Fisheries

Southern Zone Rock Lobster (*Jasus edwardsii*) Fishery 2010/11

A. Linnane, R. McGarvey, J. Feenstra and P. Hawthorne

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Fishery Assessment Report to PIRSA Fisheries and Aquaculture

Government of South Australia

Southern Zone
Rock Lobster (*Jasus edwardsii*)
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This fishery assessment updates the 2009/10 report for the Southern Zone Rock Lobster Fishery (SZRLF) and is part of SARDI Aquatic Sciences ongoing assessment program for the fishery. The report provides a synopsis of information available and assesses the current status of the resource. The report also identifies both current and future research needs for the fishery.

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TABLE OF CONTENTS

LIST OF TABLES iii

LIST OF FIGURES iv

ACKNOWLEDGEMENTS vii

EXECUTIVE SUMMARY 1

1 GENERAL INTRODUCTION 3

1.1 Overview 3

1.2 Description of the Fishery 4
1.2.1 Location and Size 4
1.2.2 Environmental Characteristics 4
1.2.3 Commercial Fishery 5
1.2.4 Recreational Fishery 5
1.2.5 Illegal Catch 5

1.3 Management of the Fishery 7
1.3.1 Management Regions 7
1.3.2 Management Milestones 8
1.3.3 Current Management Arrangements 8
1.3.4 Biological Performance Indicators 11

1.4 Biology of Southern Rock Lobster 13
1.4.1 Taxonomy and Distribution 13
1.4.2 Stock Structure 13
1.4.3 Life History 14
1.4.4 Growth and Size of Maturity 15
1.4.5 Movement 16

1.5 Stock Assessment: Sources of data 16
1.5.1 Catch and Effort Research Logbook 17
1.5.2 Voluntary Catch Sampling 17
1.5.3 Puerulus Monitoring Program 19
1.5.4 Fishery Independent Monitoring Survey (FIMS) 19

2 FISHERY DEPENDENT STATISTICS 21

2.1 Introduction 21

2.2 Catch, Effort and CPUE 21
2.2.1 Zonal trends 21
2.2.2 Within-season trends 24
2.2.3 Regional trends 27
2.2.4 Within-season regional trends 31
2.2.5 Trends by depth 33

2.3 Pre-Recruit Index (PRI) 37
2.3.1 Zonal trends 37
2.3.2 Regional trends 37
2.3.3 Within-season trends 37

2.4 Mean Weight 39
2.4.1 Zonal trends 39
2.4.2 Regional trends 40
2.4.3 Within-season trends 40

2.5 Length Frequency 42

2.6 Spawning lobsters 45
2.6.1 Zonal trends 45
2.6.2 Regional trends 45

2.6.3 Within-season trends 45

2.7 Lobster Mortalities 48
2.7.1 Zonal trends 48
2.7.2 Regional trends 48
2.7.3 Within-season trends 48

2.8 Octopus Catch Rates 51
2.8.1 Zonal trends 51
2.8.2 Regional trends 51
2.8.3 Within-season trends 51

2.9 Average days fished 54
2.9.1 Zonal trends 54

2.10 High-grading 55
2.10.1 Zonal and within-season trends 55

3 FISHERY INDEPENDENT STATISTICS 57

3.1 Settlement Index 57
3.1.1 Correlations with pre-recruit indices 58

3.2 Fishery Independent Monitoring Survey (FIMS) 59
3.2.1 Legal-sized catch rates 59
3.2.2 Undersized catch rates 59
3.2.3 Water temperature and growth 59
3.2.4 Discussion 60

4 THE qR MODEL 64

4.1 Introduction 64

4.2 Methods 64

4.3 Outputs 65

4.4 qR Model Discussion 66

5 THE LENGTH STRUCTURED MODEL 72

5.1 Introduction 72

5.2 Methods 72

5.3 Outputs 73

5.4 LenMod Discussion 74

6 PERFORMANCE INDICATORS 81

7 GENERAL DISCUSSION 81

7.1 Information available for fishery assessment 81

7.2 Current Status of Southern Zone Rock Lobster Fishery 81

7.3 Implications for Management 84

7.4 Future Research Priorities 84

8 BIBLIOGRAPHY 85

LIST OF TABLES

Table 1-1 Major management milestones for the South Australian Southern Zone Rock Lobster Fishery. 9
Table 1-2 Management arrangements for the South Australian Southern Zone Rock Lobster Fishery in 2010/11. 10
Table 2-1 Table showing seasons when the TACC was not fully taken within the SZRLF..... 24

LIST OF FIGURES

Figure 1-1 Marine Fishing Areas in the Southern and Northern Zones of the South Australian Rock Lobster Fishery. 6
Figure 1-2 Satellite remote sensing image of sea surface temperature showing the extensive cold water Bonney Upwelling system across the SZRLF in February, 2008 (source: CSIRO)........ 6
Figure 1-3 The most commonly used pot in the SZRLF........ 7
Figure 1-4 Key spatial management regions in the SZRLF. 8
Figure 1-5 TACC levels at various catch per unit effort (CPUE) rates where blue is above the target level, green is at the target level, while both yellow and red are below the target level. 12
Figure 1-6 Southern rock lobster, *Jasus edwardsii*, in reef habitat. 13
Figure 1-7 Newly settled southern rock lobster puerulus 15
Figure 1-8 Percentage of licence holders participating in the SZRLF catch sampling program over the last five seasons. 18
Figure 1-9 Typical puerulus collector deployed in the SZRLF. 20
Figure 1-10 Location of Fishery Independent Monitoring Survey (FIMS) transects in the SZRLF. 20
Figure 2-1 Inter-annual trends in catch and effort in the South Australian SZRLF from 1970-2010 inclusive. 23
Figure 2-2 Inter-annual trends in catch-per-unit-effort (CPUE) in the South Australian SZRLF from 1970-2010 inclusive. 23
Figure 2-3 Within-season trends in catch and effort in the SZRLF from 2008-2010 (note: October closed to fishing in 2010). 26
Figure 2-4 Within-season trends in CPUE in the SZRLF from 2008–2010 (note: October closed to fishing in 2010). 27
Figure 2-5 Proportion of the total catch (in terms of tonnage landed) taken from MFAs 51, 55, 56 and 58 of the SZRLF in 2010. 29
Figure 2-6 Inter-annual trends in catch and effort in the main MFAs of the SZRLF from 1970-2010 (note: alternate seasonal ticks on x-axis). 29
Figure 2-7 Inter-annual trends in CPUE in the main MFAs of the SZRLF from 1970-2010 (note: alternate seasonal ticks on x-axis). 30
Figure 2-8 Within season trends in catch and effort in the main MFAs of the SZRLF for the 2010 season........ 32
Figure 2-9 Within season trends in CPUE in the main MFAs of the SZRLF from 2007-2010. 32
Figure 2-10 Percentage of catch taken from four depth ranges in the SZRLF from 2004-2010. 35
Figure 2-11 Percentage of catch taken from four depth ranges in the four main MFAs of the SZRLF from 2004-2010. 35
Figure 2-12 CPUE in four depth ranges in the SZRLF from 1970-2010. 36
Figure 2-13 CPUE in four depth ranges from 1970-2010 across the four main MFAs of the SZRLF. 36
Figure 2-14 Inter-annual trends in pre-recruit index (PRI) in the SZRLF from 1994 to 2010 as estimated from logbook data (Nov-Mar inclusive). 38
Figure 2-15 Inter-annual trends in pre-recruit index from 1994 to 2010 in the main MFAs of the SZRLF as estimated from logbook data (Nov-Mar inclusive). 38
Figure 2-16 Within-season trends in pre-recruit index in the SZRLF over the last three fishing seasons as estimated from logbook data. 39
Figure 2-17 Inter-annual trends in the mean weight of lobsters in the SZRLF for the fishing seasons between 1970 and 2010. 40
Figure 2-18 Inter-annual trends in the mean weights (± SE) of lobster for the main MFAs of the SZRLF for the fishing seasons between 1970 and 2009 (note: alternate seasons on X-axis). 41
Figure 2-19 Within-season trends in the mean weight of lobsters in the SZRLF during the 2008, 2009 and 2010 seasons. 41
Figure 2-20 Length frequency distributions of male and female lobsters combined in the SZRLF from 2008 to 2010 (MLS = minimum legal size)........ 43
Figure 2-21 A comparison of length frequency distributions (male and female lobsters combined) in the SZRLF between 2003 (CPUE of 1.80 kg/potlift) and 2010 (CPUE of 0.94 kg/potlift) fishing seasons. 44

Figure 2-22 Inter-annual trends in the number of spawning lobsters in the SZRLF between 1983 and 2010 (+/-SE). Note: October closed during 2010 season. 46
Figure 2-23 Inter-annual trends in the number of spawning lobsters/pot lift for the main MFAs in the SZRLF between 1983 and 2010 (+/- SE). Note: October closed during 2010 season. 46
Figure 2-24 Within-season trends in the catch rate of spawning lobsters in the SZRLF during the 2008, 2009 and 2010 seasons. Note: October closed during 2010 season. 47
Figure 2-25 Inter-annual trends in CPUE of dead lobsters in the SZRLF from 1996 to 2010. 49
Figure 2-26 Inter-annual trends in the number of dead lobsters/pot lift for the main MFAs in the SZRLF from 1996 to 2010. 49
Figure 2-27 Within-season trends in the catch rate of dead lobsters in the SZRLF from 2007 to 2010. 50
Figure 2-28 Inter-annual trends in catch rates of octopus in the SZRLF from 1996 to 2010. . 52
Figure 2-29 Inter-annual trends in the number of octopus/pot lift for the main MFAs in the SZRLF between 1996 and 2010. 52
Figure 2-30 Within season trends in octopus catch rates in the SZRLF during the 2007, 2008 2009 and 2010 seasons. 53
Figure 2-31 Inter-annual trends in the average number of days fished per licence in the SZRLF between the 1983 and 2010 fishing seasons. TACC = total allowable commercial catch. 54
Figure 2-32 Interannual trends in high-grading within the SZRLF from 2002 to 2010. 55
Figure 2-33 Within season trends in high-grading over the last four seasons in the SZRLF. Total catches are shown in parentheses. 56
Figure 3-1 Puerulus Settlement Index (PSI) (mean ± SE) in the SZRLF from 1991 to 2011.. 57
Figure 3-2 Correlations between SZRLF puerulus settlement index (PSI) lagged by 4 years with pre-recruit indices (PRI) from both catch sampling and logbook data. 58
Figure 3-3 Catch rates of legal-sized lobster, as determined from the 2010 FIMS in the SZRLF. The 60 m depth contour is highlighted in blue. 61
Figure 3-4 Comparison of legal size catch rates from commercial logbook data and fishery independent monitoring surveys from 2006-2010 fishing seasons. 61
Figure 3-5 Catch rate of undersized as determined from the 2010 FIMS in the SZRLF. The 60 m depth contour is highlighted in red. 62
Figure 3-6 Comparison of pre-recruit index (PRI) as determined from logbook and fishery independent monitoring surveys from 2006-2010 fishing seasons. 62
Figure 3-7 Bottom temperature as recorded at 60 m off Southend within the SZRLF during the 2010 rock lobster season. 63
Figure 3-8 Comparison of GROTAG predicted growth estimates from previous tagging studies in the 1990's with those from fishery independent monitoring surveys from 2006-2010.63
Figure 4-1 Fit of the qR model to catch in numbers (Cn) for the SZRLF, based on annual catch totals from the fishery and estimates provided by the 2010 version of the qR model. 68
Figure 4-2 Fit of the qR model to catch by weight (Cw) for the SZRLF, based on annual catch totals from the fishery and estimates provided by the 2010 version of the qR model. ... 68
Figure 4-3 Biomass estimates from 1970-2010 as generated by the qR fishery model. 69
Figure 4-4 Egg production estimates from 1970-2010 as generated by the qR fishery model. 69
Figure 4-5 Estimates of percent of virgin egg production from 1970-2010 as generated by the qR fishery model. 70
Figure 4-6 Estimates of exploitation rate from 1970-2010 as generated by the qR fishery model. 70
Figure 4-7 Estimates of recruitment from 1995-2010 as generated by the qR fishery model. 71
Figure 4-8 Estimates of annual recruitment obtained from the qR model and pre-recruit index (PRI) as undersized/potlift (Nov-Mar) obtained from logbook data. 71
Figure 5-1 Fit of the LenMod model to catch in number (Cn) for the SZRLF, based on annual catch totals from the fishery and estimates provided by the 2010 version of the model (Note: October closed to fishing in 2010). 76
Figure 5-2 Fit of the LenMod model to catch rate for the SZRLF, based on annual estimates from the fishery and those provided by the 2010 version of the model (Note: October closed to fishing in 2010). 76
Figure 5-3 Sample of model fit (black line) to commercial length frequency data for both males and females taken during the 2010 season in the SZRLF (Note: October closed to fishing in 2010). 77

Figure 5-4 Estimates of biomass provided by the 2010 LenMod model. 78
Figure 5-5 Estimates of egg production provided by the 2010 LenMod model...................... 78
Figure 5-6 Estimates of percent of virgin egg production provided by the 2010 LenMod model. 79
Figure 5-7 Estimates of exploitation rate provided by the 2010 LenMod model. 79
Figure 5-8 Estimates of recruitment obtained from the 2010 LenMod model. 80
Figure 5-9. Estimates of annual recruitment obtained from the LenMod model and pre-recruit index (PRI) as undersize numbers/pot lift (Nov-Mar) obtained from logbook data......... 80

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EXECUTIVE SUMMARY

1. This fishery assessment updates the 2009/10 report and assesses the current status of the Southern Zone Rock Lobster Fishery (SZRLF).

2. In 2010 (i.e. the 2010/11 season), the Total Allowable Commercial Catch (TACC) in the SZRLF was 1,250 tonnes. The total reported commercial catch from logbook data was 1,244.1 tonnes. This represents the first season that >99% of the TACC was taken since 2006. Consistent with trends from previous seasons, >85% of the catch was taken in depths of <60 m.

3. From 2003 (1,042,233 potlifts) to 2009 (2,049,961 potlifts) effort increased by 96% despite decreases in the TACC from 1,900 to 1,400 tonnes. In 2010, effort decreased by 36% to 1,321,824 potlifts.

4. From 2003 (1.82 kg/potlift) to 2009 (0.60 kg/potlift) catch per unit effort (CPUE) decreased by 67% in the SZRLF. In 2010, it increased by 57% to 0.94 kg/potlift. The average number of days fished increased by 84% from 95 to 175 days over the 2003-2009 period but decreased to 114 days in 2010.

5. The zonal decreases in CPUE in recent seasons were observed across all Marine Fishing Areas (MFAs), depths and months of the fishery. In 2010, CPUEs increased in all regions with catch rates highest in the southern MFAs of 56 and 58 at 0.97 and 0.99 kg/potlift, respectively.

6. Catch rate trends in the fishery are reflected in fishery independent survey data. Legal-sized catch rates from fixed site surveys decreased by 62% from 0.75 kg/potlift in 2006 to 0.28 kg/potlift in 2009. In 2010, survey derived CPUE increased by 29% to 0.36 kg/potlift.

7. Declines in CPUE are indicative of decreases in lobster biomass. Both qR and LenMod fishery models indicate that biomass decreased by over 60% from 2002 to 2009. Similar declines in egg production were observed, with 2009 egg production <10% of virgin levels. While 2010 outputs indicate that biomass increased by 27-50%, overall estimates are low in a historical context.

8. During the period of biomass decline, exploitation rate increased markedly in the fishery, peaking at about 69% in 2009. In 2010, estimates ranged between 46-53% reflecting the observed increase in biomass and decrease in catch during the season.

9. Logbook derived pre-recruit indices (PRI) decreased from 2.11 in 1999 to 0.85 undersized/potlift in 2008. Over the last two seasons PRI has increased and in 2010 was 1.43 undersized/potlift, the highest since 2002. As a result, increased levels of recruitment should continue into the fishery in 2011.

10. Increases in PRI reflect high levels of puerulus settlement observed in 2005 and 2006. The estimated period between settlement and recruitment into the fishable biomass in the SZRLF is five years, while undersized individuals are observed four years after settlement. With the exception of 2009, puerulus settlement from 2008 to 2011 was low, suggesting that recruitment from 2013 to 2016 is likely to reduce.

11. In summary, based on decreasing biomass and CPUE estimates, there are clear signs that the status of the SZRLF has declined significantly since 2003. Despite this, there were some positive signs for the fishery in 2010. The TACC was fully taken for the first time since 2006 and CPUE increased by 56% on 2009 estimates. In addition, the 2010 exploitation rate of 46-53% was the lowest since 2005 and reflects a considerable reduction from 69% reported in 2009. However, despite recent increases, it is important to highlight that with the exception of 2009, puerulus settlement from 2008 to 2011 was below average, suggesting that recruitment to the fishery will most likely be reduced from 2013 through to 2016. As a result, commercial catch rates will require close monitoring over the coming seasons to ensure that biomass levels remain sustainable over what is likely to be an extended period of low recruitment to the fishery.

1 GENERAL INTRODUCTION

1.1 Overview

This Fishery Assessment Report updates the 2009/10 report for the Southern Zone Rock Lobster Fishery (SZRLF) and is part of the SARDI Aquatic Sciences ongoing assessment program for the fishery. The aims of the report are to provide a comprehensive synopsis of information available for the SZRLF and to assess the current status of the resource in relation to the performance indicators provided in the Management Plan for the fishery.

The report is divided into eight sections**.**

The first section is the General Introduction that: (i) outlines the aims and structure of the report; (ii) describes the environmental characteristics and history of the SZRLF; (iii) outlines the management arrangements including biological performance indicators and reference points; (iv) provides a synopsis of biological and ecological knowledge of the southern rock lobster, *Jasus edwardsii*; and (v) details the data sources from which the current assessment is made.

Section two provides a synopsis of the fishery dependent statistics for the fishing seasons between 1970/71 and 2010/11. Inter-annual and within-season trends in catch, effort and catch per unit effort (CPUE) of both legal and undersized lobsters at zonal and regional spatial levels are presented. This section also analyses catch rates of important groups such as dead individuals and spawning females as well as reporting on issues such as average number of fishing days per licence and levels of discarded catch due to high-grading within the fishery.

The third section presents fishery independent data from two sources. The first source is the settlement index, as estimated from the puerulus monitoring program within the zone. It also compares inter-annual variations in the settlement rates of puerulus with pre-recruit indices lagged by four years. The second source provides outputs from the Fishery Independent Monitoring Survey (FIMS) for the fishery.

The fourth section presents estimates of fisheries indicators obtained from the qR model (McGarvey et al. 1997; McGarvey and Matthews 2001) while the fifth section presents outputs from the length structured model (LenMod) for the fishery.

The sixth section uses information provided in sections two to five to assess the status of the fishery against the biological performance indicators and reference points defined in the SZRLF Management Plan.

Section seven is the General Discussion. It synthesises the information presented, assesses the status of the fishery, and identifies future research priorities.

The eighth section is the bibliography, which provides a list of research papers and reports that are cited in the report.

1.2 Description of the Fishery

1.2.1 Location and Size

The SZRLF includes all South Australian waters between the mouth of the Murray River and the Victorian border and covers an area of 22,000 km^2 (Figure 1-1). It is divided into seven Marine Fishing Areas (MFAs), but the majority of fishing occurs in four MFAs (51, 55, 56 and 58).

1.2.2 Environmental Characteristics

Geology and Oceanography

The sea-floor in the Southern Zone consists mainly of reefs made of bryozoan or aeolianite limestone. The limestone matrix has eroded to form ledges, crevices, undercuts and holes which provide ideal habitat for lobsters. These reefs are almost continuous, separated by small stretches of sand substrate (Lewis 1981).

The salinity and temperature of the surface water over the continental shelf in the SZRLF varies seasonally, with minimum salinity and maximum temperature (35.2 psu, 18 ºC) during summer and maximum salinity and minimum temperature (35.6 psu, 14 ºC) during winter (Lewis 1981; Middleton and Platov 2003; McClatchie and Ward 2006).

Continental shelf waters are vertically well-mixed during winter. However, during summer the prevailing south-easterly winds result in an upwelling of sub-surface nutrient-rich, cold water (11-12 ºC) which intrudes onto the continental shelf (Schahinger 1987). Known locally as the Bonney Upwelling (Figure 1-2), this results in an increase in productivity of phytoplankton which may contribute to the high densities of southern rock lobster in the SZRLF (Rochford 1977; Lewis 1981).

1.2.3 Commercial Fishery

Southern rock lobster have been fished in South Australian waters since the 1890s, but the commercial fishery did not develop until the late 1940s and early 1950s when overseas markets for frozen tails were first established (Copes 1978; Lewis 1981). There has been a gradual change to live export since then with over 90% of the current commercial catch exported live, mainly to China. More recently, efforts have also been made to export live lobsters into the United States market.

Lobsters are caught using pots (Figure 1-3) that are set overnight and hauled at first light. The pots are steel-framed and covered with wire mesh that incorporates a moulded plastic neck. The catch is stored live in holding wells on vessels before being transferred to live holding tanks at the numerous processing factories.

1.2.4 Recreational Fishery

There is an important recreational fishery for lobsters in the SZRLF. Recreational fishers are allowed to use drop-nets, pots or SCUBA to take lobsters during the same season as commercial fishers. All recreational lobster pots must be registered.

The most recent survey of recreational rock lobster fishers was undertaken during the 2007/08 South Australian Recreational Fishing survey (Jones 2009). An average of 106,483 (±54,423) rock lobsters was caught by South Australian residents in 2007/08, with 47,875 (±20,331) of these harvested and 58,608 (±36,148) released, representing a release rate of 55%. Overall, total numbers caught decreased by 12% from the 2001/02 survey (Venema et al. 2003) but release rates increased by 26%. The catch represents a total recreational harvest of about 60 tonnes, of which 55 tonnes (92%) came from the SZRLF.

Rock lobster pots/nets were the main method of capture (96%) with various diving methods accounting for the remainder. The proportion taken by rock lobster pots, as opposed to drop nets is the subject of further analysis, however, the on-site surveys indicated that drop nets comprised a very small proportion of the total harvest.

1.2.5 Illegal Catch

The implementation of systems for monitoring the Total Allowable Commercial Catch (TACC) combined with the prior reporting system has reduced opportunities for the disposal of illegal catches in the SZRLF. It is considered unlikely that illegal fishing is currently a significant source of fishing mortality.

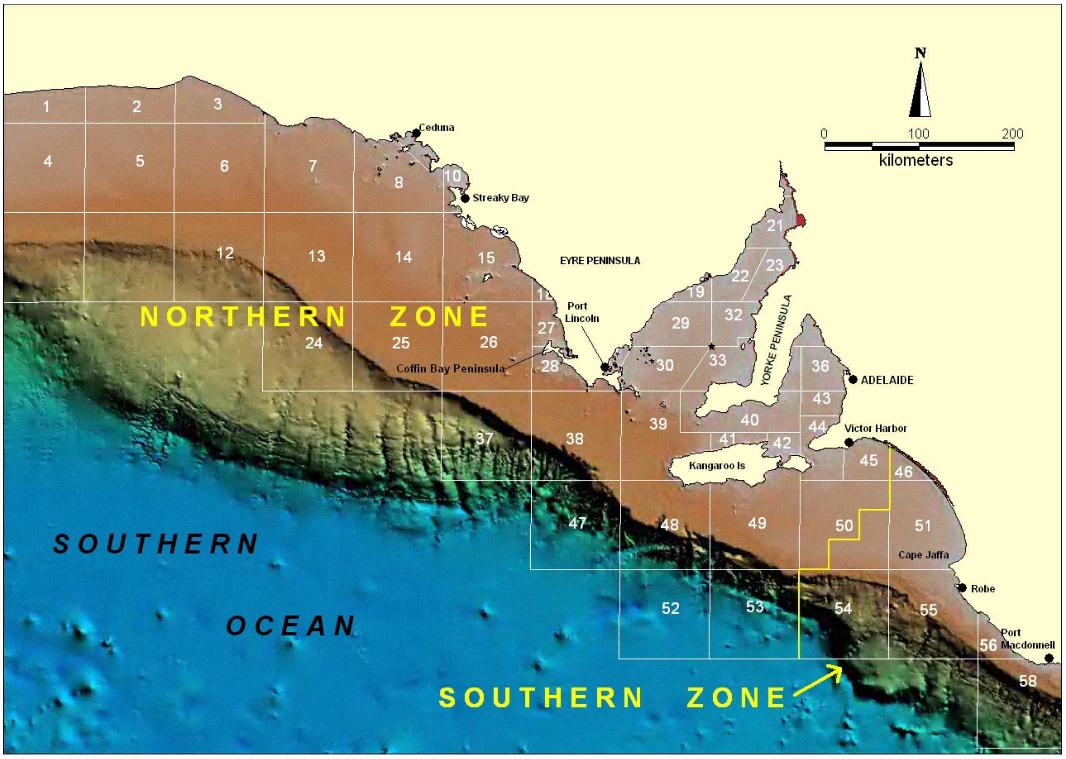

Figure 1-1 Marine Fishing Areas in the Southern and Northern Zones of the South Australian Rock Lobster Fishery.

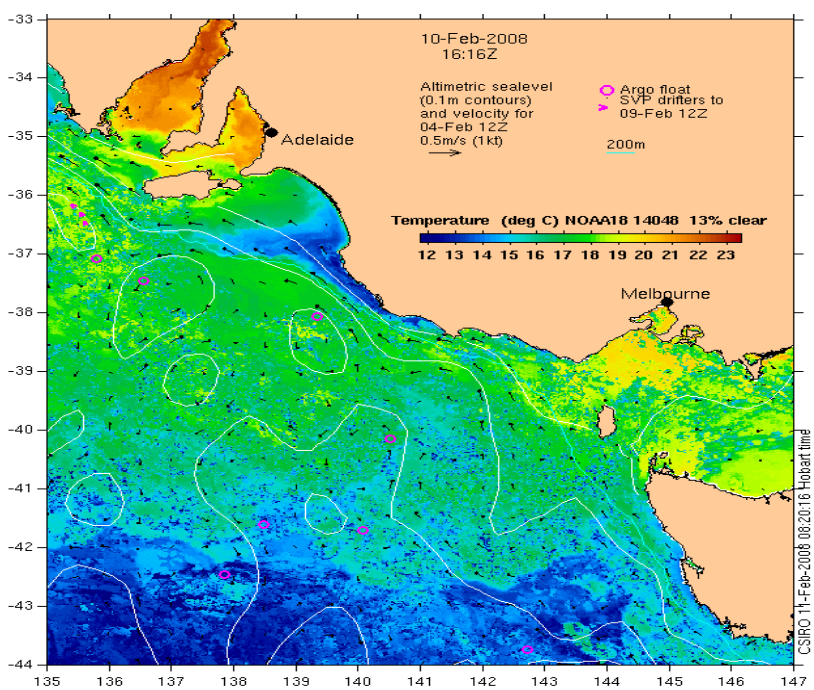

Figure 1-2 Satellite remote sensing image of sea surface temperature showing the extensive cold water Bonney Upwelling system across the SZRLF in February, 2008 (source: CSIRO).

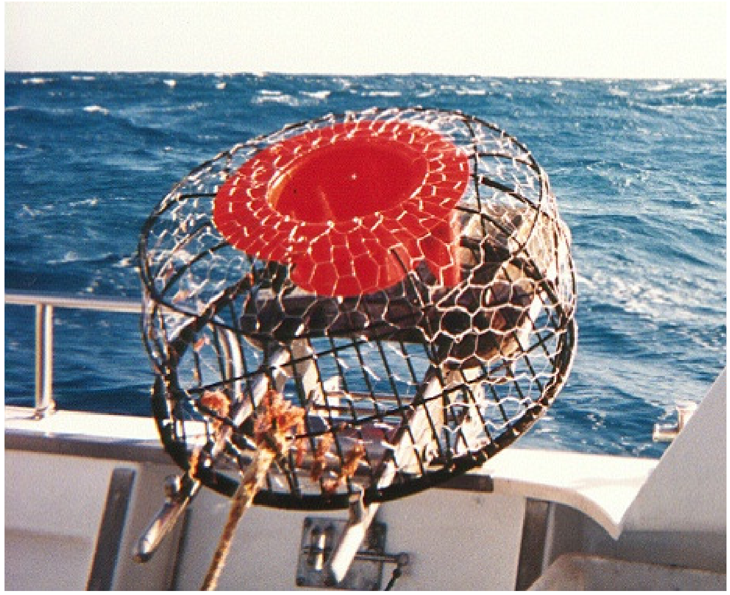

Figure 1-3 The most commonly used pot in the SZRLF.

1.3 Management of the Fishery

The commercial SZRLF is a limited entry fishery with a total of 181 licences. The majority of vessels fish from Port MacDonnell and Robe (Figure 1-1). The broad statutory framework for the sustainable management of this resource is provided by the *Fisheries Management Act 2007*. General regulations that govern the SZRLF are described in the *Fisheries Management (General) Regulations 2007* and specific regulations are established in the *Fisheries Management (Rock Lobster Fisheries) Regulations 2006*. The policy, objectives and strategies to be employed for the sustainable management of the SZRLF are described in the *Management Plan for the South Australian Southern Zone Rock Lobster Fishery* (Sloan and Crosthwaite 2007). Recreational fishers are regulated under the *Fisheries Management (General) Regulations 2007.*

1.3.1 Management Regions

The Management Plan for the SZRLF is currently under review The previous Management Plan (Sloan and Crosthwaite 2007) detailed key biological performance indicators that were assessed at both whole-of-fishery (zonal) and regional levels (Figure 1-4). Currently, the three specific regions are: MFA 55 (Region A), MFA 56 (Region B) and MFA 58 (Region C). The aim of regional assessment was to refine management of the fishery to a finer spatial scale and ensure that greater precaution was factored into management arrangements. Regional assessment also allowed known spatial variations in biological features such as growth rate (McGarvey et al. 1999a) and size of maturity (Linnane et al. 2008; Linnane et al. 2009) to be taken into consideration.

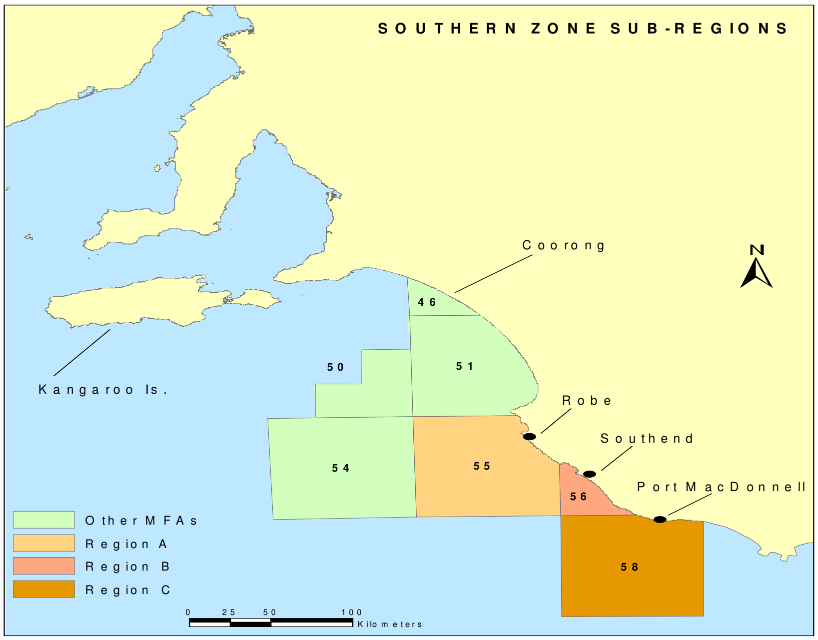

Figure 1-4 Key spatial management regions in the SZRLF.

1.3.2 Management Milestones

Management arrangements have evolved since the inception of the fishery with the most recent review in 2011. The major management milestones are shown in Table 1-1.

1.3.3 Current Management Arrangements

Details of management arrangements for the 2010/11 season are provided in Table 1-2. The commercial fishery is managed using a combination of input and output controls. Traditionally, the season extended from October 1st to May 31st. In 2010/11, October was closed to fishing. There is a minimum legal size of 98.5 mm carapace length (CL), prohibition on the taking of berried females and several sanctuaries where lobster fishing is prohibited. Fishers may use up to 100 of the total number of pots (maximum 100) endorsed on their licence at any one time to take lobster.

The TACC is set annually and is divided proportionally between licence holders as individual transferable quotas (ITQ's). Each licence holds one quota unit entitlement for each pot entitlement held. If a pot entitlement is transferred, a quota unit must also be transferred at the same time to the same licence, and vice versa. The daily catch of individual vessels is monitored via catch and disposal records by PIRSA Fisheries Compliance. In 2010, the SZRLF TACC was 1,250 tonnes.

Table 1-1 Major management milestones for the South Australian Southern Zone Rock Lobster Fishery.

