Fishery Assessment Report to PIRSA

Northern Zone Rock Lobster (*Jasus edwardsii*) Fishery 2005/06

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This fishery assessment updates the 2004/05 report for the Northern Zone Rock Lobster Fishery (NZRLF) 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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EXECUTIVE SUMMARY

1 This fishery assessment updates the 2004/05 report and assesses the current status of the Northern Zone Rock Lobster Fishery (NZRLF). The report also identifies both current and future research needs for the fishery.

2 In 2005/06, a total of 585,389 potlifts landed a catch of 476.4 tonnes. This was 43.6 tonnes below the TACC (520 tonnes). Catch in 2005/06 was also 46.6% below the lower reference limit identified in the Management Plan (891 tonnes in 1994) but represented a 30.3 tonne increase from 2004/05 (446.1 tonnes). This is the first season that catch has increased in the NZRLF since 1998.

3 The Catch-Per-Unit-Effort (CPUE) for 2005/06 was 0.82 kg/pot lift. This was 34.4% below the lower reference limit identified in the Management Plan (1.25 kg/pot lift in both 1995/96 and 1996/97) but a marginal increase of 0.02 kg/potlift from 2004/05 (0.80 kg/potlift). This is the first season that CPUE has increased in the NZRLF since 1999.

4 The mean weight of lobsters in 2005/06 (calculated from season totals of catch in numbers and weight) was 1.09 kg, which is within the reference limit range identified in the Management Plan (1.06 – 1.13 kg). Mean weight has decreased over the last three seasons, which may indicate that recruitment to the fishery is increasing.

5 The pre-recruit index (PRI) for 2005/06 (calculated from voluntary catch sampling data) was 0.49 undersize/pot lift, which is above the upper reference limit identified in the Management Plan (0.108 – 0.345 undersize/potlift). This is the fourth season in succession in which the PRI has increased.

6 In 2006/07, the puerulus settlement index (PSI) was 0.89 puerulus/collector, which is the second highest settlement index since sampling began in the NZRLF. However, overall trends in PSI recorded since 1996 are low compared to the SZRLF suggesting that settlement in the NZRLF is sporadic.

7 Outputs from the qR model suggest that egg production in the 2005/06 season was 428 billion eggs, which is 37% below the lower reference limit (679 billion eggs in 1995/96) and one of the lowest in the history of the fishery.

8 Outputs from both the qR and newly developed LenMod fishery models suggest that lobster biomass also remains at one of the lowest levels in the fishery's history. However, the decreasing trend in biomass observed since 1999 was arrested in 2005/06, with outputs from both models showing a marginal increase in biomass from 2004/05 estimates.

9 The exploitation rate in 2005/06, was 0.241 which is below the lower reference limit identified in the Management Plan (0.250 in 1993/94).

10 Forecasts of future biomass under a range of quota levels (300 to 600 tonnes), based on outputs from the qR model, suggest that the biomass will increase in 2006/07 and 2007/08 for all quota levels examined, reflecting recruitment into the fishery from the strong puerulus settlement in 2002/03. However, biomass will decrease in 2008 for quotas of ≥400 tonne as a result of low puerulus settlement in 2003/04 and 2004/05. Biomass is predicted to increase in 2009/10 and 2010/11 under all quota levels examined, due to peaks in puerulus settlement observed in 2005/06 and 2006/07.

11 In conclusion, while the status of the NZRLF remains at a historically low level based on current estimates of catch, catch rate and egg production, there are some positive signs for the future. Namely, catch and catch rate increased in 2005/06 for the first time since 1998/99. PRI also continued to increase in 2005/06. It is predicted that these increases reflect the high puerulus settlement observed in 2002/03, which is due to enter the fishable biomass in 2006/07, but which may have been observed earlier in some regions in 2005/06 due to variations in growth rates. The strength of the 2002/03 puerulus settlement will be quantified during the 2006/07 fishing season. However, given the level of variation in recruitment to the NZRLF and the degree of uncertainty associated with puerulus settlement data, careful consideration should be given as to how pulses of recruitment are conserved. It may be necessary for management arrangements to be developed that afford greater levels of protection for recruitment pulses during the stock rebuilding phase, as these pulses may need to sustain catches for extended periods.

1 GENERAL INTRODUCTION

1.1 Overview

This Fishery Assessment Report updates the 2004/05 report for the Northern Zone Rock Lobster Fishery (NZRLF) and is part of 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 NZRLF and to assess the current status of the resource.

The report is divided into ten 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 NZRLF; (iii) outlines the management arrangements for the fishery and identifies the current biological performance indicators and reference points; (iv) provides a synopsis of biological and ecological knowledge of the southern rock lobster, *Jasus edwardsii*; and (v) summarises previous assessments of the NZRLF.

Section two provides a synopsis of the fishery dependent statistics for the NZRLF from 1970/71 to 2005/06. This section examines inter-annual, within-season and spatial patterns in catch, effort and catch-per-unit-effort (CPUE) in the Marine Fishing Areas (MFAs) that comprise the NZRLF.

The third section presents fishery independent outputs from the puerulus monitoring programme. It also compares inter-annual variations in the settlement rates of puerulus with pre-recruit indices lagged by three years.

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 newly developed length frequency model for the fishery. Outputs from both models are compared in this section of the report.

The sixth section provides outputs from other programs or surveys that were undertaken during the course of the season. In 2005/06 in the NZRLF, this was primarily the bycatch monitoring program.

The seventh section uses information provided in sections two, three, four and five to assess the status of the fishery against the biological performance indicators and reference points defined in the NZRLF Management Plan (Zacharin 1997).

Section eight is the General Discussion. It synthesises the information presented, assesses the status of the fishery and the level of uncertainty in the assessment.

The ninth section is the bibliography, which provides a list of research papers and reports that are directly relevant to research and management of the NZRLF and/or which are cited in this report. Section ten is the Appendix.

1.2 Description of the Fishery

1.2.1 Location and Size

The NZRLF includes all South Australian marine waters between the mouth of the Murray River and the Western Australian border and covers an area of 207,000 km^2 (Figure 1-1). The NZRLF is comprised of 42 Marine Fishing Areas (MFAs), but most of the fishing is conducted in ten MFAs (7, 8, 15, 27, 28, 39, 40, 48, 49 and 50).

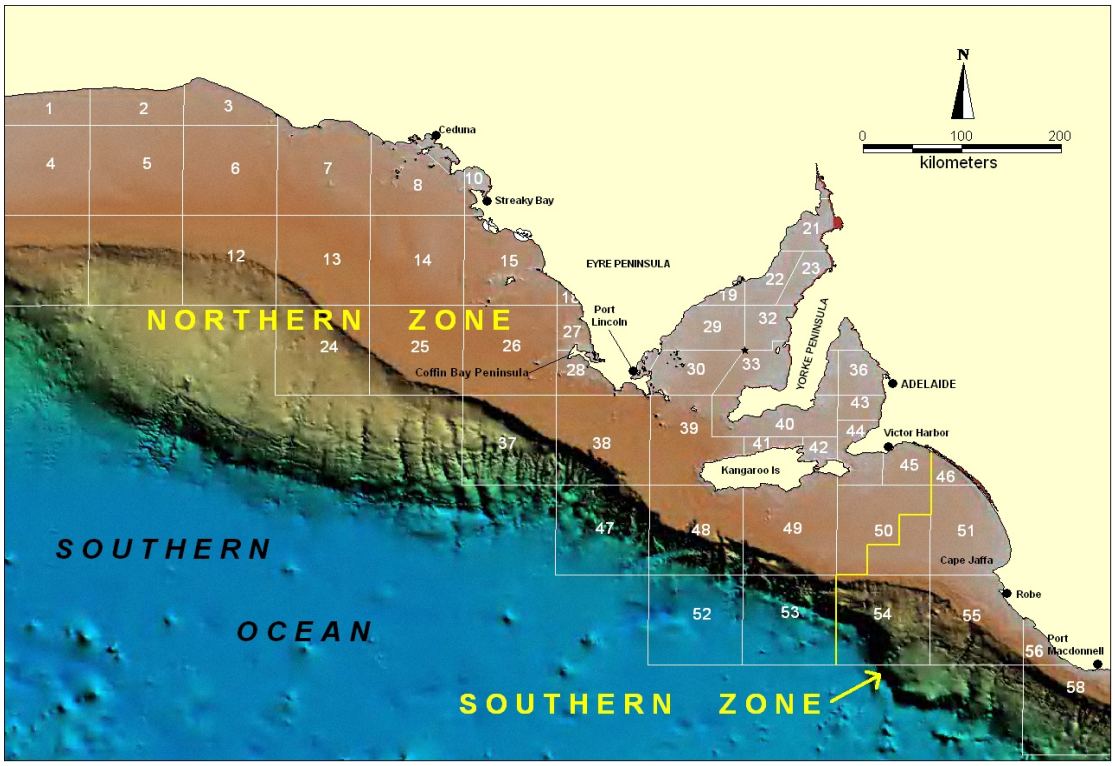

Figure 1-1 Marine Fishing Areas in the Northern and Southern Zones of the South Australian Rock Lobster Fishery.

1.2.2 Environmental Characteristics

Geology

Geologically, the NZRLF can be divided into two subregions. From Gulf St Vincent to the South Australia/Western Australia border, the marine substrate is comprised mainly of a vast basement of granitic rocks (Lewis 1981). Reef communities and habitats for lobsters are confined to relatively small patches where this basement of granite projects through the overlying sands. Some additional small areas of limestone reef occur off Elliston. The remainder of the NZRLF (i.e. from Gulf St Vincent to the

Murray Mouth) is comprised of a metamorphosed basement with intrusions of igneous rocks, particularly granites. These intrusive granites produce peaked reefs that provide discrete localised habitats for lobsters that are interspersed by large expanses of sand. Granite does not erode as easily as the limestone reefs in the Southern Zone Rock Lobster Fishery and granite reefs thus lack the numerous ledges, crevices and undercuts which provide ideal habitats for lobsters. Densities of lobsters on the granitic reefs of the NZRLF are generally lower than those on the limestone reefs of the SZRLF.

Oceanography

The southern Australian continental shelf is storm-dominated with high (>2.5 m) modal deep-water wave heights. Winds are predominantly south-easterly during summer and north-westerly during winter.

During summer, currents flow westward along the coast of the eastern Great Australian Bight and eastward over the shelf break (Herzfield and Tomczak 1997; Evans and Middleton 1998; Herzfield and Tomczak 1999). The Flinders Current (Bye 1972) flows from east to west along the continental slope, and is the source of cold, nutrient rich water that upwells onto the continental shelf from depths of around 600m (Figure 1-2). The mean summer wind direction over the shelf from Robe to the head of the Great Australian Bight is favourable for upwelling. South-easterly winds transport warm surface water offshore and cold, nutrient rich water is upwelled from below (Middleton and Cirano 2001). The water layer above the thermocline is characterised by medium salinity (35.6 parts per thousand, i.e. ppt), low nutrient levels (NO_3 <0.1 μg/l) and high temperatures (18 to 19°C). Water below the thermocline has lower salinity (< 35.5 ppt), higher nutrient levels (NO_3 >0.2 μg/l) and lower temperatures (~14°C). Sea surface temperatures during summer are lower near the coast (e.g. 14-15°C), especially along the western Eyre Peninsula and off the western tip of Kangaroo Island, and higher offshore (18-20°C) (Figure 1-2, Ward et al. 2001a, b).

During winter, water over the continental shelf is vertically homogeneous, well mixed and characterised by low nutrient levels (NO_3 <0.25 μg/l), high salinities (> 36 ppt) and medium temperatures of ~17°C (Figure 1-3) (Ward et al. 2001a). Westerly,

downwelling-favourable winds lead to the formation of an eastward coastal current along the shelf break from Cape Leeuwin to the east coast of Tasmania (Cirano and Middleton 2002). The presence of this coastal current suppresses the upwelling of water from the Flinders Current, which flows underneath the coastal current at a depth of around 600m, onto the shelf (Middleton and Cirano 2001). Sea surface temperatures are lower inshore than offshore at this time (Ward et al. 2001a; Ward et al. 2001b).

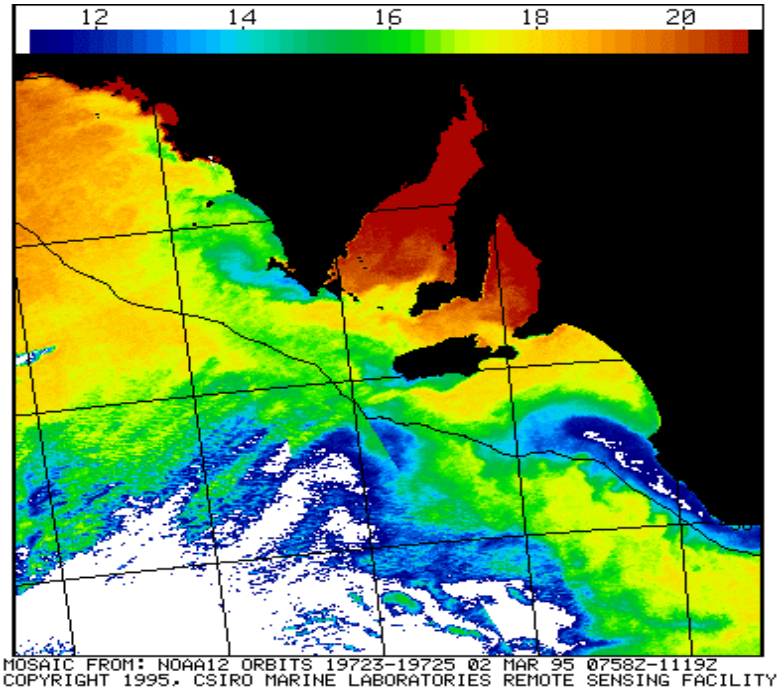

Figure 1-2 Sea-surface temperatures over the continental shelf of South Australia during summer and autumn. An upwelling can be seen, where cooler water (dark blue) has moved onto the inner continental shelf.

1.2.3 Commercial Fishery

The southern rock lobster, *J. edwardsii*, has 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). Since then there has been a gradual change to live export. Currently over 90% of the commercial catch is exported live to overseas markets.

Commercial fishers predominantly harvest lobsters using steel-framed pots covered with wire mesh and incorporating a moulded plastic neck (Figure 1-4). Pots are generally set overnight and retrieved the following day. The catch is initially stored live in holding wells on boats and then transferred to live holding tanks at the numerous processing factories around the State.

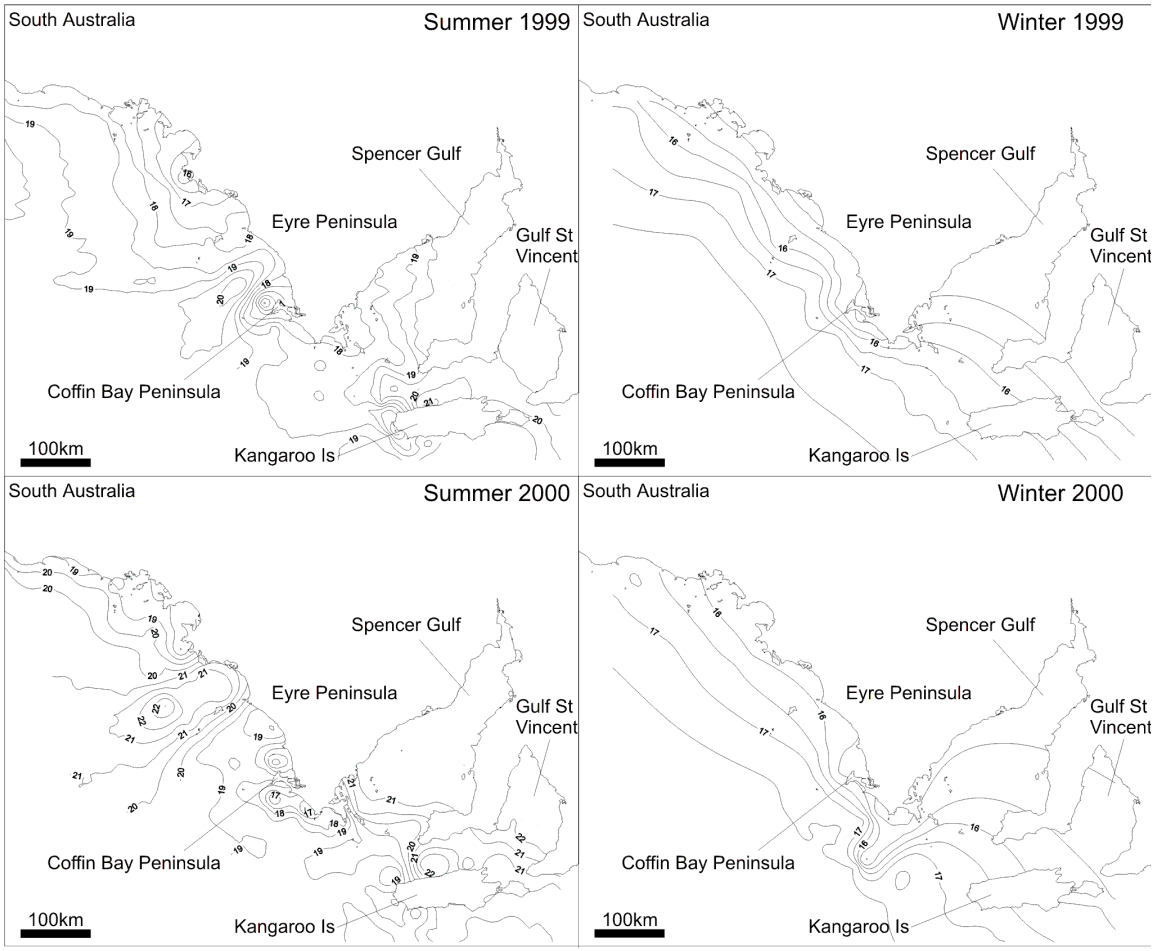

Figure 1-3 Contour plots of sea surface temperatures obtained from in situ measurements taken from the RV Ngerin during summer and winter of 1999 and 2000.

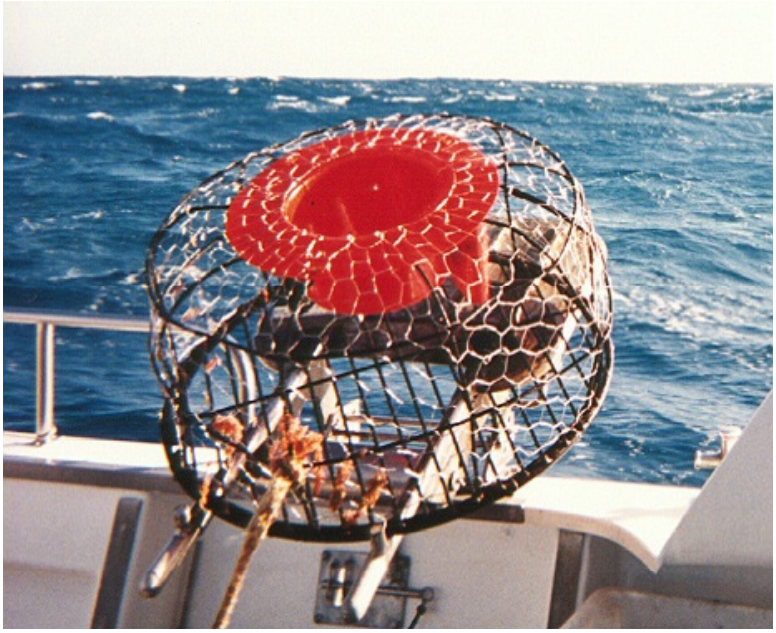

Figure 1-4 The most commonly used pot in the NZRLF.

1.2.4 Recreational Fishery

There is an important recreational fishery for lobsters within the boundaries of the NZRLF. Recreational fishers are allowed to take lobsters by diving, or by using hoop nets, drop nets or pots (pot numbers restricted by limit on registrations), during the same season as commercial fishers. All recreational lobster pots must be registered.

Recreational potters (with registered pots), drop netters and divers were estimated to have harvested 118 tonnes of rock lobsters, across South Australia, during the 2001/02 fishing season (Venema et al. 2003). In 2003, this equated to 4.7% (by weight) of the combined catch of commercial and recreational fishers across both Zones in South Australia. This was considered to be an underestimate of the total recreational catch of rock lobsters in South Australia as it does not adequately address the harvest of drop/hoop netters without registered pots, fishers using other gear types or the catches of charter boats.

A new survey of recreational fishers was undertaken during the 2004/05 season (Currie et al. 2006). Based on data from registered pot fishers only, the estimated State recreational catch in the 2004/05 season was 83.17 tonnes of which 74.62 came from the SZRLF and 8.56 from the NZRLF. The number of recreational pot registrations in the South Australian Rock Lobster Fishery for 2004/05 was 5,656. The number of individual pots in use was 9,827. Future estimation of the total

recreational rock lobster catch would be enhanced by the establishment of a comprehensive database of all recreational fishers that take rock lobsters using all methods (Venema et al. 2003; Currie et al. 2006).

1.2.5 Illegal fishing

Some illegal lobster fishing has, and is, undoubtedly undertaken in the NZRLF. However, as in most fisheries, the size of the illegal catch has not been quantified. 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.

1.3 Management of the Fishery

1.3.1 Management Milestones

Management arrangements have evolved since the inception of the fishery and when the commercial fishery was reviewed in 1997. The major management milestones for the NZRLF are shown in Table 1-1.

Table 1-1 Major management milestones for the South Australian Northern Zone Rock Lobster Fishery (Zacharin 1997).

Date	Management milestone
1968	Limited entry declared
1985	10% pot reduction; max number of pots 65
1992	10% pot reduction; max number of pots 60
1993	1 week closure during season
1994	LML increased from 98.5 to 102mm CL; further "1 week" closure
1995	Further "1 week" closure added
1997	Flexible closures introduced
1999	Extra 3 days of fixed closure added Ballot to determine if size should increase to 105 mm – affirmed for 2000 season
2000	LML increased from 102 to 105 mm CL
2001	7% effort reduction
2002	8% effort reduction
2003	TACC implemented for the 2003/04 season at 625 tonnes; VMS introduced.
2004	TACC reduced to 520 tonnes vessel length and power restrictions removed.

The NZRLF was managed by input (effort) controls until the end of the 2001-02 season. This strategy was adopted in favour of output controls for the following reasons outlined in the Management Plan (Zacharin 1997):

- The fishery operates in an environment of relatively high recruitment variability, and consequently there is high annual variation in stock abundance,
- the ability of scientific research to accurately predict future recruitment strength and subsequent stock biomass for setting total allowable catch is limited,
- the potential for quota evasions would be a significant compliance risk in the NZRLF due to the expansive unpopulated coastline and the large number of suitable landing points,
- compliance costs are relatively low using input controls, and
- licence holders have demonstrated a commitment to the time management system where the number of days fished is restricted using a flexible closure strategy.

1.3.2 Current Management Arrangements

Management arrangements for the NZRLF are outlined in the Management Plan (Zacharin 1997) and in the Scheme of Management (Rock Lobster Fisheries) Regulations, 1991. At the start of 2004/05, a TACC of 520 tonnes was implemented. Details of all the management arrangements for the NZRLF for 2005/06 are provided in Table 1-2.

Table 1-2 Management arrangements for the South Australian Northern Zone Rock Lobster Fishery in 2004/05.

Control	Northern zone
Licences	69
Season	November 1 to May 31
TACC	520 tonnes
Minimum legal length (both sexes)	105 mm CL
Egg bearing females	No retention
Dead lobsters	Landed whole
Holding of live lobsters	Holding on vessel, in corfs, or on land
Total pots	3,950
Minimum pot allocation	25
Maximum pot holding	70
Escape gaps	Two gaps each 57 mm high by 110 mm along the base
Catch and effort data	Daily logbook submitted monthly
Catch and disposal records	Daily CDR records
VMS	Required on all vessels
Maximum quota holding	None
Minimum quota holding	400 quota units

The Management Plan for the NZRLF is currently being updated as a result of a major management review (S. Sloan pers. com.). A key goal of the plan is the promotion of stock recovery and greater stability in catch levels over time. The main strategy will be to restrict catch using a conservative TACC. Additionally, escape gaps were made mandatory in all commercial lobster pots in the NZRLF for the 2003/04 season. Each pot must have at least two escape gaps (57 mm high by 110 mm along the base) placed 180° apart and free of obstruction.

1.3.3 Management Objectives and Strategies

The Management Plan (Zacharin 1997) identifies biological, economic, ecological and social objectives, strategies and reference points for the NZRLF (Table 1-3). The biological and environmental objectives and strategies are relevant to this report and are described below. The management plan is currently being reviewed.

Table 1-3 Biological and environmental objectives of the Management Plan for the Northern Zone Southern Rock lobster fishery (Zacharin 1997). Note that some of the strategies are now out of date since the introduction of new management arrangements.

Objective	Strategy
Biological	
Maintain lobster population at a sustainable level across the fishery Harvest rock lobster at a size likely to provide for adequate levels of recruitment	• adopt a precautionary approach • restrict nos. of licences to 75 • set a TACC each year • set Legal Minimum Length
Environmental	
Minimise the environmental impact of rock lobster fishing	• promote environmentally sensitive fishing practices • identify areas of conservation significance that may be worthy of conservation
Minimise potential conflict with other users or marine resources	• be proactive in dealing with conservation issues that may impact on the fishery • take an ecosystem approach in considering management arrangements for the fishery

1.3.4 Performance Indicators and Reference Points

Reference points are agreed quantitative measures, used to assess performance of the fishery, based on clearly defined management objectives.

Reference points begin as conceptual criteria that capture in broad terms the management objectives of the fishery. To implement fishery management it must be possible to convert the conceptual reference point into a technical reference point, which can be calculated or quantified on the basis of biological or economic characteristics of the fishery (Caddy and Mahon 1995).

Performance indicators

Considering the stated biological objectives for the fishery (Table 1-3), the performance indicators that may be used to assess the stock status of the NZRLF are shown in Table 1-4. In addition, biomass, total catch and total effort are also used to assess the performance of the fishery.

Table 1-4 Main performance indicators for the Northern Zone Rock Lobster Fishery.

Performance Indicator	Relates to
Exploitation rate	fraction of available (legal size) lobsters taken by the fishery
Catch rates	directly relative to current stock abundance
Egg production	reflects reproductive capacity of the fishery
Pre-recruit abundance	provides forecasting tool on future stock abundance
Mean size	changes in stock structure

Reference Points

It is a key goal of the Management Plan to maintain the performance indicators within the range defined by the reference points.

