Status Report
for PIRSA Fisheries

Central Zone blacklip abalone (*Haliotis rubra*) Fishery

June 2007

Mayfield, S. and I.J. Carlson

SARDI Aquatic Sciences Publication No. RD05/0022-3
SARDI Research Report Series No. 196

Status Report
for PIRSA Fisheries

Central Zone blacklip abalone (*Haliotis rubra*) Fishery

June 2007

Mayfield, S. and I.J. Carlson

SARDI Aquatic Sciences Publication No. RD05/0022-3
SARDI Research Report Series No. 196

Title Central Zone blacklip abalone (*Haliotis rubra*) Fishery
Author(s) Mayfield, S., Carlson, I.J.

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

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

DISCLAIMER

The authors warrant that they have taken all reasonable care in producing this report. This report has been through SARDI Aquatic Sciences internal review process, and was formally approved for release by the Chief Scientist. Although all reasonable efforts have been made to ensure quality, SARDI Aquatic Sciences does not warrant that the information in this report is free from errors or omissions. SARDI Aquatic Sciences does not accept any liability for the contents of this report or for any consequences arising from its use or any reliance placed upon it.

Printed in Adelaide June 2007

Reviewers: Dr Simon Goldsworthy and Mr Paul Rogers (SARDI Aquatic Sciences)
Mr Martin Smallridge (PIRSA)

Approved by: Dr Tim Ward, Principal Scientist: Wild Fisheries, SARDI Aquatic Sciences

Signed:
Date: 8 June 2007
Distribution: PIRSA, Abalone Fishery Management Committee, SARDI Aquatic Sciences Library, CZ Abalone Fishery licence holders
Circulation: Public Domain

TABLE OF CONTENTS

EXECUTIVE SUMMARY

1. This status report updates the 2006 fishery assessment report and provides an assessment of the current status of the blacklip abalone resource in the Central Zone (CZ).

2. The fishery is concentrated in three of 12 fishing areas (26, 27 and 29) – all off Kangaroo Island.

3. For the CZ, all three measures of mean daily catch (MDC) have decreased substantially since 2000, to their lowest levels since at least 1993.

4. Strong temporal trends in MDC were also evident in the most important fishing areas. Reductions in MDC over recent years ranged between 24 and 39%.

5. CPUE in the CZ decreased substantially between 2003 and 2006. In 2006, all measures were at their lowest levels since at least 2002.

6. Fishing areas 26, 27 and 29 also exhibited strong temporal patterns in CPUE, with this metric declining substantially in each of these areas in recent years.

7. The mean length and the modal length class have both decreased and the proportion of the sample <145 mm SL has increased since 2002 in fishing area 26. Similar reductions in mean length, modal length class and the proportion of the sample >145 mm SL were also evident in fishing areas 30 and 31.

8. Estimates of retained egg production have been below 50% since 2002.

9. Nine of the 13 PIs that triggered, did so in a negative direction.

10. There is strong evidence that blacklip abalone abundance in the CZ has declined, and that the resource has weakened between 2005 and 2006. This conclusion was supported by consistent declines in CPUE and mean daily catch, reductions in the mean length and modal length class of the commercial catch in several fishing areas, and low estimates of retained egg production.

11. Consequently, it is likely that the recent, successive, substantial reductions in the TACC may be insufficient to arrest further declines in this stock.

1. INTRODUCTION

The 2006 stock assessment report for the Central Zone (CZ; Figure 1) of the South Australian abalone fishery, based on data from 1 January 1968 to 31 December 2005, concluded that the resource on which the blacklip abalone fishery was based was in its weakest position for several years (Mayfield *et al*. 2006). This conclusion was consistent with assessment reports since 2003 (Mayfield & Ward 2003, Mayfield *et al*. 2004, 2005a), and a recent stock status report (Mayfield *et al*. 2005b). There was also evidence that the resource had weakened despite the voluntary reductions in catch between 2002 and 2004, and the reduction in TACC between 2004 (42.3 t) and 2005 (29.7 t).

Concerns regarding the status of blacklip abalone stocks in previous stock assessment reports (2004 and 2005) were consistent with the perceptions of licence holders and divers in the fishery (Tokley 2004). In contrast, anecdotal observations in 2006 from a few experienced divers suggested an improvement in stock status between 2005 and 2006 (Smallridge 2006, Tokley 2006). In part response to the ambiguity between the conclusions of the 2006 stock assessment report (based on data to December 2005) and the observations of divers in the fishery during 2006, PIRSA Fisheries requested SARDI Aquatic Sciences to provide this stock status report for the CZ blacklip abalone fishery, based on data to December 2006.

The aim of this report is to assess the current status of the CZ blacklip abalone resource. It is based on data from 1 January 1968 to 31 December 2006. Following this introduction, the report is divided into three sections.

Section two documents and provides an assessment of the fishery-dependent data for blacklip abalone from 1968 to 2006. Where appropriate, this includes spatial and temporal analyses of catch, mean daily catch (MDC), catch-per-unit effort (CPUE), and the length-frequency distribution of the commercial catch.

In section three, the performance of the blacklip abalone fishery is assessed against the performance indicators and reference points identified in the management plan (Nobes *et al*. 2004). Section four is the discussion, in which the information presented in the previous sections is synthesised.