Date	Management milestone
1958	Closed season for females from 1 June-31 October and for males from 1 to 31 October
1967	Pot and boat limit introduced, no new boats to operate in the then "South-Eastern Zone"
1968	Limited entry declared, compulsory commercial catch log
1978	June, July, October closed
1980	Winter closure declared. Season from 1 October to 30 April.
1984	15% pot reduction
1987	Buyback of 40 licences (2455 pots)
1993	April closed; TACC implemented for 1993/94 season at 1720 t
1997	Management Plan for the fishery published (Zacharin 1997)
2002	TACC increased by 50 t to 1770 t
2003	TACC increased by 130 t to 1900; May opened on trial basis
2005	May trial completed. Decision to open May permanently
2007	New Management Plan for the SZ fishery published (Sloan and Crosthwaite 2007)
2008	TACC reduced to 1770 t
2009	TACC reduced to 1400 t
2010	TACC reduced to 1250 tonnes. October closed to fishing.
2011	New Harvest Strategy developed

Table 1-2 Management arrangements for the South Australian Southern Zone Rock Lobster Fishery in 2010/11.

Management tool	**Current restriction**
Limited entry	181 licences
Total Allowable Commercial Catch	1,250 tonnes
Closed season	1 June to 31 October
Total number of pots	11,923
Minimum size limit	98.5 mm carapace length (CL)
Maximum number of pots/licence	100 pots
Minimum number of pots/licence	40 pots
Maximum quota unit holding	Limited by pot holding (100 pots)
Minimum quota unit holding	Limited by minimum pot holding (40 pots)
Spawning females	No retention
Maximum vessel length	None
Maximum vessel power	None
Closed areas	Aquatic Reserves: Margaret Brock Reef, Cape Jaffa and Rivoli Bay
Escape gaps	Optional, not mandatory at present
Monitoring tool	**Requirement**
Catch and effort data	Daily logbook submitted monthly
Catch and Disposal Records	Daily records submitted upon landing (electronic scales currently being implemented to automate this process)
Landing locations	7 designated landing sites
Landing times	Landings permitted during core hours
Prior landing reports to PIRSA	Outside core hours, 1 hour before landing
Bin tags	All bins must be sealed with a lid and an approved tag prior to lobster being unloaded from the vessel. Tags are sequentially numbered.

1.3.4 Biological Performance Indicators

In 2011, the harvest strategy for the SZRLF was reviewed. The main goal of this harvest strategy is to ensure that the southern rock lobster resource in the SZRLF is harvested within ecologically sustainable limits. To achieve this goal, it is imperative that the performance of the fishery is assessed annually. In the revised harvest strategy, this assessment will be done by utilising both primary and secondary biological performance indicators.

Primary biological performance indicator

The key biological performance indicator for this fishery is commercial catch per unit effort (CPUE) of legal-sized rock lobster (kg/potlift). CPUE in lobster fisheries is accepted as being representative of lobster abundance. As a result, it is recognised by industry and managers as a measure of fishery performance that is reliable and well-understood. It is measured using catch and effort data recorded and submitted in mandatory logbook returns.

A modified “traffic light” method is used to determine the current status of the fishery relative to a target CPUE reference range, where blue is above the target range (TACC increase), green is within the target range (no change to TACC), with both yellow (TACC decrease by one level) and red (TACC decrease by two levels) below the target range (Figure 1-5). The four levels of TACC used in this harvest strategy are based on historical levels of fishery effort between 1.4 and 1.6 million pot lifts per season. The two lower TACCs (950 tonnes and 1250 tonnes) are based on 1.6 million pot lifts, while the two higher TACCs (1400 tonnes and 1600 tonnes) are based on 1.4 million pot lifts.

Secondary biological performance indicator

The secondary performance indicator is the pre-recruit index (PRI) in terms of the number of undersized lobster/potlift. PRI provides information on future recruitment to the fishery and is based on logbook data as described in Section 2.3. A reference point for PRI of 1.3 undersized/potlift will be used as a measure of fishery performance for the following year. Therefore, at any time, PRI is either above or below this reference point.

Additional performance indicators

Three additional performance measures will be used to assess the performance of the fishery. These are: a) puerulus settlement index (PSI); b) biomass estimates and levels of exploitation; and c) length-frequency data. It is important to note that additional performance indicators do not trigger a specific response in the harvest strategy and are not explicitly used in the TACC decision-making process.

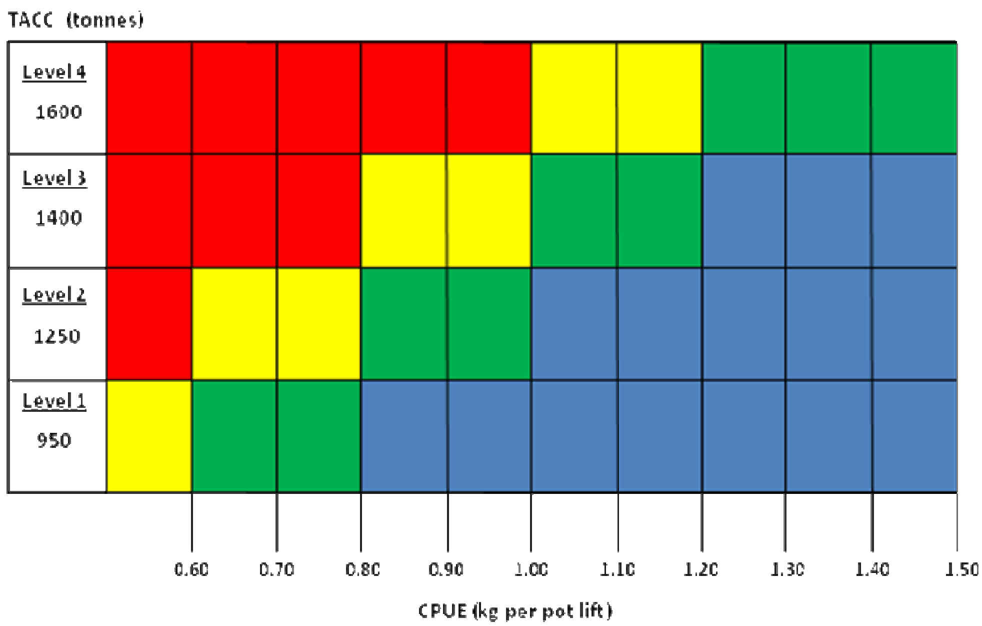

Figure 1-5 TACC levels at various catch per unit effort (CPUE) rates where blue is above the target level, green is at the target level, while both yellow and red are below the target level.

1.4 Biology of Southern Rock Lobster

1.4.1 Taxonomy and Distribution

For detailed information on all biological aspects of southern rock lobster *Jasus edwardsii* (Hutton 1875) readers should refer to Phillips (2006). Southern rock lobster (Figure 1-6), are distributed around southern mainland Australia, Tasmania and New Zealand. In Australia, the northerly limits of distribution are Geraldton in Western Australia and Coffs Harbour in northern New South Wales. However, the bulk of the population can be found in South Australia, Victoria, and Tasmania where they occur in depths from 1 to 200 m (Brown and Phillips 1994). They are generally considered omnivores, but are primarily carnivores of slow moving benthic invertebrate prey such as spiny urchin, crab and marine snail species (Fielder 1965; Johnston 2003; Hoare 2008).

Figure 1-6 Southern rock lobster, *Jasus edwardsii*, in reef habitat.

1.4.2 Stock Structure

Based on morphological and mitochondrial DNA analysis, there is little evidence of population sub-structuring across mainland Australia, Tasmania and New Zealand (Smith et al. 1980; Brasher et al. 1992; Ovenden et al. 1992). The long larval phase and widespread occurrence of larvae across the central and south Tasman Sea, in conjunction with known current flows, point to the likely transport of phyllosoma from south-eastern Australia to New Zealand, providing genetic mixing between the two populations (Booth et al. 1990).

Using a combination of biological and hydrodynamic modelling, Bruce et al. (2007) simulated the planktonic early life history of *J. edwardsii* across its geographical range. In relation to sources of recruiting pueruli to the Southern Zone, the study predicted that the most significant levels of recruitment occur from within the zone and from westerly regions although some may also come from as far east as south-eastern Tasmania in certain years. Importantly, the study found that the SZRLF had the highest levels of egg production in southern Australia and as a result, was an important source of pueruli for much of the overall south-eastern fishery of Australia.

While rock lobster stocks within South Australia cannot be differentiated based on genetic analyses, the stock is spatially discrete for management purposes based on known biological and ecological differences. As a result, the division of the stock into Northern and Southern Zones reflects known spatial variations in growth (McGarvey et al. 1999a), size of maturity (Linnane et al. 2008; Linnane et al. 2009) and habitat (Lewis 1981).

1.4.3 Life History

Southern rock lobster mate from April to July. Fertilisation is external, with the male depositing a spermatophore on the female's sternal plates (MacDiarmid 1988). The eggs are extruded shortly afterwards, where they are immediately fertilised before being brooded over the winter for about 3-4 months (MacDiarmid 1989).

The larvae hatch in early spring, pass through a brief (10-14 days) nauplius phase into a planktonic phyllosoma phase. Phyllosoma have been found down to depths of 310 m and tens to hundreds of kilometres offshore from the New Zealand coast (Booth et al. 1999; Booth et al. 2002; Bradford et al. 2005; Chiswell and Booth 2005). They develop through a series of 11 stages over 12-23 months before metamorphosing into the puerulus stage (Figure 1-7) near the continental shelf break (Booth et al. 1991; Booth and Stewart 1991; Bruce et al. 1999). A short-lived (ca. 3-4 weeks) non-feeding stage, the puerulus actively swims inshore to settle onto reef habitat in depths from 50 m to the intertidal zone (Booth et al. 1991; Phillips and McWilliam 2009).

There is substantial geographic variation in larval production. In New Zealand, it has been suggested that this may be due to variations in: (i) size at first maturity, (ii) breeding female abundance and/or (iii) egg production per recruit. Additionally, phyllosoma are thought to drift passively which, coupled with the long, offshore larval period, means that oceanographic conditions, particularly currents and eddies, may play an important part in their dispersal (Booth and Stewart 1991; Chiswell and Booth 2005; Chiswell and Booth 2008; Phillips and McWilliam 2009).

Geographic patterns in the abundance of phyllosoma may also be consistent with those in puerulus settlement (Booth 1994). Correlations between levels of settlement and juvenile abundance have been found at two sites in New Zealand (Breen and Booth 1989). In South Australia, it has been suggested that the strength of westerly winds, during late winter and early spring, may play a role in the inter-annual variation in recruitment to the SZRLF (McGarvey and Matthews 2001; Linnane et al. 2010a).

Figure 1-7 Newly settled southern rock lobster puerulus.

1.4.4 Growth and Size of Maturity

Lobsters grow through a cycle of moulting and thus increase their size incrementally (Musgrove 2000). Male and female moult cycles are out of phase by 6 months, with males undergoing moulting between October and November, and females during April to June (MacDiarmid 1989).

McGarvey et al. (1999a) demonstrated that there was substantial variation in growth rates between locations in South Australia. Growth rates also varied throughout the lives of individuals with the mean annual growth for lobsters at 100 mm carapace length (CL) ranging from 7-20 and 5-15 mm.yr^{-1} for males and females, respectively. Growth rates increased along the South Australian coast from south-east to north-west and were highest in areas of low lobster density and high water temperature.

Growth rates also appeared to be related to depth of habitat and declined at the rate of 1 mm CL yr^{-1} for each 20 m increase in depth (McGarvey et al.1999a).

Similarly, size of maturity (SOM) varies spatially within the SZRLF. Linnane et al (2008) provided SOM estimates (the size at which 50% of females reached sexual maturity i.e. L_{50}) from two regions within the fishery i.e. the North Southern Zone (NSZ; MFA 51 and 55) and South Southern Zone (SSZ; MFA 56 and 58). SOM, was higher in the NSZ (104.1 mm CL) compared to SSZ (92.3 mm CL). Approximately 20% of lobsters above the MLS in the commercial catch in the NSZ were under the L_{50} estimate. Additionally, SOM may also vary with depth in at least some areas of the SZRLF (Linnane et al., 2009a). Data from offshore (>100 m depth) sites revealed a SOM estimate of 68.4 mm CL compared to 103.3 mm CL for inshore (<60 m) females.

1.4.5 Movement

Movement patterns of the southern rock lobster were determined from 14,280 tag-recapture events from across the State between 1993 and 2003 (Linnane et al. 2005). In total, 68% of lobsters were recaptured within 1 km of their release site and 85% within 5 km. The proportion of lobsters moving >1 km ranged from 13 to 51%. Movement rates were noticeably high in the SZRLF and at Gleesons Landing lobster sanctuary off the Yorke Peninsula in the Northern Zone Rock Lobster Fishery (NZRLF) but patterns of movement differed spatially. In the SZRLF, lobsters moved distances of <20 km from inshore waters to nearby offshore reefs, whereas off the Yorke Peninsula individuals moved distances >100 km from within the sanctuary to sites located on the north-western coast of Kangaroo Island and the southern end of Eyre Peninsula.

1.5 Stock Assessment: Sources of data

SARDI Aquatic Sciences is contracted by PIRSA Fisheries and Aquaculture to: (i) administer a daily logbook program, (ii) collate catch and effort information, (iii) conduct voluntary catch-sampling, puerulus and fishery independent monitoring programs and (iv) produce annual stock assessment and status reports that assess the status of the SZRLF against the performance indicators defined in the Management Plan.

1.5.1 Catch and Effort Research Logbook

Licence holders complete a compulsory daily logbook which has been amended to accommodate changes in the fishery. For example, in 1998, the logbook was modified to include specific details about King crab (*Pseudocarcinus gigas*) fishing. In the 2000 fishing season, the logbook was again amended and the recording of undersize, spawning and dead lobster, along with numbers of octopus, became voluntary. Logbook returns are submitted monthly and are entered into the South Australian Rock Lobster (SARL) database. Fishery dependent statistics from logbook data are presented in Section 2 of this report. Details currently recorded in the daily logbook include:

1. the MFA within which the fishing took place,
2. depth in which the pots were set,
3. number of pots set,
4. weight of retained legal-sized lobsters - reported at the end of each trip or as a daily estimated weight,
5. landed number of legal-sized lobsters,
6. number of undersized lobsters caught,
7. number of dead lobsters caught,
8. number of spawning lobsters caught,
9. weight of octopus caught,
10. number of octopus caught,
11. number of giant crab pots,
12. depth of giant crab pots,
13. landed weight of giant crabs,
14. landed number of giant crabs.

Validation of catch and effort logbook data in the SZRLF can be achieved by comparing them with the catch and disposal records (CDRs) used in the quota management system. Processor records are not used for validation as lobsters may be transported to processors outside of the zone in which the lobsters were landed.

1.5.2 Voluntary Catch Sampling

Since 1991, commercial fishers and researchers have collaborated in an at-sea voluntary catch sampling program. During the life of this program there were various levels of participation, and changes to the sampling regime. The program started with commercial fishers sampling from several (usually 3) pots each day, for the duration of the fishing season. During the 1995 season, sampling was reduced to one week each month over the period of the third quarter of the moon.

In the following season, sampling was done as part of an FRDC project that aimed to determine the optimal sampling strategy required to produce quantifiable and minimum variances in mean lengths and catch rates (McGarvey et al. 1999b;

McGarvey and Pennington 2001). This study demonstrated that the optimal design should incorporate a high percentage of vessels, with sampling done on as many days as possible from a small fraction of the pots from each vessel. As a result, fishers are now encouraged to participate in the program by recording the number, size and reproductive condition (females only) of both undersized and legal lobsters from 3 pots where the escape gaps are closed. They are supported by research staff that promote the program and demonstrate the methods to new participants.

Results have shown that participation in the program varies among areas and tends to taper off as the season progresses. In recent seasons, participation in the program has been variable with 17% of licence holders taking part in the 2010/11 season (Figure 1-8). Low participation in the program may bias catch rates and length frequencies. As a result, participation in the program is strongly encouraged to ensure that future decisions for the fishery are based on reliable and robust data. Results from the voluntary catch sampling program are presented in Section 2 of this report.

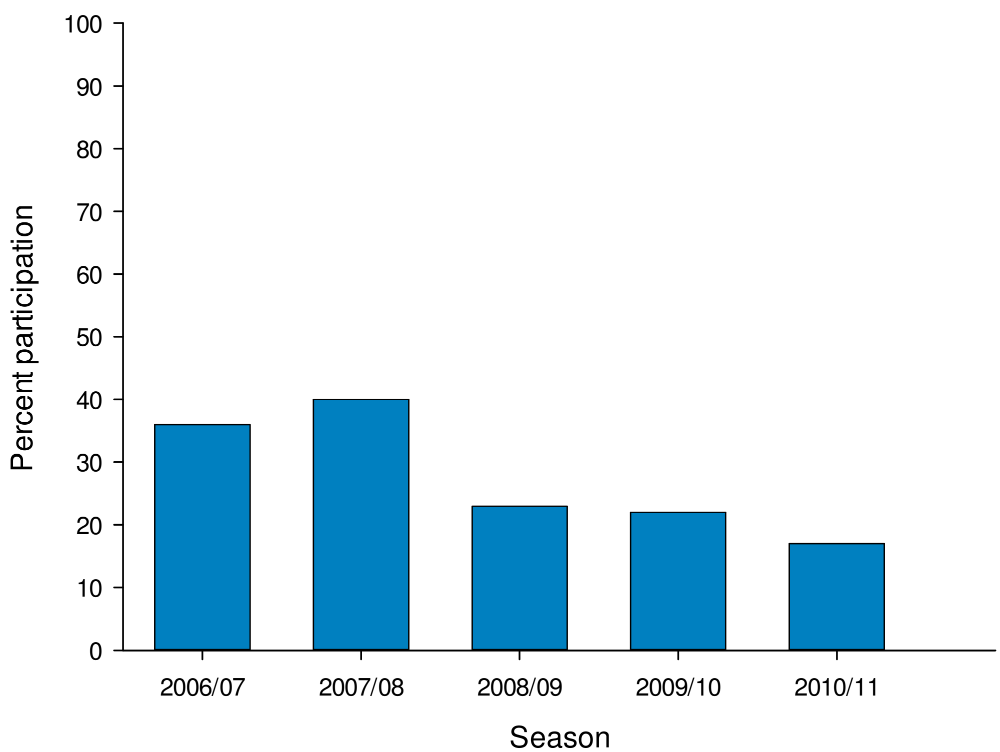

Figure 1-8 Percentage of licence holders participating in the SZRLF catch sampling program over the last five seasons.

1.5.3 Puerulus Monitoring Program

Larval recruitment processes may be related to changes in breeding stock abundance and seasonal, annual and geographic variation in recruitment to the fishery (Booth et al. 2002). As a result, knowledge of these processes may ultimately improve the robustness of fishery assessment models.

The monthly occurrence of puerulus settlement in crevice collectors (Figure 1-9) has been studied in the SZLRF at 5 main sites since 1990. These sites are located at Blackfellows Caves, Livingstons Beach, Beachport, Cape Jaffa and Kingston, with the collectors set in groups of 10 or 12. The annual Puerulus Settlement Index (PSI) is calculated as the mean monthly settlement on these collectors. This index is then related to an annual pre-recruit index (PRI) and model-estimated recruitment lagged by three and four years, respectively. Results from the puerulus monitoring program are presented in Section 3.1 of this report.

1.5.4 Fishery Independent Monitoring Survey (FIMS)

A fishery independent monitoring survey has been undertaken in the SZRLF since 2006/07. The survey design consists of 29 transects, that run from inshore (~10 m) to offshore (~120 m) grounds (Figure 1-10). Each transect line consists of 10 pots set at predetermined locations that are independent of known fishing effort. Sampling is undertaken during September, January and May of each season. All lobsters are sexed, measured, staged (females only) and tagged. Results from the survey are presented in Section 3.2 of this report.

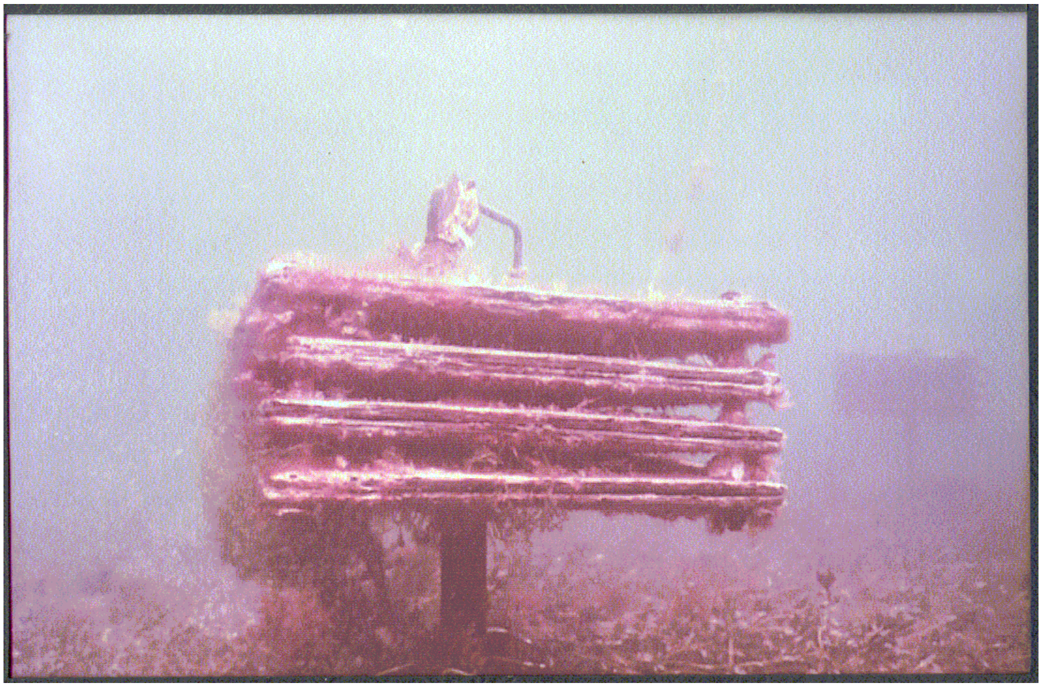

Figure 1-9 Typical puerulus collector deployed in the SZRLF.

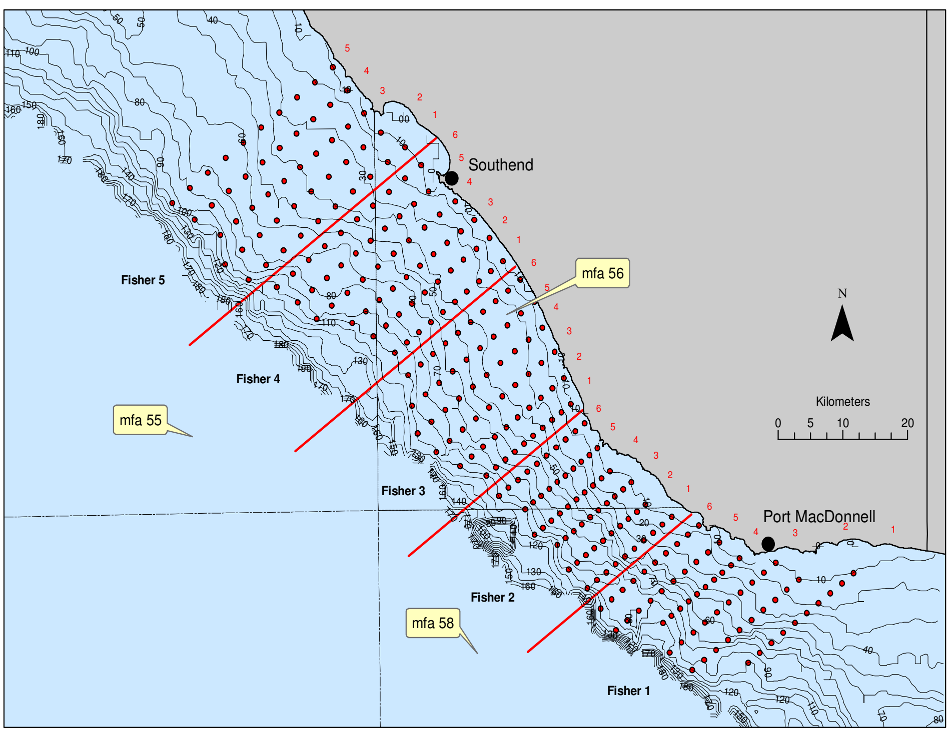

Figure 1-10 Location of Fishery Independent Monitoring Survey (FIMS) transects in the SZRLF.

2 FISHERY DEPENDENT STATISTICS

2.1 Introduction

This section of the report summarises and analyses fishery statistics for the SZRLF for the period between 1st January 1970 and 31st May 2011. For ease of reference, figures and text in this section refer to the starting year of each season e.g. 2010 refers to the 2010/11 fishing season.

The scale of spatial analyses undertaken, with respect to various fishery dependent data, reflects their importance as performance indicators within the Management Plan. For example, both catch rate (primary indicator) and pre-recruit index (secondary indicator) are presented by zone, region, and depth. Other indicators (e.g. length frequency), not directly linked to the decision-making process of the Management Plan, are presented at the zonal scale only.

Estimates presented in this section are calculated from daily data that are used to describe the inter-annual and within-season patterns in catch (kg), effort (potlifts), catch per unit effort CPUE (kg/potlift) and mean weight (kg/lobster) across both the entire zone as well as key MFAs. This section also presents statistics on important indices such as pre-recruits (undersized/potlift), spawning females, dead lobsters and octopus catch rates. Data obtained from the catch sampling program provide the length frequency distributions of lobsters.

2.2 Catch, Effort and CPUE

2.2.1 Zonal trends

Catch

Fishing patterns between 1970 and 1983 (Figure 2-1) were highly variable and some discrepancies exist between the published catches for this period and those extracted from the SARL database. Thus, estimates of absolute catch during this period should be viewed with some caution. Between 1984 and 1990 catches remained steady at about 1,500 tonnes before increasing to 1,940 tonnes in 1991. In 1993, a TACC of 1,720 tonnes was introduced, but only 1,668 tonnes were harvested (Table 2-1). From 1993 to 1997, the TACC was only taken in 1994. The TACC was taken from 1998 through to 2002 with a quota increase of 50 tonnes to 1,770 tonnes implemented in 2001. In 2003, the TACC was again increased by 130 tonnes to

1,900 tonnes which was largely taken from 2003 through to 2006. However, over the last three seasons, from 2007 to 2009 the TACC was not fully landed (Table 2-1). In 2007, a total of 1,849 tonnes were caught, representing a total catch 50.4 tonnes below the TACC. In 2008, the TACC was reduced to 1,770 tonnes but only 1,407.3 tonnes was taken, a shortfall of 362.7 tonnes. In 2009, the TACC was again reduced to 1,400 tonnes but only 1,243.3 tonnes were landed, 156.7 tonnes short of the annual quota. In 2010, the TACC was reduced for the third consecutive season to 1,250 tonnes of which 1,244.1 tonnes were landed. As a result, 2010 represents the first season that >99% of the TACC was taken since 2006.

Effort

As with catch, estimates of effort between 1970 and 1983 should be viewed with caution (Figure 2-1). A peak of 2.3 million pot lifts was recorded in 1983. Over the next decade, effort declined to 1.5 million potlifts in 1994. Effort again increased to 1.7 million pot lifts in 1997, before falling rapidly to the lowest recorded level of 854,000 pot lifts during the 2002 season. In 2003, a total of 1,042,233 potlifts were required to catch the 1,900 tonne TACC. However, over the next six seasons, effort continued to rise, peaking at 2,049,961 potlifts in 2009, the highest on record since 1987 (2,130,416). In 2010, there was a considerable reduction in effort with 1,321,824 potlifts required to take the 1,244.1 tonne catch. This represents a 36% decrease from 2009 and the lowest estimate on record since 2005 (1,183,037 potlifts).

Catch per unit effort (CPUE)

CPUE during the 1970s ranged between 0.70 and 0.90 kg/potlift (Figure 2-2). In 1980, the CPUE reached a peak of 1.06 kg/pot lift before declining to 0.77 kg/potlift in 1983. CPUE remained steady at around 0.75 kg/potlift from 1983-1988 before rising to 0.99 kg/pot lift in 1992 (the year prior to introduction of the TACC).

In 1994, the CPUE increased to 1.12 kg/potlift but decreased to 0.93 kg/potlift in 1996. From 1996 to 2002 CPUE increased substantially reaching 2.10 kg/potlift in 2002, the highest on record. However, over the next seven seasons CPUE decreased annually and in 2009 was 0.60 kg/potlift, the lowest on record. In 2010, CPUE increased to 0.94 kg/potlift, reflecting a 57% increase on 2009. CPUE figures do not take into account lobsters that were high-graded during the season i.e. returned to the water due to damage or having a low size-related market value (see Figure 2-32).

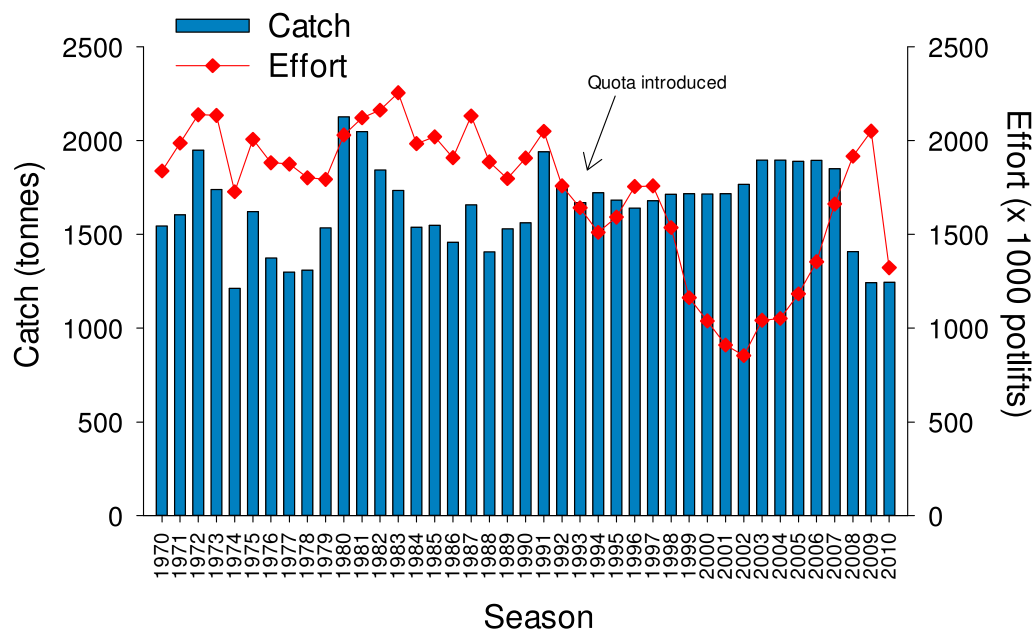

Figure 2-1 Inter-annual trends in catch and effort in the South Australian SZRLF from 1970-2010 inclusive.

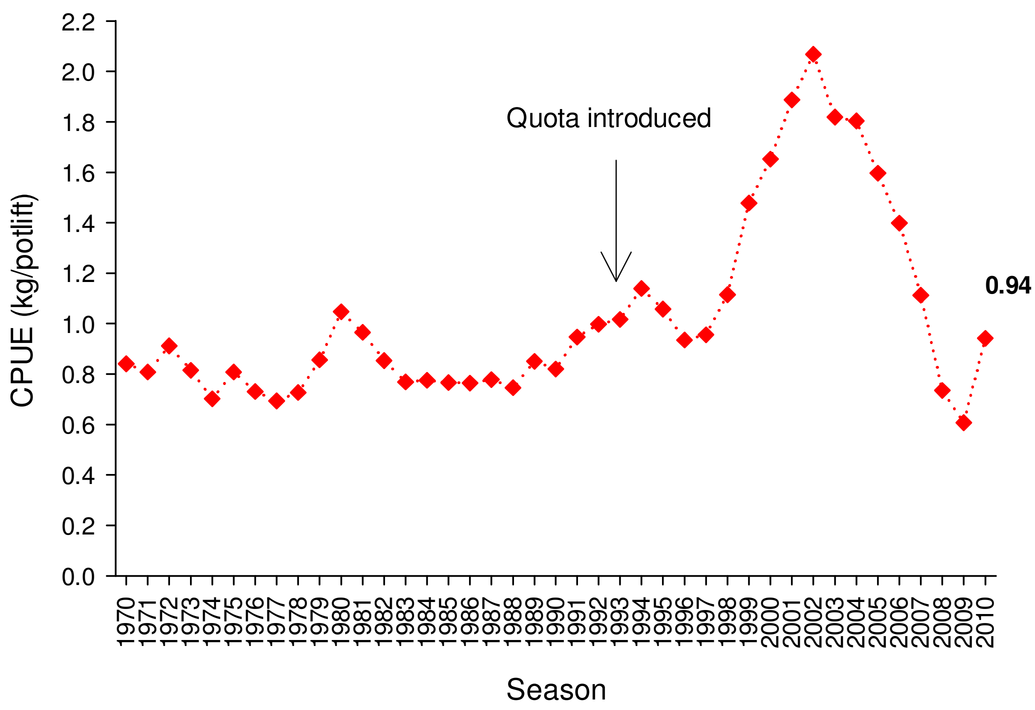

Figure 2-2 Inter-annual trends in catch per unit effort (CPUE) in the South Australian SZRLF from 1970-2010 inclusive.

Table 2-1 Table showing seasons when the TACC was not fully taken within the SZRLF.

