island (Western Australia). Adults commonly occur in topographically complex rocky reef (1-30 m depth) where they occur in crevices and caves, or at the bottom of steep rock faces.

Blacklip have a broad-scale population structure (Brown 1991). However, significant genetic differentiation can occur between sites less than 15 km apart (Shepherd and Brown 1993; Temby *et al.* 2007; Miller *et al.* 2009). Blacklip spawn during summer and autumn, though spawning may not be synchronous (Shepherd and Laws 1974; Keesing *et al.* 1995; Rodda *et al.* 1997). The annual spawning cycle may be driven by seasonal variation in water temperature (Shepherd and Laws 1974). Their size at sexual maturity varies substantially among areas. In the WZ the length at which 50% of individuals are sexually mature (L_{50}) varied between 82.3 mm (Hotspot, 2004) and 103.0 mm SL (Tungketta, 2004; Appendix 1, Table A1.1). Fecundity of 130 mm SL blacklip ranges from 0.81 to 1.7 million eggs (Table A1.2).

Growth rates of adult blacklip can be represented by the von Bertalanffy growth equation, k (yr^{-1}) and L_∞ (mm SL). In the WZ, k ranged from 0.078 yr^{-1} at West Bay (2001) to 0.406 yr^{-1} at Waterloo Bay (1969), while L_∞ ranged between 132.8 mm SL at Reef Head and 244.0 mm SL at West Bay (Appendix 1, Table A1.3). The length-weight relationships for blacklip in Region A are generally well established (Appendix 1, Table A1.4).

1.4.2. **Greenlip**

Greenlip are contiguous throughout southern Australia, with their distributions ranging from Corner Inlet (Victoria) to Cape Naturaliste (Western Australia). They commonly inhabit the edge of reefs and boulders near sand or seagrass (5 to >30 m depth) and occur in clusters of local populations, separated from other similar clusters over a range of spatial scales. This pattern of disaggregated spatial distribution is reflected in the population genetics with clusters representing putative 'metapopulations' (Shepherd and Brown 1993; Morgan and Shepherd 2006).

The size at sexual maturity of greenlip varies substantially among areas. In the WZ, the length at which 50% of individuals are sexually mature (L_{50}) varied between 76.6 mm (Anxious Bay, 2005) and 127.7 mm SL (Ward Island, 2006; Appendix 2, Table A2.1). Greenlip spawn during summer and early autumn (Keesing *et al.* 1995; Rodda *et al.* 1997) with the annual spawning cycle probably driven by fluctuations in water temperature (Shepherd and Laws 1974). The relationships between length-fecundity

(Appendix 2, Table A2.2), whole weight-fecundity (Appendix 2, Table A2.3) and length-weight (Appendix 2, Table A2.4) for greenlip in the WZ are generally well established. Adult mortality rates (M) ranged from 0.13 yr^{-1} at Ward Island to 0.40 yr^{-1} at Waterloo Bay (Appendix 2, Table A2.5).

Growth rates vary considerably in both time and space. Newly settled greenlip grew rapidly, at around 20-30 $\mu m.day^{-1}$ (Preece *et al.* 1997; Rodda *et al.* 1997). Sub-legal growth rates in the WZ ranged between 15.3 mm and 39.6 $mm.yr^{-1}$ at Yanerbie and Taylor Island, respectively (Appendix 2, Table A2.6). For adult greenlip (> 90 mm SL), growth is non-linear and can be represented by the parameters k (yr^{-1}) and L_∞ (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 2, Table A2.7).

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). Fishery assessment reports were produced annually between 1998 and 2000 (Rodda *et al.* 1998; Shepherd *et al.* 1999; Rodda *et al.* 2000). The 2001 stock assessment report provided fishery statistics for all three zones of the SAAF (Mayfield *et al.* 2001). The first dedicated WZ report (Mayfield *et al.* 2002) synthesised relevant fisheries data from 1968 to 2001. Stock assessment reports were updated annually to 2006 (Mayfield *et al.* 2005; Chick *et al.* 2006). Subsequent fishery assessment and status reports for Regions A and B of the WZ have been provided to PIRSA in alternate years (Chick *et al.* 2007, 2008; Stobart *et al.* 2010; Stobart *et al.* 2011). The most recent report (Stobart *et al*. 2011), identified rapid changes in blacklip and greenlip CPUE and mean daily catch over the past decade and ascribed these changes to an increased abundance of legal-sized abalone between 2000 and 2008 following elevated, zone-wide recruitment levels in the mid-late 1990s. For blacklip, the assessment concluded that (1) the harvestable biomass was either similar to (based on the assumption that catch rates are not hyperstable) or below (assuming catch rates are hyperstable) that prior to the recruitment pulse in the 1990s; and (2) catches from three FAs (6, 9 and 11), from which substantial catches were harvested in 2010, were unlikely to be sustainable. In contrast, abundance of legal-sized greenlip was considered to be either greater than (FD data) or similar to (FI data) those in the late 1990s. In addition, whilst catches from three important FAs (8, 9 and 14) were unlikely to be sustainable, there was the possibility that higher catches may be obtained from other FAs including 12, 13 and 15 where higher catches had been obtained in previous years and catch rates remain relatively high. Importantly, for both species, monitoring key performance measures in future years was identified as essential to determine whether recent declines in blacklip and greenlip abundance have abated.

2. BLACKLIP

2.1. Introduction

This section of the report provides an analysis of the fishery-dependent and fishery-independent data for blacklip in the WZ from 1 January 1968 to 31 December 2011. It also includes a formal analysis of the fishery's performance and stock status based on the harvest strategy described in the Management Plan (PIRSA 2012), which determines the (1) risk that blacklip stocks in the high and medium SAUs are overfished and (2) zonal stock status for blacklip. In the discussion we assess the current status of the blacklip stocks in Region A comparing the harvest strategy and the traditional weight-of-evidence assessments.

2.2. Methods

Commercial catch and effort data have been collected since 1968 in the form of daily entries to commercial logbooks submitted to SARDI, allowing spatial and temporal analyses of catch, effort and CPUE. Data on the length-frequency distribution of the commercial catch were obtained by measuring samples provided to SARDI by commercial fishers (1999 – 30 June 2005) and subsequently data provided by the Abalone Industry Association of South Australia (AIASA) from 1 July 2005 to 17 April 2008. Subsequent to this, in 2009, one sample from Neptune Islands was measured by SARDI who have also undertaken limited 'at-sea' sampling (Reef Head and Drummond in 2011). Blacklip abundance and population size structure were obtained from SARDI FI surveys which, in recent years, have been undertaken bi-annually as part of an overall rationalisation of the research program.

Fishery statistics are provided at three spatial scales. These are (1) the whole of Region A; (2) fishing areas (FAs); and (3) spatial assessment units (SAUs). The statistics provided are; catch (t, shell weight), CPUE computed using the catch-weighted mean of daily CPUE (Burch *et al.* 2011) and the proportion of large blacklip in the commercial catch (PropLge). Data are presented as mean ± standard error (se) unless otherwise stated.

Multi-dimensional scaling (MDS) was used to evaluate temporal changes in the distribution of catch among FAs and also among SAUs, where proximity between years indicates their similarity. MDS results were further interpreted with similarity percentage (SIMPER) analysis which calculates the percentage each FA or SAU contributes to the difference between each year pair (i.e. which FAs or SAUs are contributing most to the differences).

Prior to calculation of CPUE, daily data were filtered to remove records where catch was >900 kg, effort was <3 and >8 hours, the ratio of total catch over total hours was > 150 $kg.hr^{-1}$ or blacklip comprised <30% of catch. As the minimum sample size was 10 fishing records, the absence of data for this measure indicates this condition was not achieved. PropLge was the ratio of 'large' shells (>165 mm SL) to all commercial SL measurements (minimum sample size = 100); SL measurements >5 mm below the MLL (130 mm SL) were excluded. Whilst these PropLge data are provided for completeness, the limited information since 1999 impedes their interpretation and thus they are excluded from analyses on stock status.

For historical comparison, mean values of key measures of fishery performance are provided both in text and as dashed lines on graphs. These are the (1) proportion of the blacklip TACC harvested from each SAU for the 10-yr period between 2002 and 2011 (C_{02-11}); and (2) mean annual CPUE for the 20-yr period between 1990 and 2009 ($CPUE_{90-09}$). Ranking of SAUs refer first to the rank within the ten-year period (C_{02-11}), followed by the rank in 2011 separated by a hyphen (e.g. 1-5 had rank 1 over the 10-yr period and rank 5 in 2011).

The proportion of large, legal-sized blacklip from FI survey length-frequency distributions was the ratio of 'large' shells (≥ 145 mm SL) to all legal-sized (i.e. ≥ 130 mm SL) measurements. The methodology used to calculate, score and interpret PIs for the new harvest strategy is detailed in Section 1.3.2 and the Management Plan (PIRSA 2012).

2.3. **Results**

2.3.1. **Region A**

Total catches have been stable since the introduction of the TACC in 1985. The exceptions were the temporary reduction to 258 t in 1996, and the decrease to 276 t from 2010 (Figure 2.1). Total effort was stable from 1989 to 2000, decreased to a recent historical minimum in 2006, but has since increased. These temporal changes in effort were strongly reflected in CPUE which increased rapidly from 2000 to 2006 (78 $kg.hr^{-1}$), whereafter it has declined. In 2011, CPUE was 67 $kg.hr^{-1}$. This was 4% below $CPUE_{90-09}$, but 3% above the mean CPUE between 1992 and 2000 (the period prior to the increased abundance between 2001 and 2008).

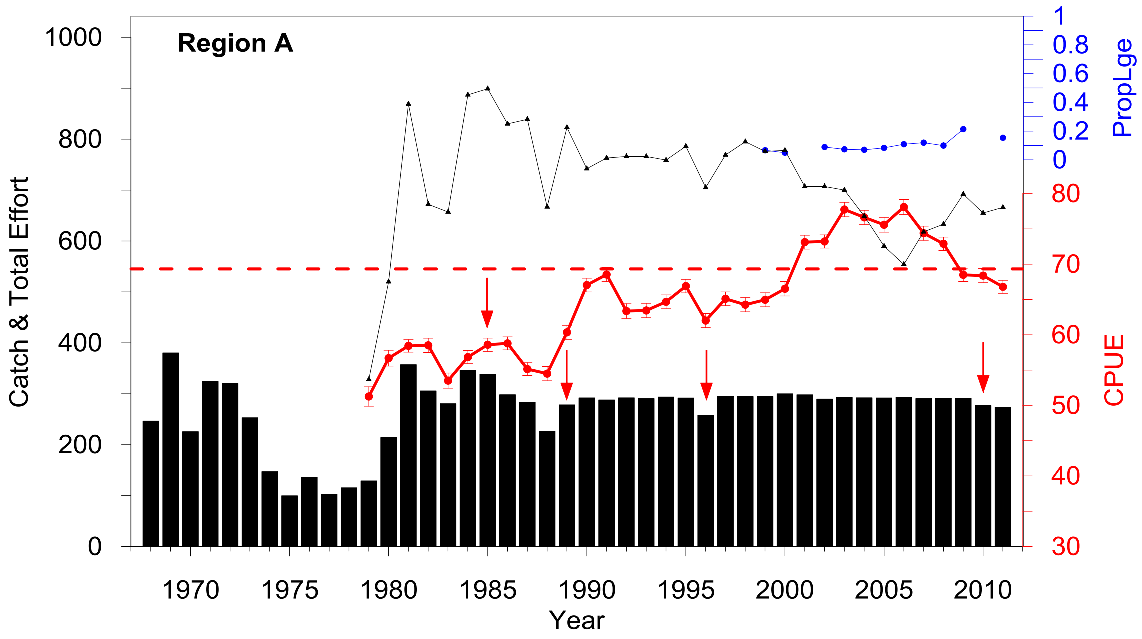

Figure 2.1. Catch (t, shell weight; black bars) of blacklip from Region A from 1968 to 2011. Total effort (days), CPUE ± se (kg.hr^{-1}) and PropLge are shown in black, red and blue lines, respectively. Red dashed line is CPUE$_{90-09}$. Red arrows indicate implementation (1985) and amendment (1989, 1996 and 2010) of TACC.

2.3.2. **Fishing areas**

*2.3.2.1. **Distribution of catch among fishing areas***

In 2011, more than 5% of the catch was harvested from FAs 12 (19.4%), 11 (17.2%), 13 (9.5%), 14 (8.3%), 8 (7.5%), 4 (7.5%), 5 (6.5%) and 9 (5.9%; Figure 2.2). Cumulatively, these represent 82% of the catch and two FAs fewer than those from which more than 5% of the catch was harvested in 2010. The total catch harvested from FA 9 in 2011 (16 t; 6%) was the lowest in more than 20 years and substantially lower than that in 2010 (37 t; 14%). Consequently, FA 9 has dropped from rank 1 in 2010 to rank 8 in 2011. In contrast, the catch harvested from FAs 11 (37 t; 13% to 48 t; 17%) and 12 (31 t; 11% to 53 t; 19%) increased over this period. The rank position of FA 12 has increased from 3rd in 2010 to 1st in 2011.

These differences were confirmed by the MDS plot, which shows that, between 2009 and 2011, there was a substantial change in the spatial distribution of blacklip catches following a long period of relative stability between 1993 and 2009 (Figure 2.3). The distribution in 2011 most resembles that from 1986. The initial change from 2009 to 2010 was primarily driven by an increase in catch from FA 13 and a decrease in FA 9, whilst the greater change between 2010 and 2011 was the result of increases and decreases in catch from FAs 12 and 9, respectively.

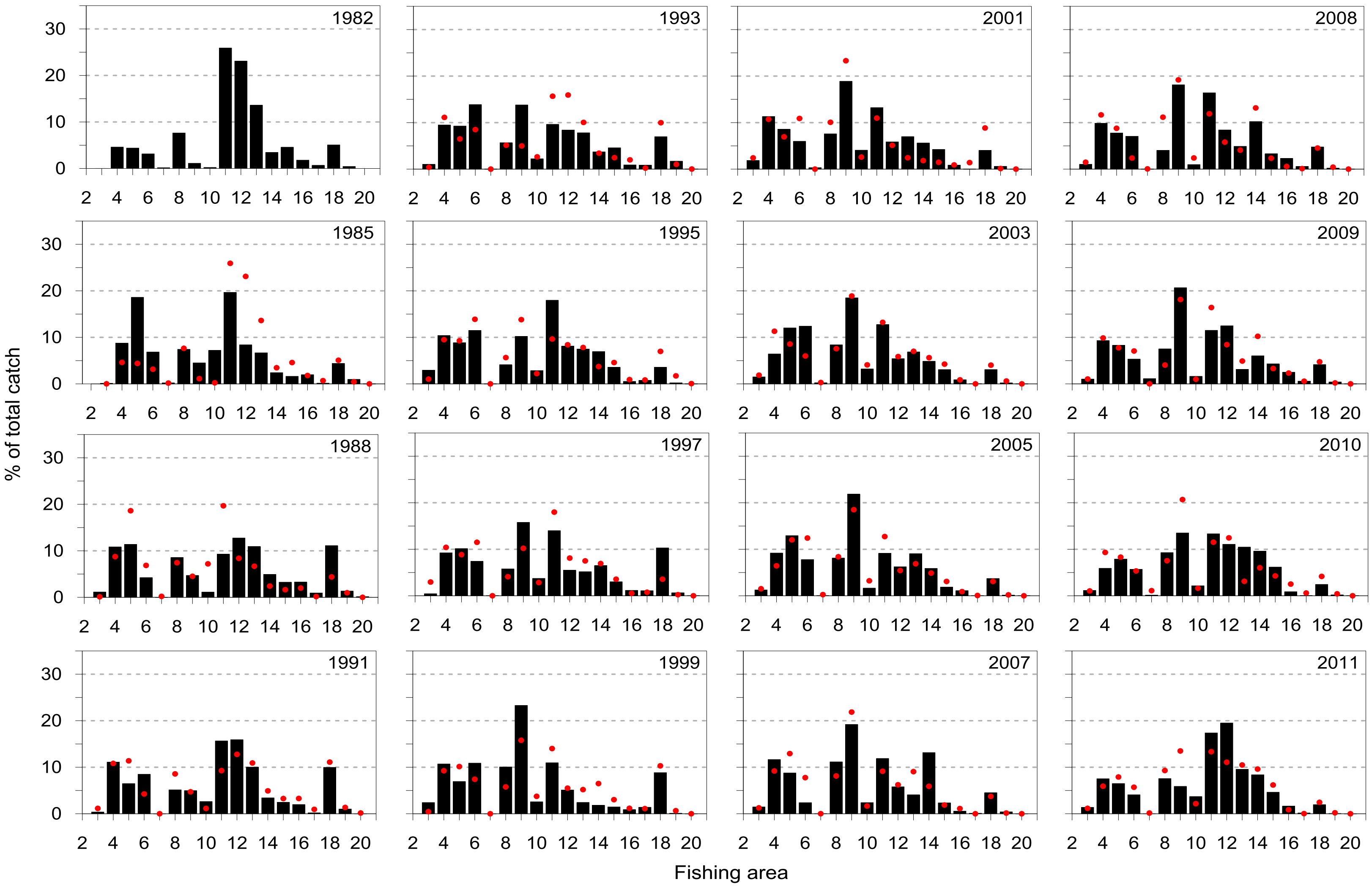

Figure 2.2. Spatial distribution of the blacklip catch (% of total catch) among each of the fishing areas in Region A between 3 year periods from 1982 to 1991, alternate years from 1991 until 2007 and annually 2007 to 2011. Red dots are catches from previous graph.

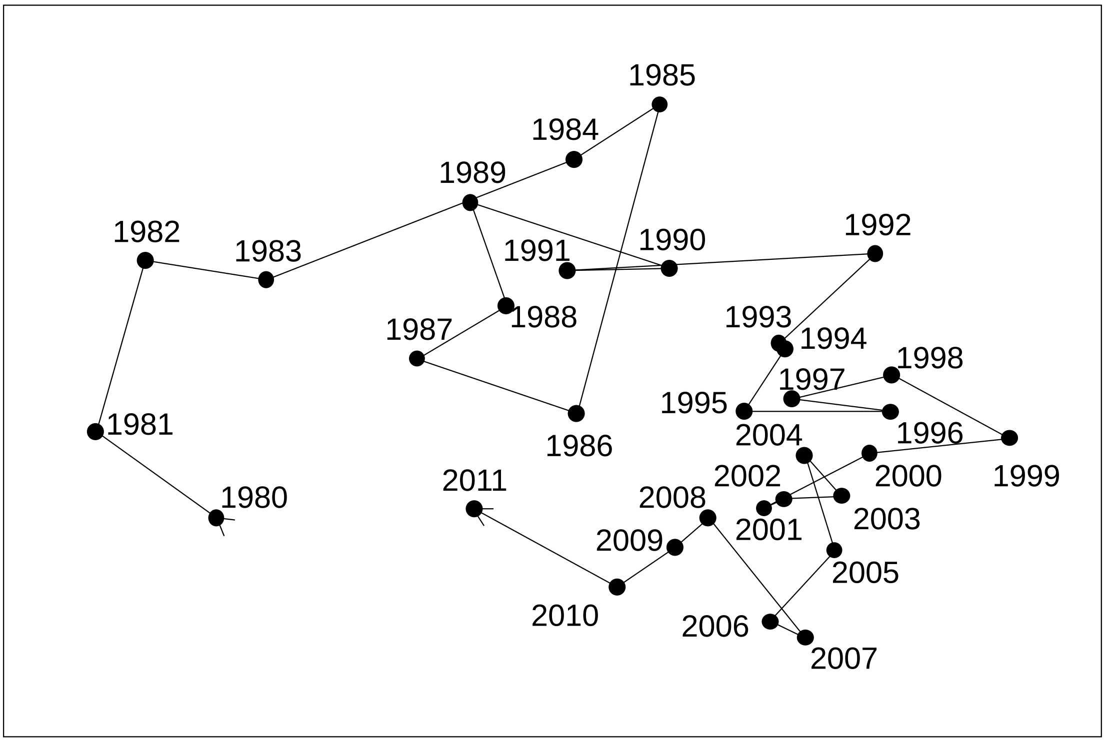

Figure 2.3. Multi-dimensional scaling (MDS) plot for FAs showing similarity among years based on blacklip catch from Region A from 1980 to 2011. 2D stress = 0.14.

2.3.3. Temporal patterns in fishing areas

Substantial catches of blacklip have been harvested from most FAs within Region A. The exceptions are FAs 7, 16, 17, 19 and 20 where catches have been low and intermittent (Figure 2.4 & Figure 2.5). Total annual catches from most FAs have been relatively stable since TACC implementation. These include FAs 3, 4, 5, 8, 10, 11, 13 and 15. In contrast to this long-term stability, temporal patterns in catch have changed substantially in several FAs over recent years. For example, mean catches from FA 6 between 1992 and 2003 were 11 $t.yr^{-1}$, but have since been substantially lower at 6 $t.yr^{-1}$. In FA 9, recent decreases in catch have been more substantial. In 2011, the catch from FA 9 was 6 t. This was 70% below the mean catch (20 $t.yr^{-1}$) between 1998 and 2009 and the lowest catch from this FA since 1991. In order to obtain the TACC, catches from other FAs have increased. This was particularly evident in FAs 12 and 14, where current catches are among the highest on record.

In 2011, mean CPUE (+se) was below $CPUE_{90\text{-}09}$ in nine of 13 FAs within which it was estimable. In addition, mean CPUE declined between 2010 and 2011 in seven of these nine FAs (78%). The largest decreases in mean CPUE were observed in FAs 9, 13, 15 and 18. In FA 9, this decrease in mean CPUE occurred despite the substantial reduction in catch (Figure 2.4 & Figure 2.5).

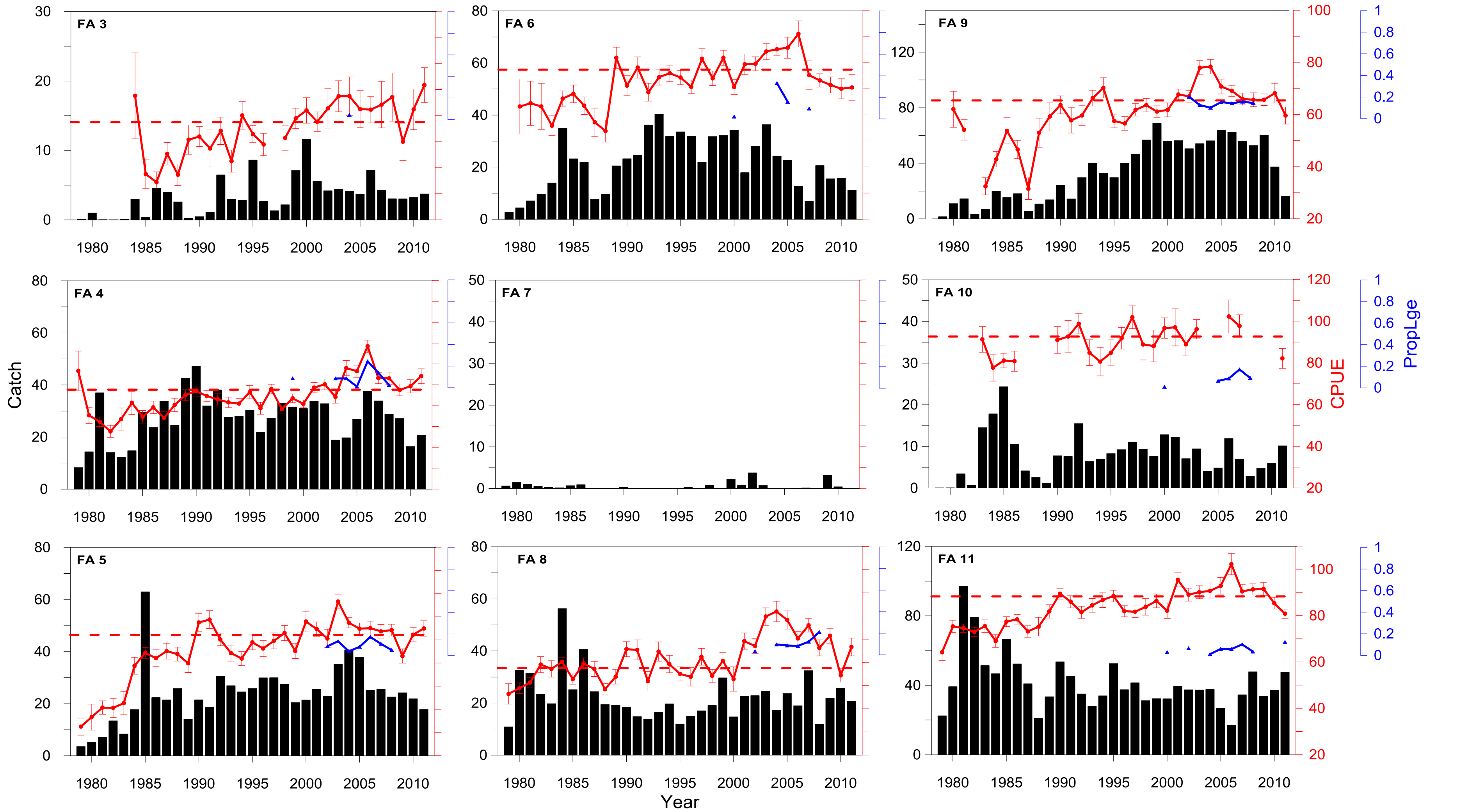

Figure 2.4. Catch (t, shell weight; black bars) of blacklip from FA 3 to FA 11 from 1979 to 2011. CPUE ± se (kg.hr^{-1}) and PropLge are shown in red and blue, respectively. Where applicabe, red dashed lines show CPUE$_{90\text{-}09}$. Note catch scales vary among graphs.

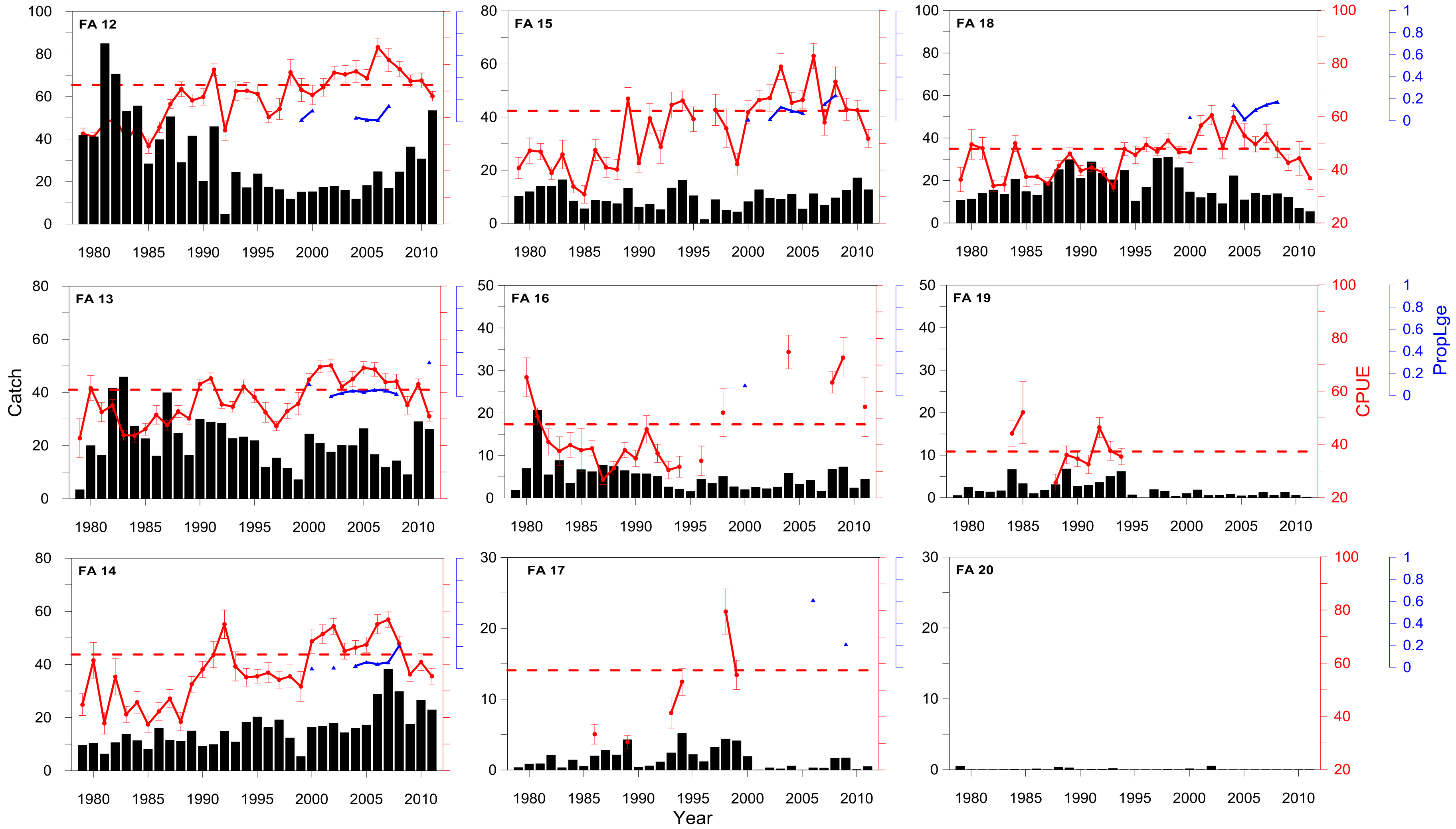

Figure 2.5. Catch (t, shell weight; black bars) of blacklip from FA 12 to FA 20 from 1979 to 2011. CPUE ± se ($kg.hr^{-1}$) and PropLge are shown in red and blue, respectively. Where applicable, red dashed lines show $CPUE_{90\text{-}09}$. Note catch scales vary among graphs.

2.3.4. **Spatial assessment units**

2.3.4.1. ***Distribution of catch among spatial assessment units***

The distribution of catch among SAUs reflects the temporal shifts in the proportions of catch harvested from FAs. Thus, in 2011, most of the catch was harvested from Drummond (24.0%), Sheringa (16.3%), Reef Head (9.2%), Avoid Bay (6.6%), Point Westall (6.6%), Searcy Bay (6.3%) and Anxious Bay (5.7%;Figure 2.6). Between 2010 and 2011, the decrease in catch from FA 9 (see section 2.3.1.1) was evident for all SAUs within this FA, with decreases in catch observed at Flinders Island (7.4 t; 3% to 4.8 t; 2%), Ward Island (17.3 t; 6% to 7.6 t; 3%) and Hotspot (12.6 t; 5% to 4.0 t; 2%). In contrast catch increased substantially at Drummond (37.6 t; 14% to 65.6 t; 24%) and, to a lesser extent, at Sheringa (36.0 t; 13% to 44.6 t; 16%), mirroring the changes in FA 12 and FA 11 during the same period. Between 2010 and 2011 there was also an increase in catch from Point Westall (12.5 t; 5% to 17.9 t; 7%) and decreases in catch from Reef Head (32.9 t; 12% to 25.2 t; 9%) and Anxious Bay (23.8 t; 9% to 15.7 t; 6%).

The MDS plot shows a cluster of years (2000-2009) in which, with the exception of 2007, the distribution of catch among SAUs remained similar, again suggesting a period of relative stability in the fishery (Figure 2.7). More recently, between 2009 and 2011, the distribution of catch among years has differed more, with the spatial distribution of catch in 2011 being most similar to that from 1980 and 1986 (Figure 2.7). For 2009 to 2010, the change was most strongly influenced by the increase in catch from Reef Head and decreases from Elliston Cliffs and Ward Island, while between 2010 and 2011 an increase in catch from Drummond and decreases from Hotspot and Ward Island resulted in the observed change.

In combination, these changes in the spatial distribution of the catch have resulted in eight high (Drummond, Sheringa, Point Westall, Ward Island, Avoid Bay, Searcy Bay, Venus Bay and Anxious Bay) and five medium (Hotspot, Reef Head, Point Avoid, Baird Bay and Flinders Island) importance SAUs for blacklip in 2011.

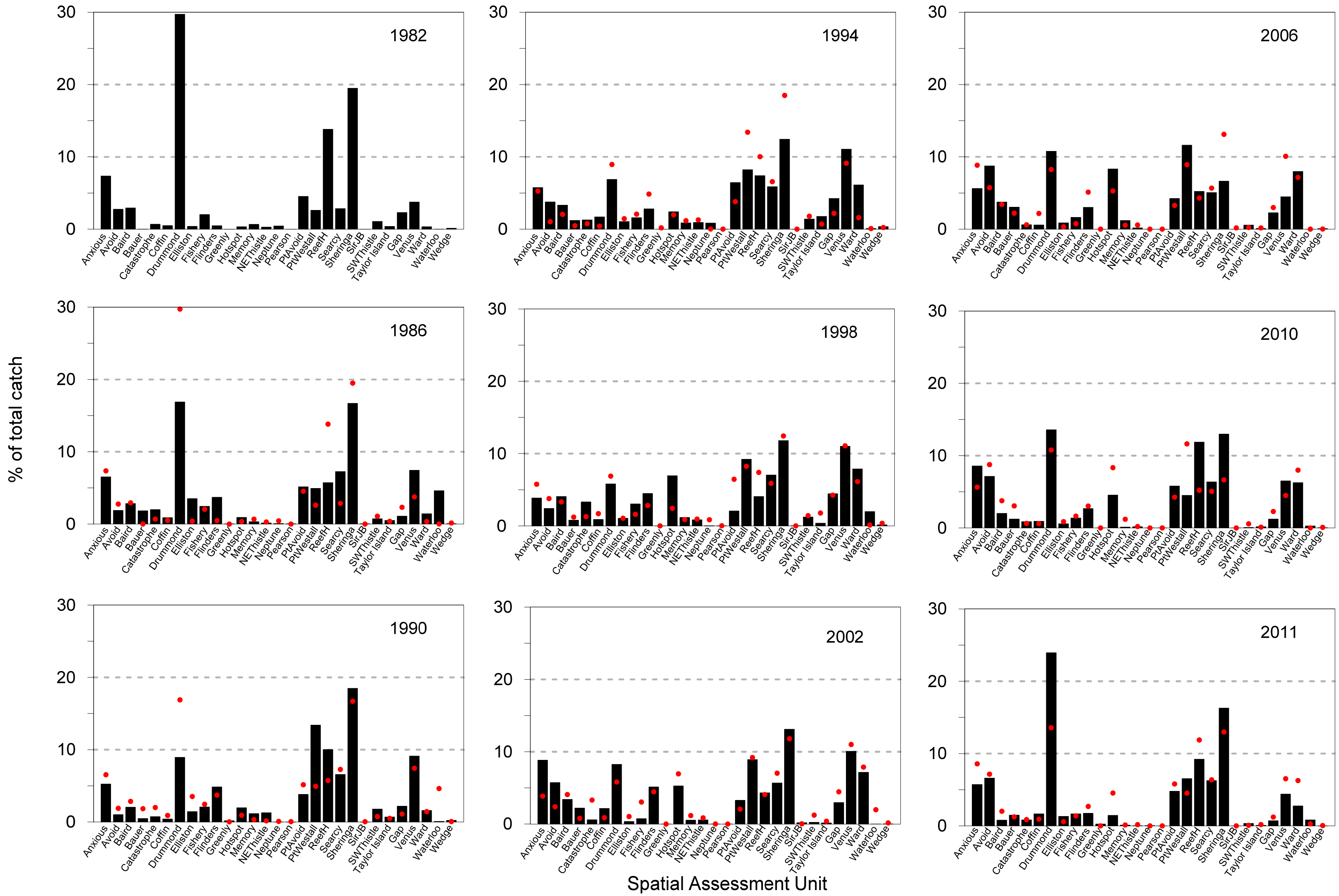

Figure 2.6. Spatial distribution of the blacklip catch (% of total catch) among each of the SAUs in Region A between 4 year periods from 1982 to 2010, and annually thereafter. Red dots are catches from previous graph.

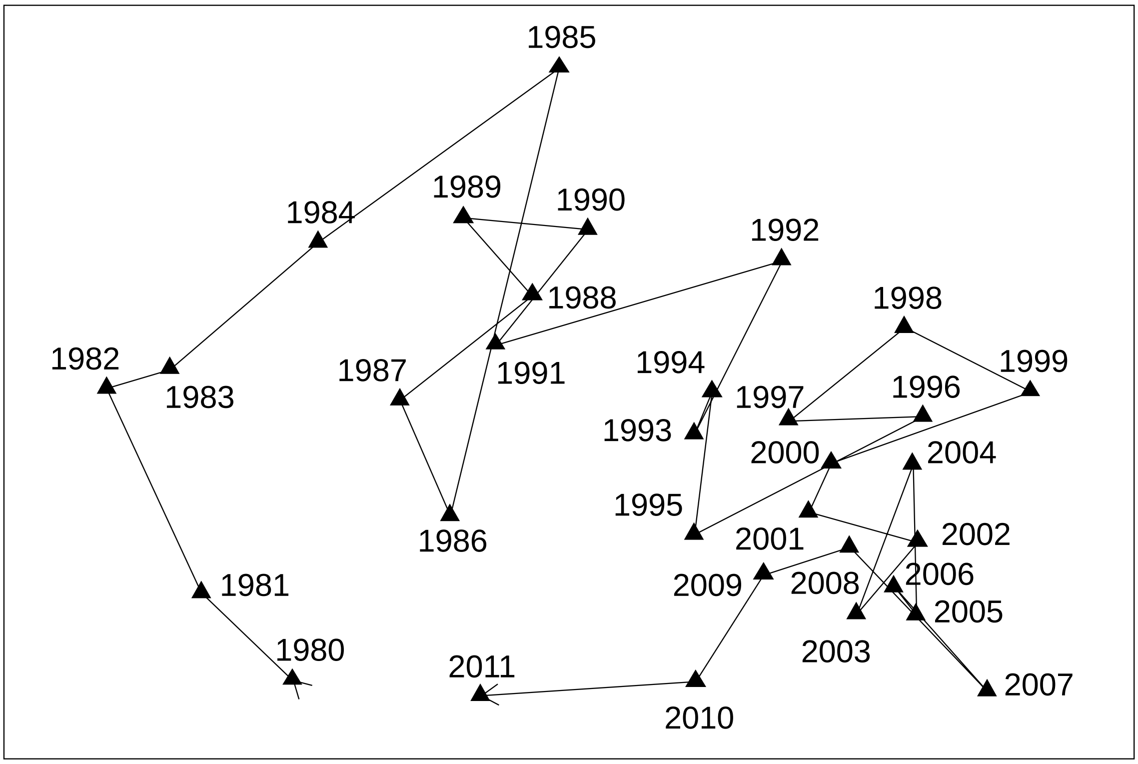

Figure 2.9. Multi-dimensional scaling (MDS) plot for SAUs showing similarity between years based on blacklip catch from Region A from 1980 to 2011. 2D stress = 0.15.