The historical data that are used to define the reference point ranges are available from commercial catch returns, catch sampling programs and a stock assessment model for the fishery, for the reference years 1992 through 1996. These are presented in Table 1-5. The current review of the management plan involves a review of the performance indicators in light of recent performance of the fishery. Catch rate and pre-recruit index will be the primary performance indicators under the proposed new harvest strategy. A key focus of the new Management Plan is fine scale spatial

management. It is proposed that the NZRLF be divided into sub-regions based on key MFAs where fishing effort is highest (Figure 1-5). As a result, where possible, the major fishery statistics in this report will be presented at both a zonal and regional level as per the objectives of the newly proposed plan.

Table 1-5 Historical data available for use in assessing appropriate biological reference points for the NZRLF.

	Reference Points					
Performance Indicator	1992	1993	1994	1995	1996	Range
Catch (tonnes)	1,064	929	891	903	903	891-1,064
Exploitation Rate[+]	0.260	0.250	0.257	0.275	0.279	0.250-0.279
Egg production (billions)[++]	865	764	716	679	679	679-865
Pre-recruit abundance[+++]	0.206	0.180	0.303	0.305	0.345	0.180-0.345
Catch rates (kg/pot lift)	1.43	1.29	1.26	1.25	1.25	1.25-1.43
Mean size (kg)[++++]	1.07	1.12	1.10	1.13	1.06	1.06-1.13

[+]The exploitation rate is the fraction of the population harvested annually, determined from the dynamic qR method using annual catches by weight and number.

[++]Total egg production (legal size females only) has been derived from the qR stock assessment model (McGarvey et al. 1997).

[+++]The pre-recruit index is undersize catch per unit of effort (CPUE) reported in voluntary catch data summed over the months of November to March (inclusive).

[++++]Mean size of rock lobster landed across the fishery.

1.3.5 Management Action Response

When one or more of the reference points described above are reached or exceeded, the management committee will undertake the following actions:

1. Notify the Minister and participants in the fishery as appropriate,
2. Undertake an examination of the causes and implications of 'triggering' a reference point,
3. Consult with the Northern Zone Rock Lobster Fishery and PIRSA on the need for alternative management strategies or actions, which may include:
    a. changes to the fishing season or,
    b. changes to the minimum size limit, or
    c. changes to the current pot restrictions.
4. Provide a report to the Minister and industry, within three months of the initial notification, on the outcomes of a review of the effect of triggering a performance indicator.

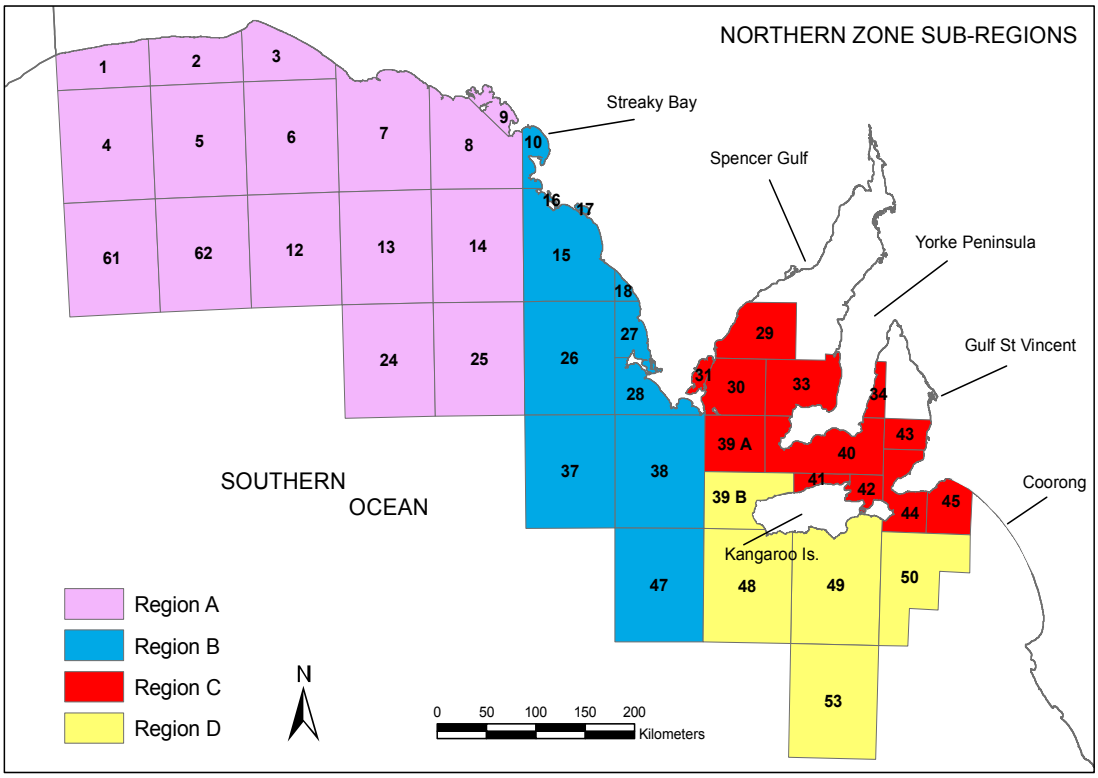

Figure 1-5 Key spatial regions as defined under the newly proposed Management Plan for the NZRLF.

1.4 Biology of Southern Rock Lobster

1.4.1 Taxonomy and Distribution

Southern rock lobster, *Jasus edwardsii* (Hutton 1875) (Figure 1-6), are distributed around southern mainland Australia, Tasmania and New Zealand (Smith et al. 1980; Booth et al. 1990). 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).

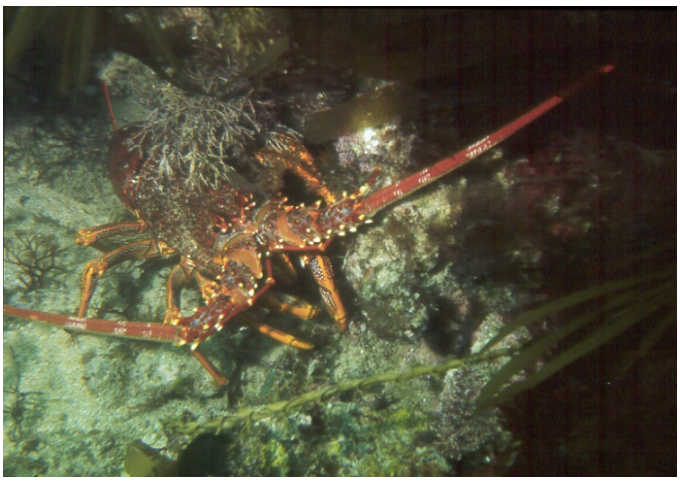

Figure 1-6 Southern rock lobster, *Jasus edwardsii,* in reef habitat.

1.4.2 Stock Structure

Few genetic or morphological differences that may indicate sub-structuring have been found in the *Jasus edwardsii* population from southern mainland Australia, Tasmania and New Zealand (Smith et al. 1980; Booth et al. 1990; Brasher et al. 1991). Similarly, mitochondrial DNA analysis has failed to detect any sub-division of the population on a smaller scale and it is likely that there is some exchange of genetic material from lobsters from south-eastern Australia to New Zealand (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).

The above notwithstanding, it is often useful to define spatially discrete fish stocks for management purposes, i.e. Northern and Southern Zones of the Southern Rock lobster fishery in South Australia. In New Zealand, clustering techniques have been used to partition rock lobster statistical areas into groups based on some characteristic of the fishery, i.e. trends in catch rates, size frequency distributions and size of maturity (Bentley and Starr 2001). This is used to provide aggregations of statistical areas, that to some degree, reflect fish stocks for stock assessment purposes.

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 and are 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, leaf-like phase called phyllosoma (Figure 1-7). Phyllosoma have been found down to depths of 60 m, tens to hundreds of kilometres offshore from the New Zealand coast (Booth et al. 1991; Booth and Stewart 1992; Booth 1994; Booth et al. 1999; Booth et al. 2002). They develop through a series of 11 stages over 12-23 months before metamorphosing into the puerulus (settlement) stage near the continental shelf break (Booth et al. 1991; Booth and Stewart 1992; Bruce et al. 1999). The puerulus actively swims inshore to settle on to reef habitat in depths from 50 m to the intertidal zone (Booth et al. 1991).

Geographic variation in larval production may be marked. 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 (Booth and Stewart 1992). 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 1992).

Geographic patterns in the abundance of phyllosoma may also be consistent with those in puerulus settlement (Booth and Stewart 1992; Booth 1994). Correlations between levels of settlement and juvenile abundance have been found at two sites in

New Zealand (Breen and Booth 1989; Booth and Stewart 1993). 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 NZRLF (McGarvey and Matthews 2001). In their study, both winds and recruitment were shown to exhibit a 10-12 year periodicity, with significant correlations between recruitment and westerly winds lagged by 5-7 years.

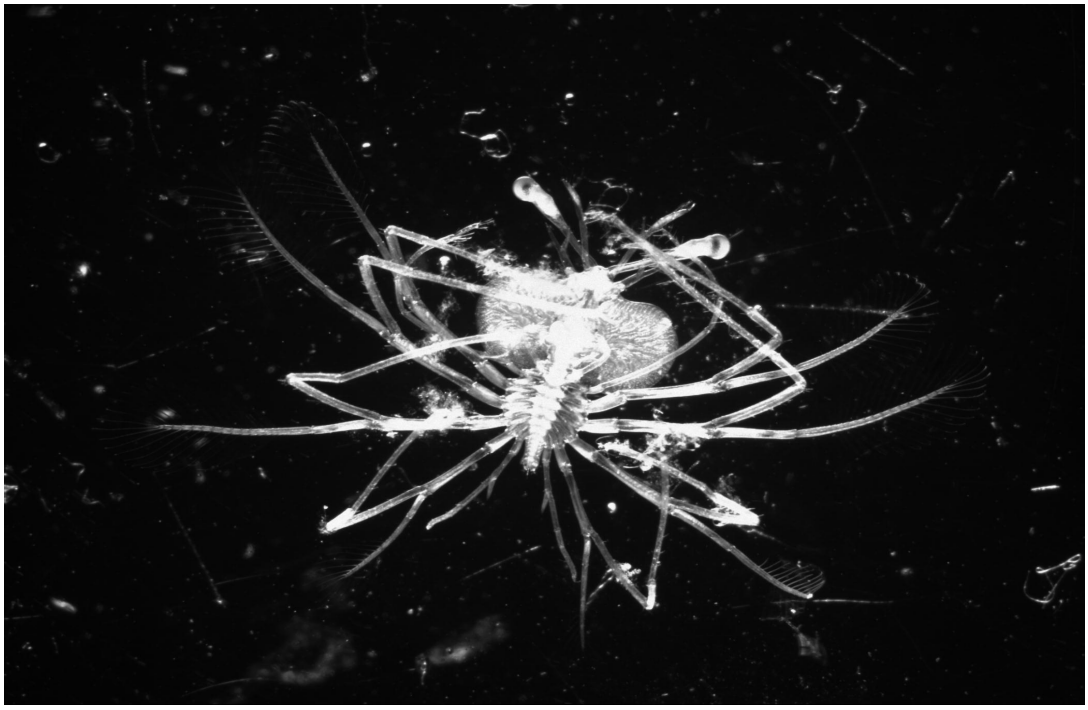

Figure 1-7 Phyllosoma taken in plankton tow from south coast of Kangaroo Island in February, 2005.

1.4.4 Growth and Size at 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).

A tagging study undertaken between 1993 and 1996, in which over 61,000 lobsters were tagged and 16,000 recaptured, demonstrated that there was substantial variation in growth rates among locations in South Australia (McGarvey et al. 1999) with a general trend of higher growth rates in the NZRLF compared to the SZRLF (Southern Zone Rock Lobster Fishery). Growth rates also varied throughout the life of individuals and the mean annual growth for lobsters at 100 mm carapace length (CL)

ranged from 7-20 and 5-15 mm per year for males and females respectively. Growth rates tended to increase along the South Australian coast from south-east to north-west and were highest in areas of low lobster density and high water temperature (McGarvey et al. 1999). Growth rates also appeared to be related to depth of habitat and declined at the rate of 1 mm per year for each 20 m increase in depth (McGarvey et al. 1999).

The size at which 50% of females are sexually mature is spatially variable, ranging between 90 and 115 mm CL (Prescott et al. 1996).

1.4.5 Movement

In South Australia, movement patterns of the southern rock lobster *Jasus edwardsii* were determined from 14,280 tag-recapture events from across the State between 1993 and 2003 (Linnane et al. 2005a). 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 in MFAs ranged from 13 to 51%. Movement rates were noticeably high in the Southern Zone Rock Lobster Fishery (SZRLF) and at Gleesons Landing lobster sanctuary off the Yorke Peninsula in the NZRLF (refer to Figure 1-1) 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 Previous Stock Assessments

The first stock assessment for the NZRLF was conducted by Copes (1978), who plotted a yield curve of catch (tonnes) against effort (pot lifts) and applied the simplest version of the Schaefer Model to suggest that the stable catch-effort relationship for the fishery was about 600 t from 400,000 pot lifts.

Lewis (1981) superimposed additional data on the yield curves generated by Copes (1978) and suggested that the potential yield from the fishery was best described by curves that indicated a potential yield of between 550 and 650 tonnes. Lewis (1981) also noted that profitability of the NZRLF would be increased through a reduction in

effort and that this would be best achieved by a reduction in both the number of units (licences) and the total number of pot lifts.

The stock assessment report produced by Prescott and Lewis (1992) used surplus production modelling to estimate the maximum sustainable yield and related parameters for the NZRLF. The report suggested that a prudent level of catch for the NZRLF based on information available was approximately 850 tonnes.

Since the mid-1990s, the qR model (McGarvey et al. 1997; McGarvey and Matthews 2001) has provided the basis for reporting against the performance indicators for the fishery (exploitation rate, egg production). Like most stock assessment models, the qR model has undergone a process of continuous refinement, as evidenced in recent rock lobster status and final stock assessment reports (Linnane et al. 2005b and c; Ward et al. 2004). The issues of changes in effective effort and the effects on stock assessments based on fishery-dependent data were identified as being significant, ongoing and unresolved by Prescott and Xiao (2001).

In addition to qR outputs, the current stock assessment provides the first outputs from the newly developed length frequency based model (Len-Mod) for the fishery.

1.6 Stock Assessment: Sources of Data

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

1.6.1 Catch and Effort Research Logbook

Licence holders complete a compulsory daily logbook that has been amended to accommodate changes in the fishery. During 1998, the logbook was modified to include specific details about giant crab fishing. In 2000/01, the logbook was amended so that the recording of numbers of undersize, spawning and dead lobsters, along with numbers of octopus became voluntary. Logbook returns are submitted monthly and are entered into the South Australian Rock Lobster (SARL) database.

Details currently recorded in the daily logbook include:

1. the MFA within which the fishing took place
2. depth at 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
15. marine scalefish retained

1.6.2 Pot Sampling

Since 1991, commercial fishers and researchers have collaborated in an at-sea pot-sampling program with the main aim of providing temporal and spatial data on pre-recruit indices, length frequencies, reproductive status, sex ratios and estimates of lobster mortality. During the life of this program there have been 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 per month over the period of the third quarter of the moon. During 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 the mean lengths and catch rates (McGarvey et al. 1999; McGarvey and Pennington 2001). This study demonstrated that the optimal design should incorporate a high percentage of boats, with sampling done on as many days as possible from a small fraction of the pots from each boat. As a result, fishers are now encouraged to sample from up to 3 research pots per trip where the escape gaps are closed. They are supported by research staff who undertake trips to sea on commercial vessels to encourage more fishers to participate in the program and to demonstrate the methods to new participants.

Participation in the program is neither random nor systematic and can vary among areas. Overall participation in the program has decreased over the last number of seasons (Figure 1-8) with only 20% of the fishery participating in 2004/05. During a series of port meetings in 2005/06, the importance of participation in the catch sampling programme was emphasised by both SARDI personnel and industry representatives. In particular, it was highlighted that future management decisions for the fishery will rely heavily on pre-recruit indices that are directly estimated from voluntary catch sampling. In 2005/06 the participation level doubled to 40% of licence holders. It is imperative that this participation level is at least maintained to ensure that future management decisions for the fishery are based on reliable and accurate data.

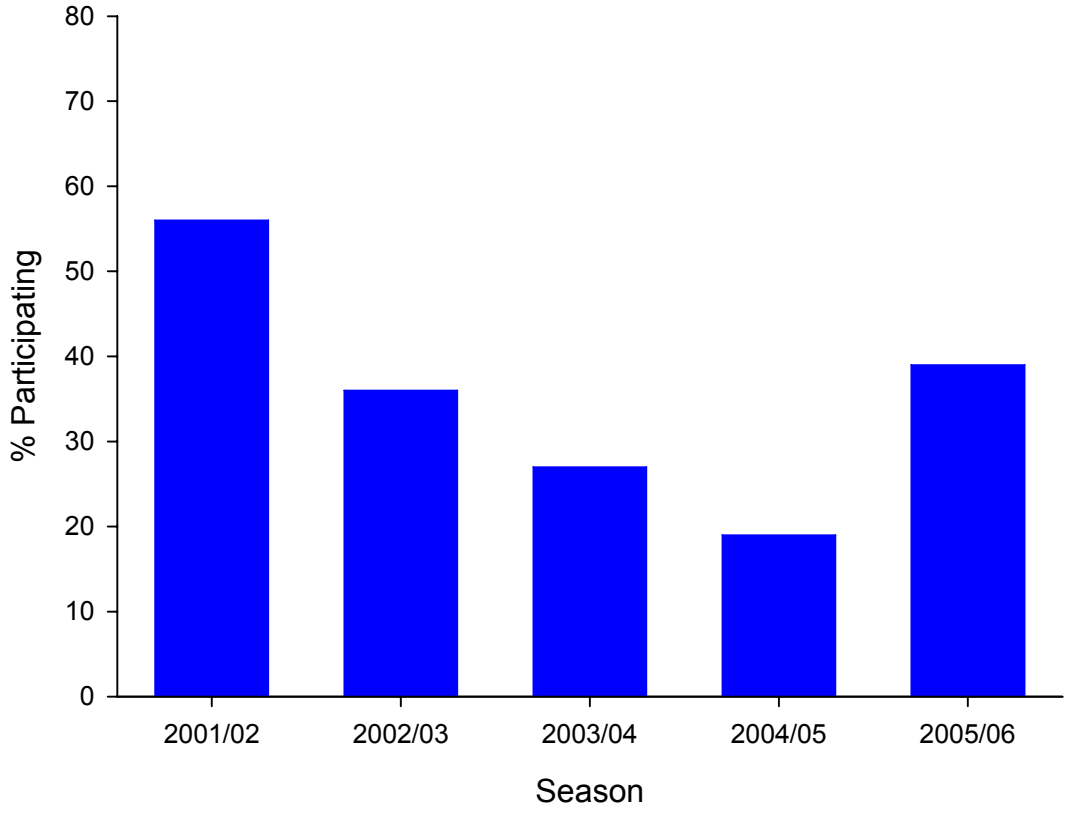

Figure 1-8. Percentage of licence holders in the NZRLF participating in the voluntary catch sampling program over the last 5 seasons.

1.6.3 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 usefulness of fishery assessment models.

Rates of puerulus and post-puerulus settlement have been monitored in the NZRLF since 1996. The four puerulus collector sites in the NZRLF are located at McLaren Point and Taylor Island (Port Lincoln) and Marion Bay and Stenhouse Bay (Yorke Penninsula). The annual Puerulus Settlement Index (PSI) is calculated as the mean monthly settlement on these collectors. Results from the puerulus monitoring program are presented in Section 3 of this report.

1.7 Other Programs/Surveys

1.7.1 By-catch monitoring program

Reports detailing the species composition and spatio-temporal trends in by-catch from the SARLF were published in 2004 and 2007 (Brock et al. 2004; Brock et al. 2007). Both identify the main by-catch species within the fishery and estimate catch rates of by-catch as determined during the 2001/02 and 2002/03 fishing seasons. They also compare the effectiveness of logbook and observer sampling strategies and comment on the appropriateness of each for application within the South Australian rock lobster fishery. SARDI scientists also undertake monitoring of by-catch from the NZRLF annually during routine onboard catch sampling. Outputs are presented in Section 5.

2 FISHERY DEPENDENT STATISTICS

2.1 Introduction

This section of the report summarises and analyses fishery statistics for the NZRLF for the period between 1 January 1970 and 31st May 2005. For ease of reference, figures and text in this section refer to the starting year of each season year e.g. 2005 refers to the 2005/06 fishing season.

Estimates presented in this section are calculated from daily data and differ slightly from estimates based on season totals that are presented in other sections of this report. Daily data 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 (no. undersized/potlift), spawning females, dead lobsters and octopus catch rates. Data obtained from the commercial catch sampling program provide the length frequency distributions of lobsters. Finally, estimates of inter-annual variations in settlement rates of puerulus are compared with pre-recruit indices lagged by three years.

2.2 Catch, Effort and CPUE

2.2.1 Inter-annual Patterns

Catch

Total catch for the NZRLF remained relatively steady at around 600-700 tonnes during the 1970s and early 1980s (Figure 2-1). The highest catch recorded during this period was 750 tonnes in 1972, i.e. the fishing season beginning in November 1972. The lowest was 560 tonnes in 1978.

The annual catch increased from 657 tonnes in 1985 to 1,221 tonnes in 1991. Between 1991 and the mid-1990s, catches declined to around 900 tonnes, before increasing again to over 1,000 tonnes in 1998 and 1999. Since 1998, the catch has declined each year to reach 446 tonnes in 2004, which is the lowest reported annual catch in the history of the fishery. The decline in the catch for the 2000 season partly reflected the increase in the minimum legal size from 102 mm to 105 mm (~5%). The further reduction in the catch for the 2001 and 2002 seasons partly reflects reductions in

fishing effort. In 2005, catch in the NZRLF was 476 tonnes. This reflects an increase in catch of 30 tonnes from 2004 and is the first time that catch increased in the fishery since 1998.

Effort

Like catches, nominal fishing effort remained relatively constant throughout the 1970s at around 450,000 pot lifts per season (Figure 2-1). However, effort almost doubled from 411,939 pot lifts in 1977 to 805,139 pot lifts in 1991. Since the peak in 1991, effort was reduced gradually to around 720,000 pot lifts per season during the mid-1990s and to 570,689 pot lifts during the 2002 season. In 2005, effort was 585,389 potlifts, an increase of 5.7% from 2004 (553,701 potlifts).

Whilst inter-annual changes in nominal effort in the NZRLF are well documented, the associated changes in effective effort are poorly understood. Copes (1978) considered that technological advances significantly increased fishing power during the 1970s. Prescott and Xiao (2001) presented analyses that suggest the catching power of (some) pots also increased during the 1980s and 1990s. Quantifying changes in the efficiency of effort is critical for the effective management of input controlled fisheries (Anon. 2002). However, the detailed information on the uptake and utilisation of technological advances by individual licence holders that are required to quantify changes in fishing efficiency are not available for the NZRLF and this issue may never be resolved completely for the fishery.

CPUE

Catch-per-unit-effort (CPUE) in the early 1970s was over 1.40 kg/pot lift (Figure 2-2). After the mid 1970s, CPUE declined steadily to 1.07 kg/pot lift in 1984. During the late 1980s, CPUE increased gradually and reached a peak of 1.50 kg/pot lift in 1990 before declining to 1.23 kg/pot lift in 1995. CPUE rose to 1.42 kg/pot lift in 1999, but then declined rapidly over the next 4 seasons. The CPUE in 2004 was 0.80 kg/pot lift which was the lowest in the history of the fishery. In 2005, CPUE increased marginally to 0.82 kg/potlift. This represents the first time that CPUE has increased in the fishery since 1999.

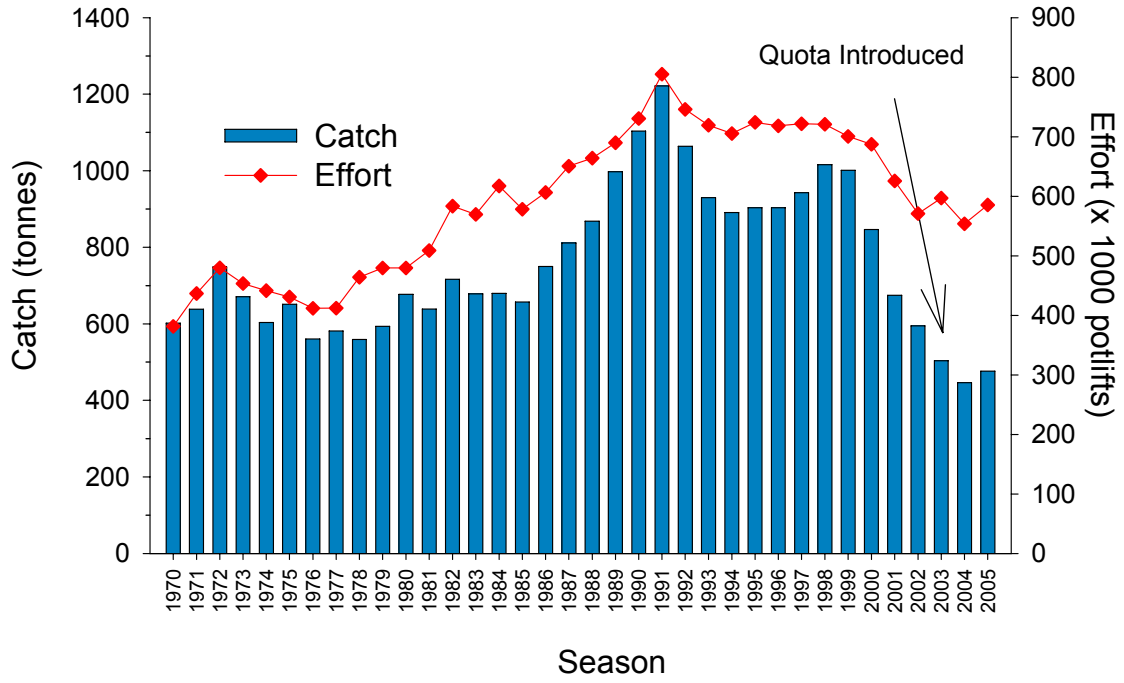

Figure 2-1 Inter-annual trends in catch and effort in the South Australian Northern Zone rock lobster fishery for seasons between 1970 and 2005.