Season	TACC (t)	Catch (t)	Shortfall (t)
1993	1720	1668	52 (3%)
1995	1720	1683	37 (2%)
1996	1720	1639	81 (5%)
1997	1720	1680	40 (2%)
2007	1900	1850	50 (3%)
2008	1770	1407	363 (21%)
2009	1400	1243	157 (11%)

2.2.2 Within-season trends

Catch

Fishing from 1970 to 1979 was conducted all year round; although the majority of the catch was taken in the summer months (refer to Linnane et al. (2006) for trends in within–season catch from 1970 to 2002). From 1980 to 1996, the highest catches were almost always taken in the first six months of the season before dropping off in April. More recently, the fishery has recorded high monthly catches from October to January, with the majority of the TACC being taken during this period (Figure 2-3).

Within-season trends in catch clearly show that the decline observed in recent seasons (Figure 2-1) occurred consistently across all months of the fishery (Figure 2-3). For example, catch in January, which is generally the highest catch month, declined from 264.6 tonnes in 2008 to 229.4 tonnes in 2009. Similar trends where observed across all other months. In 2010, when October was closed to fishing, the highest catch month was again in January with 338.2 tonnes landed. It is worth noting that since the opening of May to commercial fishing in 2003, the catch taken in this month has always been <60 tonnes.

Effort

Between 1980 and 1996, fishing effort was consistently high from October to March before dropping sharply during April (refer to Linnane et al. (2006) for trends in within–season effort from 1980 to 2002). This is likely to reflect a seasonal decline in catch rate and the fact that weather conditions are more favourable during the summer period. Since 1998, trends in effort have generally reflected those in catch with decreasing trends in potlifts from February to May.

Within season trends in effort clearly show that the increase observed in recent (Figure 2-1) seasons occurred across all months of the fishery (Figure 2-3). For example, in 2008, a total of 285,366 potlifts were required to take the 264.6 tonne catch in January. In 2009, a total of 304,776 potlifts were required to catch 229.4 tonnes in the same month. Similar increases in effort were consistent across all other months of the fishery despite decreases in monthly catches.

In 2010, effort decreased considerably within the fishery (Figure 2-1) with the most noticeable reductions observed in December, as well as the period from February to March (Figure 2-3). The overall trend in effort was similar to those in previous seasons with effort highest in the first four months of the season decreasing thereafter. Effort was highest in January at 305,130 potlifts and the lowest in May at 28,474 potlifts.

CPUE

The zonal increase in CPUE (Figure 2-2) was consistent across all months of the 2010 season (Figure 2-4). As in previous seasons, CPUE increased from November to January, before decreasing as the season progressed. As a result, CPUE was highest in January (1.10 kg/potlift) and lowest in May (0.56 kg/potlift).

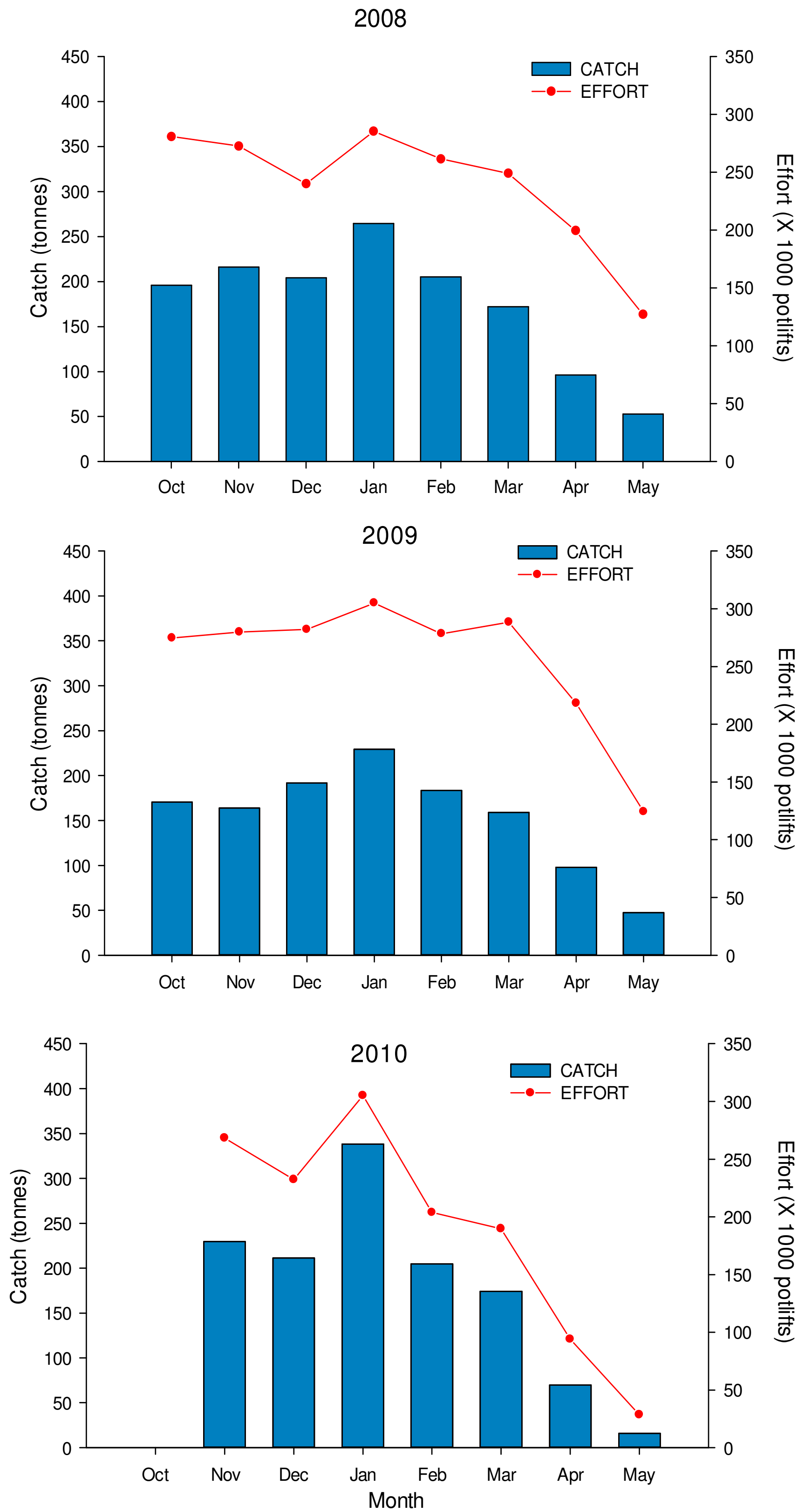

Figure 2-3 Within-season trends in catch and effort in the SZRLF from 2008-2010 (note: October closed to fishing in 2010).

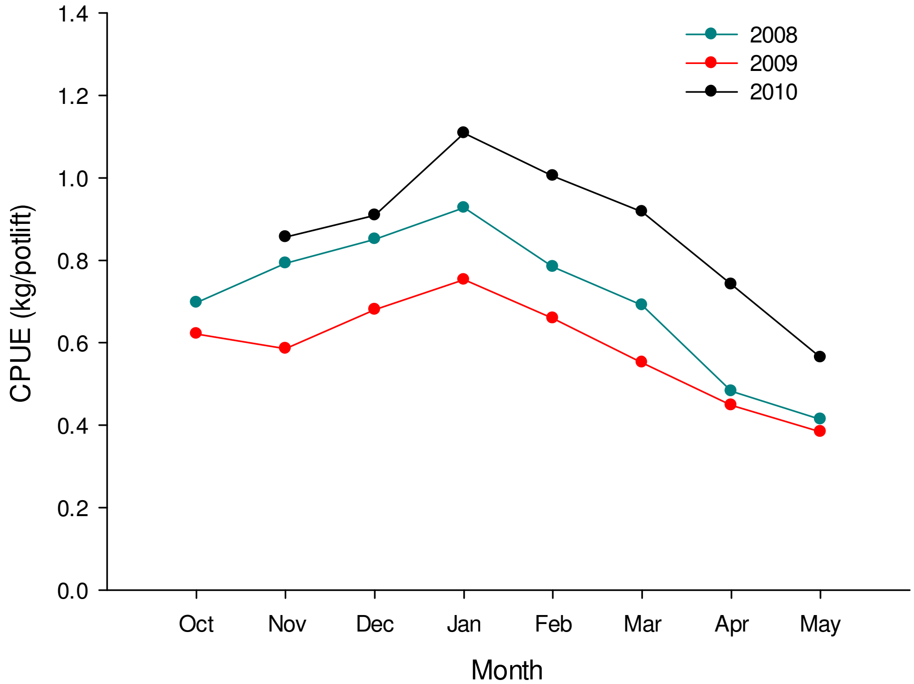

Figure 2-4 Within-season trends in CPUE in the SZRLF from 2008–2010 (note: October closed to fishing in 2010).

2.2.3 Regional trends

Over 95% of the catch in the SZRLF is currently taken from MFAs 55, 56 and 58 (Figure 1-4, Figure 2-5). Historically, MFA 51 was a more important area, but its contribution has decreased in recent seasons. The main fishery statistics for each region, as well as data from MFA 51, are presented below.

Catch

Prior to 1983, catches were similar between MFAs 55 and 56 but since then the highest catches have been consistently recorded in MFA 55 (Figure 2-6). Historically, the catch in MFA 51 ranged between 200-300 tonnes in the 1970s and early 1980s but since 1993 it has been less than 100 tonnes. Data in section 2.3.3 indicate that lobsters harvested from MFA 51 are generally larger in size and thus have low market value given the preference for smaller individuals.

Over the last 3-5 seasons, catch has decreased in all MFAs. For example, in MFA 55, the 2009 catch was 481.0 tonnes, representing a 39% decrease from 2007 (794.6 tonnes). In MFA 56, it was 360.1 tonnes, the lowest catch on record and a 43% decrease since 2005 (630.7 tonnes). The 2009 catch in MFA 58 was 300.5

tonnes, the lowest on record since 1989 (297.6 tonnes) and a 43% decrease since 2004 (520.3 tonnes).

In 2010, catches were 44.8, 455.5, 437.2 and 300.4 tonnes in MFAs 51, 55, 56 and 58, respectively (Figure 2-6). Compared to 2009 this represents a decrease of 49.9 tonnes in MFA 51 and marginal decreases of <30 tonnes in MFAs 55 and 58. The 2010 catch in MFA 56 reflects an increase of 77.1 tonnes.

Effort

As with catch, the majority of fishing effort is expended in MFAs 55, 56 and 58 (Figure 2-6). Effort decreased sharply from 1997 in all regions dropping to all time lows of 276,000 (MFA 55), 256,000 (MFA 56) and 287,000 (MFA 58) potlifts in 2002. In 2003, the TACC was increased from 1,770 to 1,900, which saw a corresponding increase in effort in all regions.

From 2003 to 2009 effort increased annually in all areas despite decreases in catch (Figure 2-6). For example, in MFA 55, effort in 2009 was 689,602 potlifts representing an increase of 96% since 2003 (350,945 potlifts). In MFA 56, effort was 654,799 potlifts, an increase of 103% since 2003 (322,000 potlifts). The 2009 effort in MFA 58 was 580,256 potlifts, the highest on record and a 68% increase since 2003 (346,000).

In 2010, effort was 51,265, 511,045, 451,060 and 301,756 potlifts in MFAs 51, 55, 56 and 58, respectively (Figure 2-6). Compared to 2009, this represents a substantial decrease in effort across all MFAs. Most notable was the decline in MFA 58 which decreased by 48% from 2009 estimates (580,257 potlifts).

CPUE

CPUE in the three main MFAs increased considerably from 1996 to 2002 peaking at 2.4, 2.3 and 1.6 kg/potlift in MFAs 55, 56 and 58, respectively (Figure 2-7). However, over the next six seasons it decreased markedly in all areas. For example, in MFA 55, CPUE in 2009 was 0.69 kg/potlift, representing a decrease of 66% from 2003 (2.04 kg/potlift). Similarly, the estimates of 0.54 kg/potlift and 0.51 kg/potlift represented decreases of 73% and 64% since 2003 in MFAs 56 and 58, respectively.

In 2010, CPUE increased in all major MFAs (Figure 2-7). The largest increases were observed in MFAs 56 (0.97 kg/potlift) and 58 (0.99 kg/potlift) where CPUE increased by 78% and 94%, respectively, compared to 2009 estimates.

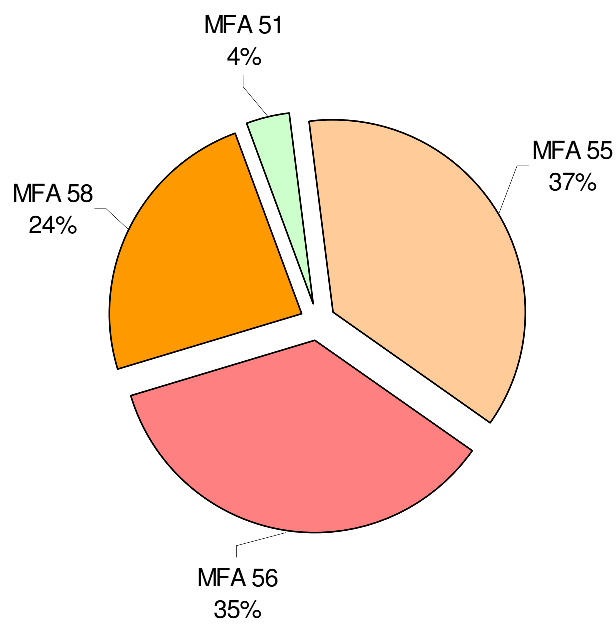

Figure 2-5 Proportion of the total catch (in terms of tonnage landed) taken from MFAs 51, 55, 56 and 58 of the SZRLF in 2010.

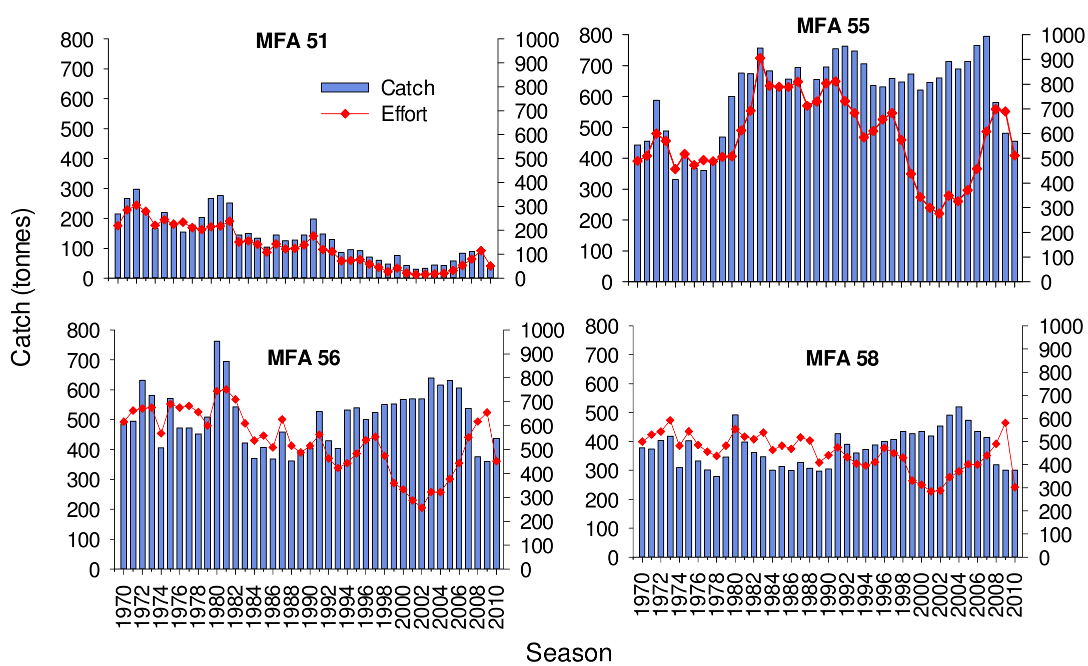

Figure 2-6 Inter-annual trends in catch and effort in the main MFAs of the SZRLF from 1970-2010 (note: alternate seasonal ticks on x-axis).

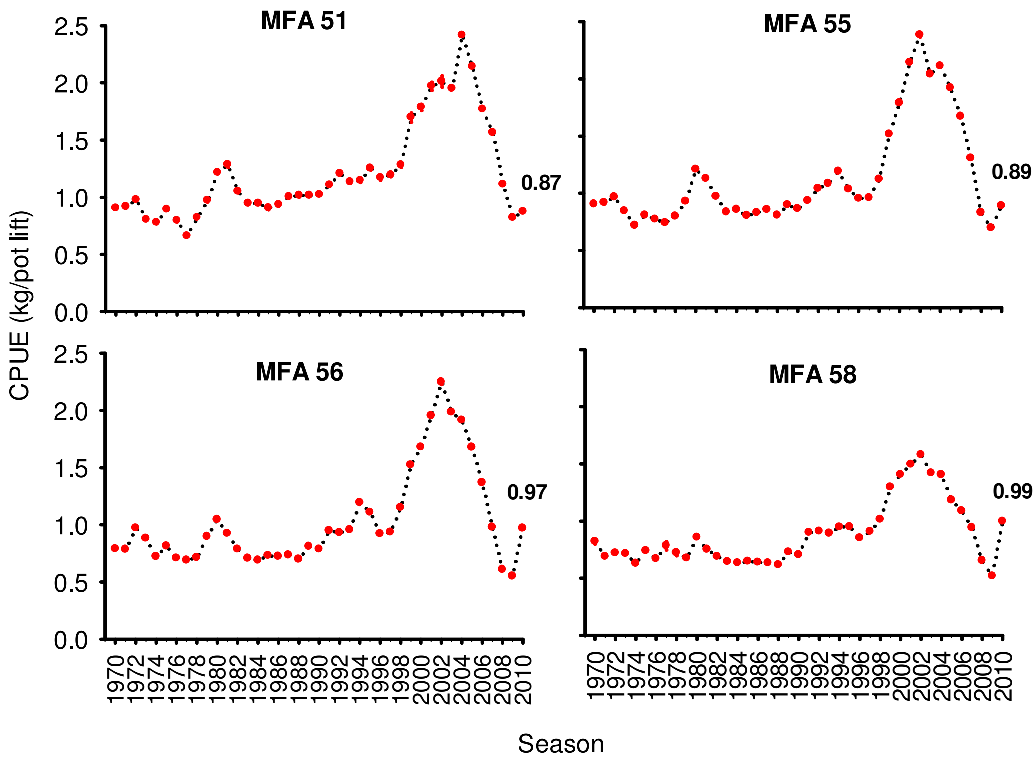

Figure 2-7 Inter-annual trends in CPUE in the main MFAs of the SZRLF from 1970-2010 (note: alternate seasonal ticks on x-axis).

2.2.4 Within-season regional trends

Catch and Effort

Within the main MFAs of 55, 56 and 58, most of the catch is historically taken during the first four months of the season (October-January) before decreasing thereafter (Figure 2-8; Note: October closed to fishing in 2010). In 2010, January was the highest catch month in all regions (12.3, 116.2, 121.9 and 85.7 tonnes in MFAs 51, 55, 56 and 58, respectively). May was the lowest catch month for all regions with <10 tonnes landed in each MFA. Overall, within-season trends in effort reflected trends in catch in all regions.

CPUE

Regional within-season trends in CPUE (Figure 2-9) broadly reflected those observed zonally (Figure 2-2). In recent seasons, in all major MFAs, within-season trends in CPUE have decreased consecutively on a monthly basis confirming that the zonal decline was not limited spatially or temporally but occurred during all months and in all regions of the fishery.

In 2010, with the exception of MFA 51, CPUE increased across all months, in all regions, compared to 2009 estimates (Figure 2-9). January was the highest catch rate month in all MFAs at 1.10, 1.03, 1.16 and 1.15 kg/potlift in MFAs 51, 55, 56 and 58, respectively. May was the lowest in all MFAs at 0.42, 0.60, 0.49 and 0.63 kg/poflift in MFAs 51, 55, 56 and 58, respectively.

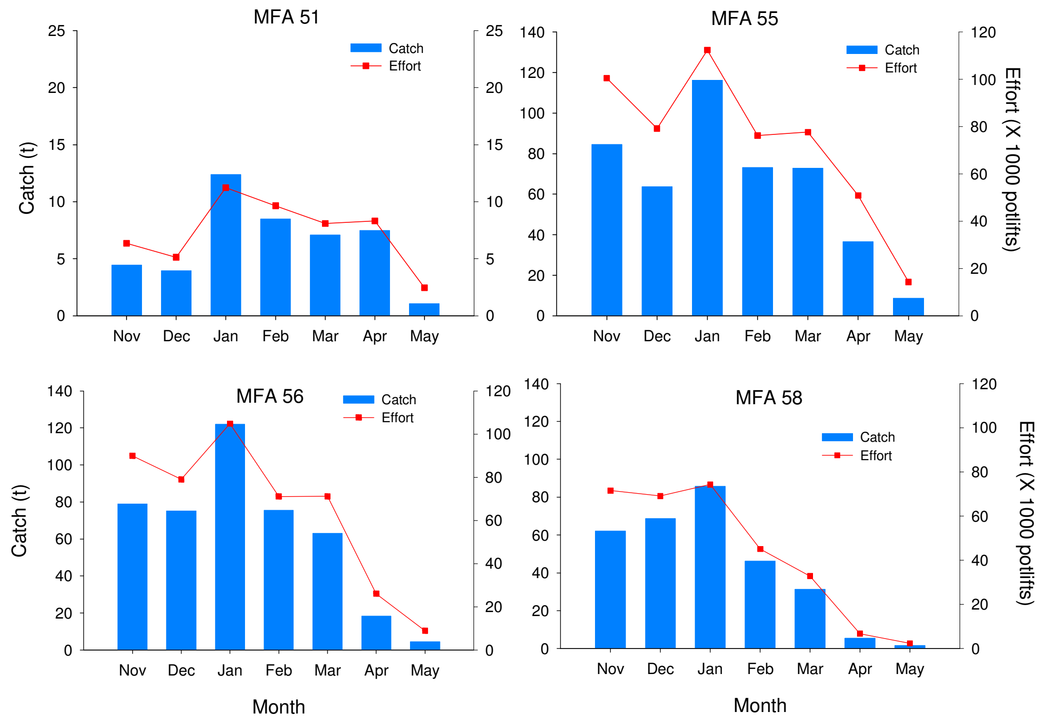

Figure 2-8 Within season trends in catch and effort in the main MFAs of the SZRLF for the 2010 season.

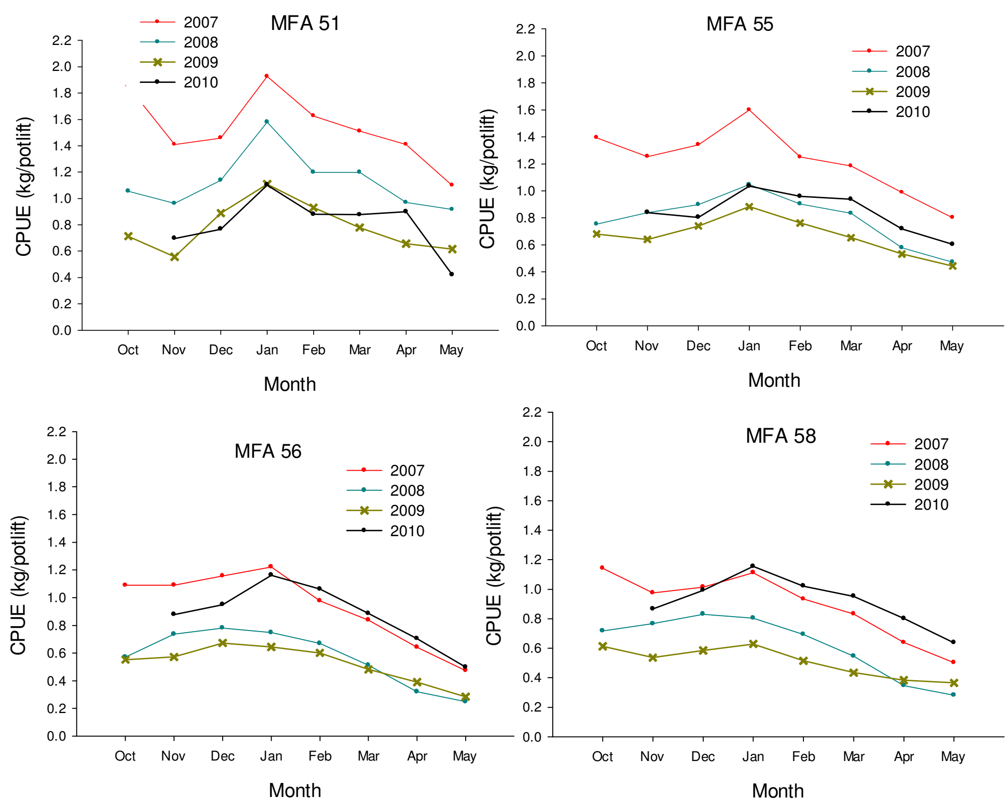

Figure 2-9 Within season trends in CPUE in the main MFAs of the SZRLF from 2007-2010.

2.2.5 Trends by depth

Zonal catch by depth

Over the last seven fishing seasons, most of the catch has been taken in the inshore grounds of the SZRLF (Figure 2-10). For example, since 2004, >85% of the catch has been taken from depths of <60 m. The proportion of catch taken in fishing depths of <30 m has been greater in recent years with 38-53% taken within this range between 2006 and 2010. Less than 5% of catch is currently taken in depths >90 m.

Regional catch by depth

Regional trends in catch by depth broadly reflect those at a zonal level (Figure 2-11). Over the last seven seasons, over 80% of the catch has generally come from <60 m depth in all regions. As with zonal estimates, the higher proportion of catch taken from 0-30 m depth over the last four seasons was notable in all MFAs. For example, 45% and 65% of the catch from MFAs 56 and 58, respectively, was taken in this depth range in 2010. As with zonal trends, <10% of total catch has been taken offshore in depths >90 m over recent seasons in all regions.

Zonal CPUE by depth

In order to assess spatial trends in catch rate by depth, logbook-estimated CPUE from four depth categories of 0-30, 31-60, 61-90 and >90 m were analysed over the period 1970 to 2010 (Figure 2-12). Temporal trends show that inshore CPUE in depths of 0-30 m and 31-60 m is consistently lower than offshore areas of 61-90 m and >90 m. Catch rate increased in all depth ranges from 1997, peaking at about 2.65 kg/potlift in depths >60 m in 2002. This compares to a CPUE of about 1.95 kg/potlift in depths <60 m in the same year. However, from 2003 to 2009, CPUE in all depth ranges decreased. For example, offshore CPUE in depths of >90 m dropped from 3.11 kg/potlift in 2004 to 0.92 kg/potlift in 2009, a decrease of 70%. Similarly, inshore CPUE in depths of <30 m decreased from 1.89 kg/potlift in 2002 to 0.61 kg/potlift in 2009, a decrease of 68%. In 2010, CPUE increased across all depth ranges and ranged from 0.88 kg/potlift in 31-60 m to 1.12 kg/potlift in 61-90 m.

Regional CPUE by depth

General trends in CPUE by depth are broadly similar across all MFAs (Figure 2-13). Overall, CPUE tends to be lower in shallower areas (0-30 m and 31-60 m) compared to deep water sites (60–90 m and >90 m). It should be highlighted that given the low percentage of overall catch taken from depths >60 m (Figure 2-10) data used to calculate CPUE in the 61-90 m and >90 m depth ranges are limited and should be treated with caution. Of specific note, however, is the general decrease in CPUE across all depths within each MFA from 2003 to 2009.

In MFA 51, annual CPUE increased in all depths from 1997 to 2004 before decreasing over the next five seasons. In 2010, catch rates in <60 m were similar to 2009 estimates but CPUE in 61-90 m increased from 0.91 to 1.42 kg/potlift. It is important to highlight that only 4% of the catch was taken in MFA 51 in 2010 (Figure 2-5). Estimates of CPUE in depths >90 m are not presented due to limited data.

In MFA 55, CPUE increased from 1997 to 2002 in all depth ranges with catch rates higher in depths of 61-90 m and >90 m compared to shallower areas (Figure 2-13). For example, in 2003, CPUE was 1.7 kg/potlift in 0-30 m compared to 3.4 kg/potlift in the >90 m range. Over the next six seasons however, CPUE generally decreased in all depth ranges. With the exception of the 61-90 m depth range, where CPUE increased from 0.75 to 1.15 kg/potlift, catch rates in 2010 in all depth ranges were marginally higher than 2009 estimates.

Trends in CPUE by depth within MFAs 56 and 58 broadly reflect those in MFA 55 with decreases in catch rate in all depth ranges in both MFAs over the last seven seasons. For example, in MFA 56, CPUE decreased by 77% from 2.2 kg/potlift in 2002 to 0.5 kg/potlift in 2009 in 0-30 m. Within depths of 61-90 m, it decreased by 84% from 3.3 kg/potlift to 0.5 kg/potlift over the same period. Consistent trends are also evident in MFA 58 with CPUE decreasing by 68% from 1.6 kg/potlift in 2002 to 0.5 kg/potlift in 2009 in depths of 0-30 m. In 2010, considerable increases in CPUE were observed across most depth ranges in MFAs 56 and 58 compared to 2009. For example, in MFA 56, CPUE in 0-30 m increased from 0.57 to 1.01 kg/potlift. Similarly, in MFA 58, it increased from 0.52 to 1.02 kg/potlift in the same depth range. In the 31-60 m depths catch rates increased from ~0.5 to ~0.9 kg/potlift in both MFAs. Overall, these data suggest that the zonal increase in CPUE in 2010 (Figure 2-2) was primarily driven by increased catch rates within inshore grounds (<60 m), within the southern MFAs of 56 and 58.

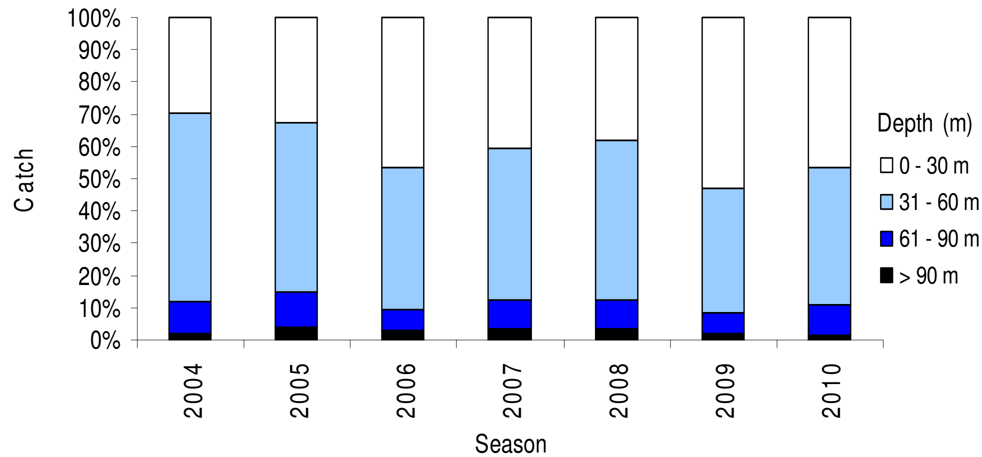

Figure 2-10 Percentage of catch taken from four depth ranges in the SZRLF from 2004-2010.

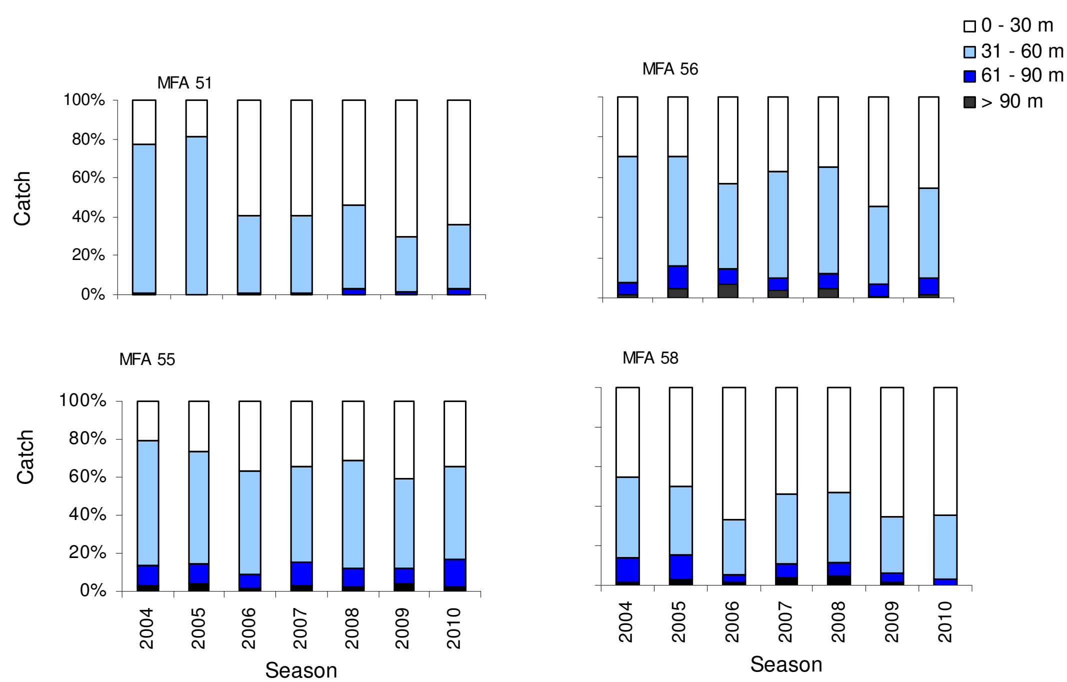

Figure 2-11 Percentage of catch taken from four depth ranges in the four main MFAs of the SZRLF from 2004-2010.