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

Drummond (Rank 1-1; 12.0% C_{02-11})

Drummond is the most important blacklip SAU in Region A. Catch decreased from a historic high in 1981 to substantially lower, but relatively stable catches between 1994 and 2005, whereafter it has increased. Between 2010 and 2011 catch increased by 74% to 66 t, a level similar to that recorded in the early 1980s; this represented 24% of the Region A blacklip catch in 2011 (Figure 2.10). CPUE generally increased from 1979 (57 kg.hr^{-1}) to the maximum in 2006 (88 kg.hr^{-1}). However, it has subsequently declined and, in 2011 (69 kg.hr^{-1}), was at the lowest level since 1996 and 8% below $CPUE_{90-09}$.

FI surveys at Drummond Point indicated that the proportion of large, legal-sized blacklip varied between years (range: 12-27%), with most size classes represented in all years (Figure 2.11). Density of legal-size and sub-legal-size blacklip have remained similar since surveys began in 2005, although observed densities were slightly higher in 2008 and 2009 (Figure 2.12).

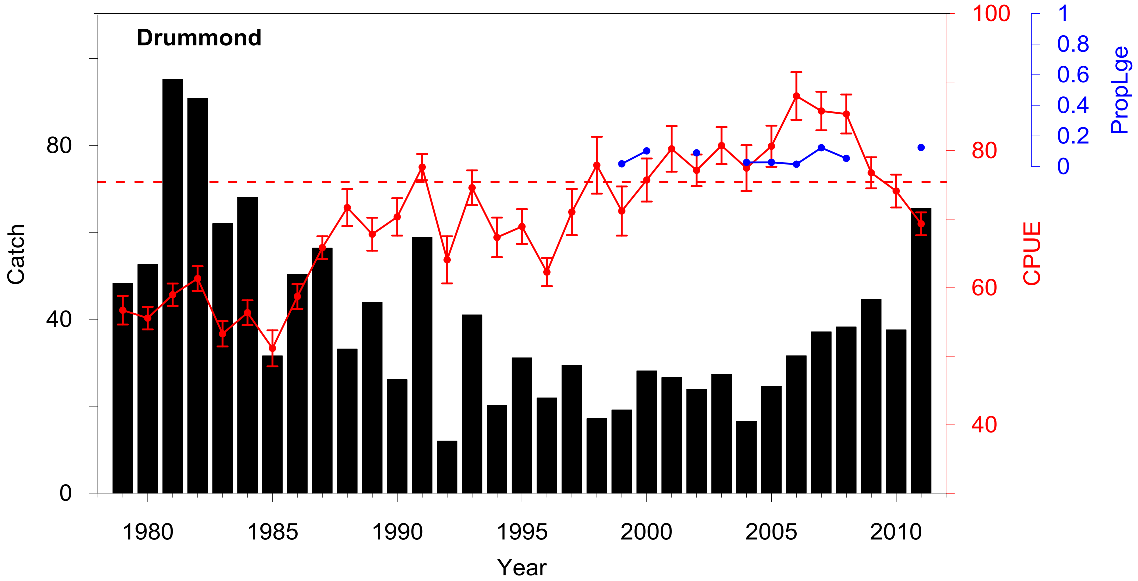

Figure 2.10. Catch (t, shell weight; black bars) of blacklip from Drummond from 1979 to 2011. CPUE ± se (kg.hr^{-1}) and PropLge are shown in red and blue, respectively. Red dashed line shows $CPUE_{90-09}$.

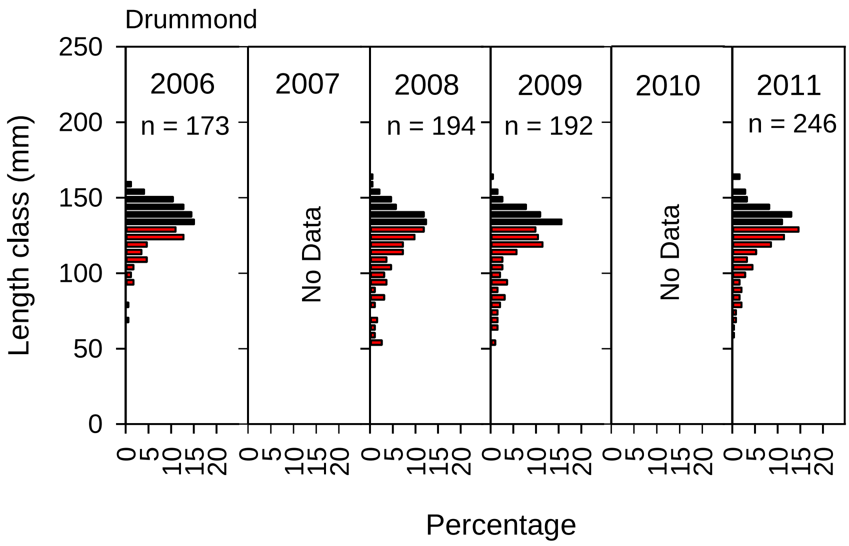

Figure 2.11. Length-frequency distributions of legal-sized (black bars) and sub-legal-sized (red bars) blacklip at Drummond (map-code 12B) observed on fishery-independent surveys from 2006 to 2011. Length classes represent the upper length of each 5 mm bin. n = number of blacklip measured. Bin classes < 50 mm pooled.

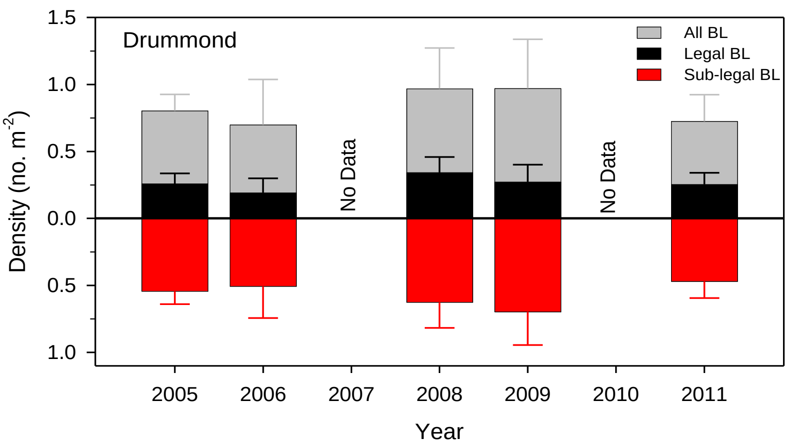

Figure 2.12. Mean ± se density (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) blacklip at Drummond (cross drops; map-code 12B) from 2005 to 2011.

Sheringa (Rank 2-2; 11.0% C_{02-11})

Although catches from Sheringa have oscillated among years, on an approximate six-year cycle, they halved from the high levels in the early 1980s to the mid 2000s, with reduced catch in 2005 and 2006 a consequence of industry agreeing with PIRSA to reduce the level of catch for this period (Figure 2.13). Since 2006, catches have increased and, in 2011 (45 t), was at the highest level since 1995, constituting 16% of the blacklip catch from Region A (Figure 2.13). With the exception of an anomalously high value in 2006, CPUE has remained relatively stable since 1990. However, it has decreased substantially between 2010 and 2011 (83 kg.hr^{-1}), to the lowest level since 1989, and was 8% below $CPUE_{90-09}$.

FI surveys at Sheringa indicated that the proportion of legal-sized blacklip varied considerably between 2005 and 2011 (range: 44-81%), with the largest size classes evident in all years (Figure 2.15). However, the density of legal-sized blacklip halved between 2008 and 2009, and remained low during 2011 (Figure 2.14). Similarly, the density of sub-legal-sized blacklip was lowest in 2009 and remained relatively low in 2011.

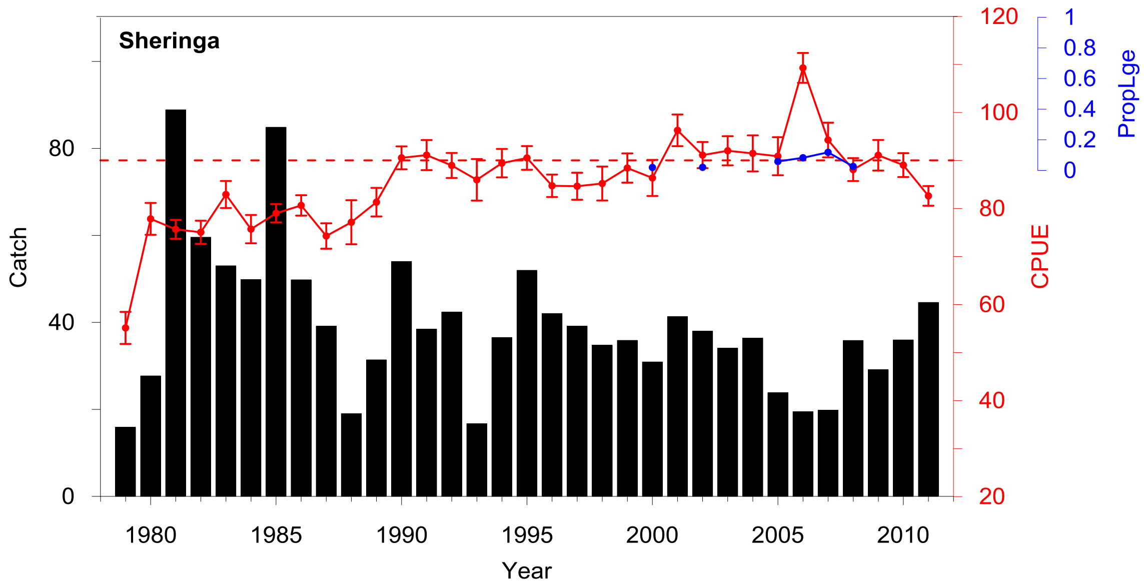

Figure 2.13. Catch (t, shell weight; black bars) of blacklip from Sheringa from 1979 to 2011. CPUE ± se (kg.hr^{-1}) and PropLge are shown in red and blue, respectively. Red dashed line shows $CPUE_{90-09}$.

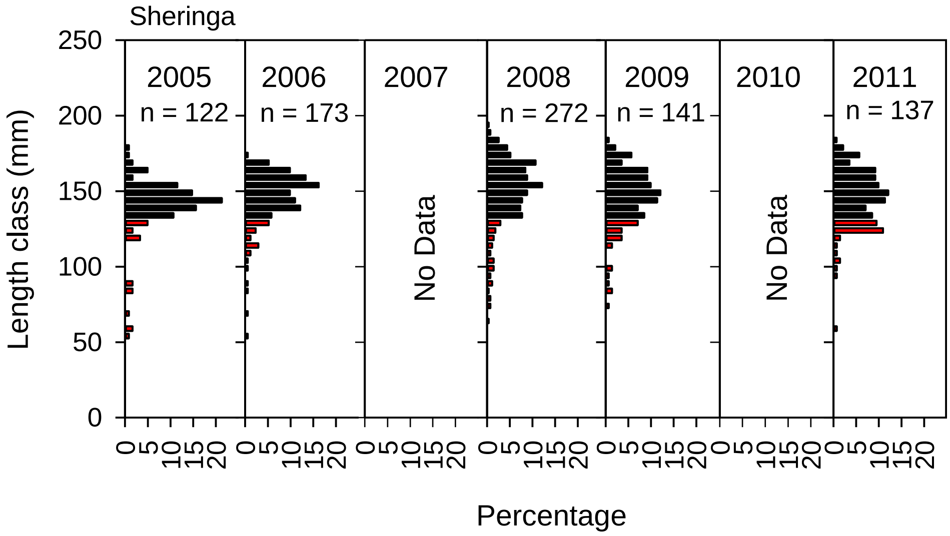

Figure 2.15. Length-frequency distributions of legal-sized (black bars) and sub-legal-sized (red bars) blacklip at Sheringa (map-code 11A) observed on fishery-independent surveys from 2005 to 2011. Length classes represent the upper length of each 5 mm bin. n = number of blacklip measured. Bin classes < 50 mm SL pooled.

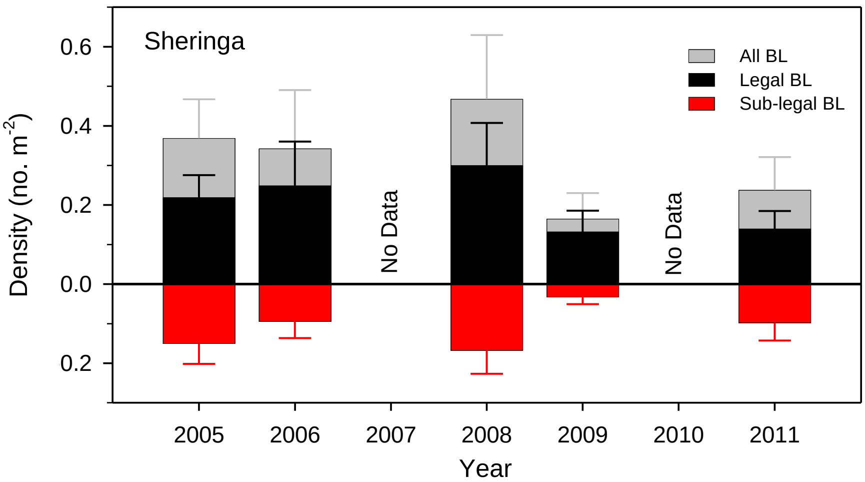

Figure 2.14. Mean ± se density (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) blacklip at Sheringa (cross drops; map-code 11A) from 2005 to 2011.

Point Westall (Rank 3-5; 7.5% $C_{02\text{-}11}$)

Following modest catches in the 1980s, annual catches from Point Westall have been relatively stable, varying between about 15 and 25 $t.yr^{-1}$ (Figure 2.16). While catch and CPUE fell consistently from recent peaks in 2006 (34 t and 90 $kg.hr^{-1}$, respectively), the downward trends were reversed in 2010. Between 2010 and 2011 CPUE increased to 76 $kg.hr^{-1}$ which was 11% above $CPUE_{90\text{-}09}$ and amongst the highest on record (Figure 2.16).

FI surveys at Granites indicated that the proportion of large, legal-sized blacklip has been relatively stable since 2005 (range: 17–25%; Figure 2.17). Similarly, good representation of sub-legal (Figure 2.17) and consistent densities of legal and sub-legal-sized blacklip since surveys began in 2005 (Figure 2.18) indicate overall blacklip abundance is stable.

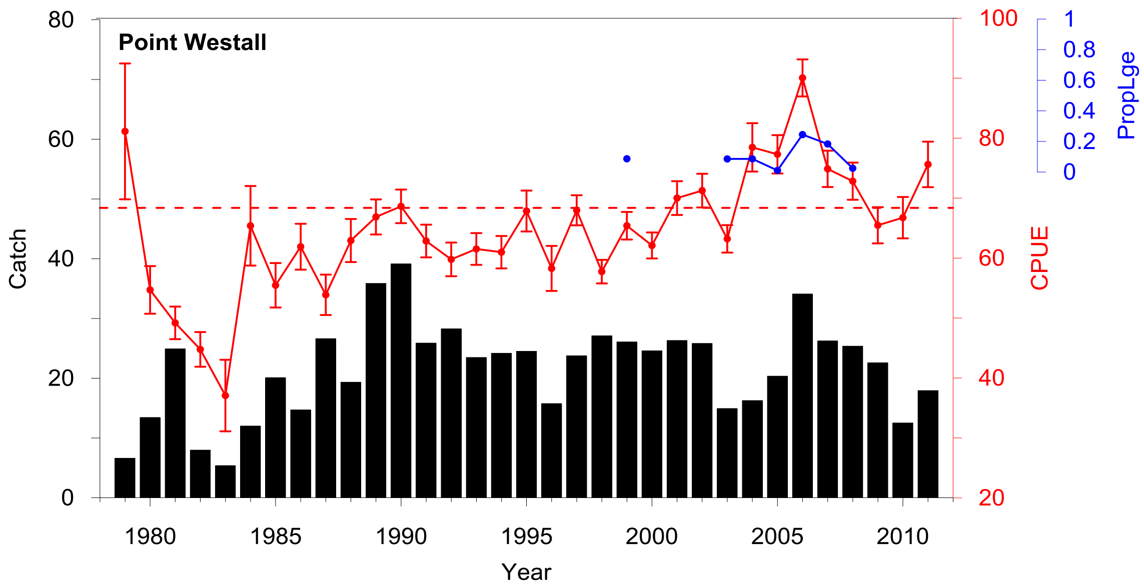

Figure 2.16. Catch (t, shell weight; black bars) of blacklip from Point Westall from 1979 to 2011. CPUE ± se ($kg.hr^{-1}$) and PropLge are shown in red and blue, respectively. Red dashed line shows $CPUE_{90\text{-}09}$.

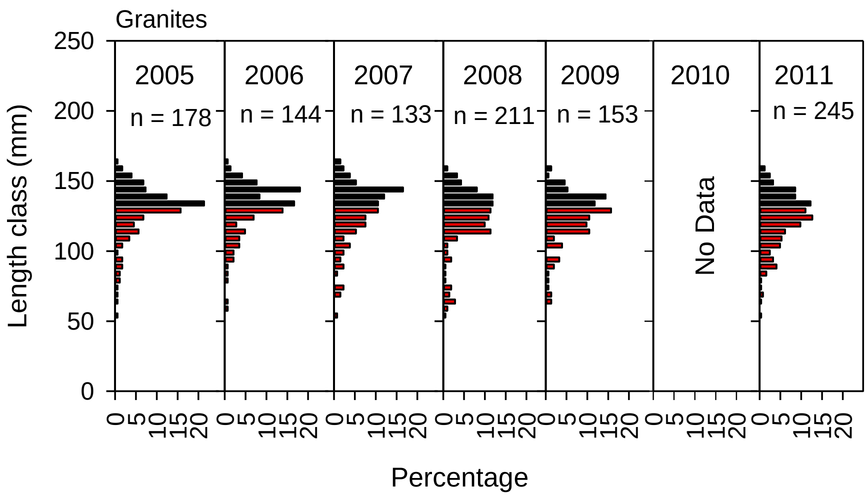

Figure 2.17. Length-frequency distributions of legal-sized (black bars) and sub-legal-sized (red bars) blacklip at Point Westall (Granites map-code 4B) observed on fishery-independent surveys from 2005 to 2011. Length classes represent the upper length of each 5 mm bin. n = number of blacklip measured. Bin classes < 50 mm SL pooled.

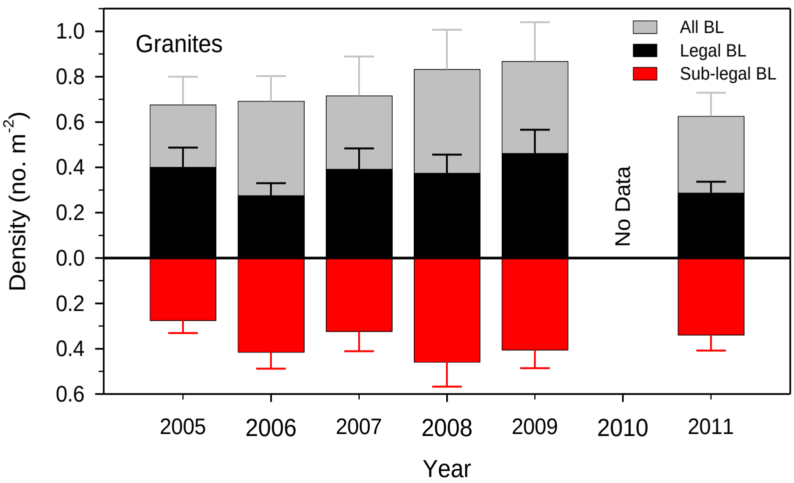

Figure 2.18. Mean ± se density (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) blacklip at Point Westall (cross drops; Granites map-code 4B) from 2005 to 2011.

Ward Island (Rank 4-10; 7.5% $C_{02\text{-}11}$)

Between 1979 and 1991, catch from Ward Island was less than 6 t. Following this, catch more than doubled, remaining stable at about 19 $t.yr^{-1}$ from 1993 to 2010 (Figure 2.19). However, in 2011, catch decreased by 56% to the lowest level since 1991 (8 t), and represented 3% of the blacklip catch from Region A. CPUE was relatively stable between 1992 and 2010, although substantially higher in 2003 and 2004. CPUE declined substantially between 2010 and 2011. In 2011, CPUE (61 $kg.hr^{-1}$) was 18% below $CPUE_{90\text{-}09}$, at the lowest level since 1989 and among the lowest on record for this SAU.

FI surveys at Ward Island indicated that the proportion of large, legal-sized blacklip varied between 48% and 62% prior to 2009 but, in 2011, decreased to 24%, with no blacklip >164 mm SL observed (Figure 2.20). Similarly, the density of legal-sized blacklip in 2011 was 30% lower than the mean density between 2005 and 2009 (Figure 2.21).

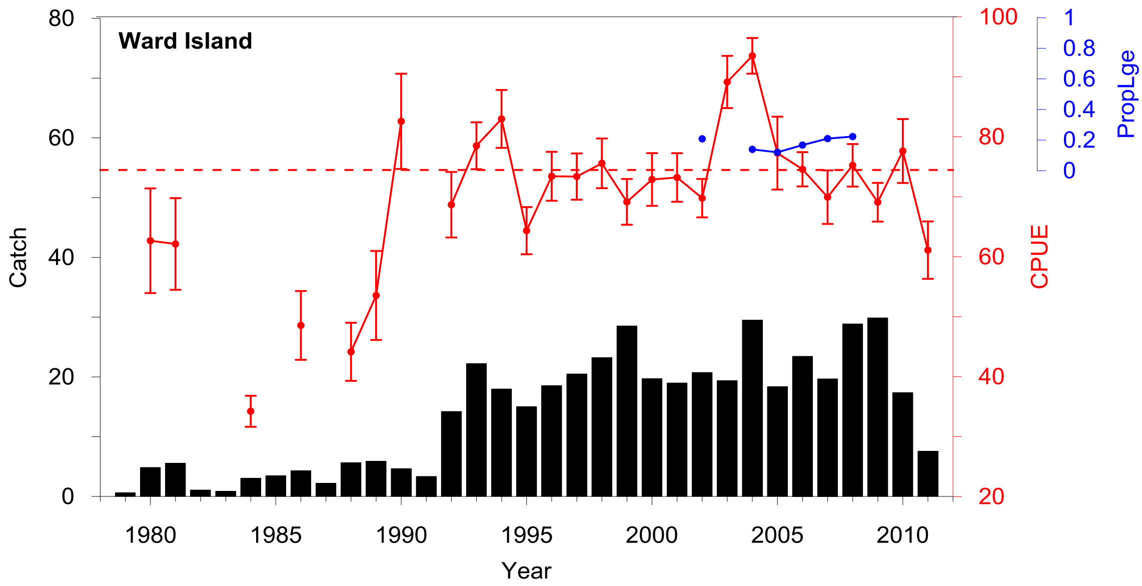

Figure 2.19. Catch (t, shell weight; black bars) of blacklip from Ward Island from 1979 to 2011. CPUE ± se ($kg.hr^{-1}$) and PropLge are shown in red and blue, respectively. Red dashed line shows $CPUE_{90\text{-}09}$.

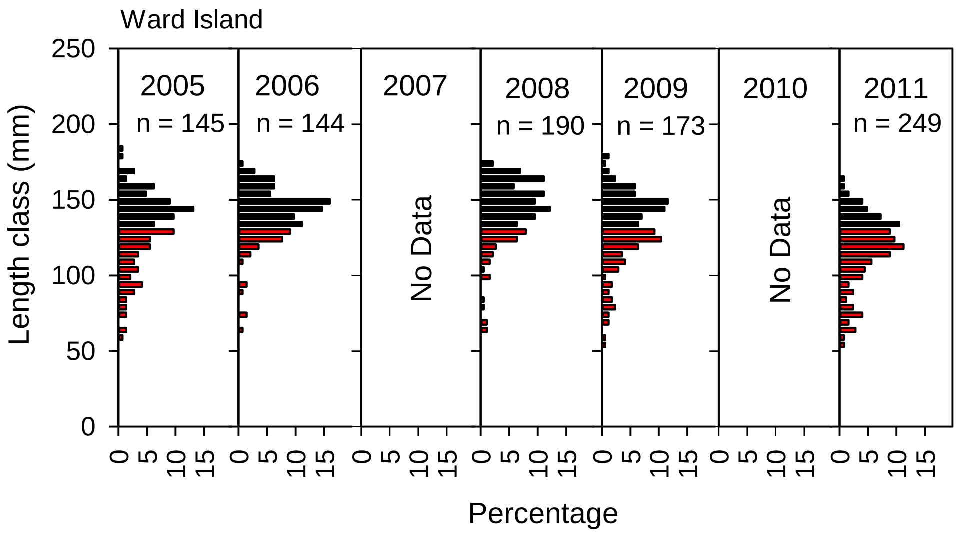

Figure 2.20. Length-frequency distributions of legal-sized (black bars) and sub-legal-sized (red bars) blacklip at Ward Island (map-code 9A) observed on fishery-independent surveys from 2005 to 2011. Length classes represent the upper length of each 5 mm bin. n = number of blacklip measured. Bin classes < 50 mm SL pooled.

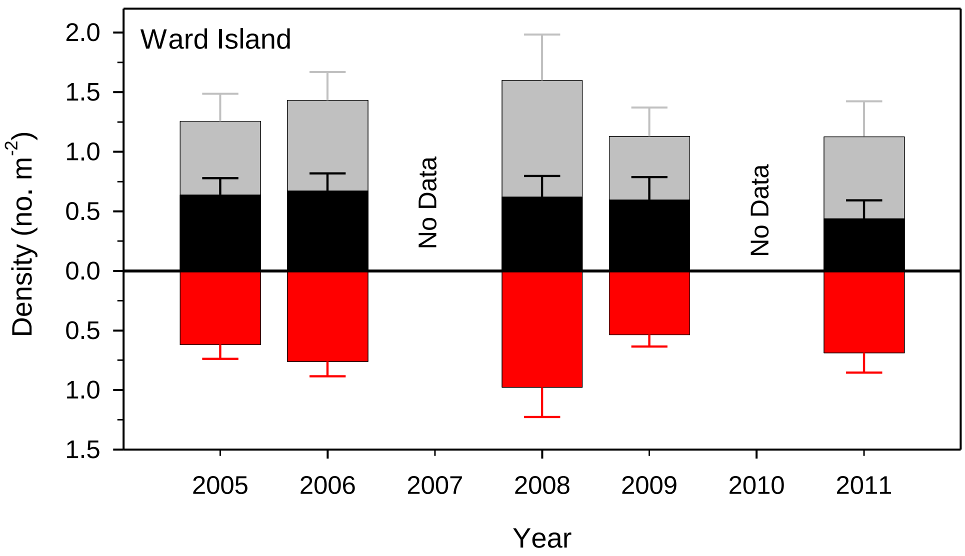

Figure 2.21. Mean ± se density (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) blacklip at Ward Island (cross drops; map-code 9A) from 2005 to 2011.

Avoid Bay (Rank 5-4; 7.1% C_{02-11})

Catch from Avoid Bay was relatively stable between 1979 and 2005, ranging between about 5 and 15 $t.yr^{-1}$ (Figure 2.22). Subsequent catches between 2006 and 2008 were substantially higher, whereafter they have remained at about 15 $t.yr^{-1}$. However, CPUE has declined substantially over recent years, from a recent maximum in 2007 and, in 2011 (56 $kg.hr^{-1}$), it was at the lowest level since 1999 and 14% below $CPUE_{90-09}$.

FI surveys at Black Rocks began in 2009 and indicate that the proportion of large, legal-sized blacklip has decreased from 44% in 2009 to 30% in 2011 and, whilst previously evident, in 2011 no blacklip >164 mm SL were observed (Figure 2.23). Similarly, density estimates of legal-sized blacklip have halved between 2009 and 2011 (Figure 2.24). In contrast, the density of sub-legal blacklip was relatively stable among years.

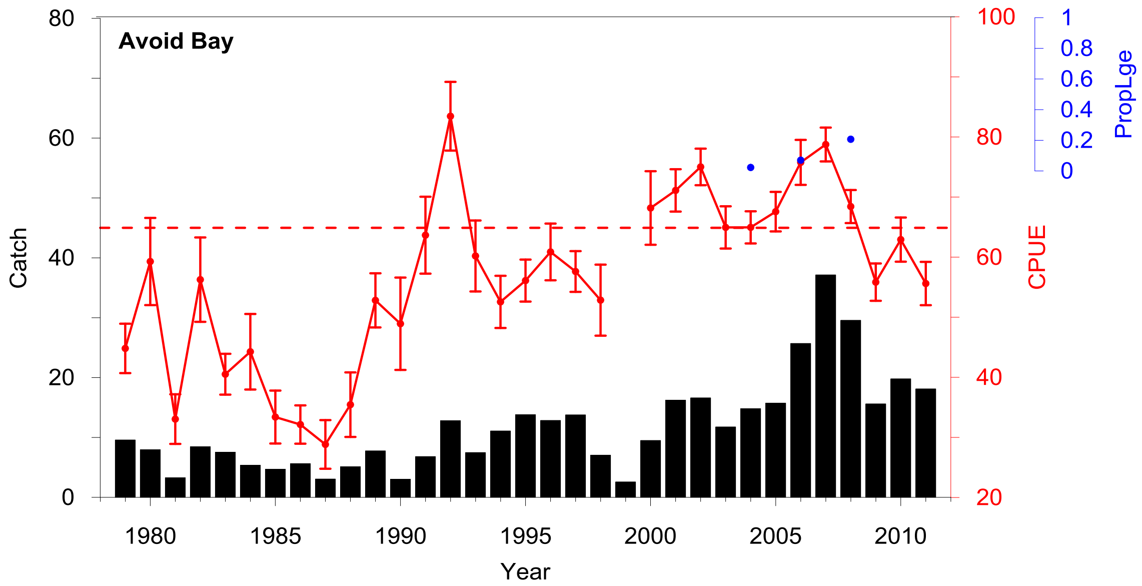

Figure 2.22. Catch (t, shell weight; black bars) of blacklip from Avoid Bay from 1979 to 2011. CPUE ± se ($kg.hr^{-1}$) and PropLge are shown in red and blue, respectively. Red dashed line shows $CPUE_{90-09}$.

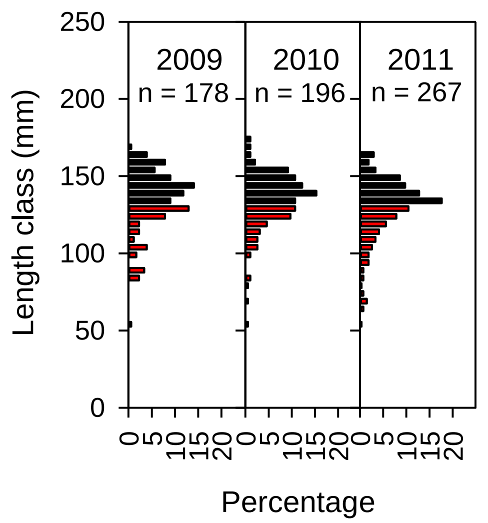

Figure 2.23. Length-frequency distributions of legal-sized (black bars) and sub-legal-sized (red bars) blacklip at Black Rocks (map-code 14D) observed on fishery-independent surveys from 2009 to 2011. Length classes represent the upper length of each 5 mm bin. n = number of blacklip measured. Bin classes < 50 mm SL pooled.

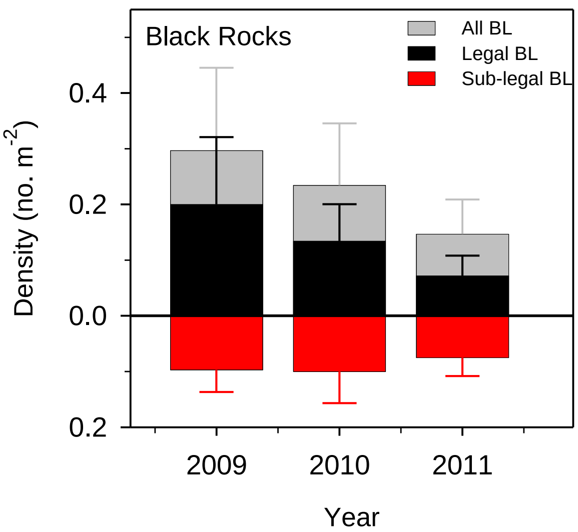

Figure 2.24. Mean ± se density (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) blacklip at Black Rocks (cross drops; map-code 14D) from 2009 to 2011.

Searcy Bay (Rank 6-6; 7.1% $C_{02\text{-}11}$)

Since 1981, annual catches from Searcy Bay have been relatively stable, ranging between about 15 and 25 $t.yr^{-1}$, with the exception of a substantial catch harvested from this SAU in 1985 (54 t; Figure 2.25). CPUE has fluctuated among years and, following a relatively low estimate in 2009, has increased to 4% above $CPUE_{90\text{-}09}$ in 2011. There are no FI surveys for this high importance SAU.

Venus Bay (Rank 7-9; 6.9% $C_{02\text{-}11}$)

Catch from Venus Bay increased considerably from 1979 to 1984, oscillated among years up to 2003, and has subsequently declined (Figure 2.25). In 2011, catch was amongst the lowest on record (12 t), representing 4% of the blacklip catch from Region A. CPUE was relatively stable between 1989 and 2002, following which it increased to a historic high in 2006. Between 2006 and 2007, there was a large (22%) decrease in CPUE, which has subsequently stabilised at approximately 8% below $CPUE_{90\text{-}09}$. In 2011 CPUE (68 $kg.hr^{-1}$) was at the lowest level since 1996 and 11% below $CPUE_{90\text{-}09}$. There are no FI survey data for this high-importance SAU.

Anxious Bay (Rank 8-7; 6.4% $C_{02\text{-}11}$)

With the exception of a high catch in 1984, annual catches from Anxious Bay have been relatively stable among years, ranging between about 10 and 25 $t.yr^{-1}$ (Figure 2.25). In 2011, the catch from this SAU was 16 t, about 30% below that harvested in 2010 (24 t). CPUE remained relatively stable between 1979 and 2000, whereafter it increased to a historic high in 2007. CPUE decreased rapidly between 2007 and 2010, to among the lowest level on record. In 2011, CPUE was similar to that in 2009 and equivalent to $CPUE_{90\text{-}09}$. There are no FI survey data for this high-importance SAU.

