Fishery Assessment Report to PIRSA

Northern Zone Rock Lobster (*Jasus edwardsii*) Fishery 2008/09

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This fishery assessment updates the 2007/08 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 2007/08 report and assesses the current status of the Northern Zone Rock Lobster Fishery (NZRLF) against the performance indicators detailed in the Management Plan for the resource. It also provides information on a range of additional indices that are important to the fishery and identifies key areas of future research.

2 In 2008 (i.e. the 2008/09 season) the Total Allowable Commercial Catch (TACC) in the NZRLF was 470 tonnes. The total reported commercial catch from logbook data was 402.7 tonnes. With the exception of marginal increases in 2005 and 2006, the catch has decreased annually over the last ten seasons. This represents a 60% decrease in zonal catch since 1998 (1015.8 tonnes) and a 20% decrease since the introduction of the TACC system in 2003 (503.3 tonnes).

3 Since its introduction, the TACC has never been taken in the NZRLF. In 2003, only 503 tonnes of a 625 tonnes quota were landed. In 2004, the TACC was reduced to 520 tonnes of which only 446 tonnes were taken. Over the next three seasons, the TACC was retained at 520 tonnes but only 476, 491 and 459 tonnes were taken in 2005, 2006 and 2007 respectively. In 2008, the TACC was reduced to 470 tonnes but only 403 tonnes were taken.

4 Total effort has not decreased at a similar rate to total catch. In 2008, the zonal effort was 600,347 potlifts. This represents a 16.7% decrease since 1998 (720,816 potlifts) and a 0.5% increase since 2003 (596,961 potlifts).

5 The zonal Catch-Per-Unit-Effort (CPUE; November to April inclusive) for 2008 was 0.68 kg/potlift, the lowest on record. This represents a 54% decrease since 1999 (1.49kg/potlift) and a 21% decrease since 2003 (0.86 kg/potlift).The 2008 estimate is below the zonal limit reference trajectory (LRT) of 1 kg/potlift over 12 years. In 2008, all regional CPUE estimates were below the respective LRTs.

6 The puerulus settlement index (PSI) in 2009 was 0.34 puerulus/collector, which was below the long term average for the fishery (~0.42 puerulus/collector). This follows two of the lowest PSIs on record in 2007 (0.08 puerulus/collector) and 2008 (0.11 puerulus/collector). Given that PSIs in 2005 (0.81 puerulus/collector) and 2006 (0.89 puerulus/collector) were two of the highest settlements on record, these trends highlight the sporadic nature of settlement in the NZRLF.

7 In 2008, the pre-recruit index (PRI) was 0.67 undersized/potlift, the highest on record. Given that the period between PSI and PRI is ~3 years, this presumably reflects high settlement in 2005. The zonal 3-year average PRI (2006-2008) was 0.44, which is above the long-term Limit Reference point (LRP) for the NZRLF. The regional 3-year average approximated the long-term LRP in Region B but was above it in Regions C and D.

8 There is close agreement between the qR and LenMod fishery models in relation to the current status of the NZRLF. Both models indicate that biomass and egg production have decreased markedly over the last two decades. Biomass in 2008 was ~1,300-1,400 tonnes, the lowest estimate on record. This represents a decrease of ~60% from 1990 (3,300–3,900 tonnes). Similar declines in egg production suggest that 2008 values represent only 9-14% of virgin egg production levels. Current exploitation rates range between 28-30%.

9 It is clear that up to 2008, TACCs have not been set at levels that constrain catch, which is inconsistent with the aim of stock rebuilding defined in the Management Plan. This is confirmed by the fact that 2008 represents the sixth successive season in which the TACC has not been landed. As a result, biomass has declined, which has translated into poor fishery performance as reflected by the continued decrease in both zonal and regional catch rates.

10 While the fishery is currently at a historically low level, the increase in PRI in 2008 is positive. This cohort likely to reflects the 2005 settlement pulse which should enter the fishable biomass as legal-sized lobsters during the 2009 season. Increased recruitment may continue in 2010 based on the 2006 settlement. However, settlement in 2007 and 2008 was low suggesting that recruitment in 2011 and 2012 will be poor. Therefore, given the level of variation in recruitment to the NZRLF and the sporadic nature of settlement, careful consideration should be given as to how pulses of recruitment are protected. Specifically, conservative TACCs are required to ensure that when peaks in recruitment enter the fishable biomass in 2009 and 2010, they are protected to maintain biomass over the following period of low recruitment. This report highlights that, in the absence of TACCs that restrain catch, the biomass of lobsters has declined to a historically low and overfished level.

1 GENERAL INTRODUCTION

1.1 Overview

This Fishery Assessment Report updates the 2007/08 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 in relation to the performance indicators provided in the Management Plan (Sloan and Crosthwaite 2007).

The report is divided into eight sections. Section one 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) details the data sources from which the current assessment is made.

Section two provides a synopsis of the fishery dependent statistics for the NZRLF between the 1970/71 and 2008/09 fishing seasons. This section examines inter-annual, and within-season trends in catch, effort and catch-per-unit-effort (CPUE) of both legal and undersized lobsters at zonal and regional spatial levels. Mean weight and length-frequency data are also analysed.

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.

Section four presents estimates of fisheries indicators obtained from the qR model (McGarvey et al. 1997; McGarvey and Matthews 2001), while the fifth section presents outputs from the length structured model (LenMod) for the fishery. Outputs from both models are compared and discussed in this section of the report.

The sixth 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 (Sloan and Crosthwaite 2007).

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

The eighth section is the bibliography, which provides a list of research papers and reports that are directly relevant to research and management of the NZRLF.

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). It 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).

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 granite rocks (Lewis 1981). Reef communities and habitats for lobsters are confined to relatively small patches where basement granite projects through the overlying sands. Some additional 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 produce peaked reefs that provide discrete localised habitats for lobsters, interspersed by large expanses of sand. Granite does not erode as easily as the limestone reefs in the Southern Zone Rock Lobster Fishery and thus lack the numerous ledges, crevices and undercuts which provide ideal habitats for lobsters.

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 (Middleton and Platov, 2003).

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). In summer the mean 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 Platov 2003). The water layer above the thermocline is characterised by medium salinity (35.6 psu), low nutrient levels (NO_3 <0.1 ug/l) and high temperatures (18 to 19°C). Water below the thermocline has lower salinity (< 35.5psu), higher nutrient levels (NO_3 >0.2 ug/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).

During winter, water over the continental shelf is vertically homogeneous, well mixed and characterised by low nutrient levels (NO_3 <0.25 ug/l), high salinities (> 36 ppt) and medium temperatures of ~17°C. 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 2004). 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.

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. More recently, efforts have also been made to export live into the United States market.

Commercial fishers predominantly harvest lobsters using steel-framed pots covered with wire mesh and incorporating a moulded plastic neck (Figure 1-3). 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.

1.2.4 Recreational Fishery

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

The most recent report on recreational rock lobster fishers was undertaken during the 2007/08 South Australian Recreational Fishing Survey (Jones 2009). An estimated 106,483 (+/-54,423) rock lobster were caught by South Australian residents in 2007/08, with 47,875 (+/-20,331) of these harvested and 58,608 (+/-36,148) released, representing a release rate of 55%. Overall, total numbers caught decreased by 12% from previous surveys but release rates increased by 26%. The catch represents a total recreational harvest of ~60 tonnes, of which it was estimated that ~5 tonnes (8%) came from the NZRLF.

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

1.2.5 Illegal fishing

The implementation of systems for monitoring the Total Allowable Commercial Catch (TACC) has reduced opportunities for the disposal of illegal catches in the NZRLF. As a result, it is considered unlikely that illegal fishing is currently a significant source of fishing mortality in the zone.

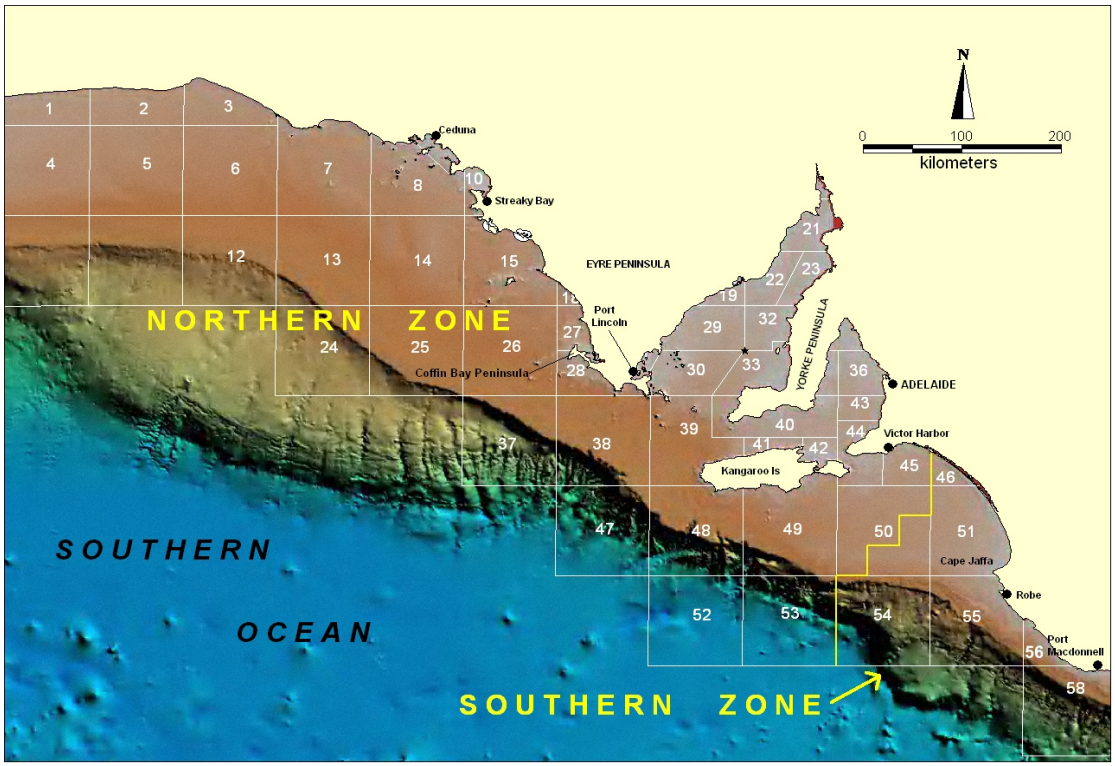

Figure 1-1 Marine Fishing Areas in the Northern and Southern Zones of the South Australian Rock Lobster Fishery.

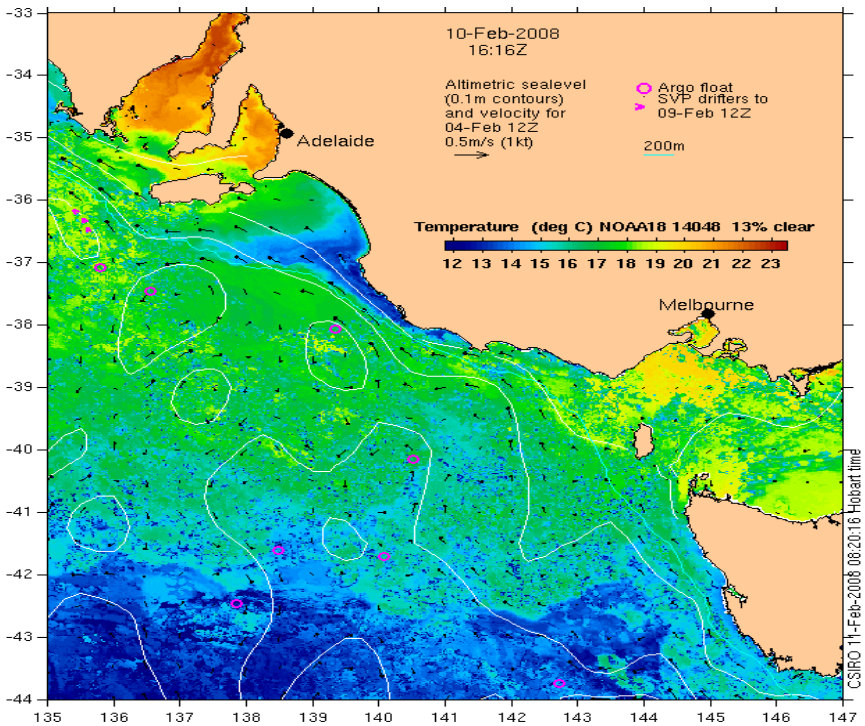

Figure 1-2 Sea-surface temperatures over the continental shelf of South Australia during February 2008. An upwelling can be seen where cooler water (dark blue) has moved onto the inner continental shelf (source: CSIRO).

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

1.3 Management of the Fishery

The commercial NZRLF is a limited entry fishery with a total of 68 licences. Port Lincoln on the Eyre Peninsula is a base for the majority of the fleet (Figure 1-1). The statutory framework for ecologically sustainable management of this resource is provided by the *Fisheries Management Act 2007*. General regulations that govern the NZRLF are described in the *Fisheries Management (General) Regulations 2007* and the specific regulations are established in the *Fisheries Management (Rock Lobster Fisheries) Regulations 2006*. The policy, objectives and strategies to be employed for the sustainable management of the NZRLF are described in the *Management Plan for the South Australian Northern Zone Rock Lobster Fishery* (Sloan and Crosthwaite 2007). Recreational fishers are regulated under the *Fisheries Management (General) Regulations 2007.*

1.3.1 Management Milestones

Management arrangements have evolved since the inception of the fishery with the most recent review being in 2008 (Table 1-1).

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

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	Legal minimum length (LML) increased from 98.5 to 102 mm CL; further "1 week" closure
1995	Further "1 week" closure added
1997	Flexible closures introduced. Management Plan for the fishery published (Zacharin 1997)
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 season at 625 tonnes; VMS introduced.
2004	TACC reduced to 520 tonnes. Vessel length and power restrictions removed.
2007	New Management Plan published (Sloan and Crosthwaite 2007)
2008	TACC reduced to 470 tonnes

1.3.2 Current Management Arrangements

Details of the management arrangements for 2008/09 are provided in Table 1-2. Currently, the commercial fishery is managed by a combination of input and output controls. The season extends from November 1st to May 31st of the following year. There is a minimum legal size of 105 mm carapace length, prohibition on the taking of berried females, and several sanctuaries where lobster fishing is prohibited. The dimensions of lobster pots, including mesh and escape gap size, are also regulated. Fishers may use up to 100 of the total number of pots endorsed on their licence at any one time to take lobster.

The TACC is set each year and is divided proportionally between licence holders as individual transferable quotas (ITQ's). Each licence holds one quota unit entitlement for each pot entitlement held. If a pot entitlement is transferred, a quota unit must also be transferred at the same time to the same licence, and vice versa. The daily catch of individual boats is monitored via catch and disposal records. In 2008/09, the quota was 470 tonnes.

Table 1-2 Management arrangements for the South Australian Northern Zone Rock Lobster Fishery in 2008/09.

Management tool	Current restriction
Total Allowable Commercial Catch	470 tonnes
Closed season	1 June to 31 October
Total number of pots	3,950
Minimum size limit	105 mm CL
Maximum number of pots/licence	100 pots
Minimum number of pots/licence	20 pots
Maximum quota unit holding	Unlimited
Minimum quota unit holding	320 quota units
Spawning females	No retention
Maximum vessel length	None
Maximum vessel power	None
Closed areas	Gleeson Landing Reserve
Catch and effort data	Daily logbook submitted monthly
Catch and Disposal Records	Daily records submitted upon landing
Landing times	Landings permitted at any time during the season
Prior landing reports to PIRSA	1 hour before removing lobster from boat
Escape gaps	2 gaps per pot
Vessel Monitoring System (VMS)	Operational VMS units required on all vessels during the season
Bin tags	All bins must be sealed with a lid and an approved tag prior to lobster being unloaded from the vessel. Tags are sequentially numbered.

1.3.3 The Management Plan

Goals, Objectives and Strategies

The Management Plan for the NZRLF identifies biological, economic, ecological and social goals, objectives, and strategies for the resource. Particularly relevant to this report are the biological and environmental objectives which are described below in Table 1-3. The primary goal of the Management Plan is biomass rebuilding. The primary tool to achieve this is through the setting of an annual TACC in accordance with decision rules identified in the Plan.

Table 1-3 Biological and environmental objectives of the Management Plan for the Northern Zone Southern Rock lobster fishery (Sloan and Crosthwaite 2007).

Goal	Objectives	Strategies
1. Maintain ecologically sustainable stock levels	*1a. Return the stock to a level that will support sustained catch rates within target and limit reference levels between now and 2016.*	▪ Set the TACC annually, in accordance with TACC decision rules in the harvest strategy. ▪ Maintain all other existing input and output controls.
	1b. Fishing is conducted at a level that provides protection from overfishing during extended periods of low recruitment.	▪ Monitor the number of pre-recruits in the fishery through the voluntary catch sampling program, as an index of future recruitment strength. ▪ Set the TACC annually, in accordance with TACC decision rules in the harvest strategy. ▪ Monitor larval settlement in the fishery, as an index of future recruitment strength. ▪ Use escape gaps to minimise pot-induced juvenile mortality rates.
	1c. Ensure sufficient biological and environmental information exists to inform management decisions.	▪ Collect fishery-dependent information through commercial logbooks. ▪ Maintain a voluntary catch sampling program to collect additional biological information. ▪ Develop and implement a fishery-independent data collection program. ▪ Undertake recreational survey to estimate catch and effort every three years. ▪ Assess the status of the stock through quantitative stock assessment. ▪ Review and update the strategic research and monitoring plan bi-annually. ▪ Monitor recreational catch and effort levels across the State every three years

1.3.4 Management Regions

The Management Plan (Sloan and Crosthwaite 2007) details key biological performance indicators that are to be assessed at both whole-of-fishery (zonal) and regional levels (Figure 1-4). Currently, the four regions are: “The West” (Region A), “Eyre Peninsula” (Region B), “Yorke Peninsula” (Region C) and “Kangaroo Island” (Region D). The aim of regional assessment is to refine management of the fishery to a finer spatial scale and ensure that greater precaution is factored into management arrangements. Regional assessment also allows known spatial variations in biological features such as growth rate (McGarvey et al. 1999a) and size of maturity (Prescott et al. 1996) to be taken into consideration. In addition, improved spatial management ensures that the performance of one region does not mask that of another. This is of particular importance during periods of low recruitment. Similarly, if the overall fishery is performing strongly, a downturn in one area may not necessarily lead to a TACC reduction for the whole fishery.

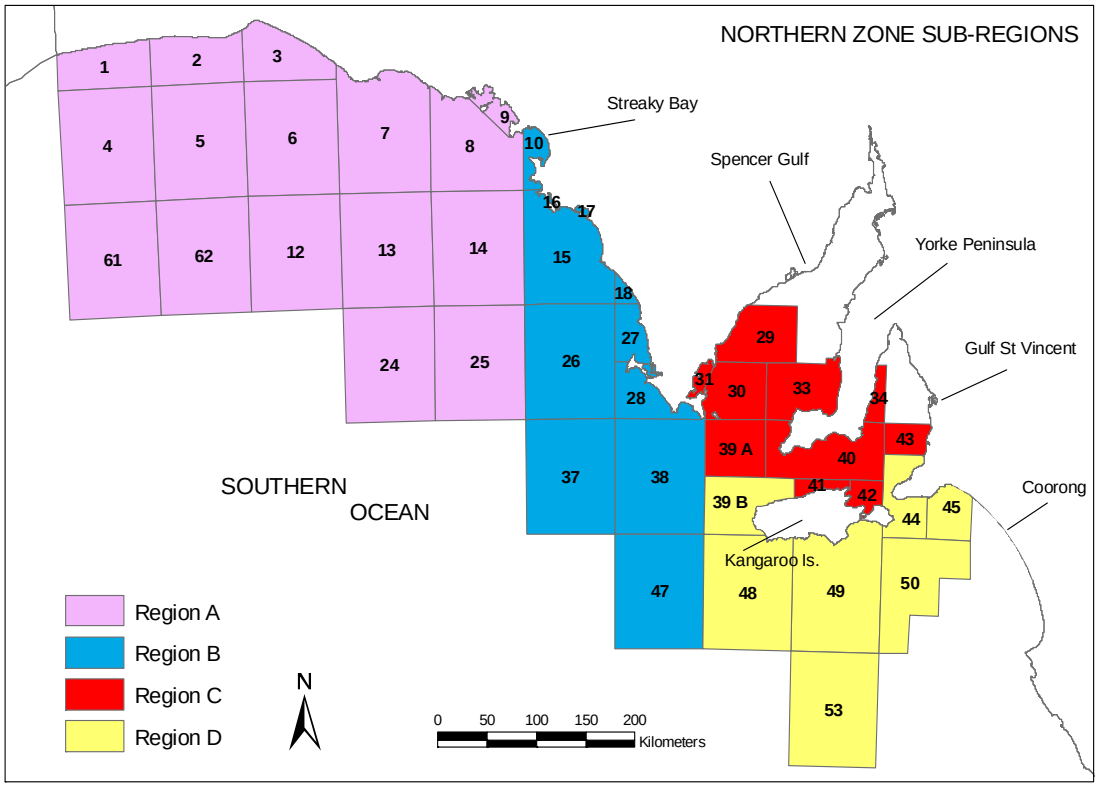

Figure 1-4 Key spatial regions as defined under the new Management Plan for the NZRLF.

1.3.5 Primary Biological Reference Points

The biological reference levels set out in the Management Plan (Sloan and Crosthwaite 2007) have been designed to provide clear guidance to the TACC setting process by defining how key performance indicator estimates should be interpreted and by explicitly linking them to a set of decision rules for TACC setting. The limit reference points (LRPs) represent unacceptable fishery performance that the fishery aims to avoid. Target reference points (TRPs) represent desirable fishery performance that the fishery aims to achieve. Therefore, overall fishery performance will be measured by evaluating annual estimates of key performance indicators, relative to established limit and target biological reference levels.

A goal of the new Management Plan is to promote stock recovery within an agreed timeframe. This goal will be achieved by ensuring that fishery performance is maintained within the reference levels that have been developed for key performance indicators. Although the plan sets out a range of biological performance indicators, reference points have only been developed for two of these i.e. catch rate and pre-recruit index. Each of these will be assessed at both a zonal and regional level in order to assess the performance of the fishery in any one year. For further details of reference points, readers should refer to Sloan and Crosthwaite (2007).

Catch rate

LRPs for catch rate have been defined taking into account:

- Historical commercial catch and effort data
- Stakeholder expectations of biological and economic performance; and
- A long-term goal to achieve stock recovery.

For the purposes of setting LRPs for catch rate, the year 2004 has been chosen as a starting point, as this represents a point when the fishery is considered to have been at its lowest point in both a biological and an economic sense. A LRP recovery trajectory has been developed for the whole fishery and for each region to allow for a gradual increase in the LRP over the recovery period.

TRPs have been defined taking into account:

- Historical commercial catch and effort data;
- Stakeholder expectations of biological and economic performance;
- A long term goal to maintain and improve stability in future catches; and
- A long-term goal to achieve a stock that will sustain a TACC of 600-700 tonnes.

Limit and target reference points have been established for both the fishery as a whole and each of the four regions, for the purposes of the TACC decision rules. Whilst the new Management Plan applies for a period of three years, the recovery trajectories relate to a twelve-year period. Details of zonal and regional LRPs and TRPs for catch rate are provided in Table 1-5.

Pre-recruit index

Only a LRP is set for pre-recruit index (PRI). Therefore PRI at any time is either above or below the reference point.

For the purposes of setting LRPs for PRI, a reference period between 1995 and 2004 (inclusive) has been chosen. This ten-year period is representative of recent fishery performance. In order to set reference points for pre-recruit abundance, the average over this period has been taken for the whole fishery and each regional area.

As set out in the decision rules of the Management Plan, the relevant measure for any particular year is the average of the most recent three years. For example, in calculating the PRI for 2008/09, the average of 2006/07, 2007/08 and 2008/09 will be used to determine whether PRI is considered to be above or below the reference levels. Zonal and regional LRPs for pre-recruit index are provided in Table 1-4.

Table 1-4 Zonal and regional limit reference points for pre-recruit index for the NZRLF.

Region	Pre-recruit index (Pot sampling data)
Northern Zone	0.33
A	0.03
B	0.19
C	0.42
D	0.61

Table 1-5 Zonal and regional limit and target reference points for catch rate (kg/potlift) based on a 12-year recovery time period.

Rock Lobster Season	Year number	Whole Zone		Region A		Region B		Region C		Region D	
		Target	Limit	Target	Limit	Target	Limit	Target	Limit	Target	Limit
2004 (*data*)	0	0.82	0.82	0.94	0.94	0.75	0.75	0.78	0.78	0.87	0.87
2005	1	0.86	0.84	0.98	0.95	0.79	0.76	0.81	0.79	0.90	0.88
2006	2	0.89	0.85	1.02	0.97	0.83	0.78	0.83	0.79	0.93	0.89
2007	3	0.93	0.87	1.06	0.98	0.86	0.79	0.86	0.80	0.97	0.90
2008	4	0.96	0.88	1.09	0.99	0.90	0.80	0.89	0.80	1.00	0.91
2009	5	1.00	0.90	1.13	1.01	0.94	0.81	0.91	0.81	1.03	0.92
2010	6	1.04	0.91	1.17	1.02	0.98	0.83	0.94	0.82	1.06	0.94
2011	7	1.07	0.93	1.21	1.03	1.01	0.84	0.97	0.82	1.09	0.95
2012	8	1.11	0.94	1.25	1.05	1.05	0.85	0.99	0.83	1.12	0.96
2013	9	1.14	0.96	1.29	1.06	1.09	0.86	1.02	0.83	1.16	0.97
2014	10	1.18	0.97	1.32	1.07	1.13	0.88	1.05	0.84	1.19	0.98
2015	11	1.21	0.99	1.36	1.09	1.16	0.89	1.07	0.84	1.22	0.99
2016	12	1.25	1.00	1.40	1.10	1.20	0.90	1.10	0.85	1.25	1.00

1.3.6 Secondary Performance Indicators

The Management Plan also sets additional performance indicators to supplement the key performance measures used in the decision rules (Table 1-6). These performance indicators provide supplementary information for fishery assessment. They also provide information for periodic review to ensure that performance indicators are adequate measures for fishery assessment. These additional performance indicators do not trigger a specific response. They only require that a management issue be considered, without dictating what the response should be.