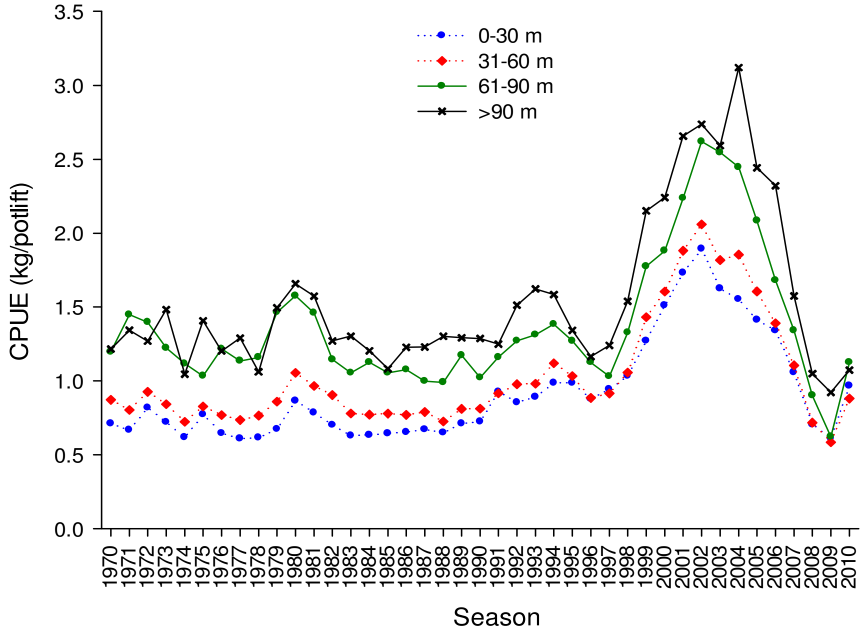

Figure 2-12 CPUE in four depth ranges in the SZRLF from 1970-2010.

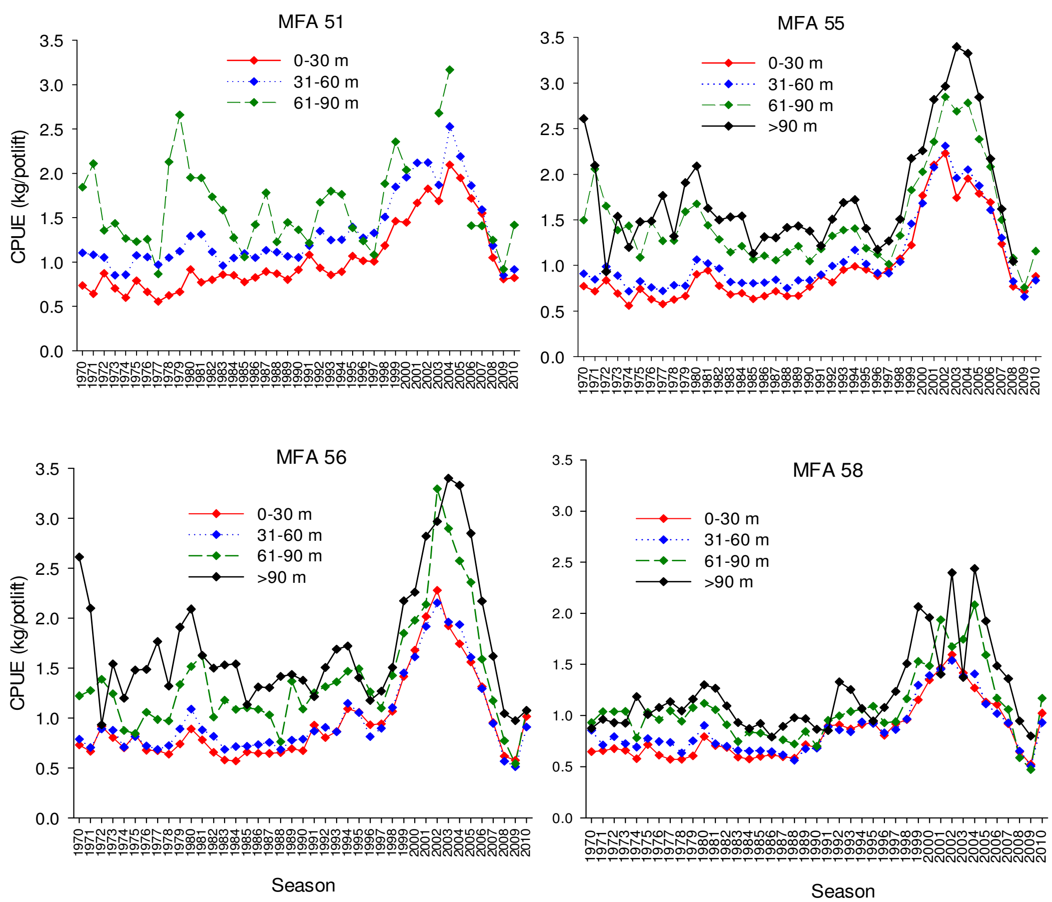

Figure 2-13 CPUE in four depth ranges from 1970-2010 across the four main MFAs of the SZRLF.

2.3 Pre-Recruit Index (PRI)

2.3.1 Zonal trends

The new harvest strategy for the SZRLF utilises logbook estimated PRI as an indication of future recruitment to the fishery (Figure 2-14). Long term trends show a general decline in undersized lobster abundance from 1998 to 2008, with the 2008 estimate of 0.85 undersized/potlift the lowest on record. This corresponds with an overall decline in legal size fishery catch rates over much of the same period (Figure 2-2). Over the last two seasons, PRI has increased and in 2010 was 1.43 undersized/potlift, the highest since 2002 (1.74 undersized/potlift). The increase in PRI in 2009 and 2010 reflects strong puerulus settlement observed in the fishery in 2005 and 2006 (Figure 3-1). In the SZRLF, the period between settlement and PRI is 4 years with recruitment into the fishery one year later (i.e. 5 years after settlement).

2.3.2 Regional trends

PRI increases with latitude between the Coorong and the Victoria/South Australia border with lowest numbers of undersized caught in MFAs 51 and 55 compared to MFAs 56 and 58 (Figure 2-15). Over the last 16 years PRI has remained relatively constant in both MFAs 51 and 55, generally remaining below 0.5 undersized/potlift. The highest PRI levels are usually observed in MFAs 56 and 58. With the exception of an increase in 2006, PRIs generally declined in both MFAs from the late 1990s to 2008. Since then, PRIs have increased and in 2010 were 2.06 and 3.96 in MFAs 56 and 58, respectively. This represents the highest PRI since 2002 (2.12 undersized/potlift) in MFA 56 and the highest on record in MFA 58.

2.3.3 Within-season trends

In 2010, October was closed to fishing in the SZRLF, but with the exception of April and May, was consistently higher across all other months of the fishery compared to 2009 estimates (Figure 2-16). PRI was highest in January at 1.64 undersized/potlift and lowest in May at 0.46 undersized/potlift.

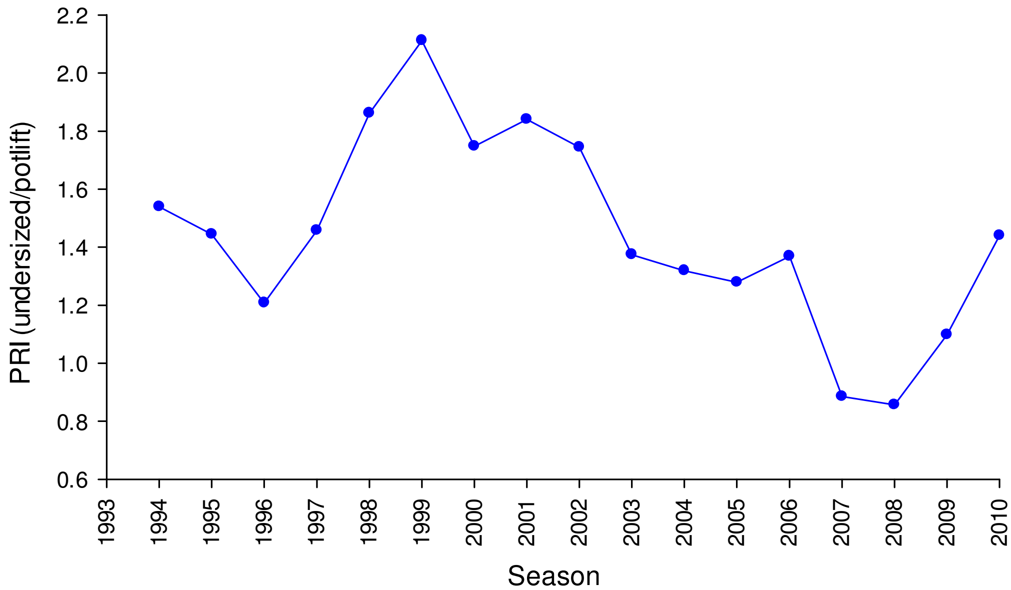

Figure 2-14 Inter-annual trends in pre-recruit index (PRI) in the SZRLF from 1994 to 2010 as estimated from logbook data (Nov-Mar inclusive).

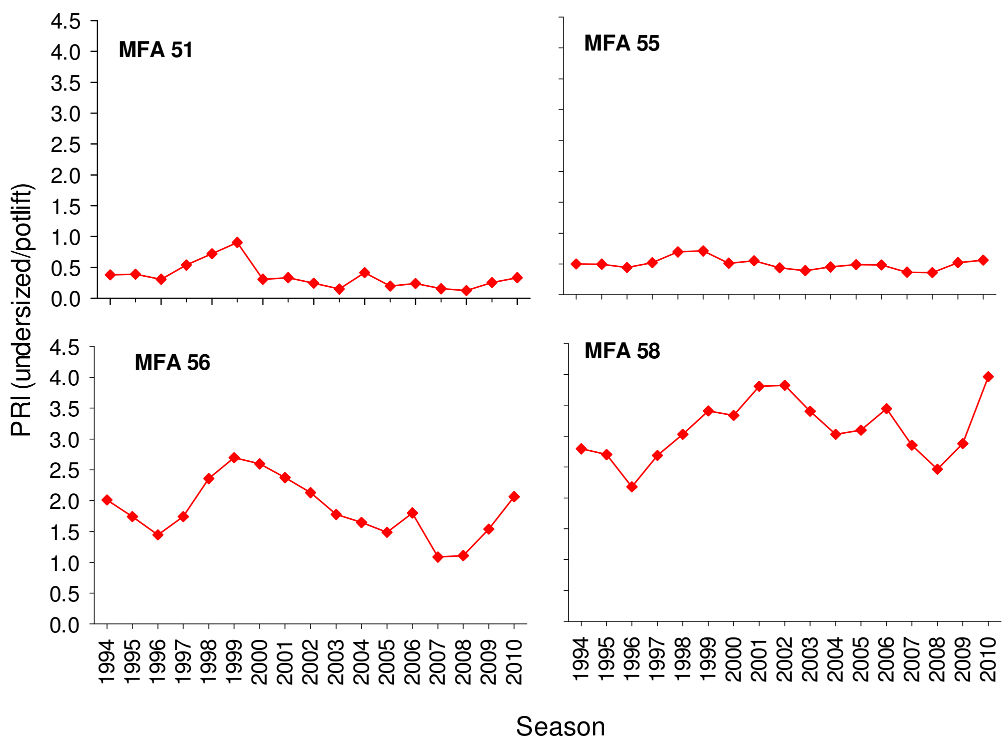

Figure 2-15 Inter-annual trends in pre-recruit index from 1994 to 2010 in the main MFAs of the SZRLF as estimated from logbook data (Nov-Mar inclusive).

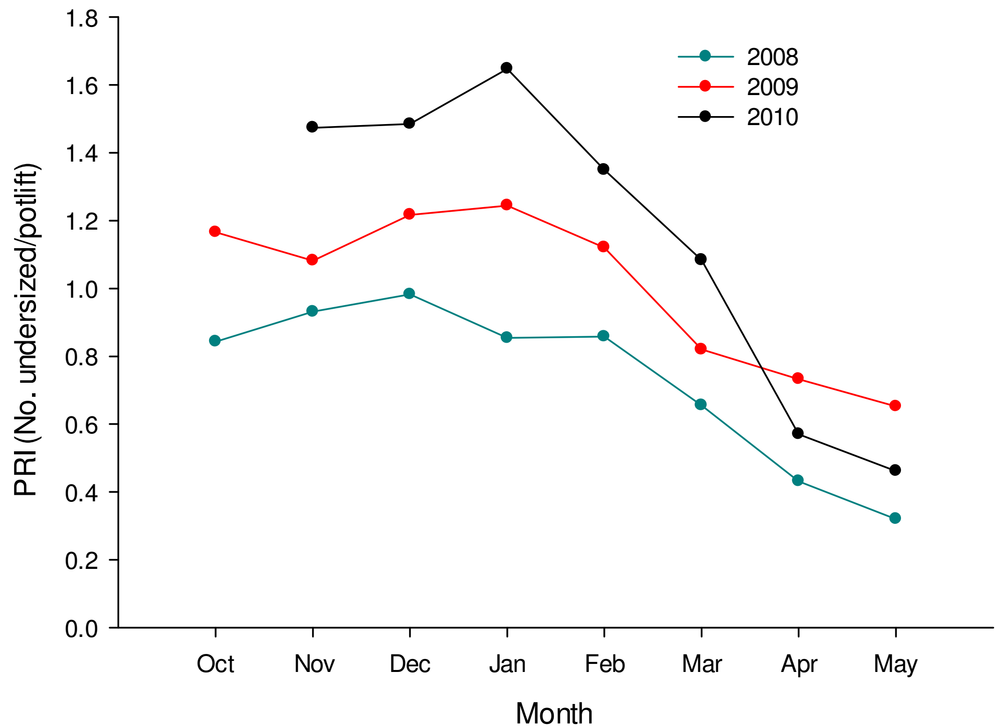

Figure 2-16 Within-season trends in pre-recruit index in the SZRLF over the last three fishing seasons as estimated from logbook data.

2.4 Mean Weight

2.4.1 Zonal trends

The pattern of rise and fall in mean weight generally reflects long-term patterns of recruitment, with low mean weights resulting from influxes of small lobsters into the fishable biomass and high mean weights resulting from several consecutive years of low recruitment (Figure 2-17). From 1982 to 1991, mean weight decreased from 0.88 to 0.79 kg before rising to 0.84 kg in the mid 1990s. Mean weight reached an all time low of 0.76 kg in 1999 before increasing over the next four seasons to reach 0.85 kg in 2003. Over the next three seasons, mean weight decreased and in 2006 was 0.80 kg. In 2007, mean weight once again increased to 0.83 kg and remained at this level in 2008. Over the last two seasons there has been a notable decrease in mean weight with the 2010 estimate of 0.70 kg the lowest on record. High-grading (the selection of smaller sized individuals due to higher unit value; Figure 2-32) has the capacity to impact on mean weight estimated from logbook data. However, as seen in Figure 2-32, levels of high-grading appear to have decreased in recent seasons, presumably in response to decreasing catch rates within the fishery.

2.4.2 Regional trends

Lobster mean weight decreases with increasing latitude from the mouth of the Murray River (MFA 51) to the Victoria/South Australia border (MFA 58) (Figure 2-18). Up to 1998, the inter-annual trends in mean weight has been variable in MFAs 51 and 55, but have gradually declined in MFAs 56 and 58. From 1998 to 2002/2003 mean weight generally increased across all four MFAs before decreasing over the next 5-6 seasons (with the exception of MFA 51). In 2010, mean weight decreased in all major MFAs with estimates of 0.89, 0.79, 0.65 and 0.62 kg in MFAs 51, 55, 56 and 58 respectively. These values represent the lowest mean weights on record in all four regions.

2.4.3 Within-season trends

Since the 1970s there has been a consistent trend of increasing lobster mean weight as the season progresses (refer to Linnane et al. 2006, for estimates). On average, the smallest lobsters are caught in October/November and the largest later in the fishing season. In 2010 (when October was closed to fishing), with the exception of April and May, mean weight was consistently lower across all months compared to the 2009 season (Figure 2-19). Mean weight was lowest in November at 0.65 kg and highest in May at 0.87 kg.

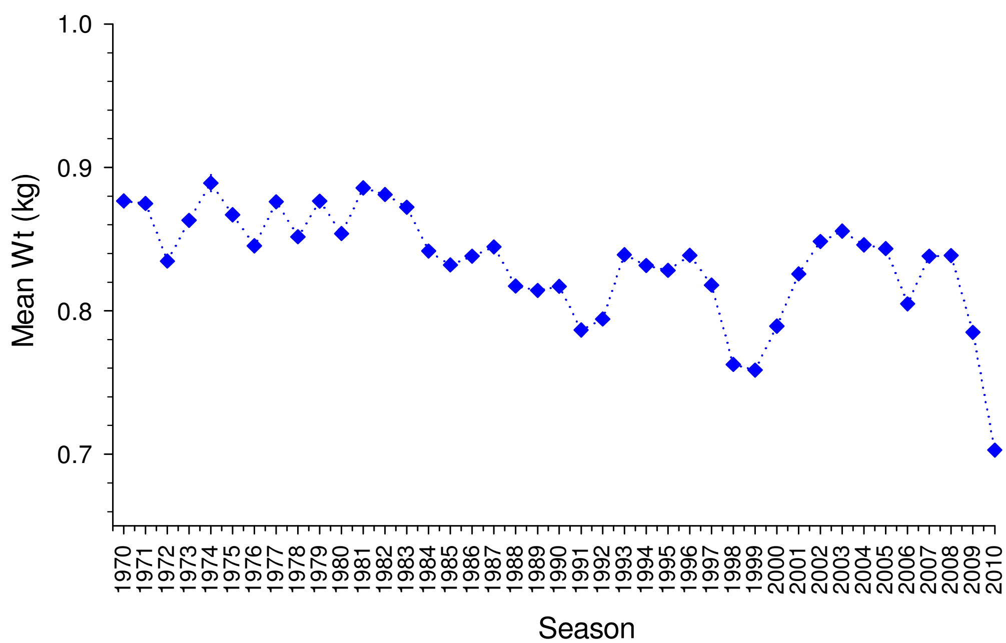

Figure 2-17 Inter-annual trends in the mean weight of lobsters in the SZRLF for the fishing seasons between 1970 and 2010.

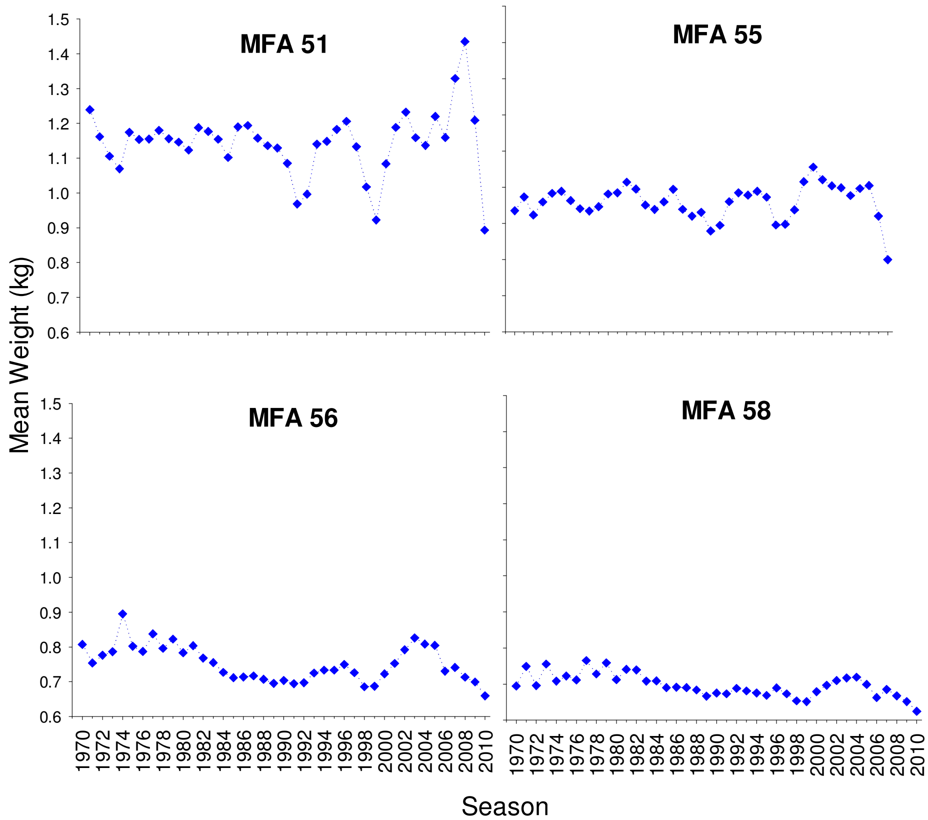

Figure 2-18 Inter-annual trends in the mean weights (± SE) of lobster for the main MFAs of the SZRLF for the fishing seasons between 1970 and 2009 (note: alternate seasons on X-axis).

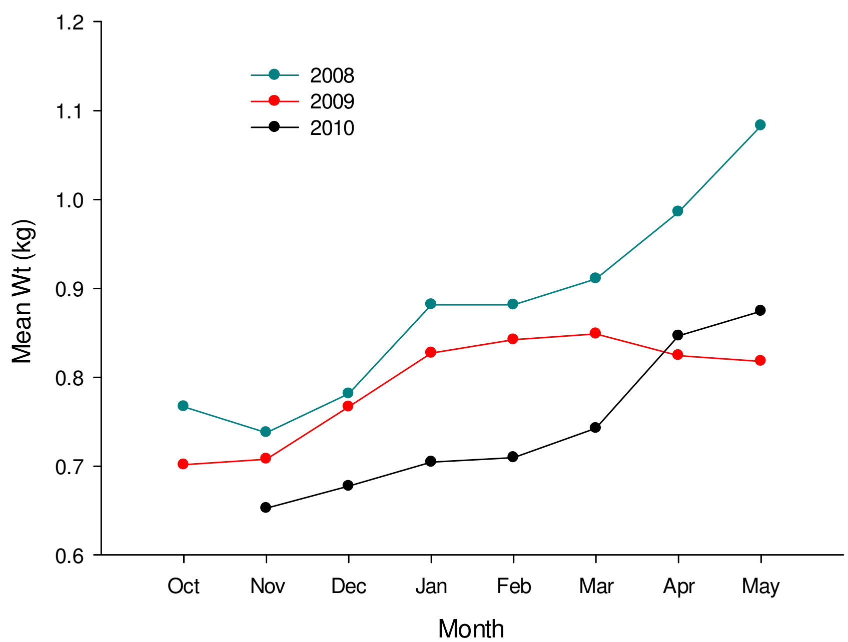

Figure 2-19 Within-season trends in the mean weight of lobsters in the SZRLF during the 2008, 2009 and 2010 seasons.

2.5 Length Frequency

Since 1991, when the voluntary catch sampling program began, between 5,000 and 30,000 lobsters have been measured annually (refer to Linnane et al. 2005, for all length frequency outputs). As well as providing a comparison of changes in size structure over time, length frequency data are a critical component of the length structured model (LenMod) (see section 5 of this report).

Male lobsters, which grow faster and reach larger sizes than females (McGarvey et al., 1999a), range between 70 and 200 mm CL. Female lobsters range between 70 and 150 mm CL. In 2010, a total of 16,392 lobsters were measured of which 7,579 were males and 8,813 females. To compare temporal changes in size structure, male and female data were combined and analysed from 2008 to 2010 (Figure 2-20). Between 2008 and 2009 the frequency of lobsters above the MLS decreased as reflected by the decrease in legal size catch rates over the same period (Figure 2-2). For example, the percentage of lobsters above the MLS in 2008 was 56%. In 2009, this decreased to just 38%. In 2010, the percentage of lobsters above the MLS increased to 48% reflecting the increase in legal size catch rate in the same season.

While the percentage of lobsters above the MLS decreased between 2008 and 2009, it increased for individuals below 98.5 mm CL (Figure 2-20). For example, the percentage of lobsters below the MLS in 2008 was 44%. In 2009, this increased to 62%. This reflected the high PRI expected from strong settlement observed in 2005 and 2006 (Figure 2-14 and see Figure 3-1) which entered the fishery in 2010 as observed in increases to legal size catch rates. The percentage of lobsters below the MLS in 2010 was 52% indicating that strong levels of recruitment are again expected to enter the fishery in 2011.

Length frequency data from 2010 were compared with those from 2003 (when CPUE was ~1.8 kg/potlift) (Figure 2-21). In 2003, size classes above the MLS accounted for 77% of all lobsters landed. In particular, size classes from 98-130 mm CL were highly prevalent accounting for 55% of all legal sized lobsters. In 2010, 45% of all lobsters were within this size range. It is worth noting that lobster catchability from commercial traps can vary by both size and sex depending on environmental or behavioural variability (Miller, 1990; Frusher and Hoenig, 2001). Current data indicates that lobsters <70 and >150 mm CL are rarely caught, which is consistent with the size-selectivity of trap caught spiny lobsters in other fisheries (e.g. Goni, 2003a). As a result, data required to estimate population length frequency from commercial fishing traps alone, should be treated with some caution.

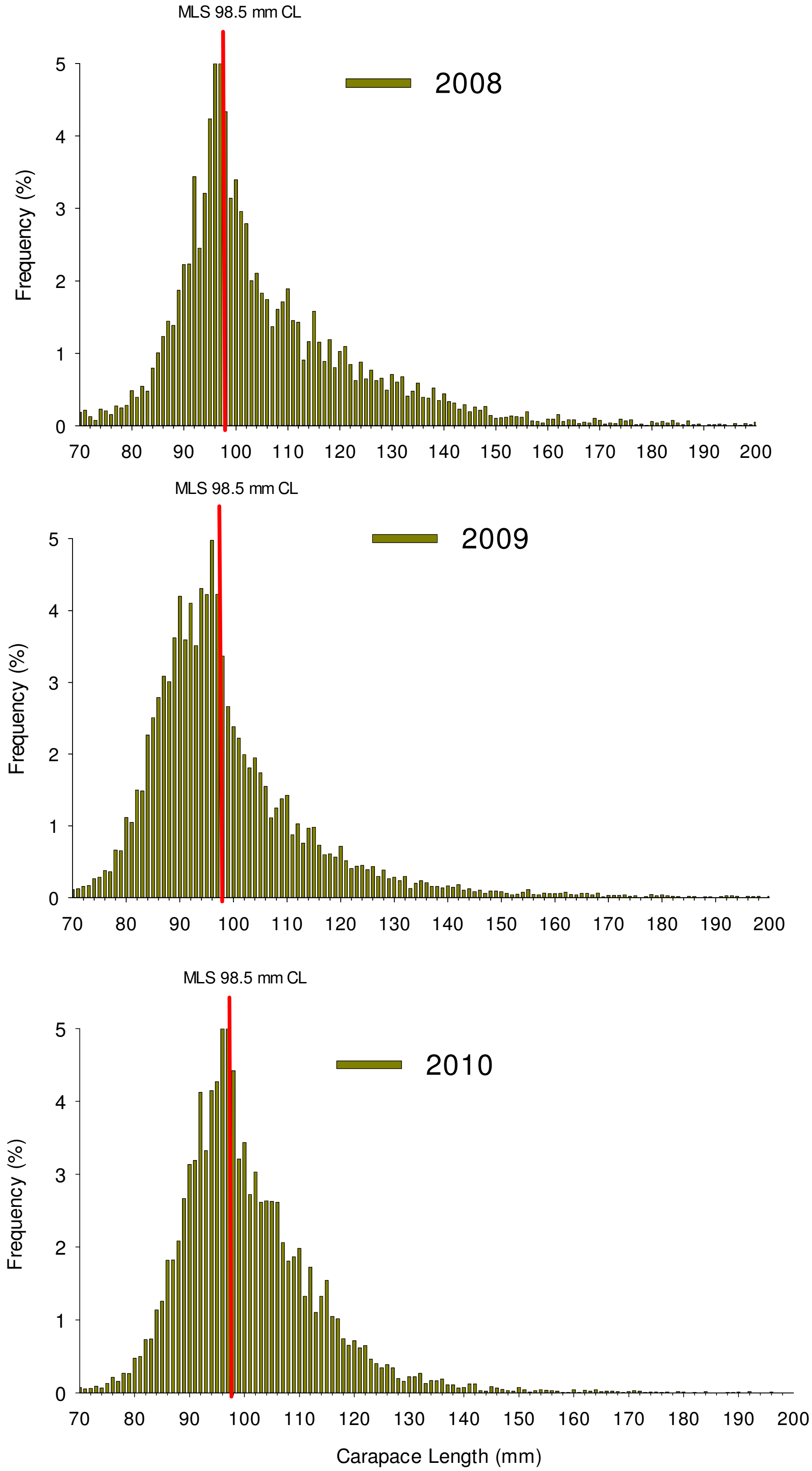

Figure 2-20 Length frequency distributions of male and female lobsters combined in the SZRLF from 2008 to 2010 (MLS = minimum legal size).

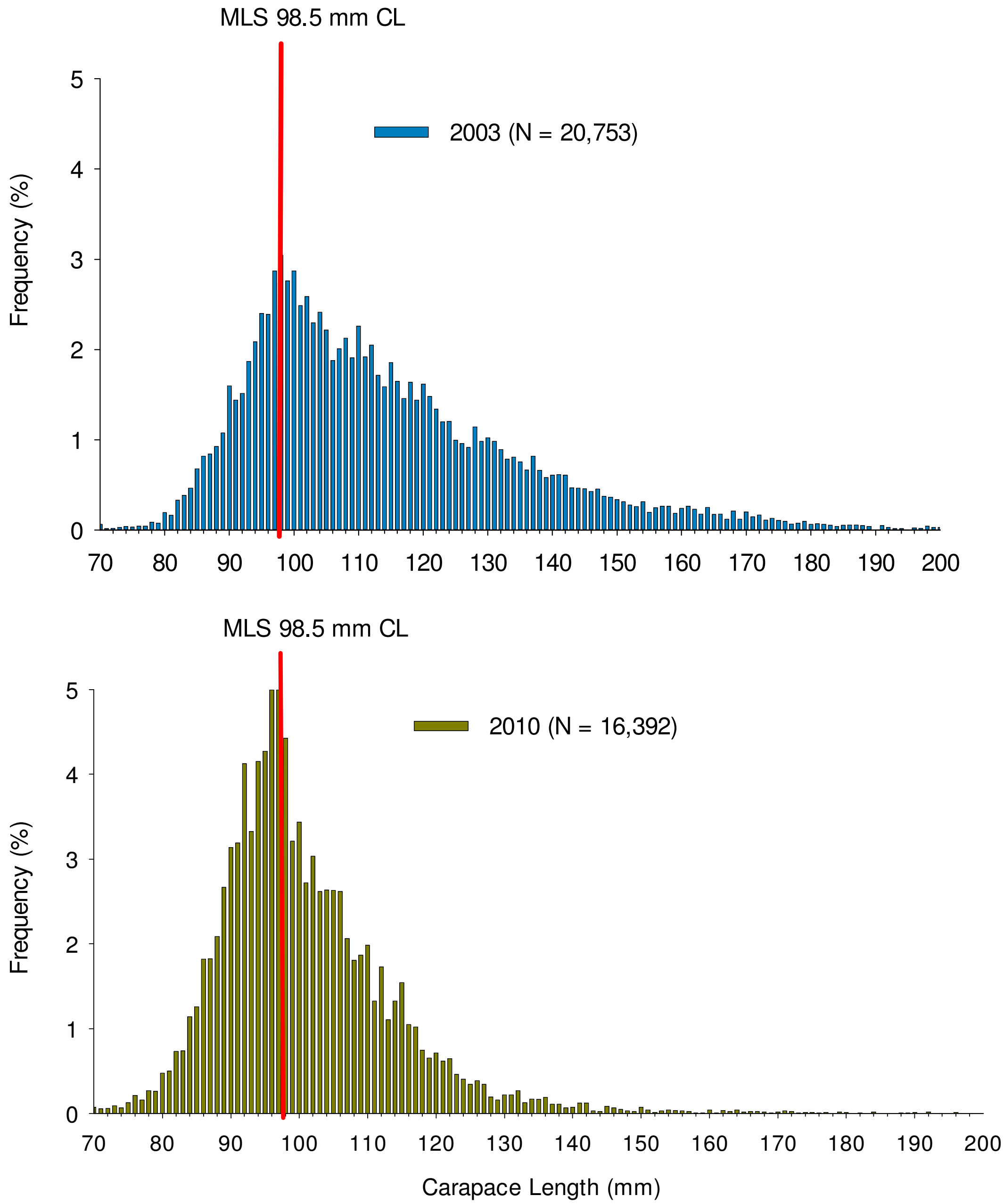

Figure 2-21 A comparison of length frequency distributions (male and female lobsters combined) in the SZRLF between 2003 (CPUE of 1.80 kg/potlift) and 2010 (CPUE of 0.94 kg/potlift) fishing seasons.