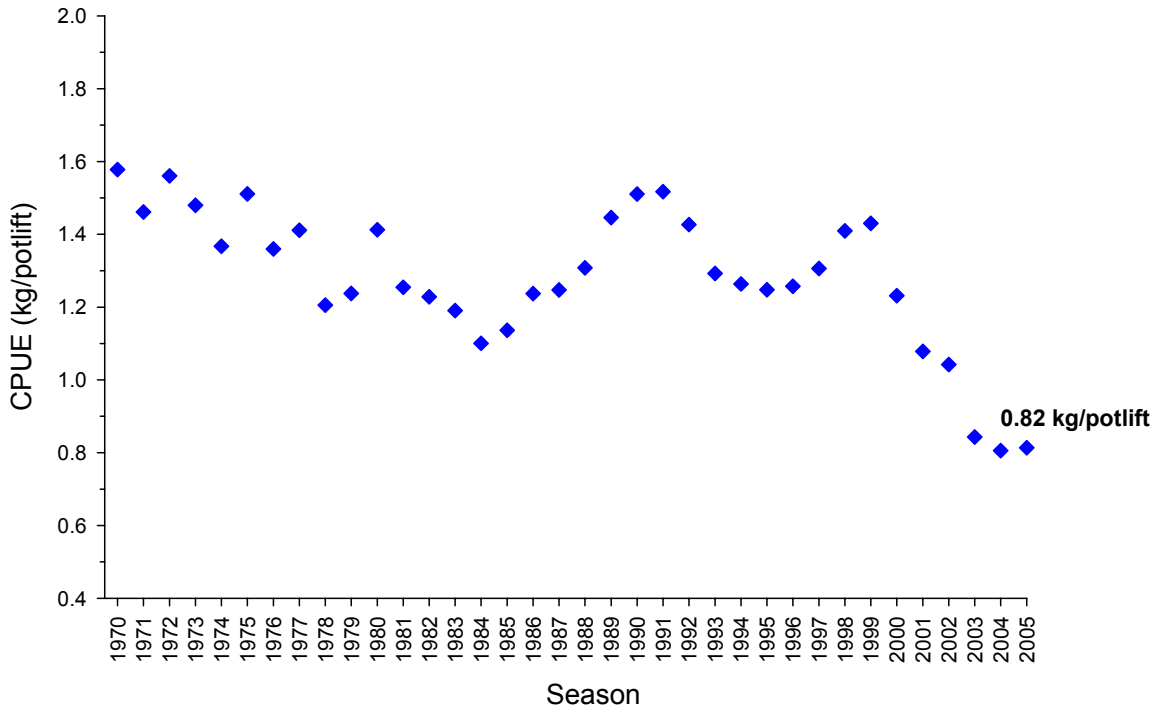

Figure 2-2 Inter-annual trends in CPUE in the South Australian Northern Zone rock lobster fishery for seasons between 1970 and 2005.

2.2.2 Within-season Patterns

Catch and effort

Within-season trends in catch and effort in the NZRLF between 1970 and 2002 are presented in Linnane et al. (2006). In the 1970s and 1980s, monthly catch and effort levels were highest during the first five months of each season (November to March), with the largest catch often taken during January. During this period, monthly catch and effort levels during April and May were generally relatively low. During the 1990s, effort was expended more evenly across the entire season, and monthly catches in April and May were higher than in the previous two decades (but still generally lower than catches in the previous five months of each season).

Within seasons trends in catch and effort over the last three seasons were similar (Figure 2-3). The highest catches were taken from January to March with May being the lowest catch month. In 2005, the highest catch was taken in January (97.1 tonnes) with the lowest catch taken in May (21.1 tonnes). Trends in effort reflected monthly trends in catch.

CPUE

The within-season trend in CPUE was similar for the 1970s, 1980s and 1990s (Figure 2-4). The highest CPUEs were recorded during December, January and February. Mean monthly CPUEs for all months were highest during the 1970s and lowest during the 1980s, with the estimates for the 1990s lying between the two extremes.

Within season trends in CPUE have been consistently similar over the last three seasons (Figure 2-5). Over this period, CPUE increased from November to January before decreasing as the seaon progressed. In 2005, CPUE was highest in January at 0.93 kg/potlift and lowest in May at 0.57 kg/potlift.

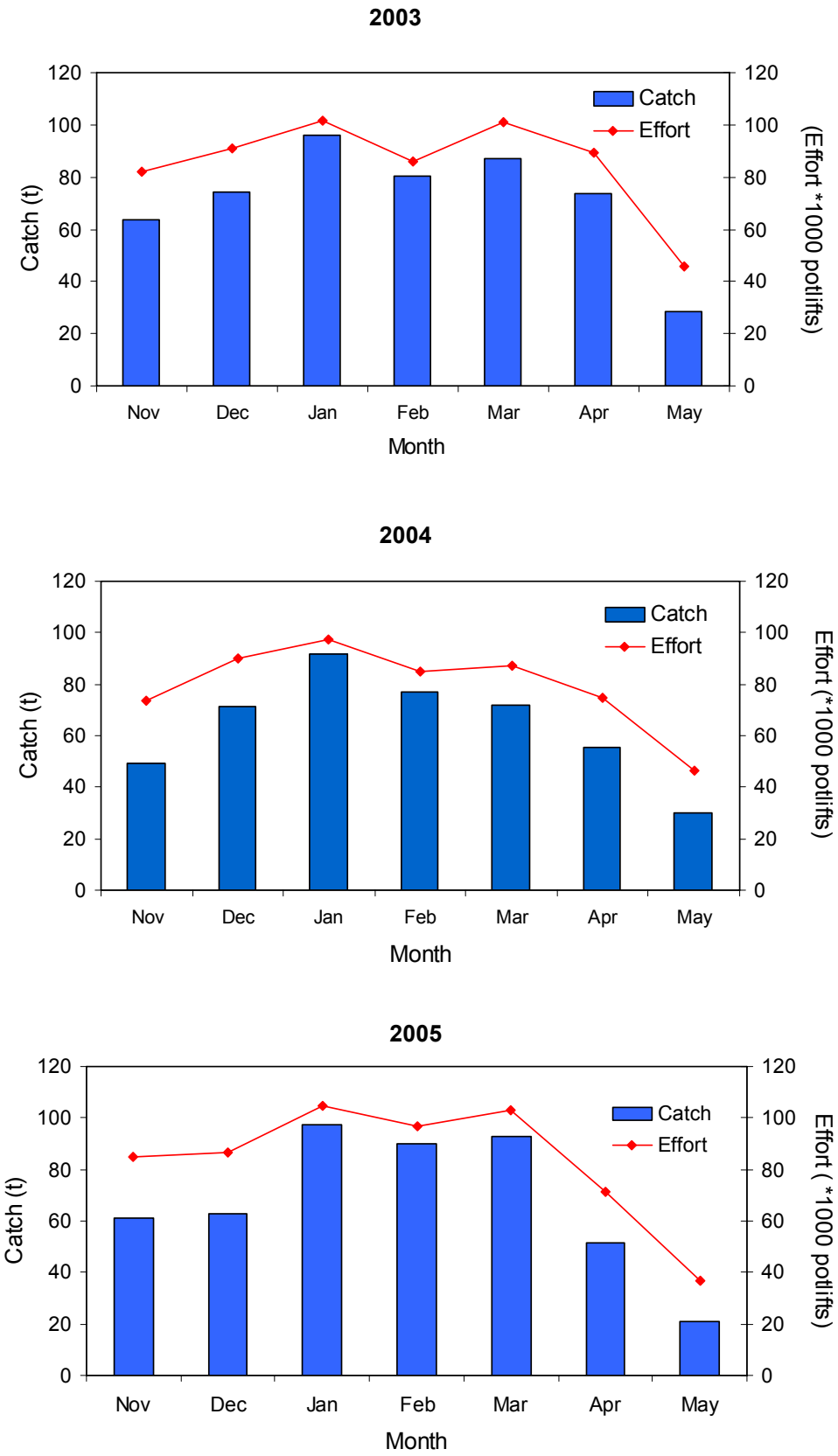

Figure 2-3 Comparison of within-season trends in catch and effort in the NZRLF for the 2003, 2004 and 2005 fishing seasons.

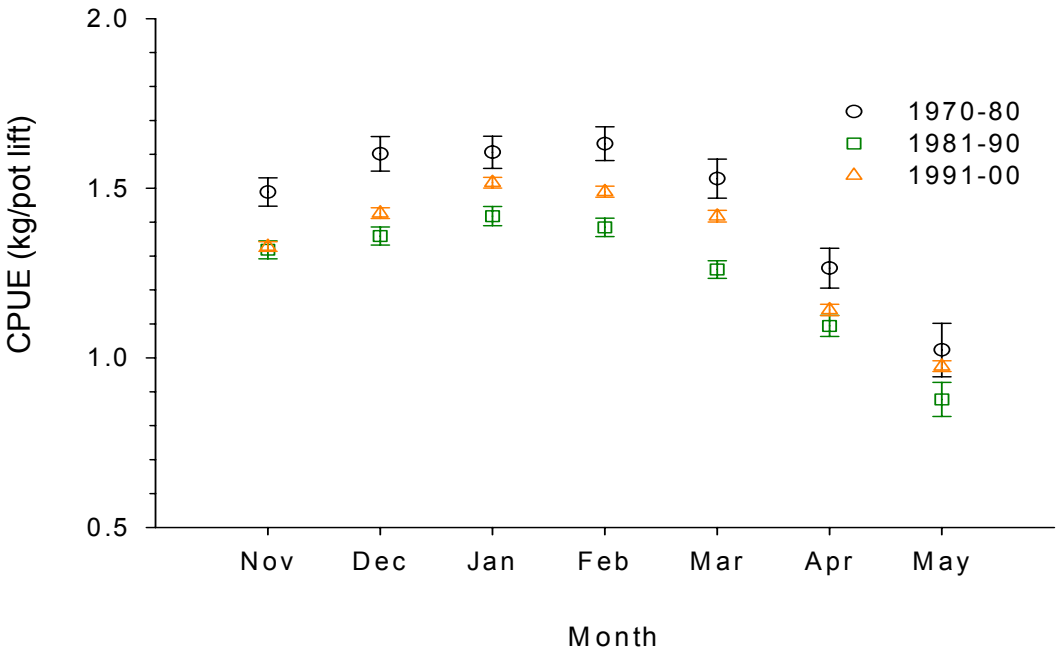

Figure 2-4 Within season trends in CPUE (+/- SE) in the NZRLF for the 1970s, 80s and 90s.

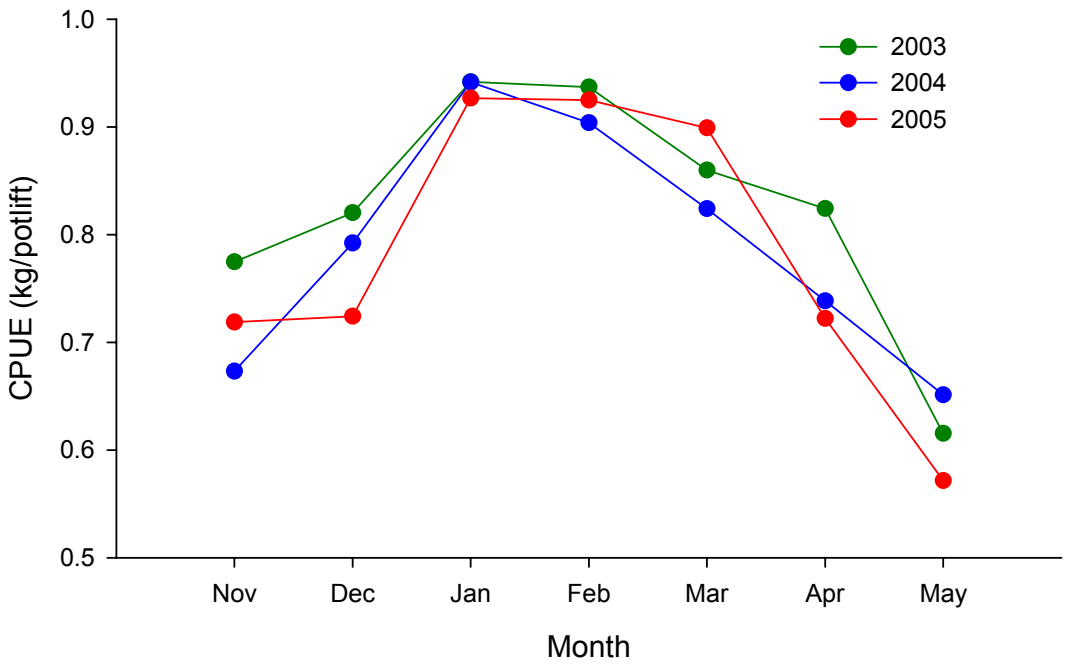

Figure 2-5 Within season trends in CPUE in the NZRLF over the last three seasons.

2.2.3 Patterns across key MFAs

Catch

Figure 2-6 shows inter-annual catch and effort data for the 10 main MFAs (7, 8, 15, 27, 28, 39, 40, 48, 49 and 50) (refer to Figure 1-1 for location of MFAs) in the NZRLF from 1970 to 2005. In 2005, over 90% of the catch came from these MFAs with over 70% taken in MFAs 28, 39, 40, 48 and 49 (Table 2-1; Figure 2-8 and refer to Figure 1-1). Over the period 1999 to 2004, there have been noticeable decreases in catches in MFAs 39, 40, 48 and 49 (Figure 2-6). Similarly, catches have decreased consistently in MFAs 15 and 28 since 1998 and 1997 respectively. In 2005, catch decreased marginally in MFAs 39, 40 and 49 but increased in MFAs 8, 15, 27, 28 and 49. The most notable increase in catch was observed in MFA 28 where catch increased by 39.4% from 62.7 tonnes in 2004 to 87.4 tonnes in 2005.

Inter-annual changes in total catch (Figure 2-1) are reflected in the patterns observed across the main MFAs (Figure 2-6). Specifically, there is a general trend of increasing catch over time, with peaks in the early 1990s and late 1990s in both zonal and regional graphs.

Effort

As in inter-annual patterns (Figure 2-1), effort across MFAs has closely reflected trends in catch (Figure 2-6). In 2005, the majority of effort occurred in MFAs 28, 39, 40, 48 and 49. Most notable was MFA 40, where a considerable increase in effort over the last three seasons has not lead to a notable increase in catch.

CPUE

The ten major MFAs in the NZRLF show similar inter-annual trends in CPUE, with peaks in CPUE during the 1970s, early 1990s and late 1990s and low CPUEs in the early 1980s (Figure 2-7). Since the late 1990's, the CPUE has generally declined in most MFAs. In 2005, CPUE increased in all the MFAs located in the western region of the fishery i.e. 7, 8, 15, 27 and 28. However, catch rates continued to decline in the eastern MFAs of 39, 40, 48, 49 and 50.

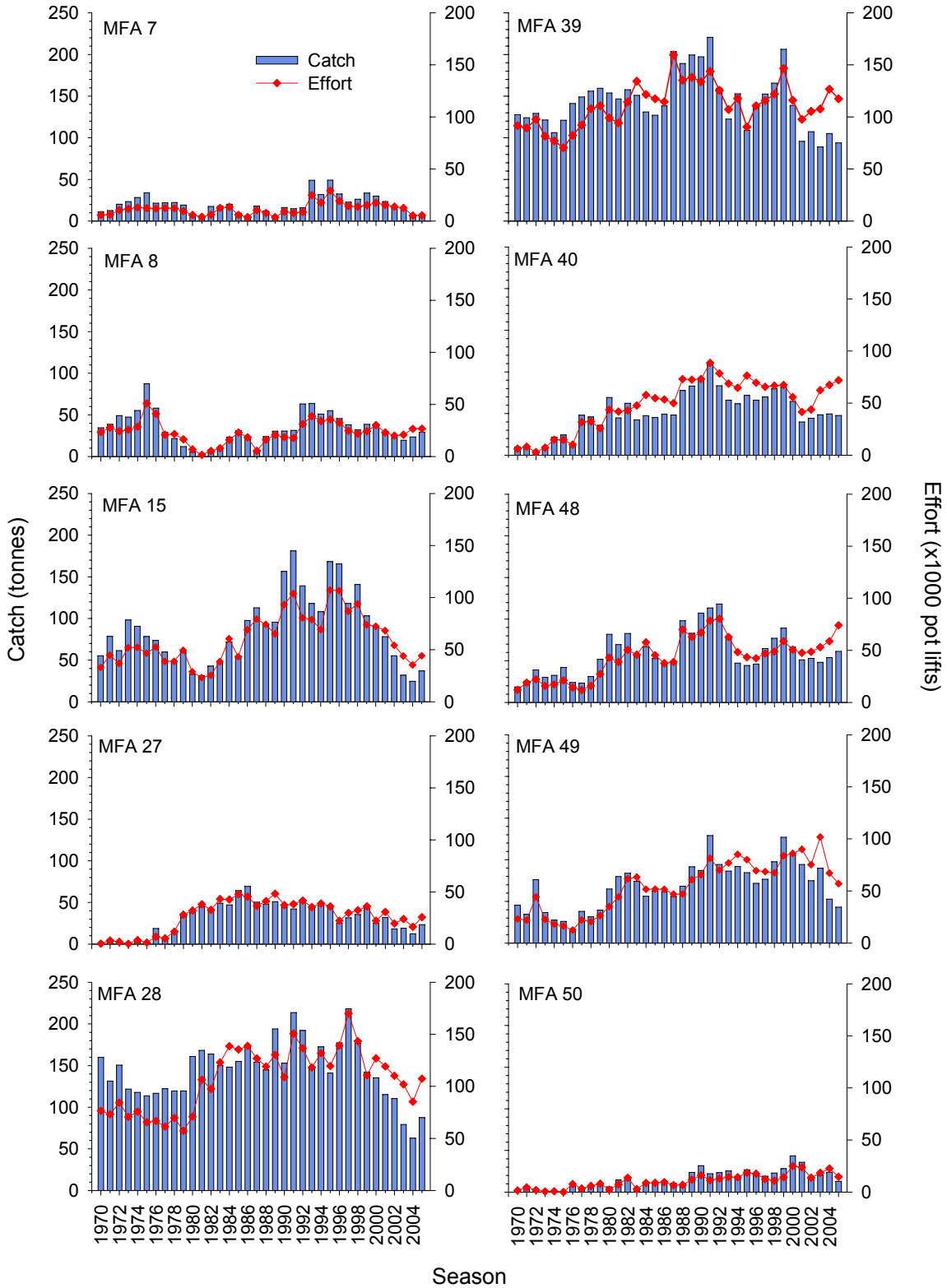

Figure 2-6 Inter-annual trends in catch and effort in the 10 main MFAs (from north-west to south-east) of the NZRLF for the fishing seasons between 1970 and 2005 (note: alternate seasonal ticks on X axis).

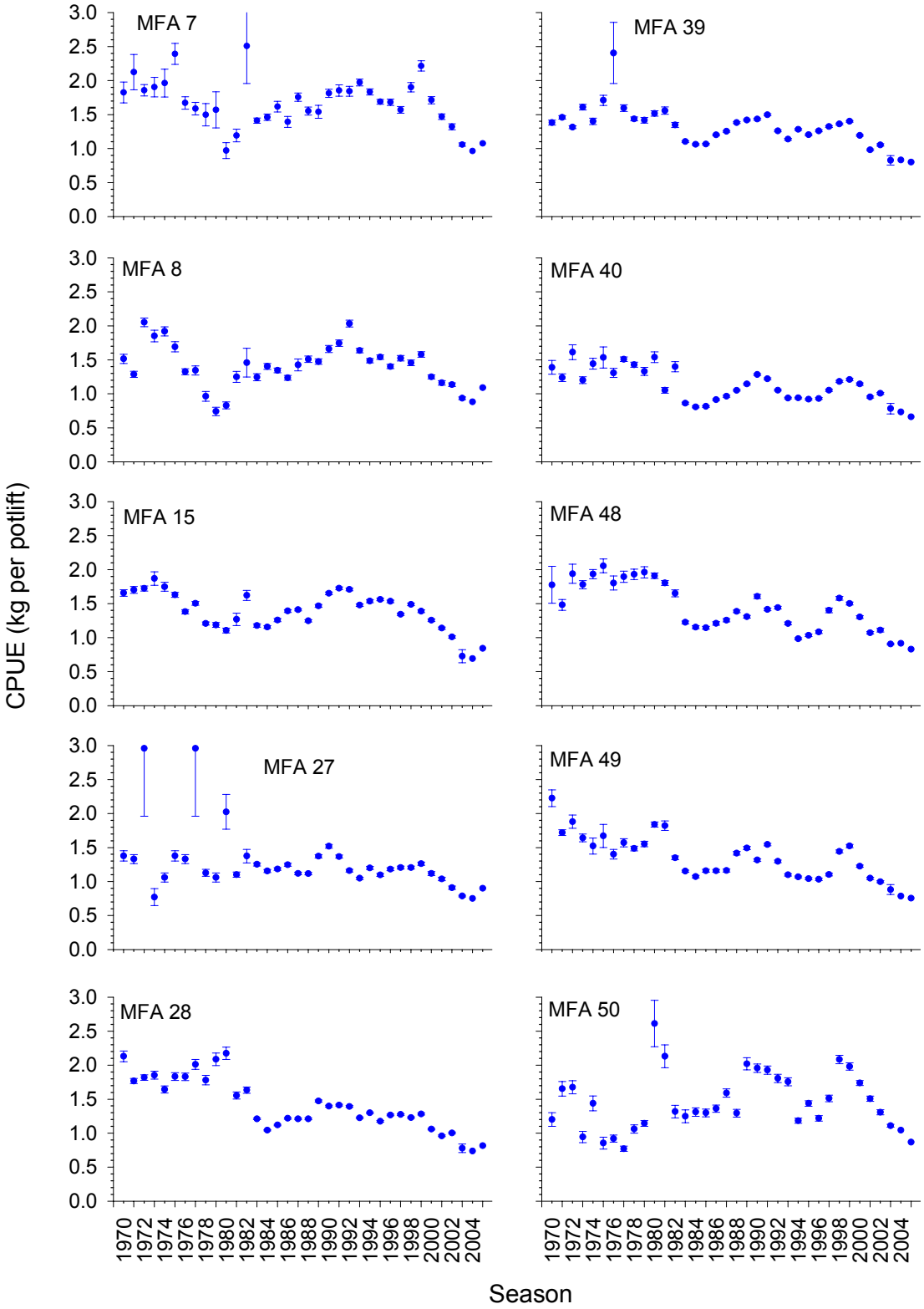

Figure 2-7 Inter-annual trends in CPUE (± SE of the mean) of the 10 main MFAs (from north-west to south-east) of the NZRLF for the fishing seasons between 1970 and 2005 (note: alternate season ticks on x axis).

Table 2-1 Total catch taken from the 10 main MFAs in the NZRLF in 2005.

MFA	Catch (t)	% Total Catch
7	5.99	1
8	29.10	7
15	37.04	8
27	23.25	5
28	87.45	20
39	93.89	21
40	47.49	11
48	61.27	14
49	43.00	10
50	12.75	3

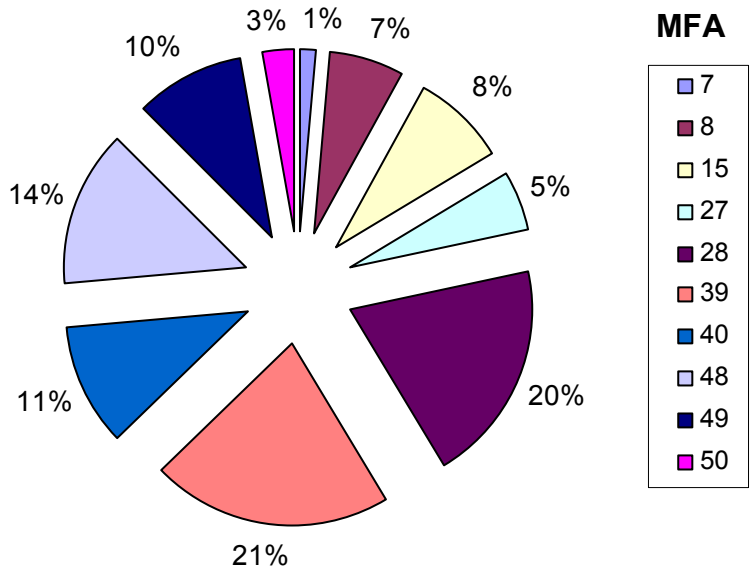

Figure 2-8 Proportion of total catch taken from the 10 main MFAs in the NZRLF in 2005.

2.3 Patterns by Region

2.3.1 Catch

Trends in catch within the newly proposed Regions of the NZRLF (refer to Figure 1-5) between 1970 and 2005 are presented in Figure 2-9. While up to 172 tonnes were taken in Region A in 1993, catches in this Region are now <50 tonnes. The majority of the catch is taken in Regions B, C and D. In recent seasons, catch in all Regions has decreased, reflecting zonal trends presented in Figure 2-1. In 2005 however, catch in Regions A and B increased for the first time in 7 seasons. In Region A, catch increased by 8.3 tonnes from 36.2 tonnes in 2004 to 44.5 tonnes in 2005. In Region B, catch increased by 47.7 tonnes from 115.6 tonnes in 2004 to 163.3 tonnes in 2005. In Regions C and D, catch continued to decrease in 2005 by 5.2 and 20.4 tonnes respectively.

2.3.2 Effort

In Regions A and B, trends in effort have generally reflected trends in catch (Figure 2-9). However, in Region C, increases in effort over the last four seasons have not resulted in a corresponding increase in catch. Similarly in Region D, effort increased substantially in 2003 despite catch remaining constant at ~220 tonnes.

2.3.3 CPUE

Trends in CPUE in all Regions between 1970 and 2005 are presented in Figure 2-10. Historically, catch rate tended to be highest in Region A, reaching >2 kg/potlift in 1990, 1992 and 1993. However, as with zonal trends in CPUE (Figure 2-2), catch rate has been decreasing in all Regions since 1999. In 2005, CPUE increased for the first time in six seasons in Regions A and B. CPUE increased from 0.94 to 1.16 kg/potlift in Region A and from 0.75 to 0.85 kg/potlift in Region B. Catch rate continued to decrease in Regions C and D in 2005.