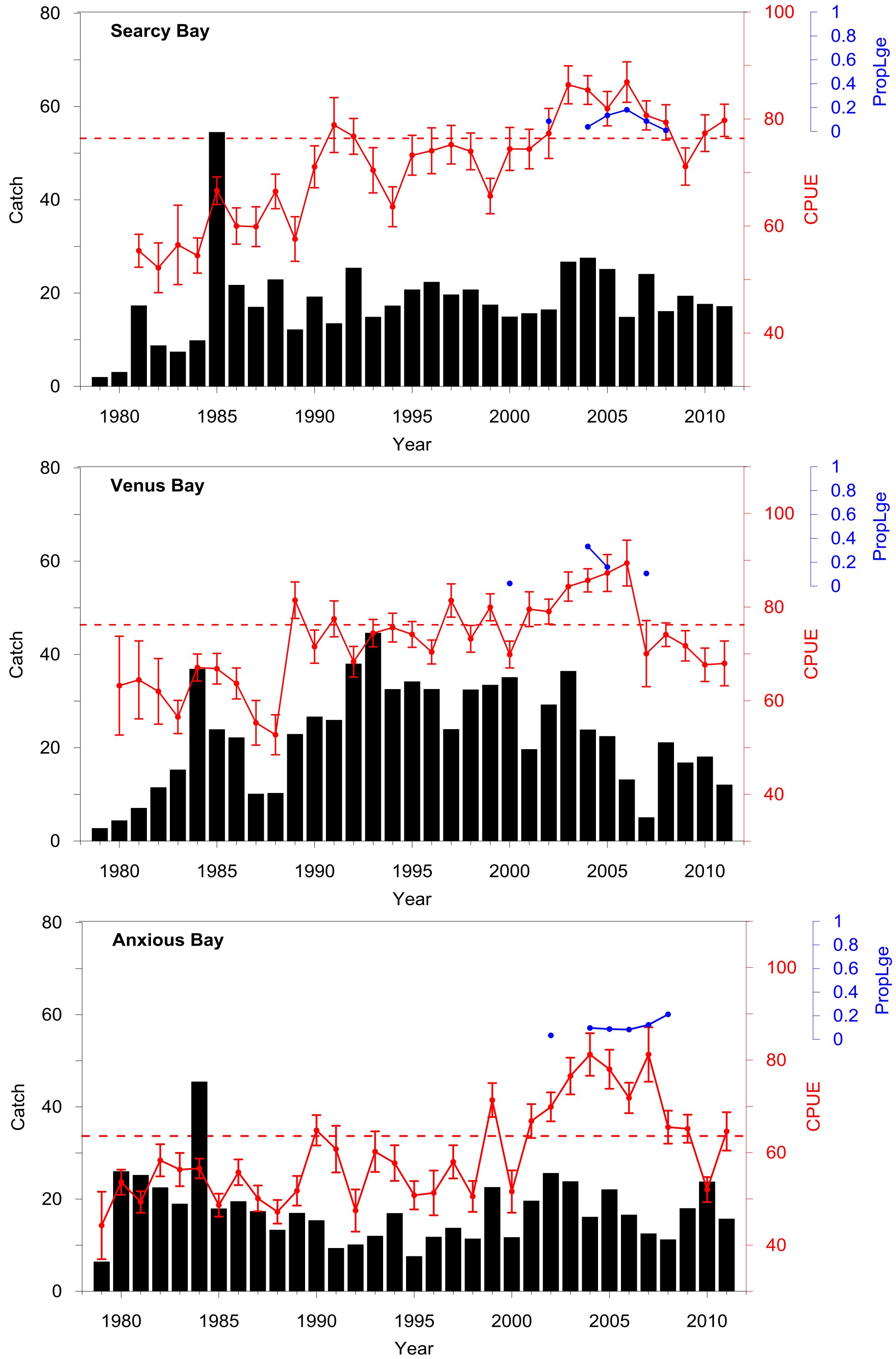

Figure 2.25. Catch (t, shell weight; black bars) of blacklip from SAUs Searcy Bay, Venus Bay and Anxious Bay from 1979 to 2011. CPUE ± se (kg.hr^{-1}) and PropLge are shown in red and blue, respectively. Red dashed line shows $CPUE_{90\text{-}09}$.

2.3.4.3. Temporal patterns in medium importance spatial assessment units

Hotspot (Rank 9-15; 6.3% $C_{02\text{-}11}$)

Annual catch from Hotspot was relatively low until 1996, whereafter it increased considerably and ranged from about 18 to 22 t.yr^{-1} between 1997 and 2009, with a historic high of 33 t in 2005. Catch has subsequently declined and, in 2011, was at the lowest level since 1991 (4 t), representing 1.5% of the blacklip catch from Region A (Figure 2.26). CPUE has fluctuated considerably among years but has generally declined since 2005. In 2011 (57 kg.hr^{-1}), it was 5% below $CPUE_{90\text{-}09}$.

The percentage of large, legal-sized blacklip observed on FI surveys at Hotspot decreased from a range of 24%-41% between 2005 and 2008 to 12% in 2009 (Figure 2.27). Data in 2011 were too limited for interpretation. Densities of legal-sized blacklip decreased considerably from 2006 to 2008 and have remained low during subsequent surveys in 2009 and 2011 (Figure 2.28), suggesting high exploitation rates. The density of sub-legal-sized blacklip remained relatively stable between 2005 and 2009 but, in 2011, declined to the lowest level recorded since surveys began.

Reef Head (Rank 10-3; 5.7% $C_{02\text{-}11}$)

Annual catch from Reef Head generally declined between 1983 and 2009. Catches in 2010 and 2011 were substantially greater and similar to those harvested from this SAU in the early 1980s (Figure 2.26). However, CPUE has declined from the maximum level in 2005 and, in 2011, was at the lowest level since 1997, amongst the lowest on record (51 kg.hr^{-1}) and 15% below $CPUE_{90\text{-}09}$.

Point Avoid (Rank 11-8; 3.7% C02-11)

Annual catches from Point Avoid have been relatively stable since 1980, although those in 2009, 2010 and 2011 were relatively high (13 – 16 t.yr^{-1}; Figure 2.29). In 2011, the catch equated to 5% of the blacklip catch for Region A. CPUE has fluctuated considerably among years, but gradually increased to 2006. However, over the last decade it has declined from historical peaks observed in 2003 and 2006. In 2011, CPUE was at the lowest level since 1999 and 18% below $CPUE_{90\text{-}09}$.

Baird Bay (Rank 12-19; 3.3% $C_{02\text{-}11}$)

Catches from Baird Bay were stable at about 10 t.yr^{-1} between 1982 and 2005, whereafter they have declined progressively. In 2011, the catch from this SAU was at the lowest level since 1981 (2 t) and represented <1% of the blacklip catch for Region A (Figure 2.29). CPUE has varied considerably among years; due to limited data, it was not estimable in 2011.

Flinders Island (Rank 13-11; 3.2% C_{02-11})

Annual catch from Flinders Island increased gradually between 1980 and 2001, whereafter it has declined. In 2011, the catch from this SAU was among the lowest on record (5 t; Figure 2.29). CPUE was relatively low between 1991 and 2000 and high from 2001 to 2011. In 2011, CPUE was similar to $CPUE_{90-09}$.

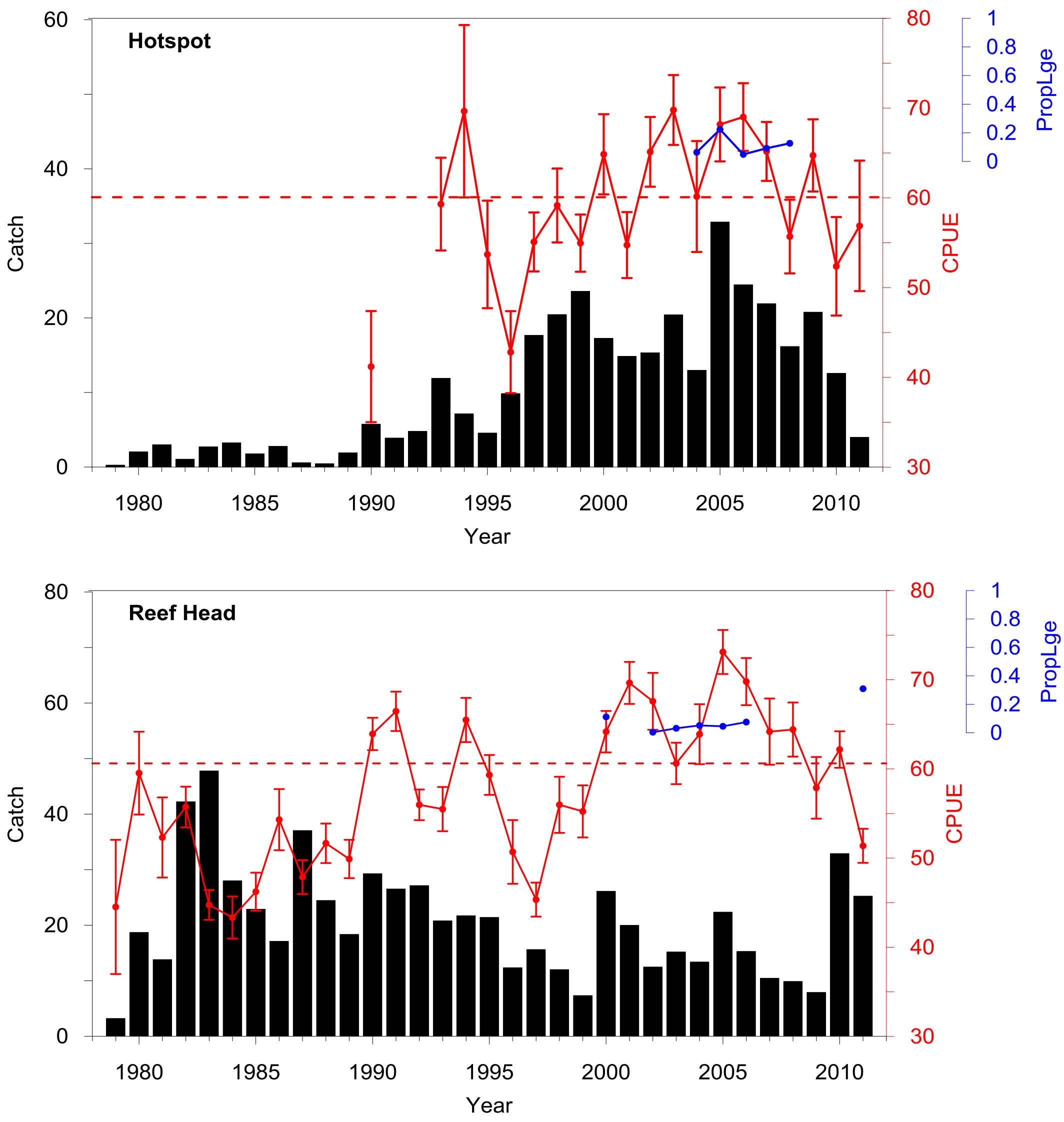

Figure 2.26. Catch (t, shell weight; black bars) of blacklip from SAUs Hotspot and Reef Head from 1979 to 2011. CPUE ± se (kg.hr^{-1}) and PropLge are shown in red and blue, respectively. Red dashed line shows $CPUE_{90-09}$.

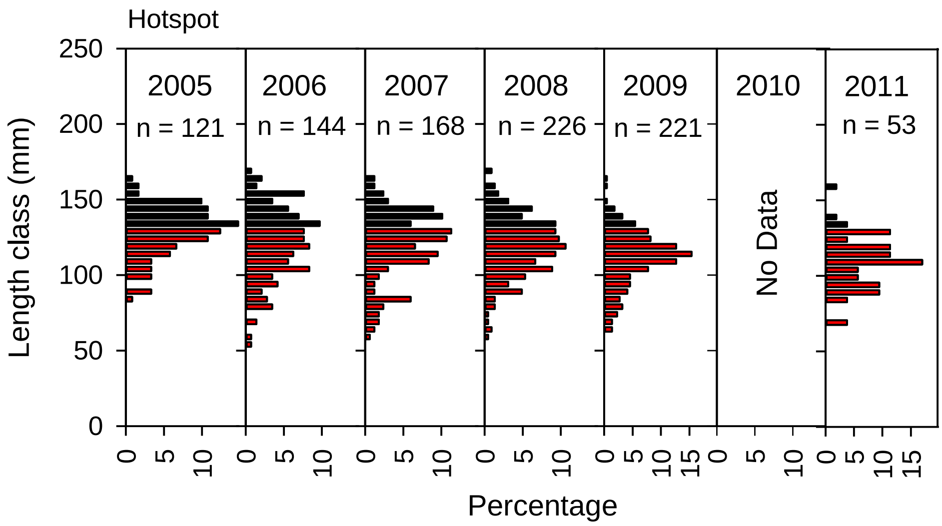

Figure 2.27. Length-frequency distributions of legal-sized (black bars) and sub-legal-sized (red bars) blacklip at Hotspot (map-code 9D) observed on fishery-independent surveys from 2005 to 2011. Length classes represent the upper length of each 5 mm bin. n = number of blacklip measured. Bin classes < 50 mm SL pooled.

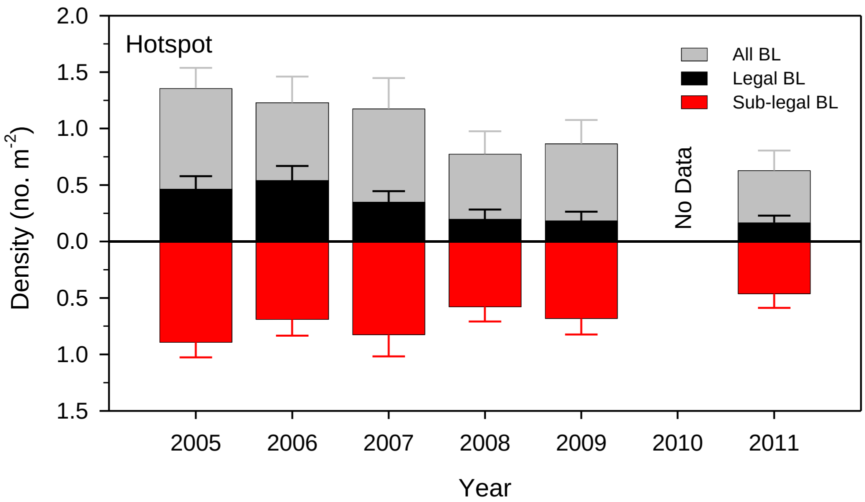

Figure 2.28. Mean ± se density (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) blacklip at Hotspot (cross drops; map-code 9D) from 2005 to 2011.

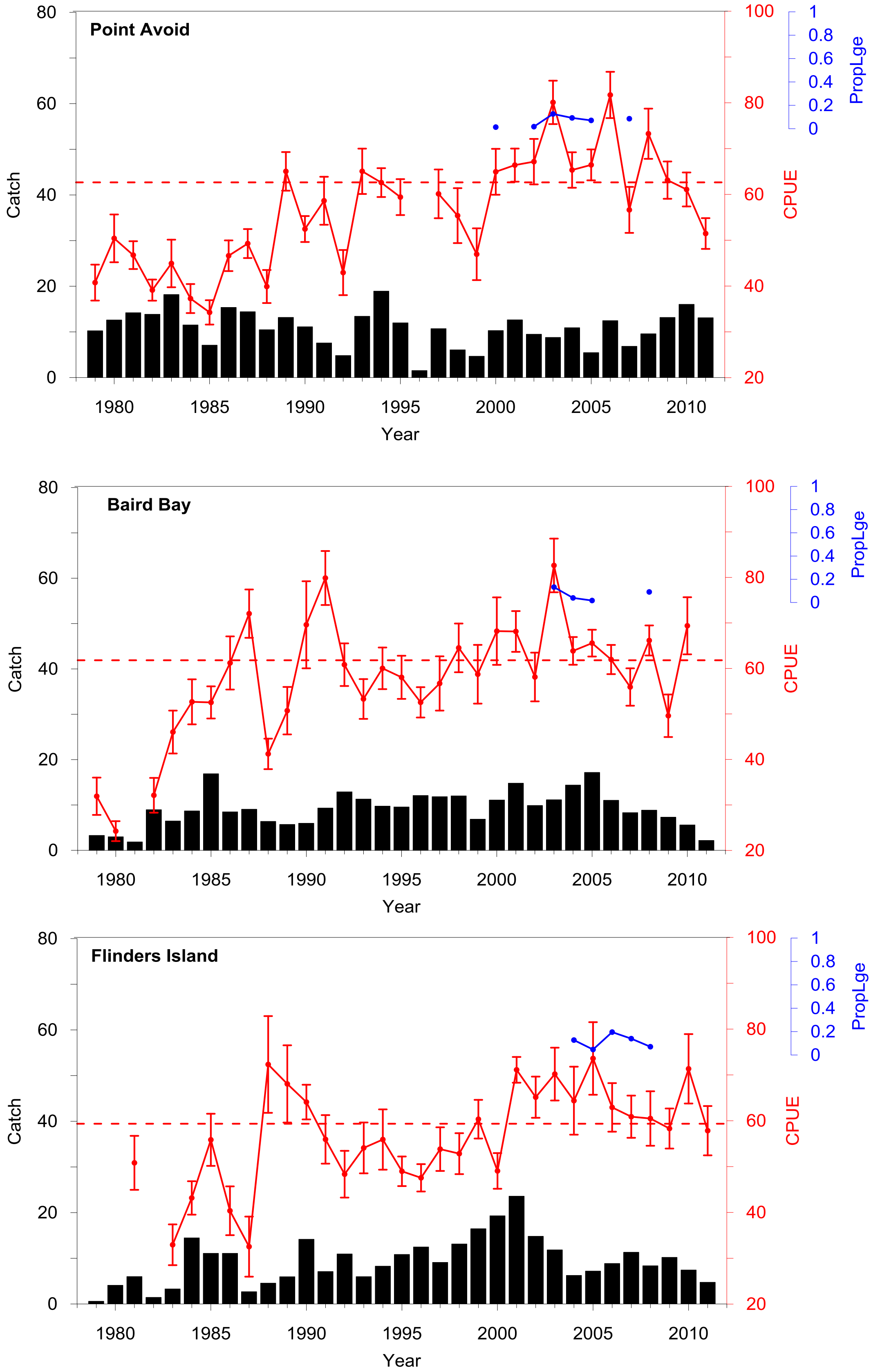

Figure 2.29. Catch (t, shell weight; black bars) of blacklip from SAUs Point Avoid, Baird Bay and Flinders Island from 1979 to 2011. CPUE ± se ($kg.hr^{-1}$) and PropLge are shown in red and blue, respectively. Red dashed line shows $CPUE_{90\text{-}09}$.

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

There were eight high and five medium importance SAUs for blacklip, with all remaining SAUs being of low importance (Table 2.1, Appendix A3.1–A3.13). It was possible to determine the risk of being overfished for 12 (92%) of these 13 SAUs.The inability to estimate CPUE on blacklip in Baird Bay in 2011, due to insufficient data (see Table 1.3), resulted in the blacklip stocks in this SAU being categorised as uncertain (Table 2.1; Appendix A3.9).

Summed PI scores of the risk that stocks in SAUs were overfished ranged between -9 (Ward Island and Venus Bay) and +5 (Drummond; Table 2.1). Three of the eight high-importance SAUs (Avoid Bay, Searcy Bay and Anxious Bay) were assigned to a green, three (Point Westall, Ward Island and Venus Bay) to a red, one (Sheringa) to a yellow and one to a blue (Drummond) risk-of-overfishing, colour-coded category (Table 2.1; Appendix 3). The medium importance SAUs were similarly distributed among risk-of-overfishing categories: one green (Hotspot), one yellow (Flinders Island) and two blue (Reef Head and Point Avoid). The catch-weighted, zonal score was -0.083, defining a zonal stock status for blacklip in Region A of sustainably fished (Table 2.1).

Table 2.1. Outcome from application of the harvest strategy described in the Management Plan for the SAAF against the blacklip fishery in Region A of the Western Zone. Grey shading identifies the performance indicators and their respective scores. ND indicates no data.

Spatial assessment unit	%Contribution to mean total catch (WZ) over last 10 years (2002-2011)	Importance	%Contribution to catch from high & medium SAU in 2011	CPUE	%TACC	PropLge	Pre-recruit Density	Legal Density	Mortality	Combined PI score	Risk of overfishing	Catch-weighted contribution to zonal score
Drummond	6.4	High	26.7	-1	6	2	-2	-1	1	5	1	0.27
Sheringa	5.8	High	18.1	-2	1	0	0	-2	-1	-4	-1	-0.18
Point Westall	4.0	High	7.3	1	-4	0	-2	-1	0	-6	-2	-0.15
Ward Island	4.0	High	3.1	-2	-2	0	0	-3	-2	-9	-2	-0.06
Avoid Bay	3.8	High	7.4	-1	2	0	ND	ND	ND	1	0	0.00
Searcy Bay	3.8	High	7.0	1	0	0	ND	ND	ND	1	0	0.00
Venus Bay	3.6	High	4.9	-4	-5	0	ND	ND	ND	-9	-2	-0.10
Anxious Bay	3.4	High	6.4	0	0	0	ND	ND	ND	0	0	0.00
Hotspot	3.3	Medium	1.6	0	-2	0	-	-	-	-2	0	0.00
Reef Head	3.0	Medium	10.3	-2	4	2	-	-	-	4	1	0.10
Point Avoid	2.0	Medium	5.3	-2	5	0	-	-	-	3	1	0.05
Baird Bay	1.8	Medium	-	ND	-6	0	-	-	-	Uncertain	Not assigned	-
Flinders Island	1.7	Medium	1.9	0	-3	0	-	-	-	-3	-1	-0.02
The Gap	1.1	Low		-	-	-	-	-	-	-	Not assessed	
Cape Bauer	0.9	Low		-	-	-	-	-	-	-	Not assessed	
Fishery Bay	0.8	Low		-	-	-	-	-	-	-	Not assessed	
Coffin Bay	0.8	Low		-	-	-	-	-	-	-	Not assessed	
Unassigned WZ RG A	0.8	Low		-	-	-	-	-	-	-	Not assessed	
Cape Catastrophe	0.5	Low		-	-	-	-	-	-	-	Not assessed	
Elliston Cliffs	0.4	Low		-	-	-	-	-	-	-	Not assessed	
Waterloo Bay	0.4	Low		-	-	-	-	-	-	-	Not assessed	
Memory Cove	0.3	Low		-	-	-	-	-	-	-	Not assessed	
SW Thistle	0.2	Low		-	-	-	-	-	-	-	Not assessed	
NE Thistle	0.1	Low		-	-	-	-	-	-	-	Not assessed	
Taylor Island	0.1	Low		-	-	-	-	-	-	-	Not assessed	
Neptune Islands	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Wedge Island	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Greenly Island	NA	Low		-	-	-	-	-	-	-	Not assessed	
Sir Joseph Banks	NA	Low		-	-	-	-	-	-	-	Not assessed	
Pearson Island	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Sum	**53.1**		**100.0**									**-0.083**

2.5. Discussion

Blacklip comprises 57% (276 $t.yr^{-1}$) of the combined abalone TACC (*i.e.* blacklip and greenlip) in Region A. Total annual catch has been relatively stable since 1989, but was 6% lower from 2010 when the TACC was reduced following concern for the stock.

Stock assessments for this species are robust because they use both FD (notably catch, effort, and CPUE) and FI information (survey measures of population size-frequency and density). In addition, application of the harvest strategy to determine stock status was based on 13 SAUs distributed throughout the fishery, thus better representing the fished stocks when compared with that elsewhere (e.g. Central Zone blacklip fishery; Chick and Mayfield 2012). However, there are several limitations to this assessment. For example, there was a short time series over which the blacklip FI surveys have been undertaken. In addition, data on the length structure of the commercial catch, which can provide critical information to aid stock assessment, (Burch *et al.* 2011) were limited. This directly influenced the scoring of one of the six PIs for this fishery.

Previous reports presented CPUE data as evidence that the abundance of legal-sized blacklip increased rapidly between 2000 and 2006 (Chick *et al.* 2006; 2008) then declined sharply from 2006 to 2009 (Chick *et al.* 2009). These recent, spatially-consistent, rapid increases and decreases in CPUE between the early 2000s and the present are most likely the result of a widespread, strong recruitment pulse in the mid 1990s that elevated the abundance of legal-sized blacklip 6-10 years later (Stobart *et al.* (2011). Similar trends were also evident during the same period on greenlip in the WZ (see Section 3) and the Central Zone of the SAAF (Mayfield *et al.* 2010). While there are no FI survey data to support this hypothesis for blacklip, long-term FI data for greenlip provided in Section 3 provides some evidence of elevated recruitment in the mid-late 1990s.

Data presented in this report suggest that the rapid reductions in blacklip abundance observed between 2006 and 2009 in Region A have almost stopped because the CPUEs in 2009, 2010 and 2011 were similar. This relative index of blacklip abalone abundance also suggests that densities of legal-sized blacklip in 2011 may be similar to those in the late 1990s because, despite $CPUE_{90\text{-}09}$ being positively biased by the high catch rates in the mid 2000s, the CPUE since 2009 has been within 5% of this performance measure. These conclusions are based on two key assumptions. The first is that relationships between relative blacklip abundance and CPUE have remained unchanged over the last two decades, and not been influenced by factors such as increases in effective fishing effort (e.g. effort creep). The second is that the recent declines and subsequent stabilisation in CPUE are proportional to those of the blacklip stocks. This latter assumption is more tenuous because catch rates in dive fisheries can be hyperstable, as a result of divers targeting remnant aggregations (Shepherd and Rodda 2001; Dowling *et al.* 2004). For greenlip, there is some evidence that catch rates are decreasing at a slower rate than legal-sized biomass in both Region A of the WZ (see Section 3) and in the CZ (Chick and Mayfield 2012) .This indicates that catch rates on greenlip in these two fisheries exhibit hyperstability. If catch rates on blacklip in the WZ also exhibit hyperstability, declines in CPUE will lag those of the harvested stocks. Consequently, the reductions in harvestable biomass may be underestimated and the abundance of legal-sized blacklip in 2011 lower than that in the late 1990s.

However, there is increasing evidence that the recent stabilisation of harvestable biomass, reflected by CPUE across Region A, may not continue and, consequently, that the harvestable biomass of blacklip in key fishing grounds may decline in coming years unless catches can be re-distributed and maintained away from these areas. The evidence supporting this assertion includes (1) recent, substantial changes in the spatial distribution of the blacklip catch among the available fishing areas and SAUs; and (2) reductions in CPUE and estimates of density from FI surveys in key fishing grounds. This contrasts with the harvest strategy, which categorised the stock status of this fishery as sustainably fished.

Blacklip catches have generally been obtained from throughout Region A. However, since 2009 there have been substantial changes in the spatial distribution of catch among available FAs and SAUs. This was clearly evidenced by the MDS plots for catches at both of these spatial scales which indicate that the fishery has transitioned from a decade of relative stability between 2000 and 2009. For the FAs, these changes were driven by substantial reductions in catch from FA 9 and increases from FAs 12 and 13. These patterns were also clearly evident for the SAUs. Thus, catches from each of the three SAUs within FA 9 – Ward Island, Flinders Island and Hotspot – in 2011 were among the lowest on record and, collectively, >70% below that in 2009. This is in direct contrast with the substantial increases in catches from Drummond, Sheringa and Reef Head.

Analyses of catch using methods such as MDS provide valuable information on its variation among fishing areas, and through time. However, interpreting changes in the distribution of catch is complicated because fishers move among populations for reasons other than changes in abundance. These include diver preference and habit, convenience, market demands for particular product types (e.g. larger or smaller abalone), access to launching sites, changes in diver demographics, rotation of fishing grounds by divers and/or to maintain or increase expected catch rates. Nevertheless, the most likely explanation for the recent changes in the spatial distribution of catch is divers favouring fishing grounds in FAs 11, 12, 13 and 14 over those in FA 9 due to declining blacklip abundance in the Ward Island and Hotspot SAUs. This is because there is substantial evidence that the harvestable biomass of blacklip in these SAUs has declined. For example (1) current catches from both these SAUs are among the lowest on record; (2) in 2011, CPUE in the Ward Island and Hotspot SAUs was 18% and 5% below $CPUE_{90\text{-}09}$, respectively; (3) FI surveys at Hotspot show the density of legal-sized and sub-legal-sized blacklip have declined since 2006 and 2009, respectively; and (4) the proportion of large, legal-sized blacklip observed on FI surveys have decreased substantially in both SAUs.

For Ward Island, this conclusion that the harvestable biomass has declined was consistent with the outcome from applying the harvest strategy, which was a 'red' risk-of-overfishing category. This indicates that there is a high probability that the stocks in this SAU are overfished. Application of the harvest-decision rules to a 'red' risk-of-overfishing category specifies a minimum 30% reduction in the catch contribution from this SAU to the TACC, based on the mean catch over the last four years (i.e. 2008-2011). If this decision rule was implemented, the catch contribution from the Ward Island SAU to the blacklip TACC for Region A would be reduced by >6 t to 15 t. However, as the CPUE on blacklip in this SAU in 2011 was among the lowest on record, a reduction of >30% may be warranted. For Hotspot, the outcome from the weight-of-evidence assessment contrasted with that of the harvest strategy which placed blacklip in the Hotspot SAU into a ‘green’ risk-of-overfishing category. This difference arises from the inclusion of FI survey data (density and proportion of large, legal-sized blacklip in the population) into the weight-of-evidence assessment, which was not included in the harvest strategy because blacklip in the Hotspot SAU was of medium importance in 2011. Whilst the decision rules permit an increase of up to 10% in the catch contribution from this SAU to the TACC, there is little evidence to support this decision. Rather, most of the evidence would suggest a decrease in the catch contribution from this SAU to the TACC may be more appropriate.

In response to declining catches from the SAUs in FA 9, catches from the Drummond, Sheringa and Reef Head SAUs have increased substantially, whilst that from Point Avoid rose modestly. Much of the evidence available for these four SAUs suggests that the current higher catches are not sustainable. For example, there was no evidence in these SAUs that the rate of decline in CPUE since the mid 2000s was decreasing. Thus, the CPUE in 2011 in each of these SAUs was substantially below that in 2010 and 8%, 8%, 15% and 18% below $CPUE_{90-09}$ in the Drummond, Sheringa, Reef Head and Point Avoid SAUs, respectively. In addition, at Sheringa, the density of legal-sized blacklip observed on FI surveys halved between 2008 and 2009 and has remained low thereafter.

These outcomes contrast with those from applying the harvest strategy to the blacklip stocks in the Drummond, Reef Head and Point Avoid SAUs ('dark blue' risk-of-overfishing category). For these SAUs, their 'dark blue' risk-of-overfishing category score was most strongly influenced by the PI value for catch as a percentage of the TACC. For the Drummond and Reef Head SAUs, the total score was also elevated by PropLge, which was based on limited, and likely unrepresentative, sampling. Application of the harvest strategy decision rules to SAUs with 'dark blue' risk-of-overfishing category permits an increase in their catch contribution to the TACC of up to 30% of their mean catch over the last four years. Given CPUE was below $CPUE_{90-09}$ and declining, an increased catch contribution to the TACC from these SAUs would be difficult to support. For Sheringa, the weight-of-evidence assessment was consistent with the outcome of the harvest strategy – a 'yellow' risk-of-overfishing category – for which the specified decrease in contribution from this SAU to the TACC of >10% appears justified. This was also the case for Venus Bay, which was assigned a 'red' risk-of-overfishing category, for which a minimum 30% reduction in contribution to Region A's blacklip TACC is defensible. A 'green' risk-of-overfishing category was assigned to Avoid Bay despite (1) CPUE in 2011 being at the lowest level since 1999 and 14% below $CPUE_{90-09}$.; (2) the proportion of large, legal-sized blacklip observed on FI surveys decreasing substantially between 2010 and 2011; and (3) the legal-sized density declining by >50% since surveys began in 2009. The decision rules permit between a 10% increase to a 10% decrease in the catch contribution from this SAU to the TACC, with most of the data suggesting the latter may be more appropriate.

In contrast, there are three SAUs from which it may be possible to harvest additional catches because current catches are low in a historical context and/or CPUEs remain substantially above $CPUE_{90-09}$. These are the Searcy Bay, Point Westall and Baird Bay SAUs. For the Searcy Bay SAU, this was consistent with the outcome of the harvest strategy which was a 'green' risk-of-overfishing category. However, for the Point Westall SAU this conflicts with its 'red' risk-of-overfishing category. This category was assigned because current catches are low in a historical context – most likely because of diver preference, rather than reduced stock abundance – and FI estimates of pre-recruit densities were low in 2011. For the Baird Bay SAU, lack of data prevented allocation of a risk-of-overfishing category. Nevertheless, the CPUE in this SAU in 2010 was above $CPUE_{90-09}$.

In summary, the blacklip stocks in Region A appear to have benefitted from a zone-wide recruitment event that increased blacklip abundance above historical levels for approximately eight years from 2001 to 2008. Current stock levels exhibit apparent stability across Region A and may be similar to, or below, that prior to the recruitment pulse (i.e. 1990–1999), depending on the extent to which CPUE is hyperstable. Thus, overall, the weight-of-evidence assessment was consistent with application of the harvest strategy to determine stock status – based on 13 SAUs – which categorised the Region A blacklip fishery as sustainably fished. However, there is evidence that the harvestable biomass of blacklip in several key fishing grounds may decline unless current catches from these areas are reduced in coming years. Importantly, the redistribution of catches must be undertaken without overfishing blacklip stocks in other SAUs. The evidence supporting declining harvestable biomass in some important SAUs includes the substantial re-distribution of catch out of FA 9 into other traditional blacklip fishing grounds (notably the Sheringa, Drummond and Reef Head SAUs, but also the Point Avoid SAU) that contributed >50% of the blacklip catch in 2011 and, on the basis of low and declining CPUE and FI survey density estimates, do not appear capable of continuing to support these elevated catch levels.

3. GREENLIP

3.1. Introduction

This section of the report provides an analysis of the fishery-dependent and fishery-independent data for greenlip in the WZ from 1 January 1968 to 31 December 2011. It also includes a formal analysis of the fishery's performance and stock status based on the harvest strategy described in the Management Plan for the fishery (PIRSA 2012), which determines the (1) risk that greenlip stocks in the high and medium importance SAUs are overfished and (2) zonal stock status for greenlip. In the discussion we assess the current status of the greenlip stocks in Region A comparing the harvest strategy and traditional weight-of-evidence assessments.

3.2. Methods

Commercial catch and effort data have been collected since 1968 in the form of daily entries to commercial logbooks submitted to SARDI, allowing spatial and temporal analyses of catch, effort and CPUE. Weight-grade data were provided by Western Zone abalone processors. Whilst these do not replace the length-structure information, the proportion of Grade 1 greenlip in the catch (i.e. ≥230 g; PropG1) is a suitable measure to aid the greenlip stock assessment (Mayfield *et al.* 2009; Mayfield 2010). Greenlip abundance and population size structure were obtained from SARDI FI surveys which, in recent years, have been undertaken bi-annually as part of an overall rationalisation of the research program.

Fishery statistics in this report are provided at three spatial scales. These are (1) the whole of Region A, (2) individual fishing areas (FAs), and (3) SAUs. The statistics provided are catch (t, shell weight), CPUE computed using the catch-weighted mean of daily CPUE (Burch *et al.* 2011) and PropG1. Data are presented as mean ± standard error (se) unless otherwise stated.

Multi-dimensional scaling (MDS) was used to evaluate temporal changes in the distribution of catch among FAs and also among SAUs where proximity between years indicates their similarity. MDS results were further interpreted with similarity percentage (SIMPER) analysis which calculates the percentage each FA or SAU contributes to the difference between each year pair (i.e. which FAs or SAUs are contributing most to the differences).

Prior to calculation of CPUE, daily data were filtered to remove records where catch was >900 kg, effort was <3 and >8 hours, the ratio of total catch over total hours was > 150 kg.hr^{-1} or greenlip was <30% of catch. For PropG1, all records where the total catch was >1% different from the sum of the three weight-grade categories were excluded, as were all records with zero catch. As the minimum sample size for both these measures was 10 fishing records, the absence of data for these indicates this condition was not achieved.

For historical comparison, mean values are provided both in the text and as dashed lines on graphs. These are the proportion of the TACC harvested from each SAU for the 10-yr period between 2002 and 2011 (C_{02-11}) and the mean annual CPUE and PropG1 for the 20-yr period between 1990 and 2009 ($CPUE_{90-09}$ and $PropG1_{90-09}$, respectively). Ranking of SAUs refer first to the rank within the 10-yr period (C_{02-11}), followed by the rank in 2011 separated by a hyphen (e.g. 1-5 had rank 1 over the 10-yr period and rank 5 in 2011).

The proportion of large, legal-sized greenlip from FI survey size-frequency distributions was the ratio of 'large' shells (≥ 160 mm SL) to all legal-sized (i.e. ≥ 145 mm SL) measurements.

The methodology used to calculate and interpret PIs for the new harvest strategy are detailed in Section 3.4, and the Management Plan (PIRSA 2012).

3.3. Results

3.3.1. Region A

Total catches have been relatively stable since 1989 when the TACC was reduced to 207 t. The exception was the 20.7 $t.yr^{-1}$ quota increase from 2006 to 2009, that raised the TACC to 227.7 $t.yr^{-1}$ (Figure 3.1). Total effort was high and highly variable between 1979 and 1988, followed by a period of relative stability between 1990 and 1999. From 1999 total effort decreased to a historical low in 2005, after which it has increased to 2011. These temporal changes in effort were reflected in CPUE, which increased rapidly from 1999 to 2003 (75 $kg.hr^{-1}$). CPUE declined between 2003 and 2009, whereafter it has been stable at 62 $kg.hr^{-1}$, which is equivalent to $CPUE_{90-09}$ and 13% above the mean CPUE from 1990 to 1999. The proportion of Grade 1 greenlip in the commercial catch has been above $PropG1_{90-09}$ since 2001 and, in 2011, was the third highest value on record (Figure 3.1).

3.3.2. Fishing areas

3.3.2.1. Distribution of catch among fishing areas

In 2011, most of the catch (76%) was harvested from FAs 18 (20.7%), 8 (14.7%), 9 (10.0%), 13 (9.5%), 15 (8.0%), 14 (7.6%), and 12 (5.2%; Figure 3.2). This was the same number of FAs used to harvest a similar proportion (82%) of the catch in 2010. The total catch harvested from FAs 8 (31 t; 15%) and 9 (21 t; 10%) in 2011 was lower than that in 2010 (39 t; 19% and 30 t; 14%, respectively). In compensation, catches increased in 10 FAs, with the largest occurring in FA 13 (14.2 t; 7% to 19.7 t; 10%).

The spatial distribution of the greenlip catch among FAs was similar for about 20 years (i.e. 1990-2009; Figure 3.3). More recently, between 2009 and 2011, the spatial distribution of the catch has changed, with that in 2011 being most similar to those from 1981 and 2010. From 2009 to 2010, this change was primarily driven by increases in catches harvested from FAs 13 and 15, and a decrease in catch from FA 9. The changes between 2010 and 2011 were driven by increases in catch from FAs 11, 16 and 17, and the ongoing reduction in catch from FA 9.