2.6 Spawning lobsters

2.6.1 Zonal trends

Zonal trends in the catch rate of spawning i.e. ovigerous lobsters (Figure 2-22) broadly reflect those of the overall catch rate (Figure 2-2). The number of spawning lobsters/potlift generally increased from 1991 (0.08 spawners/potlift) to 2002 (0.51 spawners/potlift). Over the next eight seasons however, the CPUE of spawning lobsters has generally decreased. In 2010, it was 0.05 spawners/potlift, which is one of the lowest estimates on record. It is import to note that as October was closed for the 2010 season, indices are likely to be underestimated given that October is the highest catch month for spawning individuals in the fishery (Figure 2-4).

2.6.2 Regional trends

In general, the catch rate of spawning lobsters increases southward along the coast from the Coorong (MFA 51) to the Victoria/South Australia border (MFA 58) (Figure 2-23). Inter-annual trends indicate that there are considerably higher numbers of spawners caught in MFAs 56 and 58 compared to MFAs 51 and 55. For example, the catch rate of spawning lobsters in MFAs 51 and 55 has varied from 0.07–0.32 spawning lobsters/potlift between the seasons 1998–2004 compared to MFAs 56 and 58 which have rates between 0.45 and 0.76 spawners/potlift over the same time period. As with zonal trends, the regional catch rate of spawning spawners generally increased from 1991 to 2002 in all areas. Since 2003, the catch rate has generally decreased in all MFAs. In 2010, the catch rates of spawning lobsters were 0.01, 0.02, 0.07 and 0.13 spawners/potlift in MFAs 51, 55, 56 and 58 respectively. All were close to historical lows in each region, however, as with zonal figures, indices in 2010 are likely to be underestimated due to the October closure.

2.6.3 Within-season trends

There is a distinct, within-season pattern in the number of spawning lobsters/potlift within the SZRLF, which is strongly related to the annual reproductive cycle of the species. Hatching commences in early spring and is completed by December/January. As a result, there is a complete absence of spawning lobsters in the commercial catch after December (Figure 2-24). In 2010, October was closed to fishing but the spawning index in November was 0.2 spawners/potlift compared to 0.09 spawners/potlift for the same month in 2009.

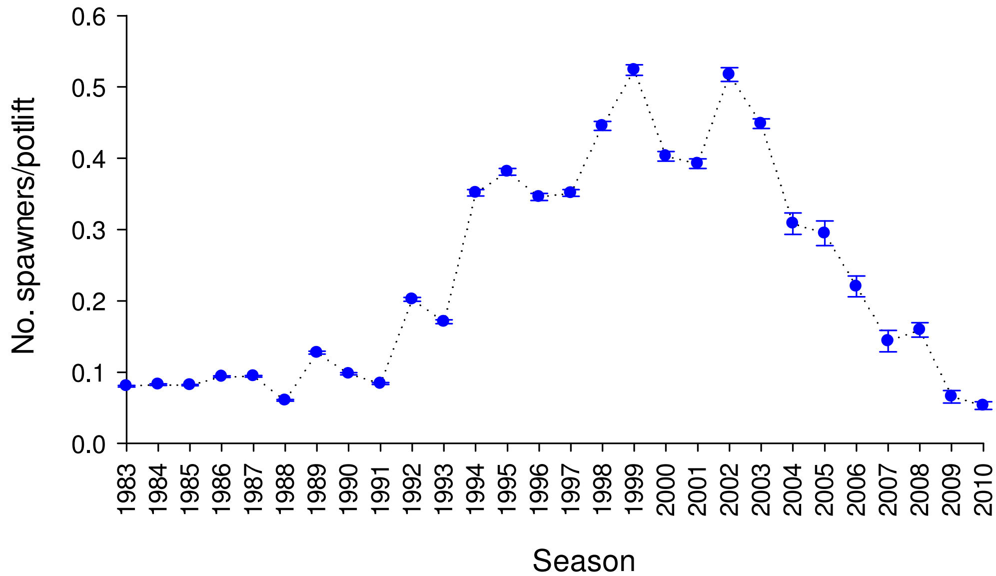

Figure 2-22 Inter-annual trends in the number of spawning lobsters in the SZRLF between 1983 and 2010 (+/-SE). Note: October closed during 2010 season.

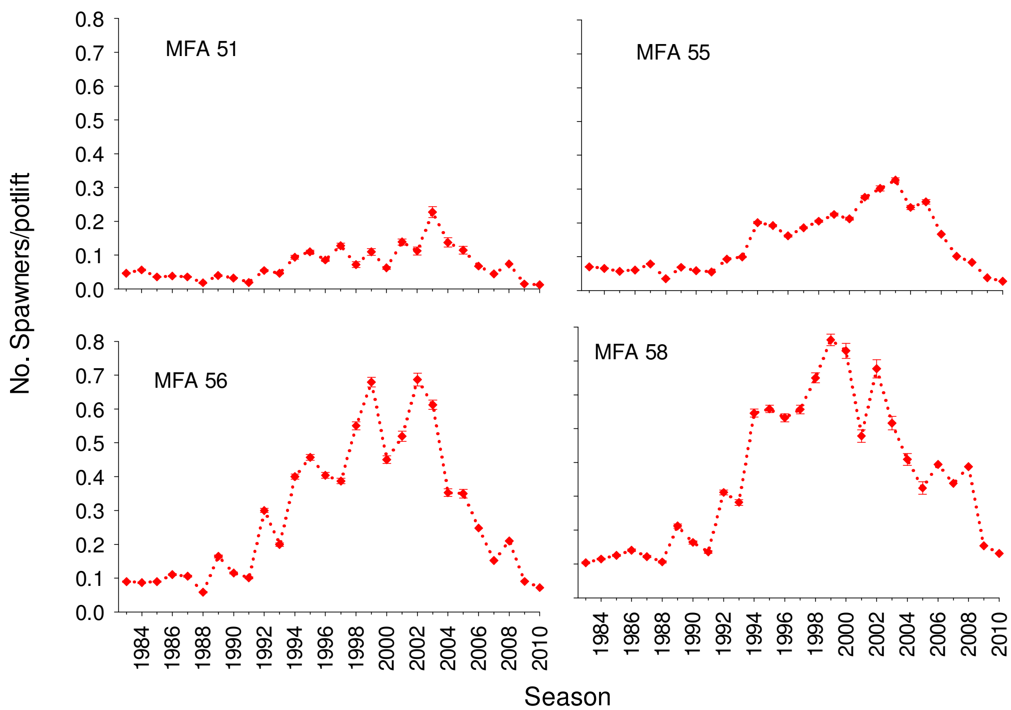

Figure 2-23 Inter-annual trends in the number of spawning lobsters/pot lift for the main MFAs in the SZRLF between 1983 and 2010. Note: October closed during 2010 season.

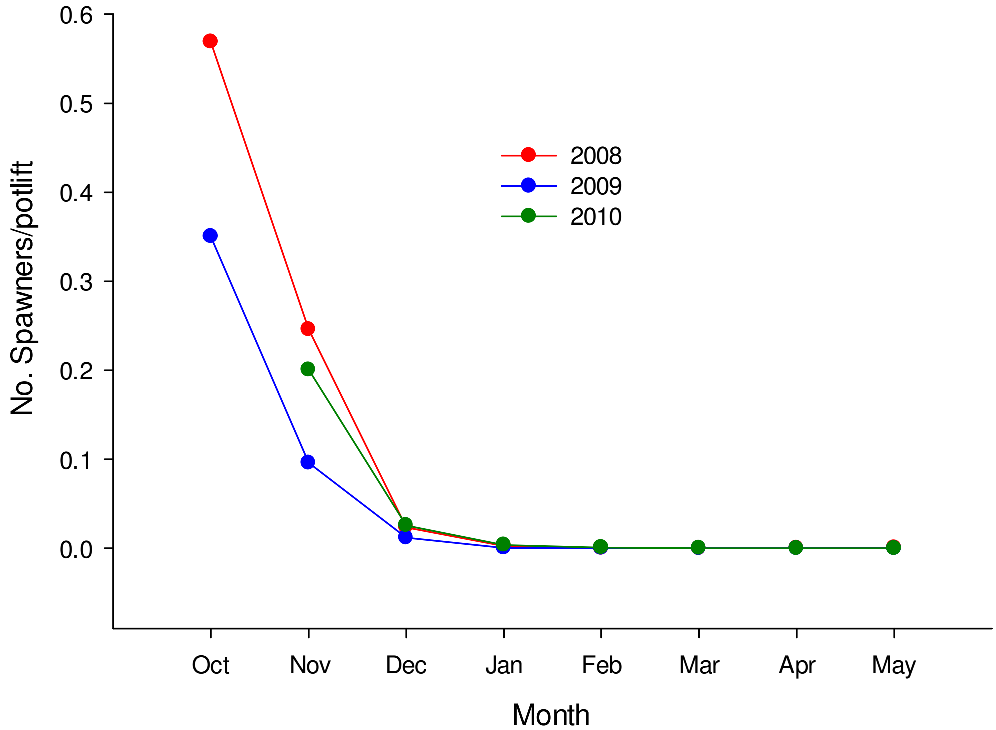

Figure 2-24 Within-season trends in the catch rate of spawning lobsters in the SZRLF during the 2008, 2009 and 2010 seasons. Note: October closed during 2010 season.

2.7 Lobster Mortalities

2.7.1 Zonal trends

The number of dead lobsters/potlift increased from 1996 (0.13 dead/potlift) to 2004 (0.27 dead/potlift) although the overall numbers were relatively low (<0.3 dead/potlift) (Figure 2-25). With the exception of 2006, the index decreased over the next four seasons and in 2009 was 0.09 dead/potlift, the lowest estimate on record. In 2010, the index increased to 0.17 dead/potlift, the highest since 2006 (0.22 dead/potlift).

2.7.2 Regional trends

Regional trends in the catch rate of dead lobsters broadly reflect those observed at the zonal level (Figure 2-26). Overall, catch rates are lower in MFA 51, compared to other regions. As with zonal trends, the CPUE of dead lobsters generally increased from 1996 to 2004 in all regions with the highest number of dead lobsters observed in 2004 in MFA 55 (0.29 dead lobsters/potlift). Over the next five seasons, lobster mortalities generally decreased in all regions with the 2009 estimates the lowest on record with the exception of MFA 58. In 2010, mortality estimates increased in all regions with indices of 0.12, 0.16, 0.18 and 0.25 dead/potlift in MFA 51, 55, 56 and 58, respectively.

2.7.3 Within-season trends

Catch rates of dead lobsters tends to be highest at the start of the season before decreasing thereafter (Figure 2-27). In 2010, this trend continued with the CPUE of dead lobsters highest in November (0.22 dead lobsters/potlift) and lowest in May (0.09 dead lobsters/potlift). Overall, the catch rate of dead lobsters was consistently higher in 2010 across all months compared to the previous three seasons.

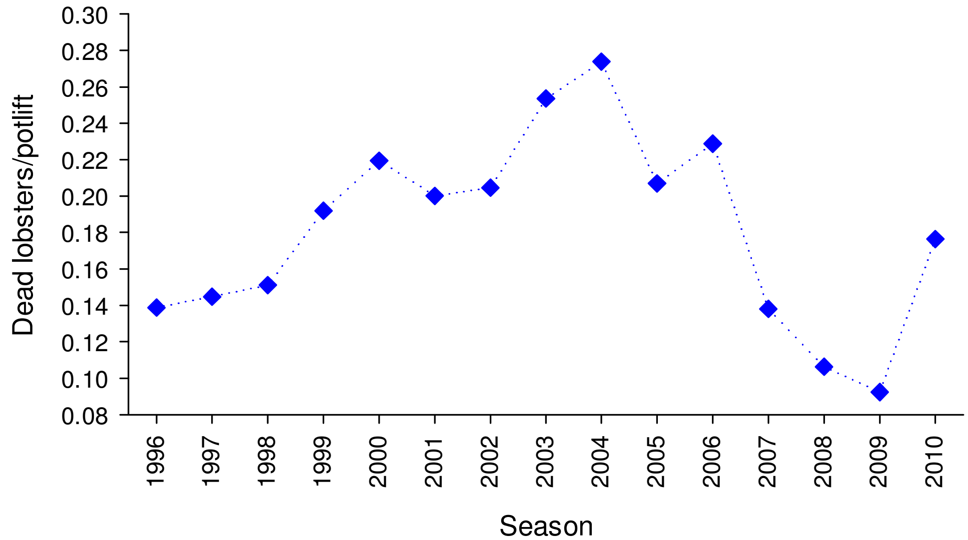

Figure 2-25 Inter-annual trends in CPUE of dead lobsters in the SZRLF from 1996 to 2010.

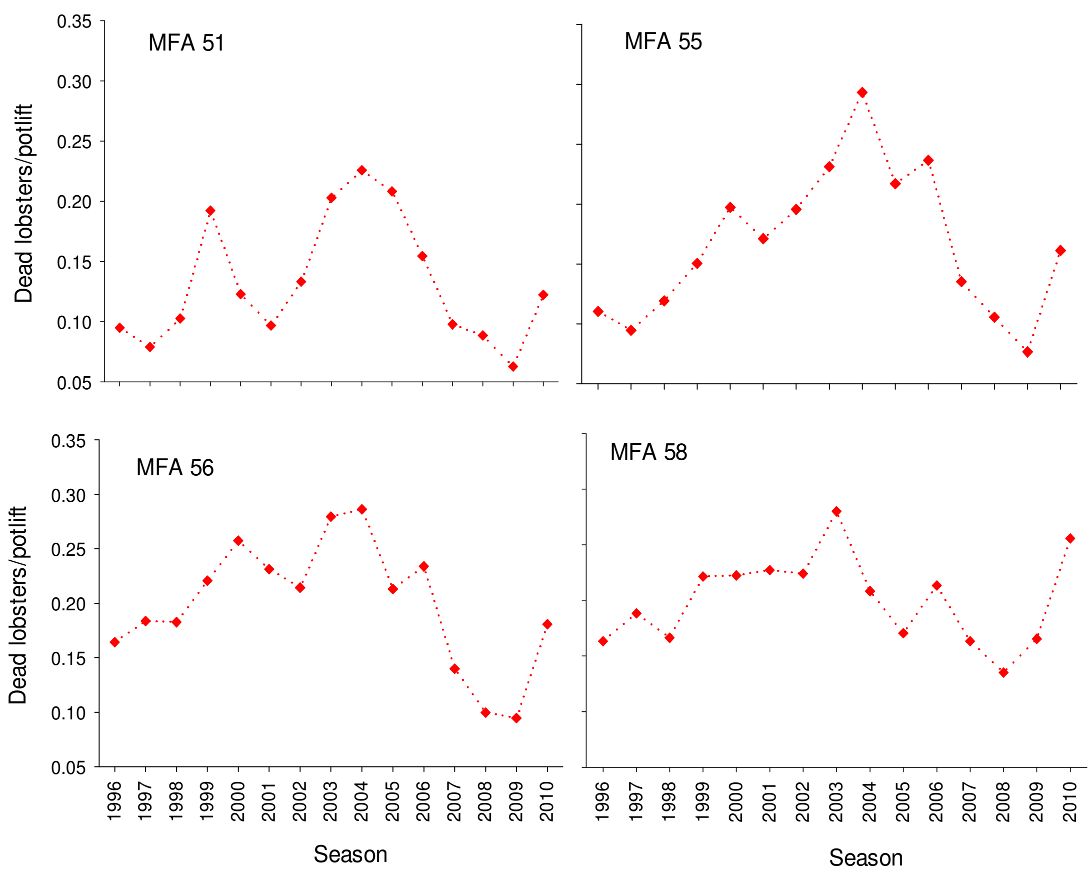

Figure 2-26 Inter-annual trends in the number of dead lobsters/pot lift for the main MFAs in the SZRLF from 1996 to 2010.

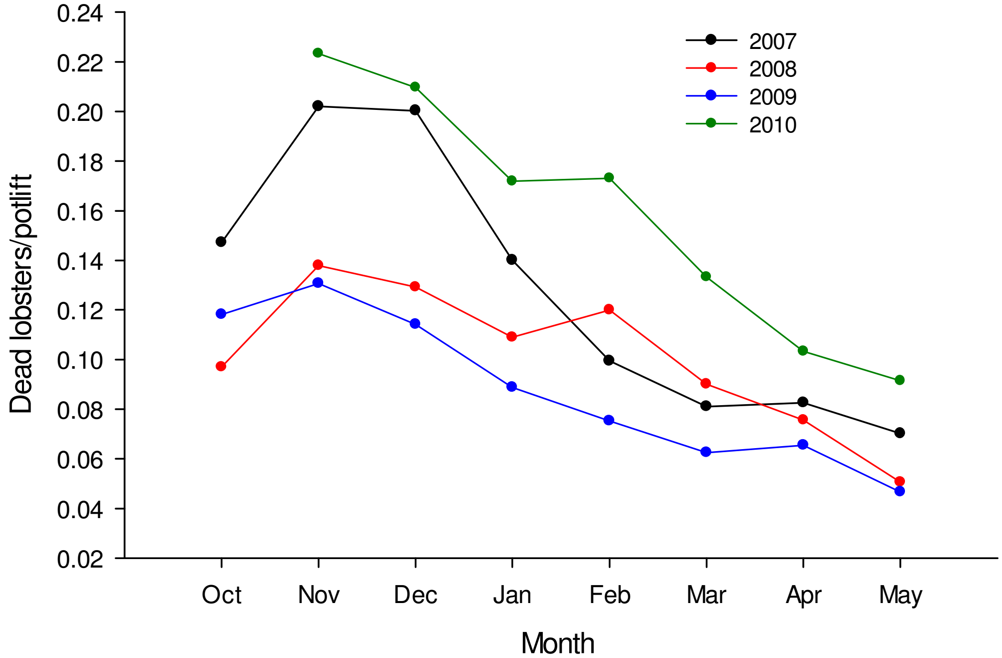

Figure 2-27 Within-season trends in the catch rate of dead lobsters in the SZRLF from 2007 to 2010.

2.8 Octopus Catch Rates

2.8.1 Zonal trends

Annual catch rates of octopus in the SZRLF have been variable over the last nine seasons (Figure 2-28). The highest catch rate was observed in 2000 at 0.05 octopus/potlift. From 2003 to 2009, catch rates generally decreased, with 2006 being the only exception. In 2009, the estimate was 0.01 octopus/potlift, the lowest catch rate on record. In 2010, the estimate increased to 0.03 octopus/potlift, the highest since 2006. Given that the majority of within pot lobster mortality is caused by octopus predation, this correlates with the increase in CPUE of dead lobsters also observed in 2010 (Figure 2-25).

2.8.2 Regional trends

Regional trends in the catch rate of octopus broadly reflect those observed at the zonal level (Figure 2-29). Overall, between 1996 and 2009, catch rate ranged between 0.01 and 0.06 octopus/potlift. In 2010, the estimates increased in all MFAs with an index of 0.03 in MFAs 51, 55 and 56 and 0.01 in MFA 58.

2.8.3 Within-season trends

Octopus catch rates are generally highest at the start of the season before decreasing thereafter (Figure 2-30). This trend continued in 2010, with the highest catch rates observed in November (October closed to fishing in 2010) before decreasing through to the end of the season. During 2010, catch rates were consistently higher across all months compared to the previous three fishing seasons. The highest catch rate was observed in November at 0.04 octopus/potlift, while the lowest was in May at 0.01 octopus/potlift.

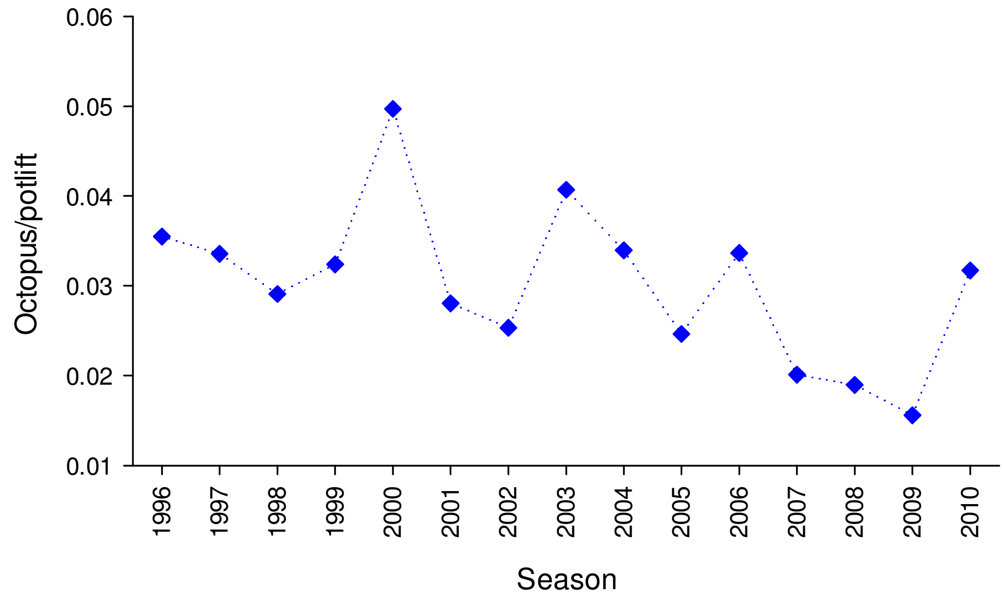

Figure 2-28 Inter-annual trends in catch rates of octopus in the SZRLF from 1996 to 2010.

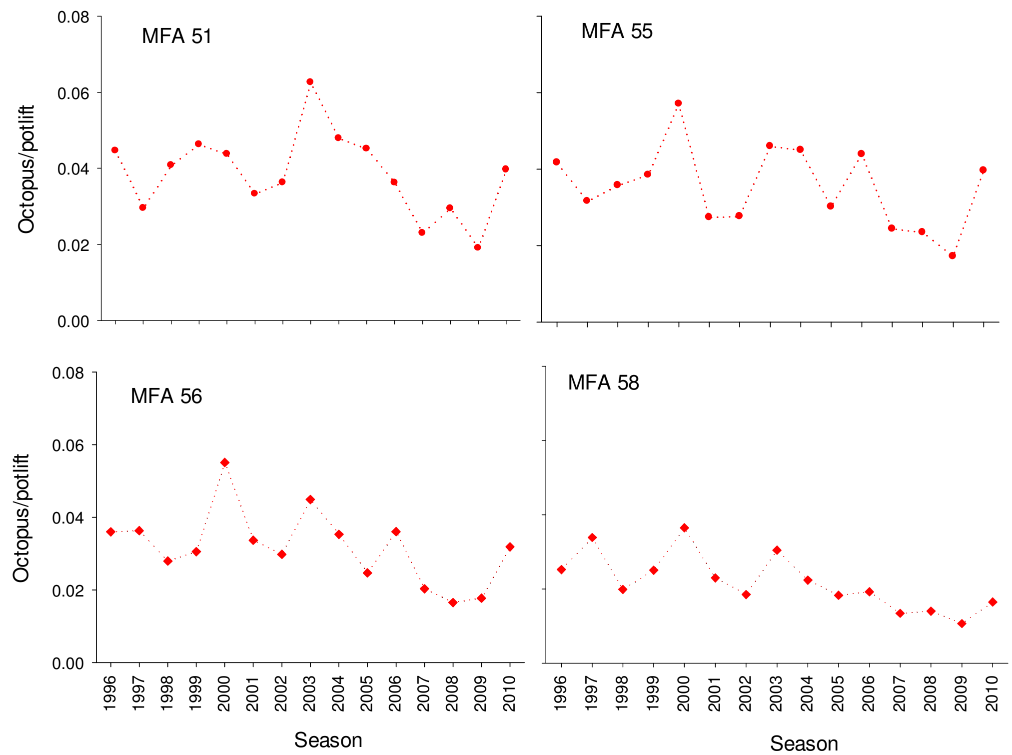

Figure 2-29 Inter-annual trends in the number of octopus/pot lift for the main MFAs in the SZRLF between 1996 and 2010.

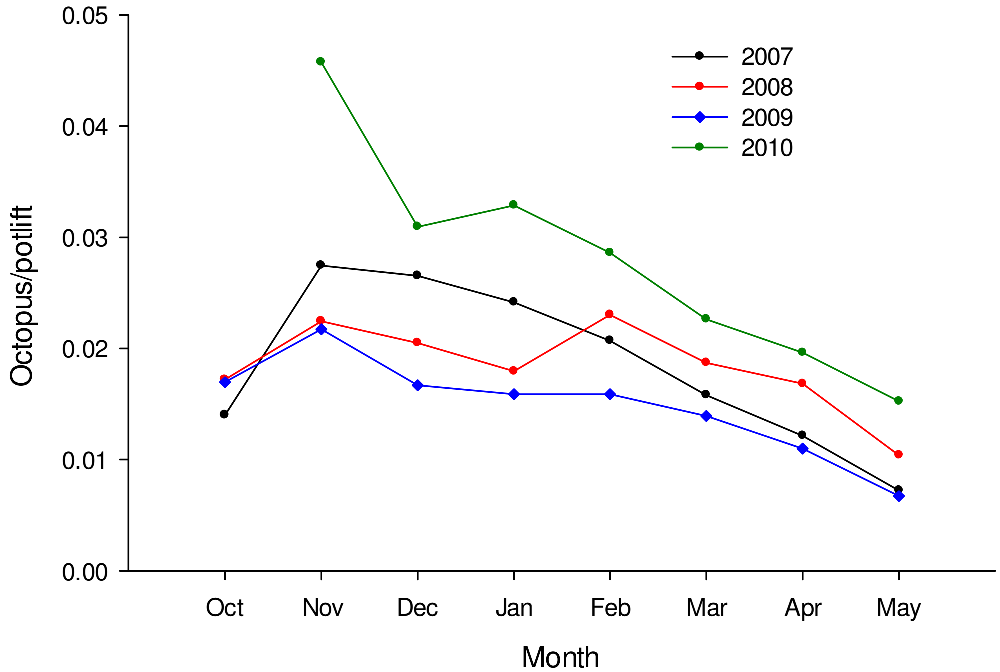

Figure 2-30 Within season trends in octopus catch rates in the SZRLF during the 2007, 2008 2009 and 2010 seasons.

2.9 Average days fished

2.9.1 Zonal trends

The average number of days fished each season per licence holder increased from 141 days in 1983 to a peak of 176 days in 1991 (out of a total number of 210 potential fishing days) (Figure 2-31). In 1993, the first year of the TACC (1,720 tonnes), the number of days fished/licence was 143. This increased to 153 days in 1997, but decreased over the next 5 seasons to a record low of 79 days in 2002. The TACC was increased from 1,770 to 1,900 tonnes in 2003 with an average of 95 days fished per licence for that season. From 2004 to 2009 the average numbers of days fished increased by 86% from 94 to 175, the highest on record, despite reductions to the TACC from 1,900 to 1,400 tonnes over the same period. In 2010, the TACC was reduced to 1,250 tonnes. The average numbers of days fished decreased by 35% to 114 days, the lowest since 2005 (105 days). Overall, this index reflects general trends in effort within the fishery which increased considerably between 2004 and 2009 before declining in 2010 (Figure 2-1).

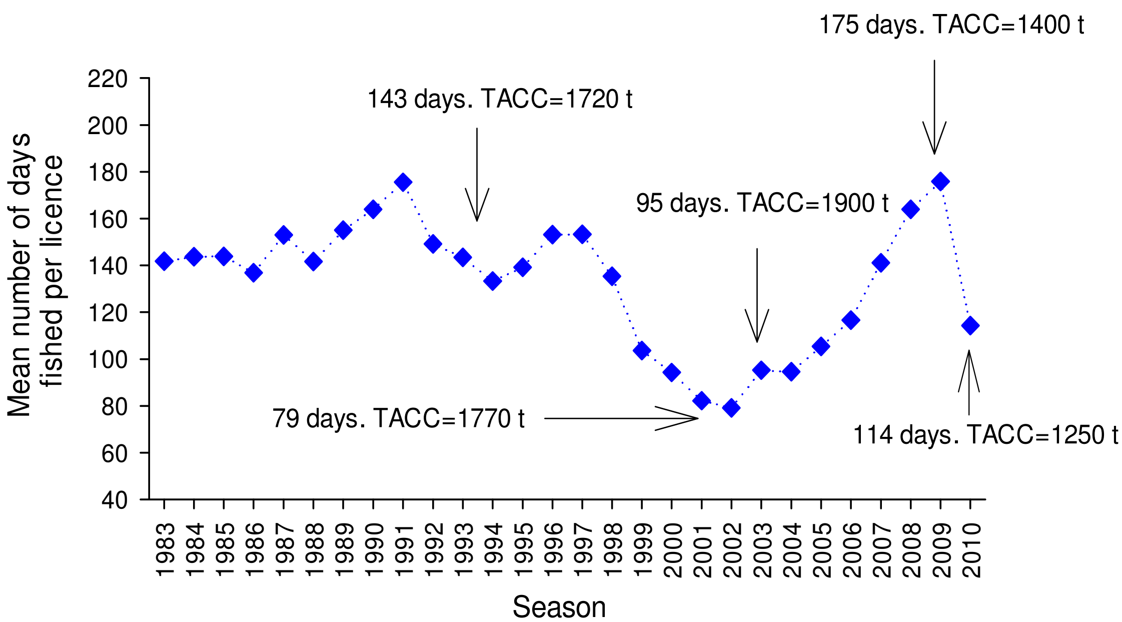

Figure 2-31 Inter-annual trends in the average number of days fished per licence in the SZRLF between the 1983 and 2010 fishing seasons. TACC = total allowable commercial catch.

2.10 High-grading

2.10.1 Zonal and within-season trends

Over the period 2002 to 2006, based on voluntary catch returns, the amount of lobsters high-graded (i.e. returned to the water due to low market value) exceeded 100 tonnes annually (Figure 2-32). However, over the next three seasons, levels of high-grading decreased and in 2009 were estimated at just 14 tonnes. This decrease is likely to reflect overall declines in legal-sized catch rate across the fishery (Figure 2-2). In 2010, discards due to high-grading increased to 20.5 tonnes. Within-season trends in high-grading are unclear and appear to vary annually (Figure 2-33). For example, in 2007, discarding increased from October to February before decreasing thereafter. However, over the next three seasons from 2008-2010, levels of discards were consistently low across all months of the season with no obvious trends. It should be highlighted that since high-grade estimates are recorded on a voluntary basis only, the total tonnage reported within logbooks is likely to be underestimated.

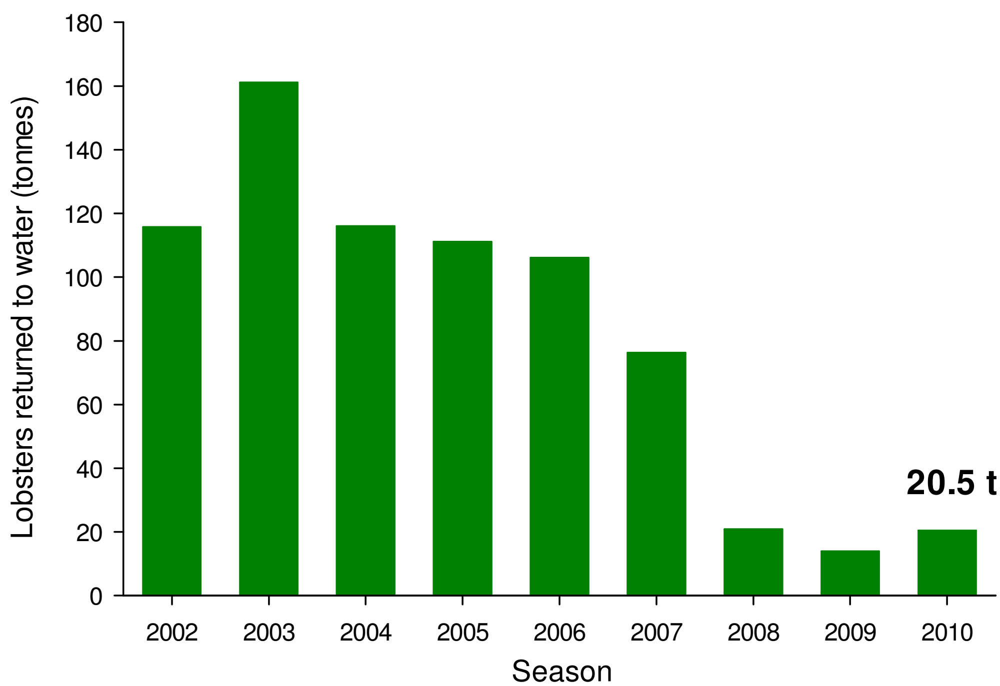

Figure 2-32 Interannual trends in high-grading within the SZRLF from 2002 to 2010.