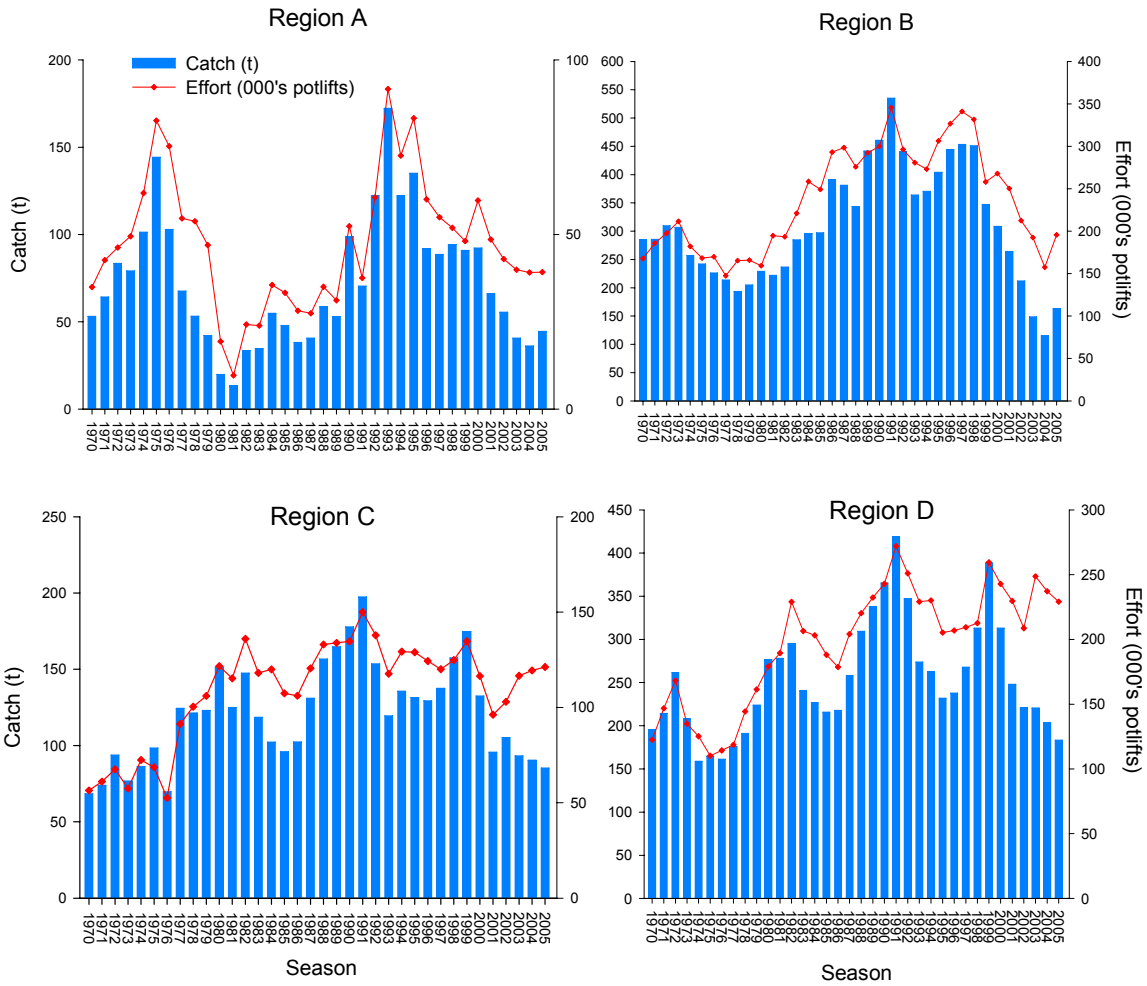

Figure 2-9 Catch and effort by region in the NZRLF from 1970 to 2005. Note that catch and effort from MFA 39 (Figure 1-1) has been apportioned 30:70 between Regions C and D.

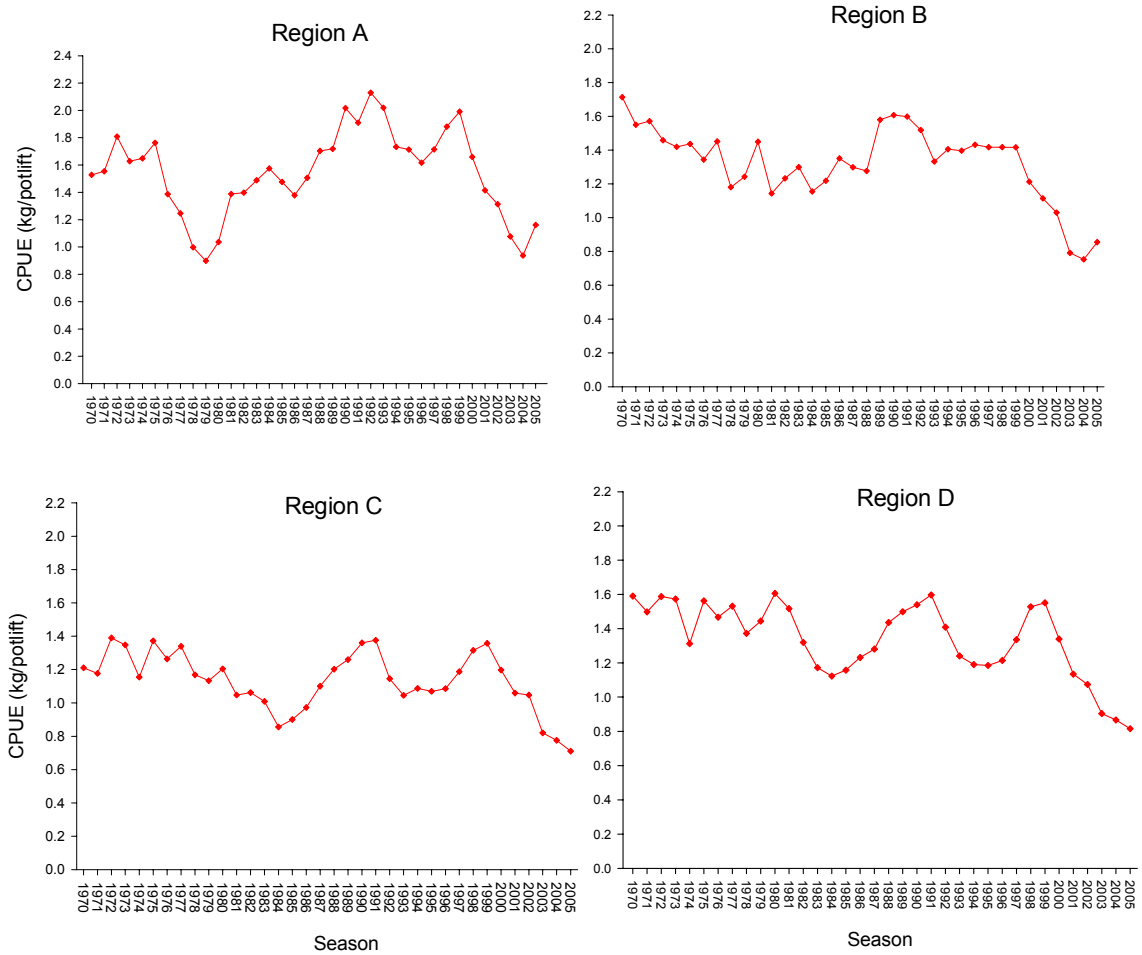

Figure 2-10 CPUE by region in the NZRLF from 1970 to 2005. Note that catch and effort from MFA 39 (Figure 1-1) has been apportioned 30:70 between Regions C and D to calculate catch rate.

2.4 Patterns by Depth

2.4.1 Catch

Since the 1970s, the majority of the catch in the NZRLF has been harvested from the 31-60 m depth range (Figure 2-11). However, in the 1970s a greater proportion of the catch was taken from waters deeper than 90 m. From 1991 onwards, an increasing proportion of the catch has come from shallower waters between 0 and 30 m in depth. In 1981-90, only 17% of the catch was harvested from 0-30 m compared to 39% in 2005. Conversely, catches in the 61-90 m depth range have declined from 21% to 9% between these two time periods. Over the last 5 seasons <10% of the catch was taken in >90 m.

Most of the main MFAs follow a similar pattern in catch with depth to that described for the entire fishery, with more of the catch coming from shallower depths (0-30 and 31-60 m) in recent years (Figure 2-12). MFA 48, located south of Kangaroo Island (Figure 1-1), is the only MFA where a notable proportion of the catch is taken in deeper waters. Over the last 5 seasons 11-31% of the catch has been taken in depths >90 m in this MFA.

2.4.2 CPUE

CPUE generally increases with depth (Figure 2-13 and Figure 2-14). Since the 1980s, CPUE has consistently been highest in depths >90 m and lowest in depths between 0 and 30 m. Prior to this period, CPUE in depths of 61-90 m was marginally higher than in depths over 90 m. The recent increase in CPUE in depths over 90 m may reflect the effects of modern technology on fishing efficiency in these depths. In 2005, CPUE was highest in January (Figure 2-14) in the lower depth ranges of 0-30 and 31-60 m and ranged from 0.46 kg/potlift (in May at 0-30m) to 0.94 kg/potlift (in January at 31-60 m). Catch rates in deeper waters >60 m were highest in February/March and ranged from 0.72 kg/potlift (in May at 61-90 m) to 1.64 kg/potlift (in February at > 90 m). Trends in CPUE by depth in 2005 were consistent with those observed in recent seasons within the NZRLF (refer to Linnane et al., 2006 for estimates between 2001 and 2004).

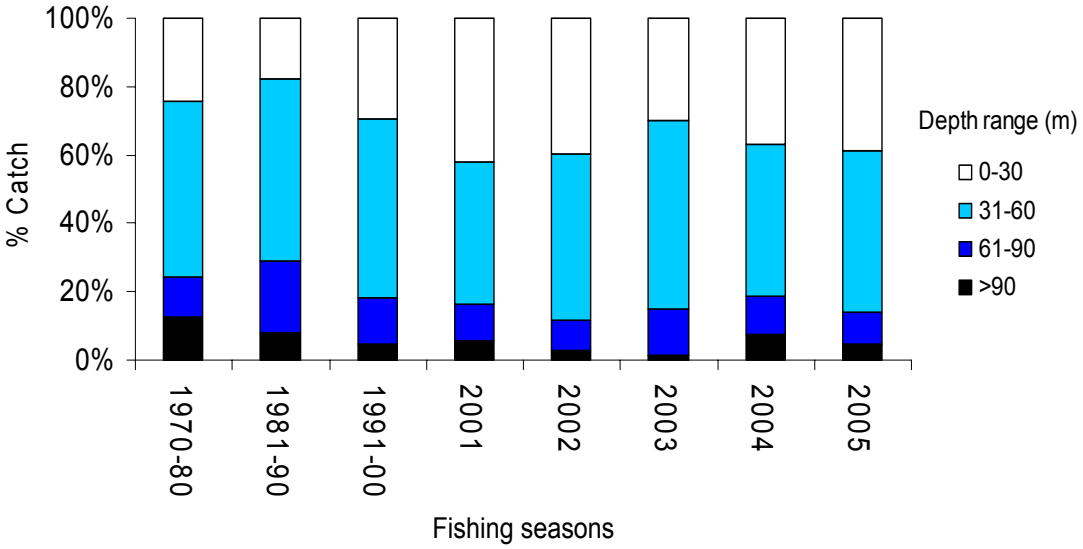

Figure 2-11 Percentage of the catch taken from four depth classes in the NZRLF during the 1970s, 1980s, 1990s and the last 5 fishing seasons seasons.

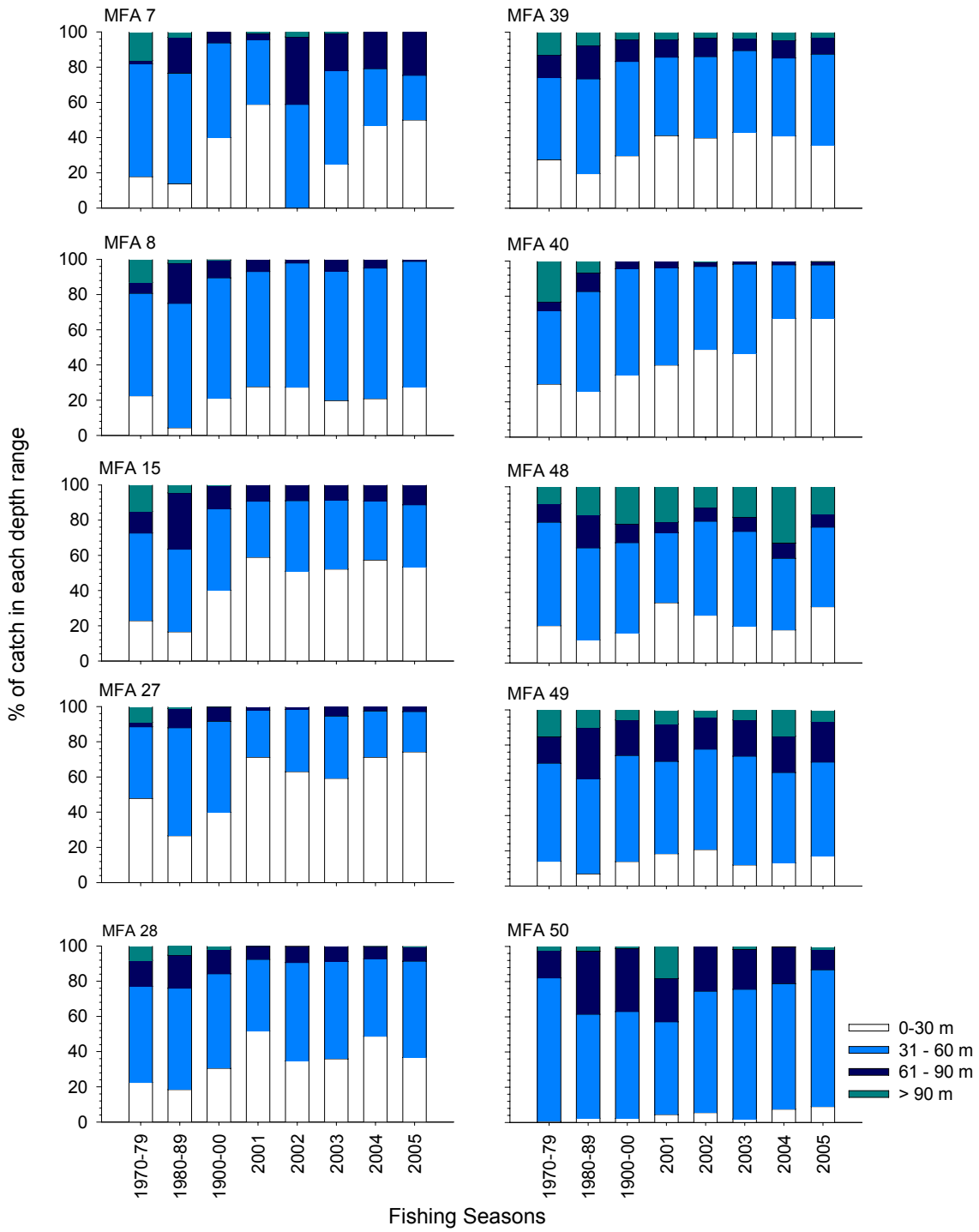

Figure 2-12 Percentage of the catch taken from four depth classes in the 10 major MFAs of the NZRLF during the 1970s, 1980s, 1990s and the last 5 seasons.

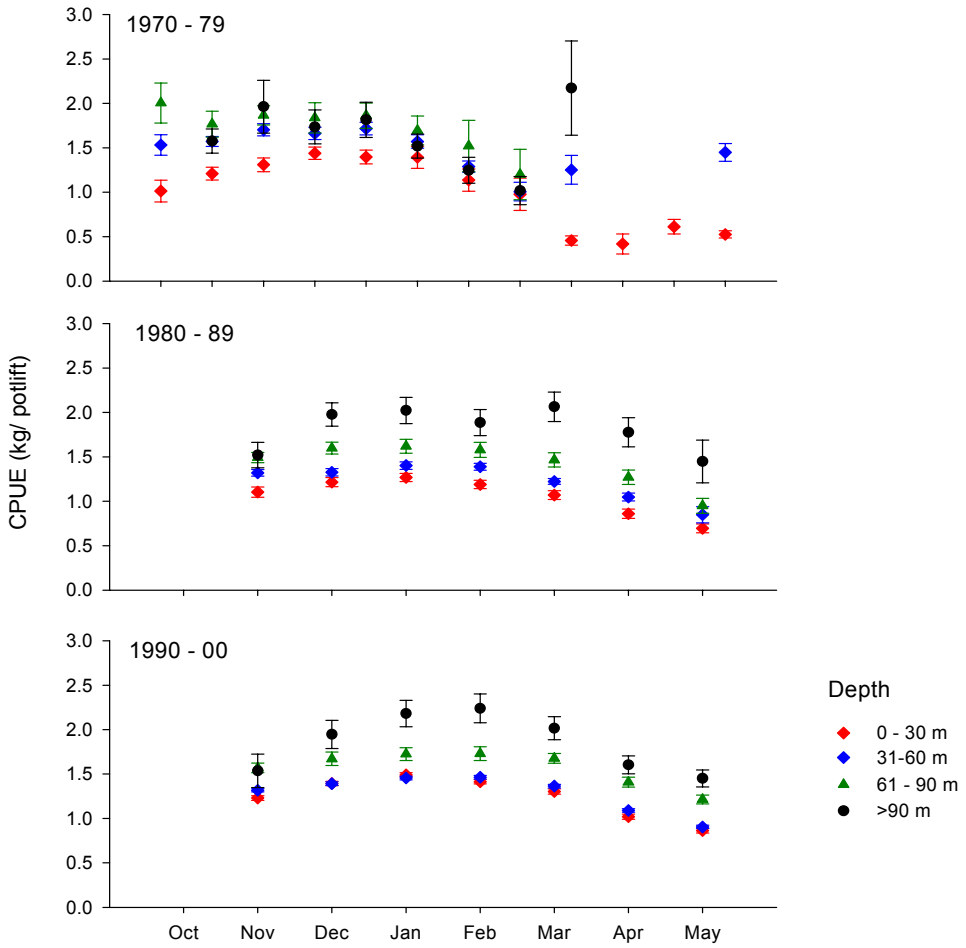

Figure 2-13 Mean monthly CPUE (+/- SE) in four depth classes in the NZRLF during the 1970s, 1980s, 1990s.

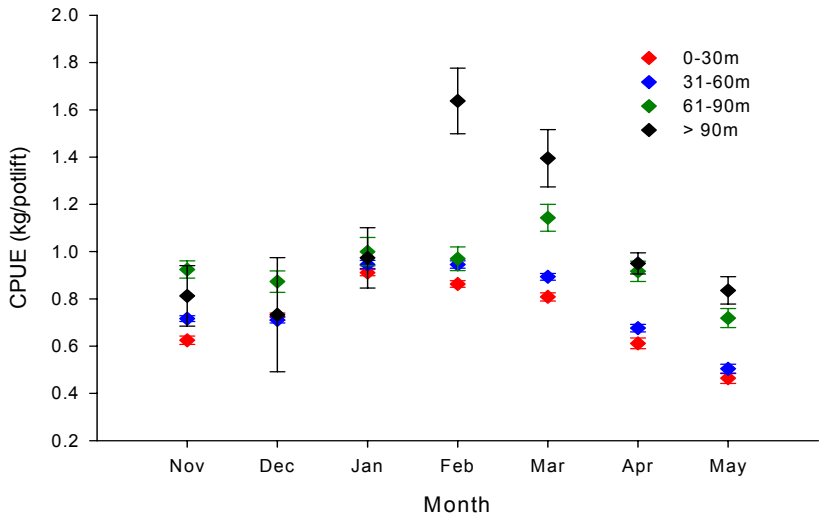

Figure 2-14 Mean monthly CPUE (+/- SE) in four depth classes in the NZRLF during the 2005 fishing season.

2.5 Mean Weights

2.5.1 Inter-annual Pattern

Since 1983, the mean weight of lobsters taken in the NZRLF has fluctuated between 1.00 and 1.21 kg (Figure 2-15). The lowest mean weight was recorded in 1988 and 1989. There were peaks in the mean weight of lobsters in 1984 (1.08 kg) and 1995 (1.16 kg), with the peak of 1.21 kg for the 2001 season being the highest mean weight recorded for the fishery. Over the next three seasons, mean weight decreased to 1.08 kg in 2004. In 2005, mean weight marginally increased to 1.09 kg. The pattern of rise and fall in mean size 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. The gradual increase in lobster mean weight observed from 1998 to 2001 probably also reflects the effects of the increases in minimum legal size from 98.5 mm to 102 mm in 1994 and from 102 mm to 105 mm in 2001. Since 2001, mean weight has decreased, which is a positive sign for the fishery and may reflect that the fishery is entering a period of higher recruitment.

2.5.2 Within-season Patterns

Since the 1970s, there has been a consistent trend of increasing mean weight as the fishing season progresses (Linnane et al. 2006). Lobsters caught early in the season (November to January) tend to be smaller than those taken later in the season (February to May). In 2005, mean monthly weight was similar to previous seasons being lowest in November at 0.92 kg and highest in May at 1.29 kg (Figure 2-16).

2.5.3 Patterns across MFA's

Mean weights of lobsters are highest in MFAs located in the north of the NZRLF (e.g. 7, 8, 15, 27; Figure 1-1), and lowest in MFAs located further south (e.g. 48, 49, 50) (Figure 2-17). Between 1983 and 1998, mean weights were relatively stable in most MFAs but tended to increase between 1998 and 2001, except in MFA 8. Since 2001, mean weight has generally decreased in most MFAs reflecting the zonal estimates of mean weight observed over the same period (Figure 2-15).

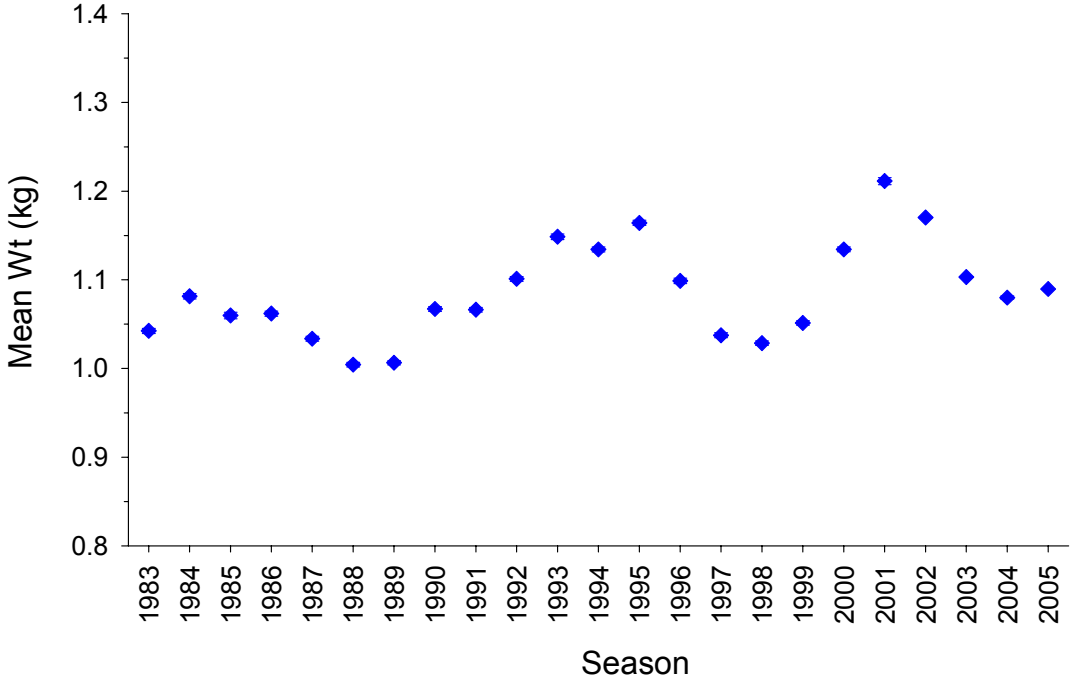

Figure 2-15 Inter-annual trends in the mean weight (± SE) of lobsters in the NZRLF for the fishing seasons between 1983 and 2005.

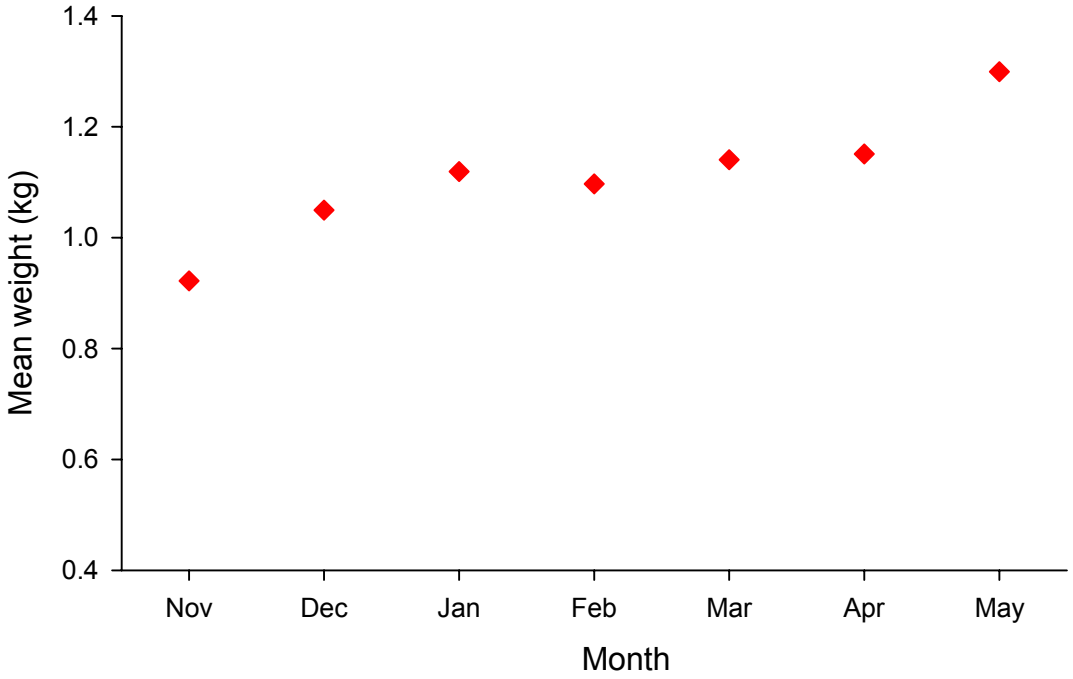

Figure 2-16 Within-season trends in the mean weight (± SE) of lobsters in the NZRLF during the 2005 season.

