Fisheries

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

A. Linnane, R. McGarvey, J. Feenstra and M. Hoare

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SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

August 2012

Fishery Assessment Report to PIRSA Fisheries and Aquaculture

Government of South Australia

Northern Zone
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This fishery assessment updates the 2009/10 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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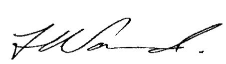
Signed: 

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EXECUTIVE SUMMARY

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

2 In 2010 (i.e. the 2010/11 season), the Total Allowable Commercial Catch (TACC) in the NZRLF was 310 tonnes. The total reported catch from logbook data was 312.2 tonnes, representing the second consecutive season that the TACC was fully taken in the history of the fishery.

3 Prior to 2009, with the exception of marginal increases in 2005 and 2006, catch in the NZRLF decreased annually from 1998 to 2008. The 2008 catch was 403 tonnes representing a 60% decrease since 1998 (1015.8 tonnes). A TACC was introduced in 2003 but was considerably under-caught during the first six seasons.

4 From 1998 to 2008, total effort did not decrease at a similar rate to total catch. In 2008, the zonal effort was 600,347 potlifts representing a 16.7% decrease since 1998 (720,816 potlifts) and a 0.5% increase since 2003 (596,961 potlifts). Over the last two seasons, total effort has decreased markedly in the NZRLF. In 2010, it was 289,925 potlifts representing a 52% decrease from 2008 (600,347 potlifts) and the lowest effort estimate on record.

5 Over the period 1999 to 2008, catch per unit effort (CPUE; November to April inclusive) decreased annually. The zonal estimate for 2008 was 0.68 kg/potlift, the lowest on record. This represents a 54% decrease since 1999 (1.49 kg/potlift) and a 21% decrease since 2003 (0.86 kg/potlift). Over the last two seasons, CPUE has risen by 57% and in 2010 was 1.07 kg/potlift, the highest on record since 2001 (1.13 kg/potlift).

6 The average number of days fished per licence holder acts as a proxy to effort levels in the fishery. Over the last two seasons it has decreased from 156 to 84 days, the lowest on record.

7 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 decreased markedly over the last two decades but with notable increases over the last two seasons. Current biomass estimates are about 2,000 tonnes, reflecting a 50% increase since 2008. Combined with reductions in catch, this has resulted in exploitation levels decreasing to about 15–17%, the

lowest on record. Models indicate that current egg production estimates represent 10-20% of virgin egg production levels.

8 Increases in biomass and catch rate over the last two seasons reflect spikes in puerulus settlement observed in 2005 and 2006. In the NZRLF, the period between settlement and pre-recruit (PRI) is three years, with four years between settlement and recruitment to the fishery. In 2011, the settlement index was 0.23 puerulus/collector which follows the 2010 settlement of 0.02 puerulus/collector, the lowest on record since monitoring began. This reflects the fifth consecutive season that settlement was below the long term average.

9 Pre-recruit indices (PRIs) increased in 2008 and 2009 due to strong settlement in 2005 and 2006 resulting in increases to catch rates in 2009 and 2010. In 2010, catch sampling and logbook data provided conflicting views in terms of future recruitment. Catch sampling estimated PRI was 0.67 undersized/potlift, the highest on record, while logbook PRI decreased by 19% from 0.26 undersized/potlift in 2009 to 0.21 undersized/potlift in 2010. It should be highlighted that catch sampling PRI in 2010 was based on ~3,500 potlifts (1.2% of total effort) the lowest on record, and as a result, estimates should be viewed with some caution.

10 In summary, the increase in biomass and subsequent catch rate estimates over the last two seasons are a positive sign for the NZRLF and are a strong indication that stock rebuilding is starting to occur within the resource. However, despite recent increases, it is important to highlight that puerulus settlement from 2007 to 2011 was below the long term average, suggesting that recruitment to the fishery will be reduced from 2011 through to 2015. As a result, commercial catch rates will require close monitoring over the coming seasons to ensure that biomass levels remain sustainable over what is likely to be an extended period of low recruitment to the fishery.

1 GENERAL INTRODUCTION

1.1 Overview

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

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 and identifies the current biological performance indicators and reference points; (iv) provides a synopsis of biological and ecological knowledge of *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 from 1970/71-2010/11. 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. It also presents data on mean weight and length-frequencies as well as other important indices such as catch rate of spawning females and average days fished per licence holder.

The third section presents fishery independent outputs from the puerulus monitoring program as an indication of future recruitment levels to the fishery.

Section four presents outputs from the qR fishery model (McGarvey et al. 1997; McGarvey and Matthews 2001), while the fifth section presents outputs from the length structured model (LenMod) for the fishery. Both sections also compare estimates of model generated recruitment with fishery dependent pre-recruit data.

The sixth section provides a general overview of the biological performance indicators for the fishery. Section seven uses information provided in sections 2-5 to assess the current status of the NZRLF.

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

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 50 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 sub-regions. 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 areas of aeolianite limestone reef can be found south of Kangaroo Island and 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.

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 600 m (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℃). Water below the thermocline has lower salinity (< 35.5 psu), higher nutrient levels (NO_3 >0.2 ug/l) and lower temperatures (~14 ℃). Sea surface temperatures during summer are lower near the coast (e.g. 14-15 ℃), especially along the western Eyre Peninsula and off the western tip of Kangaroo Island, and higher offshore (18-20 ℃) (Figure 1-2).