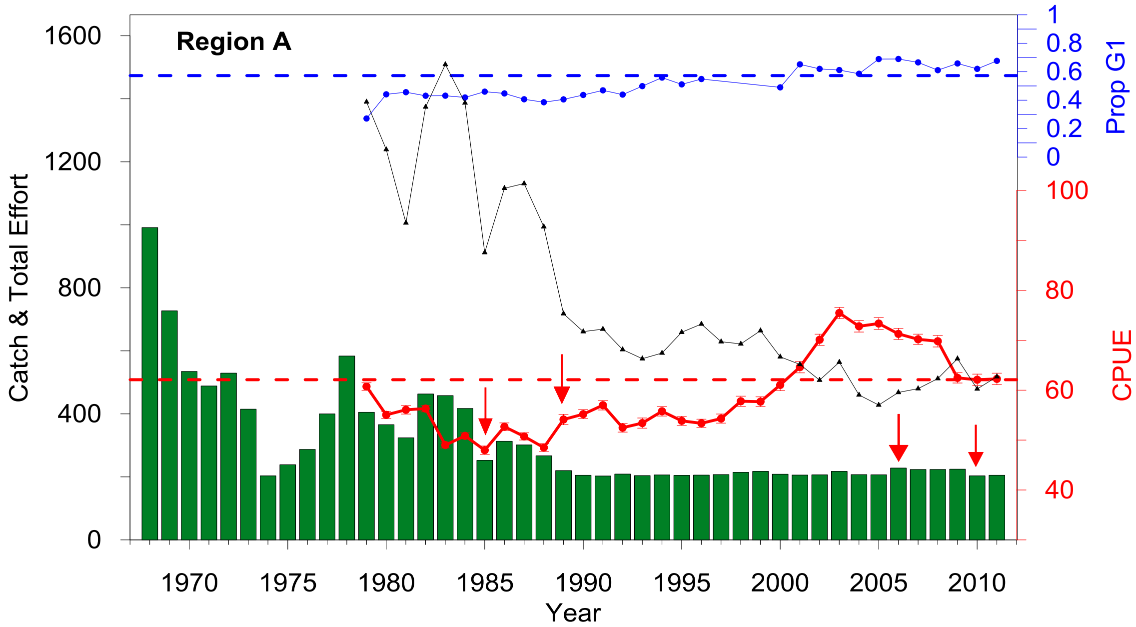

Figure 3.1. Catch (t, shell weight; green bars) of greenlip from Region A from 1968 to 2011. Total effort (days), CPUE ± se (kg.hr^{-1}) and PropG1 are shown in black, red and blue, respectively. Red and blue dashed lines are $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively. Red arrows indicate implementation (1985) and amendment (1989, 2006 and 2010) of TACC.

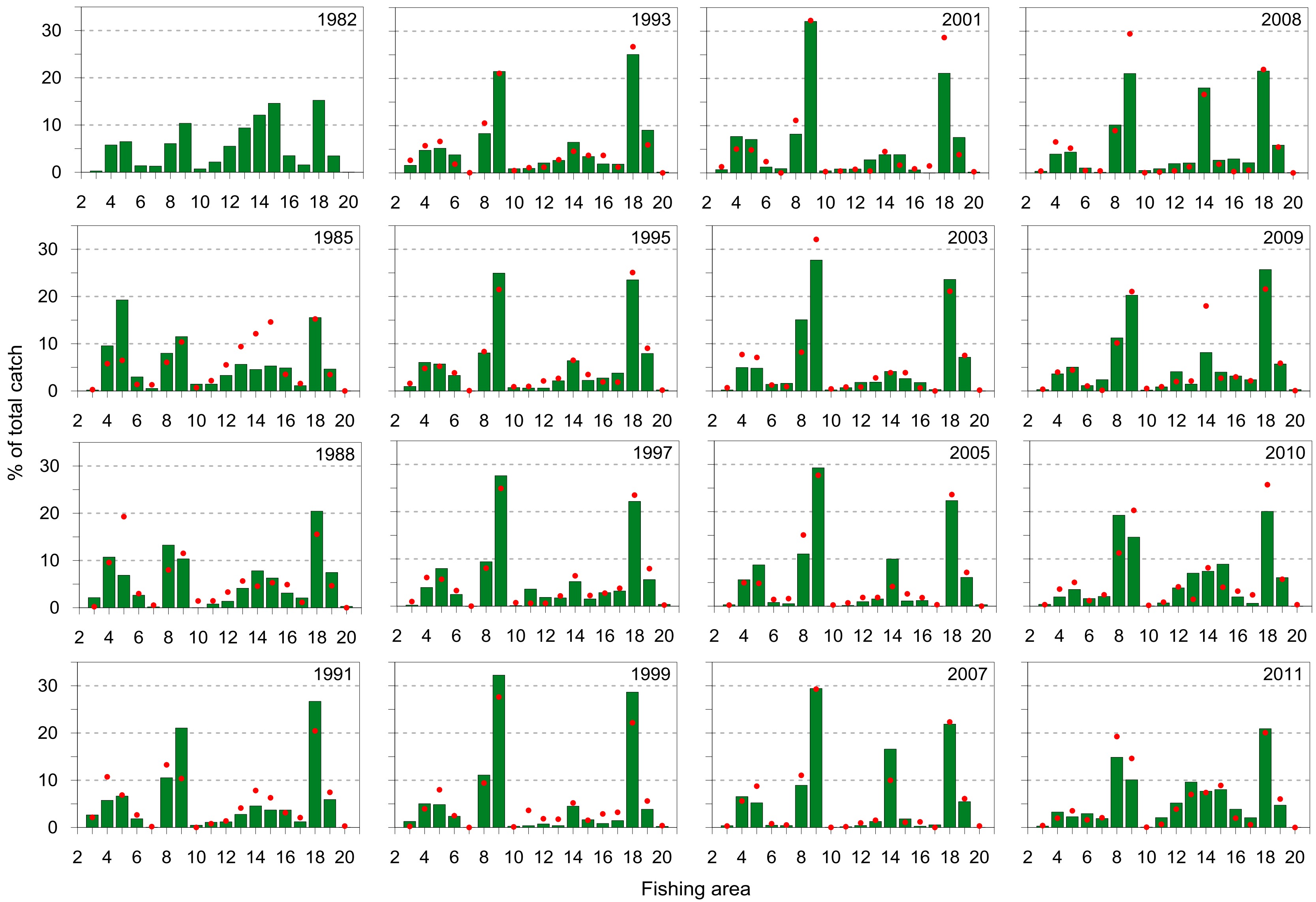

Figure 3.2. Spatial distribution of the greenlip catch (% of total catch) among each of the fishing areas in Region A between 3 year periods from 1982 to 1991, alternate years from 1991 until 2007 and annually 2007 to 2011. Red dots are catches from previous graph.

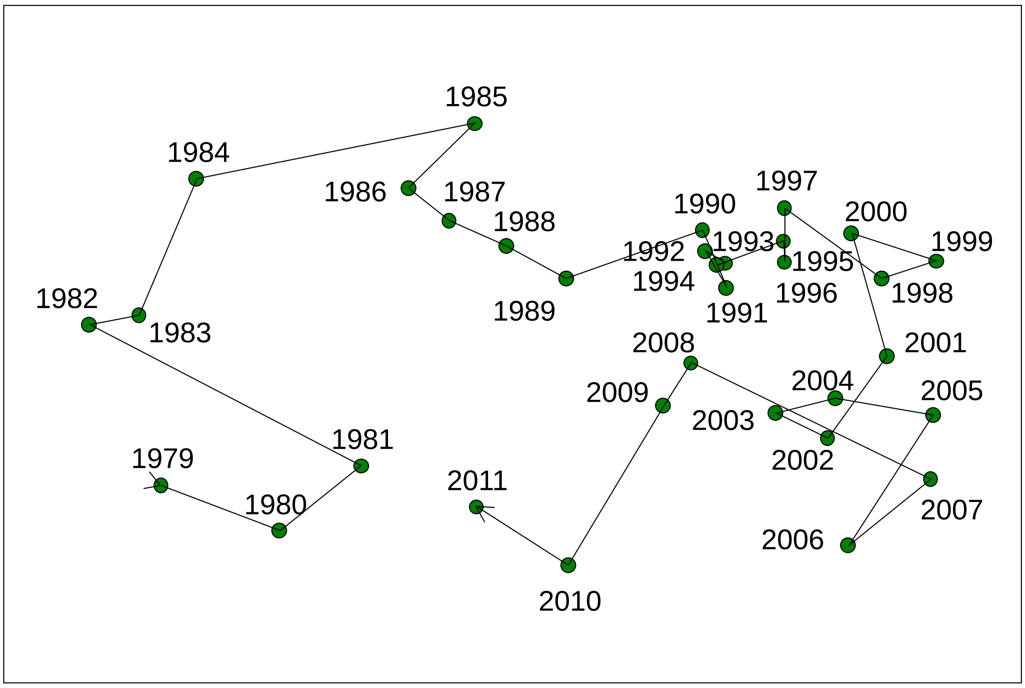

Figure 3.3. Multi-dimensional scaling (MDS) plot for FAs showing similarity among years based on greenlip catch from Region A from 1979 to 2011. 2D stress = 0.12.

3.3.2.2. ***Temporal patterns in fishing areas***

Across Region A, there are several FAs from which catches have generally been small and intermittent (Figure 3.4, Figure 3.5). This includes FAs 3, 7, 10 and 20. In some FAs, catches have declined substantially from those reported in the early to mid-1980s. For example, catches from FAs 4 and 5 frequently exceeded 20 $t.yr^{-1}$ prior to 1990, whilst, in 2011, catches from these FAs were among the lowest on record. In contrast, there are numerous FAs from which catches declined substantially between the mid 1980s and mid 2000s, whereafter catches increased substantially. These were FAs 6, 8 and 11-15, with recent increased catches from these areas reflecting the redistribution of catches among the Region A fishing grounds. This redistribution was necessary because catches from FA 9, and to a lesser extent FAs 4 and 5, have declined substantially since 2007. The catch from FA 9 in 2011 was the lowest since 1979 (i.e. >30 years). In contrast, catches from FAs 18 and 19 have been relatively stable since the 1980s.

CPUE has varied among years in most FAs. However, a common trend was relatively high CPUEs through the early 2000s, followed by their gradual decline to current values. In 2011, mean CPUE (+se) was below $CPUE_{90\text{-}09}$ in three, above this measure in five and equivalent to $CPUE_{90\text{-}09}$ in six of the 14 FAs within which it was estimable (Figure 3.4 & Figure 3.5).

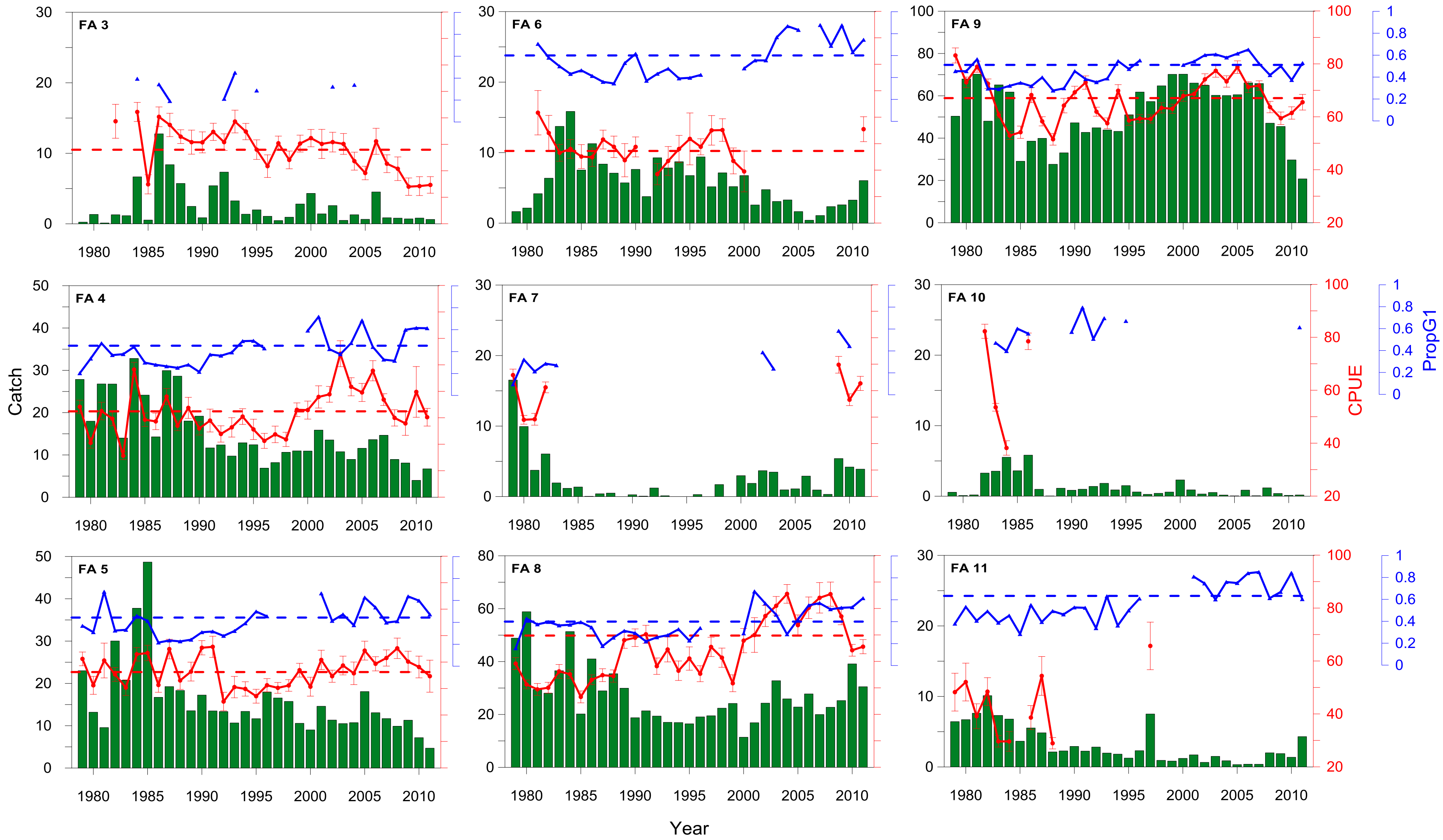

Figure 3.4. Catch (t, shell weight; green bars) of greenlip from FA 3 to FA 11 from 1979 to 2011. CPUE ± se (kg.hr^{-1}) and PropG1 are shown in red and blue, respectively. Where applicable, red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively. Note catch scales vary among graphs.

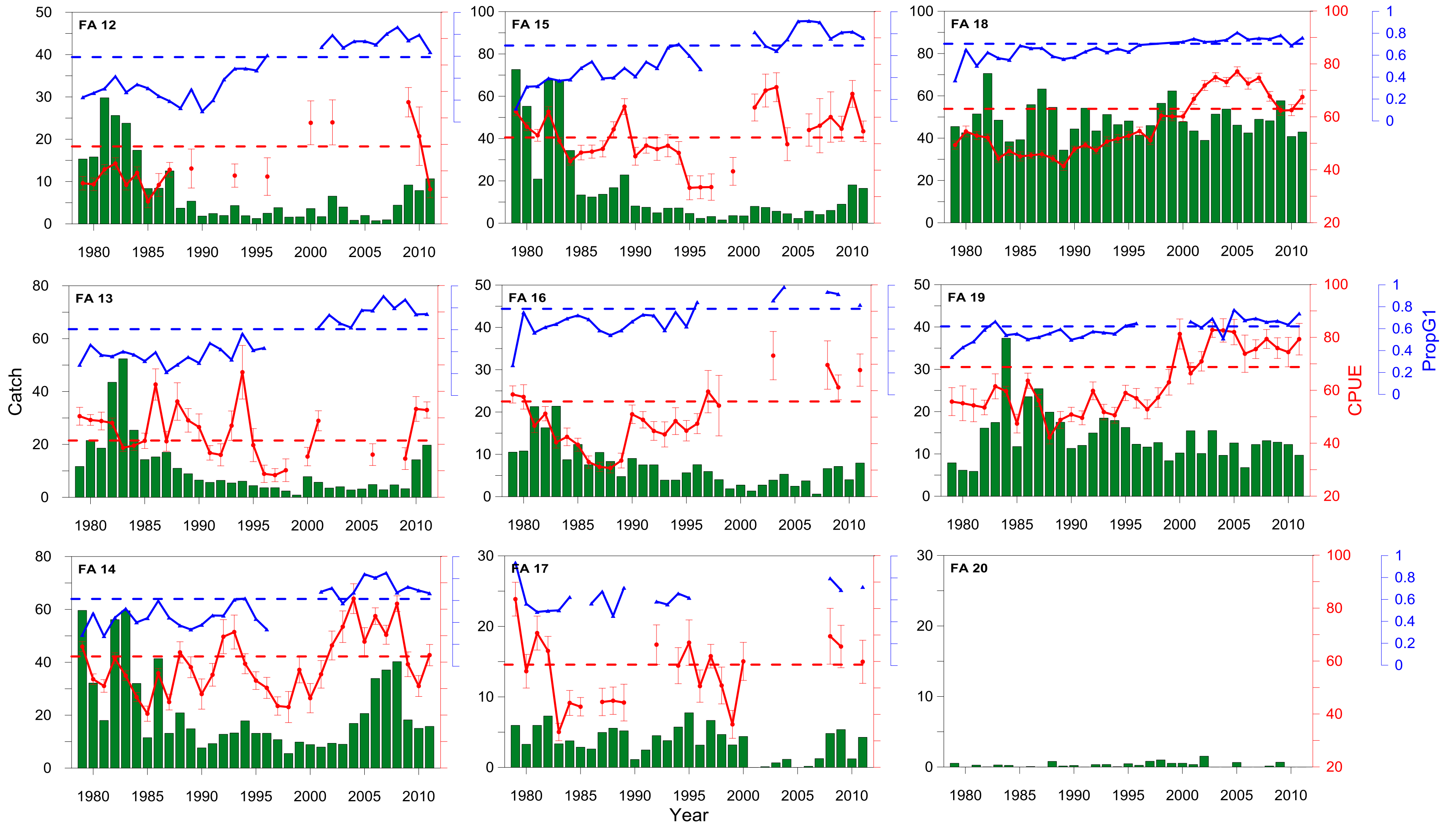

Figure 3.5. Catch (t, shell weight; green bars) of greenlip from FA 12 to FA 20 from 1979 to 2011. CPUE ± se ($kg.hr^{-1}$) and PropG1 are shown in red and blue, respectively. Where applicable, red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively. Note catch scales vary among graphs.

3.3.3. **Spatial assessment units**

3.3.3.1. ***Distribution of catch among spatial assessment units***

In 2011, most of the catch (65%) was harvested from Anxious Bay (13.5%), The Gap (10.5%), Point Avoid (8.3%), Reef Head (8.3%), Avoid Bay (6.5%), Drummond (6.4%) Taylor Island (5.9%) and Flinders Island (5.8%; Figure 3.6). Between 2010 and 2011, there were large decreases in catch from Anxious Bay (41.1 t; 20% to 27.6 t; 13%) and Hotspot (10.4 t; 5% to 2.5 t; 1%) and smaller decreases from Ward Island (9.7 t; 5 % to 6.6 t; 3%) and Wedge Island (4.9 t; 2 % to 1 t; <1%; Figure 3.6). In compensation, catches from Drummond (8.3 t; 4% to 13.2 t; 6%), Fishery Bay (4.3 t; 2% to 9.6 t; 5%) and Taylor Island (8.6 t; 4% to 12.2 t; 6%) increased.

There was a relatively stable spatial distribution of greenlip catch among SAUs from 1990 to 2009 (Figure 3.7). More recently, between 2009 and 2011, the distribution of catch among fishing areas has changed substantially, with that in 2011 most similar to that from 1985. The largest difference occurred between 2009 and 2010 and was primarily influenced by an increase in catch from Reef Head, while the smaller difference between 2010 and 2011 was the result of decreased catch from Hotspot. There have also been increased catches in recent years from the Venus Bay, Drummond, Coffin Bay and Fishery Bay SAUs.

In combination, these changes in the spatial distribution of the catch have resulted in four high (Anxious Bay, The Gap, Avoid Bay and Flinders Island) and seven medium (Hotspot, Ward Island, Taylor Island, Point Avoid, Baird Bay, Point Westall and Memory Cove) importance SAUs for greenlip in 2011.

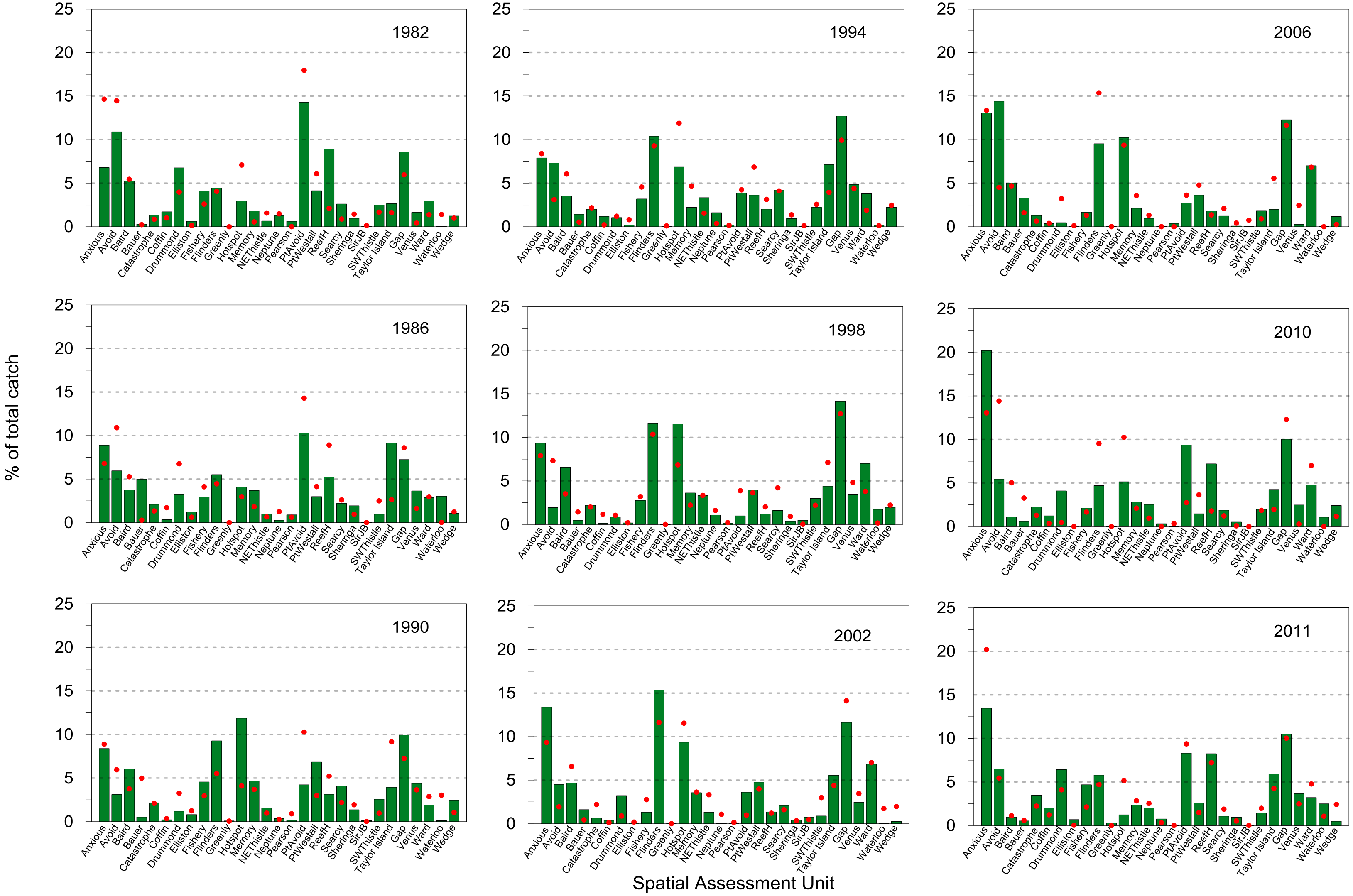

Figure 3.6. Spatial distribution of the greenlip catch (% of total catch) among each of the SAUs in Region A between 4 year periods from 1982 to 2010, and annually thereafter. Red dots are catches from previous graph.

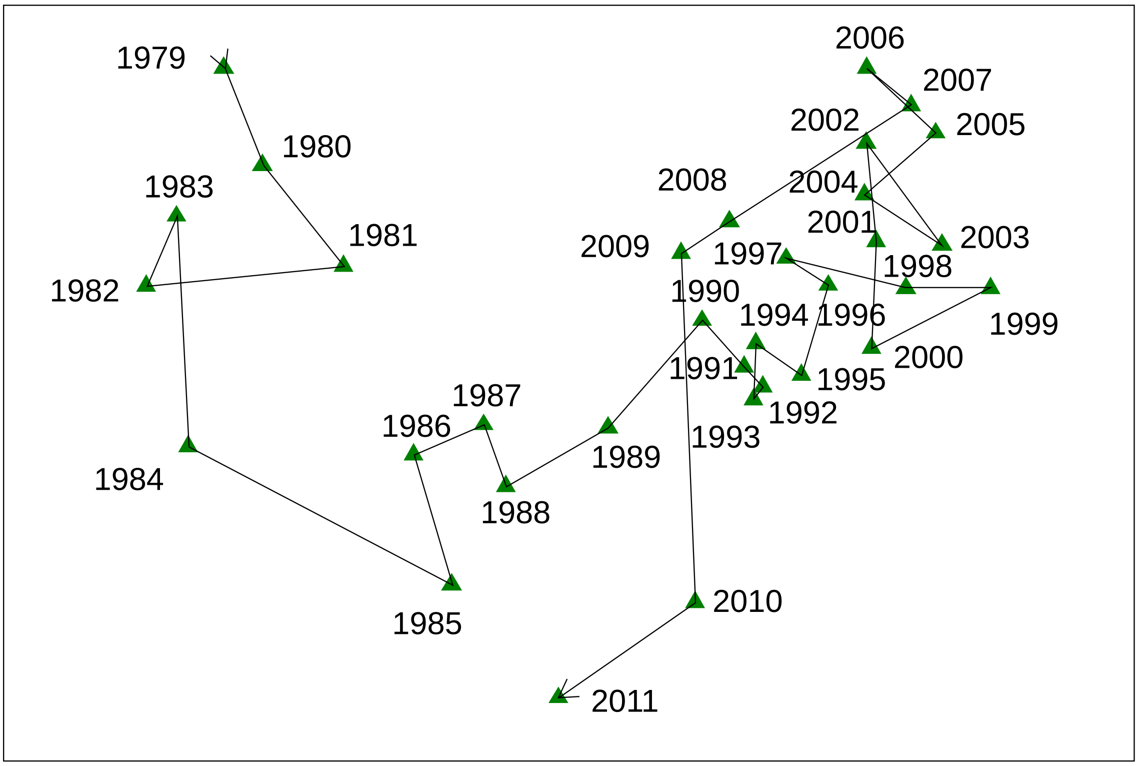

Figure 3.7. Multi-dimensional scaling (MDS) plot for SAUs showing similarity among years based on greenlip catch from Region A from 1979 to 2011. 2D stress = 0.14.

3.3.3.2. Temporal patterns in high importance spatial assessment units

Anxious Bay (Rank 1-1; 12.8% $C_{02\text{-}11}$)

Anxious Bay has been the most important greenlip SAU in Region A since 2002. Catch decreased from a historic high in 1979 to 1990, remained stable from 1990 to 2001, whereafter it increased to about 40 t in 2010 (Figure 3.8). The catch harvested from this SAU decreased by 33% between 2010 and 2011, returning to a level similar to that reported from 2002 to 2009. CPUE increased substantially between 1996 with maxima observed in 2004 and 2008, following which it declined to the lowest level in over 10 years. The CPUE in 2011 (63 kg.hr^{-1}) was similar to that in 2010, remaining 10% below $CPUE_{90\text{-}09}$. In contrast, PropG1 has exceeded $PropG1_{90\text{-}09}$ since 2005 (Figure 3.8).

FI surveys at Anxious Bay indicate that the proportion of legal-sized greenlip was relatively stable from 2004 to 2010, varying from 22% to 38% (Figure 3.9). However the density of legal-sized greenlip halved between 2007 and 2008 and remained low in 2010 (Figure 3.10). Similarly, the density of sub-legal-sized greenlip has decreased consistently from 2004 to the lowest level on record in 2010.

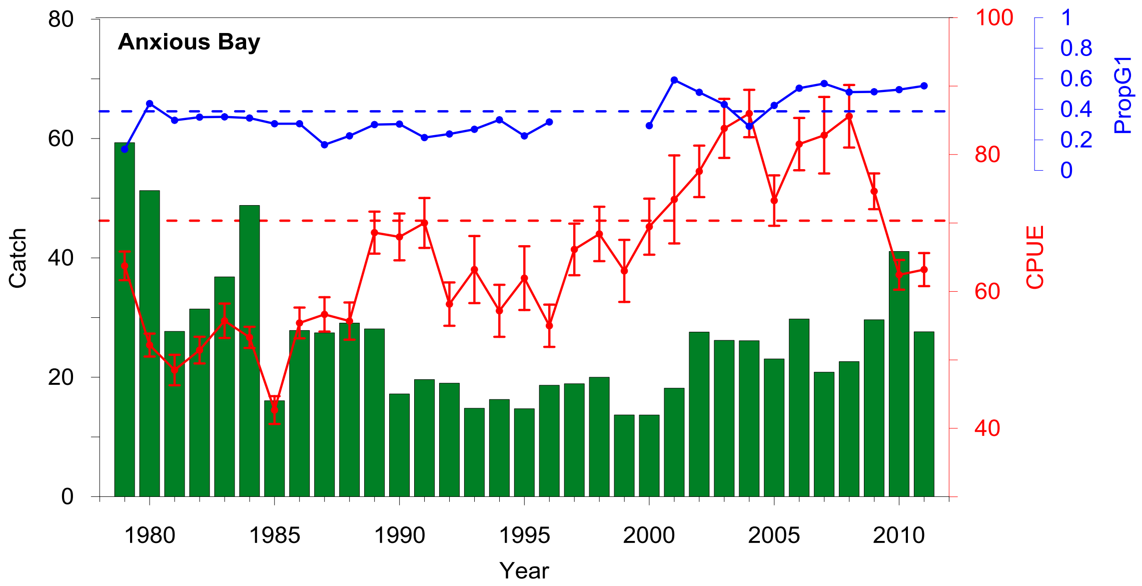

Figure 3.8. Catch (t, shell weight; green bars) of greenlip from Anxious Bay from 1979 to 2011. CPUE ± se (kg.hr^{-1}) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $\%PropG1_{90\text{-}09}$, respectively.

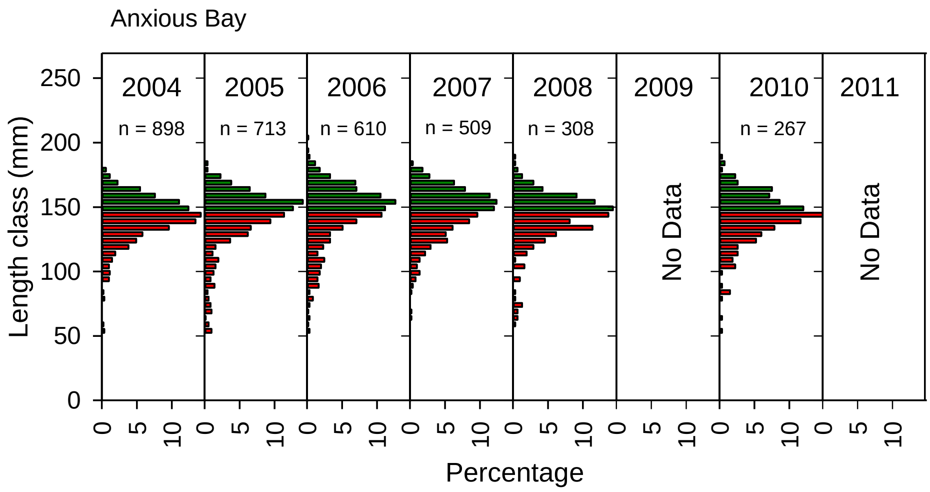

Figure 3.9. Length-frequency distributions of legal-sized (green bars) and sub-legal-sized (red bars) greenlip at Anxious Bay (map-code 8A) observed on fishery-independent surveys from 2004 to 2011. Length classes represent the upper length of each 5 mm bin. n = number of greenlip measured. Bin classes < 50 mm SL pooled.

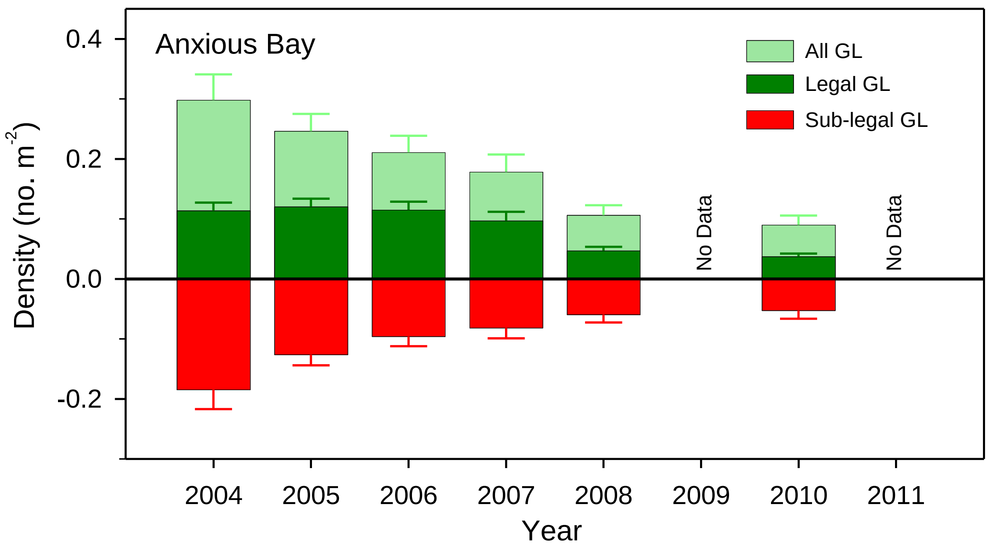

Figure 3.10. Mean ± se density (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) greenlip at Anxious Bay (lead lines; map-code 8A) from 2004 to 2011. Note sample size increased from 24 in 2005 to 32 thereafter.

The Gap (Rank 2-2; 12.5% $C_{02\text{-}11}$)

Annual catches from The Gap have been gradually declining since the recent high catches in 1999 and 2003. The catch from this SAU in 2011 (22 t) remained similar to that in 2010, which was at the lowest level since 1996 (Figure 3.11). CPUE was relatively low between 1979 and 1997 (about 51 kg.hr^{-1}), whereafter it increased to a historic peak of about 80 kg.hr^{-1} in 2005. Between 2005 and 2010, CPUE declined consistently to the lowest level since 1997. However, it increased between 2010 and 2011 (73 kg.hr^{-1}), exceeding $CPUE_{90\text{-}09}$ by 11%. The proportion of Grade 1 greenlip in the commercial catch has remained stable and, with the exception of a low value in 2010, exceeded $PropG1_{90\text{-}09}$ since 2001 (Figure 3.11).

FI timed-swim surveys at The Gap indicate that the proportion of large, legal-sized greenlip has been relatively stable between 2001 and 2011 (range: 34% to 47%), with large size classes represented in all years (Figure 3.12). Densities of sub-legal-sized and legal-sized greenlip have been relatively stable through time, with higher values in the late 1990s and mid 2000s, respectively (Figure 3.13). This stability between years was also evident for the leaded-line surveys undertaken in 2009 and 2011.