Table 1-6 Table of additional performance indicators for the NZRLF.

Goal	Objective	Performance Indicator	Description	Limit reference point
1. Maintain ecologically sustainable stock levels	*Rebuild lobster biomass*	Biomass	Reflects the sum total weight of the breeding population and is used to determine the reproductive capacity of the population.	Monitored annually and reported in stock assessment.
		Egg production	Reflects the reproductive capacity of the fishery by providing an estimation of the number of eggs produced by all mature females in the population, as a percentage of the virgin egg production.	Monitored annually and reported in stock assessment.
		Catch vs TACC	Provides an indicator of the relative abundance of lobster in the fishery.	Drops below 90%
		Mean weight	May reflect changes in the stock structure or changes in fishing practices. Higher mean weight values usually reflect a lack of newly recruited lobster in the population. Lower mean weight usually reflects a greater frequency of smaller lobster in the population due to increased recruitment.	Monitored annually and reported in stock assessment.
		Puerulus settlement index	Reflects larval (puerulus) settlement abundance and provides an index of future recruitment strength. Provides an indication of future catch in 4 - 5 years time.	Monitored annually and reported in stock assessment.

1.4 Biology of Southern Rock Lobster

1.4.1 Taxonomy and Distribution

For detailed information on all biological aspects of southern rock lobster *Jasus edwardsii* (Hutton 1875) biology, readers should refer to Phillips (2006). Southern rock lobster (Figure 1-5), 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). They are generally considered omnivores, but primarily carnivores of slow moving benthic invertebrate prey, in particular spiny urchin, crab and marine snail species (Fielder 1965; Johnston 2003; Hoare 2008).

Figure 1-5 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).

1.4.3 Life History

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

The larvae hatch in early spring, pass through a brief (10-14 days) nauplius phase into a planktonic, leaf-like phase called phyllosoma. Phyllosoma have been found down to depths of 310 m, tens to hundreds of kilometres offshore from the New Zealand coast (Booth et al. 1991; 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 stage (Figure 1-6) near the continental shelf break (Booth et al. 1991; Bruce et al. 1999). A short-lived (ca. 3-4 weeks) non-feeding stage, the puerulus actively swims inshore to settle onto reef habitat in depths from 50 m to the intertidal zone (Booth et al. 1991; Phillips and McWilliam 2009).

There is substantial geographic variation in larval production. In New Zealand, it has been suggested that this may be due to variations in: (i) size at first maturity, (ii) breeding female abundance and/or (iii) egg production per recruit (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 1991; Chiswell and Booth 2005; Chiswell and Booth 2008; Phillips and McWilliam 2009).

Geographic patterns in the abundance of phyllosoma may also be consistent with those in puerulus settlement (Booth and Stewart 1991; Booth 1994). Correlations

between levels of settlement and juvenile abundance have been found at two sites in New Zealand (Breen and Booth 1989). In South Australia, it has been suggested that the strength of westerly winds, during late winter and early spring, may play a role in the inter-annual variation in recruitment to the 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.

Using a combination of biological and hydrodynamic modelling, Bruce et al. (2007) simulated the planktonic early life history of *J. edwardsii* across its geographical range. In relation to sources of recruiting pueruli to the Northern Zone, the study predicted that while the most significant levels of recruitment occur from south west WA and locally, some may also come from as far east as south east Tasmania in certain years. Importantly, the study found that the Southern Zone rock lobster fishery was one of the most significant sources of pueruli for much of the overall south-eastern fishery of Australia, and required careful management for the sustainability of other fishery regions.

Figure 1-6 Newly settled southern rock lobster puerulus.

1.4.4 Growth and Size of Maturity

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

A tagging study undertaken between 1993 and 1996, which provided 16,000 recaptures demonstrated substantial variation in growth rates among locations in South Australia (McGarvey et al. 1999a) with a general trend of higher growth rates in the NZRLF compared to the SZRLF. 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. Along the South Australian coast from south-east to north-west growth rates tended to increase and were highest in areas of low lobster density and high water temperature. Growth rates were also related to depth and declined at the rate of 1 mm per year for each 20 m increase in depth (McGarvey et al. 1999a).

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

Movement patterns of *Jasus edwardsii* in South Australia were determined from 14,280 tag-recapture events from across the State between 1993 and 2003 (Linnane et al. 2005). In total, 68% of lobsters were recaptured within 1 km of their release site and 85% within 5 km. The proportion of lobsters moving >1 km in MFAs ranged from 13 to 51%. Movement rates were noticeably high in the SZRLF and at Gleesons Landing lobster sanctuary off the Yorke Peninsula in the 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. Technological advances in acoustic tagging could help refine intermediate and fine scale movement patterns of lobsters, which conventional tag-recapture methods lack.

1.5 Stock Assessments: 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 and puerulus 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.

1.5.1 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 (*Pseudocarcinus gigas*) 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. Fishery dependent statistics from logbook data are presented in Section 2 of this report. Details currently recorded in the daily logbook include:

1. the MFA within which the fishing took place
2. depth 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

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

1.5.2 Voluntary Catch Sampling

Since 1991, commercial fishers and researchers have collaborated in an at-sea pot-sampling program with the main aim of providing temporal and spatial data on pre-recruit indices, legal sized catch, length frequencies, female 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. In the following season, sampling was done as part of an FRDC project that aimed to determine the optimal sampling strategy required to produce quantifiable and minimum variances in the mean lengths and catch rates (McGarvey et al. 1999b; McGarvey and Pennington 2001). This study demonstrated that the optimal design should incorporate a high percentage of 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. During a series of port meetings in 2008/09, 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 data. The participation level in 2008/09 represented only 20% of licence holders (Figure 1-7). Low participation in the program may bias catch rates and length frequencies. In addition, the current Management Plan for the fishery relies heavily on pre-recruit indices as determined from voluntary catch sampling. As a result, participation in the programme is strongly encouraged to ensure that future decisions for the fishery are based on reliable and

robust data. Results from the voluntary catch sampling program are presented in Section 2 of this report.

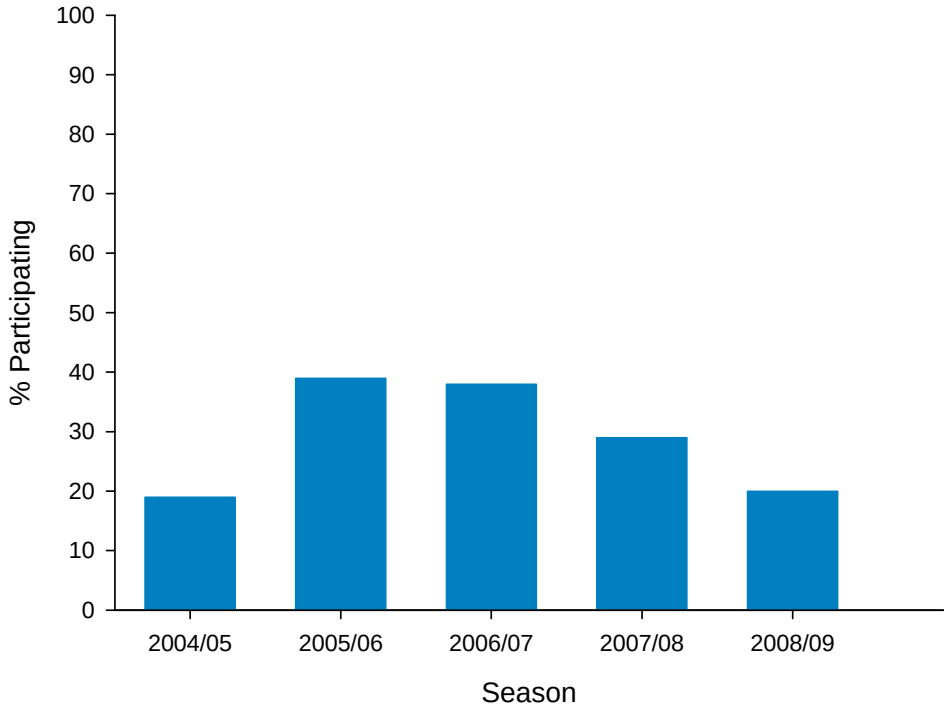

Figure 1-7 Percentage of licence holders in the NZRLF participating in the voluntary catch sampling program over the last 5 seasons.

1.5.3 Puerulus Monitoring Program

Larval recruitment processes may be related to changes in breeding stock abundance and seasonal, annual and geographic variation in recruitment to the fishery (Booth et al. 2002; Booth and McKenzie 2009). Rates of puerulus and post-puerulus settlement have been monitored in the NZRLF since 1996. Four puerulus collector sites are located in the NZRLF at McLaren Point and Taylor Island (Port Lincoln) and Marion Bay and Stenhouse Bay (Yorke Peninsula). 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.

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 2009. For ease of reference, figures and text in this section refer to the starting year of each season e.g. 2008 refers to the 2008/09 fishing season.

The scale of spatial analyses undertaken with respect to various fishery dependent data reflects their importance as performance indicators within the Management Plan for the NZRLF. For example, both CPUE and PRI (the two primary indicators) are presented by zone, region, MFA and depth. Other indicators, such as length frequency data that do not directly contribute to reference points, are presented at zonal scales only.

Estimates presented in this section are calculated from daily data and differ slightly from those based on season totals 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) both zonally and regionally. This section also presents statistics on indices such as pre-recruits and mean weights. Estimates of inter-annual variation in settlement rates of puerulus are compared with pre-recruit indices lagged by three years.

2.2 Catch, Effort and CPUE

2.2.1 Zonal trends

Catch

Total catch for the NZRLF remained relatively stable at around 600-700 tonnes during the 1970s and early 1980s (Figure 2-1). Within this period the highest catch recorded was 750 tonnes in 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. Over the next five seasons, catch declined to 446 tonnes in 2004. The decline in catch for the 2000 season partly reflected the increase in the MLS from 102 mm to 105 mm (~5%). Further reductions in catch in the 2001 and 2002 seasons partly reflect reductions in fishing effort.

Marginal increases in catch (<50 tonnes) were observed from 2004 to 2006 (491 tonnes) before a further decrease to 459 tonnes in 2007. In 2008, the NZRLF catch was only 402.7 tonnes, the lowest on record and 67.3 tonnes below the 470 tonne TACC. Overall, the 2008 figures represent a 60% decrease in catch since 1998 (1015.8 tonnes) and a 20% decrease since the introduction of quota in 2003 (503.3 tonnes). The quota has never been fully taken in the NZRLF since the introduction of the TACC system in 2003 (Table 2-1).

Effort

Nominal fishing effort in the 1970s was ~450,000 potlifts per season (Figure 2-1). However, effort doubled from 411,939 potlifts in 1977 to 805,139 potlifts in 1991. From 1991, effort fell to ~720,000 potlifts per season during the mid-1990s before decreasing further to 570,689 potlifts in 2002. Over the next five seasons, effort ranged between 553-615,000 potlifts. In 2008, it was 600,347 potlifts. Overall, while catch has fallen by 60% since 1998, effort has not declined comparatively. The 2008 estimate represents a 16.7% decrease since 1998 (720,816) and a 0.5% increase since the introduction of quota in 2003 (596,961).

Whilst inter-annual changes in nominal effort in the NZRLF are well documented, the associated changes in effective effort are poorly understood. Linnane et al. (2010) showed evidence of spatial expansion in the fishery through the 1980s and 90s likely driven by advances in global positioning systems (GPS), advanced hydro-acoustic equipment and radar. However, the data on uptake and utilisation of such technological advances by individual licence holders are not available for the NZRLF thus complicating the issue of quantifying increases in fishing efficiency.

CPUE

Catch-per-unit-effort (CPUE) in the early 1970s was over 1.40 kg/potlift (Figure 2-2). After the mid 1970s, it declined steadily to 1.1 kg/pot lift in 1984. During the late 1980s, it increased and reached a peak of 1.50 kg/potlift in 1990 before declining to 1.31 kg/potlift in 1995. CPUE rose to 1.49 kg/potlift in 1999, but then declined rapidly over the next five seasons to 0.82 kg/pot lift in 2004. The next two seasons saw a marginal increase to 0.87 kg/potlift before decreasing to 0.76 kg/potlift in 2007. In 2008, CPUE again fell to 0.69 kg/potlift, the lowest on record. This represents a 54% decrease since 1999 (1.49kg/potlift) and a 21% decrease since the introduction of quota in 2003 (0.86 kg/potlift).

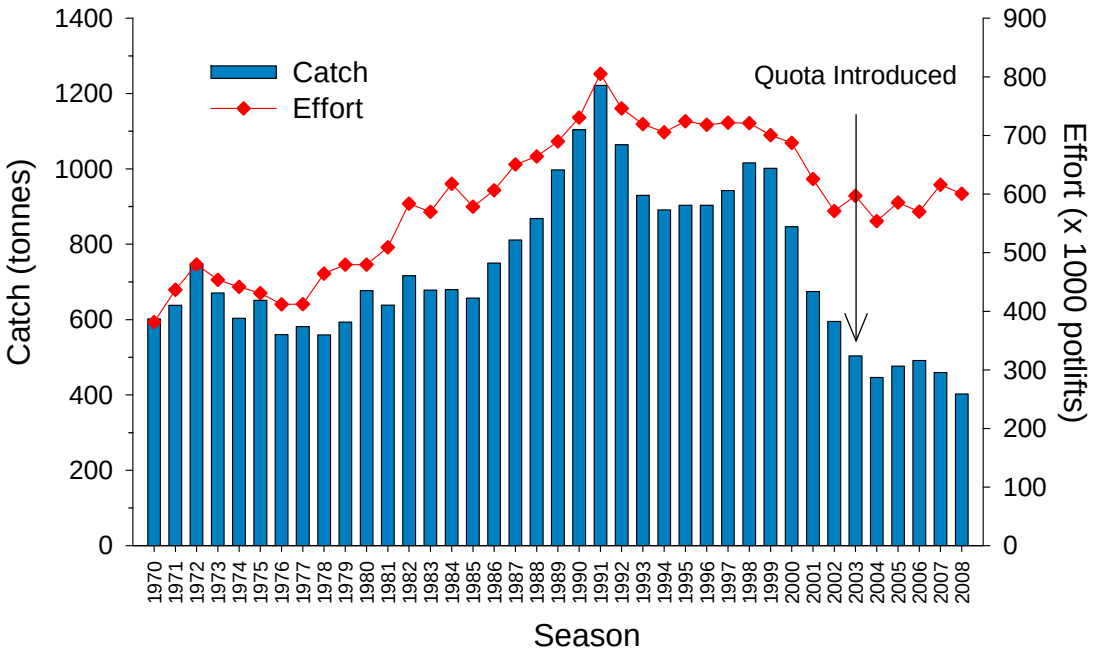

Figure 2-1 Inter-annual trends in catch and effort in the South Australian Northern Zone rock lobster fishery between 1970 and 2008.

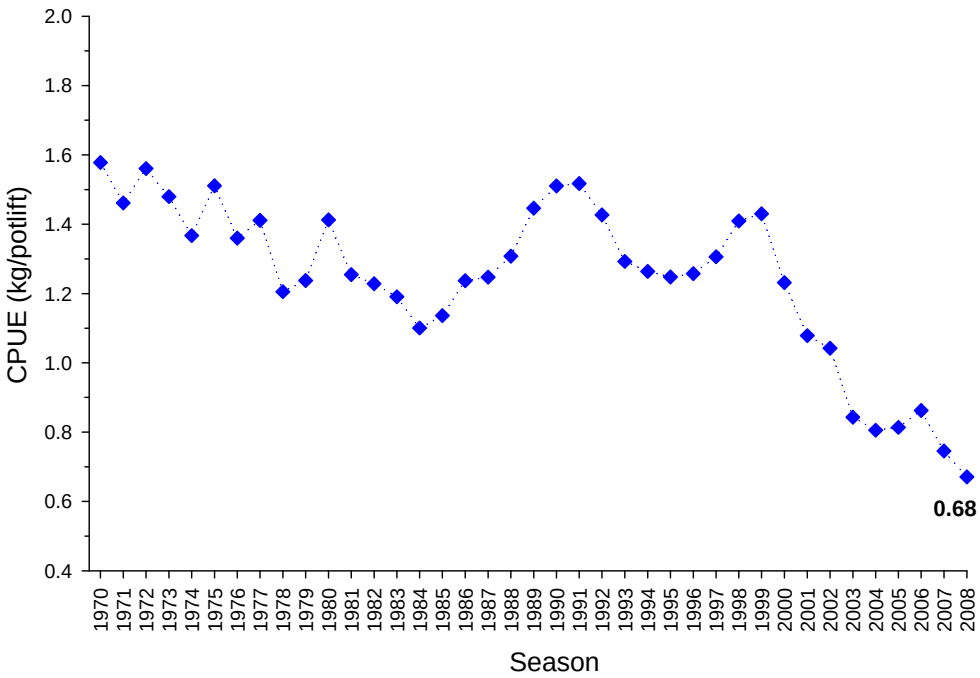

Figure 2-2 Inter-annual trends in CPUE in the South Australian Northern Zone rock lobster fishery for seasons between 1970 and 2008 (based on November-April logbook data inclusive).

Table 2-1 Chronology of Total Allowable Commercial Catch (TACC) versus actual landed catch in the NZRLF from 2003 – 2008 (t = tonnes).

Season	TACC (t)	Landed Catch (t)	Shortfall (t)	% TACC
2003	625	503	122	80
2004	520	446	74	86
2005	520	476	44	92
2006	520	491	29	94
2007	520	459	61	88
2008	470	403	67	86

2.2.2 Within-season trends

Catch and effort

The within-season trends in catch and effort in the NZRLF are temporally consistent. The majority of the catch is taken in the first four to five months of the season with highest catch generally in January. Trends in effort usually reflect those of catch.

In 2008, trends in catch and effort reflected those from previous seasons (Figure 2-3). Approximately 85% (343.1 tonnes) of the total catch (402.7 tonnes) was taken from November to March inclusive. The highest catch was taken in January (89.5 tonnes) with the lowest taken in May (16.9 tonnes). Trends in effort reflected monthly trends in catch with the highest effort in January (108,925 potlifts) and March (102,406 potlifts).

CPUE

As with catch and effort, within-season CPUE is temporally consistent (Figure 2-4). CPUE generally increases for the first three to four months of the season before decreasing thereafter. In 2008, trends were similar to those from previous seasons. CPUE increased from 0.48 kg/potlift in November to 0.82 kg/potlift in January before decreasing to 0.50 kg/potlift in May.

It is important to note that the zonal decrease in CPUE in 2008 (Figure 2-2) was observed across all months of the season. The 2008 monthly CPUE estimates were consistently lower than those observed in 2007 from November thorough to May (Figure 2-4). The most notable decrease was in November for which the 2008 estimate of 0.48 kg/potlift was ~30% below that for 2007 (0.68 kg/potlift).

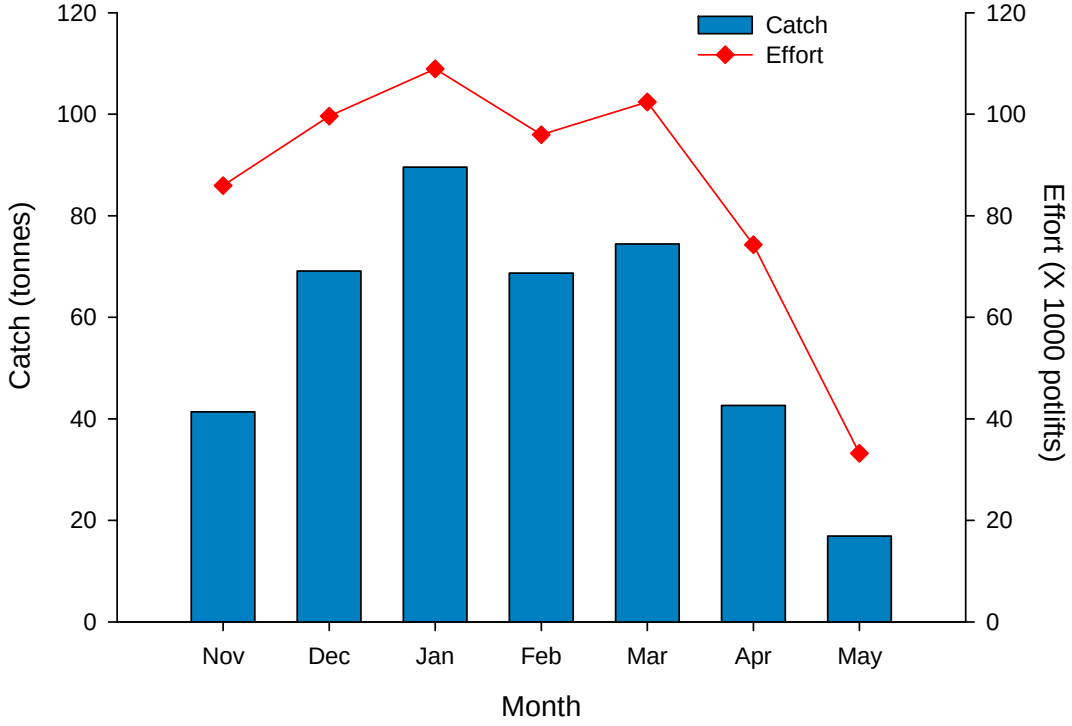

Figure 2-3 Within-season trends in catch and effort in the NZRLF during the 2008 fishing season.

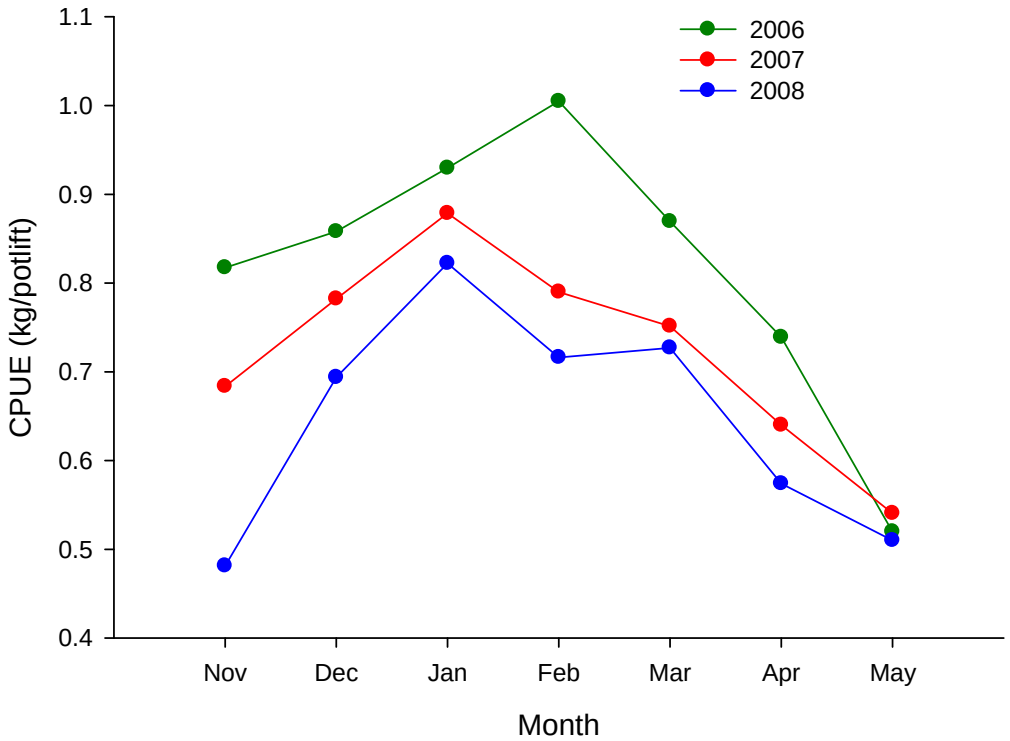

Figure 2-4 Within-season trends in CPUE in the NZRLF for the 2008 fishing season.

2.2.3 Trends across key MFAs

Catch

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 2008 are provided in Figure 2-5. Consistent with previous seasons, in 2008 ~90% of the catch came from these MFAs with 78% taken in MFAs 15, 27, 28, 39, 40, 48 and 49 (Table 2-2; Figure 2-7). During 2008, catch increased marginally (<5 tonnes) in MFAs 7 and 8 however, overall catch in these regions are low. Catch decreased in all other MFAs in 2008. The most notable was MFA 28 where catch decreased from 95.2 to 75.1 tonnes from 2007. Long term trends in catch show substantial declines in all major MFAs within the NZRLF especially MFAs 15, 28, 39 and 49. For example, catch in MFA 15 has decreased by 68% from 141 tonnes in 1998 to 45 tonnes in 2008. Similarly, catch in MFA 28 has decreased by 65% from 218 tonnes in 1997 to 75 tonnes in 2008. Comparable decreases in catch over the same time periods are also evident in MFAs 39 and 49.

Effort

As in inter-annual patterns (Figure 2-1), effort across MFAs closely reflects trends in catch (Figure 2-5). Over the last five seasons there have been notable increases in effort in MFAs 15 and 28, while effort has generally decreased in MFAs 39 and 49. In 2008, the majority of effort occurred in MFAs 15, 28, 39, 40, 48 and 49. Most notable is MFA 28, where effort increased by 38% from 85,246 potlifts in 2004 to 117,677 potlifts in 2008.

CPUE

The ten major MFAs in the NZRLF show similar inter-annual trends in CPUE, with peaks in catch rate during the 1970s, early 1990s and late 1990s and low CPUEs in the early 1980s (Figure 2-6). Since the late 1990's, the CPUE has generally declined in most MFAs. In 2008, with the exception of a marginal increase in MFA 8, CPUE continued to decrease across all major MFAs. The 2008 estimate is currently the lowest CPUE on record in MFAs 7, 28, 39, 40, 48 and 49 which combined, contributed ~72% of the total catch in the NZRLF in 2008.