During winter, the atmospheric cooling and the predominantly westerly winds lead to the formation of cold, salty dense water within the Gulfs and along the coast that is downwelled to depths of 250 m or so (Middleton and Bye 2007). This downwelling and wind-mixing leads to water over the continental shelf that is vertically homogeneous, well mixed and characterised by low nutrient levels (NO3 <0.25 ug/l), high salinities (> 36 ppt) and medium temperatures of ~17℃. The westerly winds also 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 600 m, onto the shelf.

1.2.3 Commercial Fishery

The southern rock lobster, *Jasus edwardsii*, has been fished in South Australian waters since the 1890s, but the commercial fishery did not develop until the late 1940s and early 1950s when overseas markets for frozen tails were first established (Copes 1978; Lewis 1981). Since then there has been a gradual change to live export. Currently, over 90% of the commercial catch is exported live to overseas markets.

Commercial fishers predominantly harvest lobsters using steel-framed pots covered with wire mesh. Lobsters enter pots via 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 vessels before being transferred to holding tanks at numerous processing factories around the State.

1.2.4 Recreational Fishery

There is an important recreational fishery for lobsters in the NZRLF. 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) lobster were caught 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 the 2001/02 survey (Venema et al. 2003) but release rates increased by 26%. The catch represents a total recreational harvest of about 60 tonnes, of which about 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.

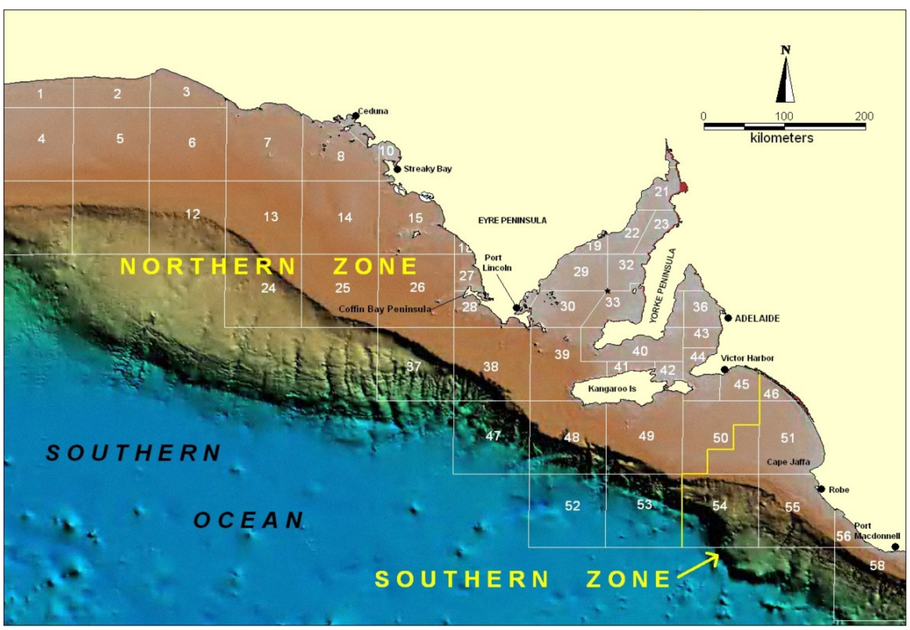

Figure 1-1 Marine Fishing Areas in the Northern and Southern Zones of the South Australian Rock Lobster Fishery.

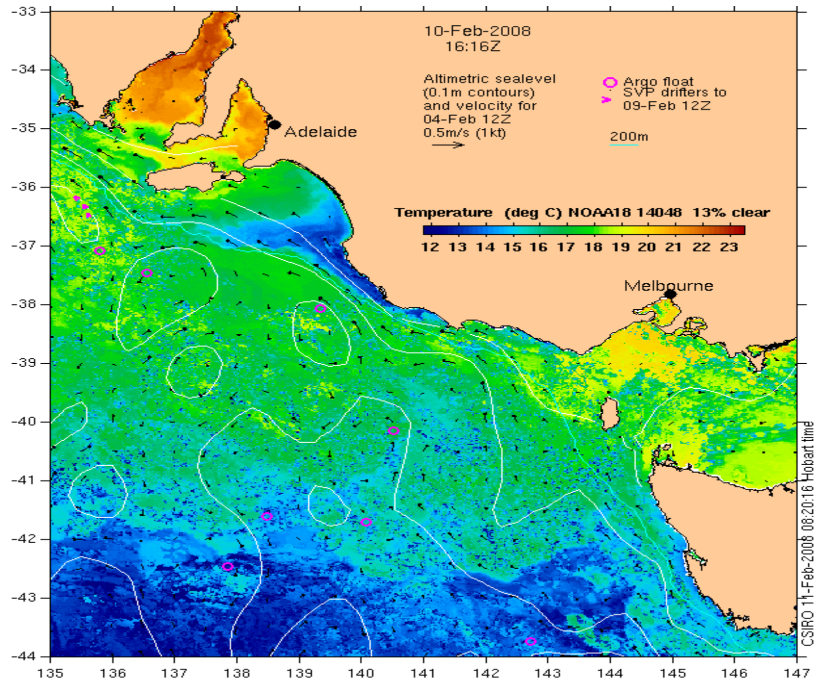

Figure 1-2 Sea-surface temperatures over the continental shelf of South Australia during February 2008. An upwelling can be seen where cooler water (dark blue) has moved onto the inner continental shelf (source: CSIRO).