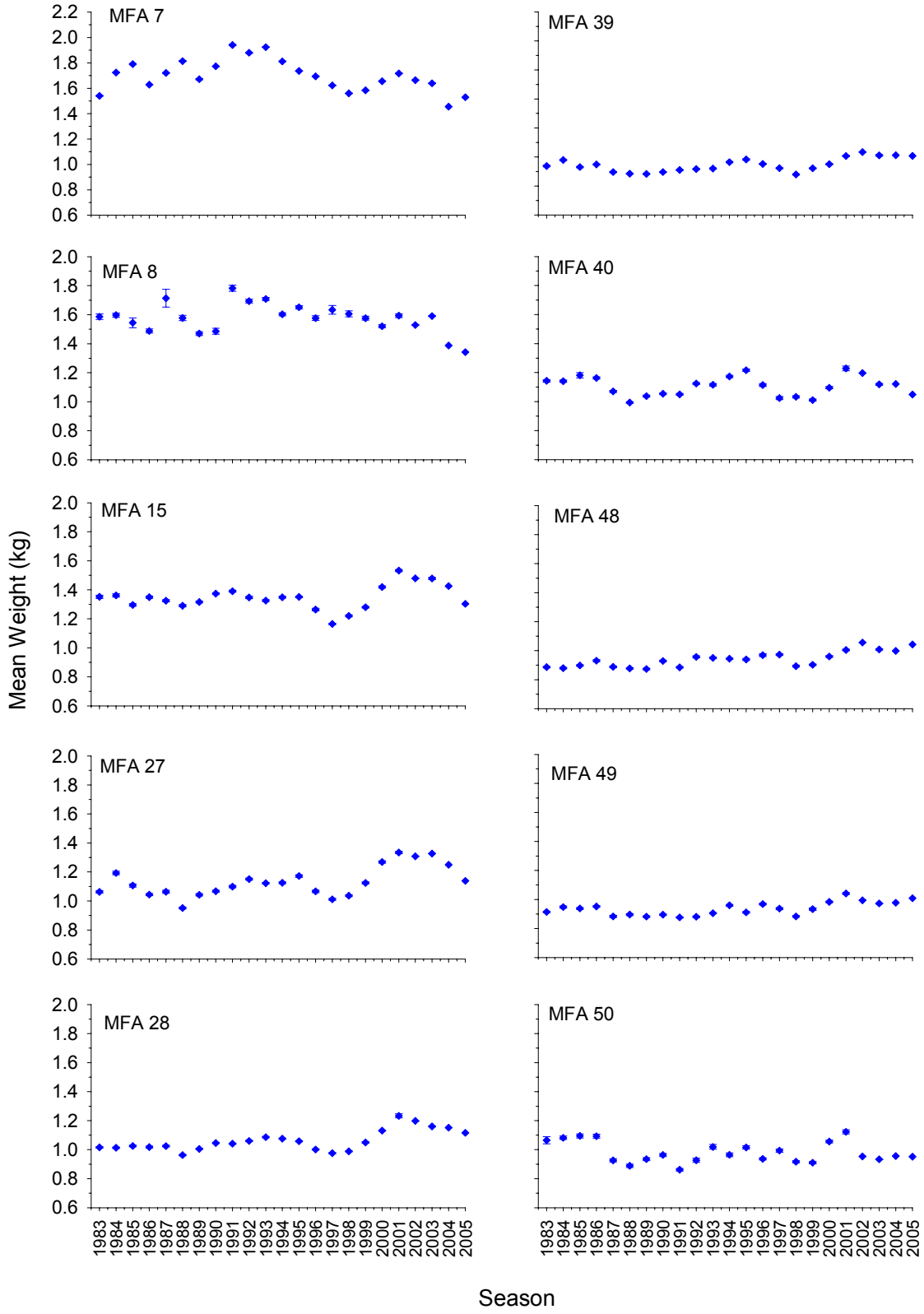

Figure 2-17 Inter-annual trends in the mean weights (± SE) of lobsters for the main MFAs of the NZRLF for the fishing seasons between 1983 and 2005.

2.6 Length Frequency

Since 1991, between 3,200 and 18,000 male lobsters and between 3,200 and 15,500 female lobsters, have been measured annually (refer to Linnane et al., 2006 for previous length outputs). Length frequency data provide important input for length transition matrices that are an integral component of the length frequency model (LenMod) outputs (see Section 5 of this report). Male lobsters, which grow faster and reach larger sizes than females, range between 70 and 210 mm CL, whereas few females are larger than 150 mm CL. The median size for males ranges between 115 – 125 mm CL, whereas for females it ranges between 105 – 115 mm CL. A total of 13,770 lobsters were measured in 2005 (Figure 2-18). Of these, 62% of male lobsters and 51% of females were above the Minimum Legal Size (MLS) of 105 mm CL.

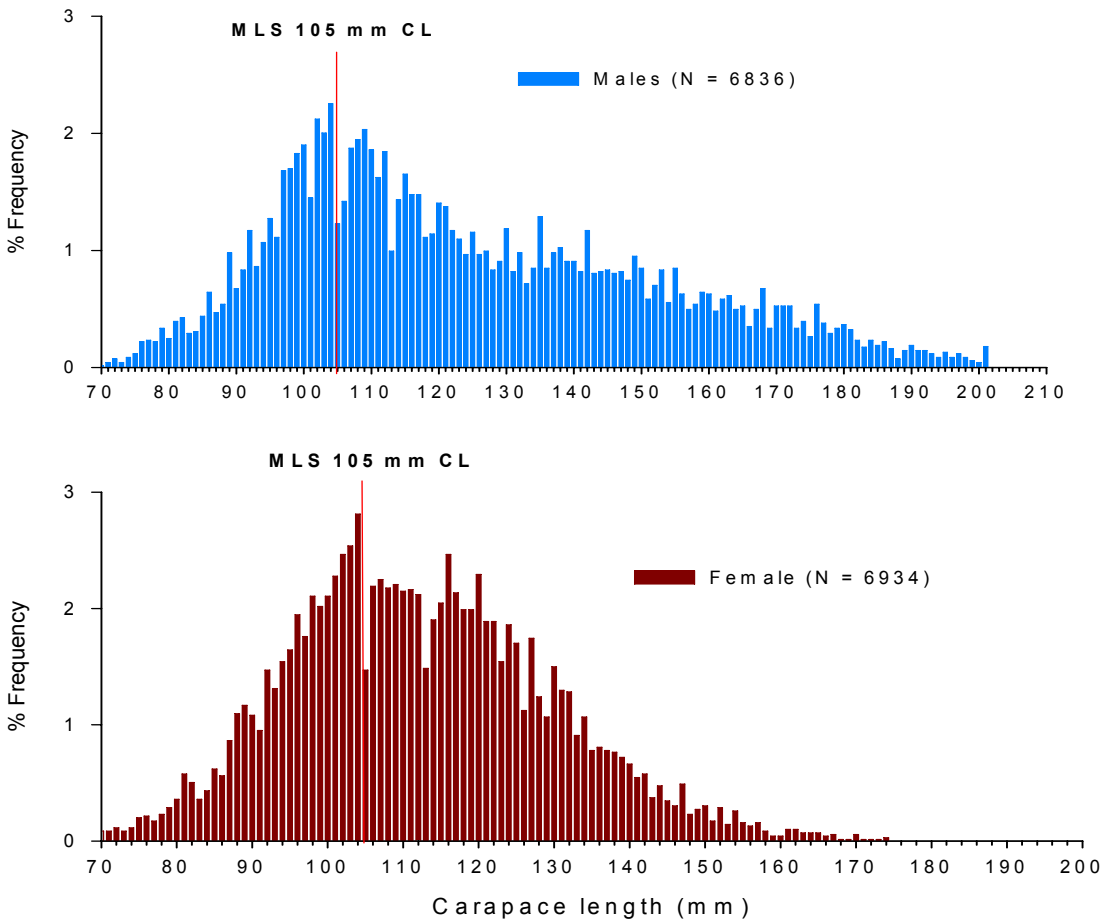

Figure 2-18 Length frequency distributions of male and female lobsters in the NZRLF 2005 fishing season.

2.7 Pre-Recruit Index

2.7.1 Inter-annual pattern (voluntary catch sampling data)

The mandatory introduction of escape gaps in the NZRLF in 2003 means that data required to calculate a pre-recruit index (PRI - mean number of undersize lobster per pot lift) is now dependent on voluntary catch sampling (where the escape gaps from up to 3 research pots are closed). PRI increased over the period 1994 to 1998 peaking at 0.51 undersize/potlift before decreasing to an all time low of 0.22 undersized/potlift in 2001 (Figure 2-19). Over the next three seasons, PRI increased to 0.27 undersized/potlift in 2004. In 2005, PRI increased further to 0.49 undersized/potlift, which is the second highest estimate on record since sampling began.

2.7.2 Within season trends

Within season trends in the pre-recruit index are presented in Figure 2-20. In 2005, PRI was highest in February at 0.60 undersized/potlift before decreasing to 0.16 undersized/potlift in May.

2.7.3 Patterns across MFAs (catch sampling data)

The PRI tends to be highest in MFAs located in the south of the NZRLF. Hence, the index is generally low in MFAs 7, 8, 15, 27 and 28 and high in MFAs 39, 40, 48, 49 and 50 (Figure 2-21). The overall trends in the NZRLF index (Figure 2-19) are reflected in PRI for the individual MFAs although estimates for early years are probably negatively biased. The PRI in most MFAs increased between 1996 and 1998 before decreasing in subsequent seasons. In 2005, the index remained low in the MFAs to the north-west of the zone (i.e. 7, 8, 15, 27, 28) although notable increases were observed in MFAs 27 and 28 compared to previous seasons. The index also increased most MFAs located in the south-east of the zone (i.e. 39, 40, 49 and 50).

2.7.4 Patterns by Region

Patterns by Region broadly reflect observed patterns in key MFAs (Figure 2-22). PRI in Region A (refer to Figure 1-5) is considerably lower than Regions B, C and D. Peaks in PRI were observed in Regions C and D in 1998 but generally decreased thereafter to 2004. In 2005, PRI increased across all Regions.

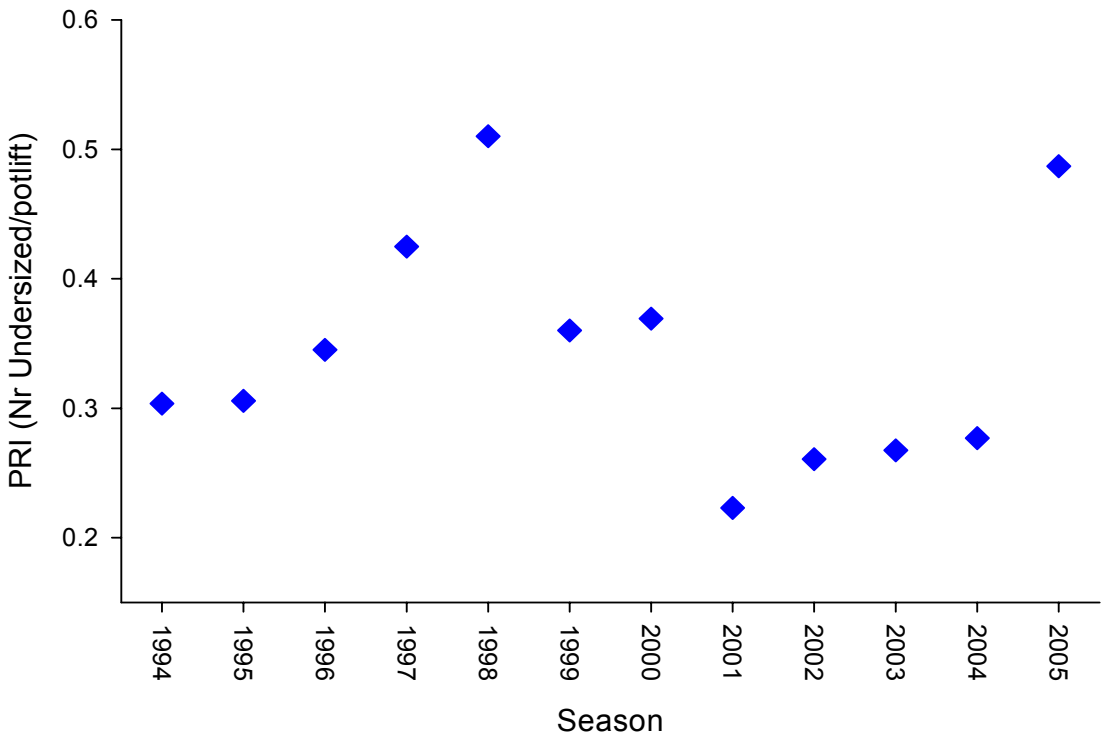

Figure 2-19 Inter-annual trends in pre-recruit index in the NZRLF from 1994 to 2005 as calculated using voluntary catch sampling data (November-March inclusive).

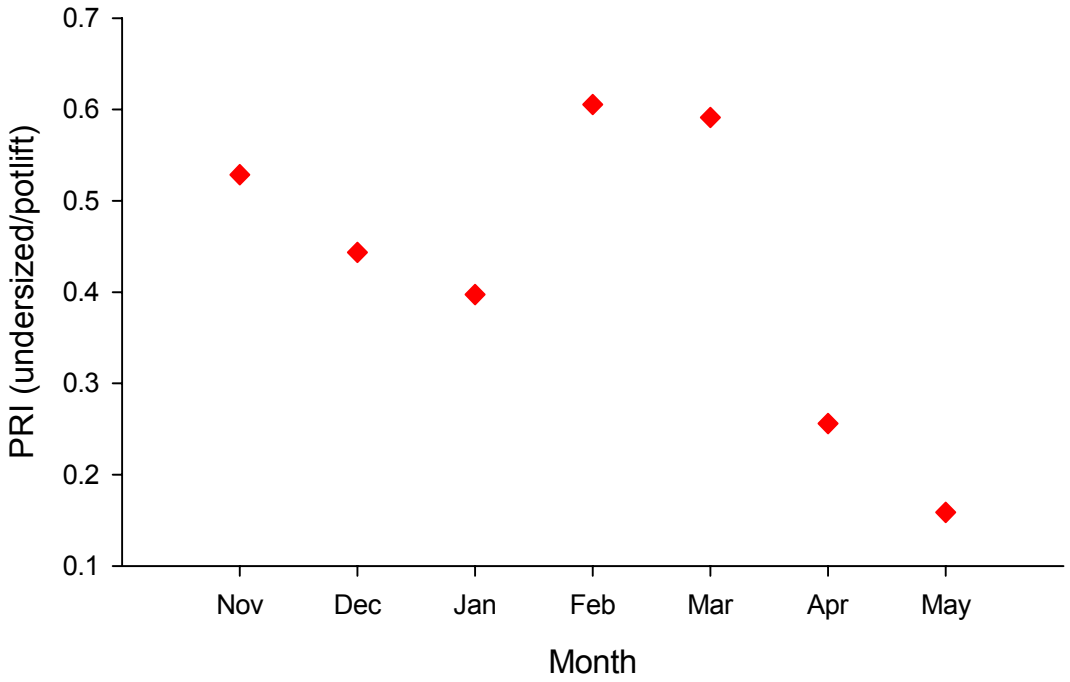

Figure 2-20 Within season trends in pre-recruit index in the NZRLF in 2005 as calculated using voluntary catch sampling data.

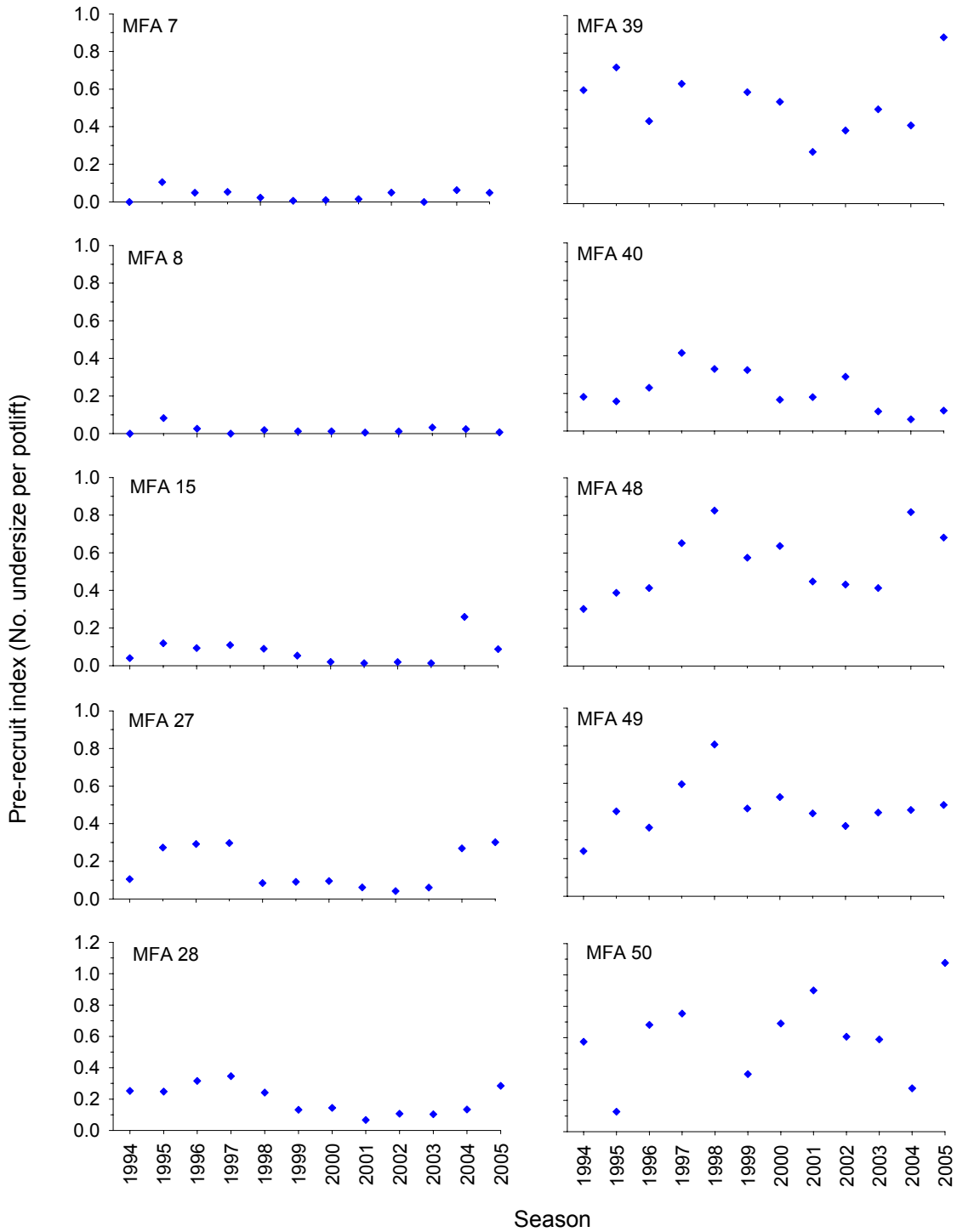

Figure 2-21 Mean pre-recruit index (catch sampling data) for MFAs in the NZRLF from 1994 to 2005. (Numerical order of MFAs is from north-west to south-east).

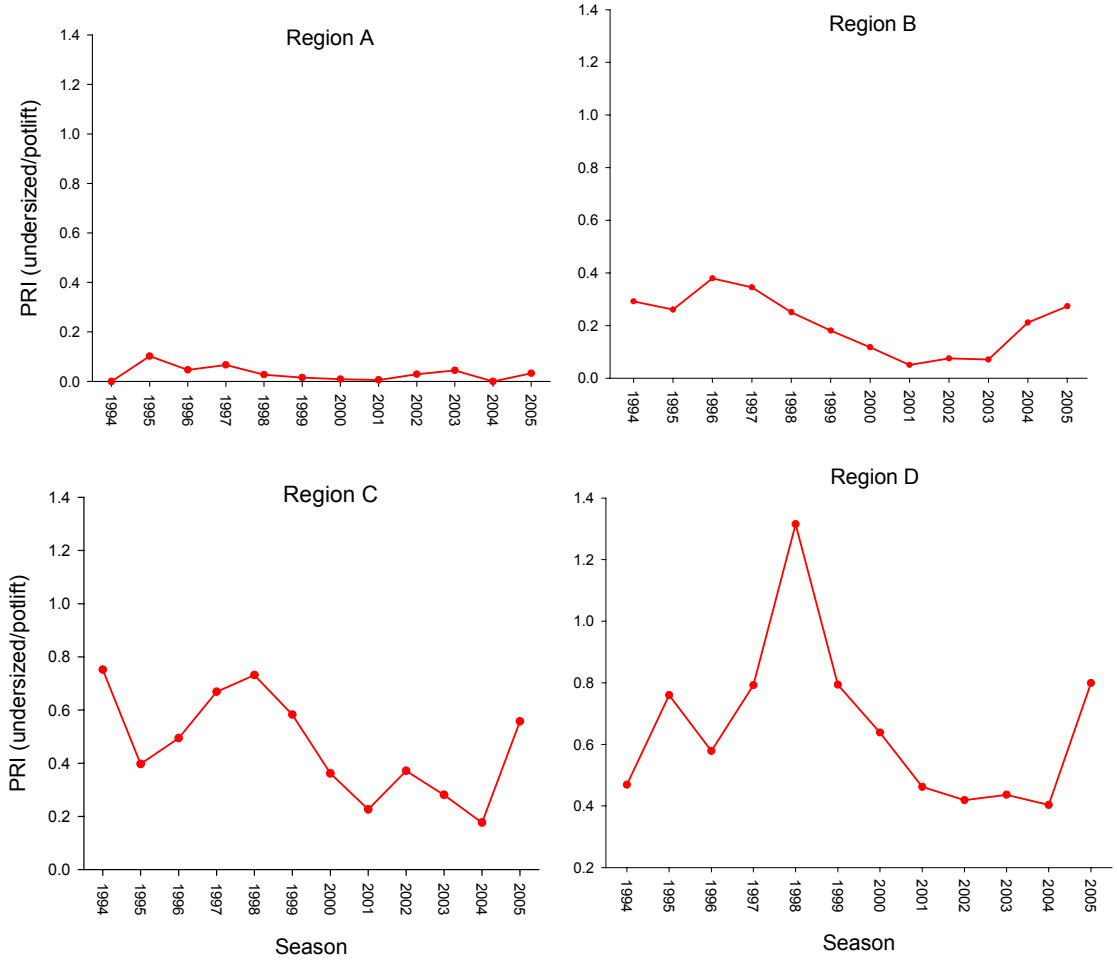

Figure 2-22 Pre-recruit Index (PRI number of undersized/potlift) by region in the NZRLF from 1994 to 2005. Note that PRI from MFA 39 (Figure 1-1) has been apportioned 30:70 between Regions C and D.

3 FISHERY INDEPENDENT STATISTICS

3.1 Settlement Index

The annual estimates of puerulus settlement index (PSI) in the NZRLF are calculated from puerulus counts observed at McLaren Point and Taylor Island (Port Lincoln), Stenhouse Bay (Yorke Penninsula) and Marion Bay (Yorke Penninsula) (Figure 3-1). The plots show that the settlement index remained relatively low from 1996 to 2001. In 2002, the highest PSI on record was observed at 1.09 puerulus/collector. Indices over the next two seasons in 2003 and 2004 were again low but increased in 2005 to 0.81 puerulus/collector. In 2006, the PSI was 0.89 puerulus/collector, which is the second highest settlement index since sampling began in the NZRLF and the first time that back-to-back peak settlements have been observed.

The PSI (lagged by 3 years) was plotted alongside pre-recruit index (PRI) as calculated from voluntary catch sampling in the NZRLF (Figure 3-2). Correlation analysis indicated that PSI was correlated to PRI over the period 1999 to 2005 (R^2 = 0.69) using a 3-year time lag. Future data points should substantiate this emerging relationship between puerulus settlement and recruitment.

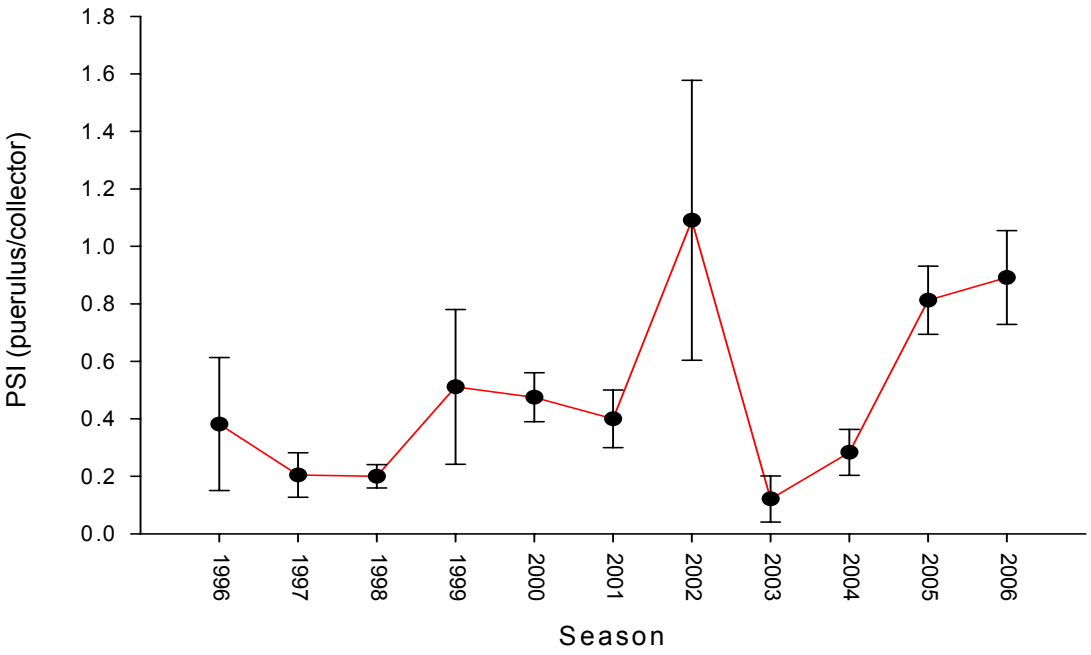

Figure 3-1 Puerulus settlement index (PSI; mean +/- SE) in the NZRLF from 1996 to 2006.