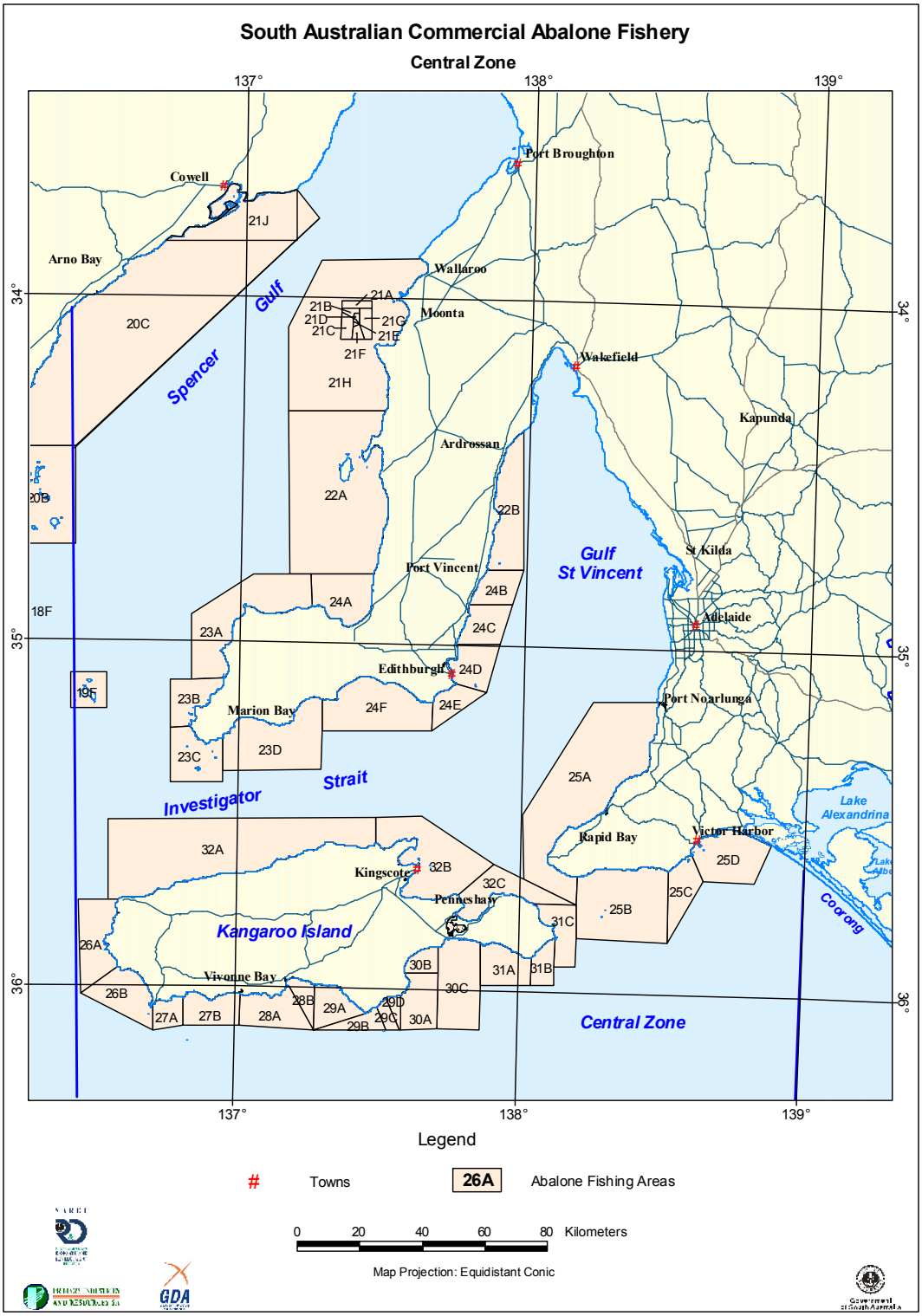

Figure 1: Fishing areas of the CZ of the South Australian abalone fishery.

2. FISHERY STATISTICS

Commercial catch and effort data for this fishery have been collected since 1968. Fishers complete a research logbook for each fishing day and submit those data to SARDI Aquatic Sciences at the end of each month. The logbook data supplied have been used to provide the spatial and temporal analyses of catch, mean daily catch (MDC) and catch-per-unit-effort (CPUE), from 1 January 1968 to 31 December 2006.

Data are provided at three spatial scales. These are (1) the whole blacklip abalone fishery (*i.e.* all areas of the CZ combined), (2) individual fishing areas, and (3) fishing areas 26 – 30 combined. These five areas comprise the principal regions of blacklip abalone harvest in the CZ, with an average of >90% of the catch being harvested from them since 2002 (Table 1).

Total catch was the sum from all commercial logbook records. Estimates of CPUE were determined using the mean ratio estimator (after Rice 1995) by using up to each of four 'decision rules' (DR; thus generating up to four measures of CPUE). These were (1) using daily records where the greenlip abalone catch was reported as zero (DR1), (2) using daily records where the blacklip abalone catch comprised at least 50% of the total catch (DR2), (3) using daily records where the blacklip abalone catch comprised at least 70% of the total catch and where fishing effort in water depths >10 m was reported as zero (DR3), and (4) apportioning reported effort against each species on the basis of their percentage contribution to the total catch (*i.e.* assuming equal catchability; DR4). The latter two DR are in addition to those used previously and were implemented to further account for the increasing catch of greenlip abalone from the principal blacklip abalone fishing areas (see Figure 2). Estimates of MDC were similarly determined, but used only up to each of the first three DR (thus generating up to three measures of MDC). Insufficient data prevented calculation of CPUE and MDC at all spatial scales for each DR. This was particularly the case for individual fishing areas (see Figures 5 and 7). Data on the length-frequency distribution of the commercial catch were obtained from shell samples provided by commercial fishers. All data are presented as mean ± 1 standard error (SE), unless otherwise stated.

2.1 Catch

Blacklip abalone catch decreased between 1970 (123 t) and 1978 (3.5 t), whereafter it increased significantly to 55.2 t in 1989 (Figure 2). Between 1990 and 2001, catches were relatively stable (40 $t.yr^{-1}$). Since 2002, catches have declined substantially. Notably, the TACC was not harvested from 2002 to 2004, with reported catches ranging between 84 and

89% of the TACC. The TACC was reduced from 42.3 t (1994 – 2004) to 29.7 t for 2005, and further reduced between 2005 and 2006 (24.3 t). Consequently, the catch in 2006 was 43% below that in 2001, and the lowest since 1985 (26.5 t).

Over the last five years (2002–2006), an average of ~80% of the blacklip abalone TACC was harvested from fishing areas 26, 27, 28 and 29 (Table 1). Levels of catch have also fluctuated inter-annually within these important fishing areas (Figure 3). For example, in fishing area 26, catches increased substantially between 1985 and 2001 (from ~5 to >20 t.yr^{-1}), whereafter they declined sharply to ~6 t in 2006. Longer-term declines in catch are evident in fishing area 29, from which catches have decreased from >12 t in 1995 to <6 t in 2006. The only fishing area within which catches have generally increased over the last decade is fishing area 28.

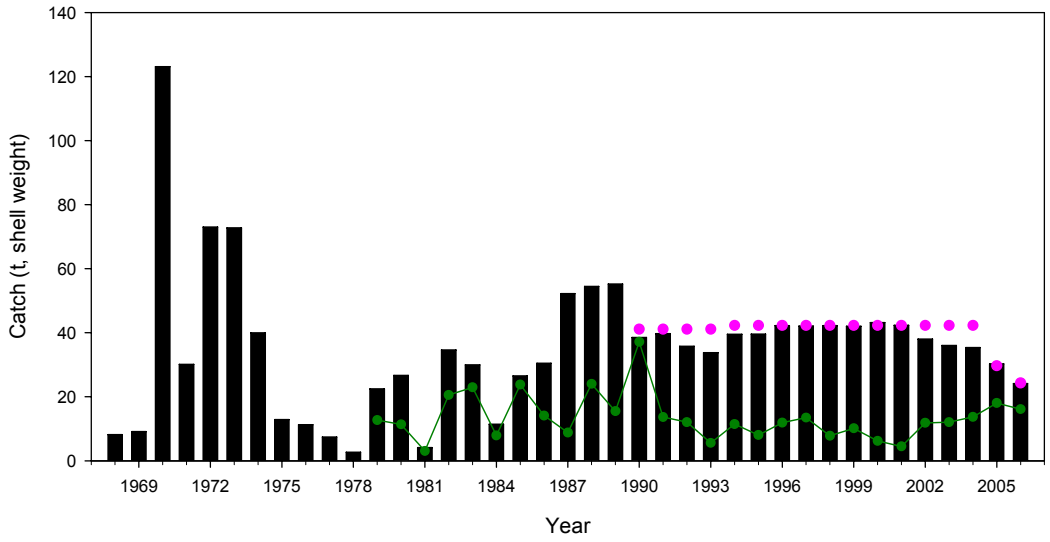

Figure 2: Catch (t, shell weight) of blacklip abalone in the CZ from 1968 to 2006 (black bars) and catch (t, shell weight) of greenlip abalone (green line) in fishing areas 26 – 30 from 1979 to 2006. Pink dots indicate the blacklip abalone TACC.