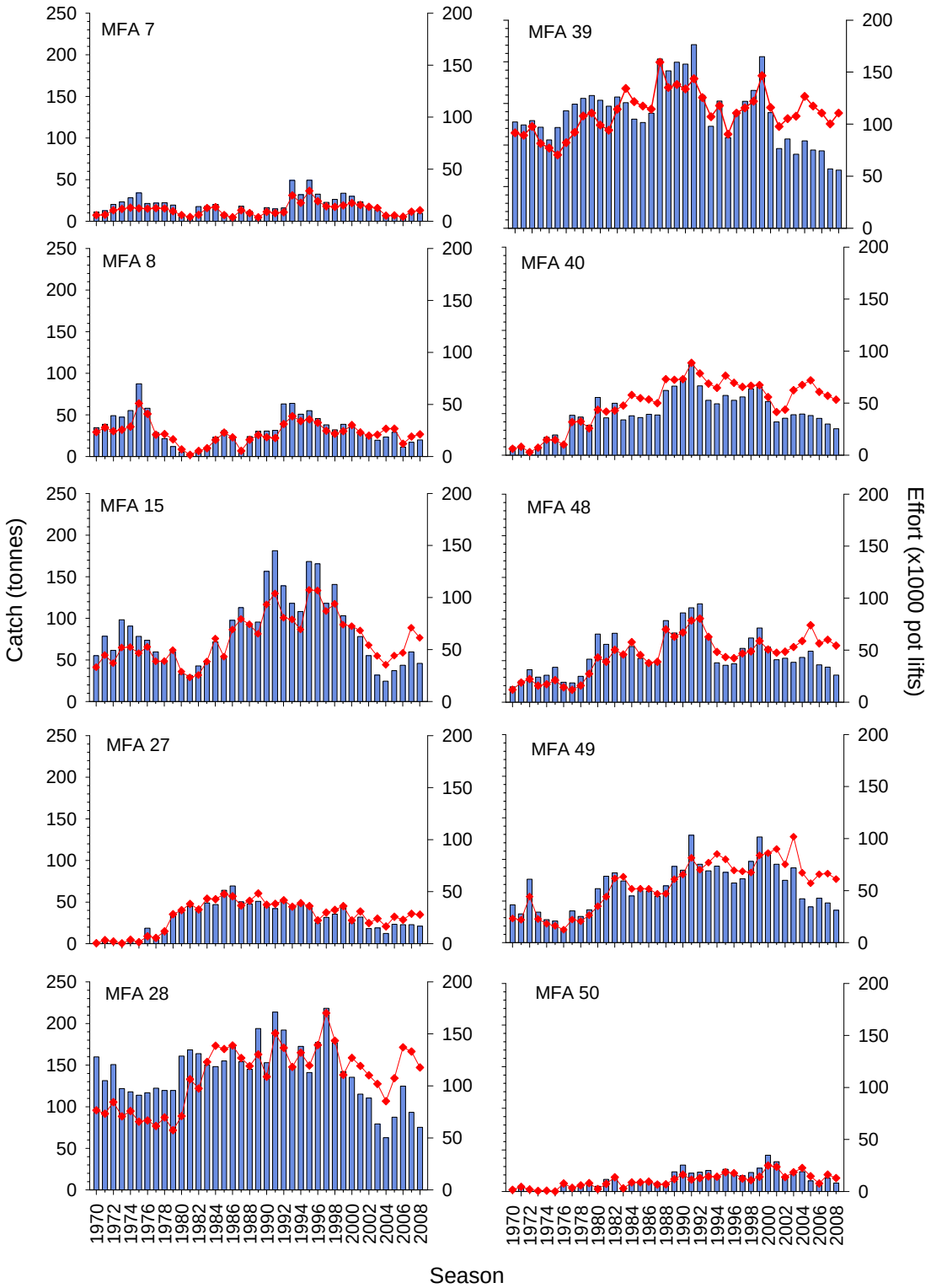

Figure 2-5 Inter-annual trends in catch and effort in the 10 main MFAs (from north-west to south-east) of the NZRLF for the fishing seasons between 1970 and 2008 (note: alternate seasonal ticks on X axis).

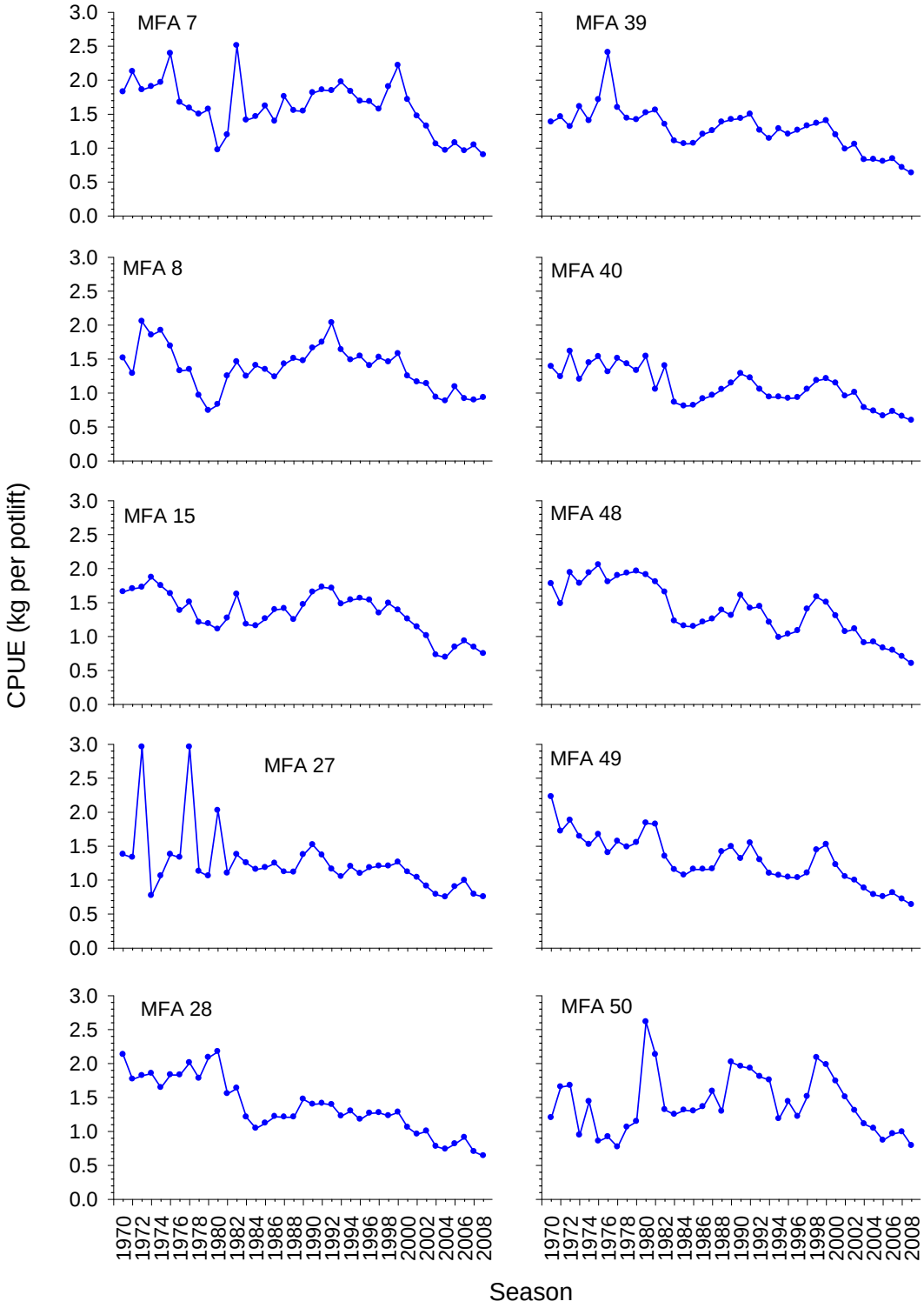

Figure 2-6 Inter-annual trends in CPUE (± SE of the mean) of the 10 main MFAs (from north-west to south-east) of the NZRLF for the fishing seasons between 1970 and 2008 (note: alternate season ticks on x axis).

Table 2-2 Total catch taken from the 10 main MFAs in the NZRLF in 2008.

MFA	Catch (t)	% Total Catch
7	9.41	3
8	19.86	6
15	45.73	13
27	21.02	6
28	75.19	20
39	69.82	20
40	31.64	9
48	32.67	9
49	38.88	11
50	10.17	3

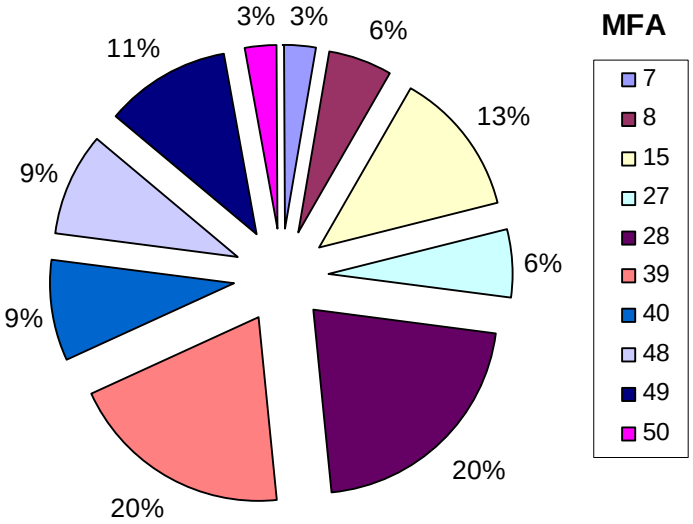

Figure 2-7 Proportion of total catch taken from the 10 main MFAs in the NZRLF in 2008.

2.3 Trends by Region

2.3.1 Catch

Regional trends in catch in the NZRLF (refer to Figure 1-4) between 1970 and 2008 are presented in Figure 2-8. While up to 172 tonnes were taken in Region A in 1993, catches in this Region are now <50 tonnes with just 34.7 tonnes landed in 2008. The majority of the catch is taken in Regions B, C and D. In recent seasons, catches in all Regions have declined, reflecting the zonal trends presented in Figure 2-1.

The 2008 season was the fourth successive one that catch has declined in Region C and the ninth successive season of decline in Region D. As a result, current catch levels in all Regions are low in relation to historical estimates. For example, the 2008 estimate in Region B of 168.7 tonnes is 63% lower than the catch of 453.34 tonnes from this Region in 1997. Similarly, the 2008 catch in Region D of 138.9 tonnes is 65% lower than the catch of 399.51 tonnes in 1999 from the same area. The 2008 catch levels in Regions C (60 tonnes) and D are the lowest on record.

2.3.2 Effort

Trends in effort generally reflect trends in catch in all Regions (Figure 2-8). However effort increased in Region B over the last four seasons, which did not translate into an increase in catch. Effort in this region has increased by 56% from 157,552 potlifts in 2004 to ~246,386 in 2008. It should also be noted that while catch has decreased by 65% since 1999 in Region D, effort has only decreased by 19% over the same period (from 266,277 to 216,284 potlifts).

2.3.3 CPUE

As with zonal trends in CPUE (Figure 2-2), there has been a general decrease in CPUE across the four Regions of the NZRLF since the late 1990s (Figure 2-9). As a result, the 2008 estimates of 0.94, 0.69, 0.61 and 0.65 kg/potlift were the lowest on record for Regions A, B, C and D respectively.

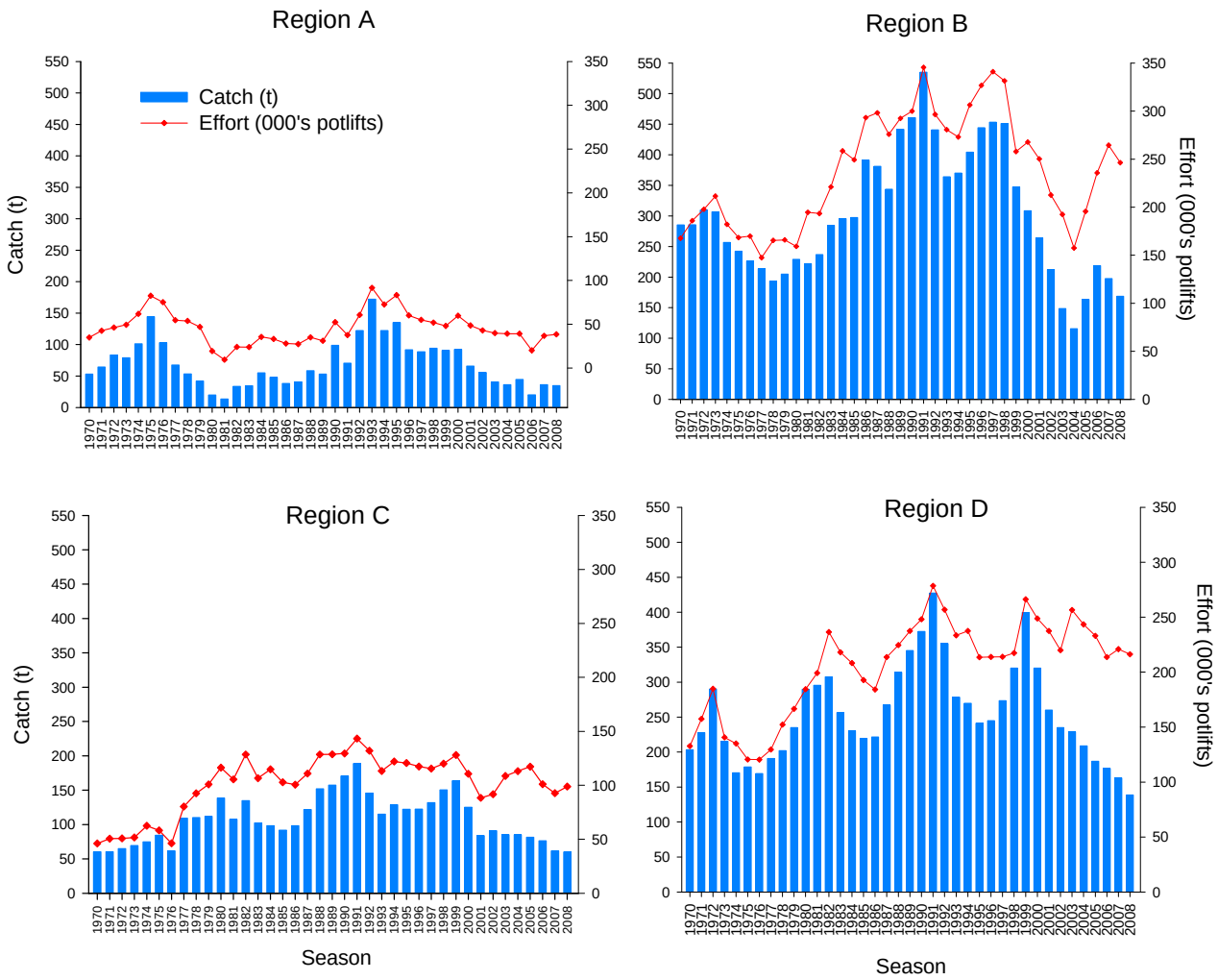

Figure 2-8 Catch and effort by region in the NZRLF from 1970 to 2008. Note that catch and effort from MFA 39 (Figure 1-1) has been apportioned 30:70 between Regions C and D.

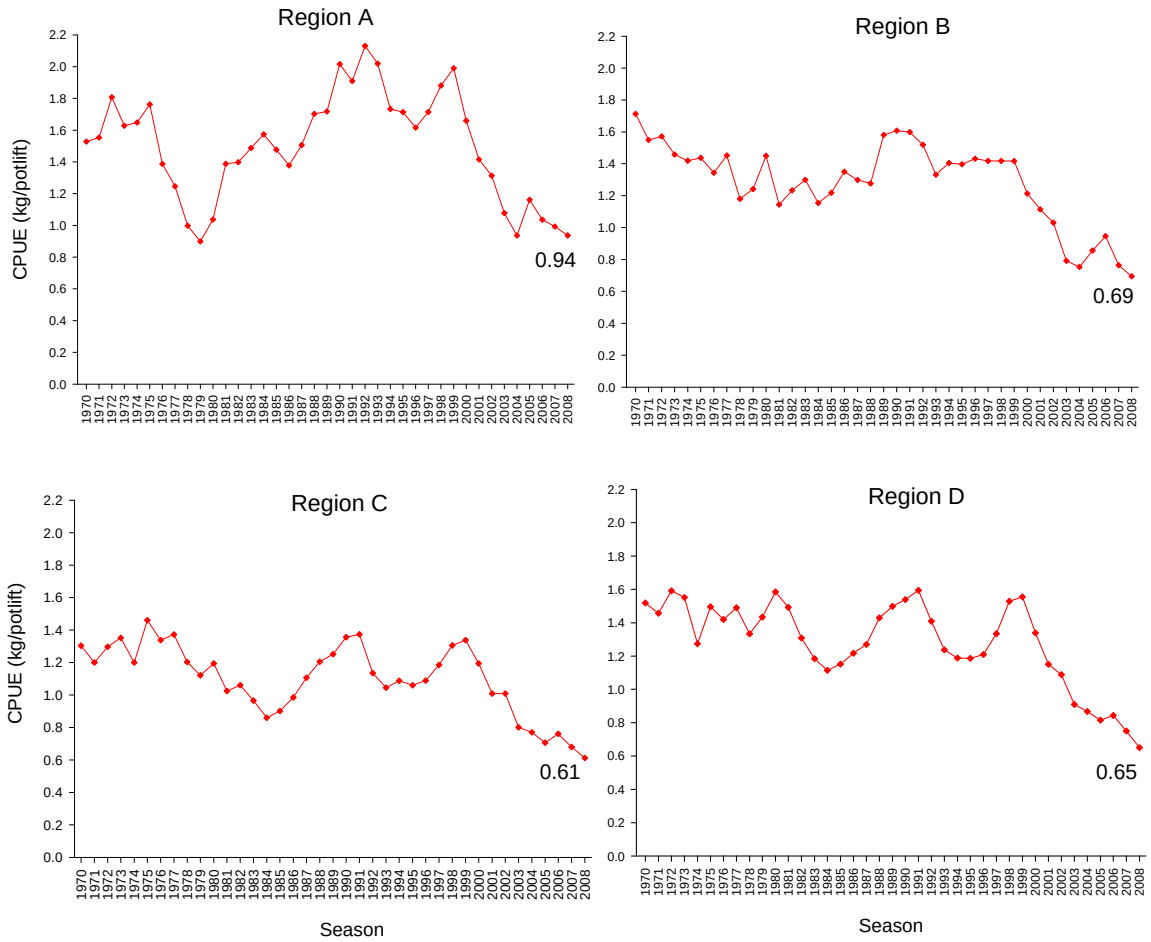

Figure 2-9 CPUE by region in the NZRLF from 1970 to 2008. Note that catch and effort from MFA 39 (Figure 1-1) has been apportioned 30:70 between Regions C and D to calculate catch rate.

2.4 Trends by Depth

2.4.1 Catch

Over the last 6 seasons, the majority (>80%) of the catch in the NZRLF has been taken at depths of <60 m (Figure 2-10). This trend continued in 2008 with 45% of catch taken from depths of 0-30 m and 44% taken from depths of 31-60 m. The deeper waters 61-90 m contributed 6% to catch with only 5% coming from depths >90 m. For zonal estimates of catch by depth pre 2001, see Linnane et al. (2007).

Most of the main MFAs follow a similar pattern in catch by depth to that described for the entire fishery, with the majority of the catch coming from shallower depths of 0-30 and 31-60 m in recent seasons (Figure 2-12). In 2008, as in previous seasons MFAs 48 and 49 located south of Kangaroo Island (Figure 1-1), were the only MFAs where a notable proportion of the catch (~20-35%) was taken in deeper waters of >60 m depth. For estimates of catch by depth pre 2001 in key MFAs, see Linnane et al. (2007).

2.4.2 CPUE

CPUE generally increases with depth in the NZRLF. Lowest catch rates are in shallower depths of 0-30 and 31-60 m while higher CPUEs are observed in waters >60 m (Figure 2-11). In 2008, in depths of <60m CPUE increased from ~0.5 kg/potlift in November to ~0.8 kg/potlift in January before decreasing over the next four months to a season low of ~0.4 kg/potlift in May. Overall trends were similar in deeper waters but at higher catch rates with the exception of January and February where CPUE fell to 0.75 and 0.57 kg/potlift respectively in depths of >90m. Catch rates in depths >60 m were highest in December and March when CPUE ranged from ~0.85–1.1 kg/potlift. Lowest catch rates in the 61-90 m depth range were observed in May at 0.46 kg/potlift. Trends in CPUE by depth in 2008 were generally consistent with those observed in recent seasons within the NZRLF (Linnane et al. 2007).

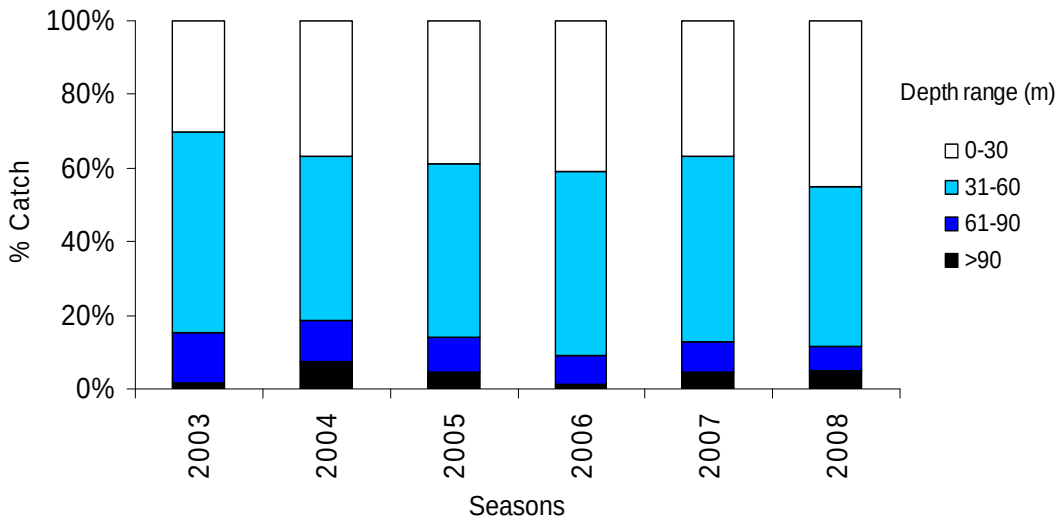

Figure 2-10 Percentage of the catch taken from four depth classes in the NZRLF from 2003-2008.

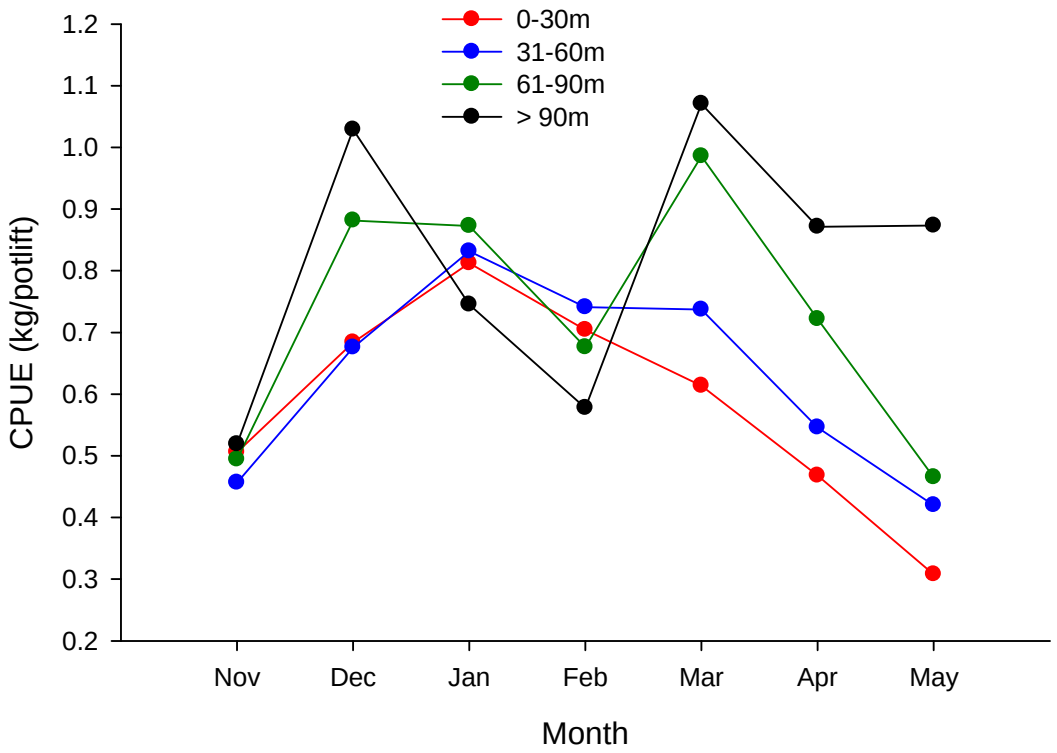

Figure 2-11 Mean monthly CPUE (+/- SE) in four depth classes in the NZRLF during the 2008 fishing season.