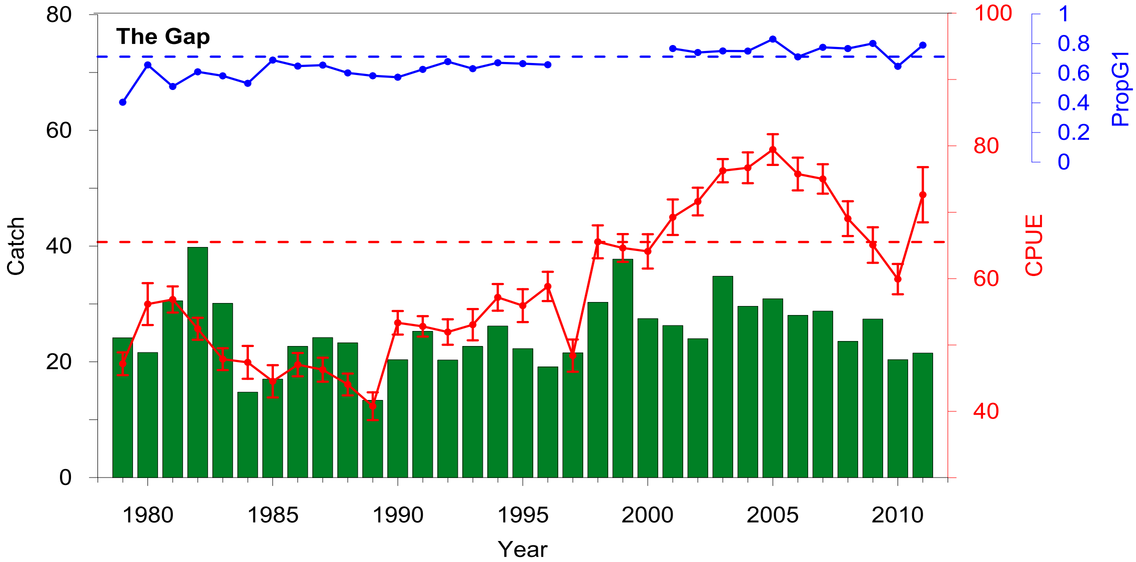

Figure 3.11. Catch (t, shell weight; green bars) of greenlip from The Gap from 1979 to 2011. CPUE ± se (kg.hr^{-1}) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

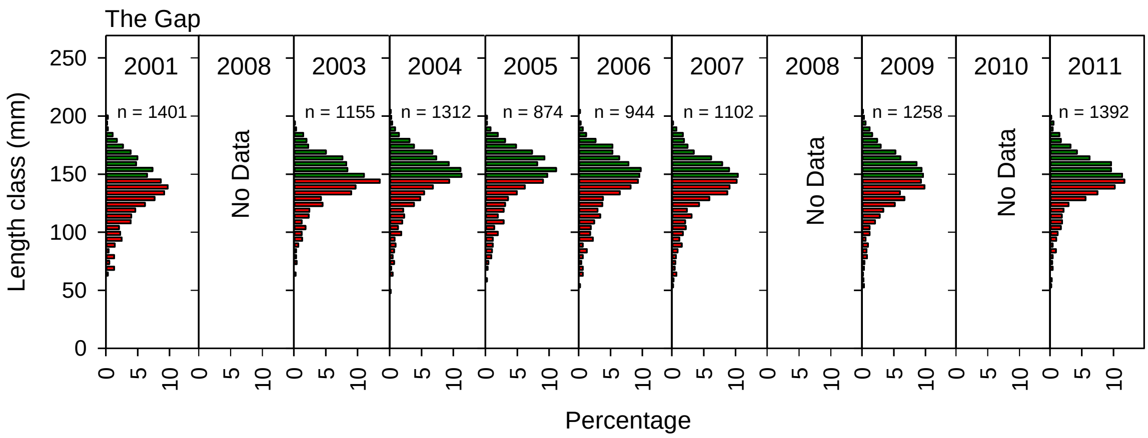

Figure 3.12. Length-frequency distributions of legal-sized (green bars) and sub-legal-sized (red bars) greenlip at The Gap (map-code 18F) observed on fishery-independent surveys from 2001 to 2011. Length classes represent the upper length of each 5 mm bin. n = number of greenlip measured. Bin classes < 50 mm SL pooled.

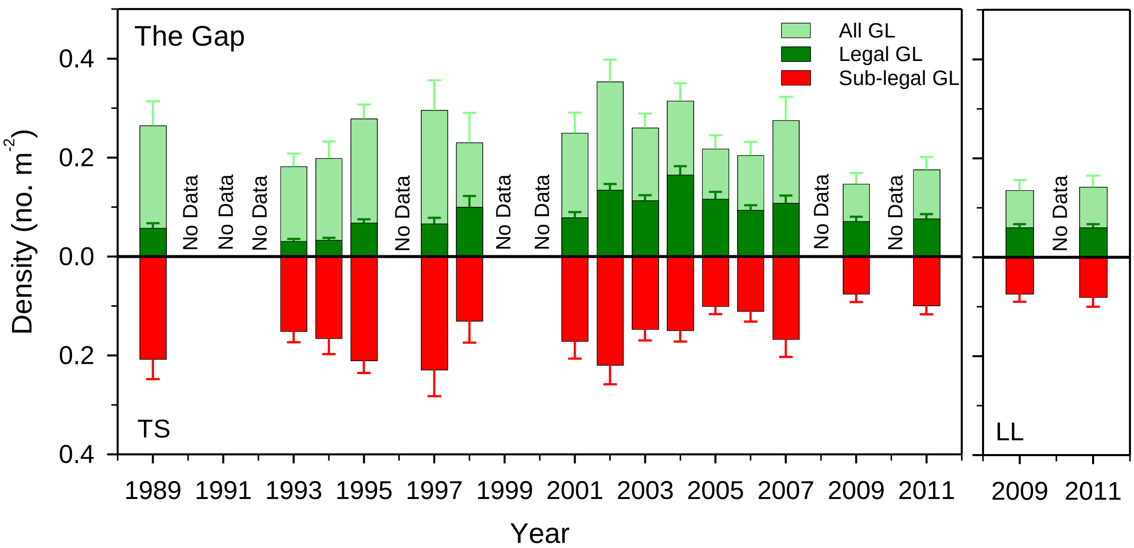

Figure 3.13. Mean ± se density (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) greenlip at The Gap (timed swims and lead lines; map-code 18F) from 1989 to 2011. TS = timed swims, LL = lead lines.

Avoid Bay (Rank 3-5; 9.5% $C_{02\text{-}11}$)

Initial high catches at Avoid Bay in 1979 and 1982 were followed by a sharp decrease to <10 t in 1985, whereafter catch was stable at about 10 $t.yr^{-1}$ until 2003 (Figure 3.14). Catches increased substantially between 2003 and 2008 (39 t), subsequently declining rapidly to historic mean levels in 2010 (11 t) and 2011 (13 t). CPUE has varied considerably among years, but has recently declined from high levels through the mid 2000s to a level similar to $CPUE_{90\text{-}09}$ in 2011. The percentage of Grade 1 greenlip in the commercial catch has remained above $PropG1_{90\text{-}09}$ since 2004 (Figure 3.14).

In contrast, the proportion of large, legal-sized greenlip in FI surveys at Avoid Bay decreased by 8% (38% to 30%) between 2008 and 2010 and, in 2010, the four largest size classes observed in previous years were absent (Figure 3.15). Furthermore, density estimates suggest that the abundance of legal-sized greenlip has halved since surveys began in 2008. The density of sub-legal-sized greenlip also reduced during this period (Figure 3.16).

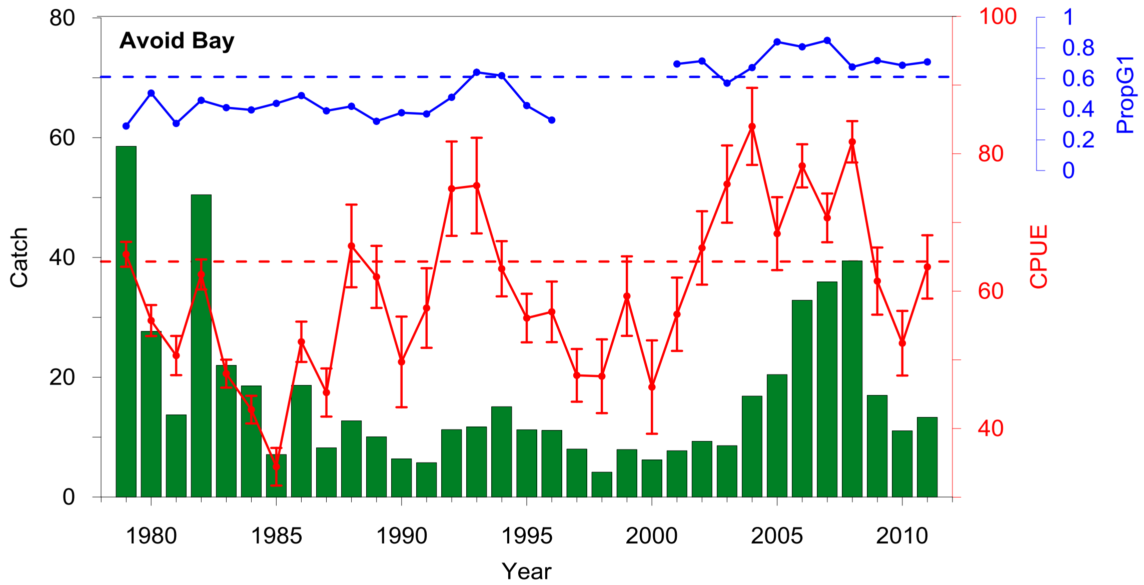

Figure 3.14. Catch (t, shell weight; green bars) of greenlip from Avoid Bay from 1979 to 2011. CPUE ± se ($kg.hr^{-1}$) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

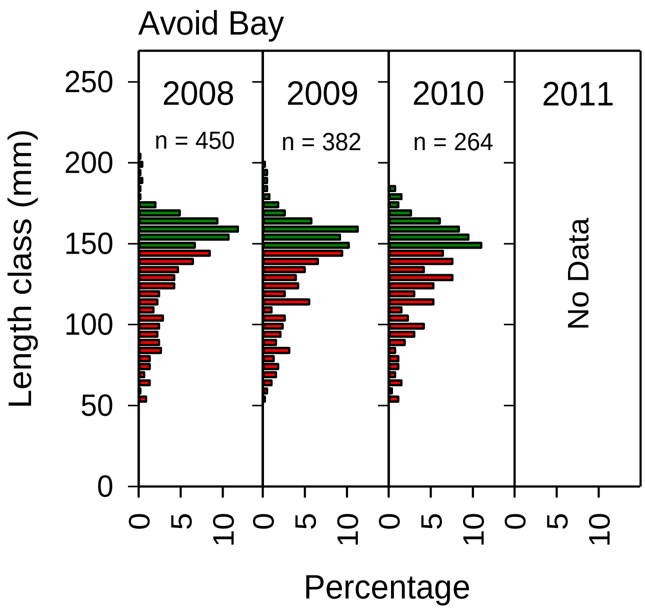

Figure 3.15. Length-frequency distributions of legal-sized (green bars) and sub-legal-sized (red bars) greenlip from Avoid Bay (map-code 14D) observed on fishery-independent surveys from 2008 to 2011. Length classes represent the upper length of each 5 mm bin. n = number of greenlip measured. Bin classes < 50 mm SL pooled.

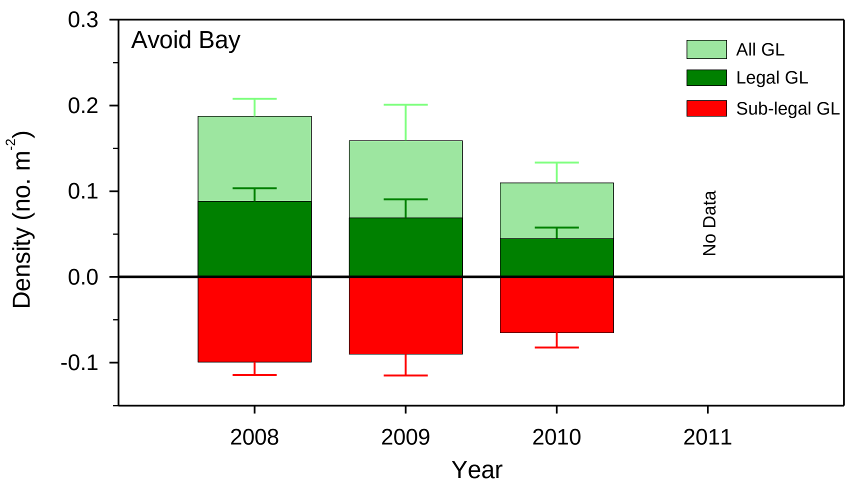

Figure 3.16. Mean ± se density (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) greenlip at Avoid Bay (lead lines; map-code 14D) from 2008 to 2011.

Flinders Island (Rank 4-8; 8.9% $C_{02\text{-}11}$)

Catch from Flinders Island has been variable throughout its history, with periods of high catches in the early 1980s, mid 1990s and early 2000s (Figure 3.17). Recently, catch has declined from about 27.9 t in 2007 to 9.6 t in 2010. This was the lowest catch from this SAU on record and, in 2011, the catch was only marginally higher. CPUE declined in the early 1980s, reaching a historic minimum in 1985, whereafter it increased to the maximum recorded value of 88 kg.hr^{-1} in 2005. CPUE declined between 2005 and 2009 – reaching the lowest level since 1988 – but has since increased. In 2011 it was equivalent to $CPUE_{90\text{-}09}$. The proportion of Grade 1 greenlip in the commercial catch has varied among years, while remaining stable around $PropG1_{90\text{-}09}$. In 2011, PropG1 was at the highest value on record (Figure 3.17).

In contrast, the proportion of large, legal-sized greenlip in FI surveys has decreased at both the Southeast Flinders and Flinders Bay survey locations. At Southeast Flinders, the proportion ranged from 39% to 46% between 2002 and 2007, but was 30% and 27% in 2008 and 2010, respectively (Figure 3.18). Similarly, at Flinders Bay, the proportion of large, legal-sized greenlip varied between 36% and 44% between 2005 and 2009, but in 2011 was 23%. The largest size classes were not observed at these survey locations in 2010 and 2011. When last surveyed, both legal and sub-legal-sized greenlip densities at both survey locations were among the lowest recorded (Figure 3.19). The density of legal-sized greenlip at Flinders Bay has declined by 77% since 2005.

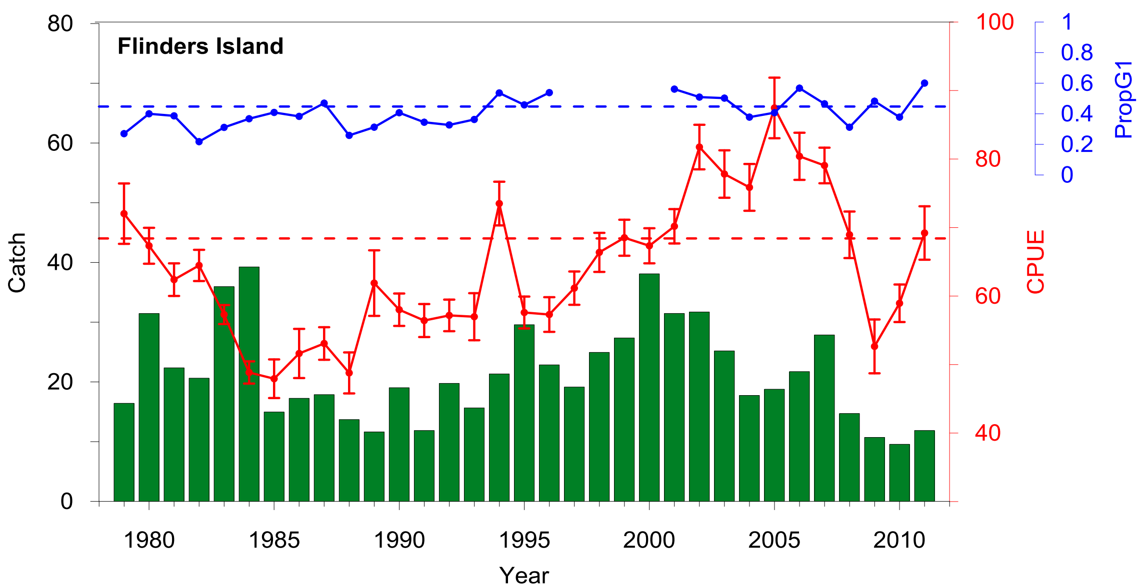

Figure 3.17. Catch (t, shell weight; green bars) of greenlip from Flinders Island from 1979 to 2011. CPUE ± se (kg.hr^{-1}) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

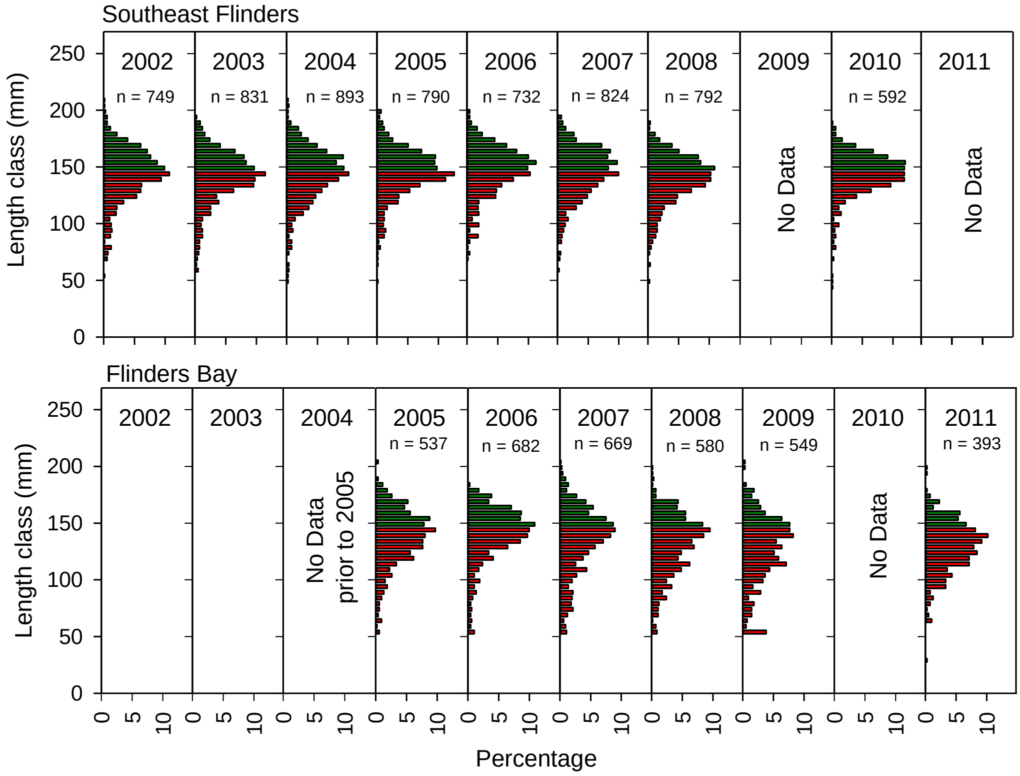

Figure 3.18. Length-frequency distributions of legal-sized (green bars) and sub-legal-sized (red bars) greenlip at Southeast Flinders (Map-code 9G & H) and Flinders Bay (map-code 9F) observed on fishery-independent surveys from 2002 to 2011. Length classes represent the upper length of each 5 mm bin. n = number of greenlip measured. Bin classes < 50 mm SL pooled

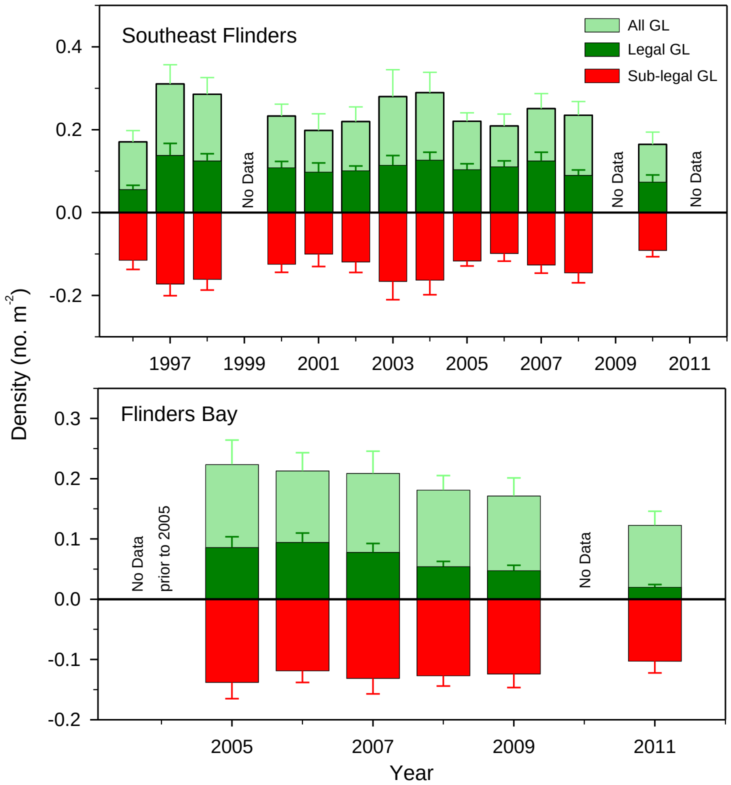

Figure 3.19. Mean ± se density (abalone m^{-2}) of all, legal-sized and sub-legal sized (see legend) greenlip at Southeast Flinders (timed swims; map-codes 9G & 9H) from 1996 to 2011 and Flinders Bay (lead lines; map-code 9F) from 2005 to 2011

3.3.3.3. Temporal patterns in medium importance spatial assessment units

Hotspot (Rank 5-19; 8.3% C_{02-11})

Catch at Hotspot varied among years between 1979 and 1995 and was stable from 1996 to 2006, whereafter it has decreased consistently (Figure 3.20). The catch from this SAU in 2011 (rank 19; 2.5 t) was the lowest since 1988 and the second lowest on record. CPUE was high, but variable, between 1979 and 1994 following which, between 1994 and 2010, it was more stable and, in 2010, similar to $CPUE_{90-09}$. CPUE was not estimable in 2011 due to limited data. The PropG1 of greenlip declined consistently from 2005 and, in 2010, was 45% below $PropG1_{90-09}$ (Figure 3.20). Both the CPUE and proportion of Grade 1 greenlip in the commercial catch could not be calculated for 2011 due to insufficient data.

The decrease in PropG1 was consistent with FI surveys where the proportion of large, legal-sized greenlip decreased from about 44% between 1987 and 2007 to 31% since 2008 (Figure 3.21). Furthermore, the density of both legal-sized and sub-legal-sized greenlip decreased by about 50% between 2008 and 2010 and remained at similarly low levels in 2011 (Figure 3.22).

Ward Island (Rank 6-12; 6.4% C_{02-11})

The annual catch from Ward Island was stable at about 13 t between 1980 and 2009 (Figure 3.20). However, between 2009 and 2011, catch from this SAU decreased to the lowest level since 1990 (7 t). CPUE has varied considerably among years. Following a short period of relative stability in the late 1990s, CPUE increased between 1999 and 2004, whereafter it has declined and, since 2008, has been below $CPUE_{90-09}$. Similarly, PropG1 has reduced since 2006 and, in 2011, was 25% below $PropG1_{90-09}$ and at the lowest level since 1992.

Patterns in FD measures are consistent with a reduction in the proportions of large greenlip observed on FI surveys at Ward Island which decreased from about 60% between 2002 and 2008 to 37% by 2010 (Figure 3.21). FI survey estimates of legal-size and sub-legal-sized greenlip density at Ward Island in 2010 were among the highest on record (Figure 3.22).

Taylor Island (Rank 7-7; 4.7% C_{02-11})

With the exception of a period of high catches in the mid to late 1980s, annual catch from Taylor Island has remained relatively stable at about 10 t (Figure 3.20). CPUE was relatively low and variable between 1979 and 1992, whereafter it increased to a historic high in 2003 (79 $kg.hr^{-1}$). Between 2003 and 2011, CPUE has varied considerably but remained relatively high and, in 2011 (74 $kg.hr^{-1}$), was 19% above $CPUE_{90\text{-}09}$. The proportion of Grade 1 greenlip in the commercial catch has been relatively stable for more than 30 years and, in 2011, was 28% above $PropG1_{90\text{-}09}$ and the second highest on record (Figure 3.20).

Point Avoid (Rank 8-3; 3.8% $C_{02\text{-}11}$)

Following high catches from Point Avoid in the 1980s, catch was stable at less than10 $t.yr^{-1}$ between 1990 and 2009. In 2010 and 2011, catch increased to 19 t and 17 t, respectively, the highest levels since 1989 (Figure 3.20). CPUE has fluctuated among years, with a historic high in 2003 and, in 2011, was equivalent to $CPUE_{90\text{-}09}$. Since 2007, the proportion of Grade 1 greenlip in the commercial catch has declined, but remained above $PropG1_{90\text{-}09}$, and high in relation to previous years (Figure 3.20).

In contrast with the reduction in PropG1, FI surveys at Point Avoid show that the proportion of large, legal-sized greenlip increased from 2003 (21%) to 2009 (32%; Figure 3.21). Similarly, the density of legal-sized greenlip in 2009 was the highest on record. However, the density of sub-legal-sized greenlip was amongst the lowest recorded (Figure 3.22).

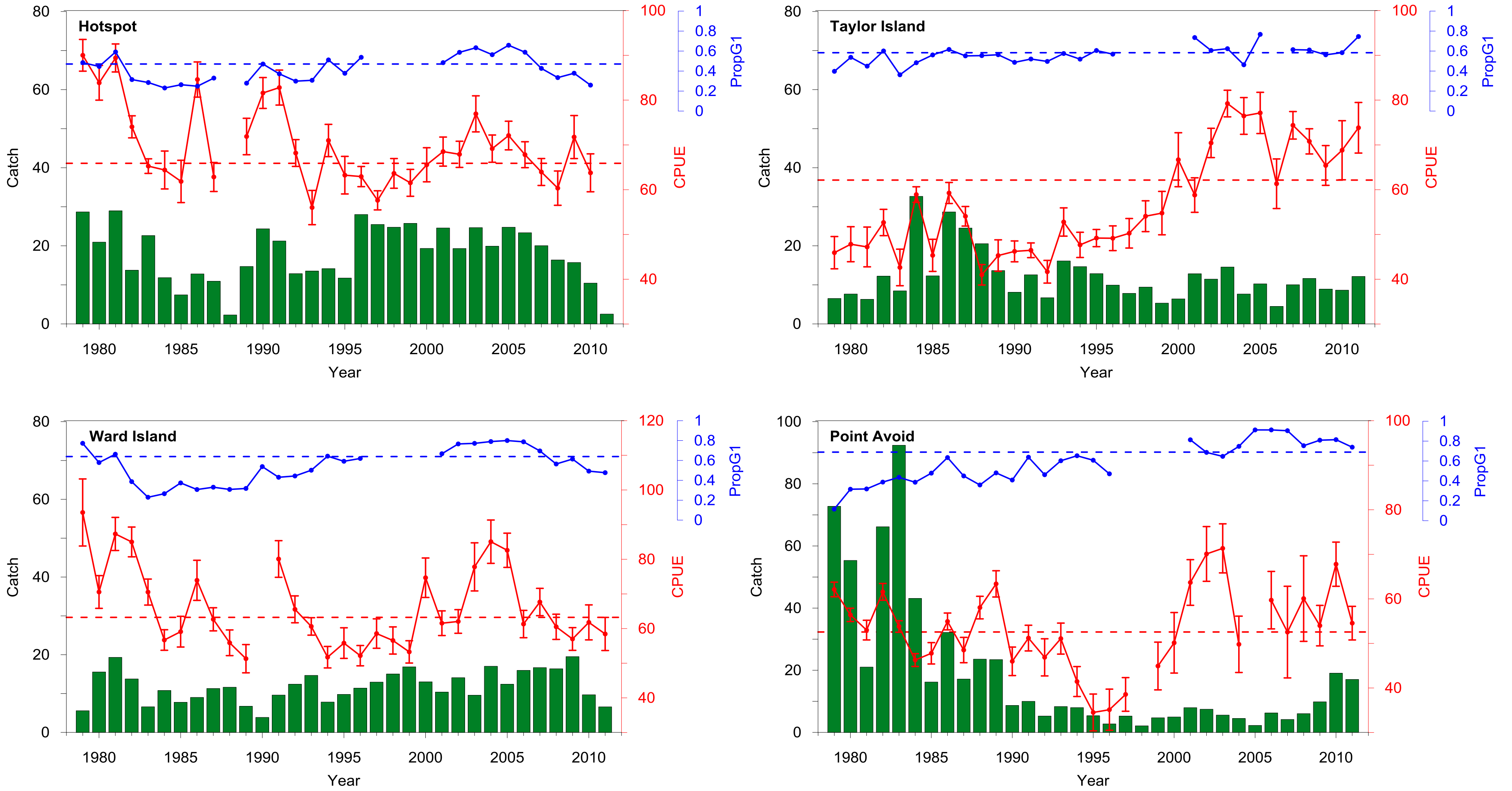

Figure 3.20. Catch (t, shell weight; green bars) of greenlip from Hotspot, Ward Island, Taylor Island and Point Avoid from 1979 to 2011. CPUE ± se ($kg.hr^{-1}$) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and $PropG1_{90\text{-}09}$, respectively.

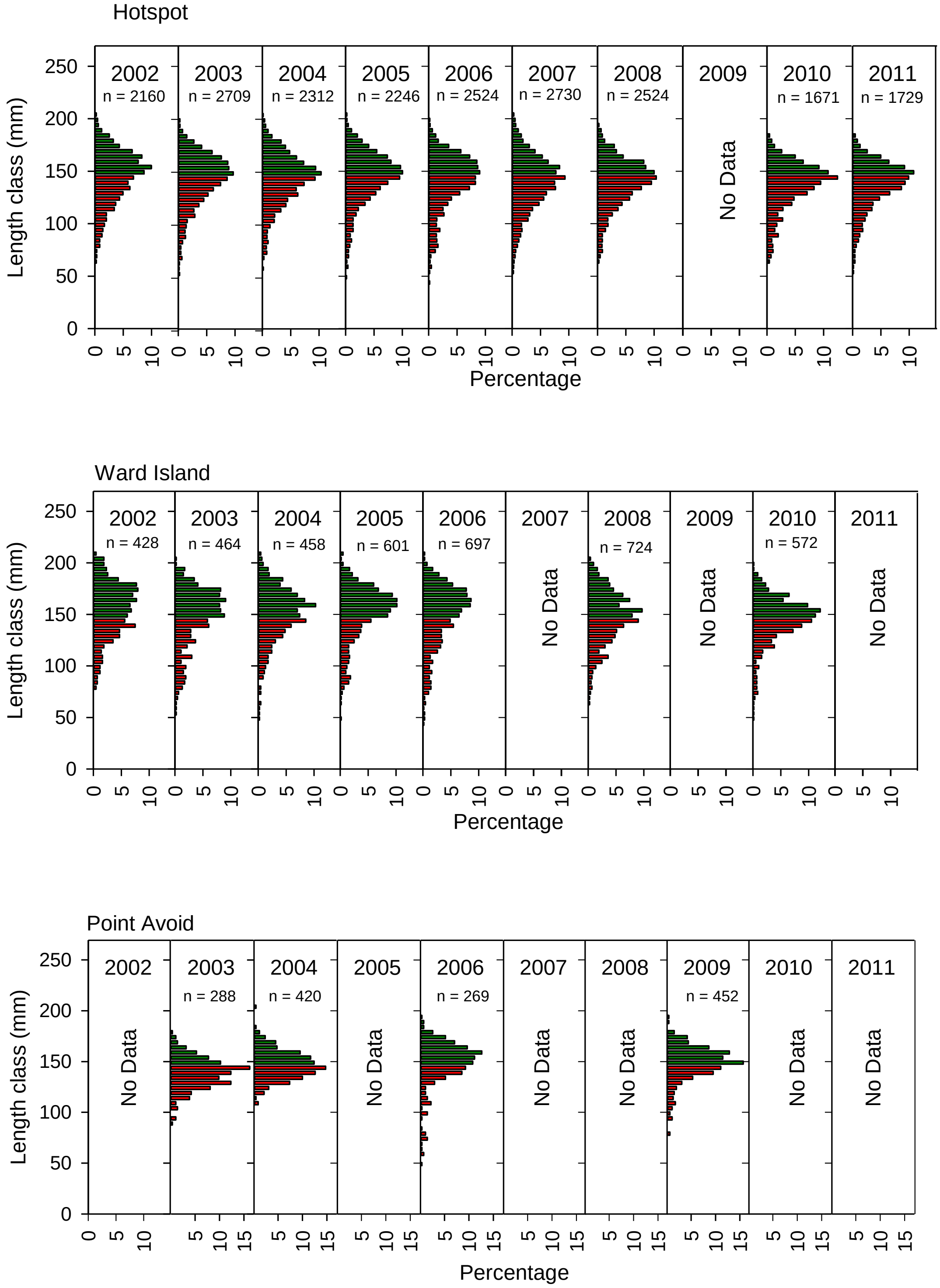

Figure 3.21. Length-frequency distributions of legal-sized (green bars) and sub-legal-sized (red bars) greenlip at Hotspot (map-code 9D), Ward Island (map-code 9A) and Point Avoid (map-code 15A) observed on fishery-independent surveys from 2002 to 2011. Length classes represent the upper length of each 5 mm bin. n = number of greenlip measured. Bin classes < 50 mm SL pooled.

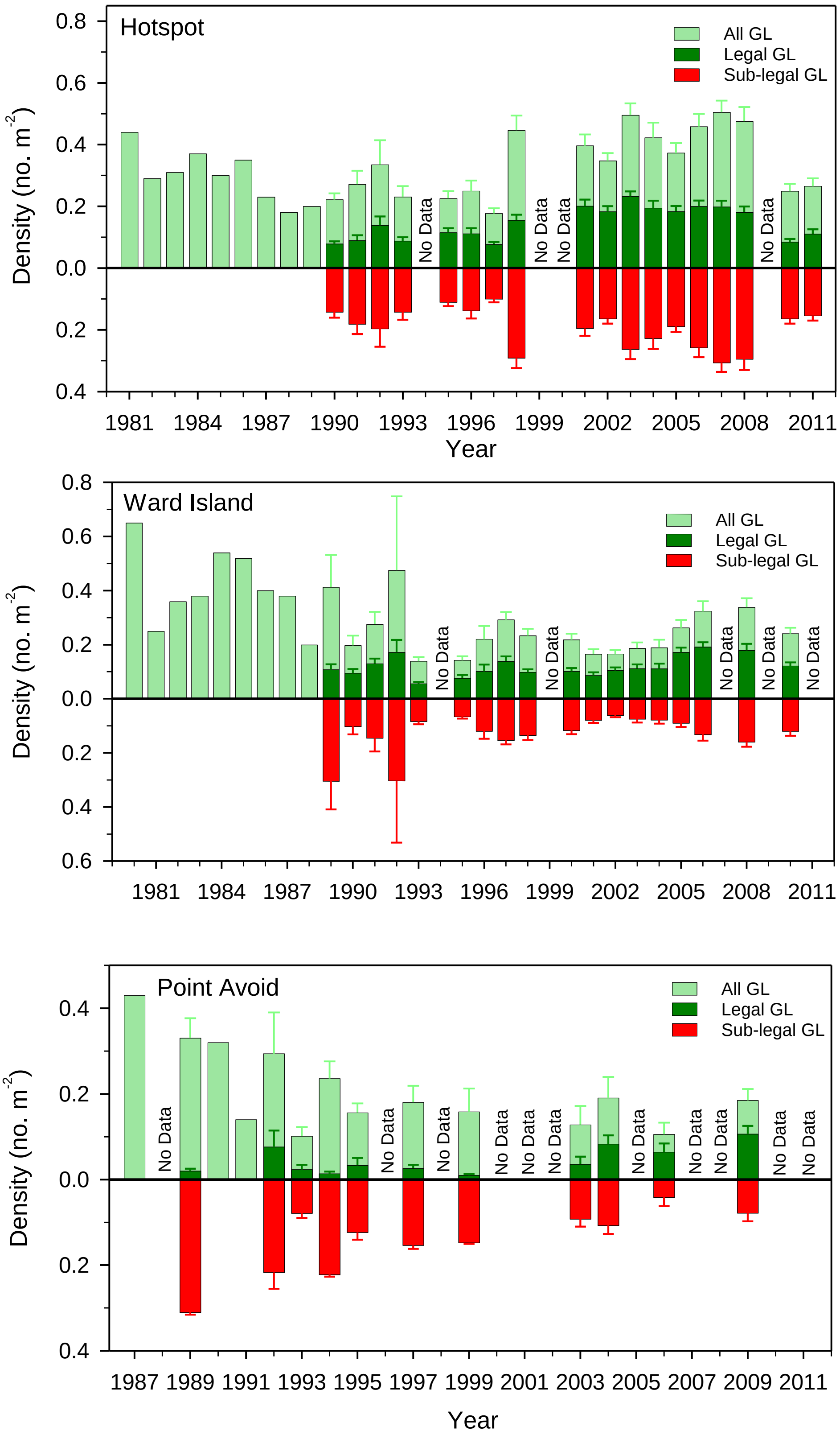

Figure 3.22. Mean ± se density (abalone.m^{-2}) of all, legal-sized and sub-legal sized (see legend) greenlip at Hotspot (timed swims; map-code 9D) from 1981 to 2011, Ward Island (timed swims; map-code 9A) from 1980 to 2011 and Point Avoid (timed swims; map-code 15A) from 1987 to 2011.

Baird Bay (Rank 9-21; 3.7% C_{02-11})

For over 20 years, annual catches from Baird Bay were relatively stable at about 10 t. However, in 2010 and 2011, the catch harvested from this SAU was substantially smaller; the catch in 2011 was the lowest on record (2 t; Figure 3.23). CPUE was more variable among years between 1979 and 1992 than during subsequent years where it has increased steadily and, in 2009, was 13% above $CPUE_{90-09}$. However, limited data prevented estimation of CPUE in both 2010 and 2011. The proportion of Grade 1 greenlip in the commercial catch has fluctuated among years and, in 2011, was equivalent to $PropG1_{90-09}$ (Figure 3.23).

Point Westall (Rank 10-13; 3.4% C_{02-11})

Annual catches from Point Westall were initially high, but more than halved between 1987 and 1991, whereafter they have remained stable at about 8 t for almost 20 years. In 2010, the catch from this SAU was the lowest on record (3 t), with little change evident between 2010 and 2011 (5 t; Figure 3.23). CPUE was variable in the 1980s, followed by a period of relative stability at low levels in the early to mid 1990s. From 1996, CPUE increased, reaching the maximum observed value in 2003, following which, it has declined consistently. In 2011, CPUE was at the lowest level since 1998 and 11% below $CPUE_{90-09}$ (Figure 3.23). The proportion of Grade 1 greenlip in the commercial catch has oscillated among years and, in 2011, was 36% above $PropG1_{90-09}$ (Figure 3.23).