Table 1: Average catch of blacklip abalone (tonnes), % of total catch and cumulative % for the fishing areas of the CZ for the period 2002 – 2006.

Fishing area	Catch (tonnes)	%	Cumulative %
26	10.6	32.2	32.2
27	8.9	27.2	59.4
29	5.3	16.1	75.5
28	2.2	6.8	82.4
31	1.5	4.5	86.9
30	1.5	4.5	91.3
23	1.3	3.9	95.2
25	1.0	3.0	98.2
32	0.4	1.3	99.5
21	0.1	0.4	99.9
24	0.0	0.1	100.0
22	0.0	0.0	100.0

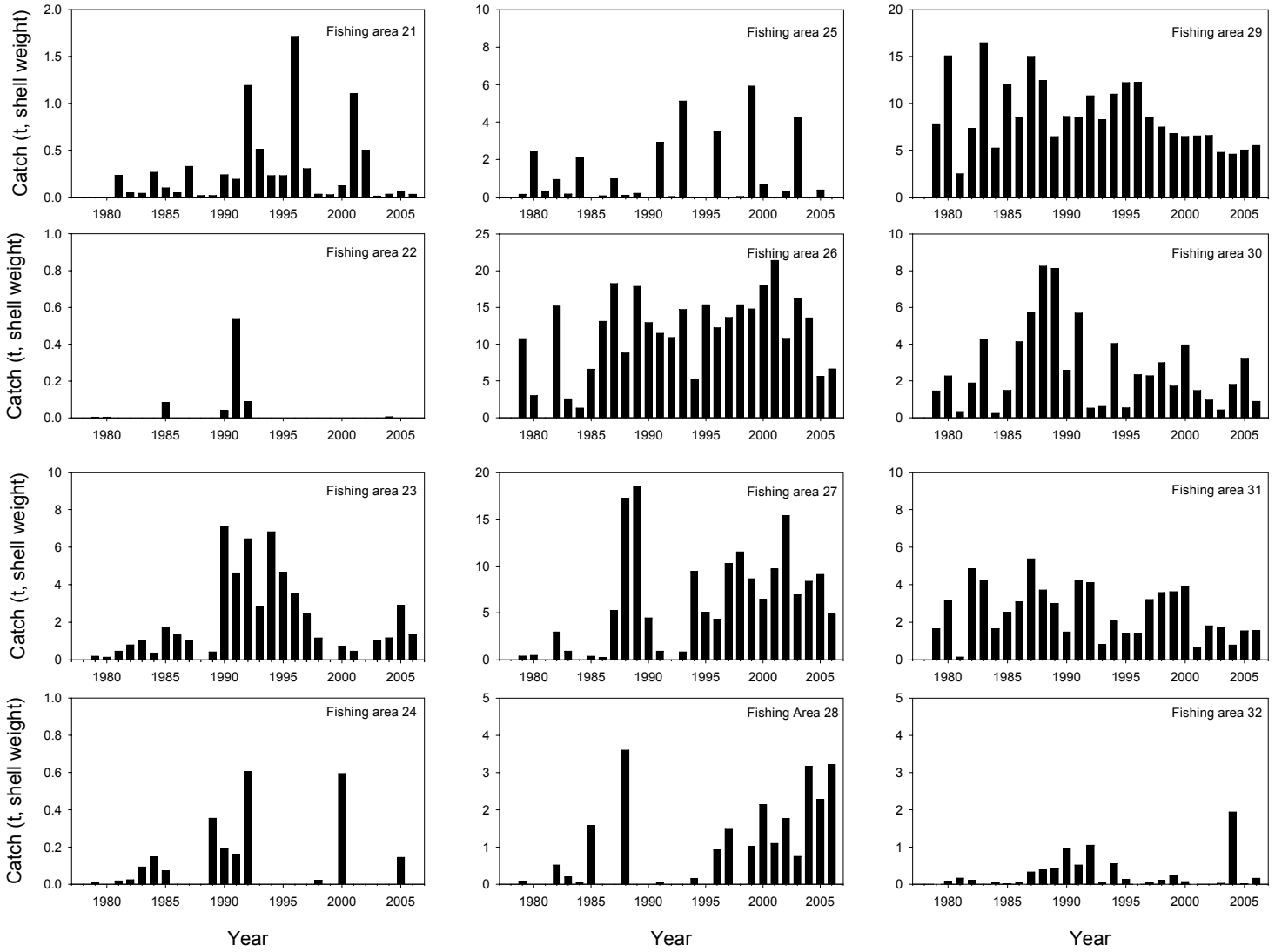

Figure 3: Catch of blacklip abalone (tonnes) in each of the fishing areas comprising the CZ from 1979 to 2006.

2.2 Mean daily catch (MDC)

There was a high degree of similarity in both the temporal pattern and magnitude of MDC among the three decision rules considered (Figure 4). This high level of consistency supports the inference that determining the MDC on blacklip abalone in the CZ from only those daily records where the blacklip abalone catch was ≥50% of the total catch is appropriate.

MDC, in all fishing areas of the CZ combined, generally increased between 1979 and 2000. Since 2000, all three measures of MDC have decreased substantially (range: 26.0 – 43.9%), to their lowest levels since at least 1993 (range: 1985 – 1993). Similar temporal patterns were evident for fishing areas 26 – 30 (Figure 4). For these areas, reductions in the measures of MDC since 2000 varied between 28.9 and 43.9%. In 2006, each was at its lowest level since at least 1997 (10 years).

There were also strong temporal trends in MDC in fishing areas 26, 27 and 29 (Figure 5). In each of these important fishing areas, MDC has declined substantially since 2000, 2004 and 2003, respectively. The reductions were greatest in fishing area 26 (29.7 and 38.9%, respectively), but exceeded 20% in fishing areas 27 (24%) and 29 (27.5%).