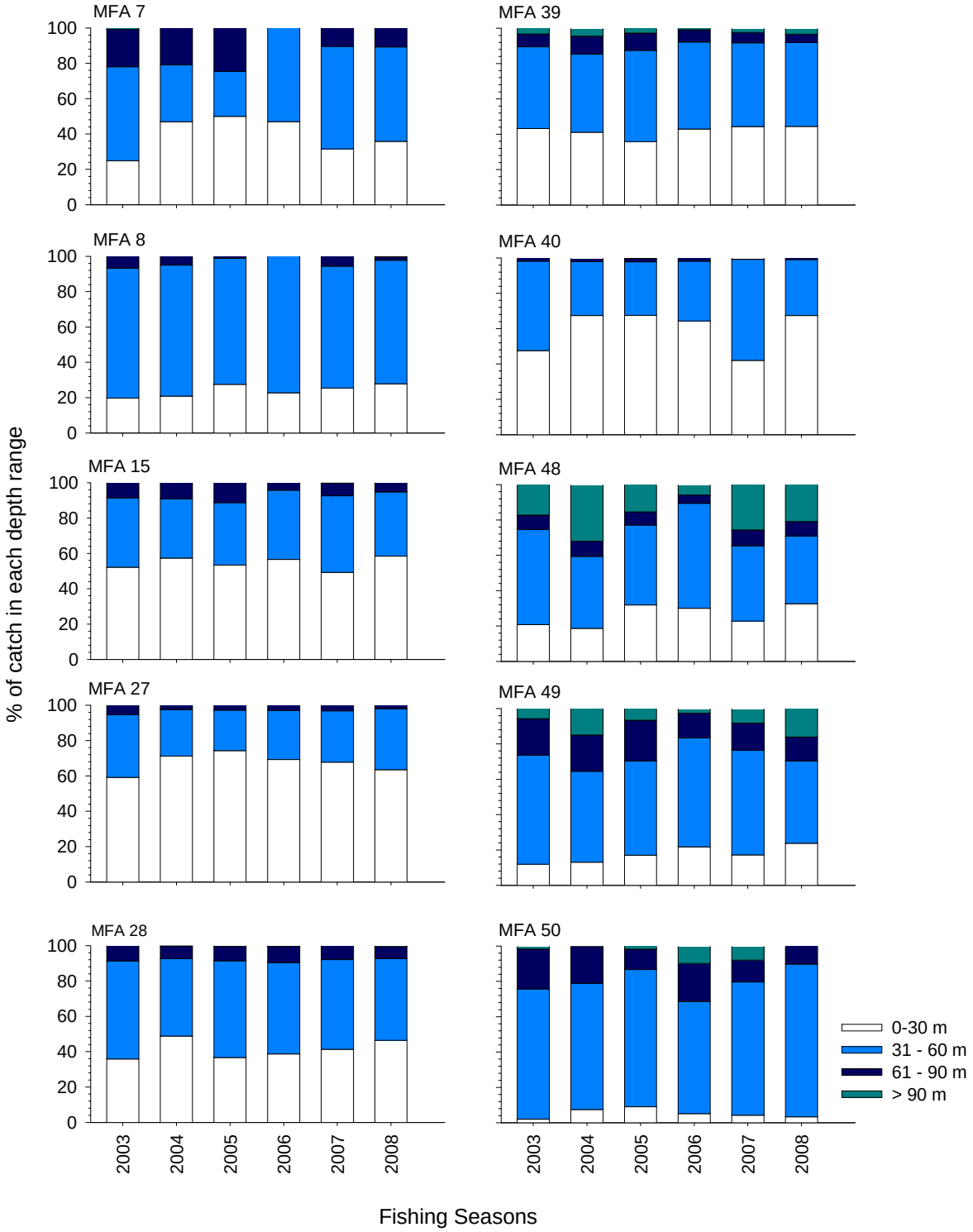

Figure 2-12 Percentage of the catch taken from four depth classes in the 10 major MFAs of the NZRLF from 2003 - 2008.

2.5 Pre-Recruit Index

2.5.1 Zonal trends

The introduction of escape gaps in 2003 means that data used to calculate a pre-recruit index (PRI - number of undersized/pot lift) is dependent on catch sampling, where the escape gaps from up to 3 pots are closed. However, it should be highlighted that participation levels in 2008 were only 20%. As a result, estimates of PRI should be viewed with caution.

PRI increased over the period of 1994 to 1998, peaking at 0.51 undersize/potlift before decreasing to 0.22 undersized/potlift in 2001 (Figure 2-13). Over the next four seasons, PRI increased to 0.49 undersized/potlift in 2005. However, over the next two seasons decreased to 0.29 undersized/potlift in 2007. In 2008, the PRI increased to 0.67 undersized/potlift, the highest on record. This presumably reflects high puerulus indices observed in 2005 (Figure 3-1), given ~3 years between settlement and PRI. Trends in logbook PRI generally compare with those from catch sampling but at lower levels, presumably reflecting the impact of escape gaps (Figure 2-14).

2.5.2 Within-season trends

In 2008, PRI increased from 0.56 undersized/potlift in November to 0.79 undersized/potlift in February before decreasing thereafter (Figure 2-15). Since the majority of undersized are caught between November and March, these months are exclusively used to calculate annual indices.

2.5.3 Trends by Region

In 2008, the regional trends in PRI (Figure 2-16) reflected those zonally (Figure 2-13). Estimates for 2008 were 0.03, 0.26, 1.17 and 0.91 undersized/potlift in Regions A, B, C and D, respectively. Note that given the low participation level in the program in 2008 (Figure 1-7), regional estimates of PRI should be viewed with caution.

2.5.4 Trends across key MFAs

The PRI is generally low in MFAs 7, 8, 15, 27 and 28 and high in the more southern MFAs of 39, 40, 48, 49 and 50 (Figure 2-17). In most MFAs, PRI increased between 1996 and 1998 before decreasing thereafter. In 2008, PRI remained low in the MFAs

in the north-west of the zone (i.e. MFAs 7, 8, 15, 27, and 28) but increased in the south-eastern MFAs of 39, 40, 49 and 50.

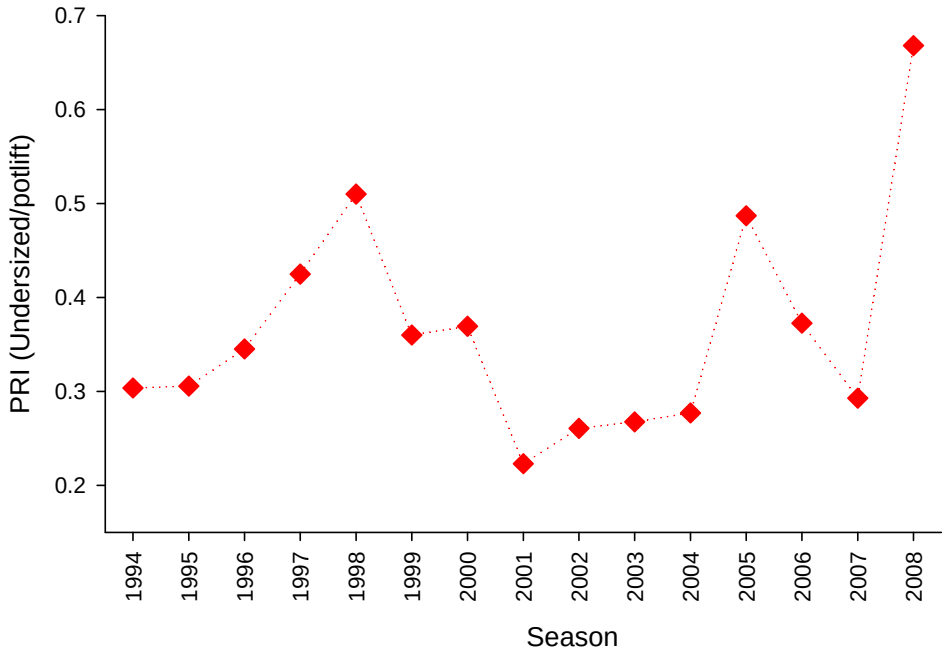

Figure 2-13 Inter-annual trends in pre-recruit index in the NZRLF from 1994 to 2008 as calculated using voluntary catch sampling data (November-March inclusive).

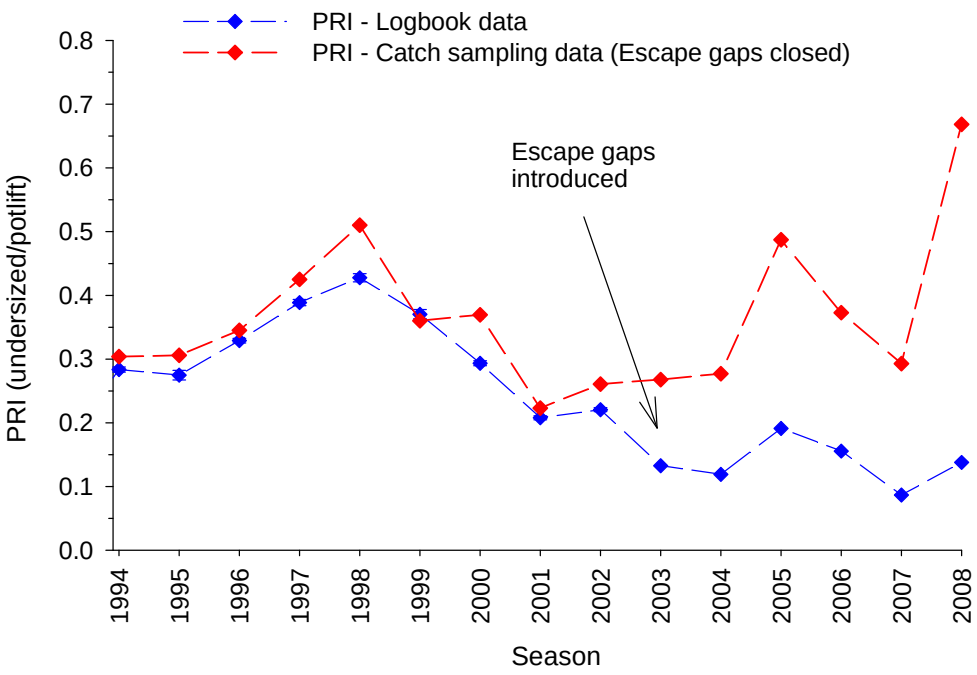

Figure 2-14 Comparison of inter-annual trends in pre-recruit index from logbook and voluntary catch sampling data from 1994 to 2008 (November-March inclusive).

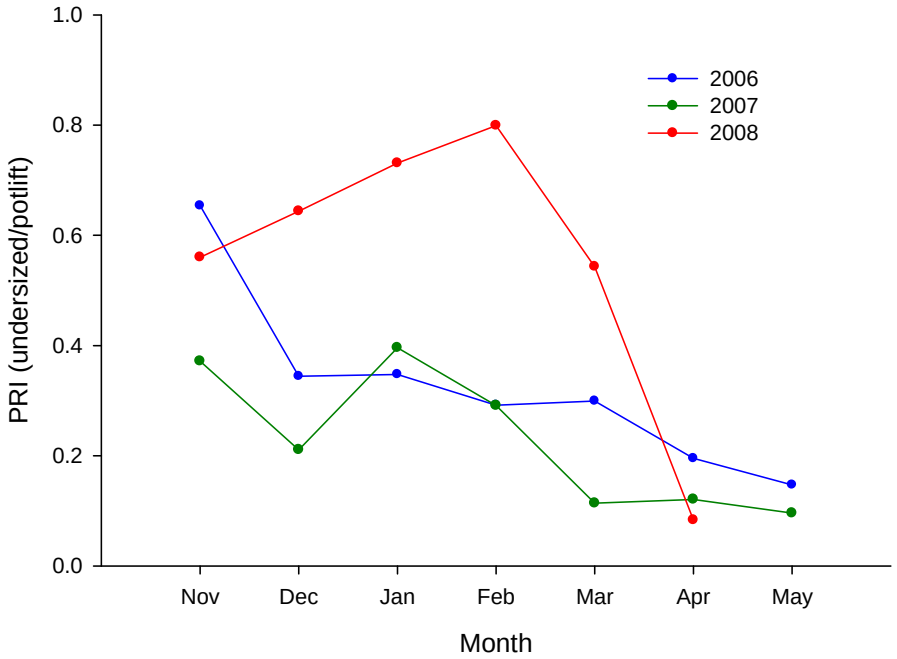

Figure 2-15 Within season trends in pre-recruit index in the NZRLF for the 2006, 2007 and 2008 fishing seasons as estimated from voluntary catch sampling data.

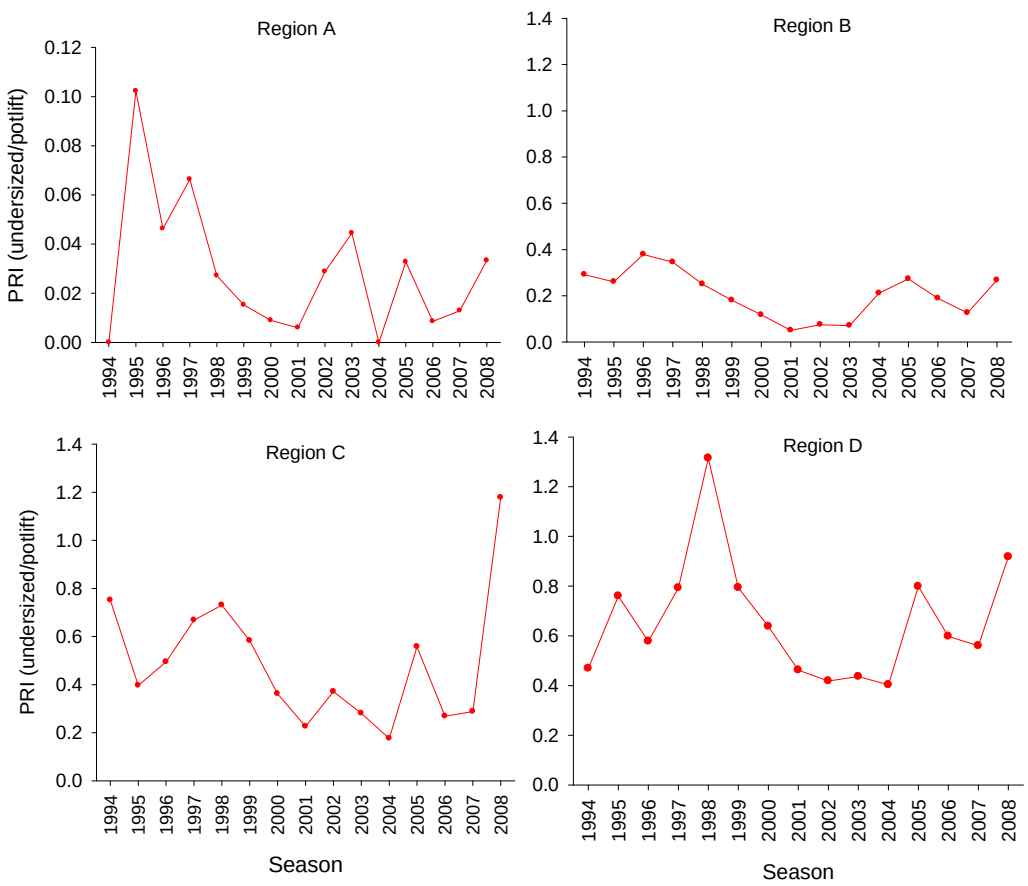

Figure 2-16 Pre-recruit index (PRI number of undersized/potlift) by region in the NZRLF from 1994 to 2008. Note that PRI from MFA 39 (Figure 1-1) has been apportioned 30:70 between Regions C and D.

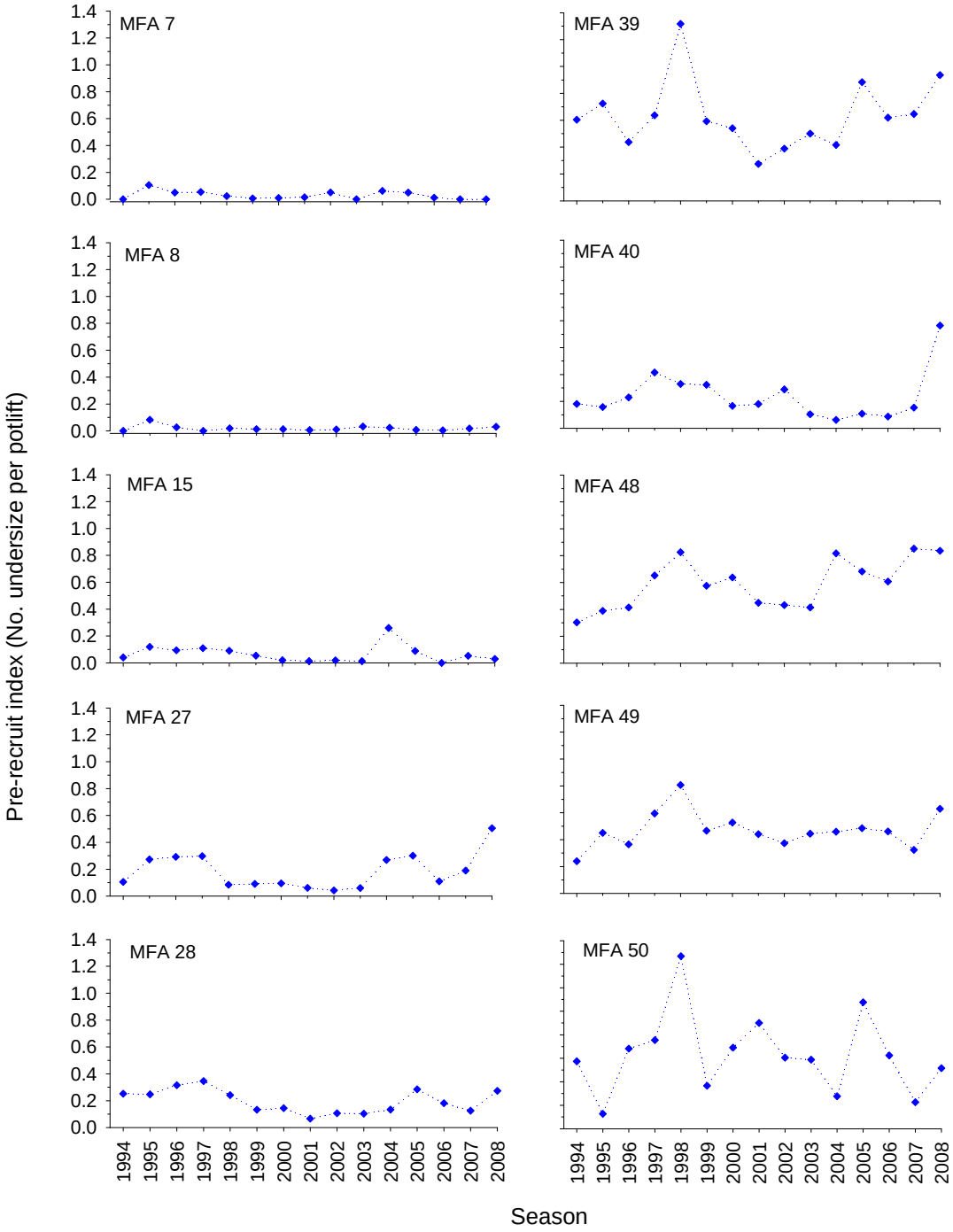

Figure 2-17 Mean pre-recruit index (catch sampling data) for MFAs in the NZRLF from 1994 to 2008 (Numerical order of MFAs is from north-west to south-east). Refer to Figure 1-1 for location of MFAs.

2.6 Mean Weights

2.6.1 Zonal trends

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. Since 1983, the mean weight of lobsters taken in the NZRLF has fluctuated between 1.00 and 1.21 kg (Figure 2-18). The lowest mean weight was recorded in 1988 and 1989 with peaks in 1984 (1.08 kg) and 1995 (1.16 kg), with that of 1.21 kg for the 2001 season being the highest recorded for the fishery. Over the next five seasons, mean weight decreased, declining to a historical low of 1.0 kg in 2006. During 2007, mean weight increased markedly to 1.13 kg before decreasing marginally to 1.10 kg in 2008. From 1998 to 2001 the gradual increase in lobster mean weight probably 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.

2.6.2 Within-season trends

Since the 1970s, there has been a consistent trend of increasing mean weight as the fishing season progresses indicating that smaller lobsters are caught early in the season (November to January) compared to those between February to May (Figure 2-19). In 2008, mean monthly weight was similar to previous seasons being lowest in November at 0.96 kg and highest in April at 1.25 kg.

2.6.3 Trends across key MFA's

Mean weights of lobsters are highest in MFAs located in the north of the NZRLF (e.g. MFAs 7, 8, 15, 27), and lowest in MFAs located further south (e.g. 48, 49, 50) (Figure 2-20). Between 1983 and 1998, mean weights were relatively stable in most MFAs but increased between 1998 and 2001, except in MFA 8. Since 2001, mean weight has generally decreased in most MFAs reflecting the zonal estimates of mean weights over the same period (Figure 2-18). However, in 2007, mean weight increased in all major MFAs. In 2008, there were decreases in MFAs 7, 15, 28, 39, 40 and 50 while marginal increases were recorded MFAs 8, 48 and 49.

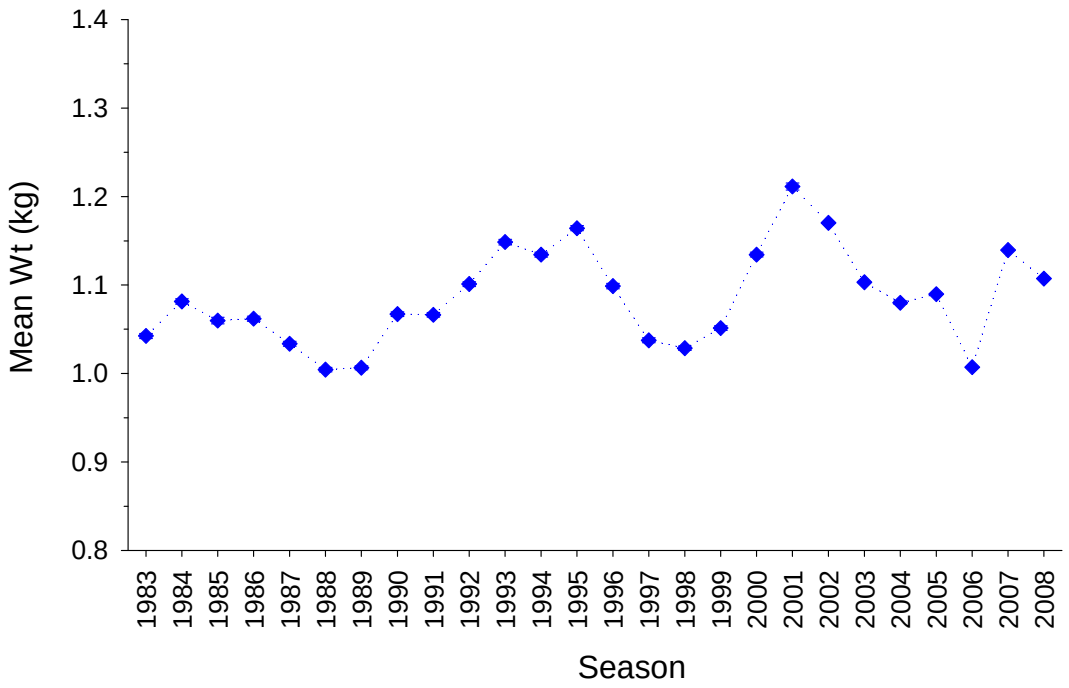

Figure 2-18 Inter-annual trends in the mean weight of lobsters in the NZRLF for the fishing seasons between 1983 and 2008.

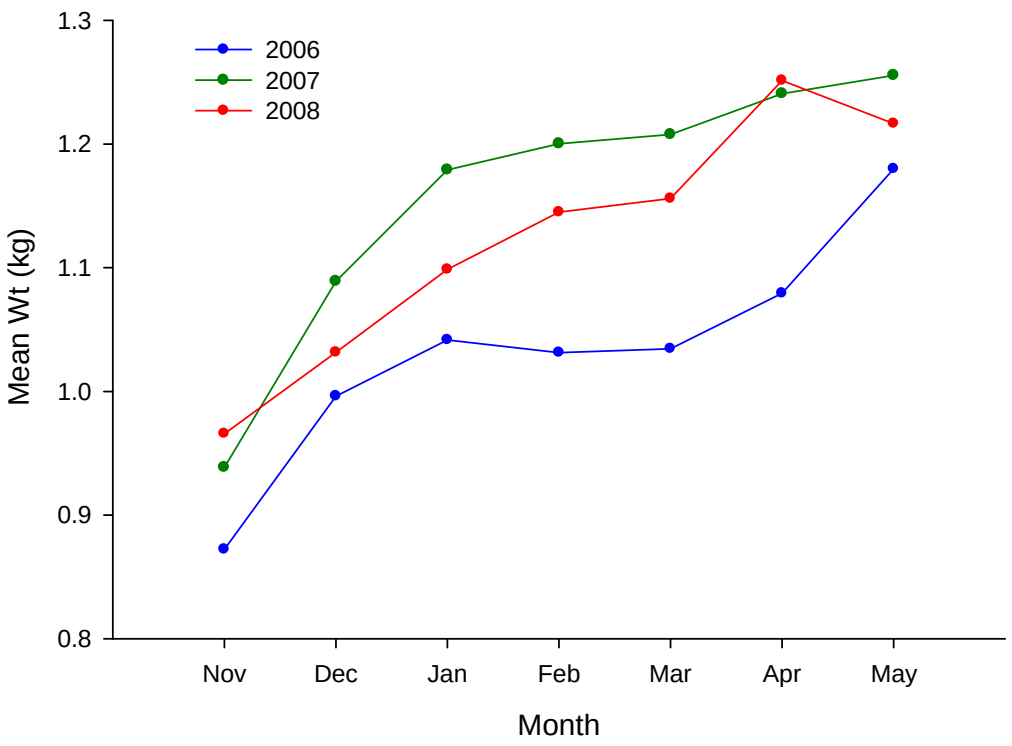

Figure 2-19 Within-season trends in the mean weight of lobsters in the NZRLF during the 2006, 2007 and 2008 seasons.