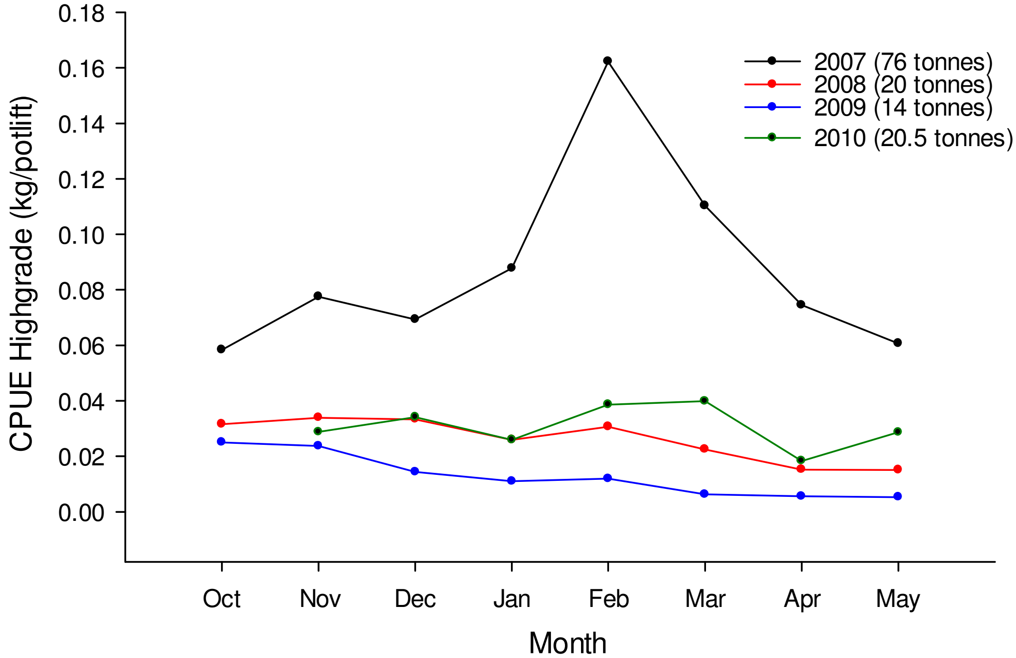

Figure 2-33 Within season trends in high-grading over the last four seasons in the SZRLF. Total catches are shown in parentheses.

3 FISHERY INDEPENDENT STATISTICS

3.1 Settlement Index

Puerulus collectors in the SZRLF are located at Blackfellows Caves, Livingstones Bay, Beachport, Cape Jaffa and Kingston. The annual Puerulus Settlement Index (PSI) is calculated from the mean monthly settlement recorded on collectors (Figure 3-1). Based on tagging studies, the period between settlement and pre-recruit (PRI-undersized) is about 4 years, with recruitment occurring into the fishery one year later (i.e. 5 years after settlement).

The PSI increased from one of the lowest settlements on record in 2003 (0.78 puerulus/collector) to the highest since monitoring began in 2006 (5.0 puerulus/collector). The increase in PRI (Figure 2-14) observed in 2009 reflects the high PSI observed in 2005 which was predicted to enter the fishable biomass in 2010. Based on the high PSI levels in 2006 and 2007, recruitment should continue into the fishery in 2011 and 2012. However, it is important to note that with the exception of 2009, settlement in the SZRLF decreased from 2008 to 2011. In particular, the estimates of 0.73 and 0.72 puerulus/collector in 2010 and 2011, respectively, are two of the lowest on record. Overall, this suggests that reduced levels of recruitment may be experienced in the SZRLF from 2013 through to 2016.

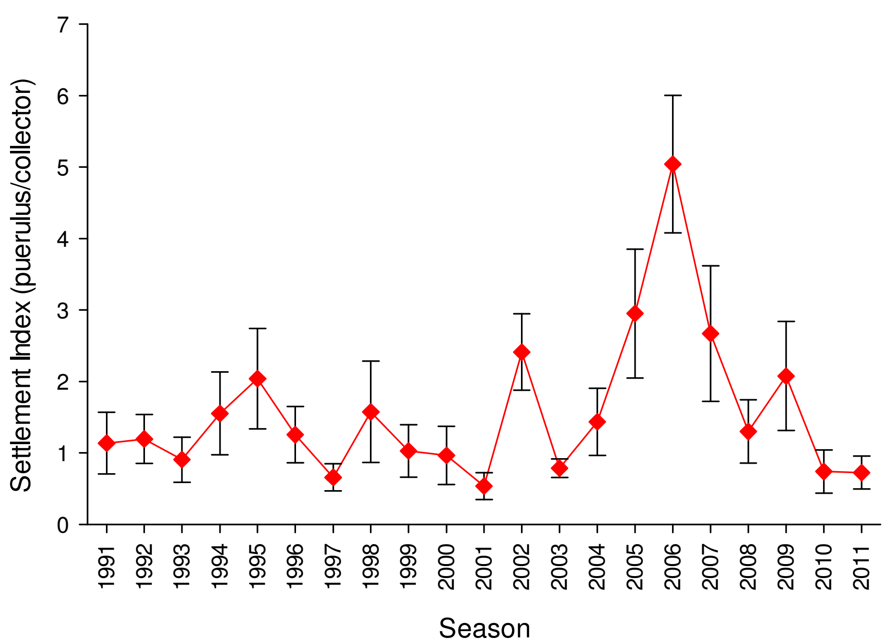

Figure 3-1 Puerulus Settlement Index (PSI) (mean ±SE) in the SZRLF from 1991 to 2011.

3.1.1 Correlations with pre-recruit indices

Based on growth analyses from tagging studies, the estimated period from settlement to recruitment to the minimum legal size of 98.5 mm CL, is approximately five years (McGarvey et al. 1999a). The period from settlement to pre-recruitment is about four years. Lagged PSIs were correlated against PRIs from both catch sampling and logbook data over the period 1995 to 2010. R values were 0.71 over the complete time series for catch sampling PRI and PSI and 0.02 between PSI and logbook PRI. More recently, from 2006-2010, both catch sampling and logbook PRI estimates were strongly correlated with PSI with R values of 0.88 and 0.83 respectively. Importantly, high PSIs in 2002, 2005 and 2006 were reflected by increases in PRIs in both sampling methods in 2006, 2009 and 2010. For correlations between PRIs and model estimated recruitment from both the qR and LenMod models, see sections 4 and 5 of this report.

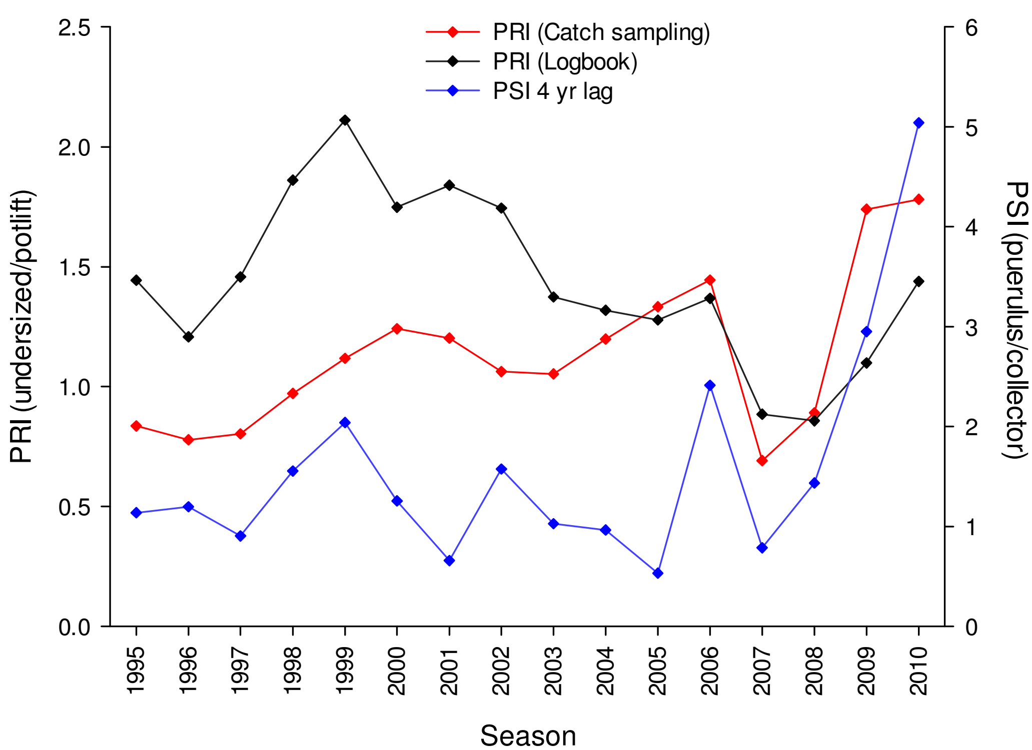

Figure 3-2 Correlations between SZRLF puerulus settlement index (PSI) lagged by 4 years with pre-recruit indices (PRI) from both catch sampling and logbook data.

3.2 Fishery Independent Monitoring Survey (FIMS)

3.2.1 Legal-sized catch rates

Average weight (kg) of lobsters was extrapolated from known length/weight relationships (Prescott et al., 1996) to provide spatial estimates of CPUE (kg/potlift) (Figure 3-3). Total legal-sized CPUE in 2010 (all surveys combined) was 0.36 kg/potlift, representing a 29% increase from 2009 when the zonal estimate was 0.28 kg/potlift (Figure 3-4). Such trends are consistent with trends observed from fishery dependent data (Figure 2-2) where logbook derived CPUE increased by 57% from 2009 estimates. Survey estimates in 2010 reflected increases in CPUE from both inshore (<60 m) and offshore (>60 m) areas. For example, inshore CPUE (<60 m) in 2010 was 0.38 kg/potlift compared to 0.33 kg/potlift in 2009, an increase of 15%. Offshore CPUE (>60 m) in 2010 was 0.33 kg/potlift compared to 0.20 kg/potlift in 2009, an increase of 65%.

3.2.2 Undersized catch rates

Spatial trends in the numbers of undersized/potlift, based on 2010 independent surveys, are provided in Figure 3-5. Total PRI in 2010 (all surveys combined) was 0.62 undersized/potlift representing a decrease of 10% from 2009 when the zonal estimate was 0.69 undersized/potlift (Figure 3-6). While survey PRIs decreased in 2010, logbook derived PRIs increased for the second consecutive season. Spatially in 2010, inshore PRI (<60 m) was 0.89 undersized/potlift compared to 0.99 undersized/potlift in 2009, a decrease of 10%. Offshore PRI (>60 m) was 0.22 undersized/potlift compared to 0.25 undersized/potlift in 2009, a decrease of 12%.

3.2.3 Water temperature and growth

Temperature logger data obtained from a fixed monitoring station located off Southend (at ~60 m depth) (Figure 1-4) within the SZRLF indicates that the 2010/11 season was not an exceptional one in terms of the strength of the Bonney Upwelling (Figure 3-7). While temperatures dropped below 12 ^{o}C for a brief period in January of 2011, temperatures were generally between 13-17 ^{o}C for most of the 2010/11 season. In order to investigate what impact this may have on growth, tag recaptures from a previous tagging study undertaken in the 1990s were compared with those from FIMS undertaken from 2006 to 2010 (Figure 3-8). Predicted female growth at 100 and 120 mm CL was higher than the previous 3 seasons at 7.5 and 3.2 mm CL, respectively. Tag returns were not sufficient to allow for analyses of male growth.

3.2.4 Discussion

The spatial outputs of lobster abundance described during the 2010 independent surveys are similar to those previously observed in recent seasons (see Linnane et al. 2011). In general, legal-sized lobster abundance tends to be higher in some offshore sites (>60 m) in the northern region of the zone compared with inshore grounds (<60 m). However, areas of high abundance were not continuous and tended to be in the form of discrete isolated regions. This presumably reflects the limited availability of suitable lobster habitat in deeper waters. Abundances of undersized lobsters tended to be highest in regions further south in MFA 58 with some discrete areas of high juvenile abundance in offshore grounds in MFA 55.

Overall, the trends in legal catch rate from the 2010 fishery independent survey confirm those from fishery dependent logbook data. In particular, the 29% increase in survey CPUE between 2009 and 2010 reflects the 57% increase observed in logbook data. In relation to PRI, trends between survey and fishery dependent sources of data were divergent in 2010. Survey PRI decreased by 10% from 2009 while logbook estimates increased by 31%.

A preliminary analysis on lobsters tagged and subsequently recaptured as part of the independent survey suggests that growth in females during 2010 was higher than in recent seasons. Factors affecting growth rate of lobsters are numerous and include temperature, habitat, food availability, density dependence and social interactions (Thomas et al., 2003; Goni et al., 2003b). Increases in growth rates within the fishery in 2010 may be linked to the obvious lack of intensive cold-water upwelling that can be characteristic of the region. Overall, temperatures rarely dropped below 12 ^{o}C during the season and from March to May increased steadily from 13 to 17 ^{o}C.

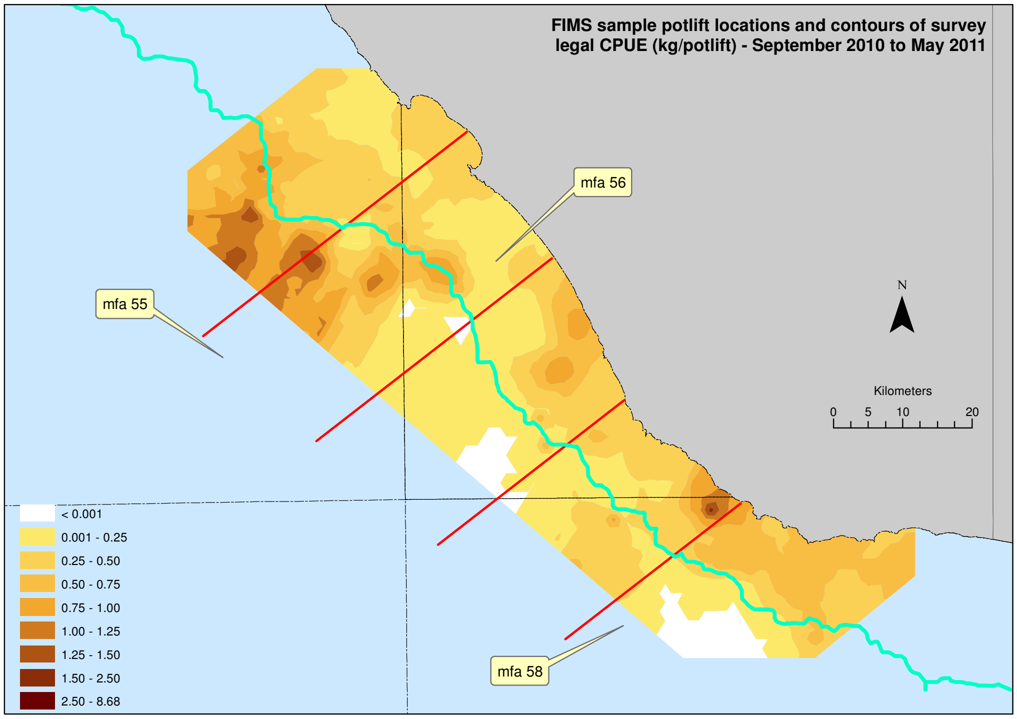

Figure 3-3 Catch rates of legal-sized lobster, as determined from the 2010 FIMS in the SZRLF. The 60 m depth contour is highlighted in blue.

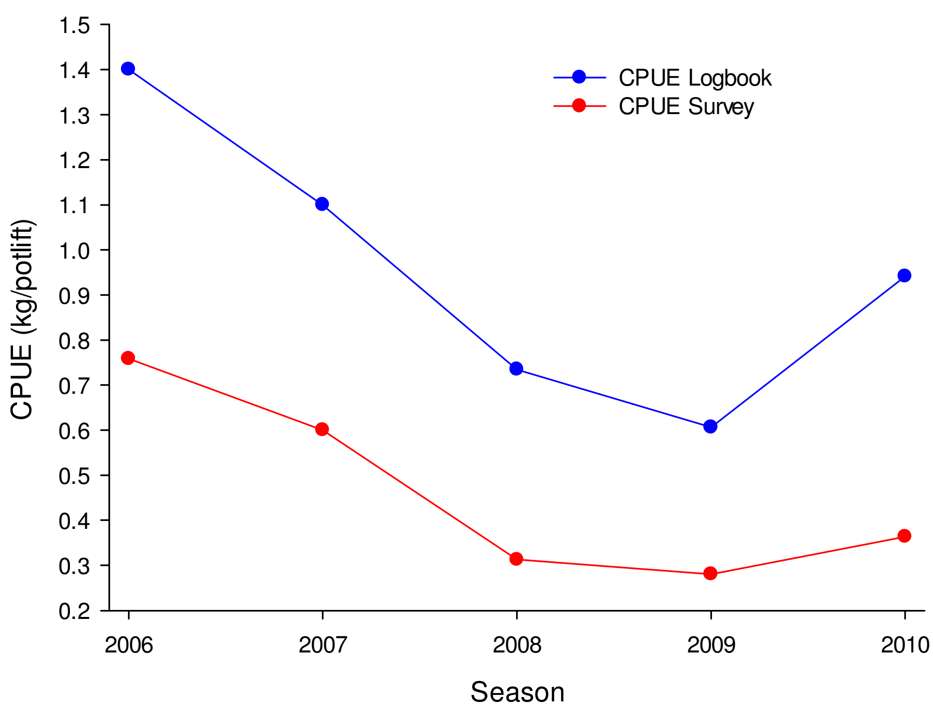

Figure 3-4 Comparison of legal size catch rates from commercial logbook data and fishery independent monitoring surveys from 2006-2010 fishing seasons.

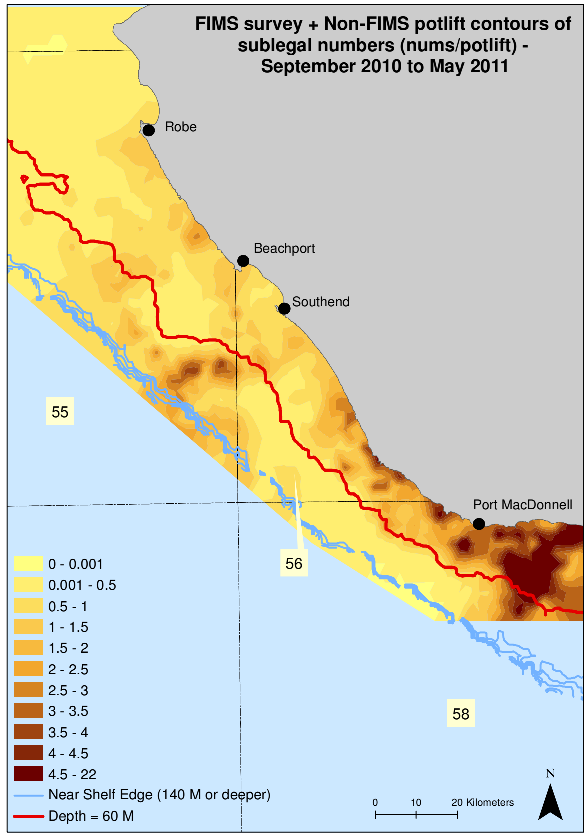

Figure 3-5 Catch rate of undersized as determined from the 2010 FIMS in the SZRLF. The 60 m depth contour is highlighted in red.

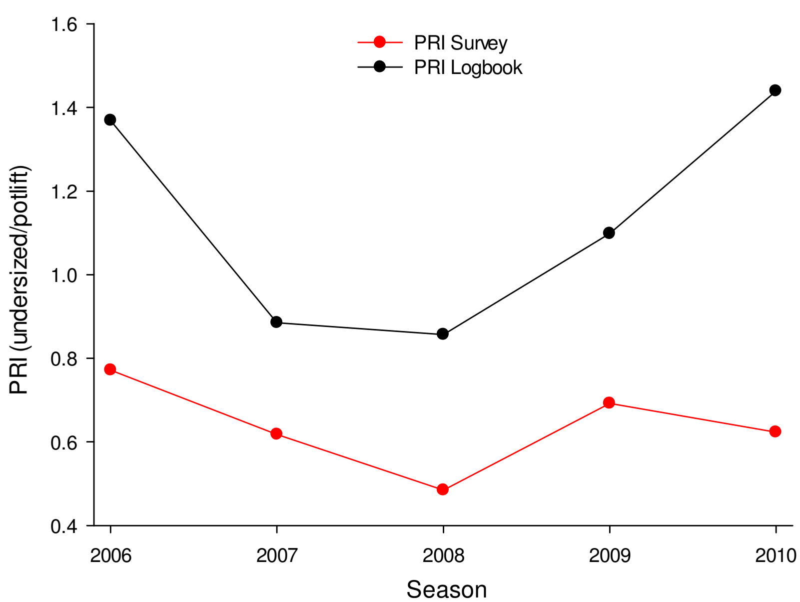

Figure 3-6 Comparison of pre-recruit index (PRI) as determined from logbook and fishery independent monitoring surveys from 2006-2010 fishing seasons.

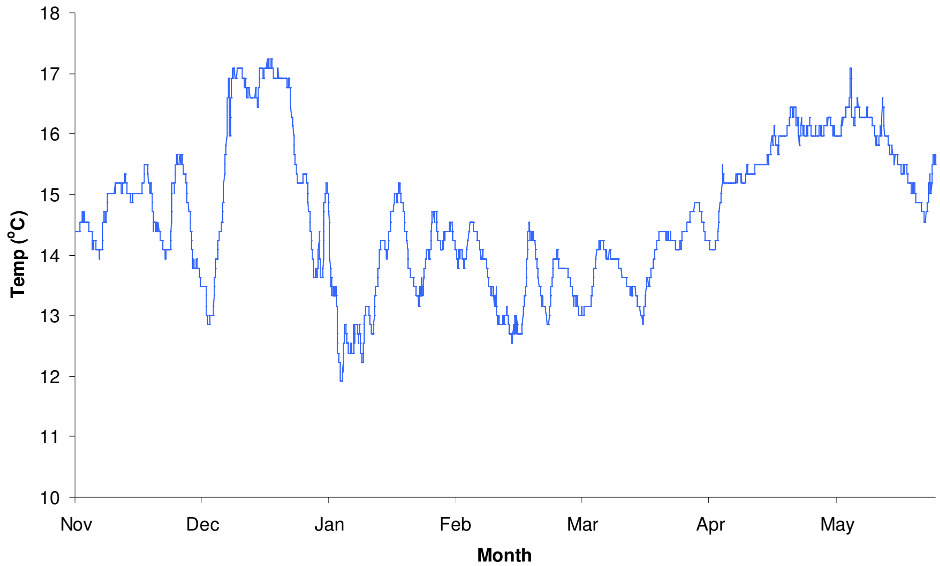

Figure 3-7 Bottom temperature as recorded at 60 m off Southend within the SZRLF during the 2010 rock lobster season.

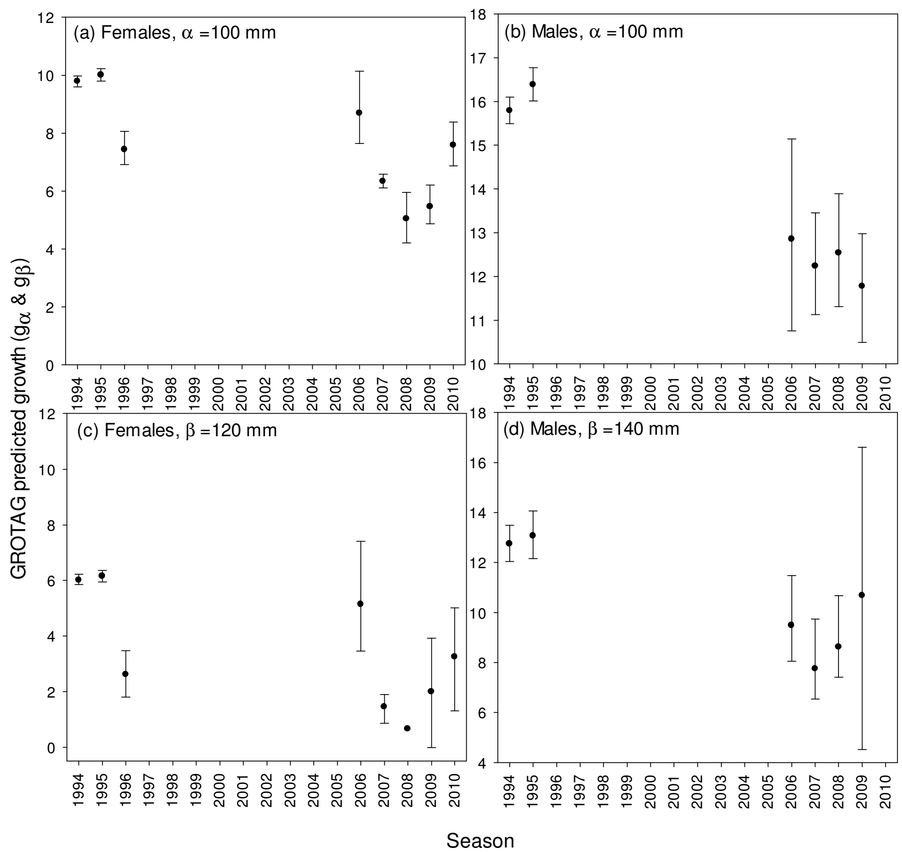

Figure 3-8 Comparison of GROTAG predicted growth estimates from previous tagging studies in the 1990's with those from fishery independent monitoring surveys from 2006-2010.

4 THE QR MODEL

4.1 Introduction

The qR model (McGarvey et al 1997; McGarvey and Matthews 2001) has been used to generate estimates of performance indicators such as biomass, egg production and exploitation rate for the SZRLF. Outputs from the qR model have been presented in stock assessment reports for the SZRLF since 1997.

A review of the stock assessment research conducted by SARDI Aquatic Sciences (Breen and McKoy 2002) concluded that the qR model was an appropriate tool for assessing exploitation rate and recruitment. The model has been refined over time, most notably during the peer review process for publication of McGarvey and Matthews (2001). Hence, outputs from the current version of the model differ from those presented in previous stock assessment reports.

This section of the report has two objectives: (i) to generate annual estimates of biomass, egg production, % virgin egg production and exploitation rate for the SZRLF using data from 1970 to 2010; and (ii) to compare estimates of recruitment obtained using the qR model with an independent measure of pre-recruit abundance (PRI).

4.2 Methods

A detailed description of the qR model is provided in McGarvey and Matthews (2001). The qR model fits to annual catch in weight (*Cw*, in kg) and annual catch in number (*Cn*, in numbers of lobsters landed). The model is effort conditioned with effort (*E*) taken from logbook data and a Baranov survival model using a Schaefer catch relationship ($Cn=qEN$) is assumed. The estimation likelihood is written as a modified normal and fitted numerically. Recruitment in each year is estimated as a free parameter.

Stock assessment models (e.g. delay-difference and biomass dynamic) that fit to catch and effort data normally have available only catch in weight (*Cw*), and rely on *CwPUE* as a measure of relative fishable biomass. Adding catches in numbers to the fitted data set provides information about yearly mean size of lobsters in the legal catch, otherwise available only from length-frequency data. Catch in weight divided by catch in number gives the mean weight of an average landed lobster. Because reported catches in weight and number constitute a 100% sample, the quality of information obtained about changes in mean size from catch data is far more precise than that obtained from length frequencies, which typically constitute a 0.1% to 1.0%

sample fraction. Thus, the qR model uses *CwPUE* as a relative measure of change in abundance and mean weight as a measure of change in size structure. McGarvey et al (2005) demonstrated, using simulated data, that adding catch in number dramatically improves the accuracy and precision of stock assessment estimates. These inputs are also used in LenMod, together with length-sex frequency samples.

The PRI provides a direct measure of yearly recruitment that is independent of qR-inferred estimates. It therefore provides a check on the accuracy of the qR model recruitment outputs. The annual PRI used in this section of the report is based on average undersize CPUE from November to March in each fishing season from commercial logbooks.

In 2008, a new definition of the qR model estimated biomass was implemented. Rather than taking the model biomass from the start of the year, when model biomass is at its yearly maximum, the average level of biomass during each full model year was reported. This was undertaken to generate qR biomass estimates that are quantitatively comparable with those from LenMod which also uses a year-average biomass definition.

4.3 Outputs

Goodness of Fit

Estimates of catch in numbers and weight from the qR model fit closely to reported total catches of *Cn* and *Cw* obtained from the SZRLF (Figure 4-1 and Figure 4-2).

Biomass

Outputs from the qR model, based on yearly averages, indicate that the biomass in the SZRLF increased from 1996, peaking at 5,139 tonnes in 2002 (Figure 4-3). Over the next seven seasons biomass decreased considerably and in 2009 the zonal estimate was 1,794 tonnes, the lowest on record. In 2010, biomass increased to 2,697 tonnes, representing a 50% increase from 2009.

Egg production

Trends in estimated egg production in the SZRLF increased from 1996, peaking at 673 billion eggs in 2003 (Figure 4-4). Over the next six seasons it decreased and in 2009 was 322 billion eggs, the lowest on record. In 2010, egg production increased to 385 billion, which equates to 9% of virgin production (Figure 4-5).

Exploitation rate

The exploitation rate decreased from 64% in 1996 to 34% in 2002, the lowest estimate on record (Figure 4-6). Over the last seven seasons it increased and in 2009 was estimated to be 69%, the highest estimate on record. In 2010, exploitation decreased to 46%, the lowest since 2005 (44%).

Estimates of recruitment and correlations with pre-recruit indices

Estimates from the qR model suggest that recruitment levels increased from 1996 and peaked at about 4 million lobsters in 1999 (Figure 4-7). Since then, estimates have generally decreased and in 2009 were about 1.6 million lobsters, one of the lowest estimates on record. In 2010, the number of recruits to the fishery was estimated at 3.3 million reflecting an increase of 106% on 2009. Temporal trends in recruitment estimated by qR were strongly correlated (R^2=0.90) with pre-recruit indices (PRI) from logbook data over the period 1995-2010 (Figure 4-8).

4.4 qR Model Discussion

Details of the qR model, and simulation testing of its performance have been described in a number of peer-reviewed papers (McGarvey et al. 1997; McGarvey and Matthews 2001; McGarvey et al 2005). The model estimates from simulated data yielded close agreement with 'true' fishery indicators from the simulated fishery for yearly varying recruitment, biomass, and exploitation rate. Moreover, these simulated data tests found that the model estimates were relatively insensitive to errors in natural mortality rate, and some other common assumptions. However, these estimates were relatively sensitive to assumed weights at age (McGarvey and Matthews, 2001; McGarvey et al. 2005).

The latest qR model estimates reflect the rise and fall in catch rates of legal size lobsters over the period 1996 to 2010 (Figure 2-2). Average yearly biomass in the SZRLF increased considerably from 1996, peaking at 5,139 tonnes in 2002. However, from 2003 to 2009 lobster biomass decreased and in 2009 was 1,794 tonnes. This represents a decrease in biomass of 61% from 2003 (4,659 tonnes) when the TACC was increased to 1,900 tonnes from 1,770 tonnes. Similarly, egg production has decreased by 52% since 2003 and current estimates are also the lowest on record. In 2009, the TACC was reduced from 1,770 to 1,400 tonnes; however, evidence now indicates that the rate of biomass decline has been greater than that of catch. As a result, exploitation rate increased over this period and in

2009 was 69% representing an increase of 103% since 2002 (34%) and the highest estimate on record.

qR recruitment estimates indicate that recruitment in the SZRLF generally declined over a ten year period from 1999 with the 2009 estimate of 1.6 million recruits one of the lowest on record. It is worth noting that model estimates of recruitment were highly correlated with logbook PRI, as well as LenMod estimates of recruitment (see next Section). This strongly suggests that the SZRLF experienced an extended period of reduced recruitment levels to the fishable biomass, which combined with higher TACC levels (>1,700 tonnes), ultimately lead to poor fishery performance over this period. In 2010, the TACC was reduced to 1,250 tonnes. In the same season, recruitment to the fishery increased from 1.6 to 3.3 million individuals resulting in an increase to biomass estimates and a reduction in exploitation levels from 69% to 46%. The increase in recruitment to the fishery also reflects the increase in legal size catch rates in 2010 (Figure 2-2).

Most of the uncertainty in the model estimates lies in the assumed values of input parameters, notably (1) natural mortality, (2) mean weights-at-age, and (3) CPUE as a measure of biomass. Steady-state analysis by McGarvey et al. (1997) showed that catch under-reporting has essentially no effect on the qR estimates of exploitation rate, while yearly estimates of biomass and recruitment are reduced by the percentage of under-reporting. Similarly, McGarvey and Matthews (2001) and McGarvey et al. (2005) showed that (1) model estimates are relatively insensitive to errors in the assumed natural mortality rate, but that these estimates (2) were, like any size-based assessment, generally sensitive to the assumed growth inputs of weight-at-age. The impact of differing levels of rising effective effort, and thus of the principal assumed cause of deviation in trends of CPUE and stock biomass was tested in the Northern Zone fishery where rising effective effort is presumed to be significant (Linnane et al. 2010b). In the Southern Zone, due to the widespread occurrence of fishable habitat, the impact of rising effective effort is not considered to be large.