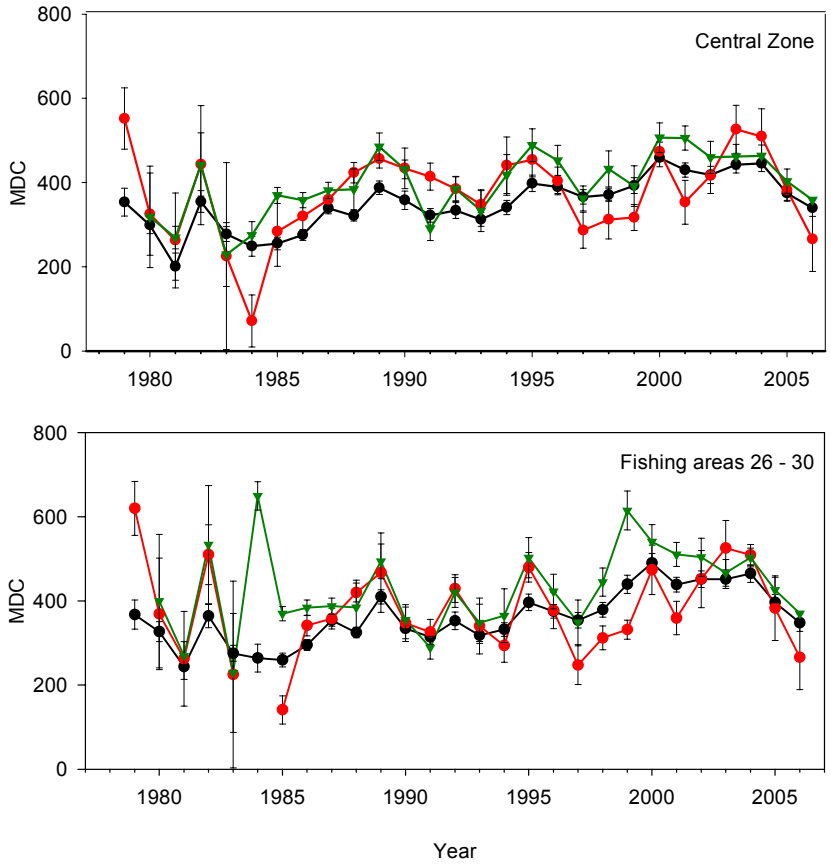

Figure 4: MDC (kg.day^{-1}) on blacklip abalone (red, black and green lines reflect DR1-3, respectively) from 1979 to 2006 for all fishing areas of the CZ combined, and for fishing areas 26 – 30 (combined).

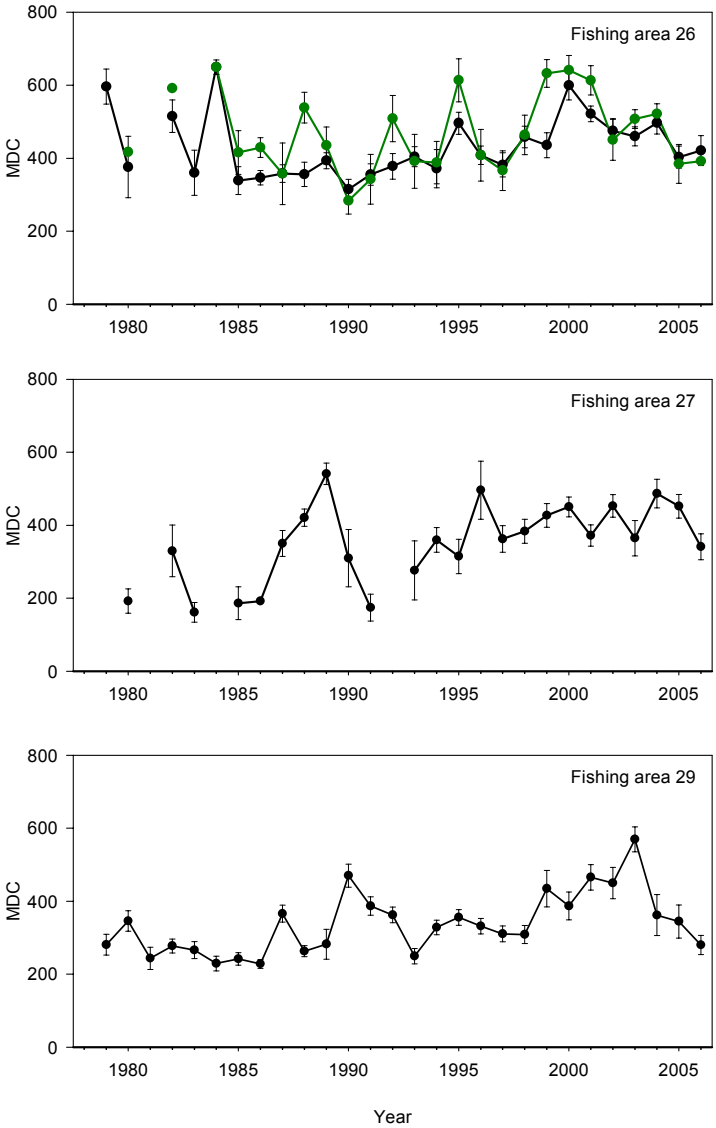

Figure 5: MDC (kg.day^{-1}) on blacklip abalone (black and green lines reflect DR2 and DR3, respectively) in fishing areas 26, 27 and 29 from 1979 to 2006.

2.3 Catch-per-unit effort (CPUE)

As with MDC, there was a high degree of similarity in both the temporal pattern and magnitude of CPUE among the four decision rules considered (Figure 6). Again, this high level of consistency supports the inference that determining the CPUE on blacklip abalone in the CZ from only those daily records where the blacklip abalone catch was ≥50% of the total catch is appropriate.

The mean CPUE, in all fishing areas of the CZ combined, increased steadily from 1979 to maximum observed levels in 1989 (Figure 6). Between 1989 and 1990 the CPUE declined sharply. From 1990 to 2003 the CPUE fluctuated inter-annually, but remaining ~10% below maximum observed levels. All measures of CPUE decreased substantially between 2003 and 2006 (range: 9.6 – 27.8%). Similar temporal patterns were evident for fishing areas 26 – 30

(combined; Figure 6). For these areas, reductions in the measures of CPUE since 2003 ranged between 11.5 and 26.1%. In 2006, each was at its lowest level since at least 2001 (range: 1997 – 2001).

Stronger temporal trends in CPUE were evident in fishing areas 26, 27 and 29 (Figure 7). Notably, in each of these important fishing areas, the CPUE has declined substantially since 2000, 2004 and 2003, respectively. In fishing area 26, all measures of CPUE have decreased substantially since 2000 (range: 13.0 – 19.2%). Both measures of CPUE in fishing area 27 increased consistently between 1996 and 2004, whereafter they have declined sharply (13.8 and 24.3%, respectively). In fishing area 29, both measures of CPUE increased substantially from 1992 to maximum observed levels in 2003, whereafter they have declined sharply. The reductions in both measures of CPUE in fishing area 29 since 2003 (>40%) are considerably greater than those observed in fishing areas 26 or 27.