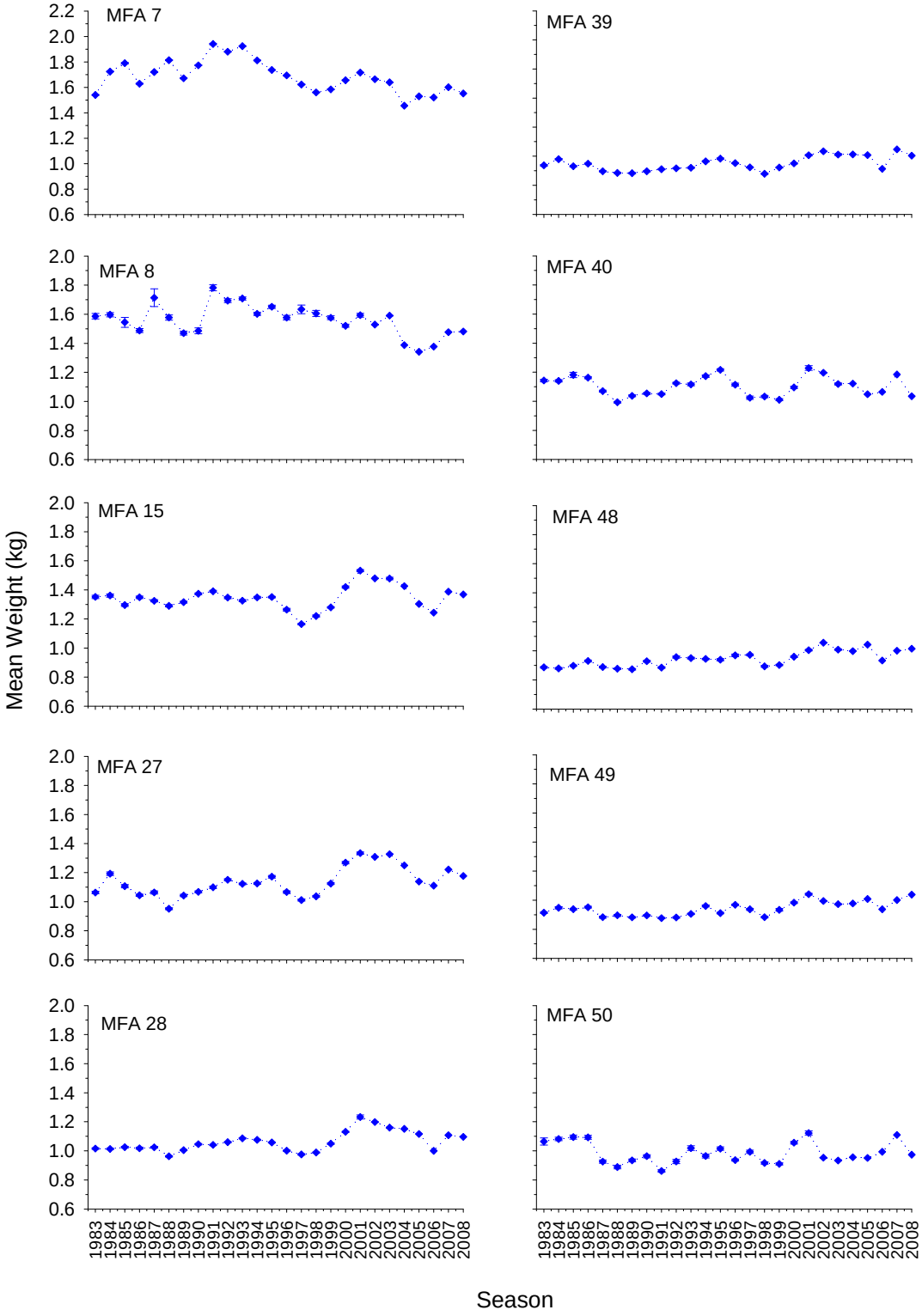

Figure 2-20 Inter-annual trends in the mean weights of lobsters for the main MFAs of the NZRLF for the fishing seasons between 1983 and 2008.

2.7 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) as part of the voluntary catch sampling programme. The number of lobsters measured is proportional to the level of participation in the programme which has ranged between 20-40% over the last five seasons (Figure 1-7).

In 2008, a total of 4,540 lobsters were sampled (Figure 2-21). Of these, 51% were males and 49% females. Male lobsters, which generally grow faster and reach larger sizes than females, ranged between 70 and 200 mm CL. In contrast, few females were larger than 150 mm CL. In 2008, the size classes of lobsters reflected estimates from pre-recruit indices (Figure 2-13) with the frequencies highest for both males and females below the MLS of 105 mm CL. For example, in 2008, 45% and 48% of all males and females lobsters respectively were below the MLS. This represents a noticeable increase from 2007 when these size classes represented only 20% and 29% of all males and females, respectively (Figure 2-22). However, while undersized numbers appear to have increased, the frequencies of legal sized individuals decreased between 2007 and 2008. For example, in 2007, the size classes for both sexes were dominated by lobsters above the MLS, particularity in the 110–140 mm CL size range for males and the 105-125 mm CL size range for females (Figure 2-22). In 2008, the frequency of individuals in these size classes clearly decreased (Figure 2-21) reflecting the observed decrease in zonal catch rate of legal sized lobsters within the fishery (Figure 2-2).

Given that a fishery independent survey has yet to be implemented in the NZRLF, all length frequency data presented in this report are from fishery dependent sources. Limitations associated with fishery dependent estimates of size should be noted. Specifically, lobster catchability varies by both size and sex (Frusher and Hoenig, 2001) and is highly dependent on a variety of factors such as environmental or behavioural variability (Addison, 1995). As observed from the NZ catch sampling program, lobsters <70 and >210 mm CL are rarely landed by commercial fishing pots, which is consistent with the size selectivity of trap-caught spiny lobsters in other fisheries (e.g. Goni et al., 2003). As a result, data required to estimate length frequencies are limited to specific size classes that are highly fishery dependent and should therefore be treated with some caution.

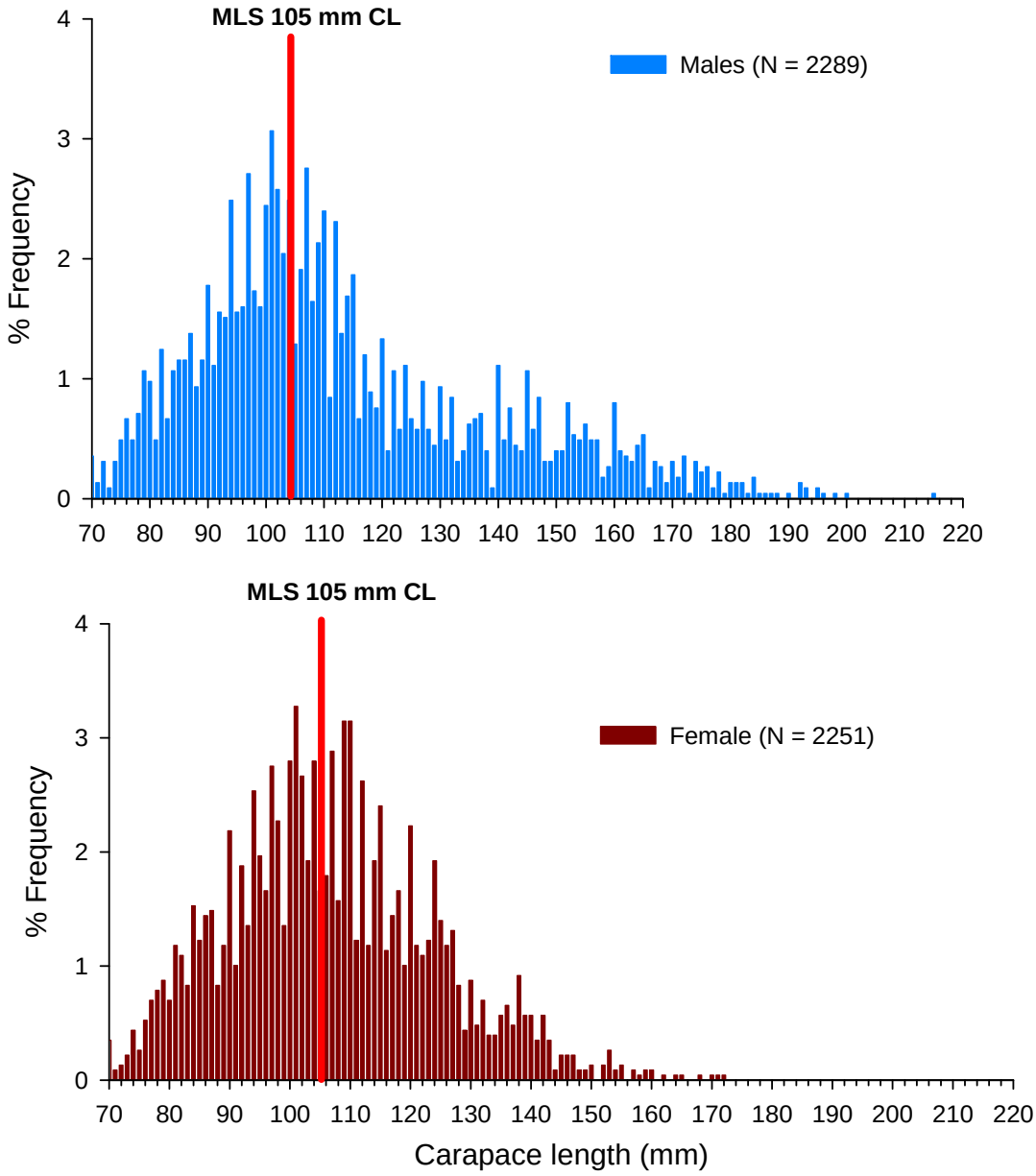

Figure 2-21 Length frequency distributions of male and female lobsters in the NZRLF 2008 fishing season.

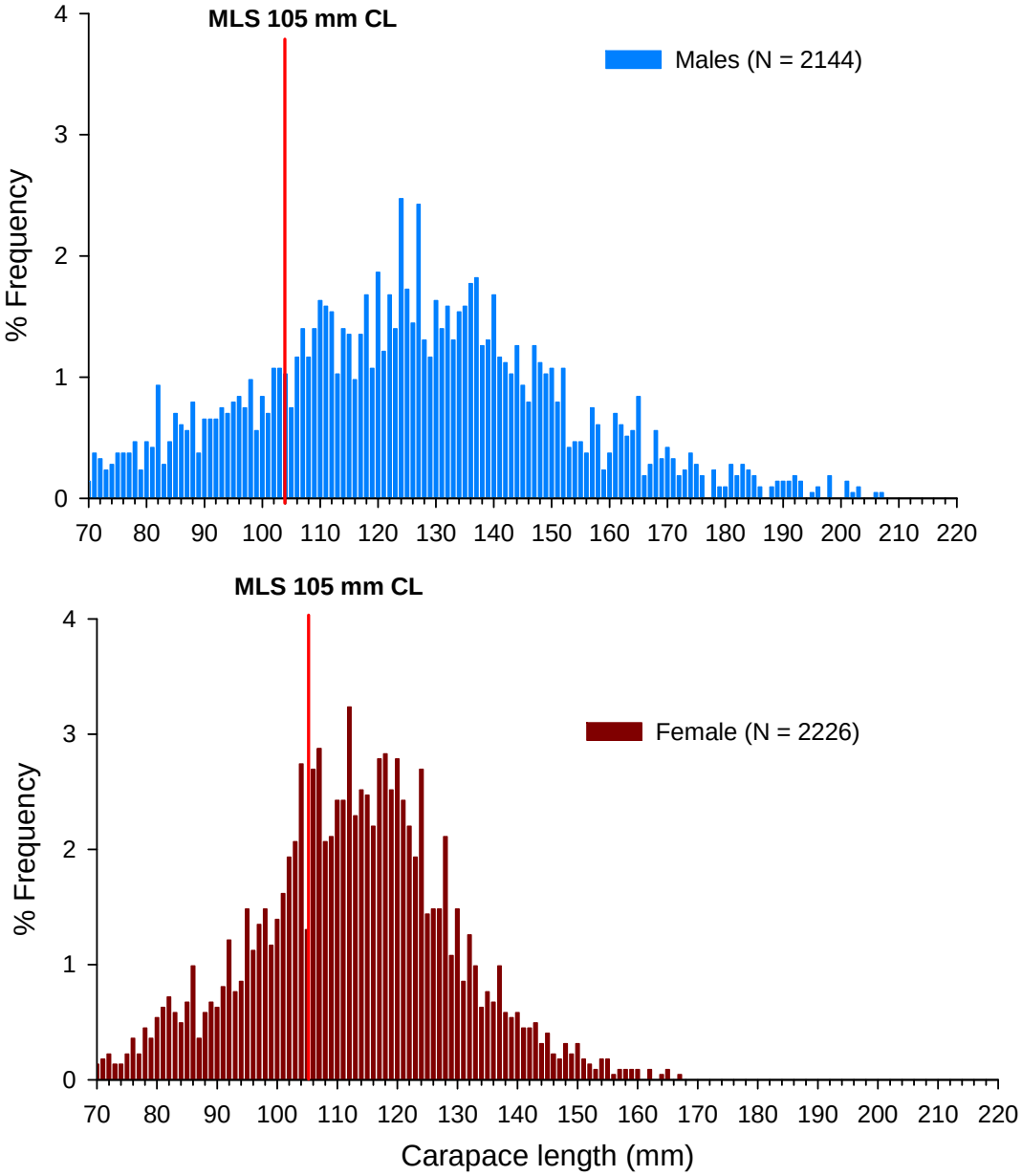

Figure 2-22 Length frequency distributions of male and female lobsters in the NZRLF during the 2007 season.

2.8 Spawning lobsters

In the NZRLF, the majority of spawning (i.e. ovigerous) lobsters are caught in November and December as per the annual reproductive cycle of the species (Phillips, 2006). Zonal trends in the catch rate of spawners (Figure 2-23) broadly reflect those of overall catch rate (Figure 2-2). The number of spawning lobsters/potlift decreased from 0.09 spawners/potlift in 1997 to 0.01 spawners/potlift in 2001. Since then, the index has remained low and has not exceeded 0.03 spawners/potlift. In 2008, the estimate was 0.01 spawners/potlift, representing an 88% decrease in catch rate since 1997 (0.08 spawners/potlift). Overall, the findings suggest a considerable decrease in the biomass of spawning lobsters in the NZRLF over the last 10 seasons.

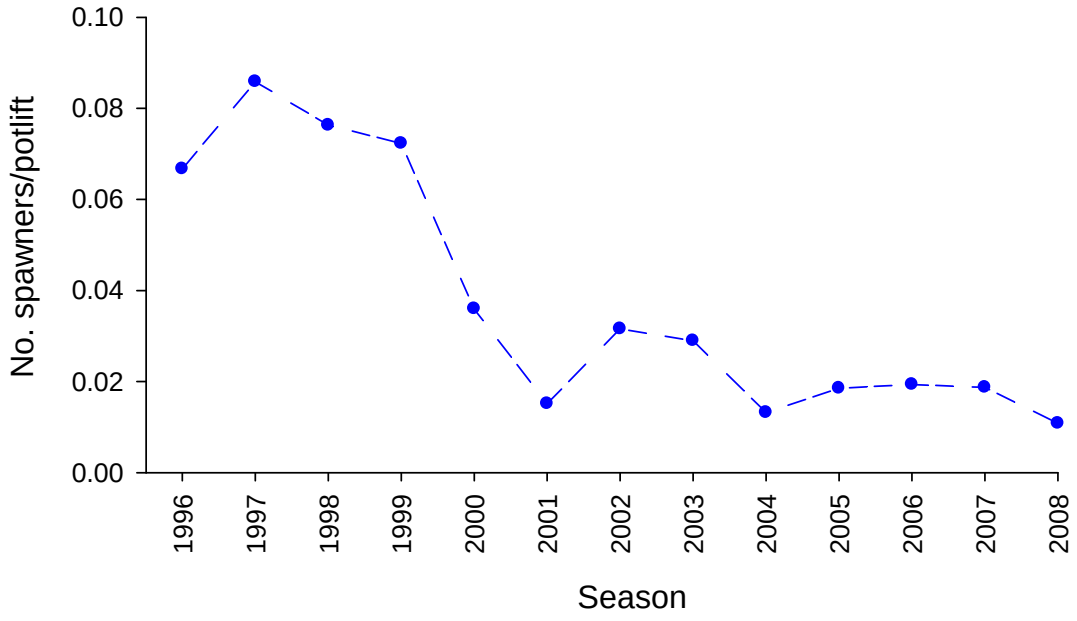

Figure 2-23 Inter-annual trends in the number of spawning lobsters in the NZRLF between 1996 and 2008.

2.9 Lobster Mortalities

Overall, the numbers of dead lobster, as recorded in logbook data since 1996, appear low and have never exceeded 0.1 dead/potlift (Figure 2-24). Between 1996 and 1999, estimates ranged between 0.07 and 0.09 dead/potlift before decreasing to ~0.04 dead/potlift in 2001. Since then, the index has not exceeded 0.05 dead/potlift and in 2008 was ~0.04 dead/potlift. The majority of in-pot mortality is caused by predation from the maori octopus (*Octopus maorum*) (Brock and Ward 2004; Brock et al., 2007). Temporal trends in the catch rate of this species in the NZRLF are provided in Section 2.10.

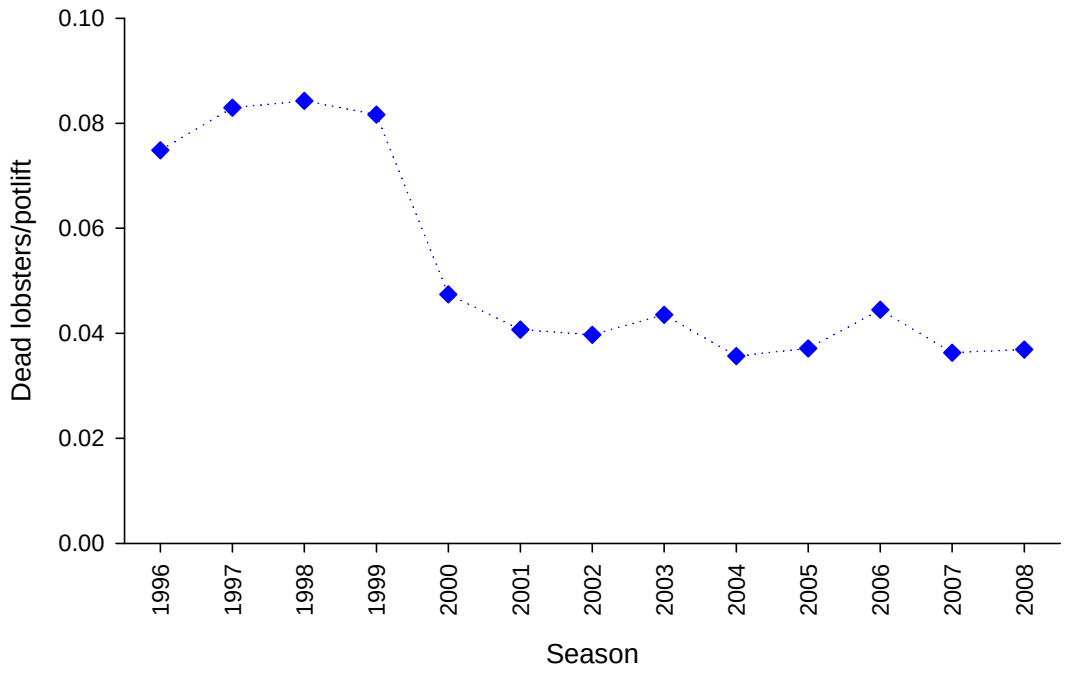

Figure 2-24 Inter-annual trends in CPUE of dead lobsters in the NZRLF from 1996 to 2008.

2.10 Octopus Catch Rate

Annual catch rates of octopus in the NZRLF are low and since 1996 have not exceeded 0.025 octopus/potlift (Figure 2-25). Temporal trends indicate that the highest CPUE of 0.022 octopus/potlift was record in 1998. Over the next 9 seasons however, catch rates decreased and now rarely exceed 0.005 octopus/potlift. In 2008, the estimate was 0.004 octopus/potlift. Temporal trends in octopus catch rate are strongly correlated with those observed for dead lobsters over the time period of 1996 – 2008 (R^2 = 0.94; see Figure 2-24).

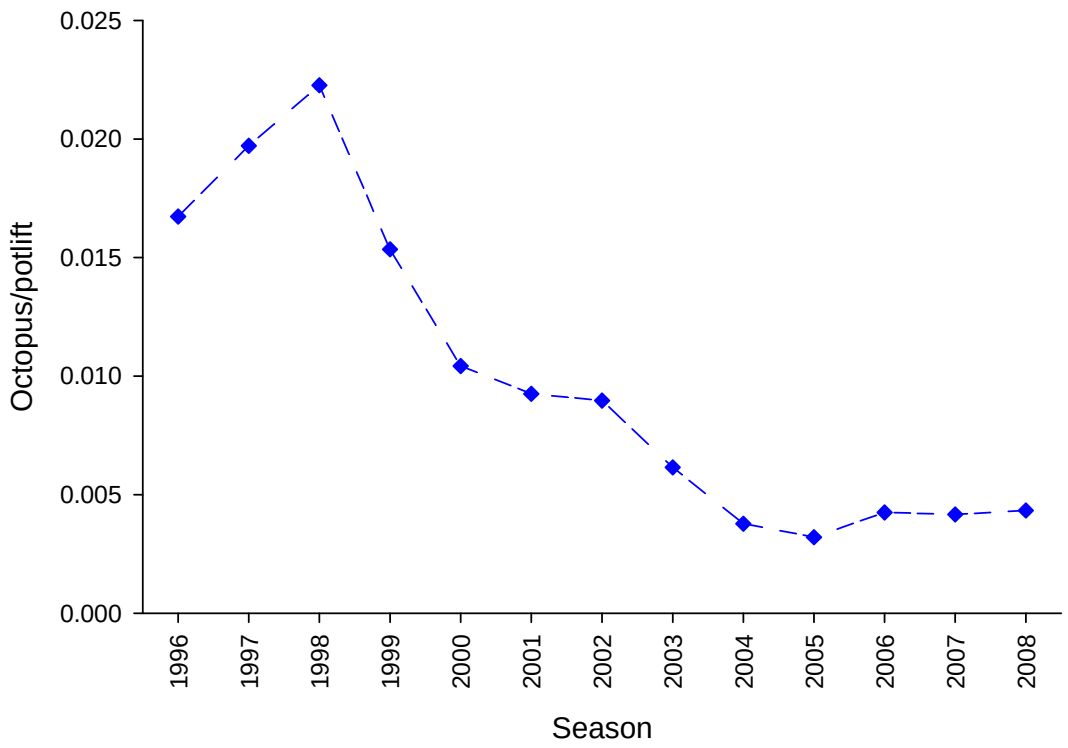

Figure 2-25 Inter-annual trends in catch rates of octopus in the NZRLF from 1996 to 2008.

2.11 Average days fished

The average number of days fished/licence holder is a proxy for total fishing effort within the NZRLF. It decreased from ~180 days in the mid-late 1990s to 144 days in 2002 (Figure 2-26). During this period, the fishery was managed using input controls that included restrictions on the numbers of days fished. In particular, in 2001 and 2002 the number of allowable fishing days was reduced by 8% each year in response to sustainability concerns in the fishery. Since then, the average number of days fished has increased marginally to 156 days in 2008. In 2003, the fishery changed to output controls in the form of a TACC system. However, current data indicate that, to date, the TACC (introduced in 2003 at 625 tonnes and subsequently reduced to 470 tonnes in 2008), has had minimal impact on constraining effort in the fishery. This is highlighted by the fact that the 2008 estimate of 156 days fished is only 15% less than that recorded in 1997 (184 days), when the fishery was still managed under input controls.

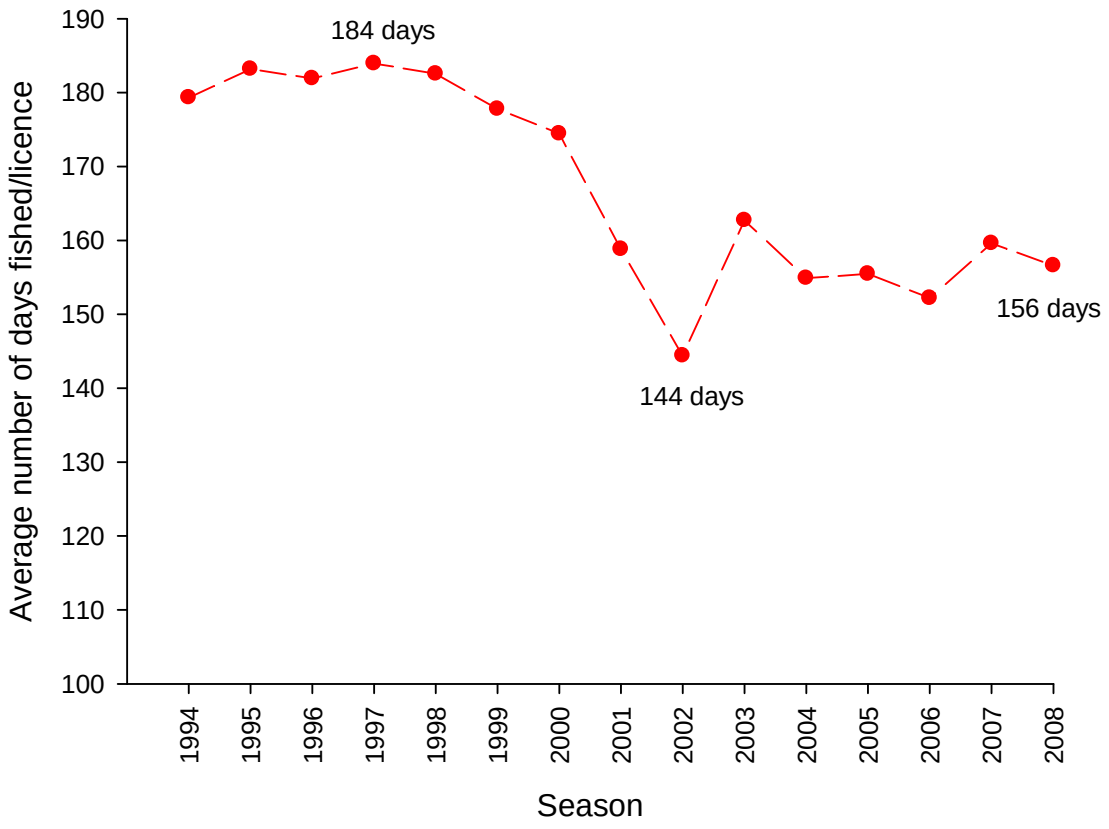

Figure 2-26 Inter-annual trends in the average number of days fished per licence in the NZRLF between the 1994 and 2008 fishing seasons.

3 FISHERY INDEPENDENT STATISTICS

3.1 Puerulus Settlement Index

The annual estimates of puerulus settlement index (PSI) in the NZRLF are calculated from puerulus counts made at McLaren Point and Taylor Island on the Eyre Peninsula and Stenhouse Bay and Marion Bay on the Yorke Peninsula (Figure 1-1). From 1996 to 2001, the PSI remained relatively low (Figure 3-1). In 2002, the highest PSI on record of 1.09 puerulus/collector was observed. However, PSI decreased again in 2003 and 2004, with the 2003 estimate of 0.12 puerulus/collector one of the lowest settlements on record. High settlement was observed in 2005 and 2006, with the estimates of 0.81 and 0.89 puerulus/collector the highest since 2002. However, in 2007 and 2008, two of the lowest settlements on record were recorded with estimates of 0.08 and 0.11 puerulus/collector, respectively. Settlement in 2009 was 0.34 puerulus/collector, which was below the long-term average of ~0.42 puerulus/collector. The period between settlement and recruitment to the fishery in the NZRLF is believed to be ~5 years. Overall, these results highlight the variable nature of settlement in the fishery.