Memory Cove (Rank 11-15; 3.3% C_{02-11})

Annual catches at Memory Cove have been relatively stable since 1981, ranging between approximately 5 and 10 $t.yr^{-1}$ (Figure 3.23). CPUE increased substantially from a relatively low level between 1981 and 1994 and, in 2011, was 17% above $CPUE_{90-09}$. The proportion of Grade 1 greenlip in the commercial catch has been greater than $PropG1_{90-09}$ since 2008 and, in 2011, was 19% above the $PropG1_{90-09}$ and at the second highest level on record (Figure 3.23).

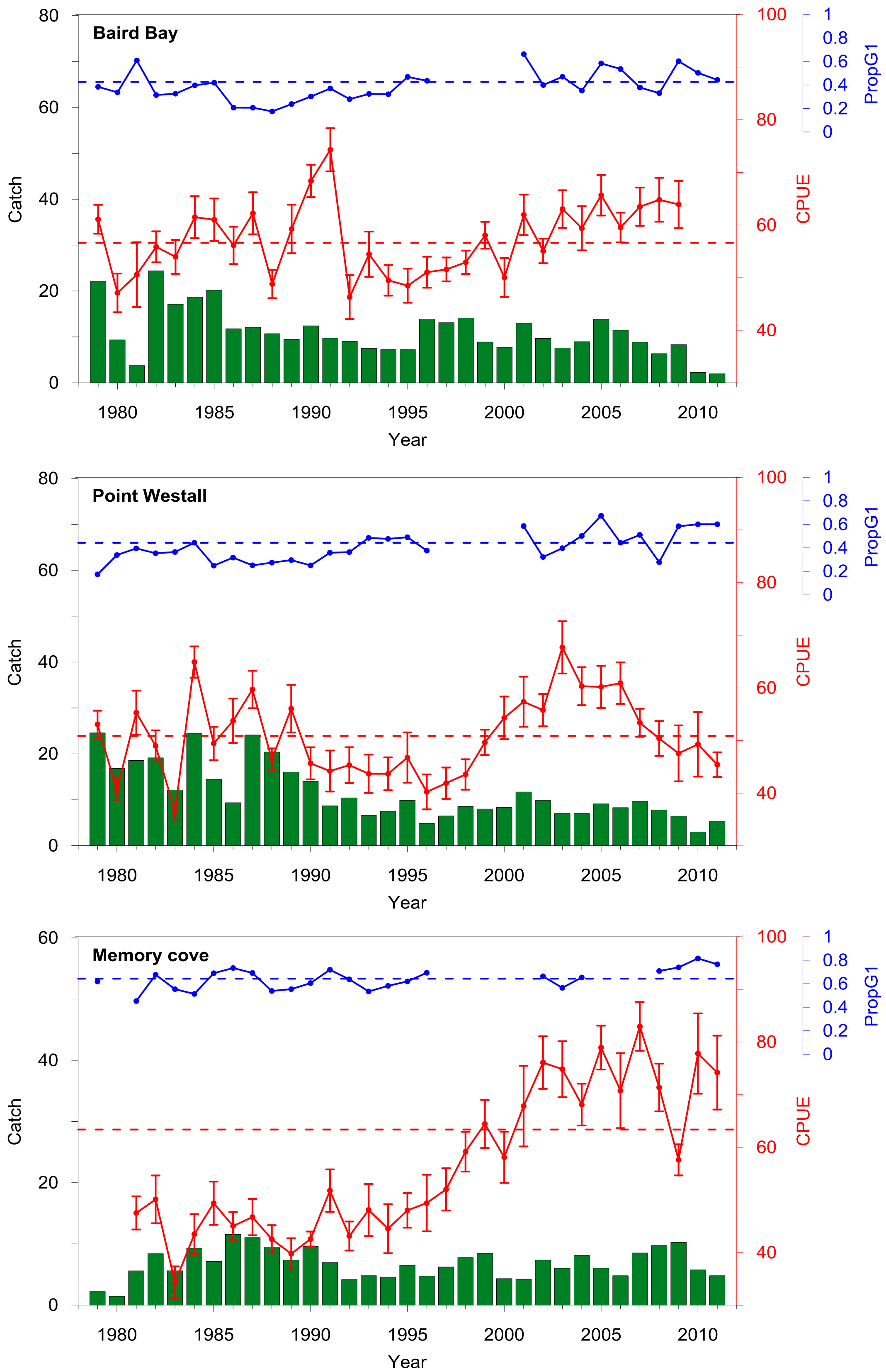

Figure 3.23. Catch (t, shell weight; green bars) of greenlip from Baird Bay, Point Westall and Memory cove from 1979 to 2011. CPUE ± se ($kg.hr^{-1}$) and PropG1 are shown in red and blue, respectively. Red and blue dashed lines show $CPUE_{90\text{-}09}$ and PropG1 $_{90\text{-}09}$, respectively.

3.4. **Risk-of-overfishing in SAUs and zonal stock status**

There were four high and seven medium importance SAUs for greenlip, with all remaining SAUs being of low importance (Figure 1.3, Table 3.1, Figure A4.1–A4.10). It was possible to determine the risk of being overfished for nine (82%) of these 11 SAUs; the inability to estimate CPUE on greenlip in Hotspot and Baird Bay in 2011, due to insufficient data (see Table 1.3), resulted in the greenlip stocks in these SAUs being categorised as uncertain (Table 3.1; Appendix A4.5 and A4.6, respectively).

Summed PI scores ranged between -13 (Flinders Island) and +10 (Memory Cove; Table 3.1). One of the four high importance SAUs (Avoid Bay) was assigned to a green, one (Flinders Island) to a red, one (The Gap) to a yellow and one to a blue (Anxious Bay) risk-of-overfishing, colour-coded category (Table 3.1; Appendix 4). The medium-importance SAUs were similarly distributed among risk-of-overfishing categories: one red (Ward Island), one green (Point Westall), one dark blue (Taylor Island) and two light blue (Memory Cove and Point Avoid). The catch-weighted zonal, score was 0.208, defining a zonal stock status for greenlip in Region A of sustainably fished (Table 3.1; Appendix 4).

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

Spatial assessment unit	%Contribution to mean total catch (WZ) over last 10 years (2002-2011)	Importance	%Contribution to catch from high & medium SAU in 2011	CPUE	%TACC	PropG1	Pre-recruit Density	Legal Density	Mortality	Combined PI score	Risk of overfishing	Catch-weighted contribution to zonal score
Anxious Bay	5.1	High	23.0	-2	5	3	-1	-1	0	4	1	0.23
The Gap	4.9	High	17.9	1	-2	1	-4	0	0	-4	-1	-0.18
Avoid Bay	3.8	High	11.1	0	0	0	0	0	0	0	0	0.00
Flinders Island	3.5	High	9.9	0	-7	2	-3	-3	-2	-13	-2	-0.20
Hotspot	3.3	Medium	-	ND	-5	ND	-	-	-	Uncertain	Not assigned	-
Ward Island	2.5	Medium	5.5	0	-3	-4	-	-	-	-7	-2	-0.11
Taylor Island	1.8	Medium	10.1	1	0	2	-	-	-	3	1	0.10
Point Avoid	1.5	Medium	14.2	3	6	0	-	-	-	9	2	0.28
Baird Bay	1.5	Medium	-	ND	-7	0	-	-	-	Uncertain	Not assigned	-
Point Westall	1.4	Medium	4.4	0	-6	5	-	-	-	-1	0	0.00
Memory Cove	1.3	Medium	4.0	3	0	7	-	-	-	10	2	0.08
Reef Head	1.0	Low		-	-	-	-	-	-	-	Not assessed	
Drummond	1.0	Low		-	-	-	-	-	-	-	Not assessed	
Fishery Bay	0.9	Low		-	-	-	-	-	-	-	Not assessed	
SW Thistle	0.8	Low		-	-	-	-	-	-	-	Not assessed	
Searcy Bay	0.7	Low		-	-	-	-	-	-	-	Not assessed	
Cape Catastrophe	0.7	Low		-	-	-	-	-	-	-	Not assessed	
Wedge Island	0.6	Low		-	-	-	-	-	-	-	Not assessed	
Venus Bay	0.6	Low		-	-	-	-	-	-	-	Not assessed	
NE Thistle	0.6	Low		-	-	-	-	-	-	-	Not assessed	
Unassigned WZ RG A	0.6	Low		-	-	-	-	-	-	-	Not assessed	
Cape Bauer	0.4	Low		-	-	-	-	-	-	-	Not assessed	
Waterloo Bay	0.3	Low		-	-	-	-	-	-	-	Not assessed	
Coffin Bay	0.2	Low		-	-	-	-	-	-	-	Not assessed	
Neptune Islands	0.2	Low		-	-	-	-	-	-	-	Not assessed	
Sheringa	0.2	Low		-	-	-	-	-	-	-	Not assessed	
Sir Joseph Banks	NA	Low		-	-	-	-	-	-	-	Not assessed	
Elliston Cliffs	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Pearson Island	0.0	Low		-	-	-	-	-	-	-	Not assessed	
Greenly Island	NA	Low		-	-	-	-	-	-	-	Not assessed	
Sum	**39.4**		**100.0**									**0.208**

3.5. **Discussion**

Greenlip comprises 43% (207 $t.yr^{-1}$) of the combined abalone TACC (i.e. blacklip and greenlip) in Region A. Stock assessments for this species use both FD and FI survey information which substantially improves their reliability.

Total catch has been stable at about 207 $t.yr^{-1}$ since 1989. The exception was the four-year period from 2006 to 2009 during which the TACC was 10% higher due to the high abundance of greenlip during that period which was clearly evidenced by rapid, zone-wide increases in CPUE and high greenlip densities observed on FI surveys (Mayfield *et al.* 2005). More recent reports demonstrated that the abundance of legal-sized greenlip peaked in the early to mid-2000s, whereafter it decreased (Chick *et al.* 2008; 2009). The rapid increases and decreases in CPUE through the 2000s were most likely the result of a strong recruitment period in the 1990s that elevated the abundance of legal-sized greenlip 6-10 years later (Stobart *et al.* 2011). This was consistent with higher abalone abundance, derived from the rapid increases in CPUE, observed during the same period on greenlip in the Central Zone of the SAAF (Mayfield *et al.* 2010) and blacklip in the WZ. The decrease in CPUE between 2008 and 2009 signalled the end of these relatively higher greenlip abundances and the TACC was returned to 207 $t.yr^{-1}$ from 2010. Consequently, the decisions to increase the TACC from 2006 to 2010 and reduce it from 2010 appear to have been both appropriate and timely.

Stobart *et al.* (2011) noted that the CPUEs in 2009 and 2010 were similar, indicating that the declines in harvestable biomass were slowing. Data presented in this report confirms that, since 2009, CPUE across Region A has been stable at $CPUE_{90\text{-}09}$ which was substantially greater than that during the 10-year period (1990-1999) immediately preceding the rapid increase in CPUE. Similar patterns were evident across most FAs. Thus, in 2011, CPUE was below $CPUE_{90\text{-}09}$ in three, above this measure in five and equivalent to $CPUE_{90\text{-}09}$ in six of 14 FAs within which it was estimable. Whilst this infers that the abundance of legal-sized greenlip in 2011 may be higher than during the 1990s, despite the large reduction in catch rates from the recent maximum in 2003, this conclusion is reliant on two key assumptions. As with blacklip, they are (1) that recent declines in CPUE are directly proportional to those of the greenlip stocks; and (2) that relationships between relative greenlip abundance and catch rates have remained unchanged over the last decade, and not been influenced by factors such as increases in effective fishing effort (e.g. effort creep as a result of diving on nitrox rather than on air). This latter assumption is more robust than the first because catch rates in dive fisheries can be hyperstable, as a result of divers targeting remnant aggregations (Shepherd and Rodda 2001; Dowling *et al.* 2004). If catch rates are hyperstable, the declines in these measures lag those of the harvested stocks, which cause reductions in harvestable biomass to be underestimated. There are other positive signs for the Region A greenlip fishery. For example, total fishing effort remained low in a historical context and PropG1 was among the highest values on record in 2011, demonstrating that there were large greenlip available for harvest to meet the ongoing market demand for this product.

Fishery-dependent data suggest the abundance of legal-size greenlip is greater than that in the mid to late 1990s. This was in contrast to most of the FI data, which indicates it was similar to this historical average and suggests that catch rates are decreasing more slowly than the rate at which harvestable biomass is declining (i.e. CPUE hyperstable). Evidence from the FI data comes from the most recent estimates of legal-sized greenlip density which, when compared to the mean density through the mid to late 1990s were lower at Flinders Island and Hotspot, higher at Ward Island and Point Avoid and equivalent to this measure at The Gap. Overall, these data suggest that there have been increases in the effective fishing effort on greenlip over the past decade and, consequently, that current values of CPUE may be overestimating stock abundance.

The current legal-sized greenlip abundance is difficult to infer because there are different inferences of greenlip stock status from the FD and FI data; it is either higher than, or comparable to, that in the late 1990s. Whilst these were consistent with application of the harvest strategy to determine zonal stock status – sustainably fished – there was evidence that current trends in catch from some greenlip stocks may not be sustainable.

There have been several substantial changes in the spatial distribution of catch among fishing grounds over recent years. The most notable was the large reduction in catch from FA 9 since 2006, with the catch from this FA in 2011 the lowest in more than 30 years. In compensation, catches from FAs 8, 12, 13 and 15 have increased. Similar patterns were evident among the SAUs. Thus, catches from Hotspot, Ward and Flinders Island SAUs have declined to values among the lowest on record, whilst catches from Anxious Bay and Point Avoid have increased. There have also been increases in catch from several low-importance SAUs including Drummond, Coffin Bay, Fishery Bay, Reef Head and Venus Bay. Among these, the most substantial increases were observed in the Drummond and Reef Head SAUs. Thus, greenlip catches have been redistributed away from FA 9 into more traditional blacklip fishing grounds (i.e. non-traditional greenlip fishing grounds); the obvious exception to this was the recent increase in catch from the Anxious Bay SAU. Therefore, the current, broad distribution of catches among fishing areas and SAUs differ from that historically, when catches of greenlip were typically harvested from fewer fishing grounds throughout Region A.

There are five SAUs (Anxious Bay, Flinders Island, Ward Island, Hotspot and Drummond) within which the data suggest the abundance of legal-sized greenlip is low and/or decreasing. These include four of the six most important SAUs for greenlip in Region A – Anxious Bay, Flinders Island, Ward Island, Hotspot – from which, cumulatively, about 24% of the greenlip catch was harvested in 2011 and 40% over the last 10 years (i.e. $C_{02\text{-}11}$). The evidence is strongest for the three SAUs in FA 9 because (1) in 2011, catches from all three SAUs in this FA were among the lowest on record, and substantially below those harvested in the mid 2000s; (2) PropG1 has declined substantially in the Ward and Hotspot SAUs over recent years; and (3) the proportion of large, legal-sized greenlip observed on FI surveys was lower at all survey sites during the most recent surveys, when compared with those evident previously. This analysis was consistent with the harvest strategy, which allocated a 'red' risk-of-overfishing category to both the Ward Island and Flinders Island SAUs. Whilst no risk-of-overfishing category could be determined for the Hotspot SAU – because CPUE could not be estimated in 2011 – this SAU was categorised as 'red' in 2010 (SARDI, unpublished data). The harvest strategy decision rules for a 'red' risk-of-overfishing category specify a minimum 30% reduction in the catch contribution from these SAUs to the TACC, based on the mean catch over the last four years (i.e. 2008-2011). Application of this decision rule to the catch contribution from the Ward Island and Flinders Island SAUs to the Region A TACC would, collectively, reduce by >7 t to about 18 t.

The Anxious Bay SAU, which has been the most important SAU for greenlip since 2002, was allocated 'dark-blue' risk-of-overfishing category by the harvest strategy because the total score across all PIs was 4. This was derived from scores of -2 (CPUE), 5 (catch as a percentage of the TACC), 3 (PropG1), -1 (density of pre-recruit-sized blacklip), -1 (density of legal-sized blacklip) and 0 (mortality). The overall score was strongly influenced by the PI value for catch, which reflects the higher catches obtained from this SAU during recent years, despite the lower CPUE obtained whilst harvesting it. Application of the harvest strategy decision rules to SAUs with a 'dark-blue' risk-of-overfishing category permits an increase in the catch contribution from them to the TACC of up to 30% of the mean catch over the last four years. However, given that (1) current catches are already among the highest on record; (2) CPUE is 10% below $CPUE_{90\text{-}09}$; and (3) the density of legal-sized greenlip observed on FI surveys halved between 2007 and 2009 and have remained low since, an increased catch contribution to the TACC from this SAU should be carefully considered.

In contrast to these five SAUs, the Point Avoid and Memory Cove SAUs were allocated a 'light-blue' and the Taylor Island SAU a 'dark-blue' risk-of-overfishing category. This outcome from the harvest strategy was consistent with the weight-of-evidence assessment which suggests that these SAUs could support additional catches. Thus, application of the harvest-decision rules for 'dark-blue' (i.e. up to 30% increase) and 'light-blue' (i.e. up to 50% increase) seem appropriate. Based on historical levels of catch, it may also be possible to harvest additional catches from the Baird Bay and Venus Bay SAUs.

In summary, the greenlip stocks in Region A appear to have benefitted from a zone-wide recruitment event that increased greenlip abundance above historical levels for approximately seven years from 2002 to 2008. This pattern was also evident for blacklip. The current legal-sized greenlip abundance is either higher than, or comparable to, that in the late 1990s. Uncertainty around current relative abundance arises because the FI data suggest that CPUE may be hyperstable and underestimate recent declines in abundance. Nevertheless, both interpretations were consistent with the zonal stock status for greenlip in Region A – sustainably-fished – obtained from the harvest strategy. Despite this broad, positive conclusion, there was evidence that the sustainability of recent catches in some fishing grounds is less certain. This is because (1) there have been several substantial changes in the spatial distribution of catch among fishing areas (and associated SAUs) over recent years (i.e. large decreases from FA 9 and increases from FAs 8, 12, 13 and 15) which represent a re-distribution of catch into non-traditional greenlip fishing grounds; and (2) there are five SAUs (Anxious Bay, Flinders Island, Ward Island, Hotspot and Drummond) – from which, cumulatively, about 30% of the greenlip catch was harvested in 2011 and 40% over the last 10 years – within which the data suggest the abundance of legal-sized greenlip is low and/or decreasing.

4. GENERAL DISCUSSION

4.1. Information, data gaps and uncertainty in the assessment

Substantial information was available to assess the greenlip and blacklip stocks in the WZ including (1) a well documented history of the management of the fishery; (2) fine-scale, fishery-dependent, catch and effort data; (3) long-term, fishery-independent survey data for greenlip at seven sites and a shorter time series for blacklip at six sites; and (4) biological data. Limited information was also available on recreational and IUU catch. In addition, this fishery assessment report for Region A is the first to provide a quantitative measure of fishery status, based on an integrated suite of performance indicators within a risk analysis framework, in accordance with the Management Plan (PIRSA 2012).

There were, however, several limitations to this assessment. First, there were no FI survey data for three high-importance blacklip SAUs. These were Venus Bay, Anxious Bay and Searcy Bay. This limits application of the harvest strategy to determine the risk-of-overfishing category for these SAUs to FD data and, subsequently, reduces the available information for determining overall stock status. Data from future FI surveys in these SAUs will overcome this limitation.

Second, decision rules are applied to all data series presented in this report (Table 1.3). These decision rules are designed to exclude outliers from analyses, thereby reducing potential bias. For example, annual estimates of the catch-weighted mean of daily CPUE for greenlip (Burch *et al.* 2011) excluded records where (1) the percentage of greenlip in the catch was <30%; (2) daily effort was <3 hrs and >8 hrs; and (3) total catch/total effort was >150 $kg.hr^{-1}$. This approach, which removed approximately 10% of daily records (Burch *et al.* 2011), was adopted because both blacklip and greenlip can be harvested, but effort is not required to be apportioned among the species, within a fishing day and followed a comprehensive comparison of the current, previous and a range of alternate decision rules to generate CPUE (Burch *et al.* 2011). Although Burch *et al.* (2011) showed that temporal trends in CPUE obtained across methods were highly correlated, and thus the previous decision rules were sufficiently robust for assessment of the stocks in Region A (Stobart *et al.* 2011), they recommended that a catch-weighted mean of daily CPUE would be more appropriate to estimate CPUE as it (1) weights each daily catch and effort record objectively; (2) removes the need to ‘subset’ the data subjectively; and (3) can be applied consistently to greenlip and blacklip abalone at multiple spatial scales across the fishery.

Third, while analyses of the catch data provide useful information on the spatial and temporal distribution of catch within individual fishing areas and hence their catch histories (Chick *et al.* 2006; 2008; Mayfield and Saunders 2008; Mayfield *et al.* 2009), interpreting these patterns is complicated because fishers may move among areas to maintain, or increase, their expected levels of catch for a range of plausible reasons. These could include technological changes in the fishing fleet (e.g. trends to larger or smaller vessels) that could restrict the number of access points along the coast, market demands for particular product types (e.g. smaller or larger size abalone) and changes in abalone abundance. We use CPUE to assess stock status, based on the assumption that changes in this measure reflect changes in the abundance of the fishable stock (Tarbath *et al.* 2005; Tarbath and Gardner 2011). We note CPUE can be strongly influenced by numerous factors, including changes in abalone abundance, diver behaviour and increasing fishing efficiency, and is often viewed as a biased index of relative abundance (Harrison 1983; Breen 1992; Prince and Shepherd 1992; Gorfine *et al.* 2002). For example, catch rates may remain high as a result of re-aggregation of abalone or improved knowledge of fishing areas by fishers, thereby masking fluctuations in population size arising from local depletion (Officer *et al.* 2001). However, decreases in CPUE in abalone fisheries are considered a reliable indicator of declines in abalone abundance, particularly where effort is consistently applied (Tarbath *et al.* 2005; Tarbath and Gardner 2011).

Fourth, we were unable to use length-frequency data to determine temporal changes in the length structure and mean length of the commercial catch in the blacklip fishery through time, in a way similar to that employed in Tasmania (Tarbath and Gardner 2011) and previously in NSW (Andrew and Chen 1997). This was because interpreting the length-frequency data in this assessment was complicated by (1) the limited degree to which the current data are considered representative of the fishery; and (2) the absence of data from 2009. The lack of robust, representative, commercial, length-frequency data increases the uncertainty in the assessment of stock status (Burch *et al.* 2010). This difficulty could be overcome by five abalone being measured from each catch bag on 70% of fishing days (Burch *et al.* 2010).

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

4.2. Current status of blacklip and greenlip

There were several similarities in the current assessment of the blacklip and greenlip stocks in Region A. First, unequivocal assessment of stock status for each species was prevented by conflicting evidence from alternate datasets. Second, rapid changes in blacklip and greenlip CPUE over the past decade are best explained by an increase in the abundance of legal-sized abalone between 2000 and 2008, as a result of elevated, zone-wide recruitment in the mid-late 1990s. However, current abundance levels, relative to those through the 1990s, differ between species. For greenlip, FD and FI data suggest that current abundance either exceeds or is equivalent to that level, respectively, whilst for blacklip these data suggest it is either similar to or lower than that reference point. Third, the harvest strategy categorised the status of both fisheries as sustainably fished, which was generally consistent with the weight-of-evidence assessments. Nevertheless, for blacklip, maintenance of the current TACC appears reliant on the re-distribution of catches from several heavily-fished, traditional fishing grounds where recent increases in catch appear unsustainable. This difference between species predominantly arises because catches of both have been re-distributed from FA 9 into key blacklip fishing grounds which, for greenlip, represent non-traditional fishing areas.

4.2.1. Blacklip

Blacklip comprise the larger component of the abalone TACC in the WZ, representing 57% (276 t) of the total catch in Region A. Current stock levels exhibit apparent stability across Region A, which was consistent with the outcome from the harvest strategy which determined the Region A blacklip fishery stock status as sustainably fished. However, there was substantial evidence that these trends may not continue because the harvestable biomass of blacklip in several key fishing grounds is likely to decline unless current catches from these areas are reduced. This is because the substantial re-distribution of catch away from FA 9 into other traditional blacklip fishing grounds was associated with low and declining CPUE and FI survey density estimates in those SAUs where catch has increased. Based on these data, blacklip stocks in the Sheringa, Drummond, Reef Head and Point Avoid SAUs, from which more than 50% of the TACC was harvested in 2011, do not appear capable of continuing to support these elevated catch levels. Consequently, ongoing monitoring, stock assessment and objective application of the harvest strategy will be crucial for (1) evaluating the sustainability of current catches in key SAUs, particularly those where catch has recently increased as CPUE decreased; (2) documenting changes in abalone abundance at SAUs such as Ward Island and Hotspot from which current catches are among the lowest on record; and (3) assessing the suitability of current and future TACCs.

4.2.2. Greenlip

Greenlip comprises 43% (207 t) of the combined abalone TACC in Region A. The current legal-sized greenlip abundance is either higher than, or comparable to, that in the late 1990s. Both interpretations were consistent with the harvest strategy, which categorised stock status as sustainably fished. In contrast to this assessment, there are some SAUs where the data suggest the abundance of legal-sized greenlip is low and/or decreasing. These are the Anxious Bay, Flinders Island, Ward Island, Hotspot and Drummond SAUs, from which, cumulatively, about 30% of the greenlip catch was harvested in 2011 and 40% over the last 10 years. As with blacklip, ongoing monitoring, stock assessment and appropriate use of the harvest strategy will be critical for (1) confirming the sustainability of current catches from key SAUs in which catch has recently increased; (2) documenting changes in greenlip abundance in SAUs such as Hotspot, Ward Island, Anxious Bay and Flinders Island; and (3) assessing the suitability of current and future TACCs.

4.3. Harvest strategy for the Region A abalone fishery

There were several difficulties with implementation of the harvest strategy in Region A. First, there were no FI survey data for blacklip in three high-importance SAUs: Venus Bay, Anxious Bay and Searcy Bay. Thus, for these SAUs, application of the harvest strategy to determine the risk-of-overfishing category relied on FD data only. This reduced the information available for categorising the risk that the stocks in these three SAUs are overfished and, subsequently, the overall stock status. To overcome this limitation, FI surveys are planned for these SAUs in coming years (see Section 4.4).

Second, there were limited commercial catch sampling data for determining the proportion of large blacklip abalone harvested, which is one of the FD PIs. Sampling from 1999 to 2011 has been sporadic and mostly limited to a few licence holders. Therefore, there is a high probability that these data poorly represent both the catch and the fishery. For example, data on PropLge for the Drummond and Reef Head SAUs in 2011 resulted in scores of +2 for this PI, despite them each being obtained from a single fishing day by one licence holder. This highlights the need for decision rules defining the inclusion of data and related appropriate levels of sampling. If future sampling comprised the measurement of five blacklip from every catch-bag (Burch *et al.* 2010) it would; (1) substantially improve the validity of the reference period and scores; and (2) eliminate the need to impose a score of -1 for this PI in future assessments where <70% of fisher days are sampled. An additional problem with this PI is that values may be influenced by factors other than stock status. For example, a change in market demand towards large or small abalone would result in changes to the value of the PI measuring the proportion of large abalone in the commercial catch. As these changes could also influence CPUE, one option to resolve this problem is the use of convincing, *a priori*, information from other sources (e.g. divers, processors) to aid interpretation of these PI scores.

Third, there were several problems associated with the PI related to catch because, to avoid TACC changes driving positive or negative scores for catch, the PI for catch was selected as the proportion of the TACC harvested from that SAU. This means that SAUs from which recent, unusually high proportions of the TACC were harvested were allocated positive scores which can substantially influence the total score for that SAU. For example, in this assessment, scores of 6 and -1 were assigned for the catch and CPUE PIs, respectively, for blacklip in the Drummond SAU, which resulted in a total score of 5 and a ‘dark-blue’ risk-of-overfishing category. This was a more optimistic interpretation of stock status in this SAU than was derived through the weight-of-evidence assessment. The same problems were also evident for blacklip in the Reef Head and Point Avoid SAUs and for greenlip in the Anxious Bay SAU.

There are several possible solutions to this problem. Firstly, the PIs could be weighted, with higher weighting allocated to CPUE and FI survey abundance. Secondly, negative scores could be allocated when the proportion of the TACC harvested from a SAU exceeds the UTRP or ULRP. Thirdly, supplementary decision rules could be used that prevent an increase in catch contribution to future TACCs when the score for CPUE is negative. The catch PI could also be scored consistently with the CPUE PI (or on the cumulative scores of remaining PIs). Thus, where the CPUE PI is scored positively (≥ 0), high proportions of the TACC (i.e. PI for catch) would similarly receive positive scores. Whilst this latter approach appears complicated, it probably provides the most defensible solution.

Despite these problems, application of the harvest strategy to both species provided outcomes that were generally consistent with the weight-of-evidence assessment used in previous assessments of this stock (Chick *et al.* 2009; Stobart *et al.* 2011), thereby supporting the catch-weighted assessment of stock status.

4.4. **Future research needs**

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

There is also a need to establish FI survey sites for blacklip in three high-importance SAUs (Anxious Bay, Venus Bay and Searcy Bay) and to continue transitioning from timed-swims to leaded-lines to improve the accuracy and precision of survey estimates for greenlip. However, cessation of the timed-swim surveys requires establishment of a predictive relationship between the survey estimates of both methods to ensure that the valuable time series of survey data from timed swims can be retrospectively calibrated against the leaded-line method and used in future assessments. Consideration should also be given to continuing FI surveys in several medium-importance SAUs with a lengthy series of survey data (e.g. Hotspot for greenlip and blacklip). This will ensure data for all PIs are available once the abalone stocks in these SAUs recover and revert to being of high importance, thereby being subject to assessment using both FD and FI data.

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

Assessment of abalone in the WZ may also benefit from (1) analysing external influences (e.g. diver, dive location, month, loss of access) on CPUE through standardisation; (2) improved estimates of the magnitude and trends in IUU catch and; (3) assessment of the direct and indirect effects of commercial harvest on the ecosystem.

5. REFERENCES

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

Andrew, N. L. and Chen, Y. (1997). Optimal sampling for estimating the size structure and mean size of abalone caught in a New South Wales fishery. *Fishery Bulletin*. 95(3): 403-413.

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

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

Brown, L. D. (1991). Genetic variation and population structure in the blacklip abalone, *Haliotis rubra. Australian Journal of Marine and Freshwater Research*. 42: 77-90.

Brown, L. D. and Murray, N. D. (1992). Genetic Relationships within the Genus *Haliotis*. Abalone of the World: Biology, Fisheries and Culture. S. A. Shepherd, M. J. Tegner and S. A. Guzmán Del Próo.

Burch, P., Mayfield, S. and Chick, R. C. (2010). A fisher-based, catch-sampling program for a large-scale, benthic molluscan fishery. *Fisheries Research*. 106(3): 535-542.

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

Caddy, J. F. (2002). Limit reference points, traffic lights, and holistic approaches to fisheries management with minimal stock assessment input. *Fisheries Research*. 56(2): 133-137.

Caddy, J. F. (2004). Current usage of fisheries indicators and reference points, and their potential application to management of fisheries for marine invertebrates. *Canadian Journal of Fisheries and Aquatic Sciences*. 61: 1307-1324.

Chick, R. C. and Mayfield, S. (2012). Central Zone Abalone (*Haliotis laevigata & H. rubra)* Fishery. Fishery Assessment report for PIRSA Fisheries and Aquaculture. South Australian Research and Development Institute (Aquatic Sciences), SARDI Publication No. F2007/000611-4. SARDI Research Report Series No. 652. 67pp.

Chick, R. C., Mayfield, S., Burch, P., Turich, S. N. and McGarvey, R. (2012). Detecting change in density and biomass of a benthic marine invertebrate following commercial fishing. *Fisheries Research*. 129–130(0): 94-105.

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

Chick, R. C., Turich, N. and Mayfield, S. (2007). Western Zone Abalone (*Haliotis laevigata* and *H. rubra*) Fishery 2. Region B. Fishery Status Report to PIRSA. Adelaide. South Australian Research and Development Institute (Aquatic Sciences), SARDI Publication No. F2007/000563-1. pdf SARDI Research Report Series No. 240. 14pp.

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

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

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

Day, R. W. and Shepherd, S. A. (1995). Fisheries biology and ecology of abalone: an introduction. *Australian Journal Marine Freshwater Research*. 46(3): 3-5.

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

Elliot, N. G., Evans, B., Conod, N., Bartlett, J., Officer, R. and Sweijd, N. (2000). Application of molecular genetics to the understanding of abalone population structure- Australian and South African examples. *Journal of Shellfish Research*. 19(1): 510.

Fleming, A. (1997). Report on the Possible Genetic Effect on Wild Abalone of Translocating Brood Stock to Abalone Hatcheries. Report to the Fisheries Branch, Department of Conservation and Natural Resources. 23**.**

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

Geiger, D. L. (2000). Distribution and biography of the recent Haliotidae (Gastropoda: *Vetigastropoda*) world-wide. *Bolletino Malacologico*. 35: 57-120.

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

Guest, M. A., Nichols, P. D., Frusher, S. D. and and Hirst, A. J. (2008). Evidence of abalone (*Haliotis rubra*) diet from combined fatty acid and stable isotope analyses. *Marine Biology*. 153: 579-588.

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

Hancock, B. (2000). Genetic subdivision of Roe's abalone, *Haliotis roei* (Grey) (Mollusca: Gastropoda) in south-western Australia. *Marine and Freshwater Research*. 51: 679-687.

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

Henry, G. W. and Lyle, J. M. (2003). The National Recreational and Indigenous Fishing Survey. 200**.**

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

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

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

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

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

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

Mayfield, S., Chick, R. C., Carlson, I. J. and Ward, T. M. (2011). Invertebrate Dive Fisheries Can Be Sustainable: Forty Years of Production from a Greenlip Abalone Fishery off Southern Australia. *Reviews in Fisheries Science*. 19(3): 216-230pp.

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

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

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

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

McShane, P. E. (1991). Density-dependent mortality of recruits of the abalone *Haliotis rubra* (Mollusca: Gastropoda). *Marine Biology*. 110(3): 385-389.

McShane, P. E. and Smith, M. G. (1991). Recruitment variation in sympatric populations of *Haliotis rubra* (Mollusca: Gastropoda) in southeast Australian waters. *Marine Ecology Progress Series*. 73(2-3): 203-210.

Miller, K. J., Maynard, B. T. and Mundy, C. N. (2009). Genetic diversity and gene flow in collapsed and healthy abalone fisheries. *Molecular Ecology*. 18(2): 200-211.

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

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

Officer, R. A., Haddon, M. and Gorfine, H. K. (2001). Distance-based abundance estimation for abalone. *Journal of Shellfish Research*. 20(2): 781-786.

PIRSA (2012). Management Plan for the South Australian commercial Abalone Fishery. Adelaide. Primary industries and Regions South Australia. http://www.fisheriescouncil.sa.gov.au/__data/assets/pdf_file/0009/168138/Draft_Commercial_Abalone_Fishery_Management_Plan_-_For_Public_Comment.pdf 85pp.

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

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

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

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

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

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

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

Sainsbury, K. (2008). Best Practice Reference Points for Australian Fisheries. Australian Fisheries Management Authority and the Department of the Environment, Water, Heritage and the Arts. 169**.**

Saunders, T. and Mayfield, S. (2008). Predicting biological variation using a simple morphometric marker in the sedentary marine invertebrate *Haliotis rubra*. *Marine Ecology-Progress Series*. 366: 75-89.

Saunders, T., Mayfield, S. and Hogg, A. (2009a). Using a simple morphometric marker to identify spatial units for abalone fishery management. *ICES Journal of Marine Science*. 66(2): 305-314.

Saunders, T. M., Connell, S. D. and Mayfield, S. (2009b). Differences in abalone growth and morphology between locations with high and low food availability: morphologically fixed or plastic traits? *Marine Biology*. 156(6): 1255-1263.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Tarbath, D. and Gardner, C. (2011). Tasmanian Abalone Fishery-2010. Hobart. Institute of Marine and Antarctic Studies. University of Tasmania. 110**.**

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

Temby, N., Miller, K. and Mundy, C. (2007). Evidence of genetic subdivision among populations of blacklip abalone (*Haliotis rubra* Leach) in Tasmania. *Marine and Freshwater Research*. 58(8): 733-742.

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

6. APPENDIX

A.1 BLACKLIP BIOLOGY

Table A1.1. Size at L_{50} (mm, shell length) for blacklip at different sites in the Western Zone. Parameters (a and b) describe the proportion of mature blacklip. 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
Hotspot	2004	5	1.0042	7.495	82.3	124	31	SARDI unpublished
Hotspot	2005	5	1.0094	5.359	94.3	192	32	SARDI unpublished
Reef Head	2001	5	0.9979	6.784	87.7	189	126	SARDI unpublished
Pt Drummond	2011	6	0.9923	6.253	99.3	222	102	SARDI unpublished
Sheringa	2004	5	1.0022	5.369	97.3	130	46	SARDI unpublished
Tungketta	2004	5	0.9942	8.135	103.0	88	37	SARDI unpublished
Ward Island	2001	5	1.0353	10.720	92.0	65	36	SARDI unpublished
Ward Island	2005	5	1.000	0.333	91.8	145	7	SARDI unpublished
West Bay	2001	6	0.9917	7.040	96.1	222	185	SARDI unpublished

Table A1.2. Relationships between shell length (SL, mm) and fecundity (F, millions of eggs) for legal sized (130mm SL) blacklip at different sites in the Western Zone. The equation is of the form $F = aSL^b$. * indicates calculations based on anterior counts only.