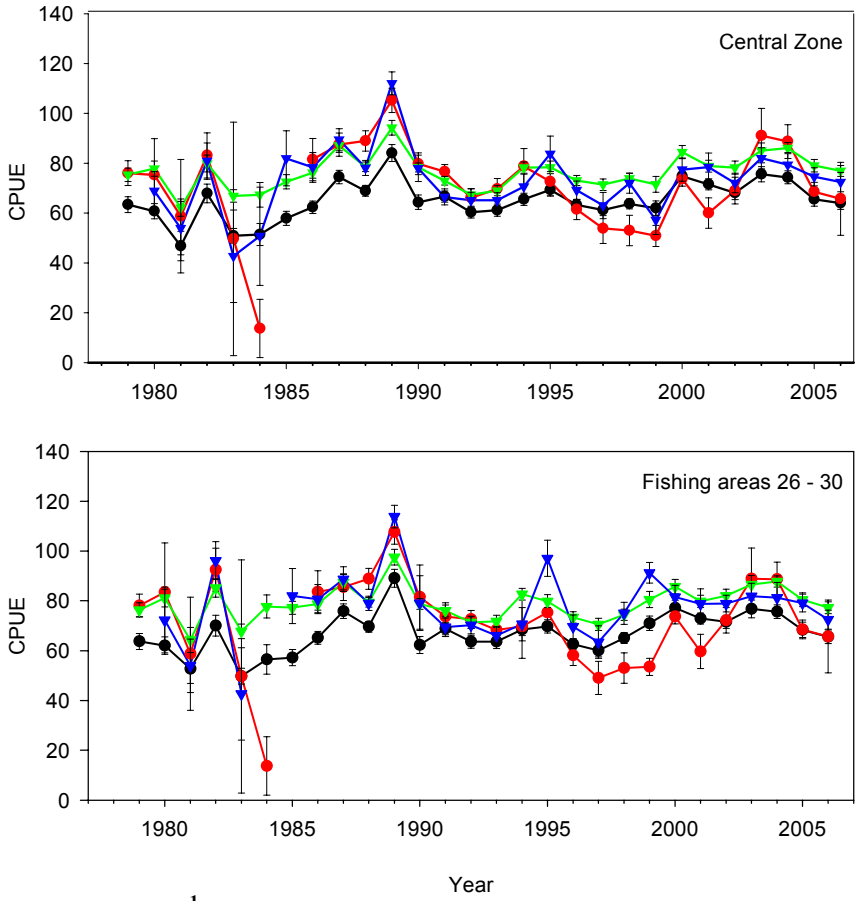

Figure 6: CPUE (kg.hr^{-1}) on blacklip abalone (red, black, green and blue lines reflect DR1-4, respectively) from 1979 to 2006 for all fishing areas of the CZ combined, and for fishing areas 26 – 30 (combined).

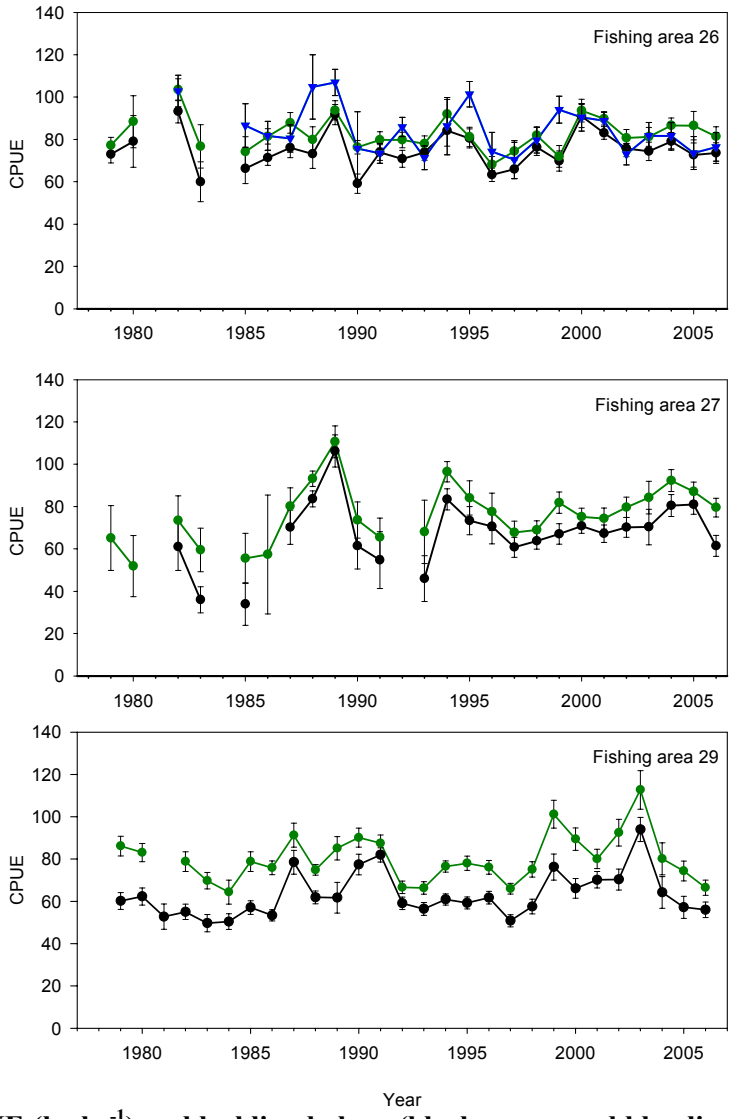

Figure 7: CPUE (kg.hr^{-1}) on blacklip abalone (black, green and blue lines reflect DR2-4, respectively) in fishing areas 26, 27 and 29 from 1979 to 2006.

2.4 Length-frequency distribution of the catch

The mean length of blacklip abalone sampled from the CZ increased between 2002 (143.5 mm shell length (SL)) and 2003 (147.5 mm SL), decreased from 2003 to 2005 (145.2 mm SL) and increased marginally between 2005 and 2006 (146.4 mm SL; Figure 8). The modal length class was 140-144 mm SL in all years. Further, although the proportion of the sample <145 mm SL increased between 2003 and 2005 (from 42.4 to 52.1%), it decreased between 2005 and 2006 (46.9%). Similar temporal patterns were evident in fishing area 27 (Figure 9).

However, in fishing area 26, the mean length has declined by >4 mm SL since 2002 (from 151.3 ± 0.6 to 147.2 ± 0.3 mm SL), the modal length class decreased from 145 – 149 mm SL (2002) to 140 – 144 mm SL (2003 – 2006) and the proportion of the sample smaller than 145 mm SL increased substantially from 24% in 2002 to >40% (2003 – 2006; Figure 9).

Similar reductions in mean length, modal length class and the proportion of the sample larger than 145 mm SL were also evident in fishing areas 30 and 31 (Figure 9).