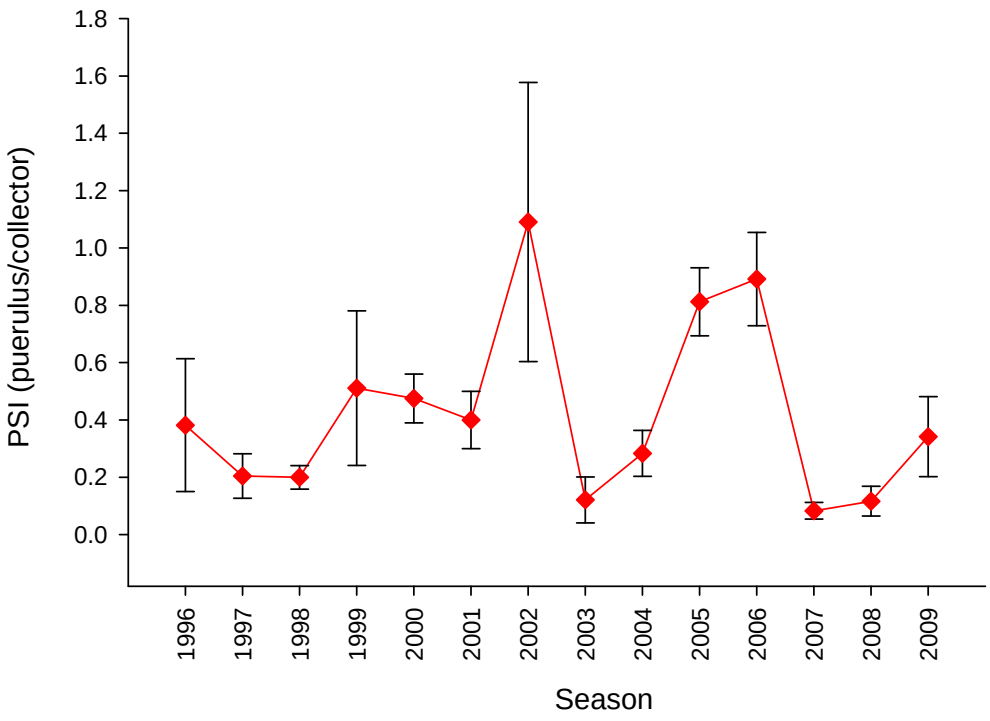

Figure 3-1 Puerulus settlement index (PSI; mean +/- SE) in the NZRLF from 1996 to 2009.

4 THE QR MODEL

4.1 Introduction

The qR model (McGarvey et al. 1997; McGarvey and Matthews 2001) is used to generate estimates of important performance indicators for the NZRLF, namely biomass, exploitation rate, egg production and recruitment.

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). Three changes to the model over time have been: (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 discrete time Schaefer catch relationship (iii) the incorporation of a 3% annual increase in effective effort over the time period of 1983 to 2000.

This section of the report has two objectives; (i) to use the 2008 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 2008 fishing season; and (ii) to compare estimates of recruitment obtained using the qR model with the independent measure of pre-recruit abundance from catch sampling and logbook data.

4.2 Methods

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

Stock assessment models (e.g. delay-difference and biomass dynamic) that fit to catch and effort data normally have available only catch in weight (*Cw*), and rely on *CwPUE* as a measure of relative fishable biomass. Adding catches in numbers to the fitted data set provides information about yearly mean size of lobsters in the legal

catch, otherwise available only from length-frequency data. Catch in weight divided by catch in number gives the mean weight of an average landed lobster. Because catches in weight and number constitute a 100% sample, the quality of information obtained about changes in mean size from catch data is far more precise than that obtained from length frequencies, which typically constitute a 0.1% to 1.0% sample fraction. Thus, the qR model uses *CwPUE* as a relative measure of change in abundance and mean weight as a measure of change in size structure. McGarvey et al (2005) demonstrated using simulated data that adding catch in number dramatically improves the accuracy and precision of stock assessment estimates. These data inputs are also used in LenMod, together with length-sex frequency samples.

The pre-recruit index, (numbers of undersized lobsters), provides a direct measure of yearly recruitment that is independent of qR-inferred recruitment, which uses only legally-sized, landed lobsters. It therefore provides a means of assessing the recruitment outputs from the qR model. The two pre-recruit indices (catch sampling and logbook-derived) used in this section of the report are 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. We also compared these with levels of puerulus settlement indices (PSI) from four years prior to the assumed age of recruitment to legal size.

Two modifications were made in recent versions of the qR model. First, the 3% yearly rising effective effort was assumed to cease after 2000. Second, the selectivity parameter that was previously included to account for a lower level of recruitment in the first age that lobsters reach legal size has now been fixed to a constant (of 1) across time.

A new definition of the qR model estimated biomass was implemented in this year's NZRLF outputs. Rather than taking the model biomass from the start of the year, when model biomass is at its yearly maximum, we now report the average level of biomass during each full model year. This was done to generate qR biomass estimates that are quantitatively comparable with those from LenMod, which also uses a year-average biomass definition.

4.3 Outputs

Goodness of fit

Estimates of catch in number and weight from the 2008 version of the qR model fitted closely with measures of *Cn* and *Cw* obtained from catch logbook data for the NZRLF (Figure 4-1 and Figure 4-2).

Biomass

Outputs from the qR model suggest that the biomass in the NZRLF has decreased considerably over the last 20-30 years (Figure 4-3). In 2008, it was estimated to be 1,401 tonnes, the lowest on record. Note that these outputs are based on average yearly biomass and therefore are lower than those presented in Linnane et al., (2009) for which start-of-year biomass was used. The 2008 value represents a 74% decline in biomass from that estimated in 1980 (5,372 tonnes) and a 53% decrease since the most recent biomass peak in 1998 (2,944 tonnes).

Egg production

Similar to biomass, the qR model indicates that total egg production has decreased considerably in the NZRLF (Figure 4-4). In 2008, it was 170 billion eggs, which equates to 13.8% of virgin egg production (Figure 4-5). The 2008 value represents a 69% decrease in egg production from that estimated in 1980 (546 billion) and a 55% decrease since the most recent peak in 1998 (375 billion).

Exploitation rate

The qR model estimates that exploitation rate increased from 12% in 1980 to 35% in 1999 (Figure 4-6). Over the next five seasons it marginally decreased to 26% in 2004 before increasing to 28% in 2008.

Comparison of estimates of recruitment from qR model with PRI and PSI

Estimates from the qR model suggest that recruitment has declined in the NZRLF over the last ten seasons (Figure 4-7). In 2008, the qR estimate of recruitment was 0.39 million which represented an increase from 2007 (0.20 million), the lowest estimate on record. Overall, the 2008 estimate represents a 75% reduction in recruitment since 1998 (1.55 million). Temporal trends in recruitment estimated by

the qR model were compared against trends in puerulus settlement index (PSI) as well as estimates of pre-recruit index (PRI) from both logbook and catch sampling data over the period 1994-2008 (Figure 4-8). The best correlation (R^2 = 0.60) between qR recruitment and PSI was obtained using a 4-year lag between settlement and recruitment. Correlations between qR recruitment and PRI, as estimated from catch sampling and logbook data, were R^2 = 0.17 and R^2 = 0.88, respectively. PRI from catch sampling data was moderately correlated (R^2 = 0.63) with PSI based on a 3 year lag. There was no correlation between PRI from logbook data and PSI under a range of time lags.

4.4 qR Model Discussion

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

The qR model outputs estimate that biomass in the NZRLF has decreased considerably since the inception of the fishery. In 2008, it was estimated to be 1,401 tonnes, the lowest in the history of the fishery. This represents a 74% decrease in biomass since 1980. Current exploitation rates are estimated to be 28%, representing one of the highest levels on record in a historical sense. Outputs indicate that exploitation levels have increased by 133% since 1980. Similar to biomass, egg production in the NZRLF has decreased considerably since the inception of the fishery with the 2008 estimates of 170 billion eggs the lowest on record. This represents a 69% decrease in egg production since 1980. Overall, the model estimated that recruitment levels into the fishery have been historically low over the last eight seasons. The 2008 estimate of 0.39 million is the second lowest on record representing an increase from 2007 estimates, but still well below historical averages.

There is relatively close agreement between qR model yearly recruitment trends and pre-recruit estimates from logbook (R^2 = 0.88). The best correlation with PSI was from catch sampling data using a 3 year lag (R^2 = 0.63) and qR recruitment to the fishery after 4 years (R^2 = 0.60).

Most of the uncertainty in the model estimates lies in the assumed values of input parameters, i.e. (1) natural mortality, (2) mean weights-at-age, and (3) CPUE as a measure of biomass. Steady-state analysis by McGarvey et al. (1997) showed that catch under-reporting has essentially no effect on the qR estimates of exploitation rate, while yearly estimates of biomass and recruitment are reduced by the proportion under-reporting. Similarly, McGarvey and Matthews (2001) and McGarvey et al. (2005) showed that (1) model estimates are relatively insensitive to errors in the assumed natural mortality rate, but that these estimates were, (2) like any size-based assessment, sensitive to the assumed growth inputs of weight-at-age.

Finally, it should be highlighted that the current version of the qR model for the NZRLF is exclusively reliant on fishery dependent data, namely catch in weight and catch in number. As a result, a current feature the model is that trends in biomass (Figure 4-3) are informed by trends in legal-sized catch rate (Figure 2-2) together with 100% samples from logbooks of mean lobster weight in the catch. Future development of the model will benefit from the inclusion of fishery independent data by a) providing a spatial component to the fishery assessment and b) allowing assessment of the overall resource rather than just areas fished.

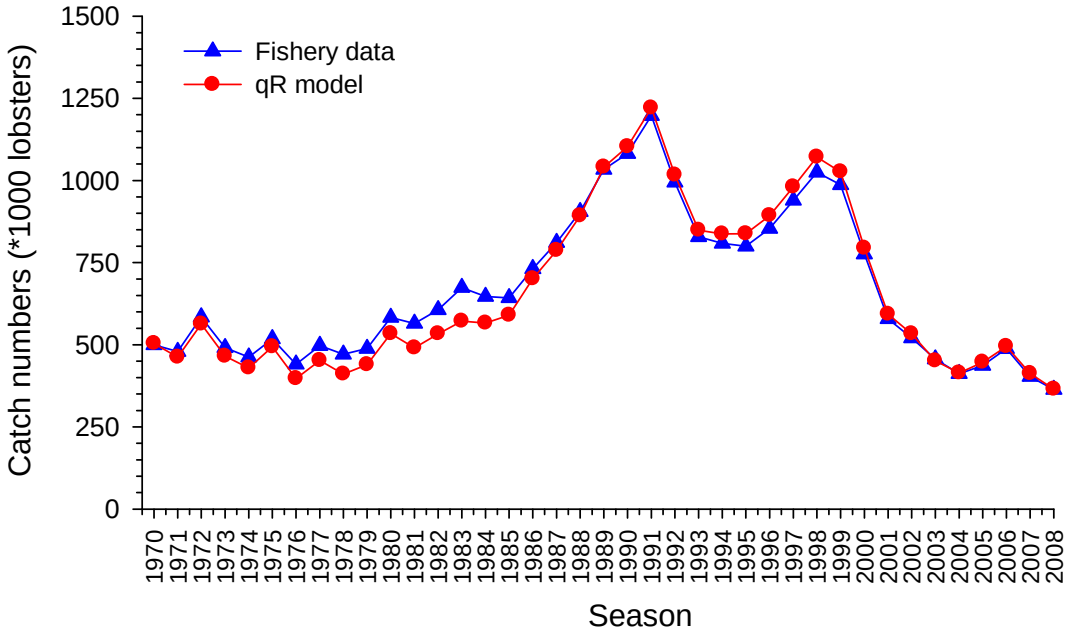

Figure 4-1 Fit of the qR model to catch in number (Cn) for the NZRLF, based on annual catch totals from the fishery and estimates provided by the 2008 version of the qR model.

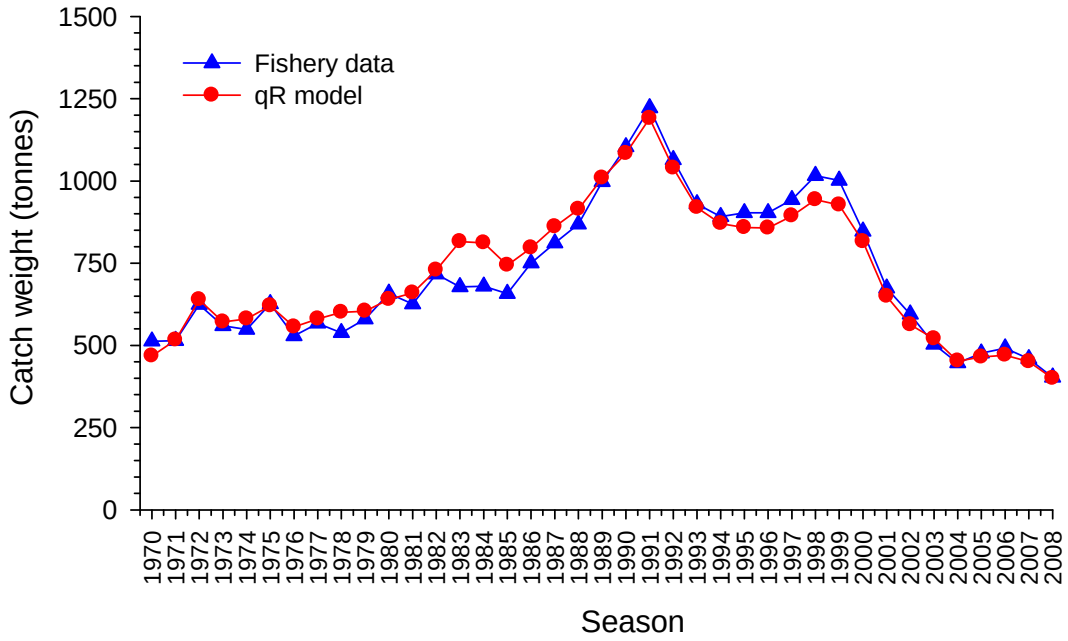

Figure 4-2 Fit of the qR model to catch in weight (Cw) for the NZRLF, based on annual catch totals from the fishery and estimates provided by the 2008 version of the qR model.

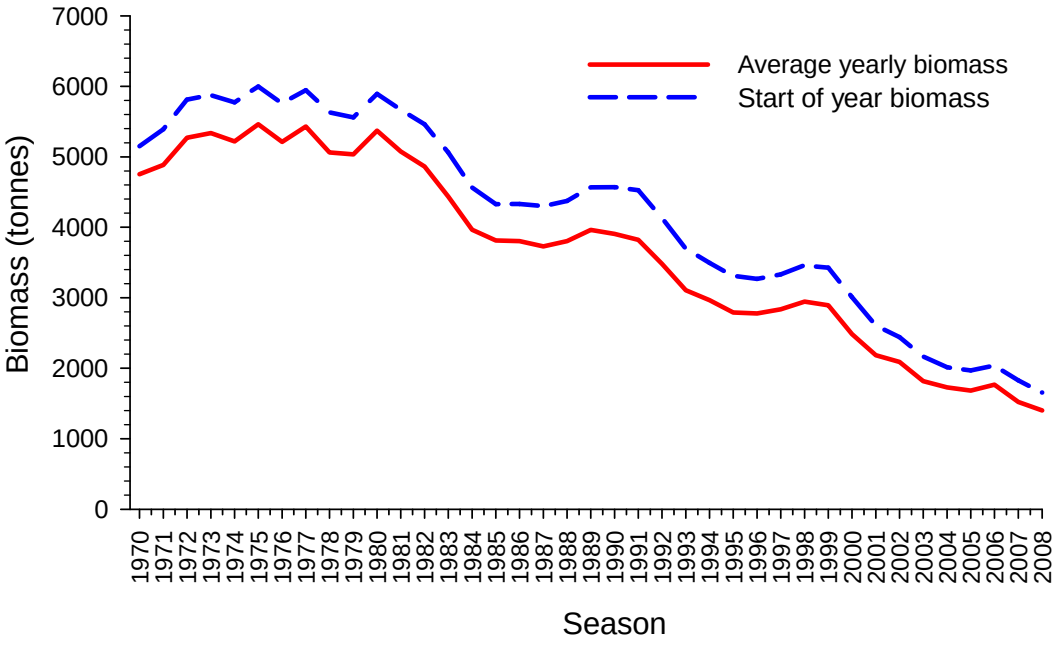

Figure 4-3 Estimates of biomass for the NZRLF provided by the 2008 qR model.

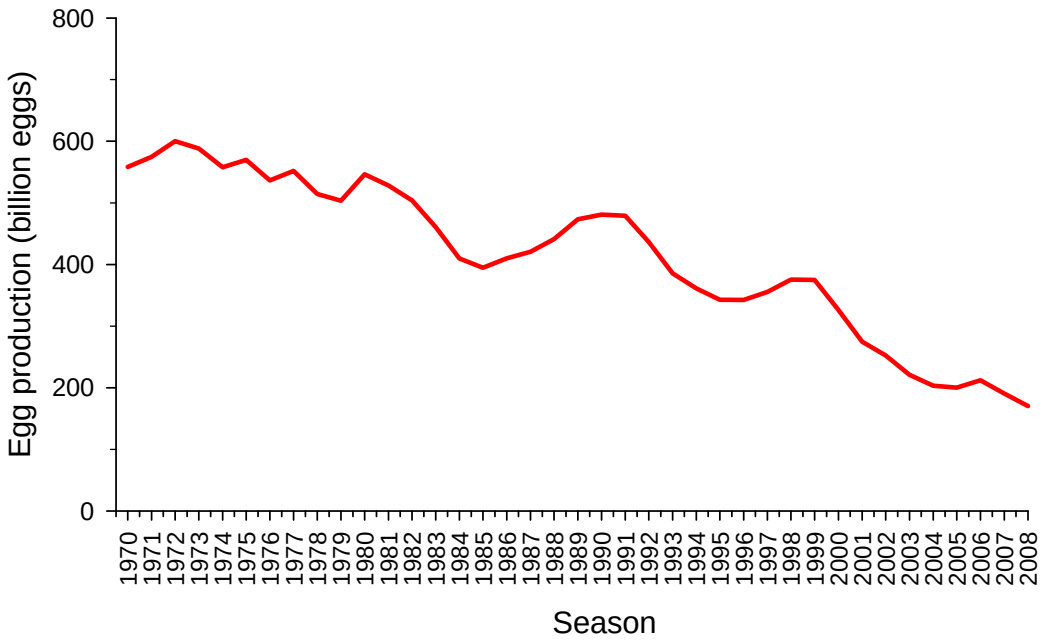

Figure 4-4 Estimates of egg production for the NZRLF provided by the 2008 qR model.

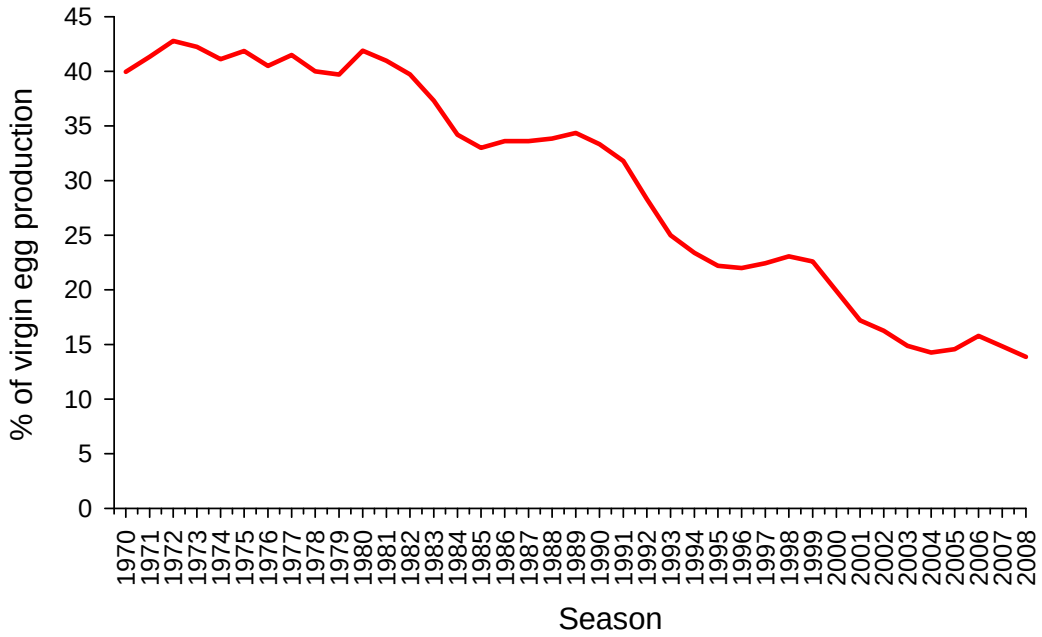

Figure 4-5 Estimates of % virgin egg production for the NZRLF, from the 2008 qR model.

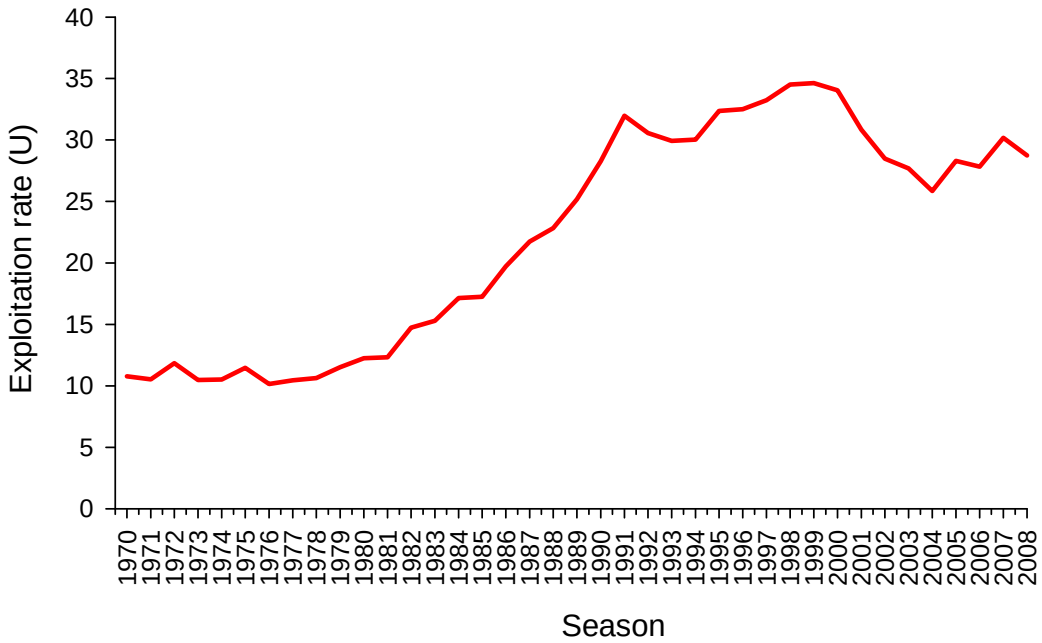

Figure 4-6 Estimates of exploitation rate for the NZRLF provided by the 2008 qR model.

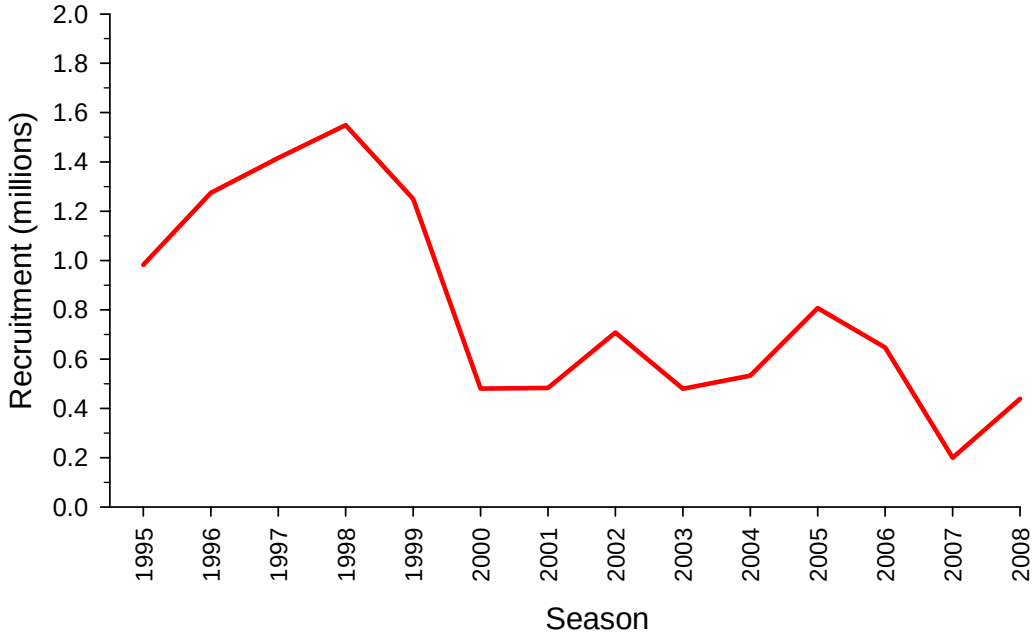

Figure 4-7 Estimates of annual recruitment for the NZRLF provided by the 2008 qR model.