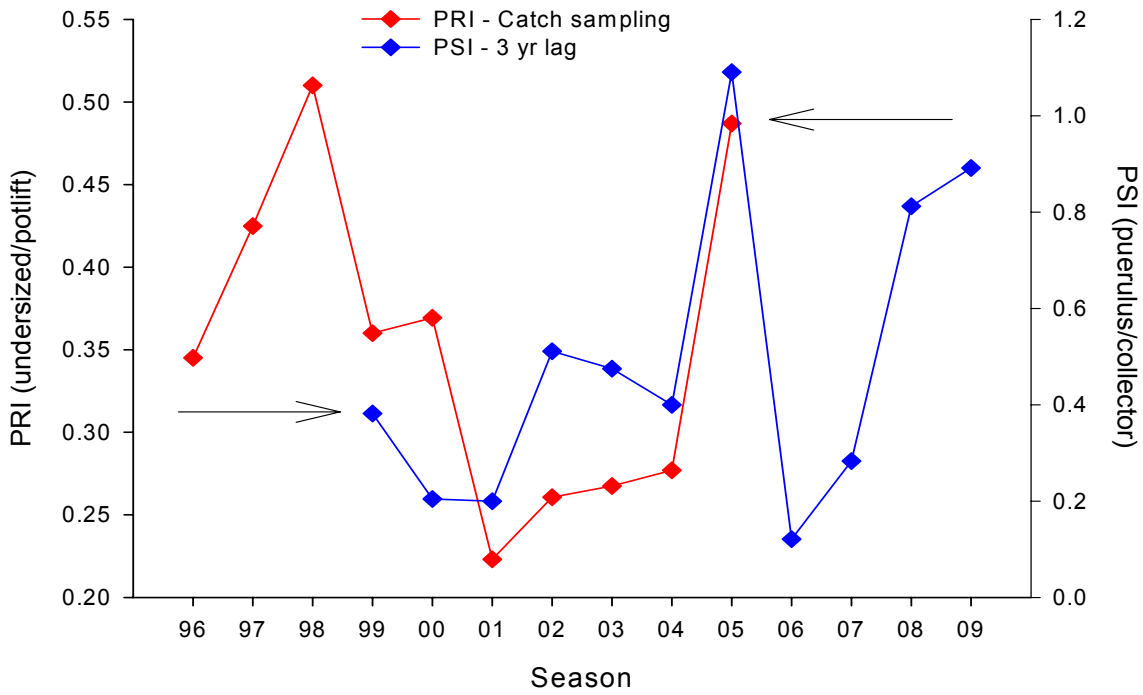

Figure 3-2 Puerulus settlement index (PSI) lagged by 3 years plotted against pre-recruit index (PRI) as calculated from voluntary catch sampling data. Arrows indicate overlapping period of correlation analyses.

4 THE QR MODEL

4.1 Introduction

The qR model (McGarvey et al. 1997; McGarvey and Matthews 2001) has been used to generate robust estimates of performance indicators (notably biomass, exploitation rate and egg production) for the NZRLF (Prescott et al. 1997; Prescott et al. 1998; Prescott and Xiao 2001).

A review of the stock assessment research conducted by SARDI Aquatic Sciences (Breen and McKoy 2002) concluded that the qR model is 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 (e.g. Prescott et al 1997a; Prescott and Xiao 2001). Three recent changes to the model are: (i) the replacement of the least squares method by normal likelihoods for the fits to catches in both number and weight; (ii) the adoption of a Baranov, rather than a simple bi-linear Schaefer catch relationship (iii) the inclusion of a puerulus-based forecasting method which is used to generate predictions of future biomass based on different quota levels and (iv) the incorporation of a 3% annual increase in effective effort over the time period 1983 to 2000.

This section of the report has three objectives; (i) to use the 2005 version of the qR model to generate annual estimates of biomass, egg production, % virgin egg production and exploitation rate for the NZRLF using data to the end of the 2005 fishing season; (ii) to compare estimates of recruitment obtained using the qR model with an independent measure of pre-recruit abundance; and (iii) to predict future estimates of biomass over a five year period under a range of alternate quota levels

The outputs from the qR model are related to the Reference Period (1992 to 1996 seasons) outlined in the Management Plan for the South Australian NZRLF (Zacharin 1997). The range of values in the Performance Indicators are generated from the qR model.

4.2 Methods

General qR model

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

Other stock assessment models (delay-difference and biomass dynamic) that fit to catch and effort data use only catch given in the weight landed (*Cw*), and rely on *CwPUE* as a measure of relative fishable biomass. The qR model adds catch totals in number of lobsters landed to the fitted data set. Because catch-in-weight divided by catch-in-number gives the mean weight of an average lobster, the addition of the catch-in-number time series brings information about yearly mean size in the legal catch, otherwise available only from length-frequency data. Because catches in weight and number constitute a 100% sample, the quality of information obtained about yearly changes in *mean* size from catch data is 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 measure of change in abundance and mean weight as a measure of change in size structure.

The pre-recruit index provides a direct measure of yearly recruitment that is independent of qR-inferred recruitment. It therefore provides a means of assessing the recruitment outputs from the qR model. The pre-recruit index used in this section of the report is based on undersized lobster CPUE for November to March due to the fact that variability in the number of undersized lobsters is lowest during this period.

Two modifications were made to the 2005 version of the qR model. First, the 3% yearly rising effective effort was assumed to cease after 2000. Second, a selectivity parameter was included to account for a reduced level of recruitment in the first age that lobsters reach legal size. This models the partial recruitment of newly arriving year classes and assumes that the entire cohort does not reache legal size in the same year. This partial recruitment vulnerability was implemented from 2003 onward,

yielding an estimated value of 67%. For purposes of projection, this implies that approximately two-thirds of the lobsters that settled in 2002 reach legal size in 2006, with the remaining third entering the legal biomass in 2007.

Future Predictions

The qR model was used to forecast biomass levels over the next 5 years in the NZRLF under four alternate quota levels (300, 400, 520 and 600 t). Under some assumed quota levels (mainly 600 tonnes), the quota would not be reached in some years, with expected catch rates and maximum effort levels. To account for this possibility, a constraint was added to the model that limited the annual simulated fishing effort to a maximum of 720,000 potlifts, which was the approximate mean level of effort exerted in the years 1993-1998.

When forecasting recruitment, 1000 sample time series of recruit numbers were generated for each of the next 5 future years (2004-2008) based on a lognormal distribution with mean and standard error taken from the numbers of puerulus settled per collector during July to October in each of the last five settlement years. These forecasted recruitments were then taken as inputs into the qR model (along with the assumed 3% rising catchability) to simulate future biomass forecasts. This approach uses measurements of the number of lobster puerulus that settled onto collectors in the NZRLF at four sites (McLaren Point, Taylor Island, Stenhouse Bay and Marion Bay), with the mean number of puerulus settled per collector from July to October of each settlement year used as the index of recruitment. Data are available from 1996 to 2005.

Analysis of previous growth estimates in the Northern Zone (McGarvey et al. 1999a) suggests a 3-4 year time lag for lobsters to grow from settled puerulus to the last moult bringing them above legal size. Here, a 4-year time lag was assumed. The mean number of puerulus settled per collector was scaled up to an estimate of predicted recruits (four years later) using the qR-estimates of recruitment for the six overlapping years when measured puerulus have now reached legal size. These are the settlement years 1996-2001 (i.e., the qR-recruitment years 2000-2005).

Recruitment Forecasting Algorithm

Define a re-scaling coefficient, $C_{P->R}$ by

$$R_y = C_{P->R} \cdot Puerulus_{y-4},$$

i.e. multiply the mean observed number of puerulus per collector in year *y-4* ($Puerulus_{y-4}$) by the scaling coefficient ($C_{P->R}$) to give recruitment in year *y* (R_y). The scaling coefficient was obtained by taking the means of both puerulus and qR-estimated R's over the four overlapping years, i.e.

$$C_{P->R} = \frac{mean\left(\{R_y, y = 2000 \text{ to } 2003\}\right)}{mean\left(\{Puerulus_y, y = 1996 \text{ to } 1999\}\right)} .$$

Then for the 5 future years (*y* = 2005 to 2009), the assumed mean level of forecasted recruitment was given by $R_y = C_{P->R} \cdot Puerulus_{y-4}$. The yearly standard deviation for puerulus-forecasted R_y which determines the level of yearly simulated recruitment variation (in each of the 1000 monte carlo runs), was given as $C_{P->R}$ times the observed standard error in the estimate of puerulus per collector for that corresponding settlement year (4 years prior).

Then, given a distinct puerulus-forecasted mean and standard deviation of Northern Zone recruitment for each of the 5 years to come, the forecasted recruit number for each year and monte carlo run was obtained by sampling from a lognormal distribution. The coefficient of variation (CV) is obtained in the usual way as standard deviation divided by mean in each year. For each of the 5 future years, the lognormal distribution describing the range of forecasted values of recruitment is defined by two parameters, μ and σ, which are derived from the mean and CV of recruitment using the formulas $\sigma = \left\{\ln\left[\mathrm{CV}^2 + 1\right]\right\}^{\frac{1}{2}}$ and $\mu = \ln(\text{mean}) - \frac{\sigma^2}{2}$.

Then choosing standardised normal variates, z_y, one for each year, using built-in Excel routines, the sampled recruitment in each forecast year was given by $R_y = \exp\left(\mu + \sigma \cdot z_y\right)$. This lognormal sampling procedure was repeated 1000 times using an Excel VBA macro to generate 1000 forecasted future 5-year recruitment time series.

4.3 Results

Performance Indicators from the qR model

Estimates of catch in number and weight from the 2005 version of the qR model, based on the assumption of a 3% change in effective effort over the time period 1983-2000, fit closely with measures of *Cn* and *Cw* obtained from the NZRLF (Figure 4-1 and Figure 4-2). Outputs from the model suggest that the biomass in the NZRLF during the 2005 season was 1,975 tonnes (Figure 4-3). Similarly, the model suggests that total egg production in 2005 was 428 billion eggs (Figure 4-4), which equates to 15.4 % of virgin egg production (Figure 4-5). While outputs of biomass and egg production continue to reflect the lowest estimates in the history of the fishery, the rate of decline for both outputs was stemmed in 2005. Specifically, the recent rapid decline in biomass and egg production from 1999 through to 2004 has been arrested in 2005, which is a positive sign for the fishery. The exploitation rate during 2005 increased marginally to 0.24 but remains one of the lowest estimates since 1989 (Figure 4-6).

Comparison of estimates of recruitment from qR model and the pre-recruit index

Temporal trends in recruitment predicted by the qR model and estimated by the pre-recruitment index determined from catch sampling data are broadly similar (Figure 4-7). The recruitment estimates from the qR model suggest that recruitment levels over the last five seasons were among the lowest in the fishery's history. In 2005, the increase in PRI was not reflected in a comparable increase in qR recruitment.

Future predictions of biomass

The mean expected start-of-year biomass for the next five years based on the mean number of puerulus settled per collector from July to October of each settlement

season is presented in Figure 4-8. Future predictions were based on a range of quota scenarios ranging from 300-600 tonnes. qR model projections suggest that the biomass will increase in 2006 and 2007 for all quotas, reflecting recruitment into the fishery from the strong puerulus settlement in 2002. Biomass is predicted to decrease under all quota scenarios (except 300 tonnes) in 2008 due to low puerulus settlement in 2003 and 2004 before increasing in 2009 and 2010 due to increased puerulus settlement in 2005 and 2006 (Figure 3-1). A sustained increase in biomass is observed over the five-year period from 2006 to 2010 at a 300 tonne quota level only.

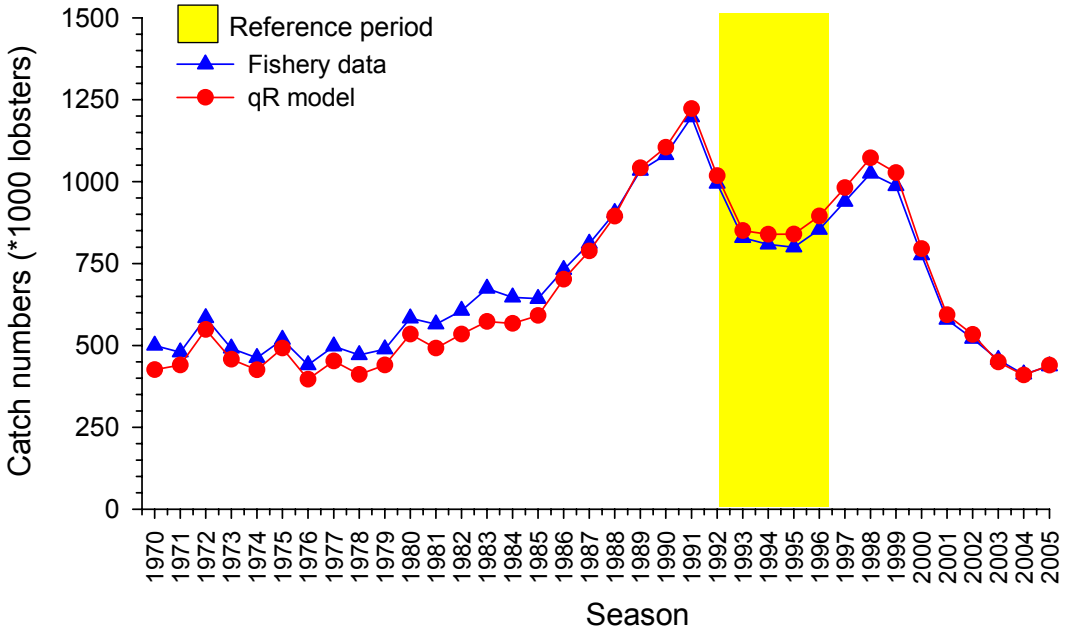

Figure 4-1 Fit of the qR model to catch in numbers for the NZRLF, based on annual catch totals from the fishery and estimates provided by 2005 version of the qR model.

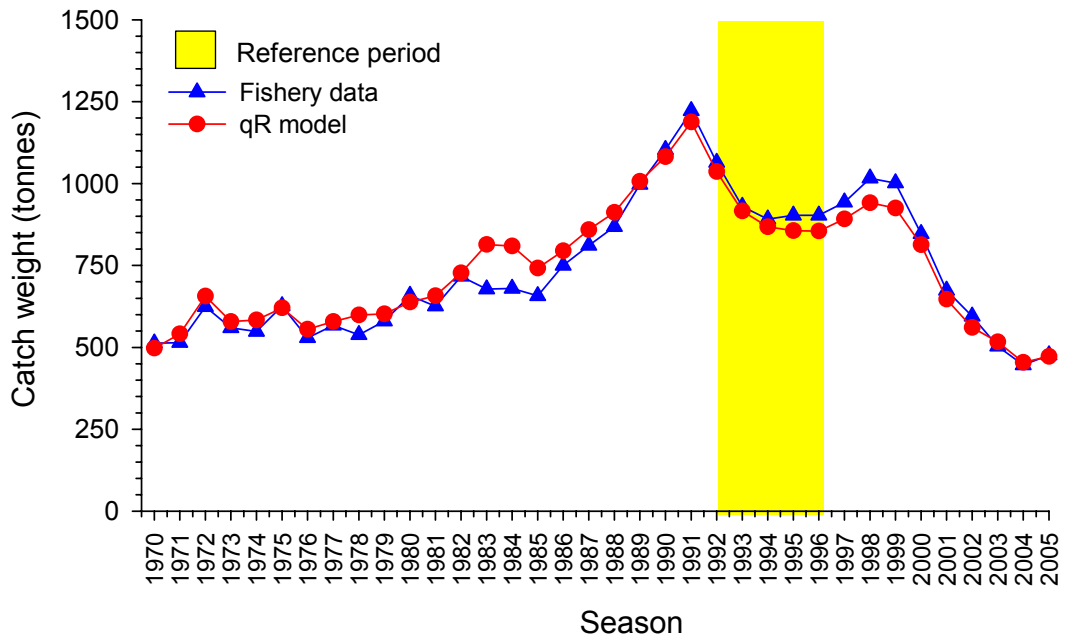

Figure 4-2 Fit of the qR model to catch by weight for the NZRLF, based on annual catch totals from the fishery and estimates provided by 2005 version of the qR model.

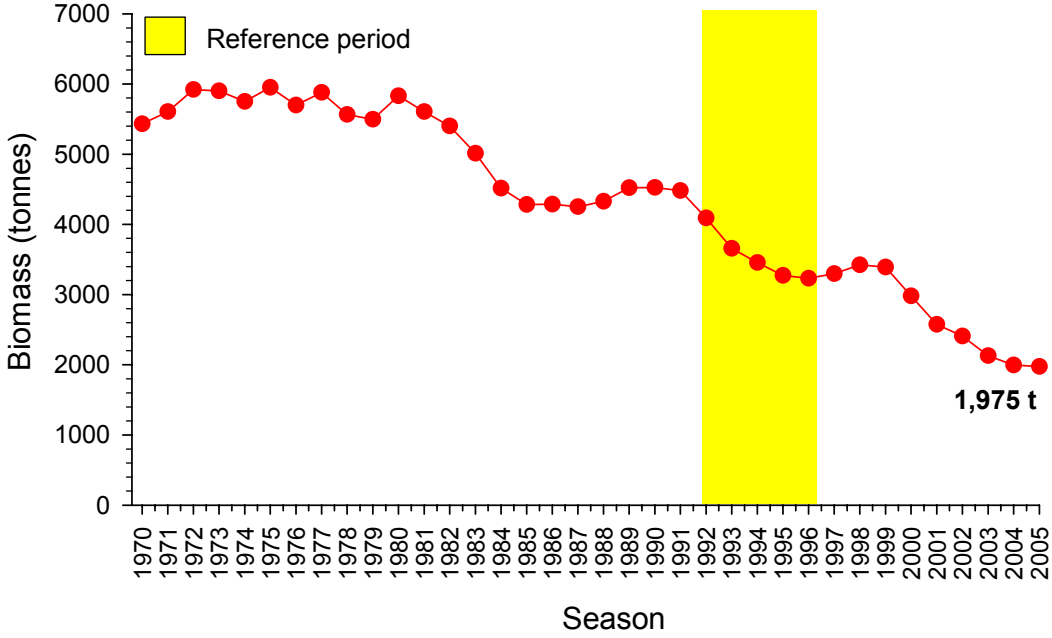

Figure 4-3 Estimates of biomass for the NZRLF, provided by the 2005 qR model.

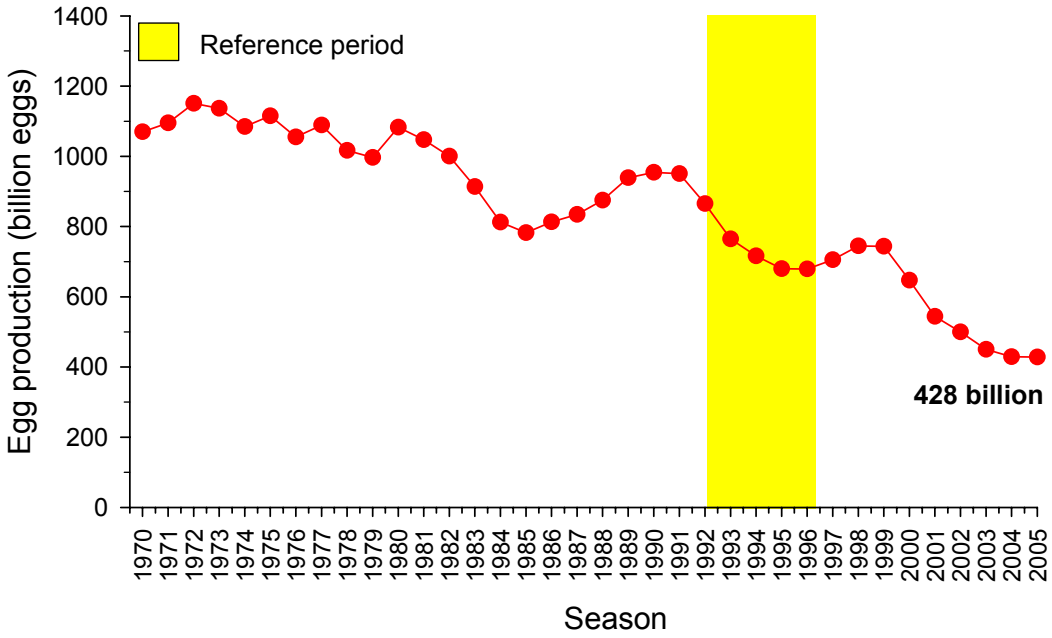

Figure 4-4 Estimates of egg production for the NZRLF, by the 2005 qR model.

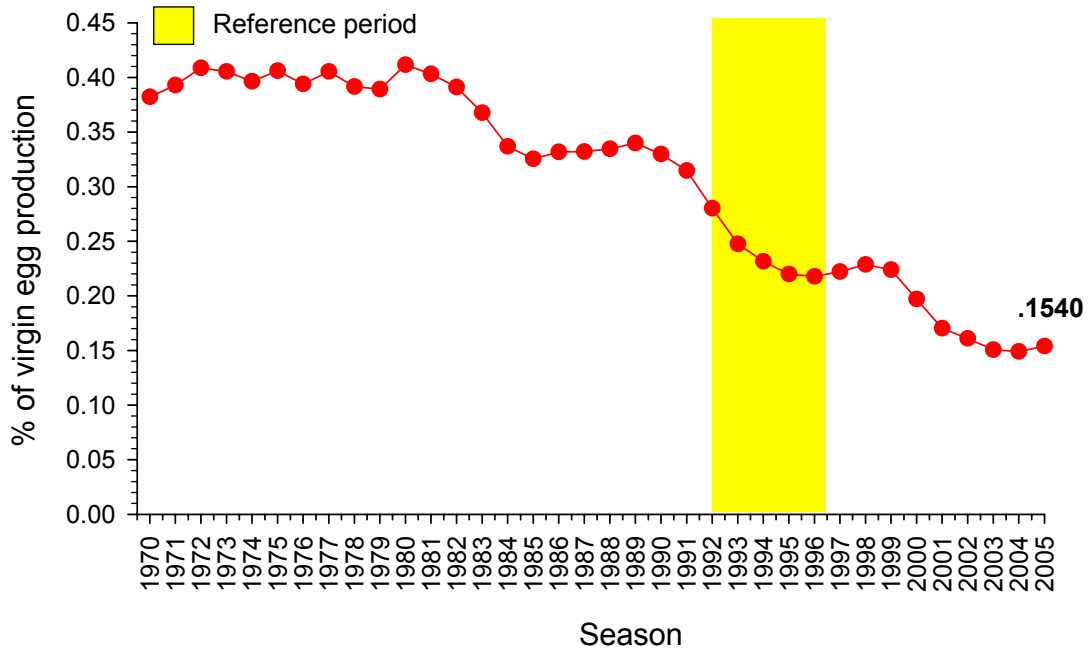

Figure 4-5 Estimates of % virgin egg production for the NZRLF, from the 2005 qR model.

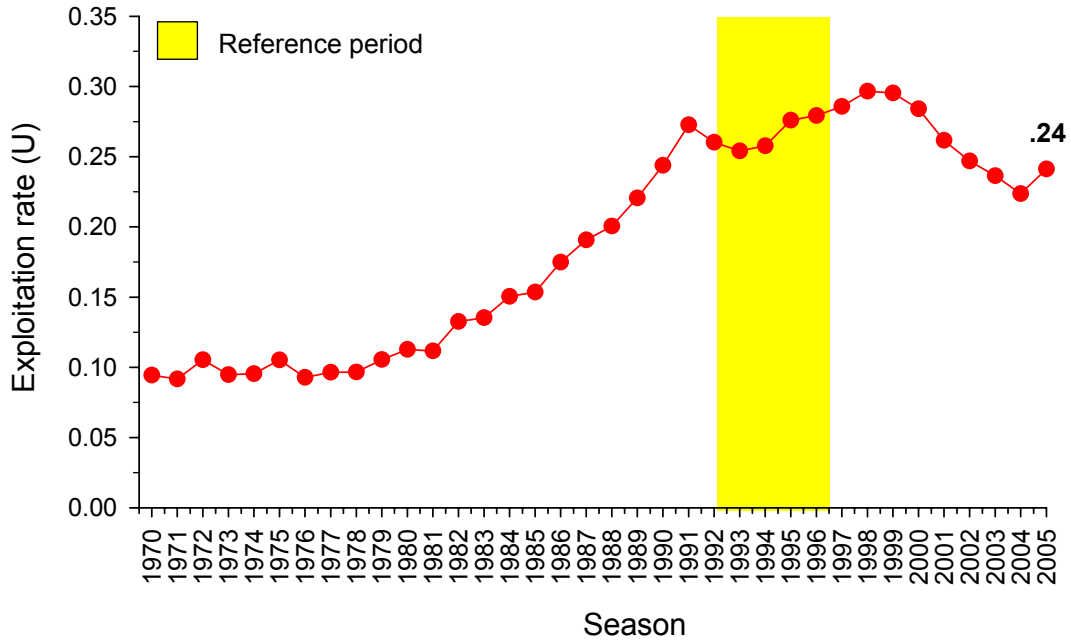

Figure 4-6 Estimates of exploitation rate for the NZRLF, obtained from the 2005 qR model.

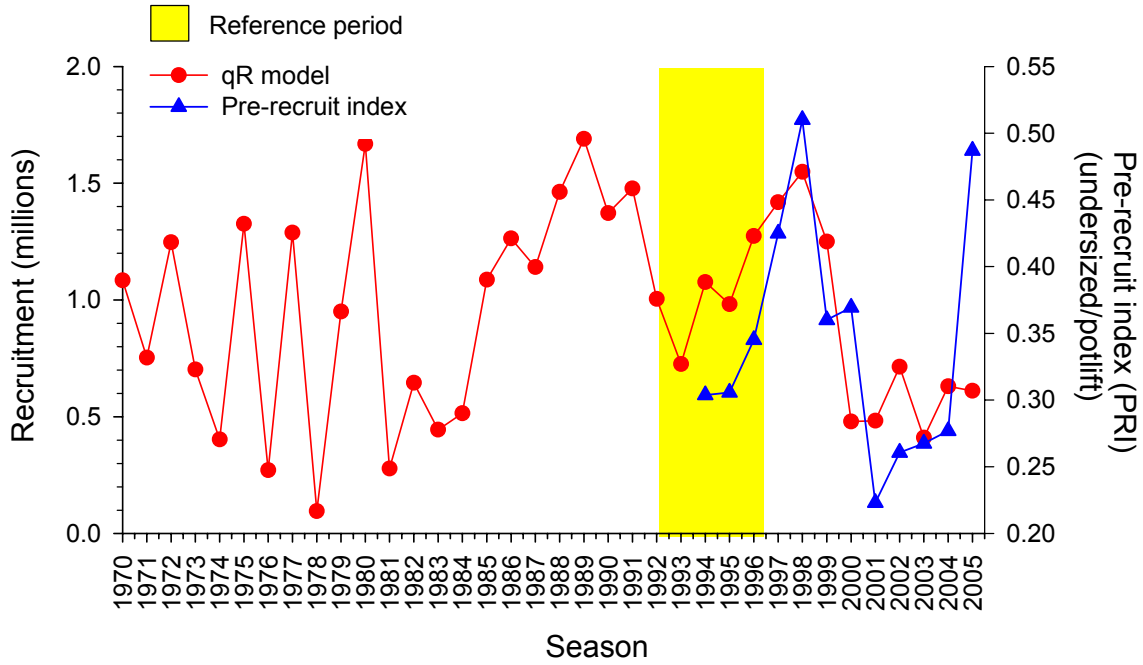

Figure 4-7 Estimates of annual recruitment for the NZRLF, obtained from the 2005 qR model, and pre-recruit index as undersized lobster per pot lift obtained from catch sampling data.