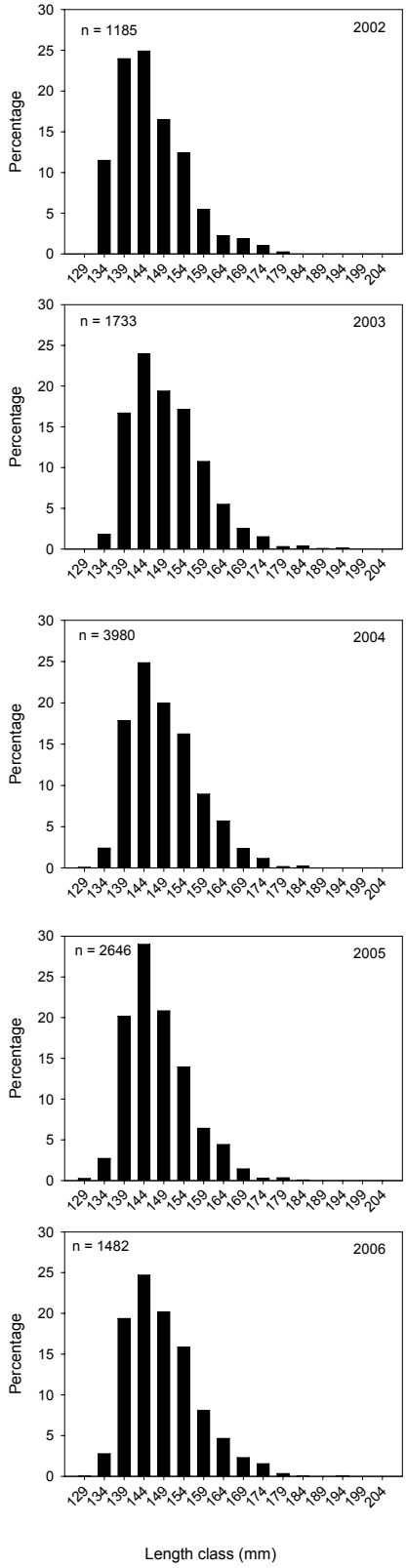

Figure 8: Length-frequency distributions obtained from measuring blacklip abalone commercial shell samples from the CZ from 2002 to 2006. Length classes are mm SL.

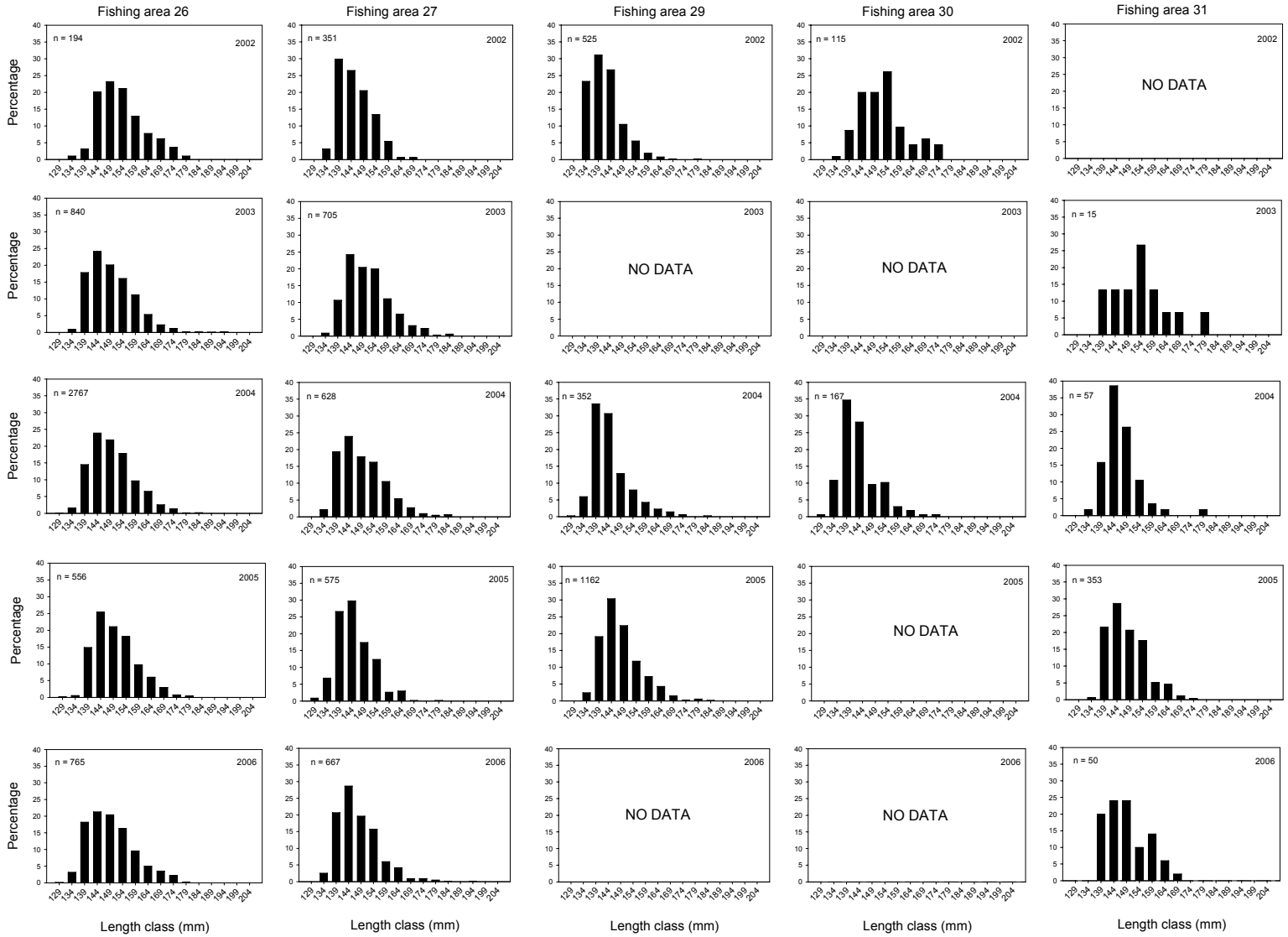

Figure 9: Length-frequency distributions obtained from measuring blacklip abalone shells from the commercial fishery in fishing areas 26, 27, 29, 30 and 31 of the CZ from 2002 to 2006. Length classes are mm SL.

3. PERFORMANCE INDICATORS

There are 63 biological PI specified for blacklip abalone in the CZ in 2006 (Nobes *et al*. 2004). Of these, 56 are addressed in this report.

Data are available to assess the performance of the blacklip abalone fishery against 30 of the 56 (54%) PI addressed in this report. Thirteen of these 30 PI (43%) have triggered (Table 2; Appendix 1). Nine (69%) of these could be considered negative for the fishery.

Fishing effort on blacklip abalone has decreased significantly from 504 hr (2002) to 322 hr (2006) over the last five years.