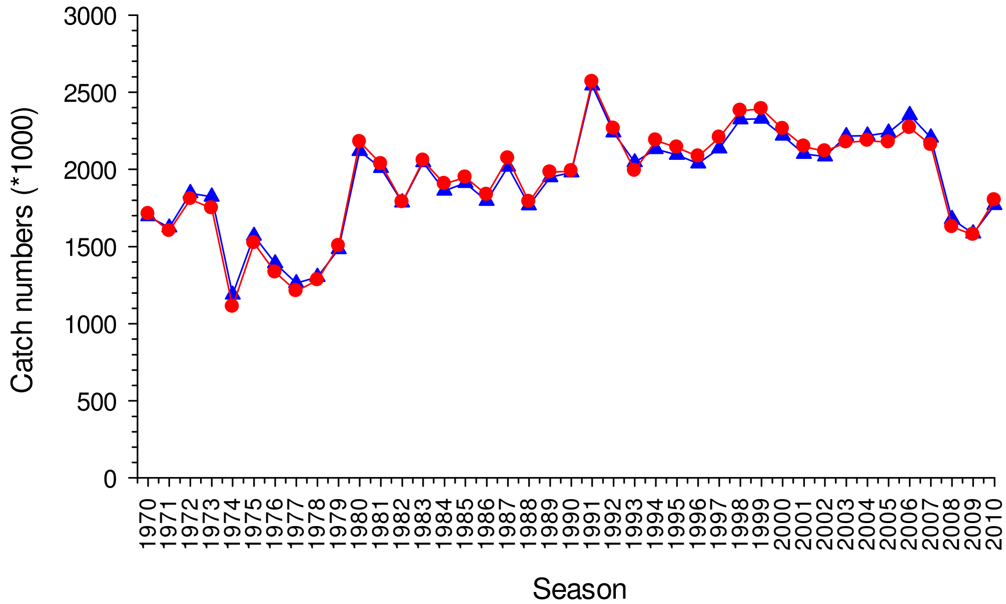

Figure 4-1 Fit of the qR model to catch in numbers (Cn) for the SZRLF, based on annual catch totals from the fishery and estimates provided by the 2010 version of the qR model.

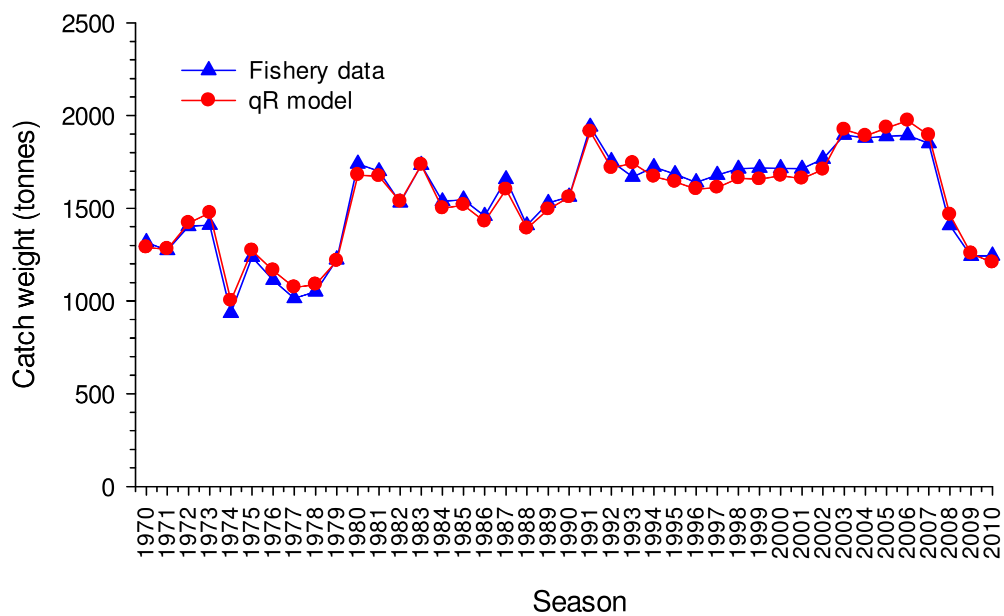

Figure 4-2 Fit of the qR model to catch by weight (Cw) for the SZRLF, based on annual catch totals from the fishery and estimates provided by the 2010 version of the qR model.

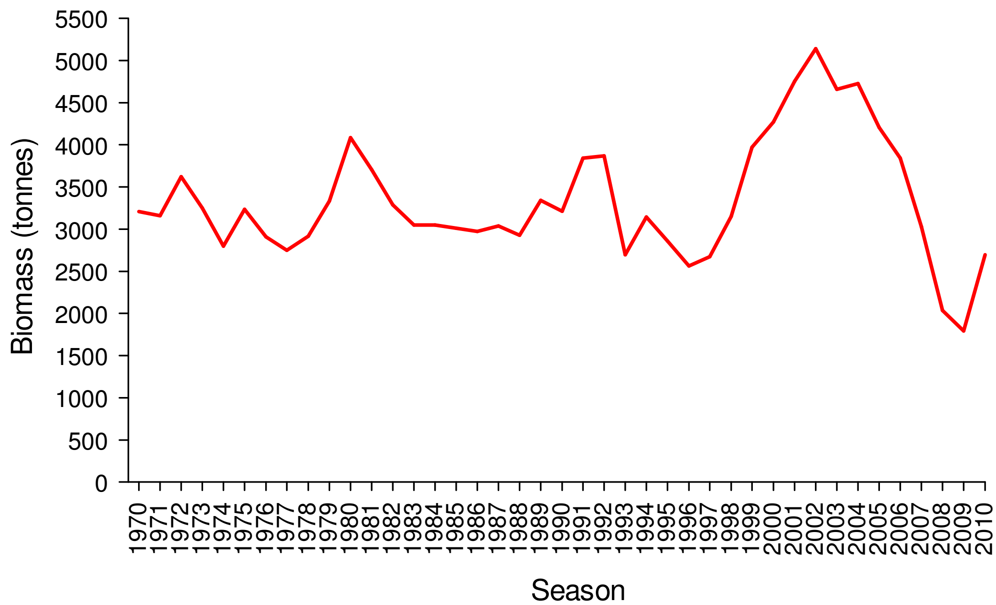

Figure 4-3 Biomass estimates from 1970-2010 as generated by the qR fishery model.

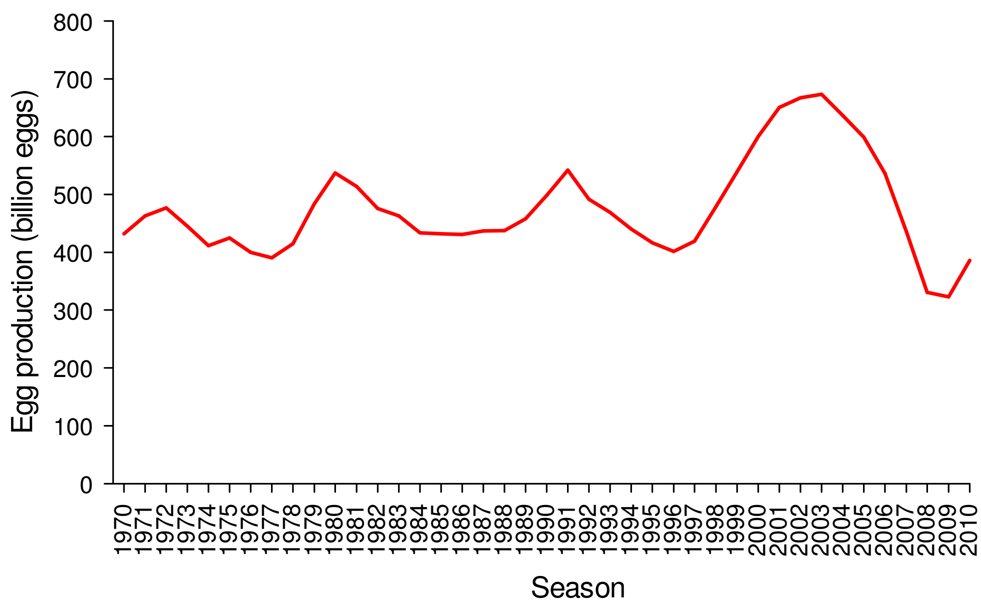

Figure 4-4 Egg production estimates from 1970-2010 as generated by the qR fishery model.

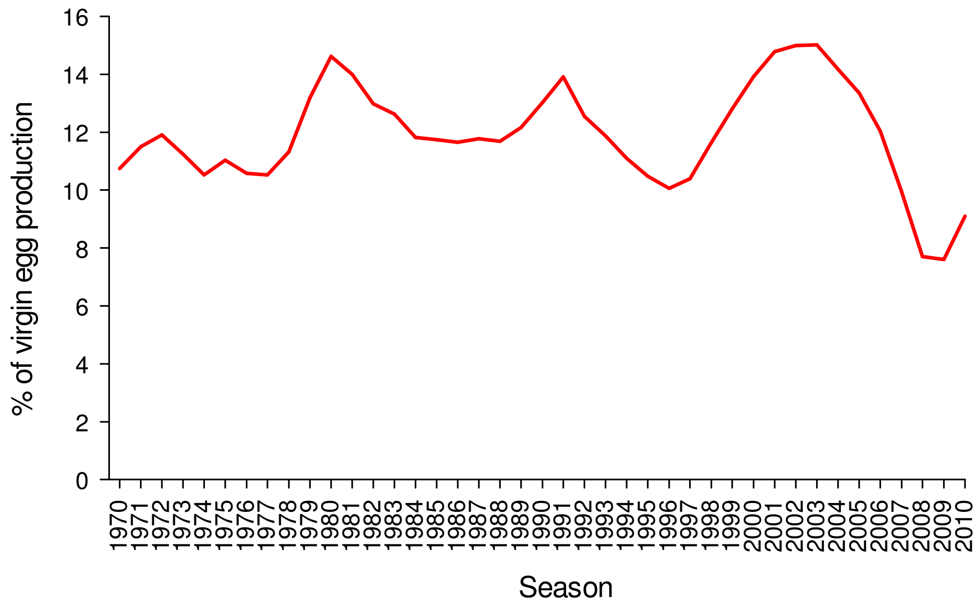

Figure 4-5 Estimates of percent of virgin egg production from 1970-2010 as generated by the qR fishery model.

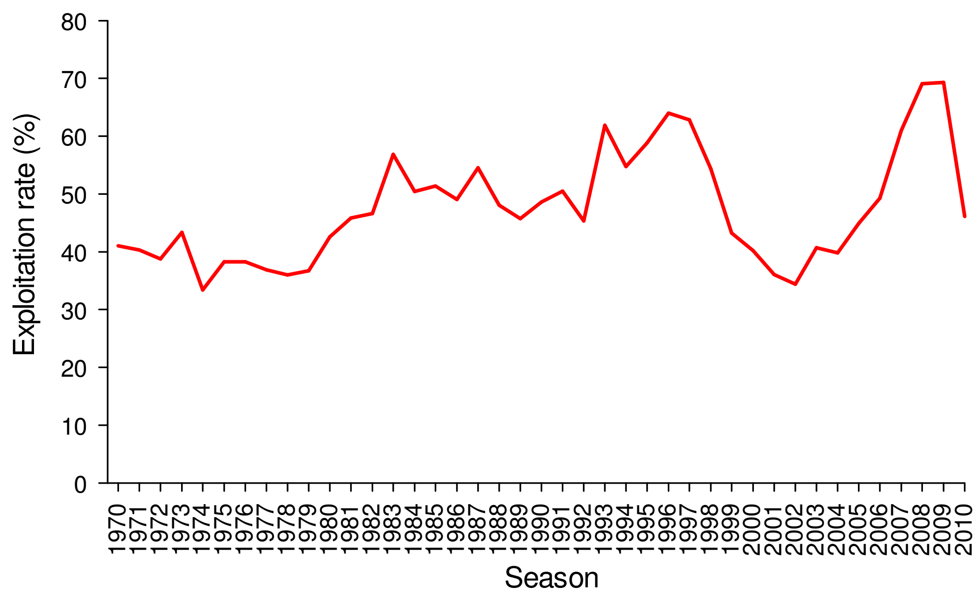

Figure 4-6 Estimates of exploitation rate from 1970-2010 as generated by the qR fishery model.

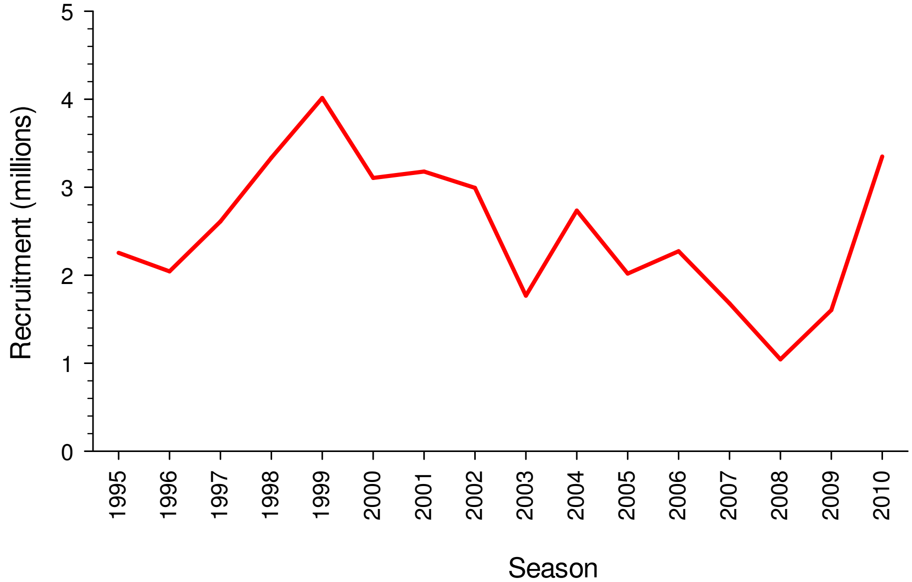

Figure 4-7 Estimates of recruitment from 1995-2010 as generated by the qR fishery model.

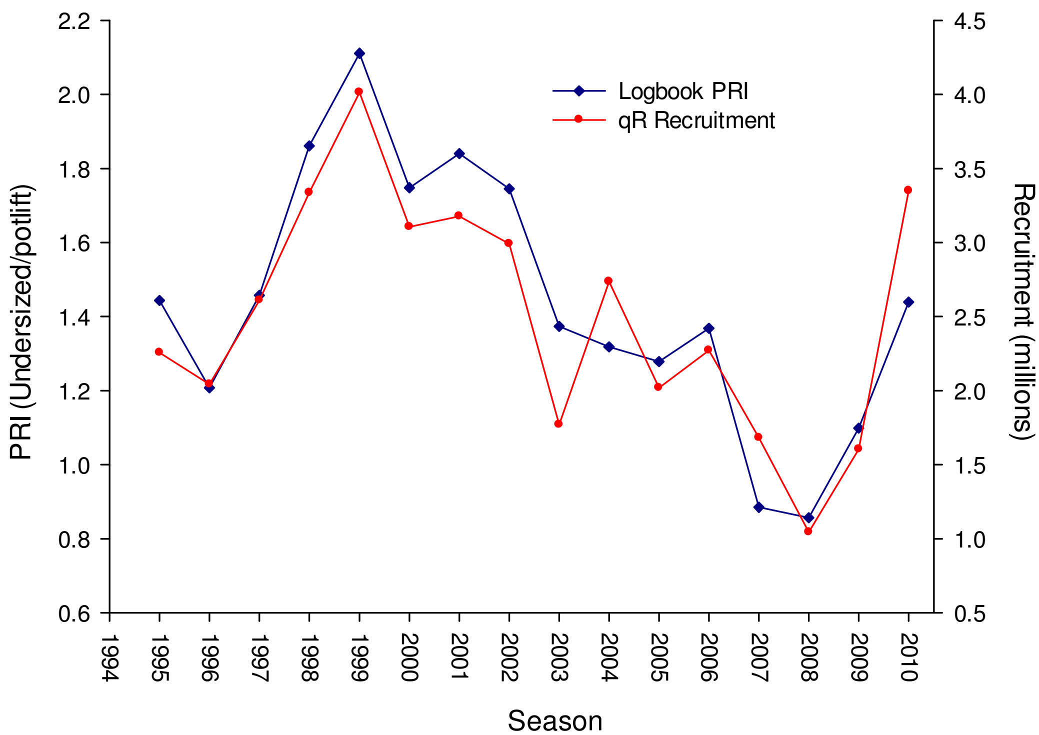

Figure 4-8 Estimates of annual recruitment obtained from the qR model and pre-recruit index (PRI) as undersized/potlift (Nov-Mar) obtained from logbook data.

5 THE LENGTH STRUCTURED MODEL

5.1 Introduction

This section of the report provides outputs from a length-structured model (LenMod) for the SZRLF. While the qR model provides estimates of biomass, recruitment and exploitation rate based on catch by weight and catch by number, LenMod fits to catch in number and to CPUE, while conditioning on catch in weight. In addition, it also incorporates length-frequency data from catch sampling, where the lobster population is broken down into size categories of differing carapace length. André Punt (Washington University) first developed the basic LenMod structure in the 1990s (Punt and Kennedy 1997). Variants of this length-based lobster model are now used for management and quota setting in most *Jasus edwardsii* fisheries, notably in New Zealand, Victoria and Tasmania.

5.2 Methods

Details of the length structured model, with simulation testing of its performance, have been described in two peer-reviewed papers (Hobday and Punt 2001; Punt 2003). The code for the South Australian LenMod has been adapted from the Victorian version of the model (Hobday and Punt 2001; Punt 2003). To incorporate the more extensive data set available from the larger South Australian fishery, a number of modifications to the model design have been implemented. These include a monthly, rather than a yearly, time step, which permits: (1) accounting for seasonal changes in the fishery, notably of catchability, male length selectivity, and of overall catch rate, (2) accounting for mid-summer recruitment to legal size, and (3) acknowledging that the majority of lobster growth in South Australia occurs during moulting periods in late autumn and early summer, rather than once yearly. In addition, the LenMod description of lobster dynamics is improved by (4) incorporating information on sex ratios in recruitment and catch inferred from voluntary catch sampling data, (5) reducing the width of length class bins from 8 mm to 4 mm, and (6) substantially refining the growth matrix estimation.

LenMod infers change and absolute levels of stock abundance principally from three data sources: (1) CPUE (see Section 2.2) to which biomass is assumed to vary in direct proportion, (2) catches in both weight and number (see Section 2.4), which provide a highly precise measure of mean weight of lobsters in the catch, and (3) length-frequency data (see Section 2.5), interpreted in combination with the length-transition matrices to yield estimates of mortality rate and absolute biomass. Data sources (2) and (3) both provide LenMod with information on size of lobsters in the catch.

Growth is modelled using length-transition matrices which specify the proportion of lobsters in each length category that grow into larger length classes during each summer and autumn moulting period. The length-transition matrices were estimated using extensive tag-recovery data. The length-transition estimation method of McGarvey and Feenstra (2001) was applied which permits widely flexible growth curves to be inferred by modelling the parameters predicting mean and variance of observed tag-recovery growth increments as polynomial functions of (starting) carapace length (CL). This method has also been adopted for use in Tasmania and Victoria. Growth matrices were estimated for each combination of sex and moulting season. As growth rates of female lobsters are known to slow substantially once they reach maturity, the flexible polynomial estimation method which accounts for changing growth (McGarvey and Feenstra 2001) was used to provide a more accurate estimation of female adult growth than a traditional von Bertalanffy model.

5.3 Outputs

Goodness of fit

Estimates of catch in number and catch rate from the LenMod model fitted closely to reported time series for *Cn* and CPUE obtained from SZRLF logbook data (Figure 5-1; Figure 5-2). In addition, both male and female model estimates fitted well to length-frequency data from the commercial catch data as shown in monthly fits from the 2010 season (Figure 5-3).

Biomass

LenMod-estimated biomass in the SZRLF increased from 1996, peaking at 4,912 tonnes in 2002 (Figure 5-4). However, over the next seven seasons, biomass decreased by 63% and in 2009 was 1,832 tonnes, the lowest on record. In 2010, biomass increased to 2,326 tonnes, representing a 27% increase from 2009. As with the qR model, it should be noted that current estimates of biomass from LenMod do not take into account the effects of discarded catch due to high-grading. However, as highlighted in Figure 2-32, the 2010 season had low levels (20.5 tonnes) of high-graded individuals thus having reduced impacts on estimates of catch rate or biomass. Despite the increase in 2010, current LenMod biomass estimates remain low in a historical context.

Egg production

Trends in estimated egg production in the SZRLF increased from 1997 and peaked at 575 billion eggs in 2003 (Figure 5-5). However, over the next six seasons it decreased and in 2009 was 259 billion eggs, the lowest on record. In 2010, egg production increased by 12% to 290 billion. This equates to 7.3% of virgin levels (Figure 5-6).

Exploitation rate

The exploitation rate in the SZRLF decreased from 57% in 1997 to 35% in 2002, the lowest estimate on record (Figure 5-7). However, as a result of decreasing biomass estimates, the exploitation rate increased over the next seven seasons and in 2009 was 68%, one of the highest estimates on record. In 2010, the exploitation rate decreased to 53%, the lowest on record since 2005 (48%).

Estimates of recruitment and correlations with pre-recruit indices

The recruitment estimates from LenMod increased from 1993, peaking at 4 million recruits in 1999 (Figure 5-8). Over the next nine seasons, estimated recruitment generally decreased and in 2008 was only 1.4 million, the lowest estimate on record. Over the next two seasons recruitment increased and in 2010 was 3 million, the highest on record since 2000 (3.1 million). Temporal trends in recruitment estimated by LenMod were strongly correlated (R^2=0.90) with pre-recruit indices (PRI) from logbook data over the period 1995-2010 (Figure 5-9).

5.4 LenMod Discussion

Overall, LenMod outputs agree with those from the qR model in terms of the status of the SZRLF. Specifically, current outputs indicate that the resource on which the fishery is based declined over the period from 2002 to 2009. For example, LenMod outputs estimate that the biomass in the SZRLF decreased by 63% (from 4,912 to 1,832 tonnes) over this period while egg production decreased by 55% (from 575 to 259 billion eggs). Since the rate of biomass decline was greater than that of catch, exploitation rate in the fishery increased from 35% to 68%, the highest on record.

There is strong evidence from fishery dependent data to indicate that the decline in fishery status is the result of poor recruitment in recent seasons. Model estimated recruitment decreased from 4 million recruits in 1999 to 1.4 million in 2008. This correlates with declines in independently derived logbook pre-recruit indices (undersized/potlift) over the same period.

Over the last two seasons, recruitment into the fishery has increased with the 2010 estimate of 3 million recruits the highest since 2000. This has lead to increases in both biomass and egg production estimates in 2010 which is reflected in increases to legal size catch rates within the fishery. In addition, the TACC in 2010 was reduced from 1,400 to 1,250 tonnes. This reduction in catch, combined with increases in biomass, has led to a notable decrease in exploitation rate from 68% in 2009 to 53% in 2010.

Despite increases in 2010, it is worth noting that current estimates of biomass and egg production remain low in an historical context. For example, 2010 egg production estimates equate to 7.3% of virgin production levels. Finally, it is worth noting the strong correlation between LenMod model-estimated recruitment and the PRI based on commercial logbook data. Given the same observations within the qR model outputs, this suggests that commercial logbook information may be a more robust measure of annual undersize lobster abundance than that provided by catch sampling information.

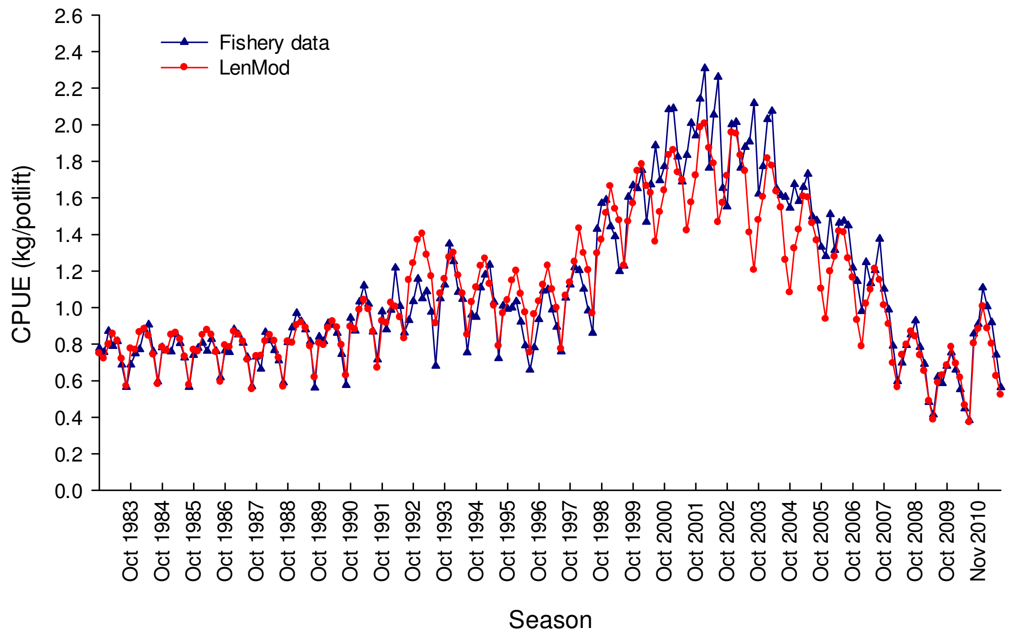

Figure 5-1 Fit of the LenMod model to catch in number (Cn) for the SZRLF, based on annual catch totals from the fishery and estimates provided by the 2010 version of the model (Note: October closed to fishing in 2010).

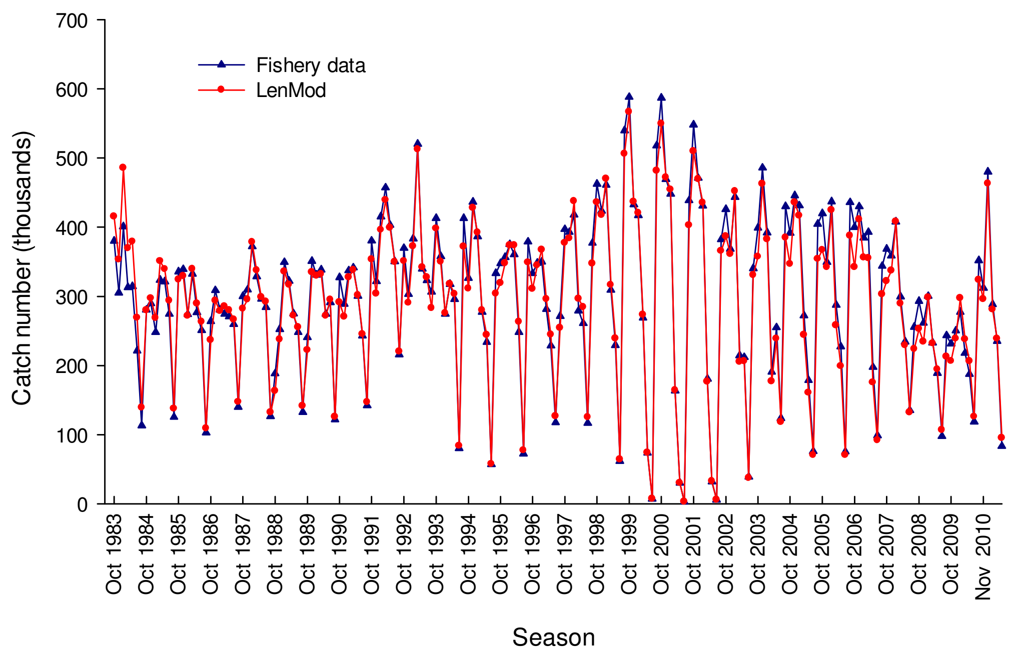

Figure 5-2 Fit of the LenMod model to catch rate for the SZRLF, based on annual estimates from the fishery and those provided by the 2010 version of the model (Note: October closed to fishing in 2010).

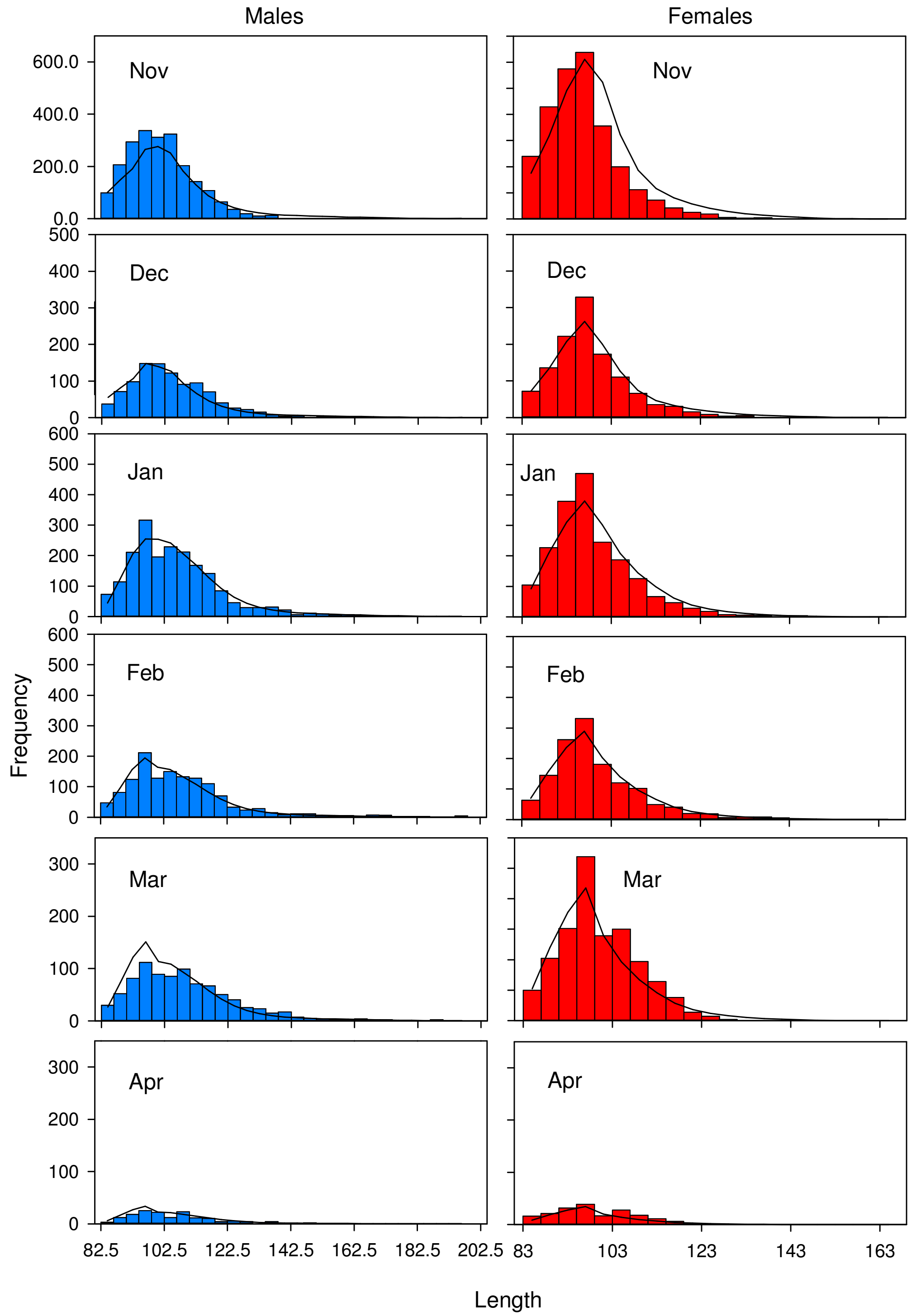

Figure 5-3 Sample of model fit (black line) to commercial length frequency data for both males and females taken during the 2010 season in the SZRLF (Note: October closed to fishing in 2010).

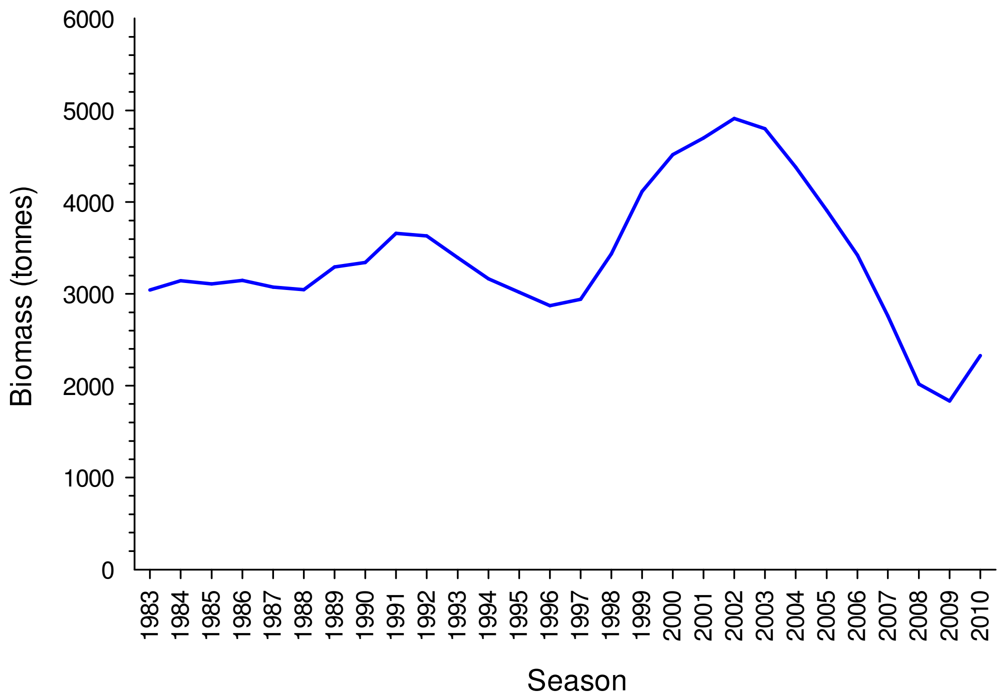

Figure 5-4 Estimates of biomass provided by the 2010 LenMod model.