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 Regions

The Management Plan for the NZRLF is currently under review. The previous 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.

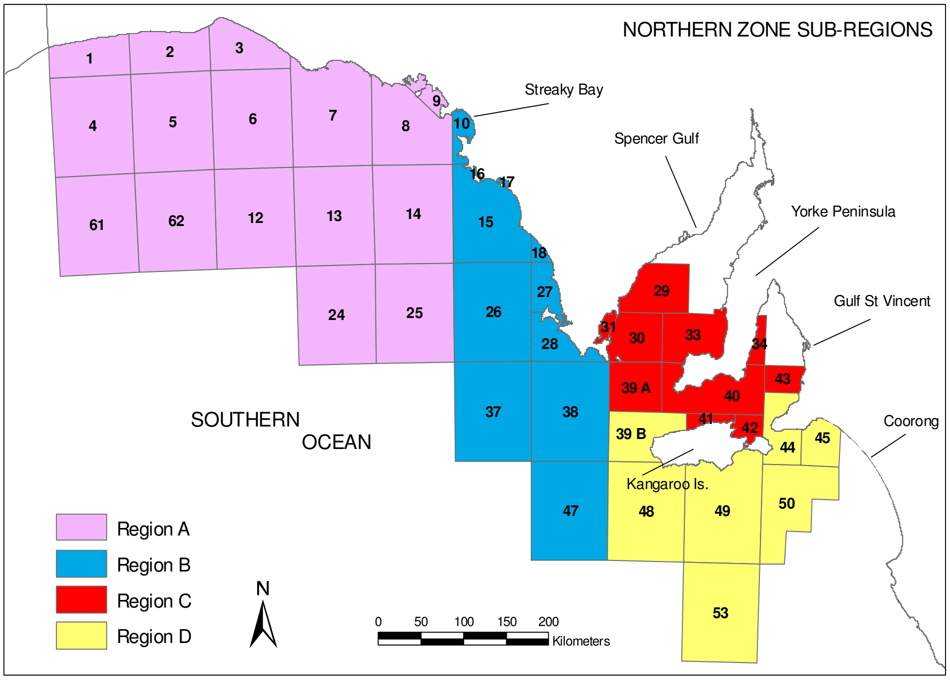

Figure 1-4 Key spatial management regions in the NZRLF.

1.3.2 Management Milestones

Management arrangements have evolved since the inception of the fishery with the most recent review in 2011 (Table 1-1).

Table 1-1 Major management milestones for the NZRLF.

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	Minimum legal size (MLS) increased from 98.5 to 102 mm carapace length (CL); further "1 week" closure
1995	Further "1 week" closure added
1997	Flexible closures introduced; Management Plan published (Zacharin 1997)
1999	Extra 3 days of fixed closure added
2000	MLS 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
2009	TACC reduced to 310 tonnes
2011	New Harvest Strategy developed

1.3.3 Current Management Arrangements

Details of the management arrangements for 2010/11 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 (CL), 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 Total Allowable Commercial Catch (TACC) is set each year and is divided proportionally between licence holders as individual transferable quotas (ITQs). Each licence holds one quota unit entitlement for each pot entitlement held. If a pot entitlement is transferred, a quota unit must also be transferred at the same time to the same licence, and vice versa. The daily catch of individual vessels is monitored via catch and disposal records. In 2010/11, the TACC was 310 tonnes.

Table 1-2 Management arrangements for the NZRLF in 2010/11.

Management tool	Current restriction
Total Allowable Commercial Catch	310 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 vessel
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.

1.3.4 Biological Performance Indicators

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

Primary biological performance indicator

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

A modified “traffic light” method is used to determine the current status of the fishery relative to a target CPUE reference range, where blue is above the target range (TACC increase by one level), green is within the target range (no change to TACC), with both yellow (TACC decrease by one level) and red (TACC decrease by two levels) below the target range (Figure 1-5). The four levels of TACCs used are based on historical levels of effort of 425,000 pot lifts per season. Given the current reduced stock levels in the fishery, only 50% of these levels will be implemented in the first three years of this harvest strategy (i.e. 310, 345, 390 and 430 tonnes). The four TACC levels which may be used in the fourth and fifth year of the harvest strategy (i.e. 310, 380, 470 and 550 tonnes) are based on historical levels of effort of 425,000 potlifts per season at 100% implementation.

Secondary biological performance indicator

The secondary performance indicator is the pre-recruit index (PRI) in terms of the number of undersized lobster/potlift. PRI provides information on future recruitment to the fishery and is based on voluntary catch sampling data as described in Section 1.5.2. A limit reference point for PRI of 0.3 undersized/potlift will be used as a measure of fishery performance for the following year. Therefore, at any time, PRI is either above or below this reference point.