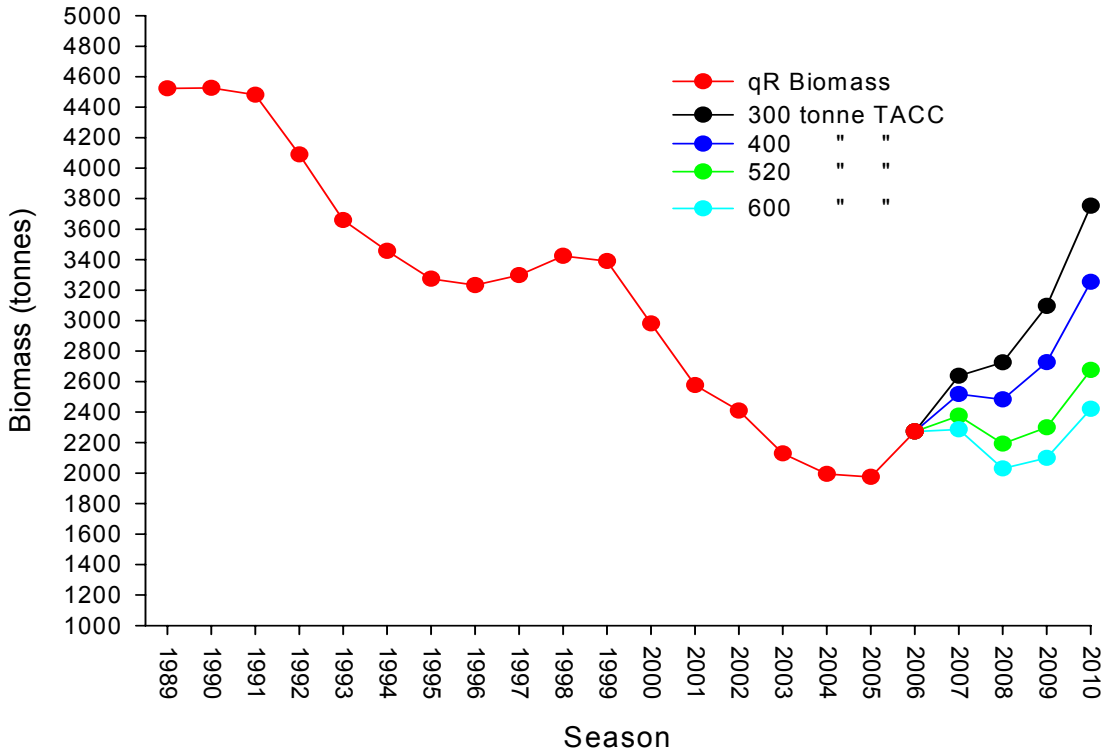

Figure 4-8 Estimates of biomass for the NZRLF and generated forecasts at different quota levels as provided by the puerulus method for the 2005 qR model.

5 THE LENGTH FREQUENCY MODEL

5.1 Introduction

This section of the report provides the first published outputs from the newly developed length-frequency based model (LenMod) for the NZRLF. Previous reports provided estimates of yearly biomass, recruitment and exploitation rate inferred from catch and effort data, using the qR model. In particular, CPUE and mean weight (Cw/Cn) in the catch, together with catch totals and estimated mean weights by age were used to estimate yearly stock performance indicators. The newly developed model aims to incorporate as much available data as possible from the fishery. In addition to CPUE and mean weight, LenMod also utilises length frequency data from voluntary catch sampling and tag recovery data for estimating growth matrices. André Punt first developed the basic model structure in the 1990's and a detailed description of the model is provided in Punt and Kennedy (1997). This model is now used for management and quota setting in most *Jasus edwardsii* fisheries, notably in New Zealand, Victoria and Tasmania.

5.2 Materials and Methods

The code for the South Australian LenMod has been adapted from the Victorian version of the model (Hobday and Punt 2001). However, in order to incorporate all the available data from the South Australian fishery, a number of modifications to the model design have been implemented. These include: (1) accounting for seasonal change in the fishery, notably catchability and fishing effort, (2) accounting for mid-summer recruitment and growth achieved by implementing a monthly, rather than a yearly, time step, (3) acknowledging that the majority of lobster growth in South Australia occurs in late autumn and early summer, rather than once yearly (4) incorporating data on sex ratios to recruitment and catch as estimated using voluntary catch sampling data, (5) reducing the length class bins from 8 mm to 4 mm size classes, and (6) substantially refining the growth descriptions.

In LenMod, growth is estimated using a length-transition matrix and is defined as the proportion of lobsters in each length category that grow into larger length classes during each seasonal moulting period. The length-transition matrix has been created using the extensive tag-recovery dataset for the NZRLF, and incorporates known

information on sex ratios as well as annual within-season moulting periods. A key feature of LenMod is the ability to account for slower growth rates of females that have reached sexual maturity (McGarvey and Feenstra 2001) thus allowing a more accurate overall estimation of growth than previously assumed using a traditional von Bertalanffy mean growth curve.

5.3 Results

Performance Indicators from the LenMod model

Estimates of catch in numbers and catch rate from the LenMod model fit closely with measurements of *Cn* and *CPUE* obtained from the NZRLF (Figure 5-1, Figure 5-2). In addition, both male and female model estimates fitted well to commercial catch length frequency data, as seen in a sample of monthly fits from the 2005 season (Figure 5-3).

Outputs from the LenMod model indicate that the biomass in the NZRLF has generally decreased since 1990, reaching a historical low of 1,603 tonnes in 2004 (Figure 5-4). In 2005, biomass marginally increased to 1,663. Similarly, LenMod trends in egg production in the NZRLF have been decreasing since 1991, reaching a historical low of 148 billion eggs in 2004 (Figure 5-5). In 2005, egg production marginally increased to 155 billion, which equates to 8.6% of virgin egg production Figure 5-6).

The exploitation rate has been decreasing in the NZRLF since 1999 reaching a low of 0.29 in 2004 (Figure 5-7). In 2005, it increased marginally to 0.30. The recruitment estimates from LenMod suggest that recruitment has fluctuated greatly since 1983 but that estimates over the period 2001 to 2004 have been the lowest in the history of the fishery (Figure 5-8). In 2005, recruitment increased and was estimated to be 0.75 million lobsters.

5.4 Model Discussion

There is close agreement from both qR and LenMod in relation to the current status of the NZRLF. Both models estimate that biomass in the zone has decreased considerably since the late 1980's reaching a historical low of between 1500 – 2000 tonnes in 2004. Similarly, both qR and LenMod agree in relation to trends in egg

production within the fishery. However, the estimated absolute levels of egg production are considerably lower in LenMod than the qR model (Figure 4-4 and Figure 5-5). The reason is that explicit accounting for lobster numbers by sex in LenMod permits a more accurate measure of egg production. Egg production in both models is a relative measure, and the absolute level (scaling on the y-axis of the time series plots) will not influence management indicators. Trends in % of virgin egg production from both models are also in agreement. Current estimates put egg production at between 9 – 15%. Current estimates from both models suggest that the rapid decrease in both biomass and egg production has been arrested, with outputs from LenMod showing a marginal increase in both these performance indicators in 2005. This is supported by the observed increase in recruitment in 2005.

The projections from the qR model based on puerulus settlement data suggest that the biomass in the NZRLF will increase in 2006 and 2007 for quotas ranging from 300-600 tonnes reflecting recruitment into the fishery from the strong 2002 puerulus settlement but will decrease in 2008 for quotas above 400 tonnes as a result of low puerulus settlement in 2003 and 2004. Projected biomass increases again in 2009 and 2010 under all quota scenarios due to predicted recruitment into the fishery from high puerulus counts observed in 2005 and 2006. Sustained biomass increase from 2006 to 2010 period is only observed at a quota level of 300 tonnes.

Predictions about the extent of future changes in the biomass need to be viewed with some caution, as the puerulus monitoring program has only been in place for eleven years, and there are only seven years of data available to link levels of puerulus settlement to levels of recruitment. Hence, whilst it is predicted that the biomass will increase as a result of the large puerulus settlements in 2002, 2005 and 2006, the quantum of this change in biomass cannot be estimated with a high degree of certainty due to the limited availability of data. The magnitude of recruitment resulting from all observed peaks in puerulus settlement should be quantified through the existing catch sampling program. Continuing the puerulus monitoring program is critical for providing robust predictions of future fluctuations in biomass under a range of management strategies.

Details of the qR model, and simulation testing of its performance have been described in three peer-reviewed papers (McGarvey et al. 1997; McGarvey and Matthews 2001; McGarvey et al. 2005). The qR 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 qR 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). Further evidence that the qR model is providing a relatively good model description is given by the close agreement of qR model yearly recruitment estimate trends and pre-recruit estimates. Finally, the fits of the qR-model predictions to yearly catch totals in weight and in number of lobsters landed are close to the data-reported values.

Because of close agreement of both models and data, most of the uncertainty 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 all yearly estimates of biomass and recruitment are reduced by the percentage of under-reporting. Similarly, McGarvey and Matthews (2001) and McGarvey et al. (2005) both 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; and (3) 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 (Ward et al. 2002). In the Southern Zone, where fishing practices, and the widespread occurrence of fishable habitat in the coastal zone, have not much altered in recent years, the impact of rising effective effort is not considered to be large.

A principal limitation of the current version of LenMod is that, like the qR model, it assumes a single fishery zone. The targeting of specific MFAs in the Northern Zone in recent years, means that catch rates may not be representative of the whole zone.

Movement of lobsters has been shown to be significant in some areas of the Northern Zone, principally from inshore to offshore (Linnane et al. 2005a) and notably for immature females. Movement of lobsters is not incorporated in the LenMod description, in part, because the LenMod Northern Zone population and fishery is not, as yet, broken down into subregions for modelling purposes.

Future development of LenMod aims to provide spatially resolved model outputs by both region and depth. Specifically, future outputs will incorporate fishery independent data to provide (1) a measure of abundance not affected by market differentials or where in the zone fishers primarily fish, and (2) a resolved spatial breakdown of estimated population biomass, exploitation rate and other management indicators.

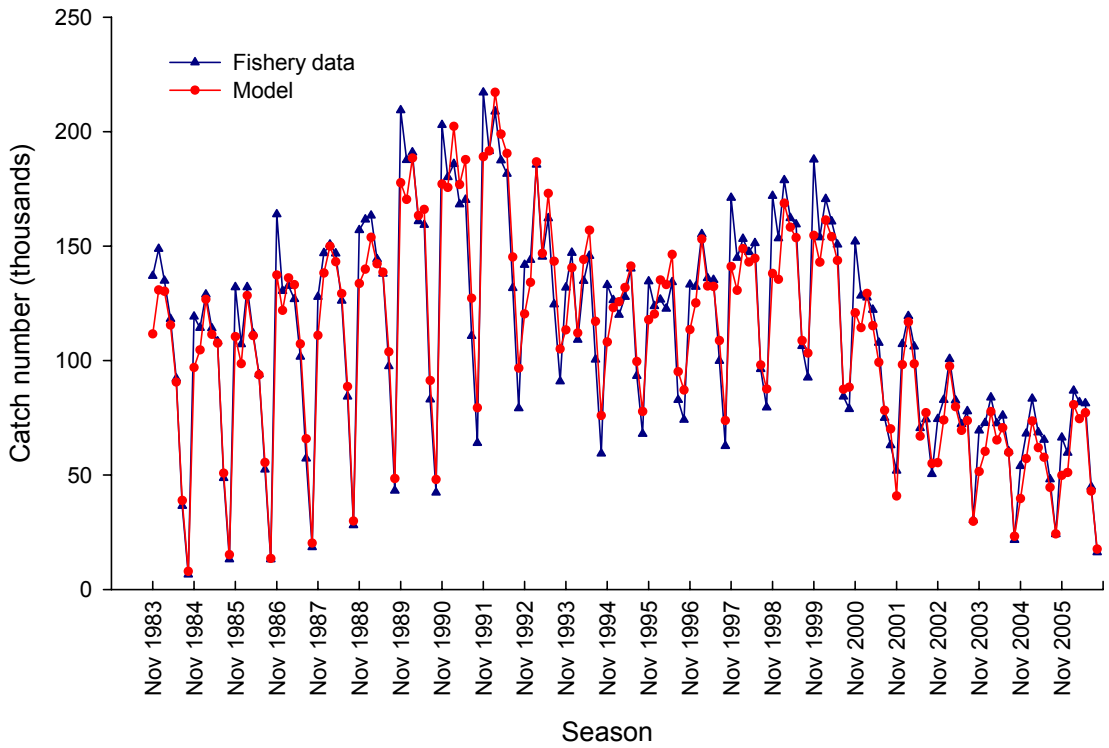

Figure 5-1 Fit of the LenMod model to catch in numbers for the NZRLF, based on annual catch totals from the fishery and estimates provided by the 2005 version of the model.

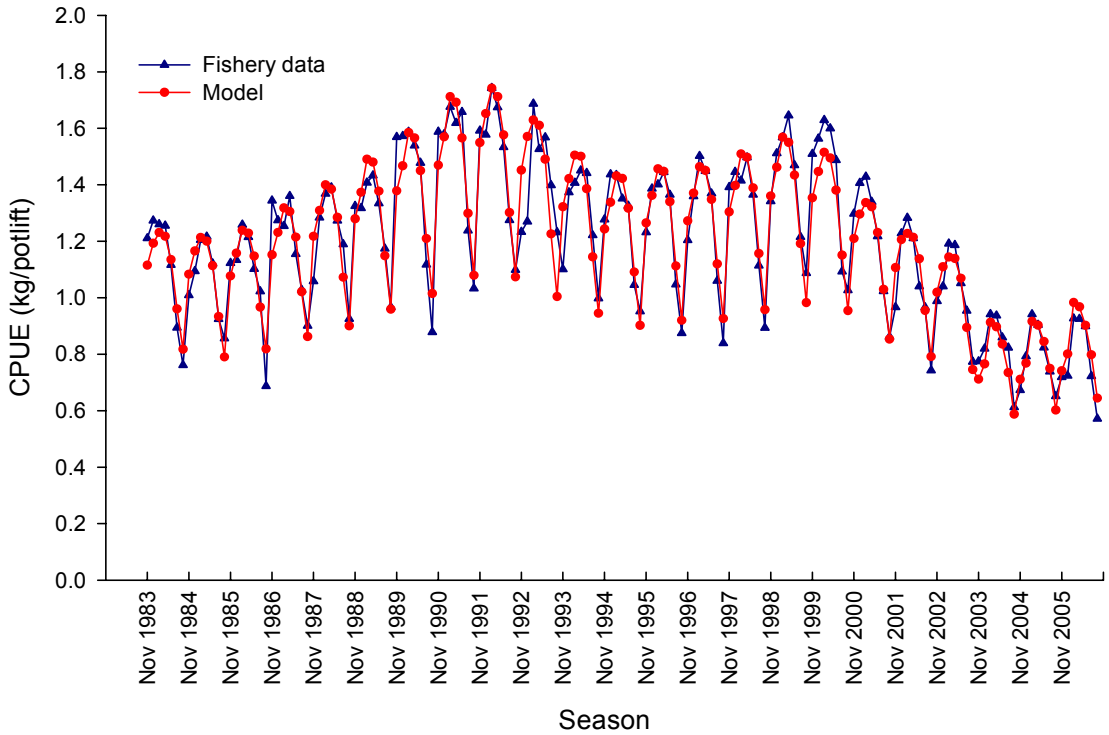

Figure 5-2 Fit of the LenMod model to catch rate for the NZRLF, based on annual estimates from the fishery and those provided by the 2005 version of the model.

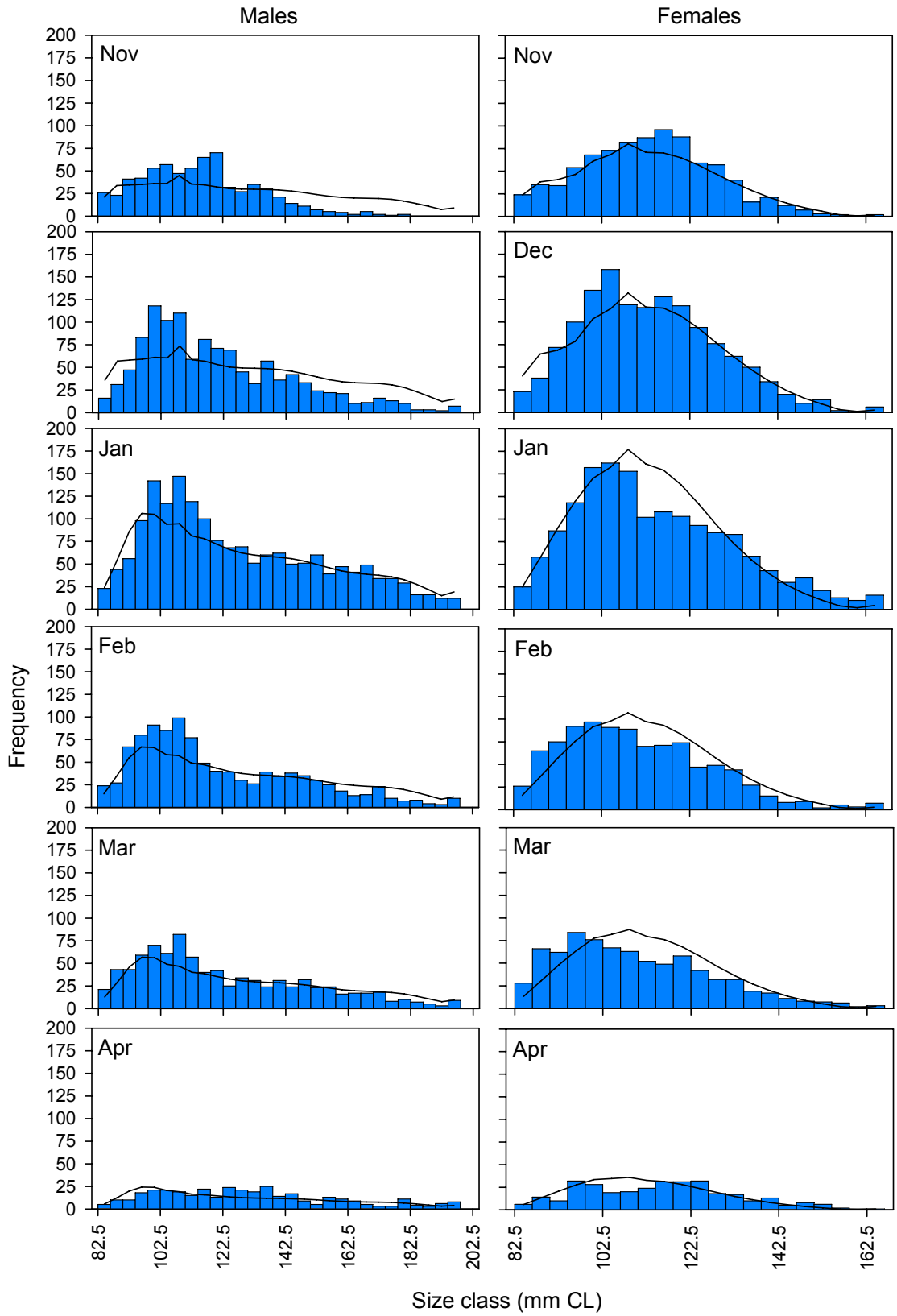

Figure 5-3 Sample of model fit (black line) to commercial length frequency data (blue bars) taken from the 2005 season in the NZRLF.

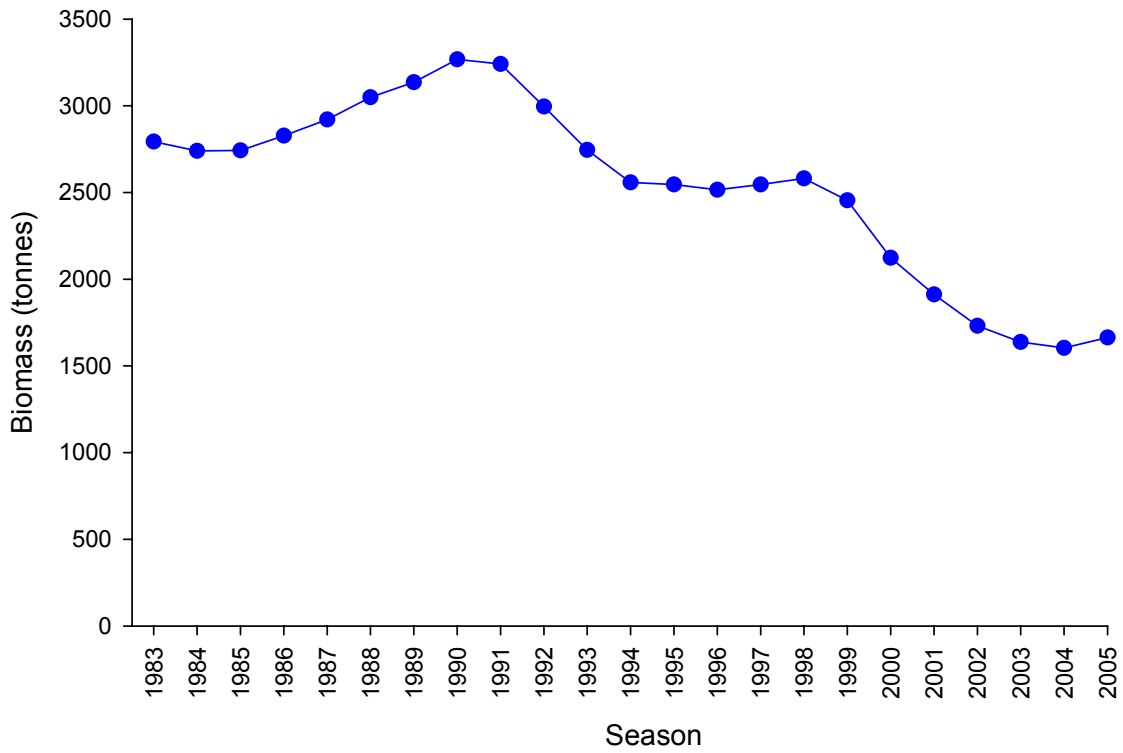

Figure 5-4 Estimates of biomass provided by the 2005 LenMod model.

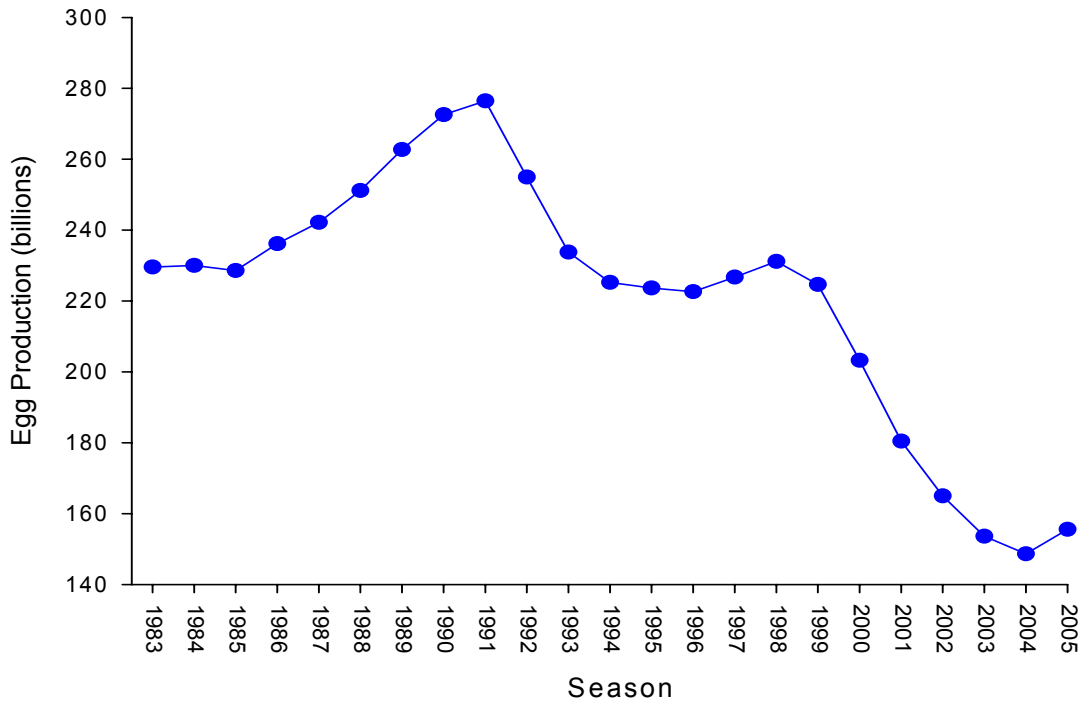

Figure 5-5 Estimates of egg production provided by the 2005 LenMod model.

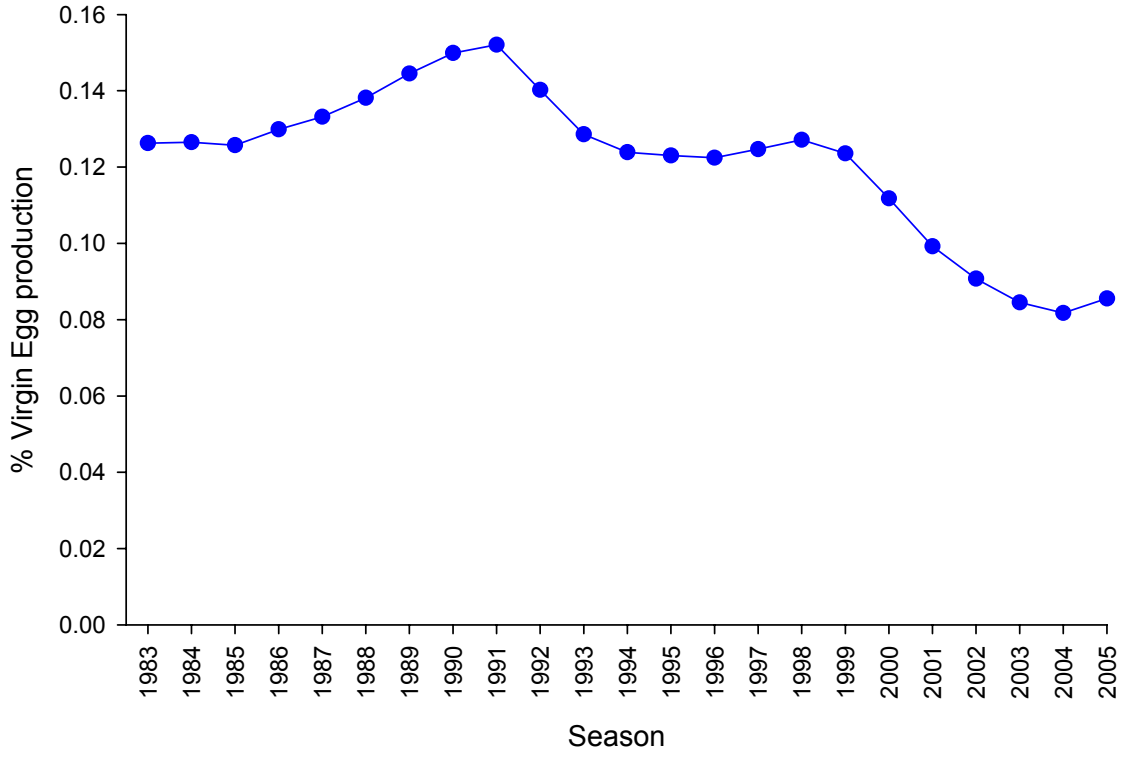

Figure 5-6 Estimates of percent of virgin egg production provided by the 2005 LenMod model.