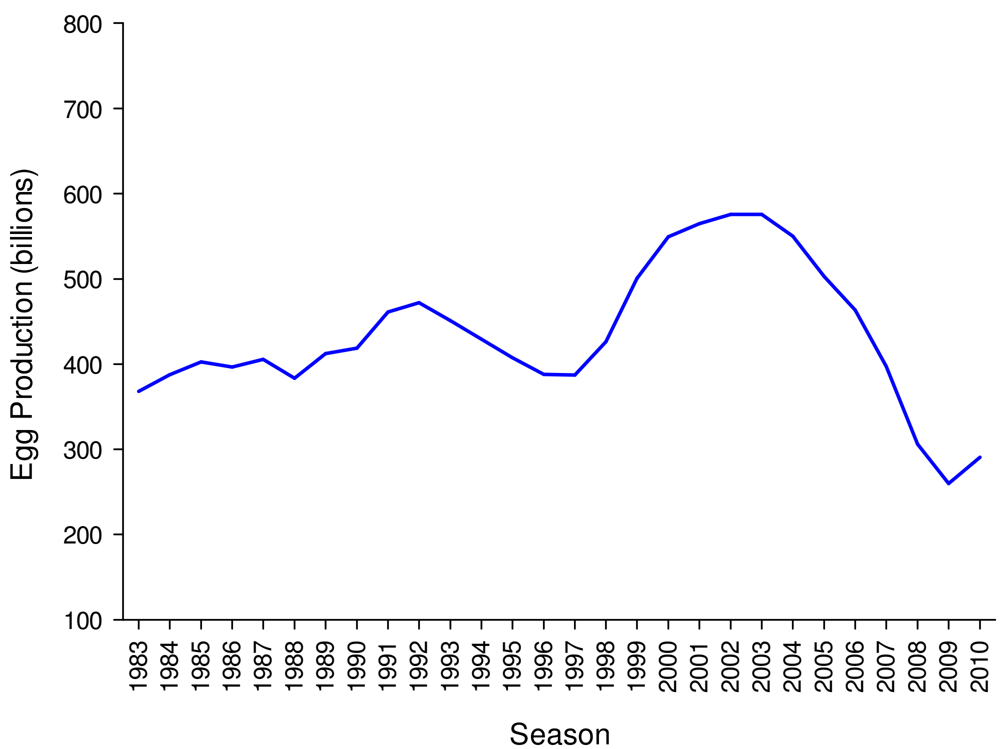

Figure 5-5 Estimates of egg production provided by the 2010 LenMod model.

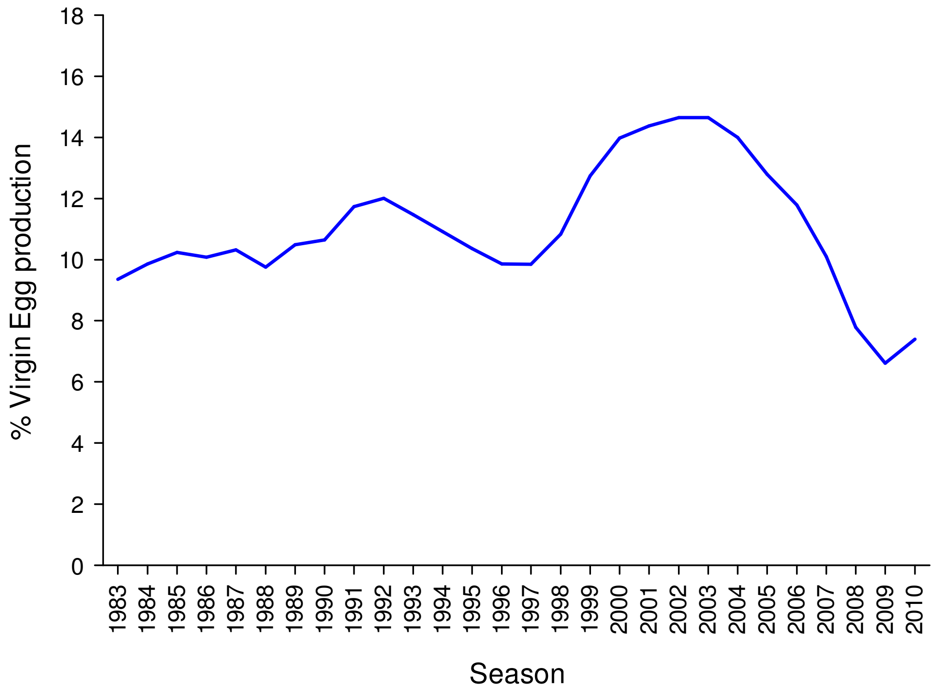

Figure 5-6 Estimates of percent of virgin egg production provided by the 2010 LenMod model.

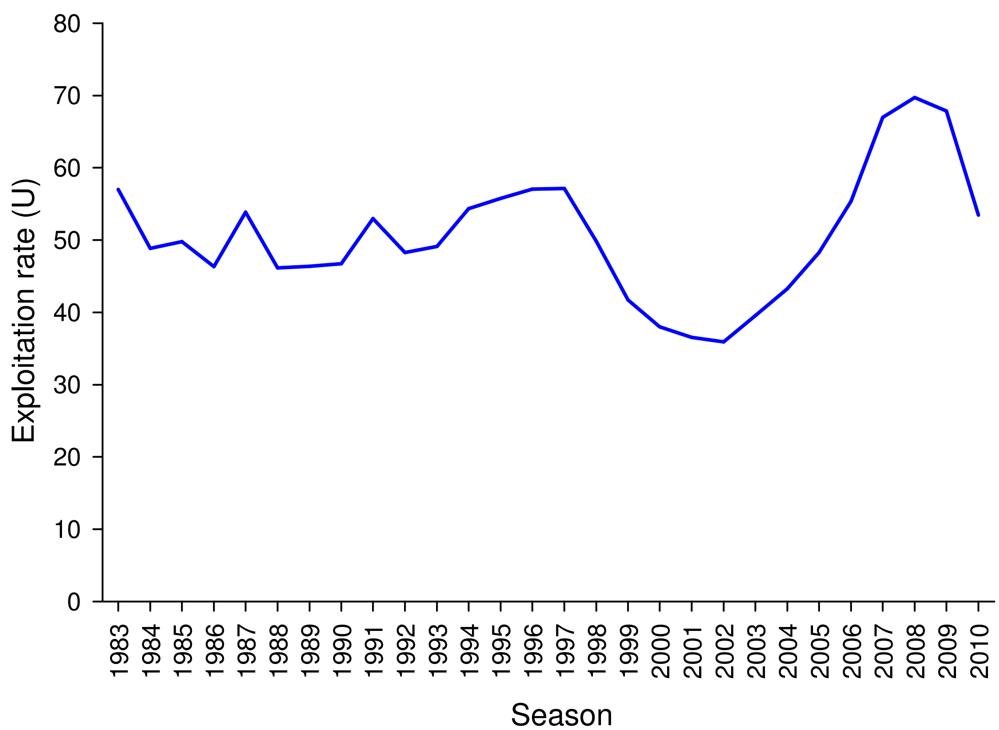

Figure 5-7 Estimates of exploitation rate provided by the 2010 LenMod model.

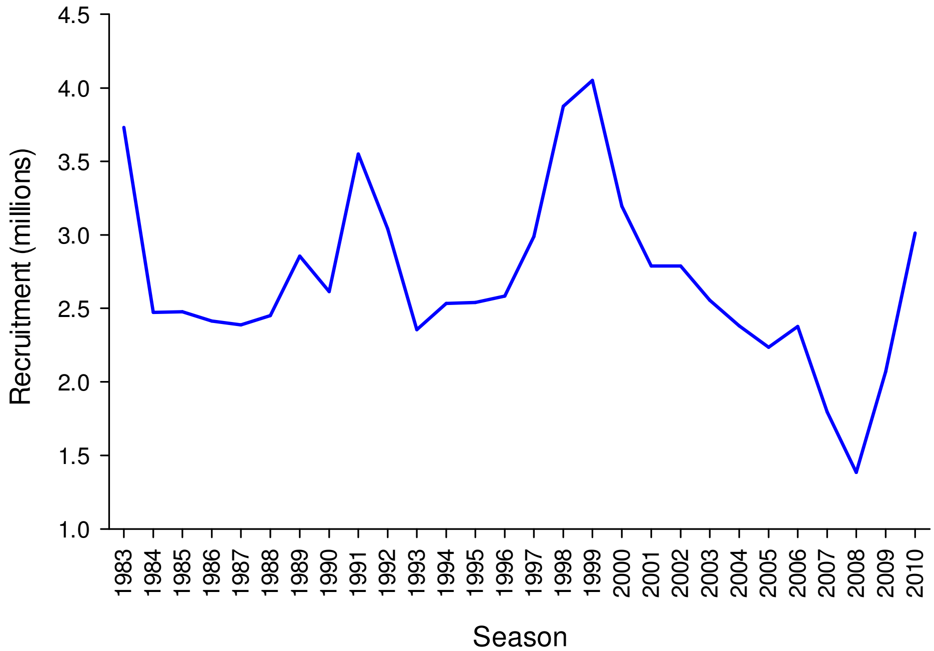

Figure 5-8 Estimates of recruitment obtained from the 2010 LenMod model.

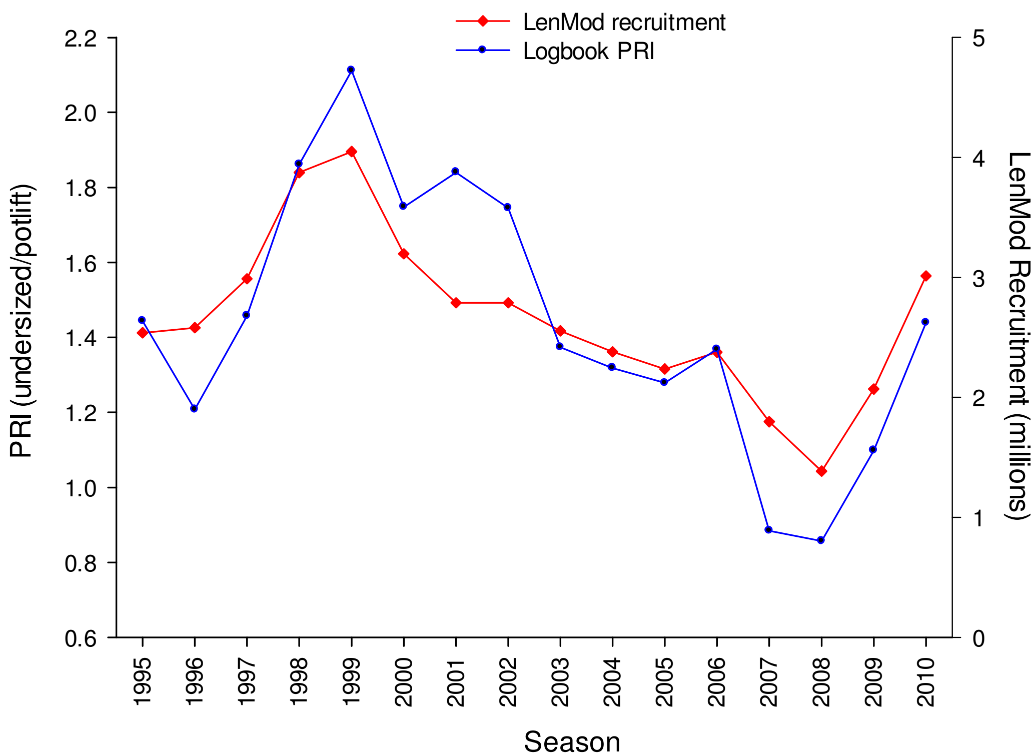

Figure 5-9. Estimates of annual recruitment obtained from the LenMod model and pre-recruit index (PRI) as undersize numbers/pot lift (Nov-Mar) obtained from logbook data.

6 PERFORMANCE INDICATORS

In 2011, the harvest strategy for the SZRLF was reviewed. During the review process, based on the fishery data to date, it was agreed that the TACC for the SZRLF would be retained at 1,250 tonnes for the 2011/12 season. The new harvest strategy details specific reference points for both the primary biological performance indicator of CPUE and the secondary indicator of PRI (see Section 1.3.4) which will be used to provide a TACC recommendation for the 2012/13 season.

7 GENERAL DISCUSSION

7.1 Information available for fishery assessment

Stock assessment of the SZRLF is aided by documentation on the history of previous management arrangements and historical stock assessment reports (e.g. Sloan and Crosthwaite, 2007; Linnane et al., 2011). Comprehensive catch and effort data have been collected since 1970. Data collected since 1983, however, provide more reliable information on overall catch rate. Voluntary catch sampling data have been collected since 1991 and provide critical information on PRI, reproductive condition of females and length frequency. Data from 1994 onwards are more robust due to low levels of participation in the early years of the program and as a result, pre-recruit information focuses on data from this period. Fishery stock assessments are also aided by fishery independent sources of data, namely annual puerulus monitoring and fishery independent monitoring surveys. The overall stock assessment is further supported by outputs from two independent fishery models specifically developed for the fishery i.e. the qR and LenMod fishery models.

7.2 Current Status of Southern Zone Rock Lobster Fishery

This report provides strong evidence to indicate a decline in the SZRLF resource from 2003 to 2009. This conclusion is based on numerous measures.

Catch rates of legal sized lobsters in the SZRLF decreased consecutively over this period. The 2009 estimate of 0.60 kg/potlift was the lowest on record since 1970 and represents a 67% decrease in CPUE since 2003 (1.82 kg/potlift). The decline has been temporally consistent, occurring across all months of the fishery.

The declines in CPUE were spatially widespread, occurring in all of the major fishing regions. In 2009, the CPUE estimates of 0.69, 0.54 and 0.51 kg/potlift were the lowest on record in MFAs 55, 56 and 58, respectively. While only 8% of the total catch was taken in MFA 51, the 2009 CPUE estimate of 0.82 kg/potlift was still one of the lowest on record in an historical context. Catch rates also decreased across a wide depth range. For example, offshore CPUEs in depths of >90 m declined from 3.11 kg/potlift in 2004 to 0.92 kg/potlift in 2009, a decrease of 70%. Similarly, inshore CPUEs in depths of <30 m declined from 1.89 kg/potlift in 2002 to 0.61 kg/potlift in 2009, a decrease of 67%.

Driving the decline in CPUE both zonally and regionally was the significant increase in fishing effort for less catch taken. Since 2003 (when the TACC was increased from 1,770 to 1,900 tonnes) effort increased by 96% from 1,042,233 potlifts in 2003 to 2,049,961 potlifts in 2009. Further evidence of increasing effort was provided by data indicating that since 2003, the average number of days fished by each licence holder increased from 95 to 175 days, an overall increase of 84%. In addition to increasing effort, catch within the fishery significantly decreased in 2009 with only 1,243 tonnes of the 1,400 tonne TACC being landed. This was the third successive season that the TACC had been significantly under-caught.

The decline in status of the SZRLF observed in fishery dependent data was also evidenced in fishery independent sources. While only four seasons of data were available for comparison, legal sized catch rates from fixed site surveys decreased annually with the 2009 estimate of 0.28 kg/potlift representing a decrease of 62% from 2006 (0.75 kg/potlift). Consistent with logbook data, survey catch rate had also decreased spatially. For example, CPUE in inshore sites decreased by 57% from 0.77 to 0.33 kg/potlift between 2006 and 2009 while offshore catch rates decreased by 73% from 0.73 to 0.20 kg/potlift over the same period.

Fishery model outputs confirmed fishery dependent and independent data in relation to the decline in status of the SZRLF resource. In particular, both qR and LenMod fishery models indicated that biomass and egg production had decreased markedly over the 2003-2009 period. Model estimates suggest that biomass in 2009 was ~1,800 tonnes, representing a decrease of over 60% since 2002. Similar decreases in egg production were observed, with both models indicating that in 2009 egg production was <10% of virgin levels. As catch had not declined at the same rate as biomass, exploitation rates increased and in 2009 were ~68%, the highest on record.

Factors driving the decline in fishery performance are clear. Both the qR and LenMod models highlight a decline in recruitment to the fishable biomass over the last decade which has translated to declines in catch rates (Linnane et al 2010c). Declines in model estimated recruitment are mirrored by decreases to pre-recruit estimates over the same period as observed from logbook data. In particular, recruitment estimates in 2007 and 2008 were two of the lowest on record confirming substantial declines in commercial catch rates during these seasons.

In 2010, fishing effort decreased substantially in the SZRLF from ~2 million potlifts in 2009 to 1.3 million in 2010. In addition, commercial catch rates increased for the first time in seven seasons. This increase was both temporally and spatially consistent, occurring across all months and in all regions of the fishery. Driving the increase were clear signs of improved recruitment to the fishery as evidenced by increases to both model based recruitment and commercial pre-recruit indices in 2008 and 2009. This is supported by length frequency data which showed that a strong cohort of lobsters observed in the 90-98 mm CL undersized size classes in 2009 entered the fishable biomass as legal size lobsters in the 98-110 CL size range in 2010.

While the relationship between settlement, pre-recruit indices and recruitment in the SZRLF is not explicit in terms of absolute biomass, there are clear signs that relative correlations exist between the indices. Based on known growth rates in the fishery (McGarvey et al., 1999a), the period between settlement and pre-recruit is ~4 years, with recruitment occurring into the fishery one year later (i.e. 5 years after settlement). High levels of settlement were observed in 2005 and 2006 which reflects the increase in pre-recruit index in 2009 and 2010. This translated to increased recruitment in 2010 which should continue in 2011. However, with the exception of 2009, puerulus settlement from 2008 to 2011 was low, suggesting that recruitment from 2013 to 2016 is likely to reduce.

In summary, based on decreasing biomass and CPUE estimates, there are clear signs that the status of the SZRLF has declined significantly since 2003. Despite this, there were some positive signs for the fishery in 2010. The TACC was fully taken for the first time since 2006 and CPUE increased by 56% on 2009 estimates. In addition, the 2010 exploitation rate of 46-53% was the lowest since 2005 and reflects a considerable reduction from 69% reported in 2009. However, despite recent increases, it is important to highlight that with the exception of 2009, puerulus settlement from 2008 to 2011 was below average, suggesting that recruitment to the fishery will be reduced from 2013 through to 2016. As a result, commercial catch rates will require close monitoring over the coming seasons to ensure that biomass levels remain sustainable over what is likely to be an extended period of low recruitment to the fishery.

7.3 Implications for Management

The Management Plan for the SZRLF is currently under review by PIRSA Fisheries. During the harvest strategy development it was agreed that the TACC would remain at 1,250 tonnes for the 2011 season.

7.4 Future Research Priorities

In 2010, only 17% of licence holders provided catch sampling data, the lowest on record. These data are critical to the spatial assessment of size distributions, pre-recruit indices and reproductive condition of females. Attempts to increase participation in the program should be an immediate research priority for the fishery.

A secondary research priority is to understand the impacts of environmental variables on lobster catchability, growth and recruitment. As a result, an FRDC funded project proposal titled "*Sustainability of rock lobster resource in south-eastern Australia in a changing environment: implications for assessment and management*" is currently being undertaken in collaboration with scientists from Victoria and Tasmania. The project aims to investigate declines in lobster recruitment across South Australia, Victoria and Tasmania, as well as the relationships between environmental signals and annual settlement trends. The final report is due for completion by October, 2012.

8 BIBLIOGRAPHY

Booth, J.D., Street, R.J. and Smith, P.J. (1990) Systematic status of the rock lobsters *Jasus edwardsii* from New Zealand and *J. novaehollandiae* from Australia. New Zealand Journal of Marine and Freshwater Research 24: 239-49.

Booth, J.D., Carruthers, A.D., Bolt, C.D. and Stewart, R.A. (1991) Measuring the depth of settlement in the red rock lobster, *Jasus edwardsii*. New Zealand Journal of Marine and Freshwater Research 25: 123-32.

Booth, J.D. and Stewart, R.A. (1991) Distribution of phyllosoma larvae of the red rock lobster *Jasus edwardsii* off the east coast of New Zealand in relation to the oceanography. In 'Proceedings of the Australian Society for Fish Biology workshop on larval biology', Hobart, pp. 138-48.

Booth, J.D. (1994) *Jasus edwardsii* larval recruitment off the east coast of New Zealand. Crustaceana 66: 295-317.

Booth, J.D., Forman, J.S., Stotter, D.R., Bradford, E., Renwick, J., and Chiswell, S.M. (1999) Recruitment of the red rock lobster with management implications. National Institute of Water Research and Atmosphere, Wellington, pp. 1-103, 99/10.

Booth, J.D., Forman, J.S. and Stotter, D.R. (2002) Settlement indices for 2000 for the red rock lobster, *Jasus edwardsii*. National Institute of Water Research and Atmosphere, Wellington, pp. 1-34, 2002/12.

Bradford, R.W., Chiswell, S.M., Wotherspoon, S., Booth, J.D., Bruce, B.D. and Jeffs, A.G. (2005) Vertical distribution and diurnal migration patterns of *Jasus edwardsii* phyllosomas off the east coast of the North Island, New Zealand. New Zealand Journal of Marine and Freshwater Research 39: 593-604.

Brasher, D.J., Ovenden, J.R. and White, R.W.G. (1992) Mitochondrial DNA variation and phylogenetic relationships of *Jasus* spp. (Decapoda: Palinuridae). Journal of Zoology 227: 1-16.

Breen, P.A. and Booth, J.D. (1989) Puerulus and juvenile abundance in the rock lobster *Jasus edwardsii* at Stewart Island, New Zealand. New Zealand Journal of Marine and Freshwater Research 23: 519-23.

Breen, P.A. and McKoy, J.L. (2002) Review of current and past stock assessments for the South Australian Northern Zone Rock Lobster: Report by NIWA to the NZRL FMC Fishery. NIWA, Wellington.

Brown, R.S. and Phillips, B.F. (1994) The Current Status of Australia's Rock Lobster Fisheries. In 'Spiny Lobster Management'. (Eds. B.F. Phillips, J.S. Cobb and J. Kittaka) Blackwell Scientific Publications Ltd., Melbourne, pp. 33-63.

Bruce, B., Bradford, R., Griffin, D., Gardner, C. and Young, J. (1999) A synthesis of existing data on larval rock lobster distribution in southern Australia. Final report to the Fisheries Research and Development Corporation, Canberra, pp. 1-57, 96/107.

Bruce, B., Griffin, D. and Bradford, R. (2007) Larval transport and recruitment processes of southern rock lobster. FRDC and CSIRO Marine and Atmospheric Research publication Nr. 2002/007. ISBN Nr 1 9210061 01 4.

Chiswell, S.M. and Booth, J.D. (2005) Distribution of mid- and late-stage *Jasus edwardsii* phyllosomas: implications for larval recruitment processes. New Zealand Journal of Marine and Freshwater Research 39: 1157-1170.

Chiswell, S.M. and Booth, J.D. (2008) Sources and sinks of larval settlement in *Jasus edwardsii* around New Zealand: Where do larvae come from and where do they go? Marine Ecology Progress Series 354: 201-217.

Copes, P. (1978) Resource management for the rock lobster fisheries of South Australia: A report commissioned by the steering committee for the review of fisheries of the South Australian Government.

Fielder, D.R. (1965) A dominance order for shelter in the spiny lobster *Jasus lalandei* (H. Milne-Edwards). Behaviour 24: 236-245.

Frusher, S.D. and Hoenig, J.M. (2001) Impact of lobster size on selectivity of traps for southern rock lobster (*Jasus edwardsii*). Canadian Journal of Fisheries and Aquatic Sciences 58: 2482-2489.

Goni, R., Quetglas, A. and Renones, O. (2003a) Differential catchability of male and female European spiny lobster *Palinurus elephas* (Fabricius, 1787) in traps and trammelnets. Fisheries Research 65: 295-307.

Goni, R., Quetglas, A. and Renones, O. (2003b). Size at maturity, fecundity and reproductive potential of a protected population of the spiny lobster *Palinurus elephas* (Fabricius, 1787) from the western Mediterranean. Marine Biology 143: 583-592.

Hoare, M.J. (2008). The effects of southern rock lobster (*Jasus edwardsii*) translocation on inshore rocky reef communities in South Australia. Hons. Thesis, Flinders University, Adelaide, pp. 92.

Hobday, D. and Punt, A.E. (2001) Size-structured population modelling and risk assessment of the Victorian southern rock lobster, *Jasus edwardsii*, fishery. Marine and Freshwater Research 52: 1495-1507.

Johnston, D.J. (2003) Ontogenetic changes in digestive enzyme activity of the spiny lobster, *Jasus edwardsii* (Decapoda; Palinuridae). Marine Biology 143: 1071-1082.

Jones, K. (2009) South Australian Recreational fishing Survey. PIRSA Fisheries, Adelaide, 84 pp. South Australian Fisheries Management Series Paper No 54.

Lewis, R.K. (1981) Southern rock lobster *Jasus novaehollandiae*: Zone N review. South Australian Department of Fisheries, Adelaide, report No. 88.

Linnane, A., Dimmlich, W.F. and Ward, T.M. (2005) Movement patterns of the southern rock lobster, *Jasus edwardsii*, off South Australia. New Zealand Journal of Marine and Freshwater Research 39: 335-346.

Linnane, A., McGarvey, R., Feenstra, J. and Ward, T.M. (2006) Southern Zone Rock Lobster (*Jasus edwardsii*) Fishery 2004/05. Final Stock Assessment Report to PIRSA Fisheries. SARDI Aquatic Sciences, Adelaide, pp. 104, publication No. RD04/0164-3, report No. 135.

Linnane, A., Penny, S. and Ward, T. (2008) Contrasting fecundity, size at maturity and reproductive potential of southern rock lobster *Jasus edwardsii* in two South Australian fishing regions. Journal of the Marine Biological Association of the United Kingdom 88: 583-589.

Linnane A. and Crosthwaite, K. (2009) Changes in the spatial dynamics of the South Australian rock lobster fishery under a quota based system. New Zealand Journal of Marine and Freshwater Research 43: 475–484.

Linnane, A., Penny, S., Hawthorne, P. and Hoare, M. (2009) Spatial differences in size of maturity and reproductive potential between inshore and offshore fisheries for southern rock lobster (*Jasus edwardsii*) in South Australia. Fisheries Research 96: 238–243.

Linnane, A., James, C., Middleton, J., Hawthorne, P., and Hoare, M. (2010a). Impact of wind stress anomalies on the seasonal pattern of southern rock lobster (Jasus edwardsii) settlement in South Australia. Fisheries Oceanography 19: 290–300.

Linnane, A, Sloan, S, McGarvey, R and Ward, T. (2010b) Impacts of unconstrained effort: Lessons from a rock lobster (*Jasus edwardsii*) fishery decline in the northern zone management region of South Australia. Marine policy 34:844-850.

Linnane, A., Gardner, C., Hobday, D., Punt, A., McGarvey, R., Feenstra, J., Matthews J. and Green, B., (2010c) Evidence of large-scale spatial declines in recruitment patterns of southern rock lobster *Jasus edwardsii*, across south-eastern Australia. Fisheries Research 105: 163–171.

Linnane, A., McGarvey, R. Feenstra, J. and Hawthorne, P. (2011) Southern Zone Rock Lobster (*Jasus edwardsii*) Fishery 2009/10. Fisheries Stock Assessment Report to PIRSA Fisheries and Aquaculture. SARDI Aquatic Sciences, Adelaide, pp. 95, publication No. F2007/000276-4, report No. 560.

MacDiarmid, A.B. (1988) Experimental confirmation of external fertilisation in the southern temperate rock lobster Jasus edwardsii (Hutton) (Decapoda: Palinuridae). Journal of Experimental Marine Biology and Ecology 120: 277-85.

MacDiarmid, A.B. (1989) Moulting and reproduction of the spiny lobster Jasus edwardsii (Decapoda: Palinurudae) in northern New Zealand. Marine Biology 103: 303-10.

McClatchie, S. and Ward, T.M. (2006). Water mass analysis and alongshore variation in upwelling intensity in the eastern Great Australian Bight. Journal of Geophysical Research 111: C8, doi:10.1029/2004JC002699.

McGarvey, R., Matthews, J.M. and Prescott, J.H. (1997) Estimating lobster recruitment and exploitation rate from landings by weight and numbers, and age-specific weights. Marine and Freshwater Research 48: 1001-08.

McGarvey, R., Ferguson, G.J. and Prescott, J.H. (1999a) Spatial variation in mean growth rates of rock lobster, Jasus edwardsii, in South Australian waters. Marine and Freshwater Research 50: 333-42.

McGarvey, R., Pennington, M., Matthews, J., Fournier, D., Feenstra, J., Lorkin, M. and Ferguson, G. (1999b). Survey sampling design and length-frequency data analysis for ongoing monitoring and model parameter evaluation in the South Australian rock lobster fishery. Final report to Fisheries Research and Development Corporation. SARDI Aquatic Sciences, Adelaide, pp. 1-119, 95/138.

McGarvey, R. and Feenstra, J.E. (2001) Estimating length-transition probabilities as polynomial functions of pre-moult length. Marine and Freshwater Research 52: 1517-1526.

McGarvey, R. and Matthews, J.M. (2001) Incorporating numbers harvested in dynamic estimation of yearly recruitment: onshore wind in interannual variation of South Australian rock lobster (Jasus edwardsii). Journal of the International Council for the Exploration of the Sea 58: 1092-99.

McGarvey, R. and Pennington, M. (2001) Designing and evaluating length-frequency surveys for trap fisheries with application to the southern rock lobster. Canadian Journal of Fisheries and Aquatic Sciences 58: 254-61.

McGarvey, R., Punt, A.E. and Matthews, J.M. (2005) Assessing the information content of catch-in-numbers: A simulation comparison of stock assessment methods based on catch and effort totals. In 'Fisheries Assessment and Management in Data-Limited Situations.' (Eds. G.H. Kruse, V.F. Gallucci, D.E. Hay, R.I. Perry, R.M. Peterman, T.C. Shirley, P.D. Spencer, B. Wilson, and D. Woodby). Alaska Sea Grant College Program, University of Alaska, Fairbanks, pp. 635-653.

Middleton, J.F. and Platov, G. (2003) The mean summertime circulation along Australia's southern shelves: A numerical study. Journal of Physical Oceanography 33: 2270-87.

Miller, R.J. (1990) Effectiveness of crab and lobster traps. Canadian Journal of Fisheries and Aquatic Sciences 47: 1228-1251.

Musgrove, R.J.B. (2000) Moult staging in the southern rock lobster Jasus edwardsii. Journal of Crustacean Biology 20(1): 44-53.

Ovenden, J.R., Brasher, D.J. and White, R.W.G. (1992) Mitochondrial DNA analyses of red rock lobster, Jasus edwardsii, supports and apparent absence of population subdivision throughout Australasia. Marine Biology 112: 319-26.

Phillips, B. (2006). Lobsters: Biology, management, aquaculture and fisheries. Blackwell Publishing Ltd., Singapore, pp. 1-506.

Phillips, B.F. and McWilliam, P.S. (2009) Spiny lobster development: where does successful metamorphosis to the puerulus occur?: a review. Reviews in Fish Biology and Fisheries 19: 193-215.

Prescott, J., R. McGarvey, G. Ferguson and M. Lorkin (1996). Population dynamics of the southern rock lobster in South Australian waters. Final report to the Fisheries Research and Development Corporation 93/086 and 93/087, 1-64.

Punt, A.E., and Kennedy, R.B. (1997). Population modelling of Tasmanian rock lobster, Jasus edwardsii, resources. Marine and Freshwater Research 48: 967-80.

Punt, A.E. (2003) The performance of a size-structured stock assessment method in the face of spatial heterogeneity in growth. Fisheries Research 65: 391-409.

Rochford, D. J. (1977) A review of a possible upwelling situation off Port MacDonnell S.A. CSIRO Aust. Div. Fish. Oceanography, 81.

Schahinger, R. B. (1987) Structure of coastal upwelling events observed off the south-east coast of South Australia during February 1983 - April 1984. Australian Journal of Marine and Freshwater Research 38: 439-459.

Sloan, S., and Crosthwaite, K. (2007) Management plan for the South Australian southern zone rock lobster fishery. The South Australian Fishery Management Series. PIRSA Fisheries publication, Adelaide, Australia.

Smith, P.J., McKoy, J.L. and Machin, P.J. (1980) Genetic variation in the rock lobsters Jasus edwardsii and Jasus novaehollandiae. New Zealand Journal of Marine and Freshwater Research 14: 55-63.

Thomas, C.W., Carter, C.G. and Crear, B.J. (2003) Feed availability and its relationship to survival, growth, dominance and the agonistic behaviour of the southern rock lobster, Jasus edwardsii in captivity. Aquaculture 215: 45-65.

Venema, S., Boxall, V. and Ward, T.W. (2003) Survey of the recreational rock lobster fishery in South Australia, during 2001/02. Final Rep. to PIRSA Fisheries Policy Group. SARDI Aquatic Sciences, Adelaide, 42 pp.

Zacharin, W. (Ed.) (1997) Management plan for the South Australian northern zone rock lobster fishery. Primary Industries and Resources South Australia, Adelaide, pp. 1-24.