Additional performance indicators

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

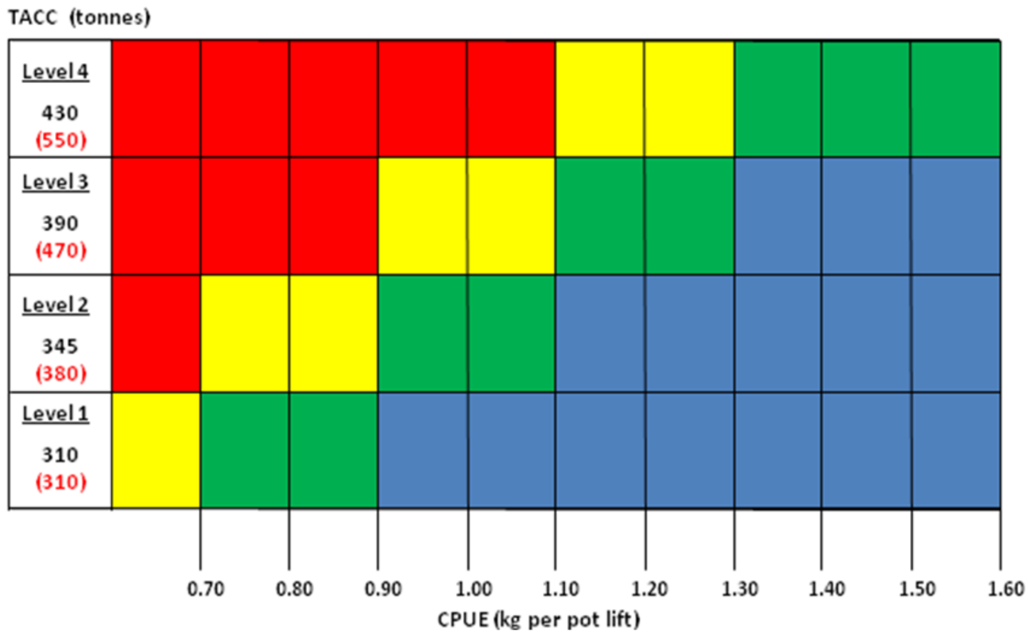

Figure 1-5 TACC levels at various catch per unit effort (CPUE) rates where blue is above the target level, green is at the target level, while both yellow and red are below the target level. The TACCs in black will be used for the first three years of the harvest strategy, while those in red brackets may be used in the fourth and fifth year.

1.4 Biology of Southern Rock Lobster

1.4.1 Distribution

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

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

1.4.2 Stock Structure

Based on morphological and mitochondrial DNA analysis, there is little evidence of population sub-structuring across mainland Australia, Tasmania and New Zealand (Smith et al. 1980; Brasher et al. 1991; Ovenden et al. 1992). The long larval phase and widespread occurrence of larvae across the central and south Tasman Sea, in conjunction with known current flows, point to the likely transport of phyllosoma from south-eastern Australia to New Zealand, providing genetic mixing between the two populations (Booth et al. 1990).

Using a combination of biological and hydrodynamic modelling, Bruce et al. (2007) simulated the planktonic early life history of *J. edwardsii* across its geographical range. In relation to sources of recruiting pueruli to the 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.

While rock lobster stocks within South Australia cannot be differentiated based on genetic analyses, the stock is spatially discrete for management purposes based on known biological and ecological differences. As a result, the division of the stock into Northern and Southern Zones reflects known spatial variations in growth (McGarvey et al. 1999a), size of maturity (Linnane et al. 2008; Linnane et al. 2011) and habitat type (Lewis 1981).

1.4.3 Life History

Southern rock lobsters 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 (Booth et al. 1991; Booth 1994). They develop through a series of 11 stages over 12-23 months before metamorphosing into the puerulus stage (Figure 1-7) near the continental shelf break (Booth et al. 1991; Bruce et al. 1999). A short (~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 (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; Linnane et al. 2010a).

Figure 1-7 Newly settled southern rock lobster puerulus.

1.4.4 Growth and Size of Maturity

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

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).

As a result of differences in growth rates, size of maturity varies spatially in the NZRLF (Linnane et al. 2011). For example, the size at which 50% of females are sexually mature in MFA 49 south of Kangaroo Island (refer to Figure 1-1) is 105.7±1.50 mm compared to 113.1±2.13 mm CL in MFA 7 in the western region of the fishery (Figure 1-9).

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. In the NZRLF, the only region where significant levels of movement occurred was in MFA 33 (see Figure 1-1) where individuals moved distances up to 100 km from within a lobster sanctuary at Gleesons Landing to sites located on the north-western coast of Kangaroo Island and the southern end of Eyre Peninsula. These results support previous findings from tagging studies of *J. edwardsii* (e.g. Gardner et al., 2003) which indicate that, in general, the species does not undertake large-scale migrations but instead exhibit long-term residency and high levels of site fidelity on temperate reef systems.

1.5 Stock Assessments and Data Sources

SARDI Aquatic Sciences is contracted by PIRSA Fisheries and Aquaculture to: (i) administer a daily logbook program, (ii) collate catch and effort information, (iii) conduct 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. For example, in1998 the logbook was modified to include specific details about giant crab (*Pseudocarcinus gigas*) fishing. In 2000/01, fishers were requested to voluntarily record numbers of undersize, spawning and dead lobsters, as well as numbers of octopus. 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. 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.