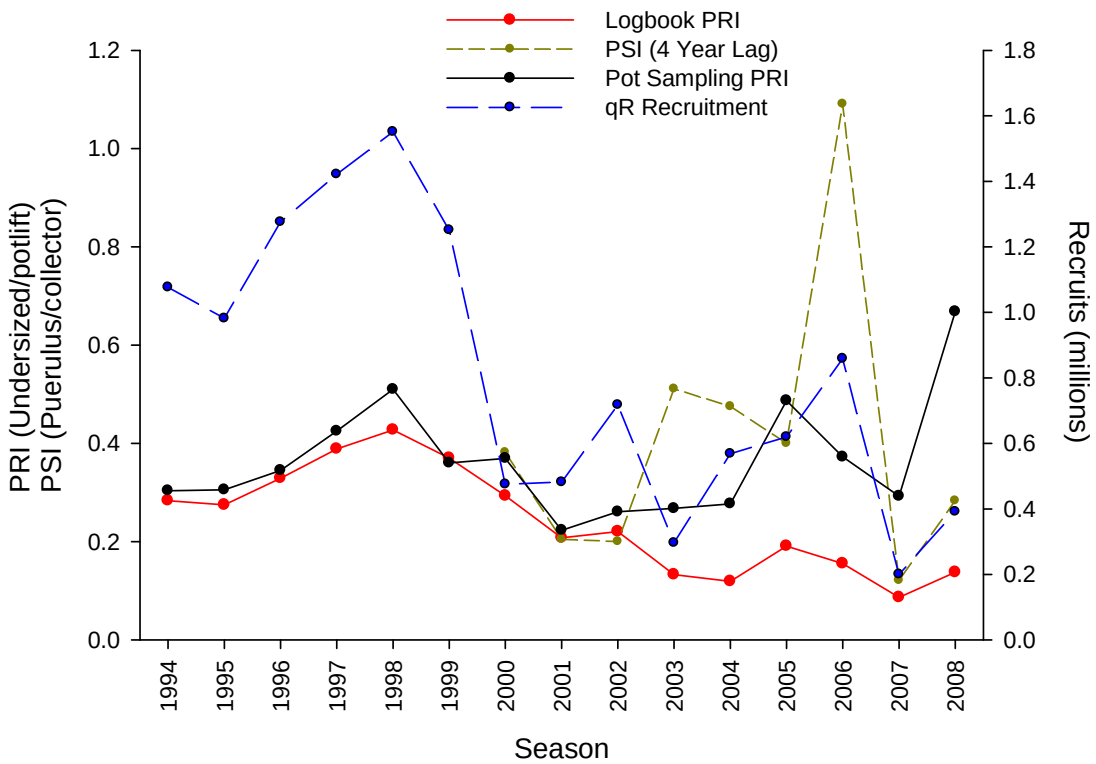

Figure 4-8 Estimates of annual recruitment provided by the 2008 qR model, pre-recruit index (PRI) as undersize numbers per pot lift (Nov-Mar) obtained from both pot sampling and logbook data and puerulus settlement index (PSI) lagged by 4 years.

5 THE LENGTH STRUCTURED MODEL

5.1 Introduction

This section of the report provides outputs from a length-structured model (LenMod) for the NZRLF. Currently, the qR model provides estimates of biomass, recruitment and exploitation rate based on from catch in weight and catch in number only. LenMod fits to catch in weight and CPUE. In addition, it also incorporates length frequency data from catch sampling, which is used, in combination with growth, to infer estimated outputs. André Punt (Washington University) first developed the basic model structure in the 1990's (Punt and Kennedy (1997). Variants of this length-based lobster model are now used for management and quota setting in most *Jasus edwardsii* fisheries, notably in New Zealand, Victoria and Tasmania.

5.2 Methods

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

LenMod infers change and absolute levels of stock abundance principally from three data sources: (1) CPUE (see Section 2.2) to which biomass is assumed to vary in direct proportion, (2) catches in both weight and numbers (see Section 2.6), which supply a highly precise (100% sample) measure of mean weight of lobsters in the catch, and (3) length-frequency data (see Section 2.7), interpreted in combination with the length-transition matrices to yield estimates of mortality rate and absolute biomass. Data sources (2) and (3) both provide LenMod with information on size of lobsters in the catch.

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

5.3 Outputs

Goodness of fit

Estimates of catch in numbers and catch rate from the LenMod model fitted closely with reported *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 shown in monthly fits from the 2008 season (Figure 5-3).

Biomass

Outputs from LenMod suggest that the biomass in the NZRLF has decreased considerably over the last 25 years (Figure 5-4). In 2008 it was estimated to be 1,301 tonnes, the lowest on record. The 2008 value represents a 60% decline in biomass from that estimated in 1990 (3,293 tonnes).

Egg production

Similar to biomass, LenMod indicates that total egg production has decreased considerably in the NZRLF (Figure 5-5). In 2008 it was 160 billion eggs, which equates to 8.8% of virgin egg production (Figure 5-6). The 2008 value represents a 51% decline in egg production from that estimated in 1991 (332 billion).

Exploitation rate

LenMod estimates that exploitation rate increased from 25% in 1983 to 41% in 1999 (Figure 5-7). Over the next five seasons it decreased to 30% in 2004 before increasing marginally to 31% in 2008.

Comparison of estimates of recruitment from LenMod with PRI and PSI

Estimates from LenMod suggest that recruitment levels have generally decreased over the last ten seasons (Figure 5-8). In 2008, the estimate of recruitment was 0.43 million which represented a marginal increase from 2007 (0.35 million), the lowest estimate on record. Overall, this represents a 69% reduction in recruitment since 1998 (1.39 million). The temporal trends in recruitment estimated by LenMod were compared against trends in puerulus settlement index (PSI) as well as pre-recruit index (PRI) estimates from both logbook and catch sampling data over the period 1994-2008 (Figure 5-9). Correlations between LenMod recruitment and PSI were poor (R^2=0.30) using a 4-year lag. Correlations between LenMod recruitment and PRI as estimated from catch sampling and logbook data were R^2=0.13 and R^2=0.94 respectively. PRI from catch sampling data was moderately correlated (R^2 = 0.63) with PSI based on a 3 year lag. There was no correlation between PRI from logbook data and PSI under a range of time lags.

5.4 Model Discussion

Details of the length structured model including simulation testing of its performance have been described in two peer-reviewed papers (Hobday and Punt 2001; Punt 2003). The LenMod outputs estimate that biomass in the NZRLF has decreased considerably since the inception of the fishery. In 2008 it was estimated to be 1,301 tonnes, the lowest in the time series. This represents a 60% decline in biomass since 1990. Trends in egg production compare with those in legal sized biomass. The 2008 estimate of 160 billion eggs is the lowest on record and currently equates to only 8.8% of the virgin level. The current exploitation rate (based on the 2008 catch of 403 tonnes) is 31% which is one of the highest in a historical context. Given the current status of the fishery, the problem of high-grading that affects the SZRLF is not considered an issue in the NZRLF. As a result, it is unlikely that biomass is underestimated due to this practice.

LenMod estimates indicate that recruitment to the legal-sized biomass has decreased over the last ten seasons with the 2008 estimate of 0.43 million

representing the lowest estimate on record and a 69% reduction in recruitment since 1998 (1.39 million). The temporal trends in recruitment predicted by LenMod were compared against trends in puerulus settlement index (PSI) as well as pre-recruit index (PRI) estimates from both logbook and catch sampling data over the period 1994-2009. While correlations between LenMod recruitment and PSI were not statistically significant (R^2 = 0.30 using a 4-year lag), they were strongly correlated with PRI based on logbook estimated data (R^2 = 0.94). Given the mandatory introduction of escape gaps in the NZRLF, this result is surprising as it could be expected that PRI from logbook data would be underestimated. PRI from catch sampling data however is estimated from pots where the escape gaps are closed. Nonetheless, given that similar results were observed in qR outputs and the importance of catch sampling estimated PRI in the current Management Plan, the robustness of this indicator needs to be closely monitored in future seasons.

The current version of LenMod, like the qR model, utilises fishery dependent data, namely CPUE and catch by weight and number. As a result, similar features to the qR model exist, namely, that trends in biomass (Figure 5-4) are informed by trends in legal-sized catch rate (Figure 2-2). The Northern Zone model outputs are non-spatial, meaning that each fishery zone is modelled as a single population. In future versions of LenMod, the lobster population and NZRLF may be differentiated into subregions, with movement rates among these subregions being estimated from tag-recovery data (McGarvey et al. 2010). Separate growth estimates (as length-transition matrices by sex) will be derived using (non-moving) tag recoveries from each subregion.

In future model development, the reported rates of discarding in relation to spawners, dead and high grading will be more accurately accounted for. A new FRDC project titled "*Sustainability of rock lobster resource in south-eastern Australia in a changing environment: implications for assessment and management*" will start in 2010. This project will focus on environmental influences on catchability and recruitment which could lead to refined measures of catch rate in the length-based model, as well as potentially permit insight into recent negative recruitment trends.

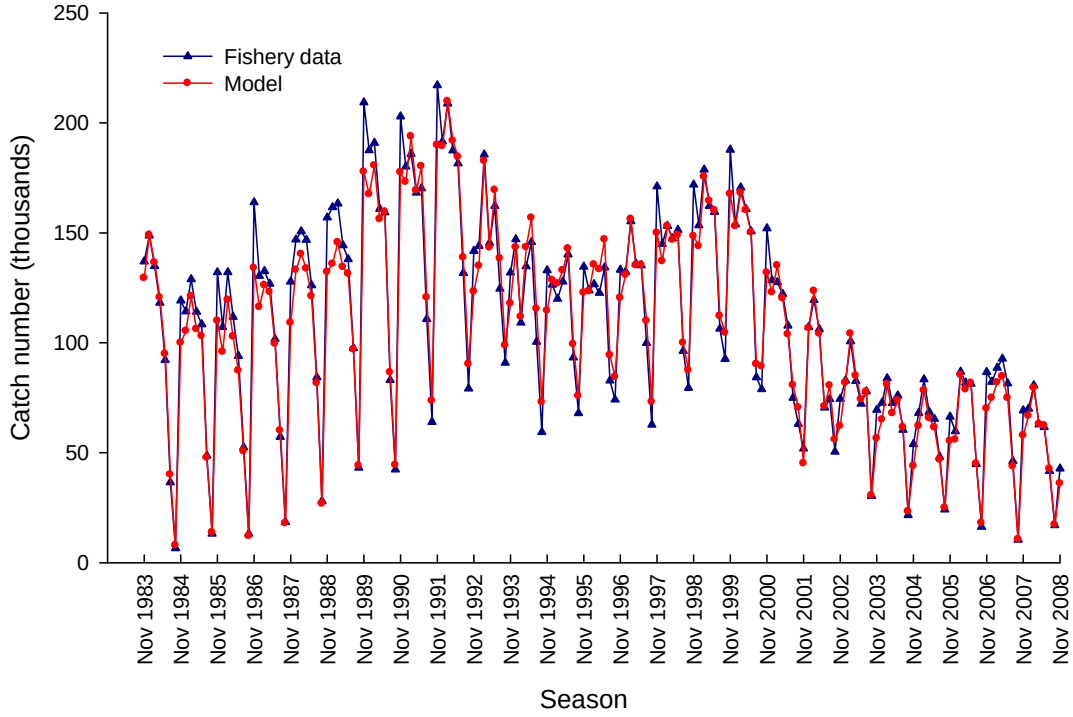

Figure 5-1 Fit of the LenMod model to monthly catch in numbers (Cn) for the NZRLF, based on annual catch totals from the fishery and estimates provided by the 2008 version of the model.

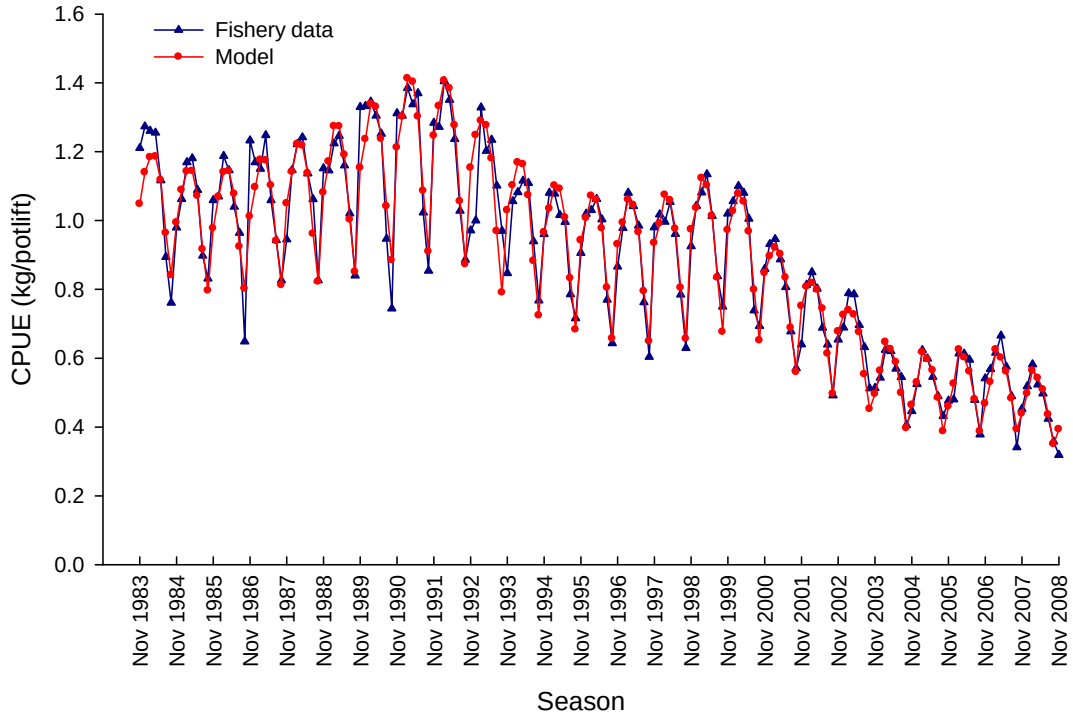

Figure 5-2 Fit of the LenMod model to monthly catch rate for the NZRLF, based on annual estimates from the fishery and those provided by the 2008 version of the model.

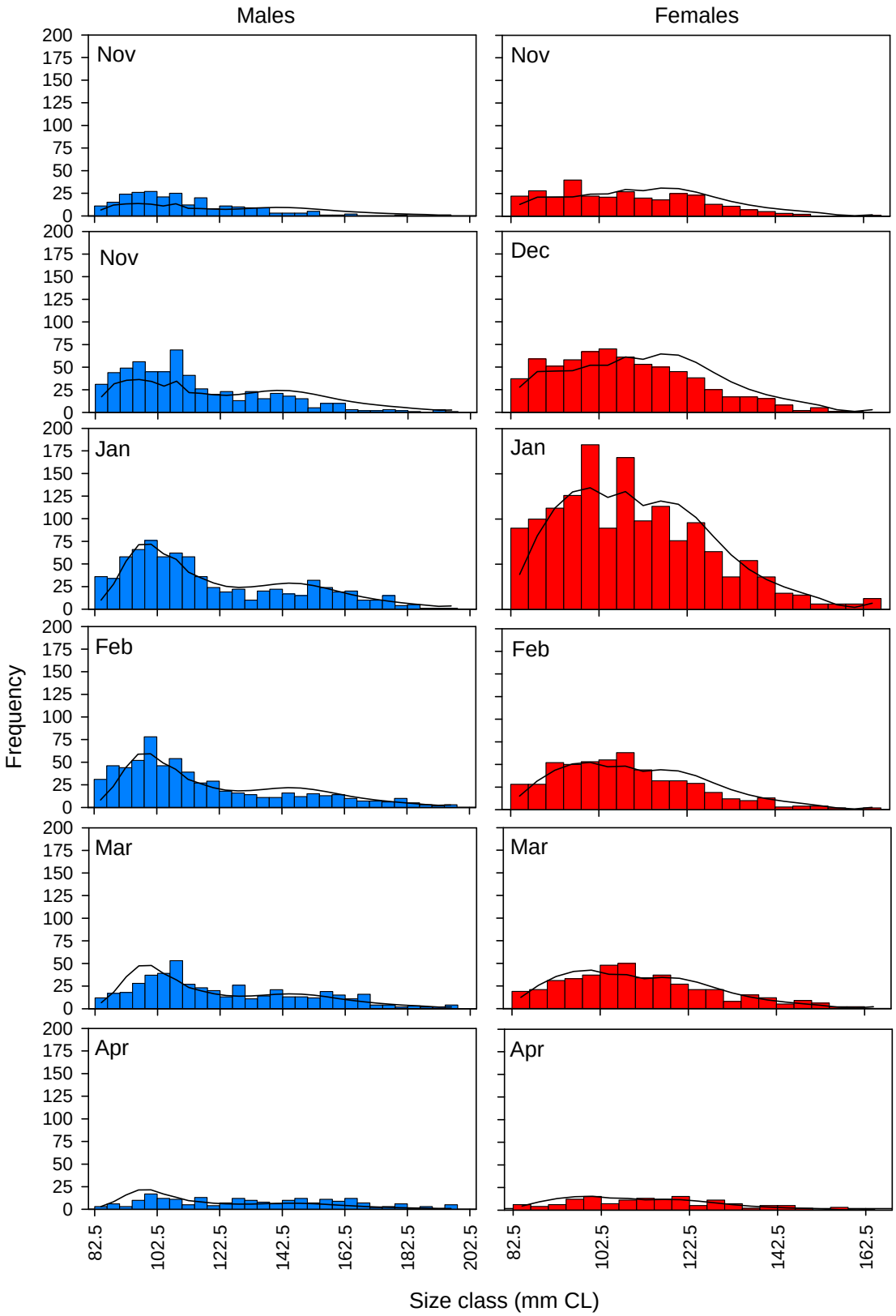

Figure 5-3 Sample of model fit (black line) to commercial length frequency data (blue bars) taken from the 2008 season in the NZRLF.

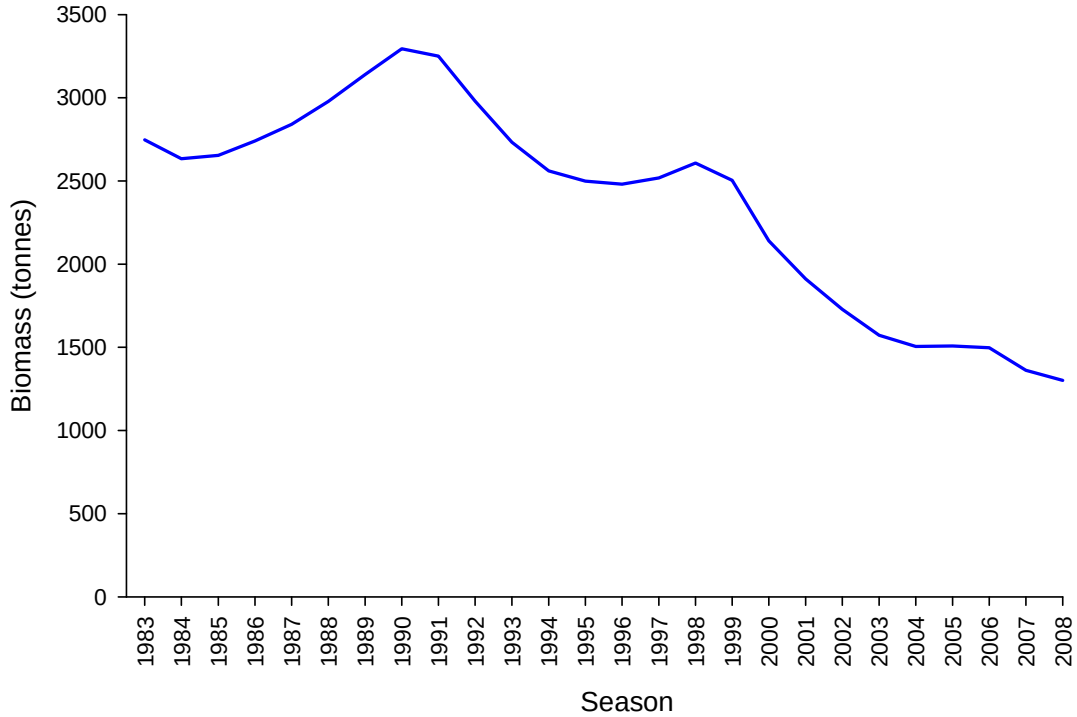

Figure 5-4 Estimates of biomass provided by the 2008 LenMod model.

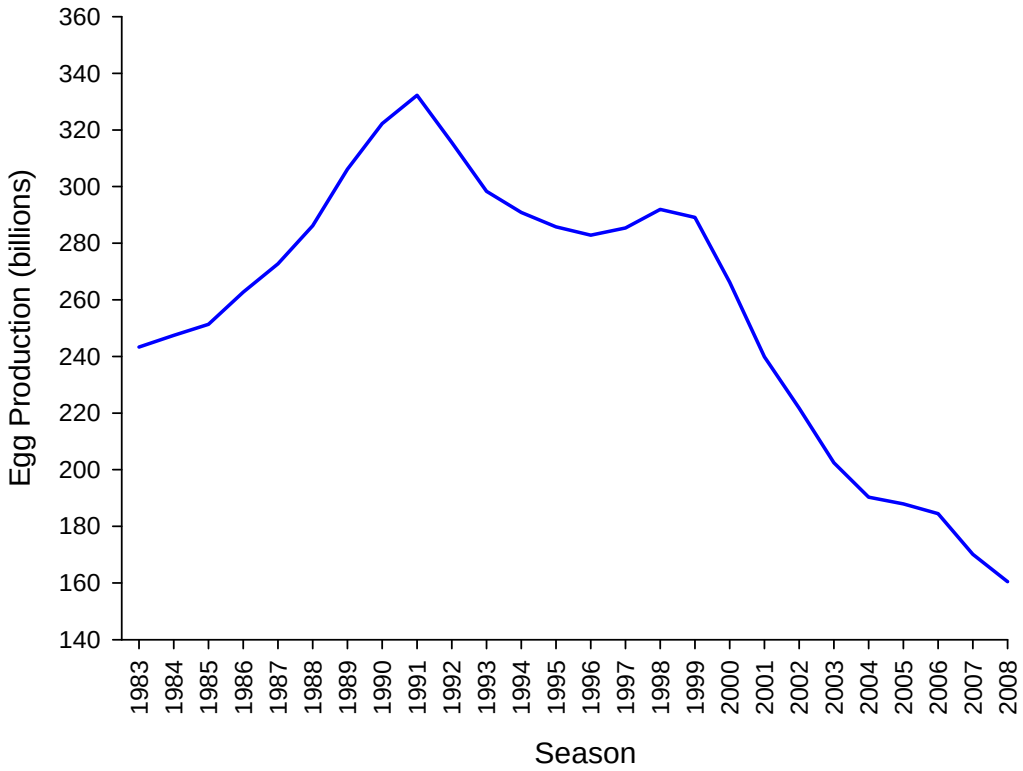

Figure 5-5 Estimates of egg production provided by the 2008 LenMod model.

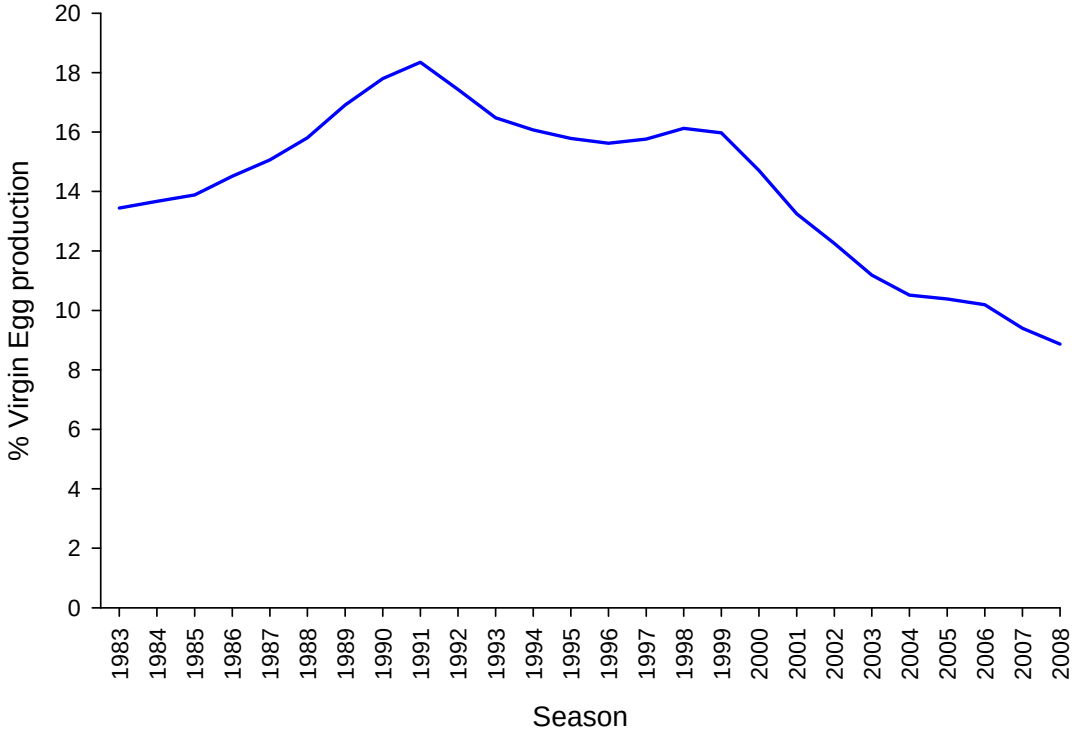

Figure 5-6 Estimates of percent of virgin egg production provided by the 2008 LenMod model.