The proportion of the TACC harvested from fishing areas 27 and 30 declined between 2005 and 2006 (from 30.0% to 20.0% and from 10.7% to 3.7%, respectively). In contrast, the proportion of the TACC harvested from fishing areas 26 and 28 increased over the same period (from 18.6% to 27.4% and from 7.5% to 13.3%, respectively). These changes resulted in change to the composition, and sequence, of the four most important fishing areas, by catch, between 2005 and 2006.

Mean daily catch decreased significantly in fishing area 27 between 2005 and 2006, and in fishing area 29 between 2002 and 2006.

Mean daily effort decreased significantly in fishing areas 27 and 29 between 2002 and 2006.

CPUE decreased significantly in fishing area 27 between 2005 and 2006, and in fishing area 29 between 2002 and 2006.

The mean length of blacklip abalone in the commercial catch increased significantly in fishing area 27 between 2005 and 2006, but decreased significantly in fishing areas 26 and 27 between 2002 and 2006.

Estimates of egg production in fishing areas 26 and 27 were <50% of 'unfished' levels.

Table 2: Assessment of the performance of the blacklip abalone fishery in the CZ and fishing areas 26, 27, 28 and 29 against the Performance Indicators prescribed in the Management Plan.

Performance indicator	Temporal scale	CZ	Area 26	Area 27	Area 28	Area 29
Commercial catch	Annual					
Commercial effort	5-year trend					
Spatial distribution of catch	Inter-annual					
Mean daily catch	Inter-annual					
	5-year trend					
Mean daily effort	Inter-annual					
	5-year trend					
CPUE	Inter-annual					
	5-year trend					
Mean length	Inter-annual					
	5-year trend					
Egg production/pristine	Annual					

Performance indicator	Temporal scale	Cape du Couedic	Cape Bouger	Cape Gantheaume
Legal-sized abalone abundance	Inter-annual			
	5-year trend			
Sub-legal-sized abalone abundance	Inter-annual			
	5-year trend			
Abundance of abalone larger than L_{50}	Inter-annual			
	5-year trend			

Trigger Point exceeded
Significant increase
No data
Trigger Point not exceeded
Significant decrease
PI not applicable

4. DISCUSSION

The last four fishery assessment reports (Mayfield & Ward 2003, Mayfield *et al*. 2004, 2005a, 2006) provided successive, well-supported evidence that the resource on which the CZ blacklip abalone fishery is based was declining. In particular, the 2006 report (Mayfield *et al*. 2006) concluded that there was considerable evidence that the resource on which the CZ blacklip abalone fishery is based remained in its weakest position for several years. This report also provided evidence that the resource had weakened despite the voluntary reductions in catch between 2002 and 2004, and the reduction in TACC between 2004 and 2005.

A TACC of 41.1 t was introduced in 1990. It was increased to 42.3 t from 1994, and remained at this level until 2004. The TACC over this 11-year period was 25% greater than the mean catch from 1968 to 1989, and 30% greater than the mean catch from 1980 to 1989 (32.5 t). The TACC was not harvested between 2002 and 2004 – an initiative by the CZ abalone fishery licence holders to reduce their catches (Tokley 2004). The TACC was reduced by 31% between 2004 and 2005 (29.7 t), and by a further 18% between 2005 and 2006 (24.3 t). These successive reductions (18 t, 42.5%) represent the largest TACC reduction for abalone in the history of the South Australian abalone fishery.

The data presented in this report provide an additional year's information on the status of the stock. With rare exception – ostensibly limited to small increases in the mean length of the commercial catch at some spatial scales, consistent with the divers observations in 2006 (Tokley 2006) – this information re-affirms and substantiates recent assessments of the fishery. The evidence that the status of the blacklip abalone stock declined between 2005 and 2006 is persuasive. This is particularly concerning given the successive reductions in catch of blacklip abalone since 2002.

Firstly, for the CZ, all three measures of MDC have decreased substantially since 2000, to their lowest levels since at least 1993. Similar temporal patterns were evident for fishing areas 26 – 30 (combined); in 2006, each measure was at its lowest level since at least 1997 (10 years). Strong temporal trends in MDC were also evident in the most important fishing areas (26, 27 and 29). Reductions in MDC over recent years have ranged between 24 and 39%.

Secondly, all measures of CPUE for the CZ decreased substantially between 2003 and 2006. This decrease was also evident for fishing areas 26 – 30 (combined). For these areas, reductions in CPUE since 2003 varied between 11.5 and 26.1%. In 2006, each was at its lowest level since at least 2001. Fishing areas 26, 27 and 29 also exhibited strong temporal

patterns in CPUE, with this metric declining substantially in each of these areas in recent years. The recent, consistent declines in CPUE and MDC are consistent with declining stock abundance (Tarbath 2005), but the extent of decline in the fishable biomass is not well understood. Nevertheless, the contagious distribution of blacklip abalone coupled with the divers ability to target aggregations and the associated hyperstability in CPUE suggest that the decline in abundance exceeds those indicated by the data.

Thirdly, while assessment of temporal changes in the length-frequency distribution of the catch is complicated by limited data, the mean length and the modal length class have both decreased and the proportion of the sample <145 mm SL has increased since 2002 in fishing area 26. Similar reductions in mean length, modal length class and the proportion of the sample >145 mm SL were also evident in fishing areas 30 and 31. These data suggest an increase in fishing pressure over recent years.

Fourthly, estimates of retained egg production for each fishing area have been below 50% since 2002 (Mayfield *et al*. 2006 and this report). These levels of egg production could be considered insufficient to sustain long-term exploitation at current catch levels (Shepherd & Baker 1998). Finally, nine (69%) of the 13 PI that triggered, did so in a direction that could be considered negative for the fishery.

The continuation of the downward trends observed in recent years is of further concern because spatial and temporal patterns in catch suggest that blacklip abalone have a limited and 'patchy' distribution in this Zone. For example, since 2002 >75% of the blacklip abalone TACC was harvested from three fishing areas (26, 27 and 29) – all off Kangaroo Island. Catches from most other areas have been sporadic, suggesting that substantial blacklip abalone populations in areas other than off the south-western corner of Kangaroo Island are rare. There are also strong temporal patterns within fishing areas, the strongest of which are evident in fishing areas 26, 27 and 29. In two of the historically most productive fishing areas, 26 and 29, catches have halved within the last decade. Small increases in catch are evident in a range of other fishing areas, especially fishing area 28. These short-term changes in catch are suggestive of a spatial shift in fishing activity brought about by reduced abundances (i.e. localised depletion) of blacklip abalone in key fishing areas (*e.g.* fishing areas 26, 27 and 29), indicated by recent reductions in CPUE.

In summary, there is considerable evidence that the resource, on which the CZ blacklip abalone fishery is based, has weakened despite the reductions in catch since 2002. Thus, it is likely that these reductions are insufficient to arrest further declines in this stock.