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 vessels, with sampling done on as many days as possible from a small fraction of the pots from each vessel. As a result, fishers are now encouraged to sample from up to three research pots per trip where the escape gaps are closed. They are supported by research staff undertaking 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 2010, the importance of participation in the catch sampling program 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 2010/11 represented only 23% of licence holders (Figure 1-8). Low participation in the program may bias catch rates and length frequencies. In addition, the new harvest strategy for the fishery relies heavily on pre-recruit indices as determined from voluntary catch sampling. As a result, participation in the program is strongly encouraged to ensure that future decisions for the fishery are based on reliable and robust data. Results from the voluntary catch sampling program are presented in Section 2 of this report.

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.

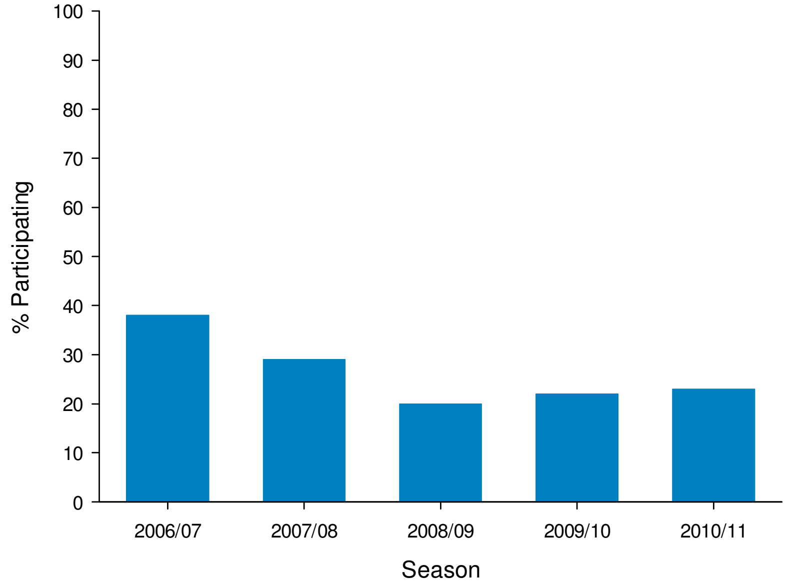

Figure 1-8 Percentage of licence holders in the NZRLF participating in the voluntary catch sampling program over the last 5 seasons.

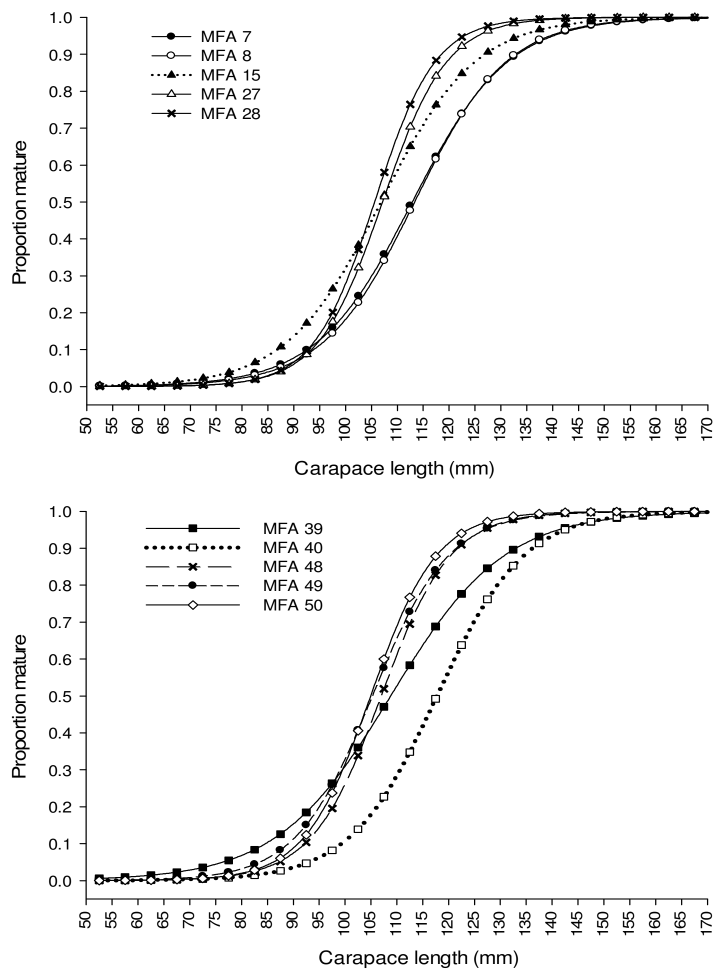

Figure 1-9 Spatial estimates of size of maturity in the NZRLF (from Linnane et al. 2011).

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 31 May 2011. For ease of reference, figures and text in this section refer to the starting year of each season (e.g. 2010 refers to the 2010/11 fishing season).

The scale of spatial analyses undertaken with respect to various fishery dependent data reflects their importance as performance indicators within the Management Plan for the NZRLF. For example, both CPUE (primary indicator) and pre-recruits (secondary indicator) are presented by zone, region, MFA and depth. Additional indicators such as length frequency data are presented at zonal scales only.