Site	Year	a	b	r	n	SL	F	Reference
Avoid Bay	2010	1.01E+01	2.46	0.49	15	130	1.60E+06	SARDI unpublished
Hotspot*	2005	2.00E-04	4.58	0.83	22	130	9.47E+05	SARDI unpublished
Point Drummond	2011	2.07E-02	3.59	0.70	20	130	8.07E+05	SARDI unpublished
Ward Island*	2005	1.87E-01	3.29	0.70	27	130	1.68E+06	SARDI unpublished

Table A1.3. Growth rate, k (yr^{-1}) and L_∞ (mm SL), for tagged blacklip at different sites in the Western Zone. Size ranges are shell length at time of tagging for recaptured abalone (mm), n is the number of recaptures. * indicates uncertainty over the time at liberty, therefore k and L_∞ may not represent annual growth (Geibel *et al.* 2010).

Site (Year recovered)	Year tagged	r^2	k	L_∞	Size range	n	Reference
Reef Head (2002)	2001	0.176	0.102	153.6	52-116	29	SARDI unpublished
Reef Head (2003)	2002	0.404	0.177	132.8	66-133	58	SARDI unpublished
Sheringa (2004)	2002	0.571	0.190	152.4	54-135	20	SARDI unpublished
Venus Bay (2002)	2001	0.448	0.295	152.7	66-124	54	SARDI unpublished
Venus Bay (2003)	2001	0.369	0.155	167.9	62-117	34	SARDI unpublished
Ward Is.. (2001)	2000	0.053	0.086	217.4	57-135	27	SARDI unpublished
Ward Is. (2002)	2000	0.182	0.139	150.2	67-129	18	SARDI unpublished
Ward Is. (2002)	2001	0.244	0.180	152.5	58-117	24	SARDI unpublished
Ward Is. (2005)	2004	0.363	0.172	167.4	40-153	24	SARDI unpublished
Waterloo Bay*	1969	0.911	0.406	144.0	57-150	52	(Shepherd and Hearn 1983)
West Bay (2001)	2000	0.078	0.078	244.0	59-127	53	SARDI unpublished

Table A1.4. Relationships between shell length (SL, mm) and total weight (TW, g) of blacklip abalone at various sites in the Western Zone. TW is calculated total weight for 130 mm legal-sized blacklip. The equation is of the form $TW = aSL^b$.

Site	Year	a	b	TW	r	n	Reference
Flinders Island	1998	6.7E-05	3.16	321	0.95	85	SARDI unpublished
Hotspot	2004	7.1E-05	3.19	391	0.98	124	SARDI unpublished
Hotspot	2005	3.0E-04	2.90	399	0.98	192	SARDI unpublished
Kiana	1999	3.2E-02	1.93	378	0.73	46	SARDI unpublished
Drummond Point	1998	6.2E-05	3.21	370	0.94	54	SARDI unpublished
Drummond Point	2011	6.4E-05	3.20	377	0.98	222	SARDI unpublished
Point Labatt	1999	1.4E-03	2.58	396	0.85	102	SARDI unpublished
Point Whidbey	1998	4.9E-05	3.26	387	0.97	49	SARDI unpublished
Price Island	1999	5.3E-04	2.75	345	0.83	50	SARDI unpublished
Reef Head	1999	1.1E-02	2.16	411	0.79	44	SARDI unpublished
Reef Head	2004	6.0E-04	2.72	345	0.94	63	SARDI unpublished
Sheringa	2004	2.0E-05	3.44	379	0.98	130	SARDI unpublished
Smoothpool	1999	6.0E-04	2.72	340	0.92	127	SARDI unpublished
Tungketta	2004	9.8E-05	3.12	395	0.98	88	SARDI unpublished
Waldegrave Island	1998	1.0E-04	3.05	274	0.94	100	SARDI unpublished
Waldegrave Island	2005	1.0E-04	3.06	294	0.98	94	SARDI unpublished
Waterloo Bay	2005	5.0E-04	2.77	362	0.94	162	SARDI unpublished
Ward Island	1998	3.0E-04	2.90	399	0.92	100	SARDI unpublished
Ward Island	2005	3.0E-04	2.86	329	0.98	145	SARDI unpublished
West Bay	1998	2.0E-04	2.94	331	0.95	99	SARDI unpublished
West Bay	1999	7.0E-04	2.72	386	0.89	99	SARDI unpublished

A.2 GREENLIP BIOLOGY

Table A2.1. Size at L_{50} (mm, shell length) for greenlip at different sites in the Western Zone. Parameters (a and b) describe the proportion of mature greenlip mature. The equation is of the form (f(x) = a/(1+exp(-((x-L50)/b)). N = total number sampled, *n* = number of abalone sampled within period of maturity transition.

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

Table A2.2. 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 A2.3. 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 and Baker 1998)
Thorny Passage	-1.57	0.014	(Shepherd and Baker 1998)
Waterloo Bay	-0.36	0.004	(Shepherd and Baker 1998)
Ward Island	-1.87	0.008	(Shepherd and Baker 1998)

Table A2.4. 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 A2.5. 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 and Baker 1998)
Thorny Passage	0.25	(Shepherd and Baker 1998)
Waterloo Bay	0.40	(Shepherd and Baker 1998)
Ward Island	0.13	(Shepherd and Baker 1998)

Table A2.6. Growth rate (mm yr^{-1}) (± SE) of sub-legal greenlip at different sites in the Western Zone.

Site	Size range (mm)	Growth rate (mm.yr^{-1} ± S.E.)	Reference
Anxious Bay	25-95	20.4 ± 1.5	(Shepherd and Breen 1992)
Avoid Bay	45-115	19.7 ± 2.4	(Shepherd and 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)

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Table A2.7. 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 (Year recovered)	Year tagged	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 (2000)	1999	0.302	0.343	157.0	110-156	40	SARDI unpublished
Flinders Is (Windmill 2005)	2004	0.692	0.365	162.8	64-177	153	SARDI unpublished
Hotspot (2003)	2002	0.477	0.256	213.5	63-158	120	SARDI unpublished
Hotspot (2004)	2002	0.659	0.306	181.7	63-131	53	SARDI unpublished
Maclaren Point	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 (2003)	2002	0.658	0.278	152.8	45-159	77	SARDI unpublished
The Gap (2004)	2002	0.731	0.263	155.0	44-165	108	SARDI unpublished
The Gap (2010)	2009	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 and Hearn 1983)
Yanerbie	1988*	0.642	0.268(0.076)	140.4(8.6)	62-135*	19	(Shepherd *et al.* 1992a)

A.3 BLACKLIP PERFORMANCE INDICATORS

High importance SAUs

Drummond

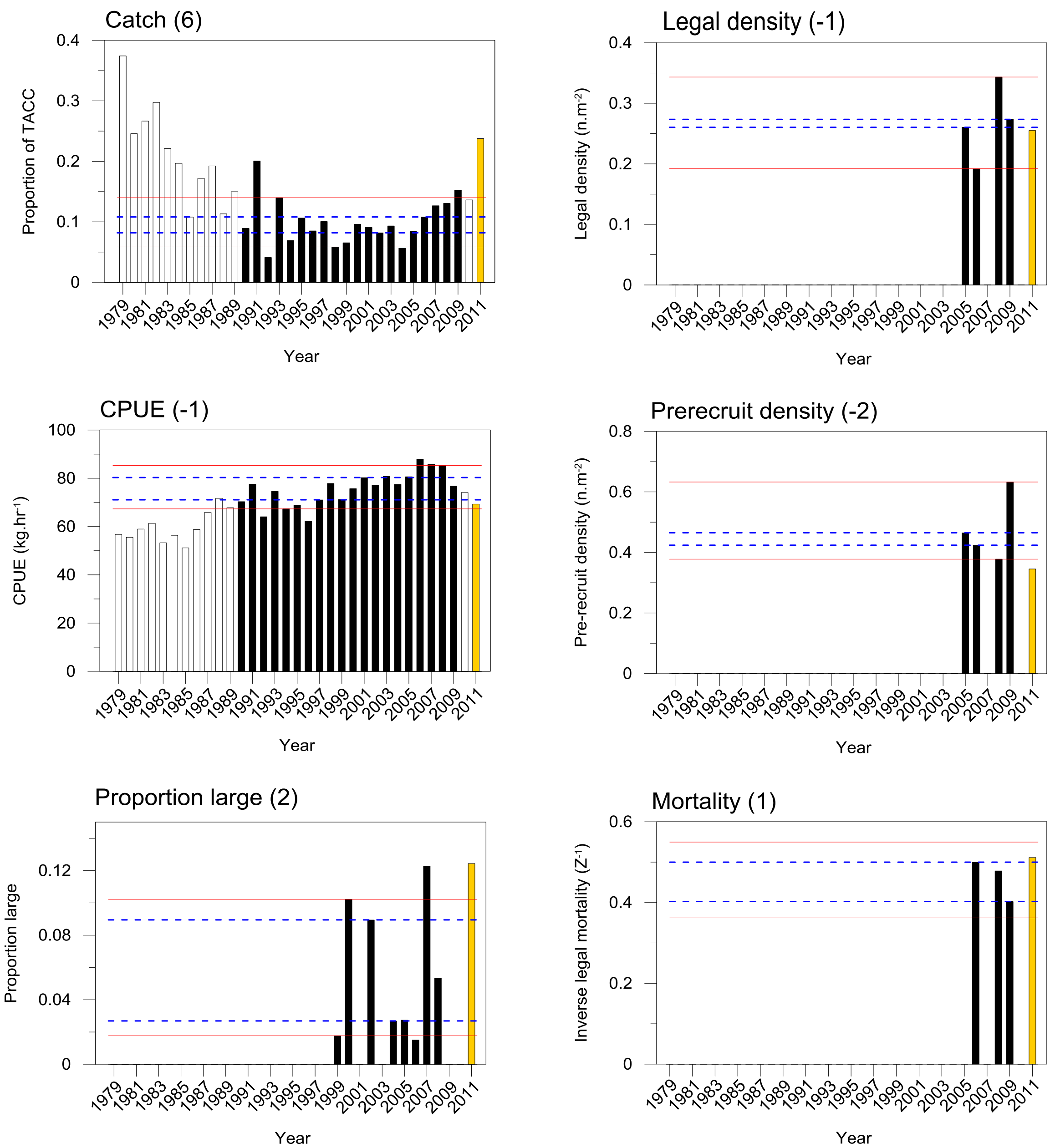

Figure A3.1. Drummond (high importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropLge, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Black 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.

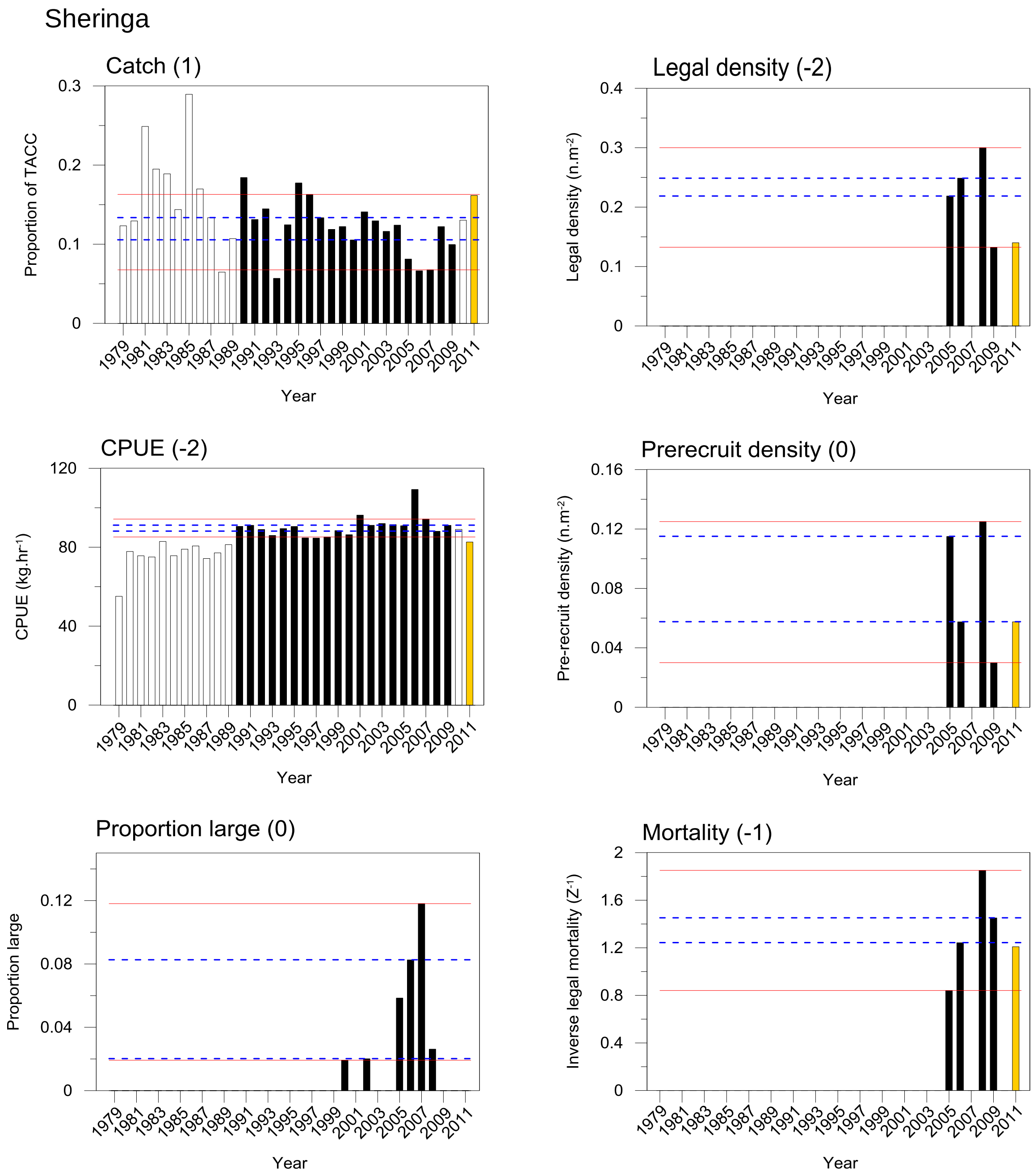

Figure A3.2. Sheringa (high importance). Performance indicators catch (Proportion of TACC), CPUE ($kg.hr^{-1}$), PropLge, legal density ($n.m^{-2}$), pre-recruit density ($n.m^{-2}$), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Black 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.

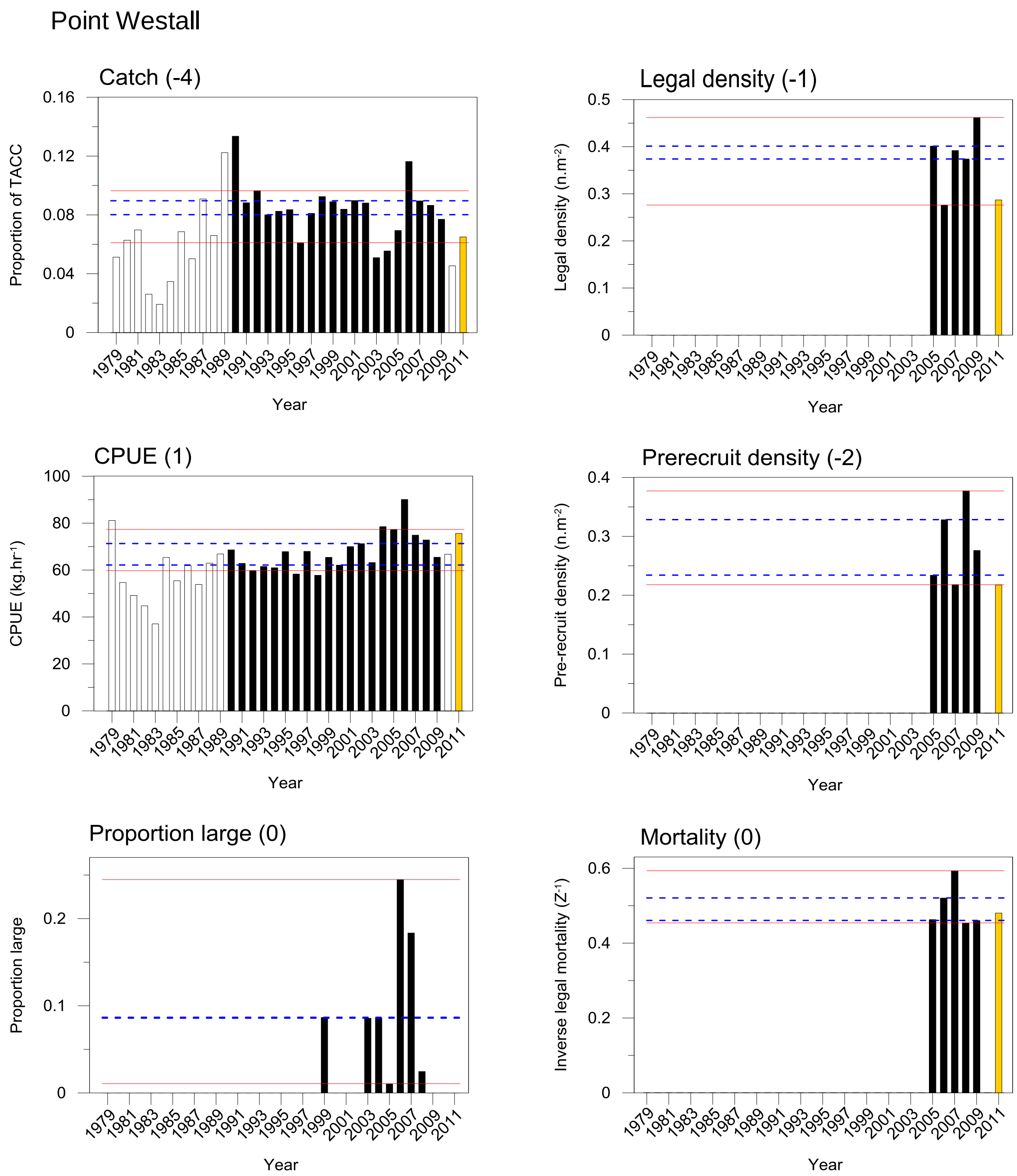

Figure A3.3. Point Westall (high importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropLge, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Black 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.

Ward Island

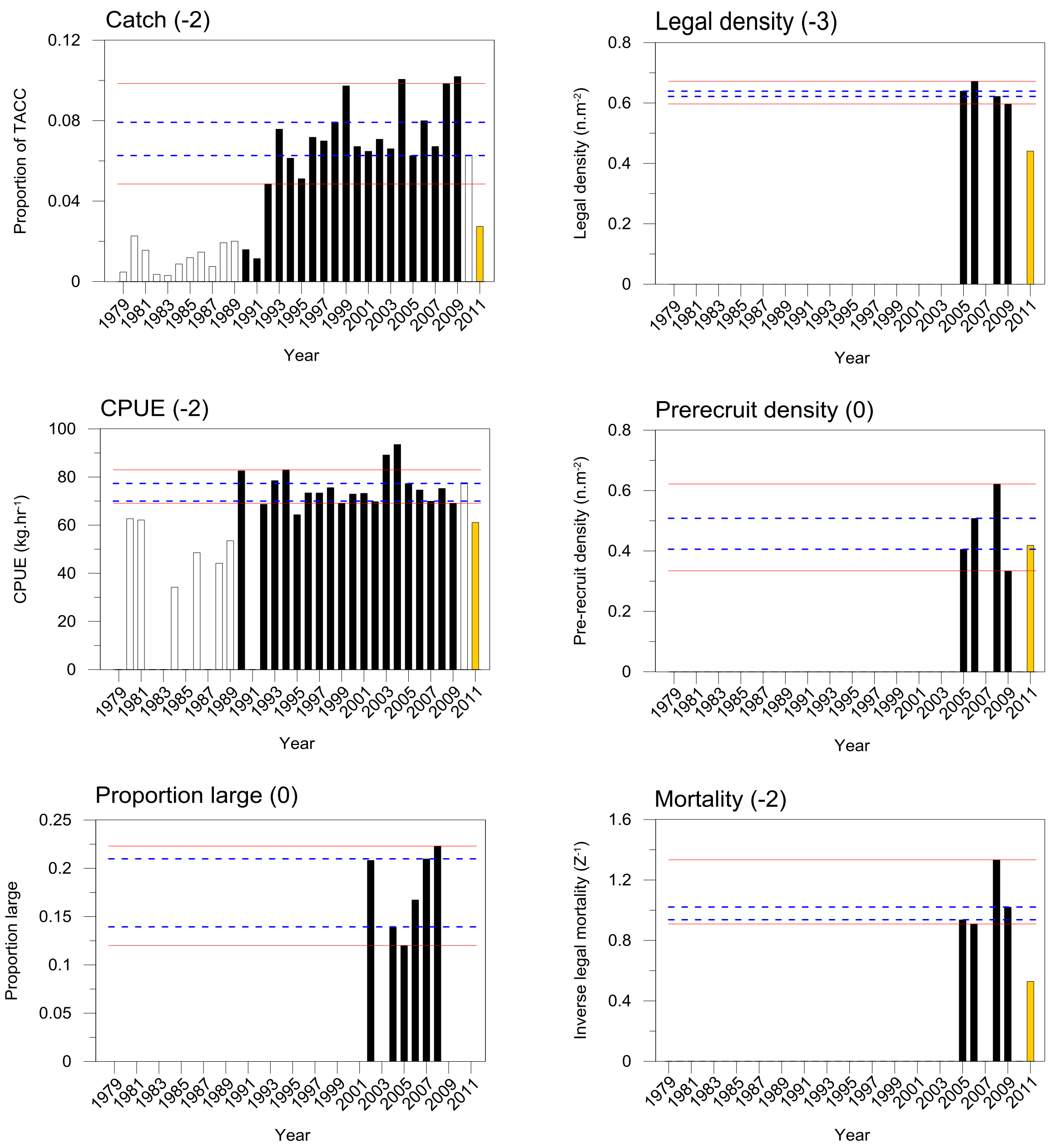

Figure A3.4. Ward Island (high importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropLge, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Black 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

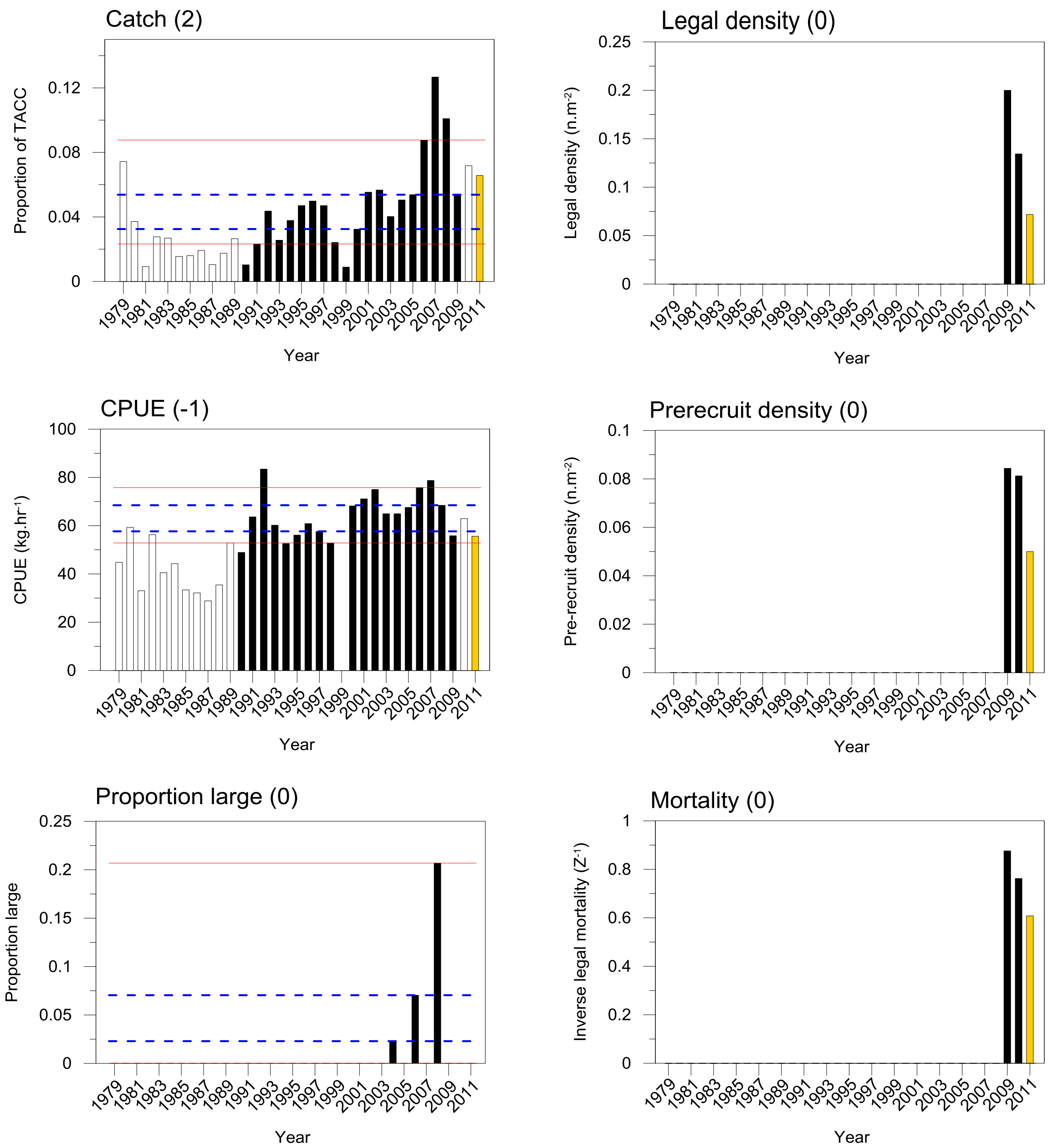

Figure A3.5. Avoid Bay (high importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropLge, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Black 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.

Searcy Bay

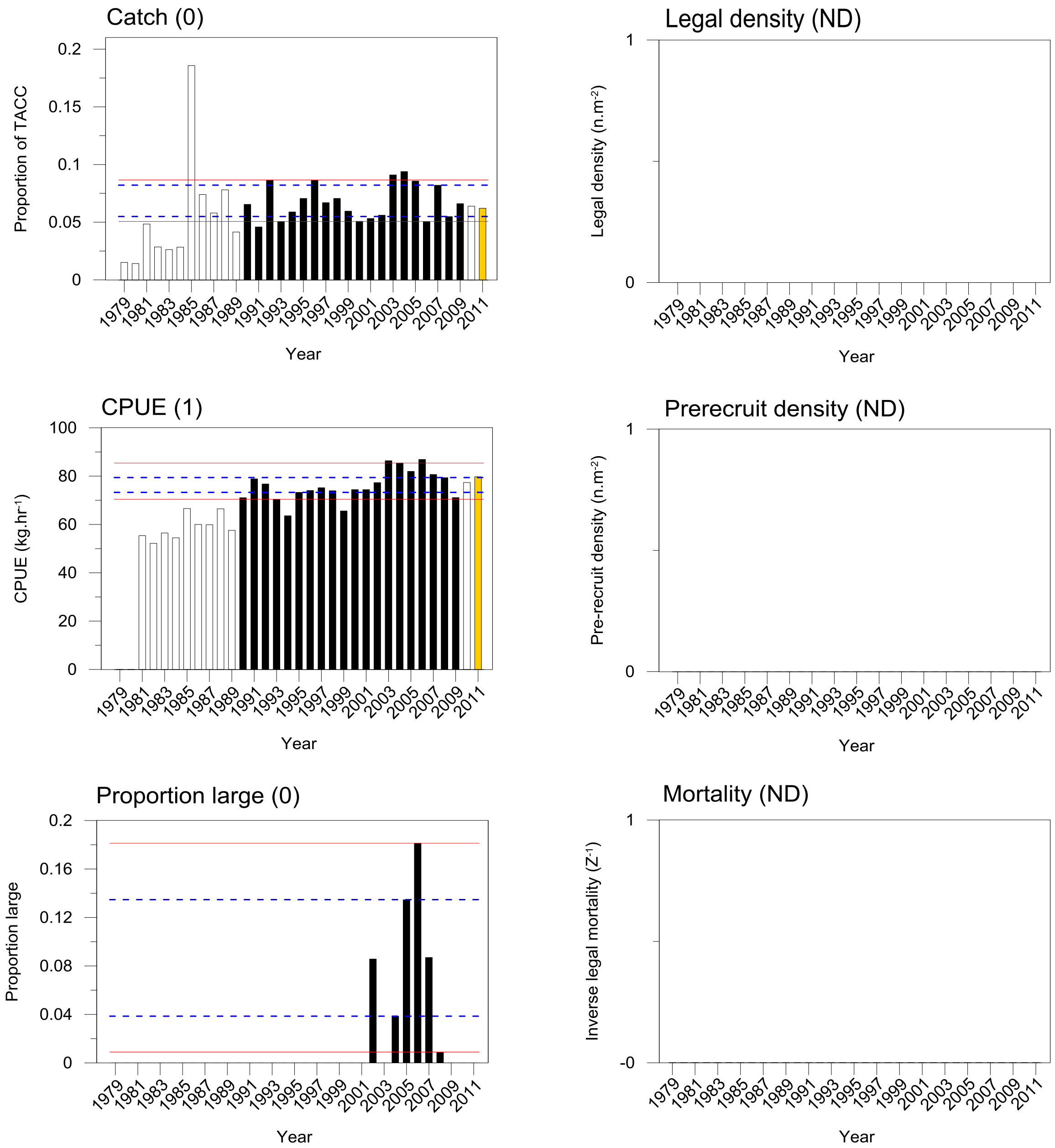

Figure A3.6. Searcy Bay (high importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropLge, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Black 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.

Venus Bay

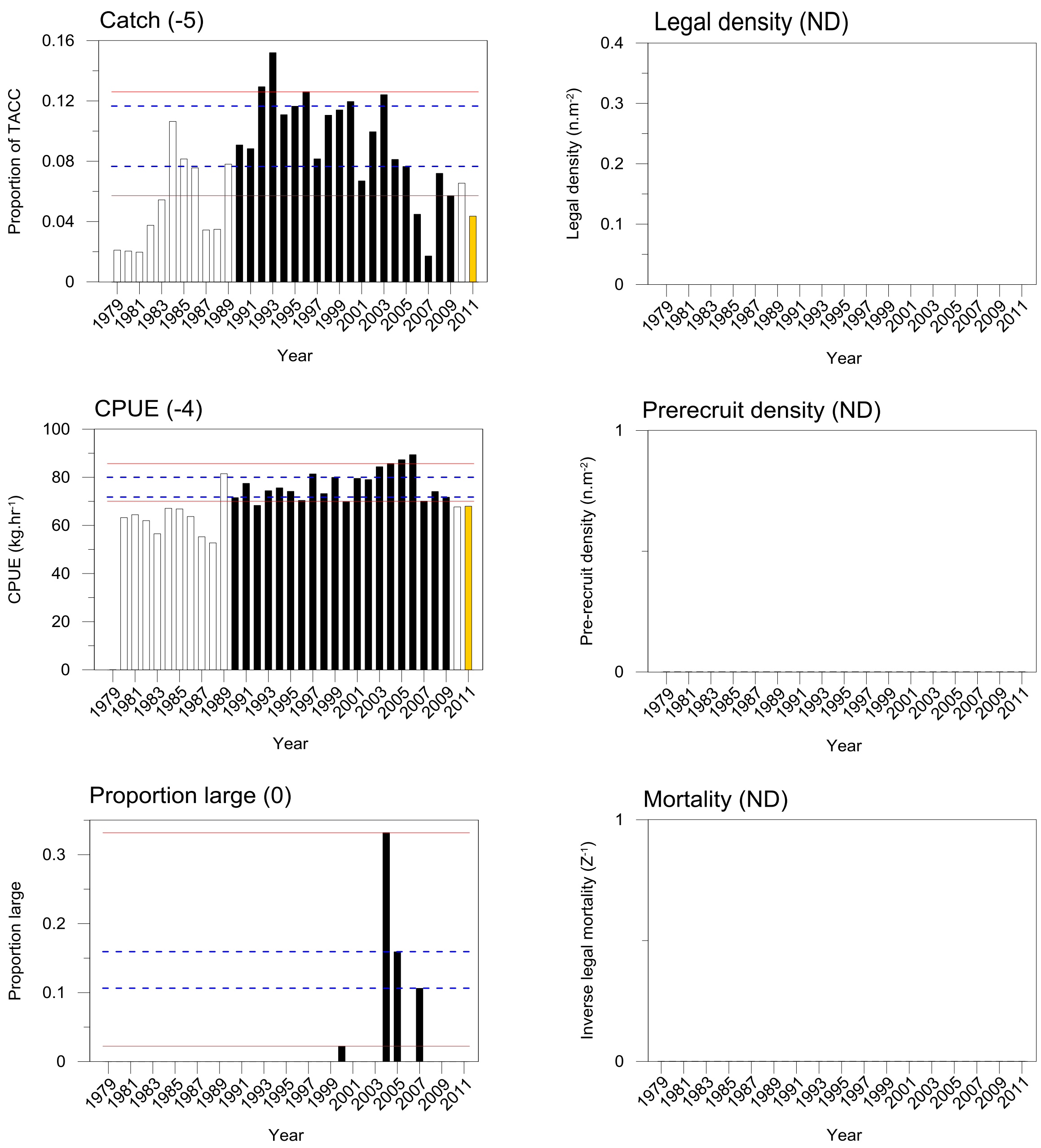

Figure A3.7. Venus Bay (high importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropLge, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Black 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.

Anxious Bay

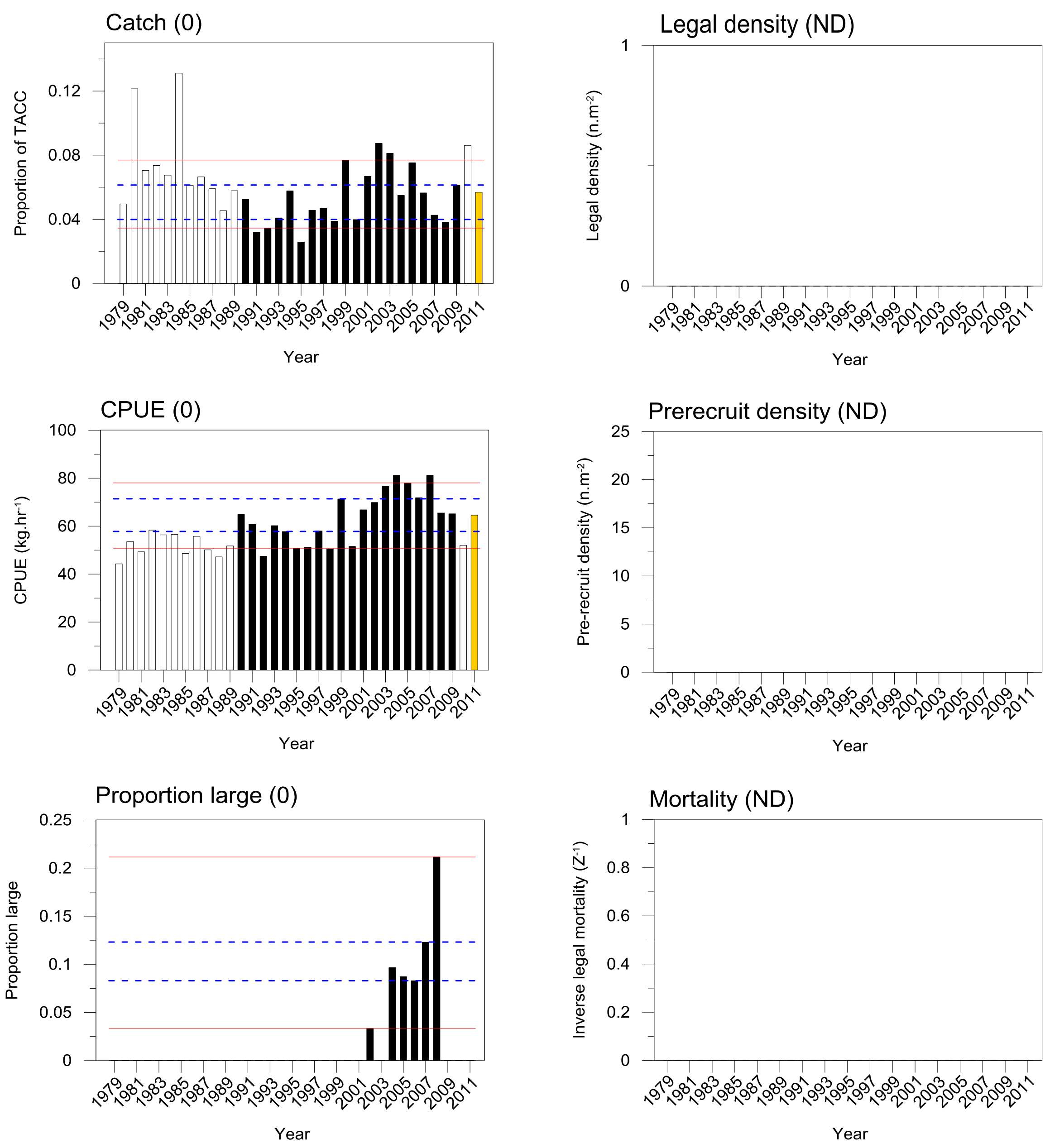

Figure A3.8. Anxious Bay (high importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropLge, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Black 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.