5. REFERENCES

Mayfield, S., Carlson, I.J. & Chick, R.M. 2006. Central Zone Abalone (*Haliotis laevigata* and *H. rubra*) Fishery. Fishery assessment report for PIRSA. SARDI Aquatic Sciences Publication No. RD05/0022-2. SARDI Research Report Series No. 166. 79pp.

Mayfield, S., Carlson, I.J. and Ward, T.M. 2005a. Central Zone Abalone (*Haliotis laevigata* and *H. rubra*) Fishery. Fishery assessment report for PIRSA. SARDI Aquatic Sciences Publication No. RD05/0022-1. SARDI Research Report Series No. 106. 79pp.

Mayfield, S., Carlson, I.J. and Ward, T.M. 2005b. Central Zone blacklip abalone (*H. rubra*) fishery. Status Report for PIRSA. SARDI Aquatic Sciences Publication No. RD05/0028-1. SARDI Research Report Series No. 113. 8pp.

Mayfield, S., Dixon, C.D., Xiao, Y. and Ward, T.M. 2004. *Central Zone Abalone (*Haliotis laevigata *and* H. rubra*) Fishery*. Fishery assessment report to PIRSA. South Australian Fisheries Assessment Series. Publication No. RD04/0158. 87pp.

Mayfield, S. and Ward, T.M. 2003. *Central Zone Abalone (*Haliotis laevigata *&* H. rubra*) Fishery*. Fishery assessment report to PIRSA Fisheries. South Australian Fisheries Assessment Series. Publication No. RD03/0192. 71pp.

Nobes, M., Casement, D. and Mayfield, S. 2004. *Management Plan for the South Australian Abalone Fishery*. South Australian Fisheries Management Series No. 42. 47pp.

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

Smallridge, M. 2006. TACC recommendations. Abalone Fishery Management Committee Agenda Paper, Meeting 67, 8 December 2006.

Tarbath, D., Mundy, C. & Haddon, M. 2005. *Tasmanian abalone fishery 2004*. Fishery Assessment Report. TAFI. 131pp.

Tokley, M. 2004. Greenlip and blacklip abalone TACC in the Central Zone abalone fishery for the 2005 quota season. Abalone Fishery Management Committee Agenda Paper, Meeting 60, 3 December 2004.

Tokley, M. 2006. Central Zone abalone fishery diver survey report. Abalone Fishery Management Committee Agenda Paper, Meeting 67, 8 December 2006.

Appendix 1: Assessment of the blacklip abalone fishery in the CZ of the South Australian abalone fishery against the biological performance indicators prescribed in the management plan. Values are mean ± SE. Red indicates statistical significance.

Performance Indicator	Units	Spatial Scale	2002	2003	2004	2005	2006	Inter-annual change	5-year trend
Commercial effort	hr	Zone	504	439	426	389	322	-	$r^2 = 0.97$, df = 3 $p < 0.05$
Mean daily catch†	kg.day^{-1}	Area 26	475.1±33.4	459.8±26.1	496.6±30.5	402.8±30.4	420.8±41.1	$t = 0.34$, df = 24 $p > 0.05$	$F_{1,107} = 1.45$ $p > 0.05$
		Area 27	452.7±30.9	364.4±48.4	486.6±39.2	451.8±32.7	340.8±35.4	$t = 2.13$, df = 27 $p < 0.05$	$F_{1,88} = 0.61$ $p > 0.05$
		Area 28	No data	No data	418.7±27.9	447.1±75.5	458.5±69.6	$t = 0.11$, df = 10 $p > 0.05$	-
		Area 29	449.8±43.0	569.6±34.2	361.7±56.1	344.2±45.4	279.9±26.6	$t = 1.31$, df = 28 $p > 0.05$	$F_{1,60} = 17.7$ $p < 0.05$
Mean daily effort†	hr.day^{-1}	Area 26	6.3±0.4	6.2±0.2	6.3±0.1	5.6±0.3	5.7±0.3	$t = 0.35$, df = 24 $p > 0.05$	$F_{1,107} = 4.15$ $p > 0.05$
		Area 27	6.5±0.1	5.2±0.3	6.0±0.4	5.6±0.3	5.6±0.4	$t = 0.06$, df = 27 $p > 0.05$	$F_{1,88} = 5.75$ $p < 0.05$
		Area 28	No data	No data	6.5±0.4	5.6±0.9	5.3±0.5	$t = 0.33$, df = 10 $p > 0.05$	-
		Area 29	6.4±0.2	6.1±0.2	5.6±0.6	6.0±0.6	5.0±0.3	$t = 1.69$, df = 28 $p > 0.05$	$F_{1,60} = 6.51$ $p < 0.05$
CPUE†	kg.hr^{-1}	Area 26	75.7±3.8	74.4±4.4	79.1±4.2	72.6±5.7	73.5±4.84	$t^{\#} = 0.13$, df = 22.6 $p > 0.05$	$F^{*}_{1,107} = 0.10$ $p > 0.05$
		Area 27	70.2±4.7	70.4±8.4	80.5±5.2	81.0±4.6	61.4±5.0	$t^{\#} = 2.90$, df = 22.6 $p < 0.05$	$F^{*}_{1,88} = 0.18$ $p > 0.05$
		Area 28	No data	No data	64.5±5.6	80.2±12.4	86.9±9.7	$t^{\#} = 0.41$, df = 8.3 $p > 0.05$	-
		Area 29	70.3±4.9	94.0±5.7	64.2±7.5	57.2±5.3	56.0±3.6	$t^{\#} = 0.19$, df = 19.4 $p > 0.05$	$F^{*}_{1,60} = 11.8$ $p < 0.05$

† Daily records where catch of greenlip abalone exceeds 50% of the total catch are excluded.
# Based on the ratio estimator (after Rice 1995).
* Based on daily CPUE.

Appendix 1 (continued):

Performance Indicator	Units	Spatial Scale	2002	2003	2004	2005	2006	Inter-annual change	5-year trend
Mean size	mm, SL	Area 26	151.3±0.6	147.5±0.3	147.6±0.2	147.2±0.3	147.2±0.4	$t = 0.02$, df = 1319 $p > 0.01$	$F_{1,5120} = 12.5$ $p < 0.01$
		Area 27	143.2±0.3	148.9±0.3	147.0±0.4	142.8±0.3	145.4±0.3	$t = 5.89$, df = 1240 $p < 0.01$	$F_{1,2924} = 16.9$ $p < 0.01$
		Area 28	No data	142.3±0.6	No data	No data	No data	-	-
		Area 29	139.5±0.3	No data	142.5±0.4	145.3±0.0.2	No data	-	-
Egg production retained	%	Area 26	48.7	45.4	46.5	42.4	47.9	N/A	N/A
		Area 27	48.3	39.9	43.0	24.2	32.6	N/A	N/A
		Area 28	No data	<30	No data	No data	No data	N/A	N/A
		Area 29	43.5	21.8	24.4	28.0	No data	N/A	N/A