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. 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). From 1985 to 1991 catch increased from 657 to 1,221 tonnes before declining to about 900 tonnes in the mid 1990s. From 1996 to 1998, catch increased from 903 to 1015 tonnes. Over the next ten seasons with the exception of marginal increases in 2005 and 2006, catch in the NZRLF decreased. In 2008, the NZRLF catch was 402.7 tonnes, the lowest on record and 67.3 tonnes below the 470 tonne TACC (Table 2-1). This represented the fifth consecutive season that the TACC had not been fully taken since its introduction in 2003 at 625 tonnes. Overall, the 2008 figures represent a 60% decrease in catch since 1998 (1015.8 tonnes) and a 20% decrease since the introduction of the TACCs in 2003 (503.3 tonnes). In 2009, the TACC was reduced to 310 tonnes and was fully taken for the first time since its inception. In 2010, it was retained at 310 tonnes and was again fully landed with a catch of 312.2 tonnes.

Effort

Nominal fishing effort in the 1970s was about 450,000 potlifts per season (Figure 2-1). However, effort doubled from 411,939 potlifts in 1977 to 805,139 potlifts in 1991, the highest on record. From 1991, it fell to about 720,000 potlifts per season during the mid-1990s before decreasing further to 570,689 potlifts in 2002. Over the next six seasons, effort ranged between 553,000-615,000 potlifts. While catch had fallen by 60% since 1998, effort had not declined in proportion. The 2008 estimate of 600,347 potlifts represented only a 16.7% decrease since 1998 (720,816) and a 0.5% increase since the introduction of quota in 2003 (596,961). In 2009, effort decreased considerably to 350,838 potlifts and in 2010 to 289,925 potlifts representing a 52% decrease from 2008 (600,347 potlifts) and the lowest effort estimate on record.

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 1990s 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

CPUE in the early 1970s was over 1.40 kg/potlift (Figure 2-2). After the mid 1970s, it declined steadily to 1.10 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 nine seasons, with the exception of marginal increases in 2005 and 2006, to 0.68 kg/potlift in 2008, the lowest on record. This represented a 54% decrease in CPUE from 1999-2008. Over the last two seasons, CPUE has risen by 57% and in 2010 was 1.07 kg/potlift, the highest on record since 2001 (1.13 kg/potlift).

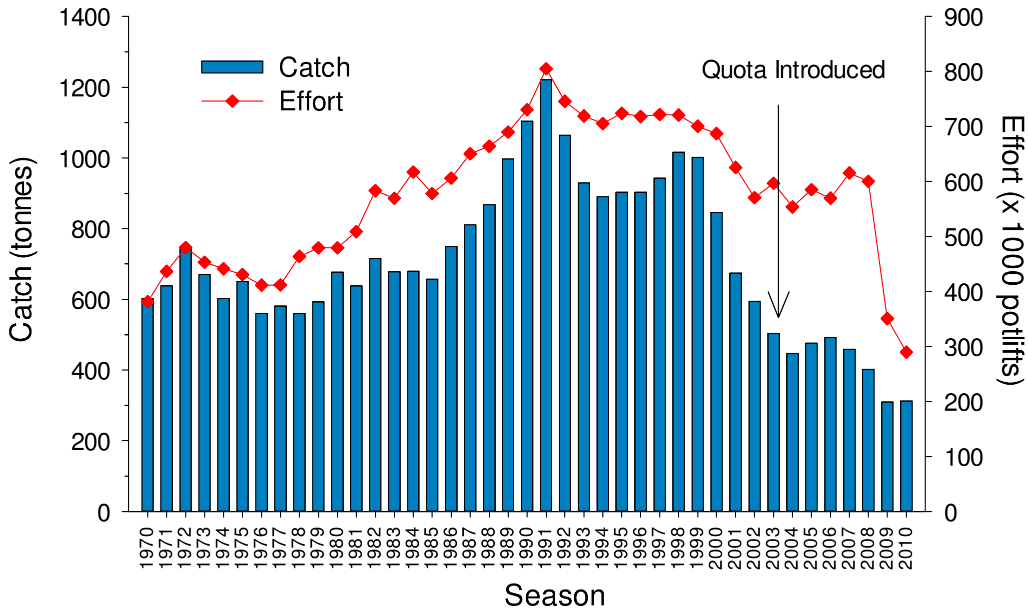

Figure 2-1 Inter-annual trends in catch and effort in the NZRLF between 1970 and 2010.