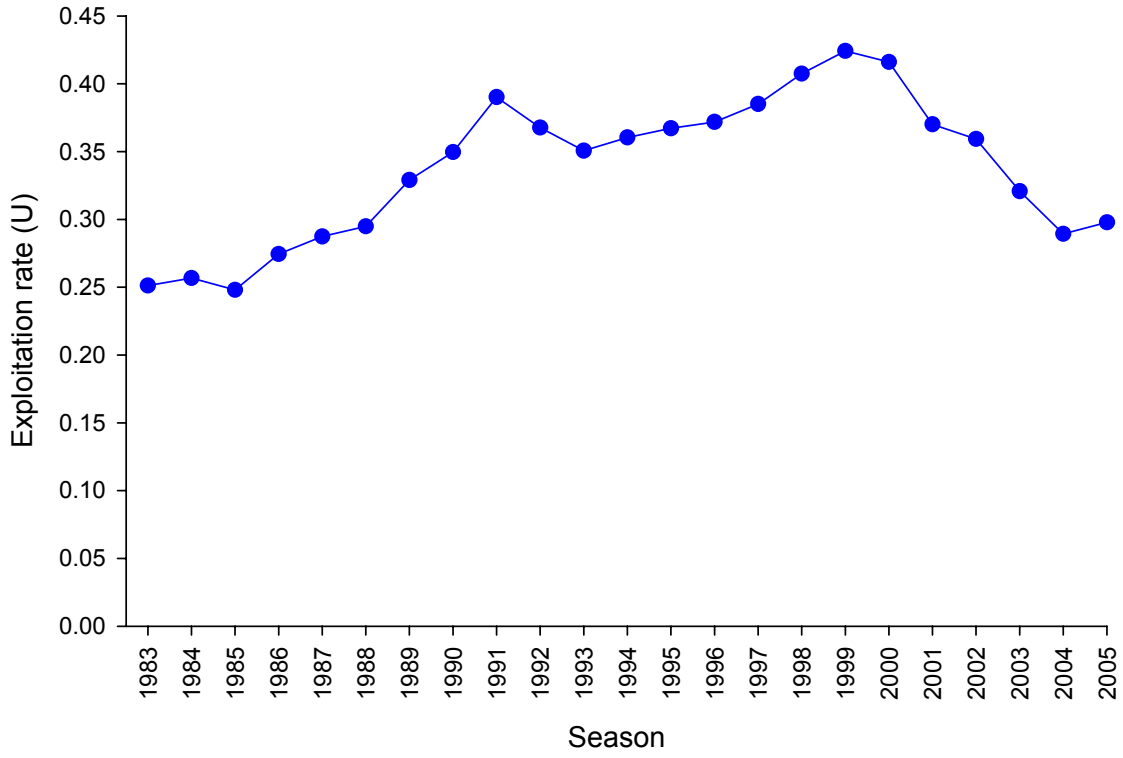

Figure 5-7 Estimates of exploitation rates provided by the 2005 LenMod model.

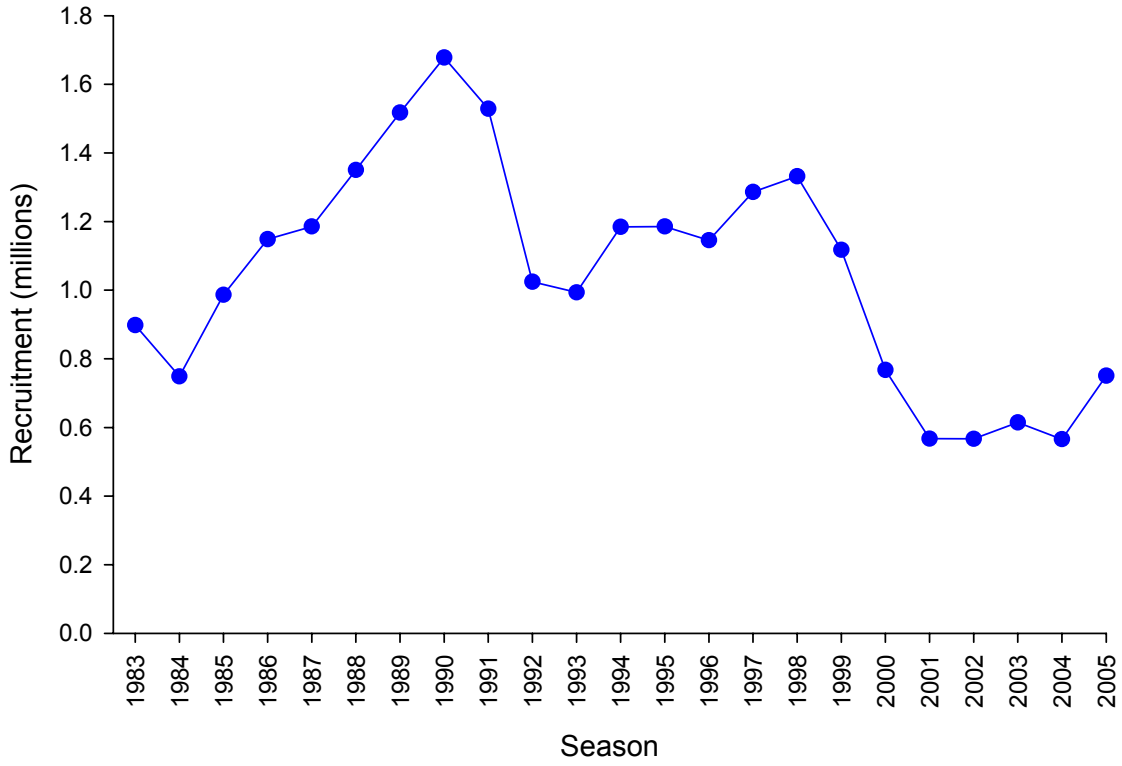

Figure 5-8 Estimates of recruitment provided by the 2005 LenMod model.

6 OTHER PROGRAMS/SURVEYS

6.1 By-catch monitoring

Results from bycatch monitoring indicate that over the last four seasons, by-catch has been dominated by crustaceans (mainly velvet and hermit crabs) and temperate reef finfish namely leatherjacket (dominated by the horseshoe leatherjacket *Meuschenia hippocrepis*) and wrasse species (dominated by the blue throat wrasse *Notolabrus tetricus*) (Figure 6-1). The remainder of by-catch was composed of slimy cod and other species. A risk assessment of by-catch species associated with the NZRLF and other major fisheries of *J. edwardsii* was undertaken in 2006. The outcomes of the assessment will, in part, address some of the recommendations made by the Department for Environment and Heritage (DEH) in relation to sustainable fishing practices (see Appendix).

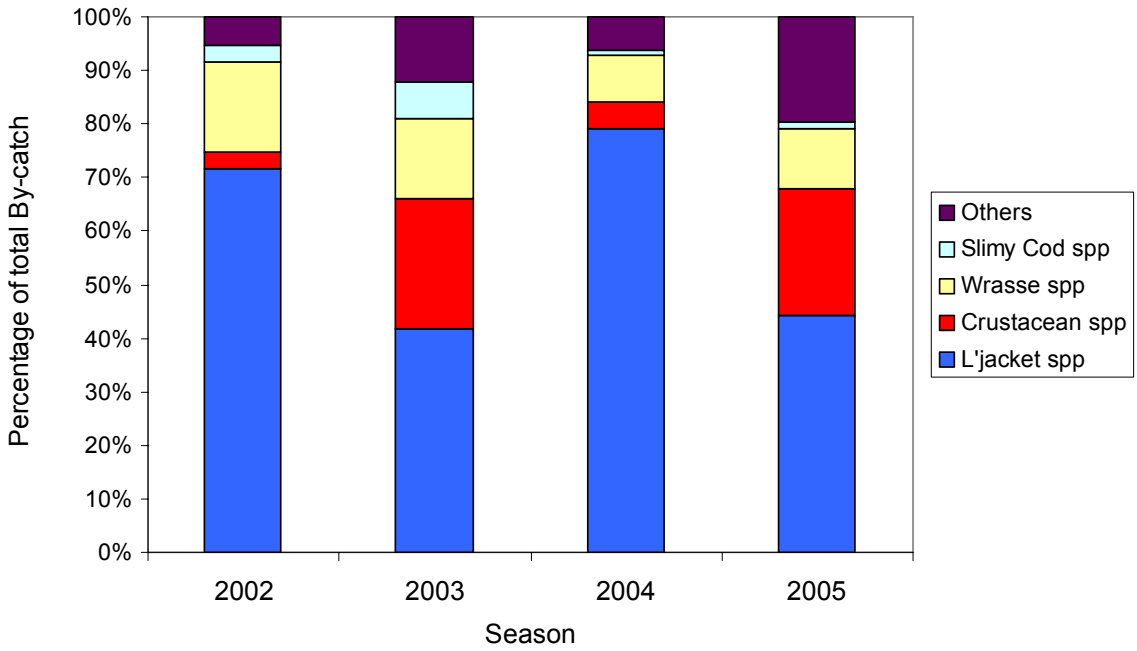

Figure 6-1 Species composition of by-catch from the NZRLF from 2002 to 2005 as determined from routine onboard catch sampling.

7 PERFORMANCE INDICATORS

Current biological performance indicators for the NZRLF are catch rate, mean weight, pre-recruit abundance, exploitation rate and egg production. Upper and lower limits for catch rate, mean weight and pre-recruit abundance are identified in the Management Plan and are the highest and lowest values to occur in the reference seasons 1992 through 1996 (Zacharin 1997) (Table 1-5). For the two performance indicators that are estimated by the qR model, i.e. exploitation rate and egg production, the upper and lower estimates derived for the reference years are used.

7.1 Catch

The catch for the reference seasons ranged between 891 tonnes in 1994 and 1064 tonnes in 1992 (Table 1-5). The catch in 2005 was 476.4 tonnes, which is 46.6% below the lower reference limit and the lowest catch on record (Table 7-1). While this is the sixth season in succession in which the catch has fallen outside the reference range identified in the Management Plan, it reflects an increase in catch of 30 tonnes from 2004 and the first time that catch has increased in the fishery since 1998.

7.2 Catch rate

The catch rate (CPUE) in the reference seasons ranged between 1.25 kg/pot lift in both 1995 and 1996 to 1.43 kg/pot lift in 1992 (Table 7-1). The CPUE in 2005 was 0.82 kg/pot lift, which is 34.4% below the lower reference limit. While this is the sixth season in succession in which the CPUE has fallen outside the reference range identified in the Management Plan, it represents a marginal increase of .02 kg/potlift from 2004 and the first increase in CPUE since 1999.

7.3 Mean Weight

The mean weight (kg) of lobsters in the reference years for the NZRLF ranged between 1.06 kg in 1996 and 1.13 kg in 1995 (Table 7-1). In 2005, the mean weight (calculated from season totals of catch in numbers and weight) was 1.09 kg, which is within the reference range identified in the Management Plan. Mean weight has decreased over the last three seasons suggesting that some recruitment may have entered into the fishable biomass in this period.

7.4 Abundance of Pre-recruits

The mandatory introduction of escape gaps to the fishery in 2003 means that the pre-recruit index (PRI) of abundance as calculated from logbook data is no longer reliable. Data on PRI as calculated from catch sampling (where the escape gaps are closed) from the period 1992 to 1996 ranged from 0.108 undersized/potlift in 1993 to 0.345 undersized/potlift in 1996 (Table 7-1). The pre-recruit index for the 2005 season (calculated from catch sampling data) was 0.49 undersized lobsters/potlift, which is positively above the upper limit reference point.

7.5 Exploitation Rate

Reference points for exploitation rate generated by the qR model ranged from 0.250 in 1993 to 0.279 in 1996 (Table 7-1). The exploitation rate for 2005 season was 0.241, which is below the lower reference limit.

7.6 Egg Production

Egg production estimates in the reference seasons ranged between 679 billion eggs in 1995 and 865 billion eggs in 1992 (Table 7-1). Egg production for 2005 was 428 billion eggs, which is 37% below the lower reference limit.

Table 7-1 Estimates of biological performance indicators for the NZRLF in 2005/06 in relation to upper and lower limit ranges. Performance indicators in red have negatively triggered, while those in green have positively triggered or are within the range identified in the Management Plan.

		Biological Reference Points	
	2005/06	Lower Limit	Upper Limit
Catch (t)	**476.4**	891	1064
Exploitation rate	**0.241**	0.250	0.279
Egg production (billions)	**428**	679	865
Pre-recruit abundance (nr. undersized/potlift from catch sampling data)	**0.490**	0.108	0.345
Catch rate (kg/potlift)	**0.82**	1.25	1.43
Mean weight (kg)	**1.09**	1.06	1.13

8 GENERAL DISCUSSION

8.1 Information available for the fishery

Stock assessment of the NZRLF is aided by documentation on the history of the management of the fishery in the Management Plan and recent stock assessments and status reports (Prescott et al. 1997; Zacharin 1997; Linnane et al. 2006). The management plan also describes the management arrangements in place at the time of this assessment and the biological reference points used for assessing the fishery. Comprehensive catch and effort data have been collected since 1970. Data collected since 1983, however, provide more reliable information on effort. Fishery stock assessments are also aided by puerulus settlement data and stock assessment model outputs. Voluntary catch sampling data have been collected since 1991 and provide critical information on length frequency, pre-recruit indices and reproductive condition of females. Data from 1994 onwards are more robust due to low levels of participation in the early years of the program.

Assessment of the NZRLF currently depends mainly upon commercial catch and effort data. Future stock assessment would be enhanced by the collection of additional fishery-independent information. A fishery-independent monitoring survey (FIMS) is currently being developed in the SZRLF. Application of the sampling protocol and data analysis procedures to the NZRLF in future years will help to substantially reduce the level of uncertainty in the assessment.

8.2 Current Status of Northern Zone Rock Lobster Fishery

The fishery-dependent data provided in this report continues to support the conclusion from recent stock assessments (e.g. Linnane et al. 2006) that the resource on which the NZRLF is based is currently in one of its weakest positions since the inception of the fishery. Several lines of evidence support this conclusion. For example, the catch for the 2005 season of 476.4 tonnes is 46.6% below the lower reference limit identified in the Management Plan and the second lowest in the history of the fishery. This decline is explained partially by recent decreases in effort and changes in market demand, however the main reason for the recent reductions in catch is the substantial decline in fishable biomass.

Catch rate in the NZRLF has decreased annually since 1999. CPUE in 2005 was 0.82 kg/potlift, which is 34.4% lower than the lower reference limit identified in the Management Plan and also the second lowest estimate in the history of the fishery.

Historically low levels of catch and catch rate are supported by outputs from both the qR and LenMod fishery models which estimate that biomass and egg production have decreased dramatically in recent seasons. The reason for the observed decrease in biomass is clear. As indicated by estimates of recruitment from the qR model, recruitment levels into the fishery have been low in recent years and have not matched extractions (catch). Hence, biomass has declined. The low level of recruitment into the fishable biomass is reflected in the high mean weight recorded in previous seasons, particularly from 1998 to 2001. The decline in egg production observed since 1999 as a result of poor recruitment reflects the decline in abundance of female lobsters in the NZRLF and therefore overall fishery biomass.

Despite the recent negative trends in some performance indicators, this report also highlights some positive signs for the future of the NZRLF. The decreasing trends in catch and catch rate since 1998/1999 have been arrested. Catch in 2005 increased by 30 tonnes from the 2004 figures, the first time that catch has increased in the NZRLF since 1998. Similarly, the CPUE increased marginally in 2005 by 0.02 kg/potlift.

Pre-recruit indices, based on voluntary catch sampling data, has increased in the NZRLF over the last 4 seasons, with the 2005 estimate being the second highest since sampling began in the early 1990's. The increase in PRI provides support for the spike in puerulus settlement observed across both the NZRLF and SZRLF in 2002. Given that the time period between settlement and recruitment in the NZRLF is estimated to be ~4 years (McGarvey et al., 1999a), the 2002 cohort would be observed as pre-recruits in 2005 (as seen in the current PRI data) before entering the fishable biomass in 2006.

Further support that the fishery may be entering a period of high recruitment is evidenced by the fact that all MFAs in 2005, that experienced an increase in catch, were located in the western region of the fishery. Growth rates in these MFAs are known to be the highest in South Australia (McGarvey et al., 1999a). It is therefore reasonable to expect that the recruitment pulse expected to enter the fishery as exploitable biomass in 2006 (Linnane et al. 2006), would be first observed in these

MFAs. Recruits in the eastern region of the fishery would enter the fishable biomass later due to slower growth rates.

The high levels of puerulus settlement recorded in the NZRLF in 2005 and 2006 are also positive signs for the future of the fishery. However, it should be noted that PSI estimates recorded since 1996 are low compared to the SZRLF suggesting that settlement peaks in the NZRLF may be sporadic due to the different oceanographic and environmental conditions influencing settlement in each zone. This is highlighted by the low PSI estimates observed in 2003 and 2004.

Forecasts of future biomass under a range of quota levels based on the outputs of the qR model, and using puerulus settlement data as an indicator of future recruitment, suggest that the exploitable lobster biomass in the NZRLF will increase in 2006 under quotas ranging from 300-600 tonnes, as a result of the strong settlement of puerulus that occurred in 2002. Biomass will decrease in 2008 for quotas above 400 tonnes as a result of low puerulus settlement in 2003 and 2004. Projected biomass increases again in 2009 and 2010 under all quota scenarios due to predicted recruitment into the fishery from high puerulus counts observed in 2005 and 2006.

Given the level of variation in recruitment to the NZRLF and the degree of uncertainty associated with puerulus settlement data, careful consideration should be given as to how pulses of recruitment are conserved. It may be necessary for management arrangements to be developed that afford greater levels of protection for recruitment pulses during the stock rebuilding phase, as these pulses may need to sustain catches for extended periods. The true strength of the 2002 peak in puerulus settlement should be quantified during 2006 fishing seasons through catch sampling pre-recruit monitoring and logbook recording of retained catches. As a result, the importance of participation in the voluntary catch sampling program as a means to attain quality pre-recruit data cannot be underestimated.

8.3 Research in response to DEH recommendations

Both current and future research needs in the NZRLF have recently been refocused by the PIRSA rock lobster research sub-committee to ensure the recommendations outlined in the assessment of the fishery by the Department for Environment and Heritage (DEH) (Anon, 2003) are addressed appropriately. The DEH report outlines

13 recommendations to the fishery relating to both management arrangements and ecologically sustainable fishing practices. A number of these recommendations are currently being addressed through either ongoing research or through proposed research projects. A full list of the DEH recommendations are provided in an appendix to this assessment report. Recommendation 4 requests:

PIRSA to continue to improve assessment of all components of non-commercial catch in the fishery to be factored into the annual stock assessment process and management of the fishery. This will include further periodic surveys or other data collection and analysis measures to enhance the assessments of recreational and indigenous catch in the fishery.

Details of management arrangements associated with recreational fishing in the NZRLF are provided in Section 1.2.4 of this report. Periodic recreational catch and effort surveys are undertaken (e.g. Venema et al. 2003), the most recent of which was conducted during the 2004/05 fishing season (Currie et al. 2006). Outcomes from this survey are presented in a previous section of this report.

Recommendation 5 requests:

PIRSA within 18 months, to review the monitoring requirements for both zones of the fishery, including options for independent monitoring appropriate to the scale of fishing and status of stocks in the main fishing areas, to identify monitoring measures necessary to confirm the status of stocks and support stock recovery strategies.

In order to overcome the inherent limitations of the fishery dependent catch and effort logbook program, a Fishery Independent Monitoring Survey (FIMS) was developed for trial in the southern zone rock lobster fishery (SZRLF) for the 2005 season. Further sampling that incorporates substantial improvements to the sampling design was undertaken in 2006. Sampling is conducted at the beginning (September), mid season (January) and end (May) of this fishing season along predetermined transects across a range of depth profiles. Data will be used as input for fishery independent models with outputs used in the determination of a fishery independent estimate of lobster abundance. Initially, the FIMS will be conducted in the SZRLF only. However, once the sampling protocol and data analysis procedures have been developed and refined, it is proposed that they will be applied to the NZRLF.

Recommendation 7 requests:

Performance measures and targets for the main byproduct species to be included in the revised management plans for both zones, and the catches of the main byproduct species should be reviewed as part of the annual stock assessment process

A report detailing the species composition and spatio-temporal trends in by-catch from the South Australian commercial rock lobster fishery as estimated using two monitoring options was finalised in 2004 (Brock et al. 2004). This report was formally published in *Marine and Freshwater Research* in 2007 (Brock et al. 2007). The report identifies the main by-catch species within the fishery and estimates catch rates of by-catch as determined during the 2001/02 and 2002/03 fishing seasons. It also compares the effectiveness of logbook and observer sampling strategies and comments on the appropriateness of each for application within the South Australian rock lobster fishery. A workshop on the outcomes of the report was undertaken in 2007 where results from bycatch surveys from other major fisheries across the geographical range of *J. edwardsii* were also presented. The outcome was a risk assessment strategy that is currently being prepared for submission to DEH. The species composition of by-catch from the NZRLF is also monitored annually through the onboard observer programme. Results are presented in a previous section of this report.

Recommendations 10, 11 and 12 request:

PIRSA within 18 months to introduce mandatory structured reporting of all interactions between the rock lobster fishery and endangered, threatened or protected species

PIRSA and industry to continue to monitor the extent of interactions between rock lobster fishery and fur seals and sea lions, and develop appropriate mitigation measures including establishment within 2 years of preliminary trigger and reference points, to minimise these interactions

PIRSA within 12 months to conduct a qualitative risk assessment of the interactions between the rock lobster fishery and protected species off SA and use the outcomes of this assessment to implement further protected species mitigation measures as required

In response to these recommendations, a project titled "Interactions of the South Australian fishery for southern rock lobster (*Jasus edwardsii*) with pinnipeds" has been submitted to the Fisheries Research and Development Corporation for funding consideration. The main objectives of the project are as follows:

1) To measure the interaction of the South Australian rock lobster fishery with pinnipeds
2) To assess the risks to pinniped populations arising from their interactions with the south Australian rock lobster fishery
3) To develop and assess methods for mitigating the interaction of pinnipeds with lobster pots
4) To determine the importance of rock lobster in the diets of Australian sealions.

Initial funding has been provided by FRDC for a desktop review study. This report is due for completion in 2006.

8.4 Future Research Priorities

Given the observed regional differences in fishery performance highlighted in this assessment, the need for improved spatial coverage of fishery dependent performance indicators is a current priority for the fishery. Future research should therefore aim to develop a user-friendly onboard electronic logbook in order to provide robust spatial data required for an accurate assessment of lobster abundance at a regional level. Given that the focus of the new Management Plan for the fishery is an emphasis on fine scale spatial management, an electronic logbook system that provides real-time fishery data across the regions identified will prove to be a vital tool in the assessment of the resource. The strategic research plan for the NZRLF will be reviewed as part of the process in developing a new Management Plan for the fishery.

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10 APPENDIX

The following is a list of recommendations by the Department of Environment and Heritage (DEH) aimed at strengthening the effectiveness of the management arrangements for the SARLF and containing the environmental risks in the medium to long term (Anon. 2003).

Recommendation 1: *PIRSA to inform the Department of the Environment and Heritage of any significant changes to the management regime of the South Australian Rock Lobster Fishery.*

Recommendation 2: *The current review of SA's Fisheries Act* 1982 *should provide for the inclusion of general community members on the two fisheries management committees. Greater efforts should also be made to increase conservation and general community involvement in stock assessments and research priority setting processes.*

Recommendation 3: *PIRSA to pursue complementary management arrangements with other Australian jurisdictions responsible for managing southern rock lobster fisheries to ensure that all removals and other relevant impacts on the stock are properly accounted for in stock assessments.*

Recommendation 4: *PIRSA to continue to improve assessment of all components of* non *commercial catch in the fishery to be factored into the annual stock assessment process and management of the fishery. This will include further periodic surveys or other data collection and analysis measures to enhance the assessments of recreational and indigenous catch in the fishery. .*

Recommendation 5: *PIRSA, within* 18 *months, to review the monitoring requirements for both zones of the fishery, including options for independent monitoring appropriate to the scale of fishing and status of stocks in the main fishing areas, to identify monitoring measures necessary to confirm the status of stocks and support stock recovery strategies. PIRSA to progressively implement priority actions identified in the review.*

Recommendation 6: *PIRSA and the SA industry to work with their Victorian counterparts to investigate and adopt appropriate measures to address quota avoidance, misreporting of catches and other illegal activities in waters near the SA-Victoria border. These measures should be built into SA's compliance strategies.*

Recommendation 7: *Performance measures and targets for the main byproduct species to be included in the revised management plans for both zones, and the catches of the main byproduct species should be reviewed as part of the annual stock assessment process.*

Recommendation 8: *PIRSA to develop within* 18 *months a conservative harvest strategy for the Northern Zone fishery, including a TAC to commence on* 1 *November 2003, that includes recovery targets and reference points, and monitoring arrangements, representative of the scale of fishing in the Zone, and stock recovery timeframes.*

Recommendation 9: *Priority should be given to early implementation of escape gaps in the Northern Zone, and should be mandatory in both zones by October 2004. Decisions on the dimensions of escape gaps in both zones to be based on the requirement to minimise fishery impacts on all bycatch species.*

Recommendation 10: *PIRSA within* 18 *months to introduce mandatory structured reporting of all interactions between the rock lobster fishery and endangered, threatened or protected species.*

Recommendation 11: *PIRSA and industry to continue to monitor the extent of interactions between rock lobster fishery and fur seals and sea lions, and develop appropriate mitigation measures, including establishment within* 2 *years of preliminary trigger and reference points, to minimise these interactions.*

Recommendation 12: *PIRSA within* 12 *months to conduct a qualitative risk assessment of the interactions between the rock lobster fishery and protected species off SA and use the outcomes of this assessment to implement further protected species mitigation measures as required.*

Recommendation 13: *PIRSA to develop measures to assess ecosystem impacts of the fishery. Consideration should be given to the appropriateness of reference areas that would allow comparison between fished and unfished areas.*