Medium importance SAUs

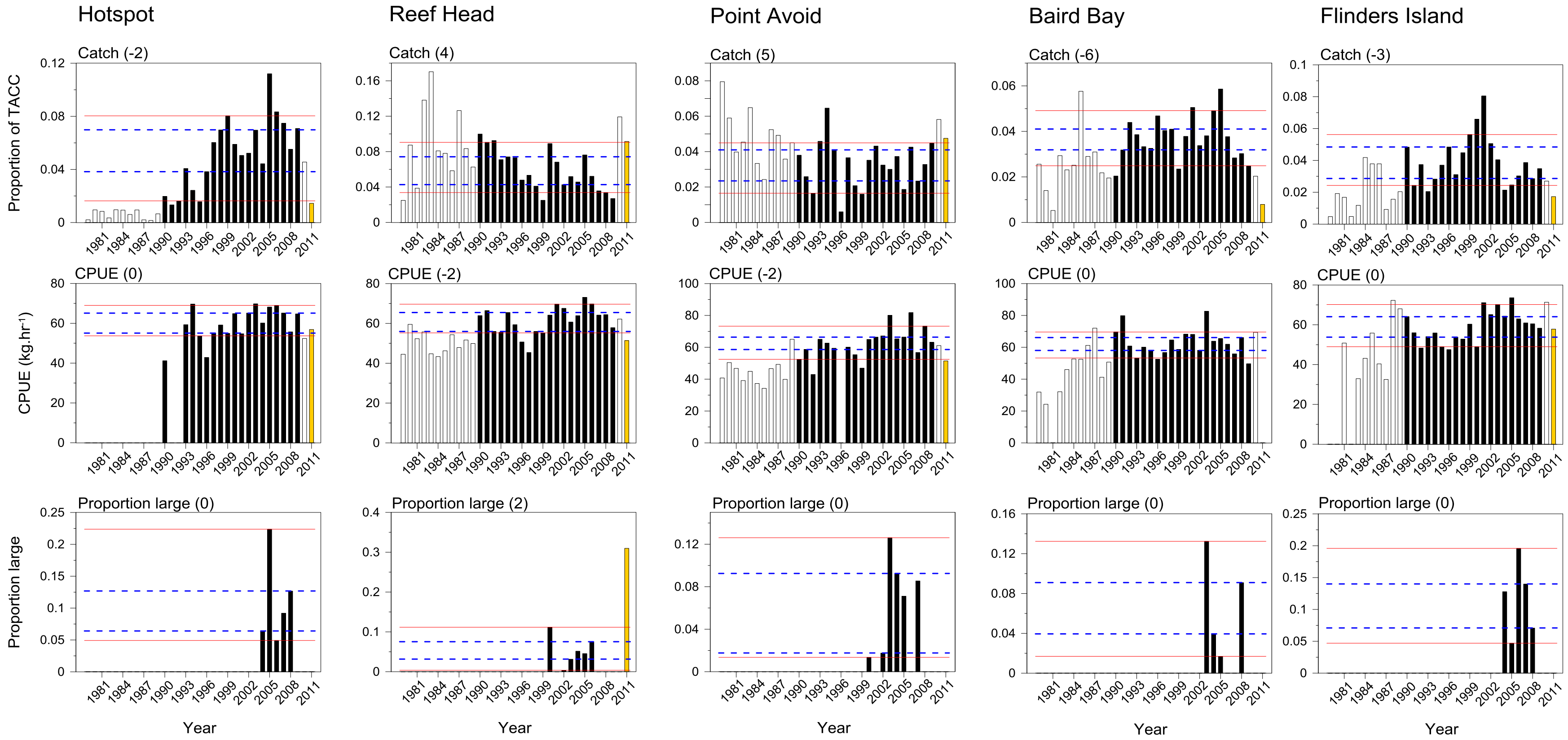

Figure A3.9. Hotspot, Reef Head, Point Avoid, Baird Bay and Flinders Island SAUs (medium importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropLge and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Black 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

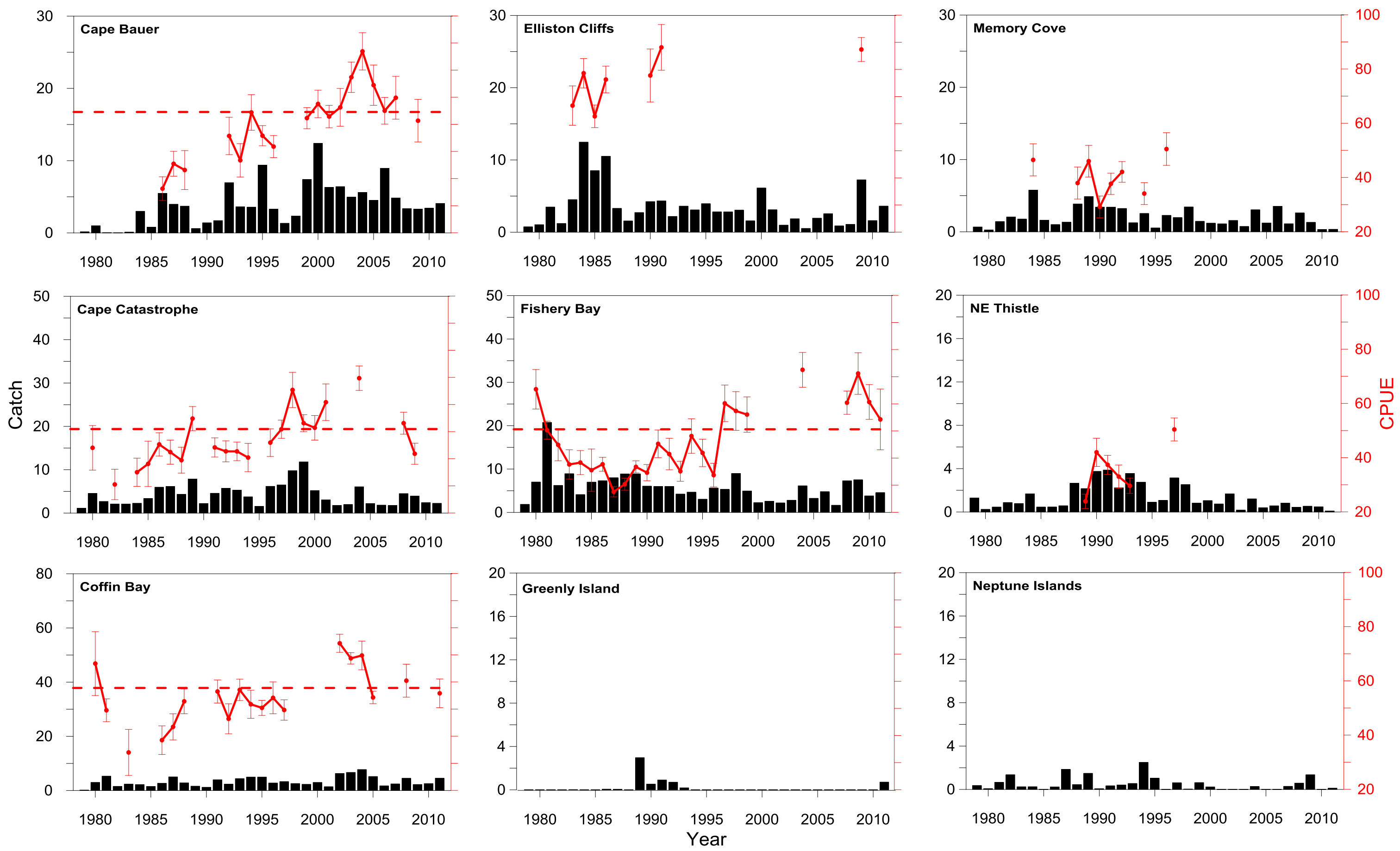

Figure A3.10. Catch (t, shell weight; black bars) of blacklip from low importance SAUs Cape Bauer, Cape Catastrophe, Coffin Bay, Elliston Cliffs, Fishery Bay, Greenly Island, Memory Cove, NE Thistle and Neptune Islands from 1979 to 2011. CPUE ± se (kg.hr^{-1}) is shown in red. Red dashed lines show $CPUE_{90-09}$ where applicable. Note catch scales vary among graphs.

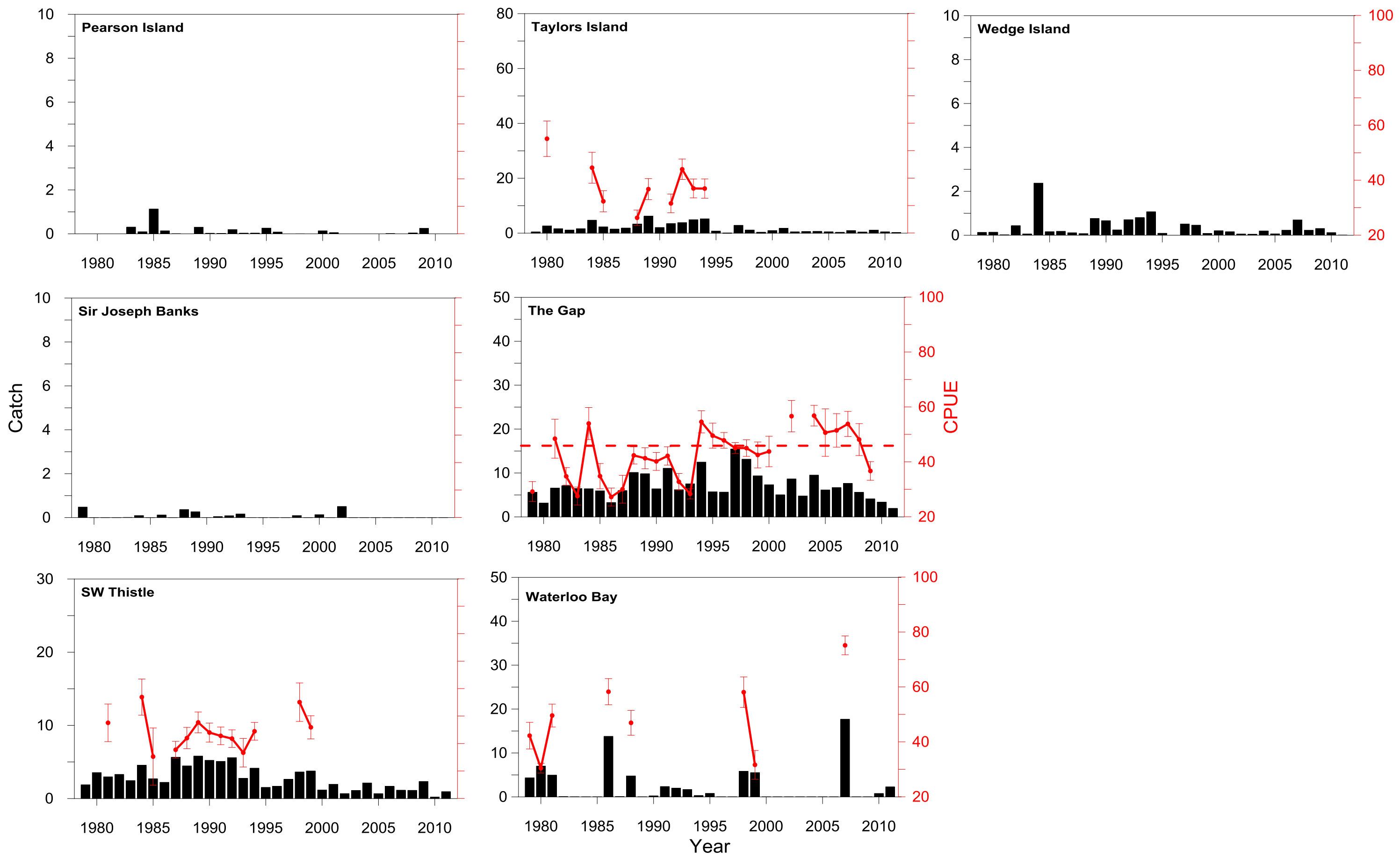

Figure A3.11. Catch (t, shell weight; black bars) of blacklip from low importance SAUs Pearson Island, Sir Joseph Banks, SW Thistle, Taylor Island, The Gap, Waterloo Bay and Wedge Island from 1979 to 2011. CPUE ± se (kg.hr^{-1}) is shown in red. Red dashed lines show CPUE$_{90\text{-}09}$ where applicable. Note catch scales vary among graphs.

A.4 GREENLIP PERFORMANCE INDICATORS

High importance SAUs

Anxious Bay

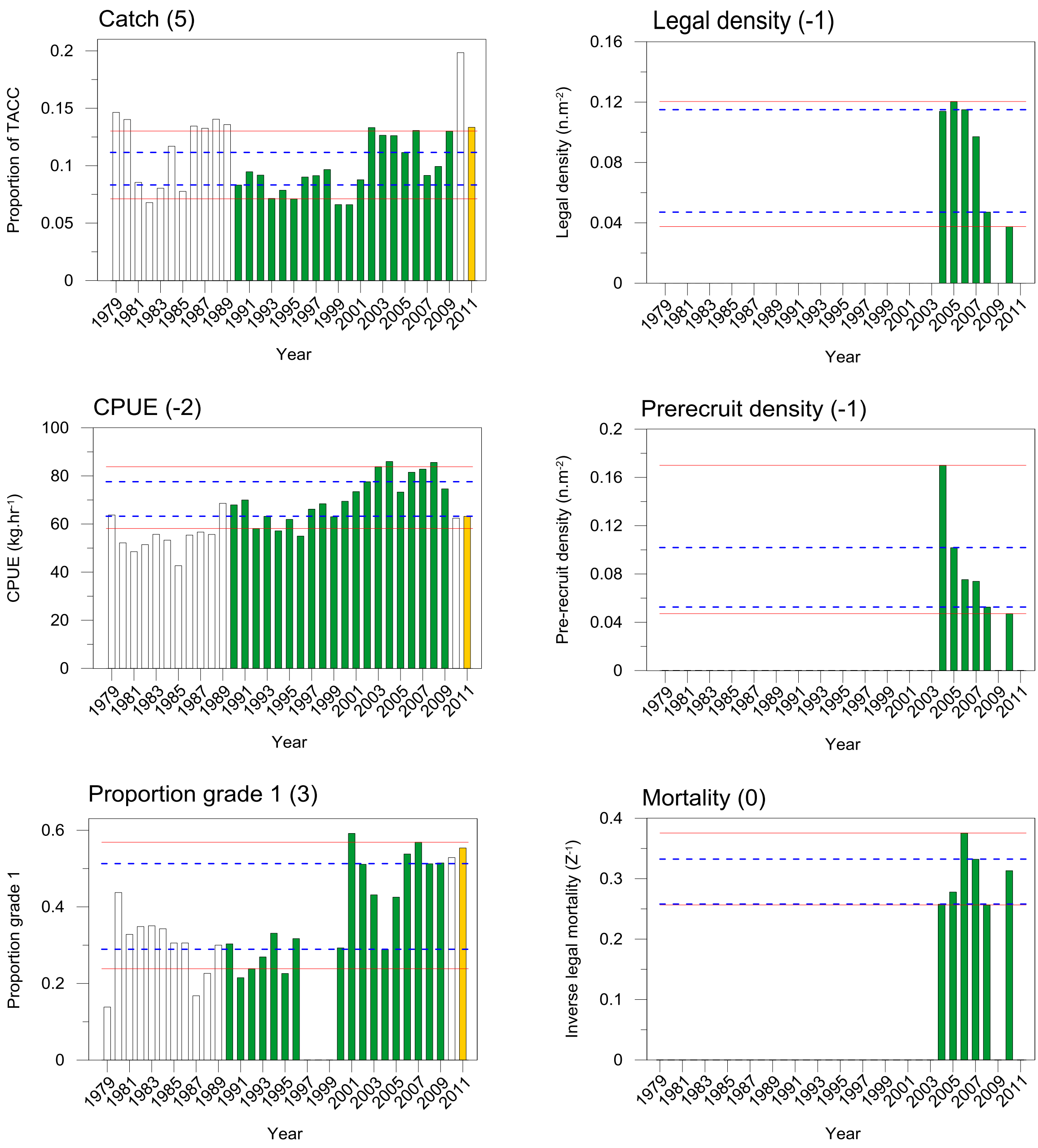

Figure A4.1. Anxious Bay (high importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropG1, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Green bars describe the data and time over which the reference points were calculated, open bars describe the measures of the PI outside the reference period and orange bars the data and year subject to assessment for each PI, i.e. the score-year.

The Gap

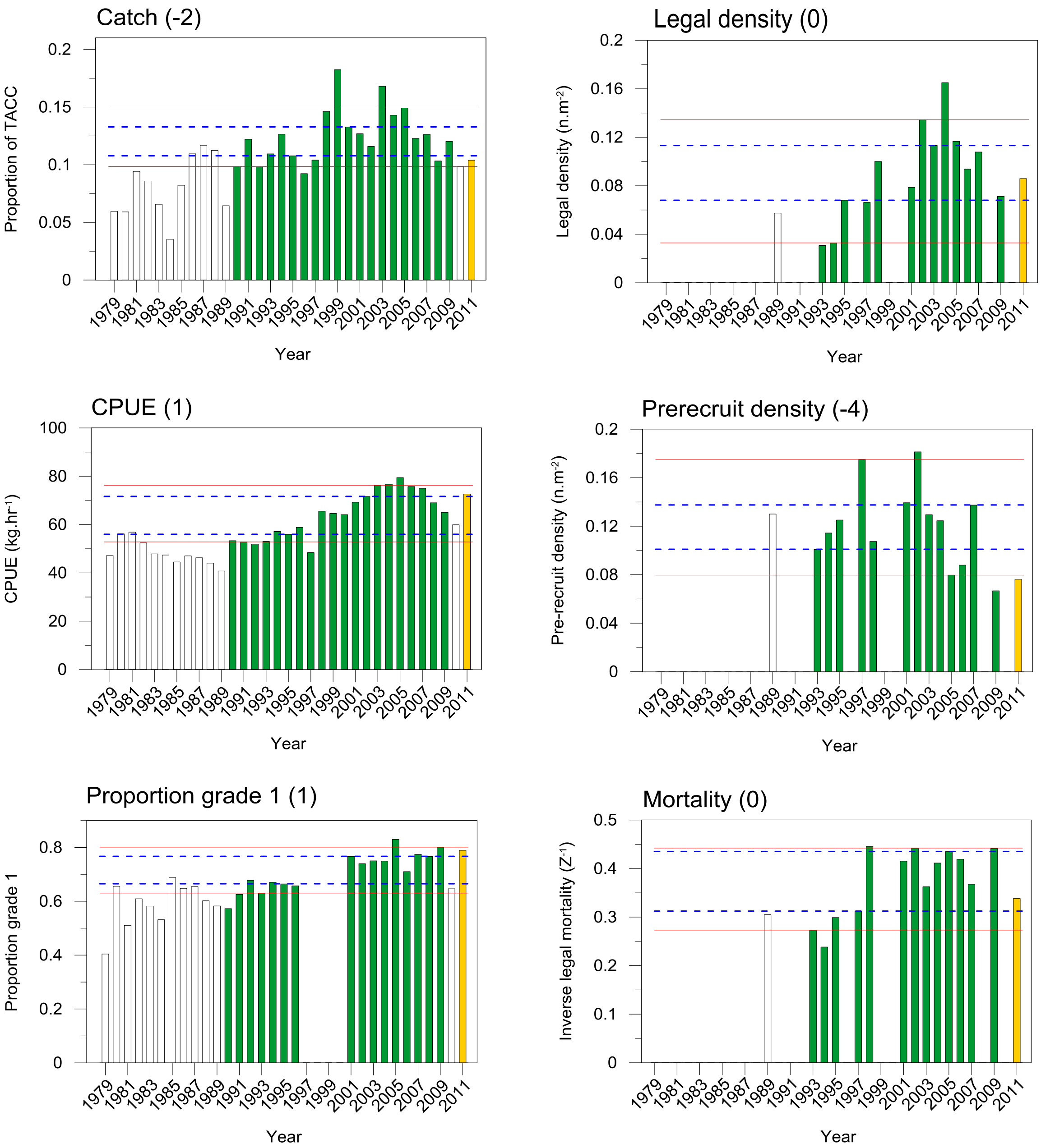

Figure A4.2. The Gap (high importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropG1, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Green bars describe the data and time over which the reference points were calculated, open bars describe the measures of the PI outside the reference period and orange bars the data and year subject to assessment for each PI, i.e. the score-year.

Avoid Bay

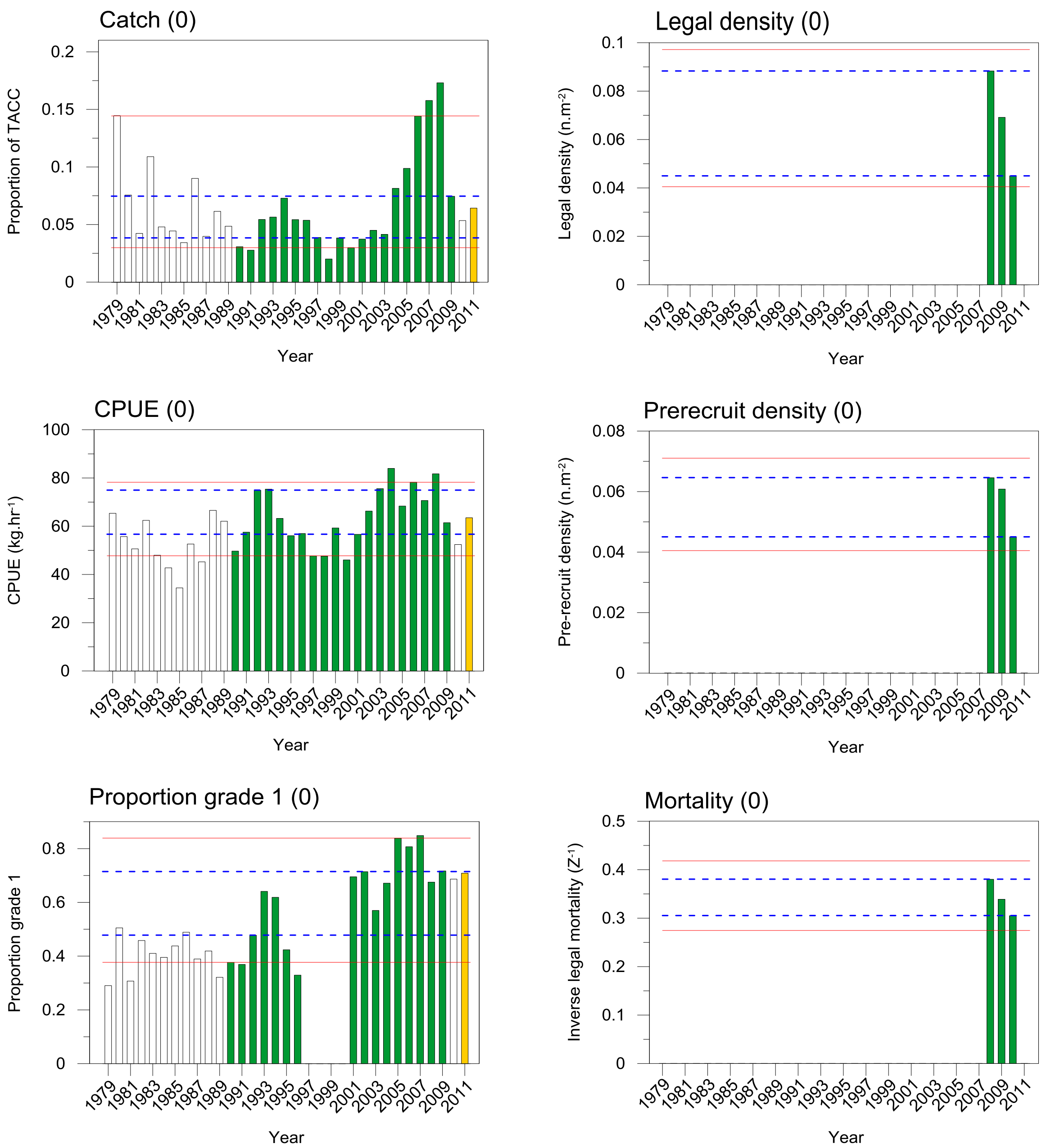

Figure A4.3. Avoid Bay (high importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropG1, legal density (n.m^{-2}), pre-recruit density (n.m^{-2}), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Green bars describe the data and time over which the reference points were calculated, open bars describe the measures of the PI outside the reference period and orange bars the data and year subject to assessment for each PI, i.e. the score-year.

Flinders Island

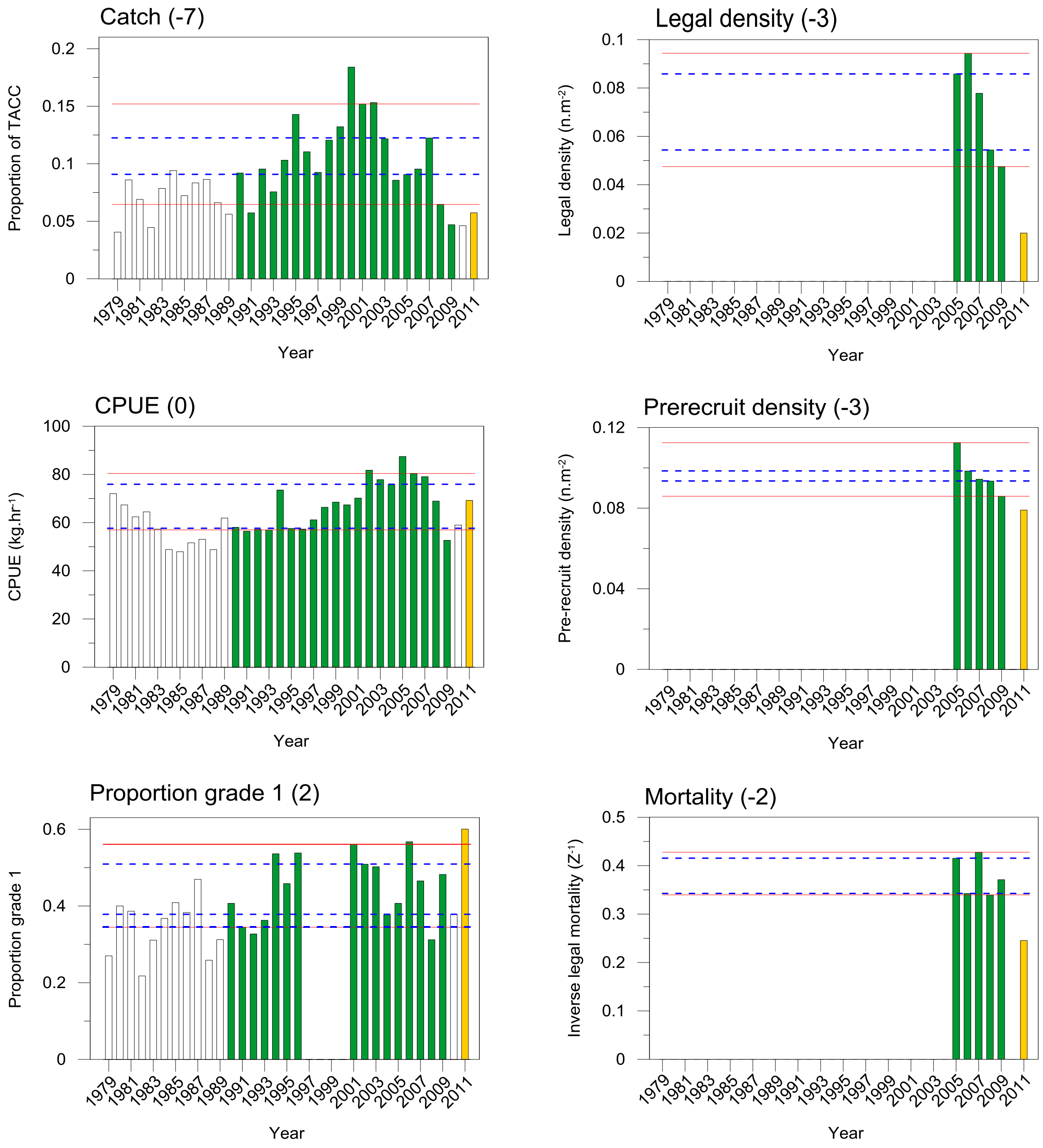

Figure A4.4. Flinders Island (high importance). Performance indicators catch (Proportion of TACC), CPUE ($kg.hr^{-1}$), PropG1, legal density ($n.m^{-2}$), pre-recruit density ($n.m^{-2}$), mortality (Z) and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Green bars describe the data and time over which the reference points were calculated, open bars describe the measures of the PI outside the reference period and orange bars the data and year subject to assessment for each PI, i.e. the score-year.

Medium importance SAUs

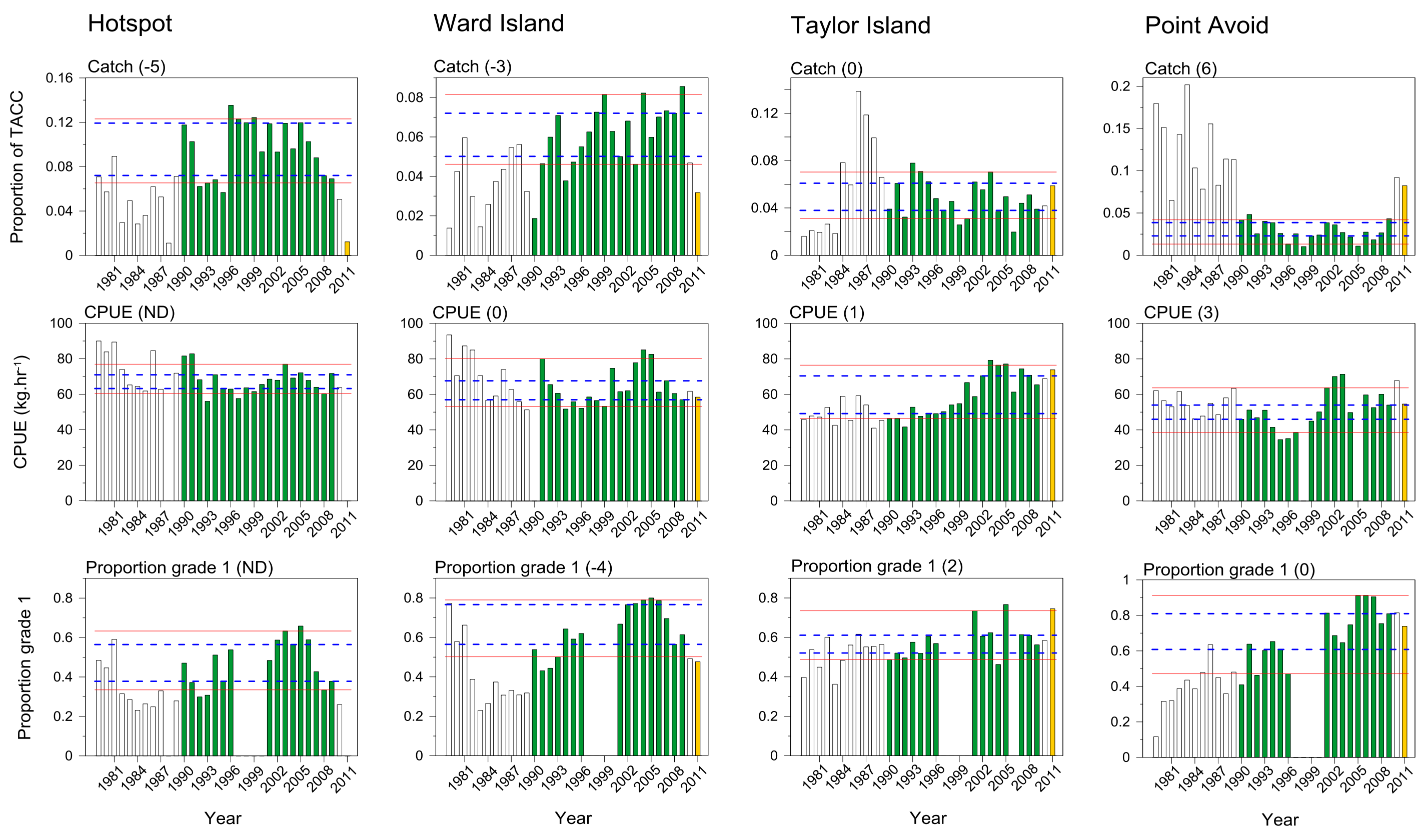

Figure A4.5. Hotspot, Ward Island, Taylor Island and Point Avoid SAUs (medium importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropG1 and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Green bars describe the data and time over which the reference points were calculated, open bars describe the measures of the PI outside the reference period and orange bars the data and year subject to assessment for each PI, i.e. the score-year.

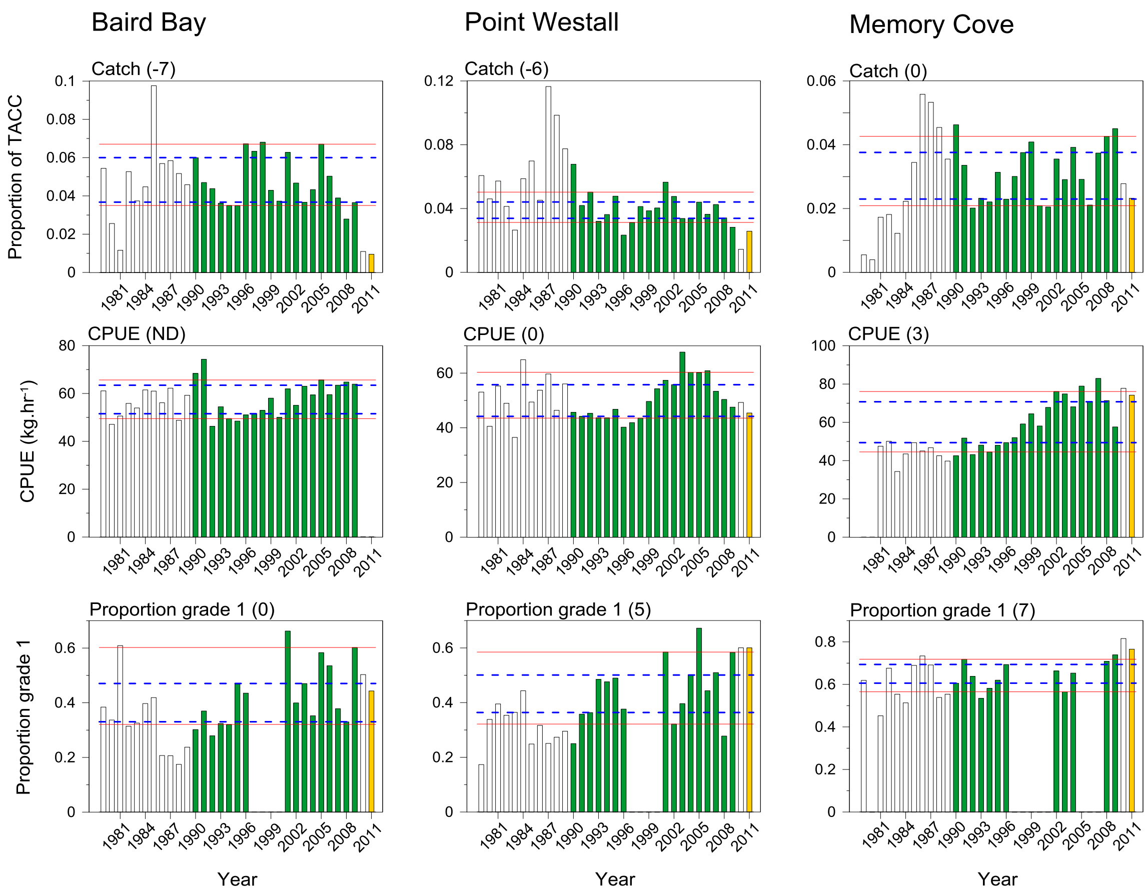

Figure A4.6. Baird Bay, Point Westall and Memory Cove SAUs (medium importance). Performance indicators catch (Proportion of TACC), CPUE (kg.hr^{-1}), PropG1 and scores from the harvest strategy. Red and blue lines are upper and lower limit and target reference points, respectively. Green bars describe the data and time over which reference points were calculated, open bars describe the measures of the PI outside the reference period and orange bars the data and year subject to assessment for each PI, i.e. the score-year.

Low importance SAUs

Figure A4.7. Catch (t, shell weight; green bars) of greenlip from low importance SAUs Cape Bauer, Cape Catastrophe, Coffin Bay, Drummond, Elliston Cliffs, Fishery Bay, Greenly Island, NE Thistle and Neptune Islands from 1979 to 2011. CPUE ± se (kg.hr^{-1}) is shown in red. Red dashed lines show CPUE$_{90-09}$ where applicable. Note catch scales vary among graphs.

Figure A4.8. Catch (t, shell weight; green bars) of greenlip from low importance SAUs Pearson Island, Reef Head, Searcy Bay, Sheringa, Sir Joseph Banks, SW Thistle, Venus Bay, Waterloo Bay and Wedge Island from 1979 to 2011. 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.