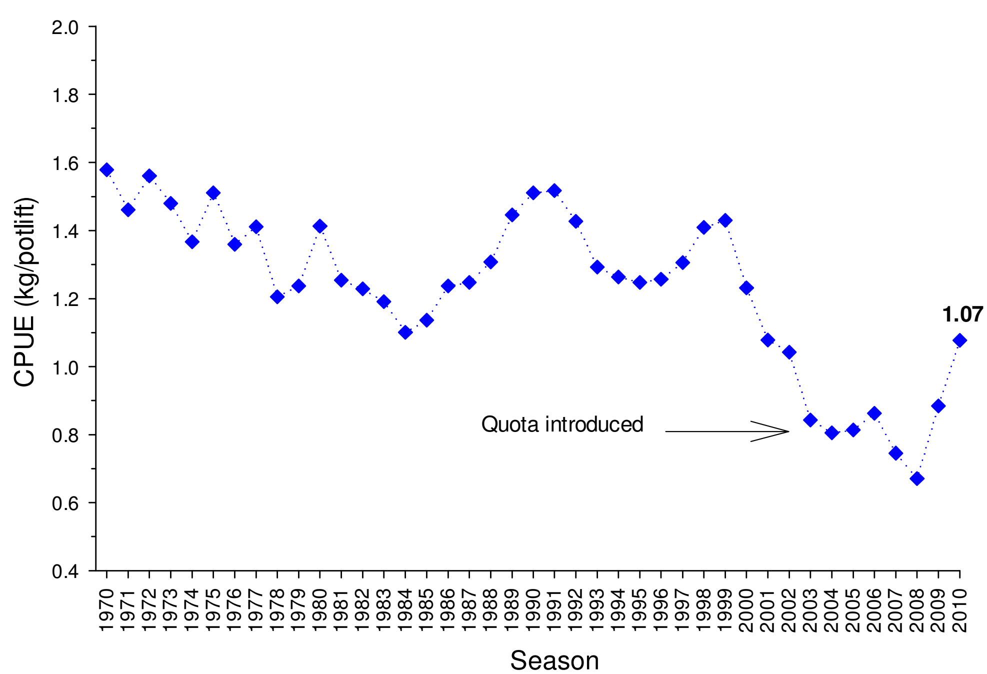

Figure 2-2 Inter-annual trends in CPUE in the NZRLF between 1970 and 2010 (based on November-April logbook data inclusive).

Table 2-1 Chronology of Total Allowable Commercial Catch (TACC) versus actual landed catch in the NZRLF from 2003 – 2010 (t = tonnes).

Season	TACC (t)	Landed Catch (t)	Shortfall (t)	% TACC taken
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
2009	310	310	0	100
2010	310	312	0	100

2.2.2 Within-season trends

Catch and effort

The within-season trends in catch and effort in the NZRLF are consistent among years. 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 2010, approximately 92% (286.6 tonnes) of the total catch (312 tonnes) was taken from November to March inclusive (Figure 2-3). The highest catch was taken in January (87.2 tonnes) with the lowest taken in May (3.4 tonnes). Trends in effort reflected monthly trends in catch with the highest effort in January (74,523 potlifts) and lowest in May (3,807 potlifts).

CPUE

As with catch and effort, within-season CPUE is consistent among years (Figure 2-4). CPUE generally increases for the first three to four months of the season before decreasing thereafter. In 2010, with the exception of December, trends were similar to those from previous seasons. CPUE increased from 1.11 kg/potlift in November to 1.17 kg/potlift in January before decreasing to 0.91 kg/potlift in May.

It is important to note that the zonal increase in CPUE in 2010 (Figure 2-2) was observed across all months of the season (Figure 2-4). The most notable increase was in November for which the 2010 estimate of 1.11 kg/potlift was about 48% above that for 2009 (0.75 kg/potlift).