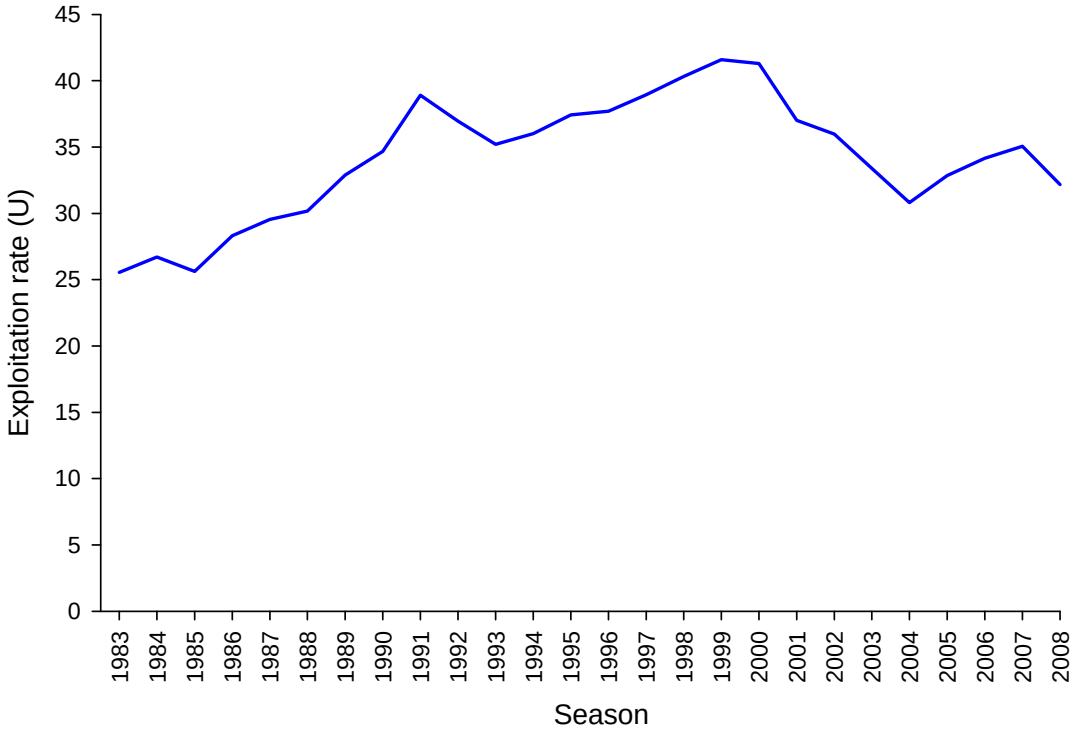

Figure 5-7 Estimates of exploitation rates provided by the 2008 LenMod model.

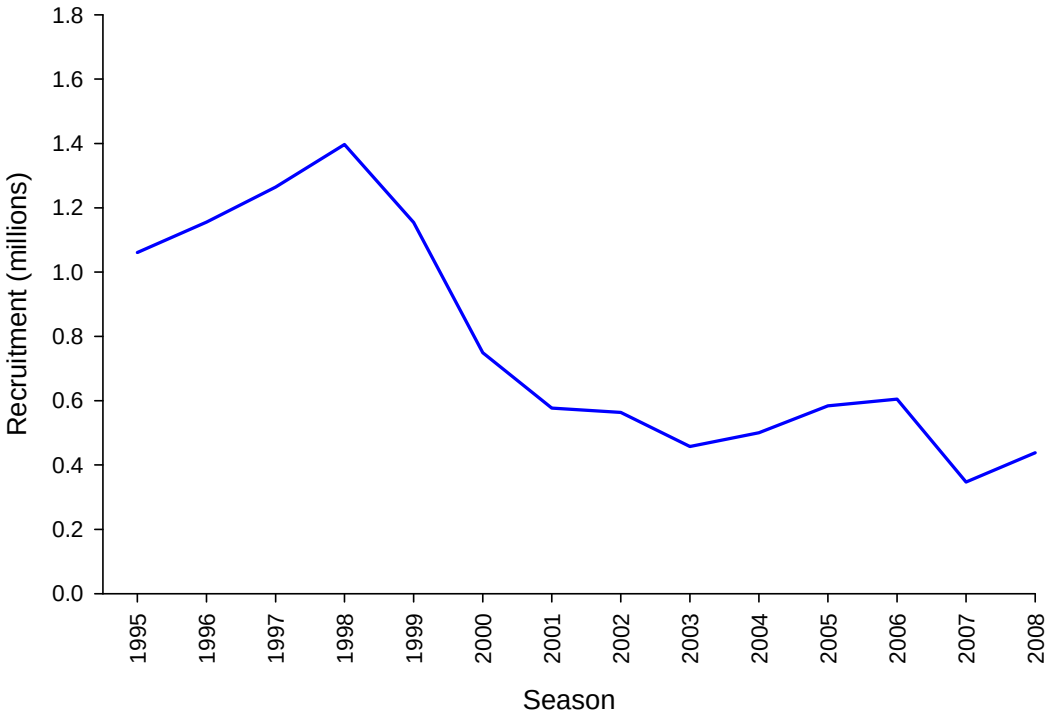

Figure 5-8 Estimates of recruitment obtained from the 2008 LenMod model.

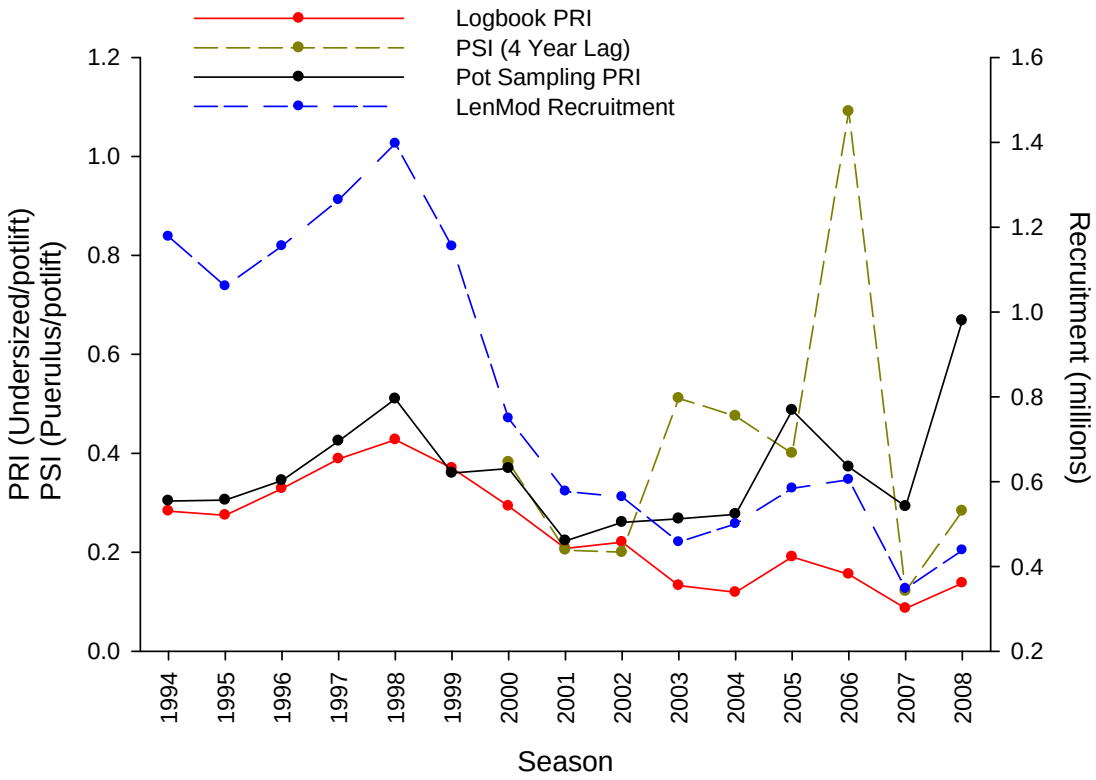

Figure 5-9 Estimates of annual recruitment obtained from LenMod, pre-recruit index (PRI) as undersize numbers per pot lift (Nov-Mar) obtained from both pot sampling and logbook data and puerulus settlement index (PSI) lagged by 4 years.

6 PERFORMANCE INDICATORS

Current biological performance indicators for the NZRLF are catch rate and pre-recruit index (PRI). Limit and target reference points (LRPs and TRPs) have been set for each indicator as defined in the Management Plan for the resource (Sloan and Crosthwaite 2007). LRP recovery trajectories have been developed for the whole fishery and for each region (see Figure 1-4 and Table 1-5).

Only a LRP is set for PRI. Therefore PRI at any time is either above or below the reference point. For the purposes of setting LRPs for PRI, a reference period between 1995 and 2004 (inclusive) has been chosen. This ten-year period is representative of recent fishery performance. In order to set reference points for pre-recruit abundance, the average over this period has been taken (Table 1-4).

6.1 Zonal Catch rate

In 2008, the zonal estimate of 0.68 kg/potlift was below the limit reference trajectory of 1.00 kg/potlift over 12 years as per the Management Plan for the resource (Figure 6-1).

6.2 Regional Catch rate

In 2008, regional CPUE estimates were below the limit reference trajectories in all of the major regions of the NZRLF (Figure 6-2).

6.3 Zonal Pre-recruit Index

In 2008, the zonal 3-year average PRI (2006-2008) was 0.44, which is above the long-term LRP for the NZRLF (Figure 6-3).

6.4 Regional Pre-recruit Index

In 2008, the regional 3-year average PRI (2006-2008) was on the long-term LRP in Region B and above it in Regions C and D (Figure 6-4).

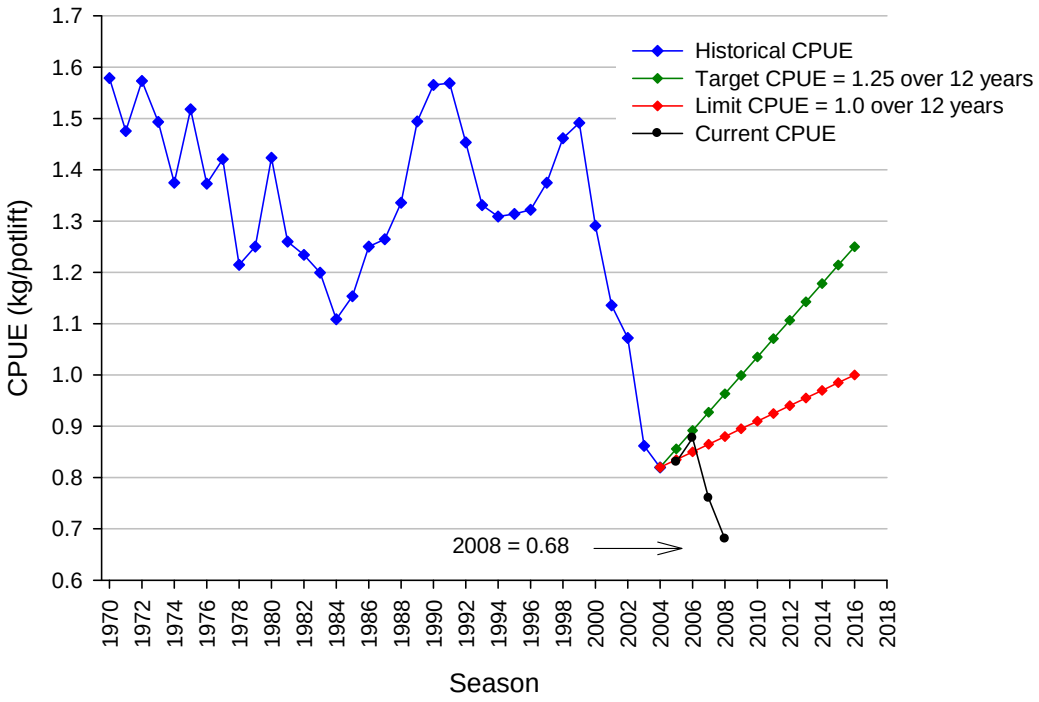

Figure 6-1 Zonal limit and target reference points for CPUE in the NZRLF including current estimates from the 2008 season.

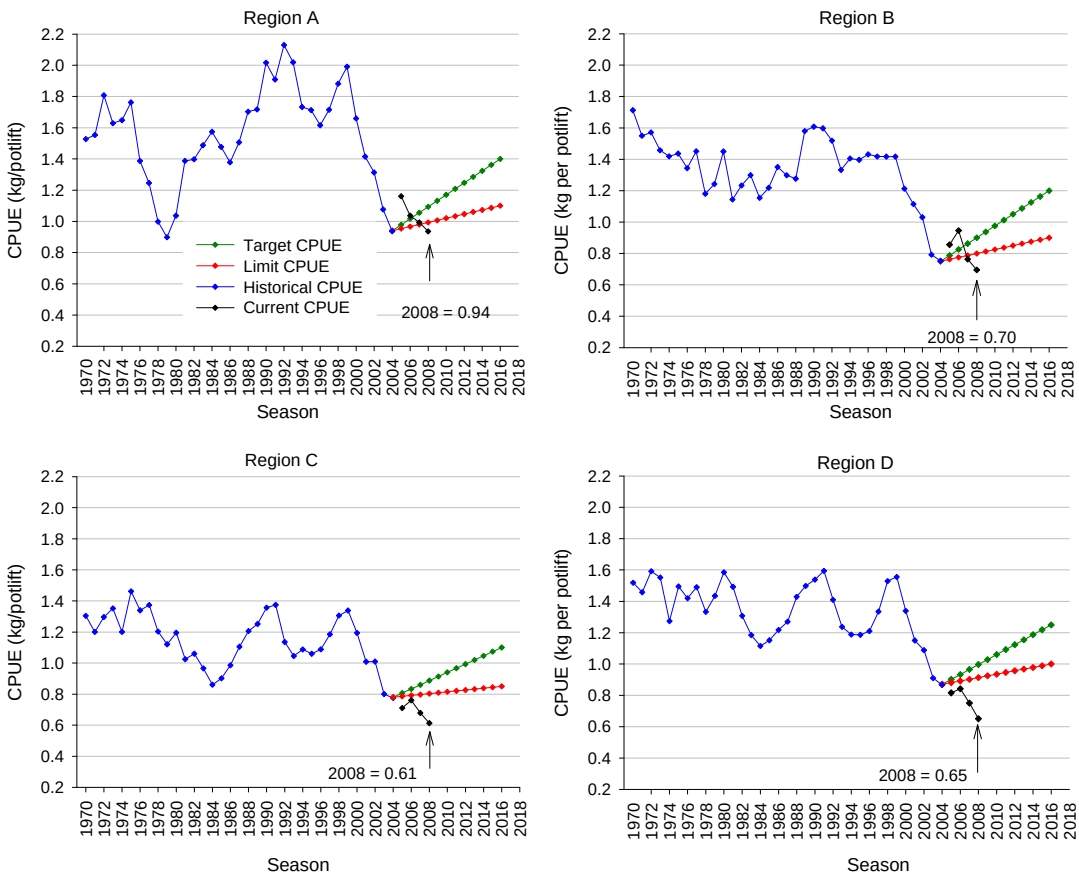

Figure 6-2 Regional limit and target reference points for CPUE in the NZRLF including current estimates from the 2008 season.

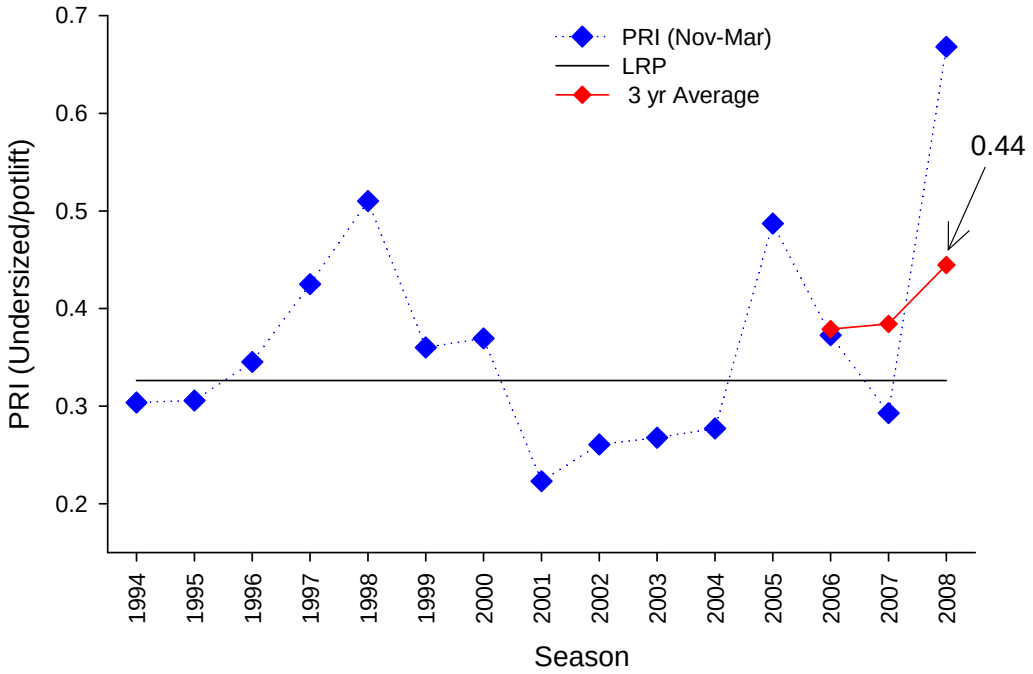

Figure 6-3. Zonal pre-recruit indices (PRI) (1994-2008) with Limit Reference Point (LRP) and current 3-year average (2006-2008).

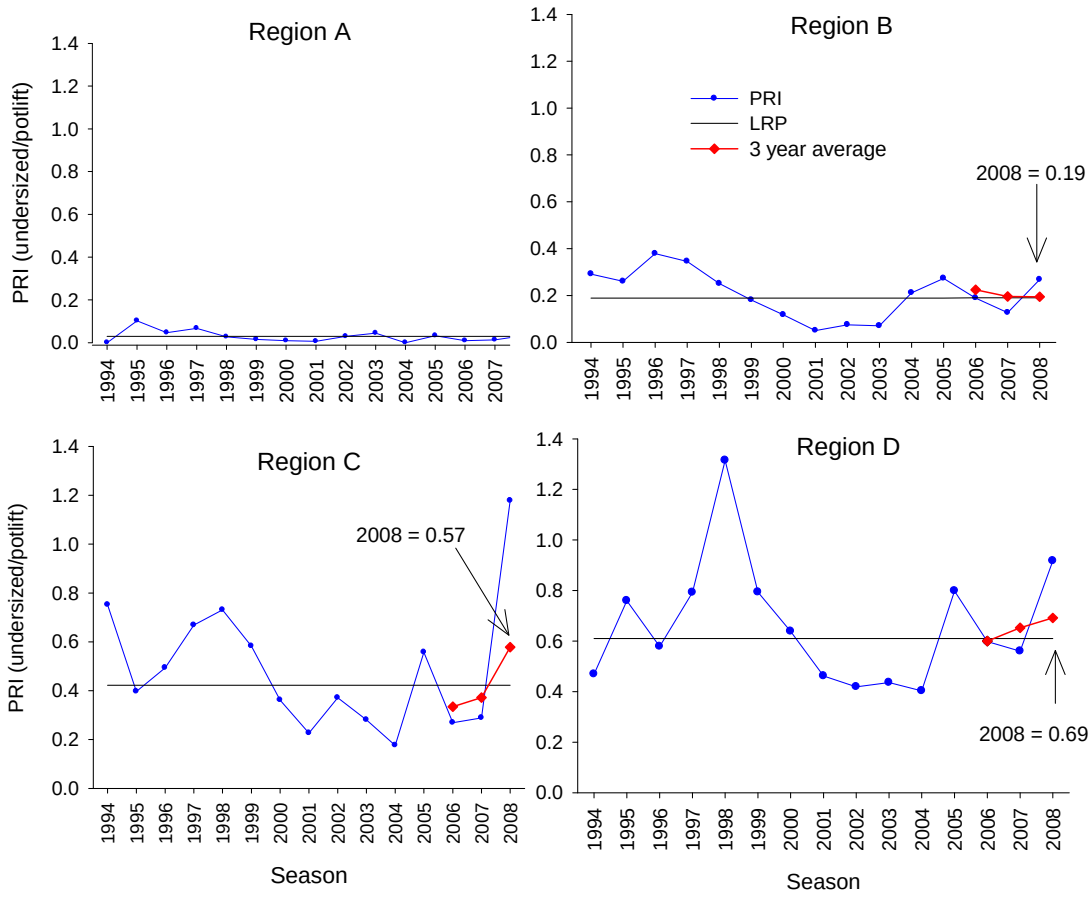

Figure 6-4 Regional pre-recruit indices (PRI) (1994-2008) with Limit Reference Points (LRPs) and current 3-year average (2006-2008).

7 GENERAL DISCUSSION

7.1 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 (e.g. Sloan and Crosthwaite 2007; Linnane et al. 2009). 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. Voluntary catch sampling data have been collected since 1991 and provide 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. Fishery stock assessments are also aided by trends in puerulus settlement data from four NZ sites. Finally, the overall stock assessment is further supported by outputs from two independent fishery models specifically developed for the fishery, i.e. the qR and LenMod fishery models.

7.2 Current Status of Northern Zone Rock Lobster Fishery

Based on data to the end of the 2008 season, there is strong evidence presented in this report to suggest that the resource on which the NZRLF is based is currently overfished. For example, the NZRLF zonal catch in 2008 was 402.7 tonnes, the lowest catch on record. With the exception of marginal increases in 2005 and 2006, the zonal catch has decreased over the last ten seasons. The 2008 catch represents a decrease in catch of 60% from 1998 (1,015 tonnes) and a 20% decrease since 2003 (503 tonnes) when the TACC system was introduced. While catch has decreased significantly, effort has not declined comparatively. In 2008, the zonal effort required to take the catch of 402.7 tonnes was 600,347 potlifts. This represents only a 16.7% decrease since 1998 (720,816 potlifts) and a 0.5% increase since 2003 (596,961 potlifts).

The temporal tend in catch and effort is reflected in catch rates for the fishery. The 2008 zonal estimate of 0.68 kg/potlift is the lowest on record. With the exception of 2005 and 2006, catch rate has decreased successively over the last nine seasons. The 2008 estimate represents a 54% decrease since 1999 (1.49kg/potlift) and a 21% decrease since the introduction of quota in 2003 (0.86 kg/potlift).

The zonal trends in fishery performance are reflected in all of the major fishing regions of the NZRLF. In 2008, >90% of the catch was taken in Regions B, C and D (refer to Figure 1-4). The 2008 catch figures of 60 and 138.9 tonnes in Regions C and D respectively were the lowest on record, while the catch of 168.7 tonnes in Region B was the fourth lowest. These trends represent consistent declines in catch of 51%, 63% and 65% in Regions B, C, and D respectively since 1999. As with zonal trends, regional effort has not decreased at comparable rates to catch. As a result, current CPUEs are the lowest on record in all major regions reflecting declines of 51%, 54% and 58% in region B, C and D respectively since 1999. On a finer spatial scale, declining trends have been observed in all of the major MFAs within the fishery over the last nine to ten seasons. In 2008 alone, catch rate decreased in 9 of the10 main MFAs with current estimates now the lowest on record in MFAs 7, 28, 39, 40, 48 and 49 which combined, contribute ~72% to the total catch in the NZRLF.

Model outputs also agree with fishery dependent data in relation to the current status of the NZRLF resource. For example, both qR and LenMod fishery models indicate that zonal biomass and egg production have decreased markedly in the NZRLF. Model estimates suggest that biomass in 2008 was ~1,300-1,400 tonnes, the lowest estimate on record. This represents a decrease in biomass of ~60% from that estimated in 1990 (3,300–3,900 tonnes). Similar declines in egg production were observed, with 2008 values representing 9-14% of virgin. Overall, current exploitation rates range between 28 and 30%.

The reason for the decrease in fishery performance is clear. TACCs have not been set at levels that constrained catch, which is inconsistent with the aim of stock rebuilding defined in the Management Plan. Since its introduction in 2003, the TACC has never been taken in the NZRLF. In 2003, only 503 tonnes of a 625 tonnes quota was landed. In 2004, the TACC was reduced to 520 tonnes of which only 446 tonnes was taken. Over the next three seasons, the TACC was retained at 520 tonnes but with only 476, 491 and 459 tonnes taken in 2005, 2006 and 2007 respectively. In 2008, the TACC was reduced to 470 tonnes but only 403 tonnes were taken. Therefore, 2008 represents the sixth successive season in which the TACC has not been landed within the fishery. As a result, biomass has declined which in turn has translated into poor fishery performance as reflected by the continued decline in both zonal and regional catch rates.

While the fishery is currently at a historically low level, the increase in PRI in 2008, as estimated from voluntary catch sampling, is positive. The increase is believed to

represent the elevated levels of puerulus settlement observed across both the NZRLF and SZRLF in 2005 and 2006. The time period between settlement and recruitment in the NZRLF is estimated to be ~4 years, with undersized individuals generally observed after ~3 years. Therefore, the 2008 undersized cohort is likely to reflect the 2005 settlement pulse which should enter the fishable biomass as legal sized lobsters during the 2009 season. Recruitment to the fishable biomass should continue in 2010 based on the 2006 settlement levels.

However, while recruitment in 2009 and 2010 is expected to increase, settlement in 2007 and 2008 was low suggesting that recruitment to the fishery 2011 and 2012 will be poor. Therefore, as stated in previous reports, given the level of variation in recruitment to the NZRLF and the sporadic nature of puerulus settlement, careful consideration should be given as to how pulses of recruitment are protected. Specifically, conservative TACCs are required to ensure that when spikes in recruitment enter the fishable biomass in 2009 and 2010, they are protected in order to maintain biomass over the following period of low recruitment. This report shows that in the absence of TACCs that restrain catch, the biomass of lobsters has declined to a historically low and overfished level.

7.3 Implications for Management

The Management Plan for the NZRLF is currently being reviewed. The previous Management Plan (Sloan and Crosthwaite 2007) required that both legal-sized catch rate and pre-recruit index performance indicators must trigger before a management response is taken. In 2008, catch rate triggered, but PRI (based on a three year average) was above the limit reference point defined in the Management Plan. However, as this report has highlighted, the TACC has never been set at a level which constrained catch. As a result, biomass has continued to decrease and stock rebuilding, as defined in the Management Plan, has not been achieved. There is therefore an immediate need to establish a TACC that constrains catch, protects existing biomass and facilitates the aim of stock rebuilding in the fishery.

7.4 Future Research Priorities

The need to understand environmental impacts on lobster catchability, growth and recruitment is a current research priority for South Australia. As a result, an FRDC funded project proposal titled "*Sustainability of rock lobster resource in south-eastern Australia in a changing environment: implications for assessment and management*"

is currently being undertaken in collaboration with scientists from Victoria and Tasmania. The project aims to investigate declines in lobster recruitment across South Australia, Victoria and Tasmania, as well as the relationships between environmental signals and annual settlement trends.

Given the importance of voluntary catch sampling to estimates of future recruitment to the fishery it is imperative that increased participation in the program is encouraged. To this end, the steps taken by industry to employ two independent observers for the 2009 season is encouraged.

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