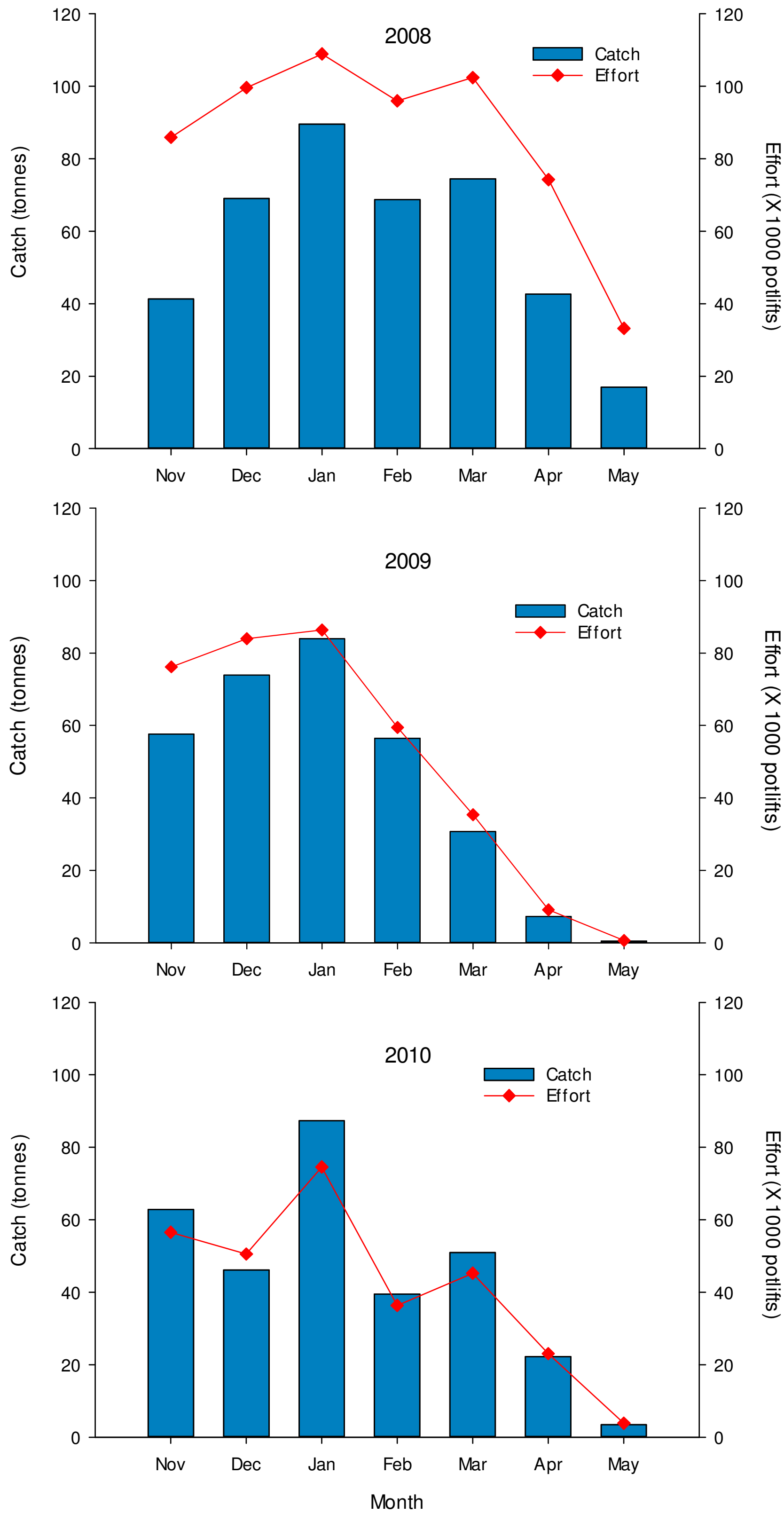

Figure 2-3 Within-season trends in catch and effort in the NZRLF from 2008-2010.

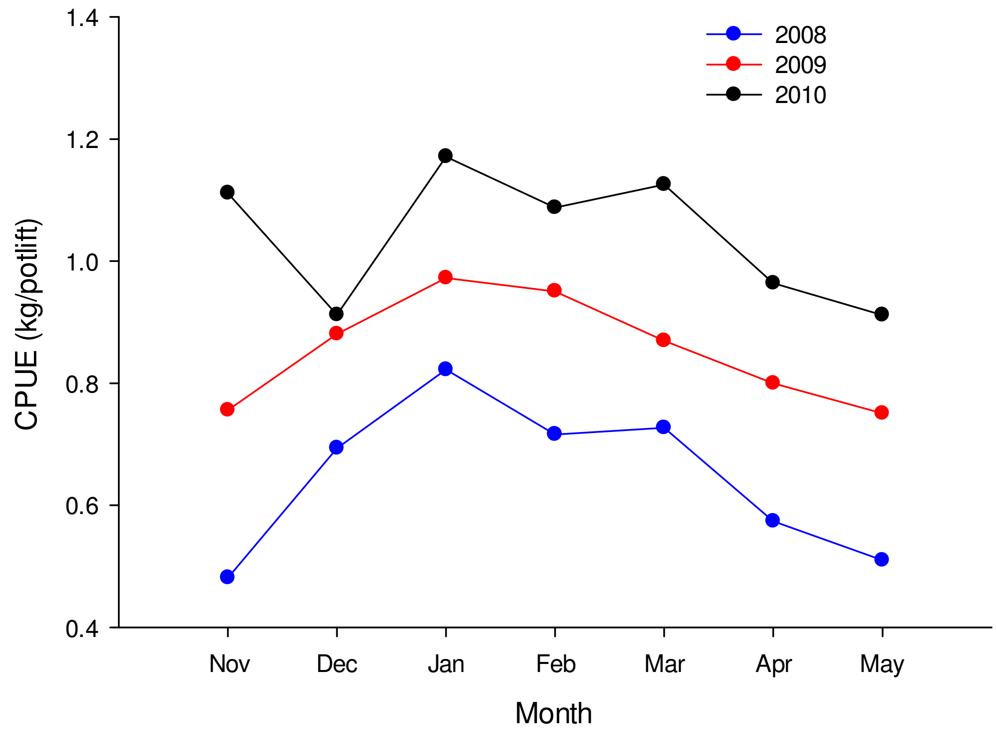

Figure 2-4 Within-season trends in CPUE in the NZRLF from 2008–2010.

2.2.3 Trends across key MFAs

Catch

In 2010, as in previous seasons, about 90% (280 tonnes) of the catch came from 10 main MFAs (7, 8, 15, 27, 28, 39, 40, 48, 49 and 50) (Figure 2-5) (refer to Figure 1-1 for location of MFAs) with about 83% (257 tonnes) taken in MFAs 15, 27, 28, 39, 40, 48 and 49 (Table 2-2). In 2010, compared to 2009, catch marginally decreased in MFAs 7, 8, 27, 28 and 50 and increased in MFAs 15, 39, 40, 48 and 49. The most notable increase was in MFA 39 where catch increased by 38% from 64.6 tonnes in 2009 to 89.6 tonnes in 2010. Long term trends in catch show substantial declines in all major MFAs especially MFAs 15, 28, 39 and 49. For example, catch in MFA 15 has decreased by 87% from 141 tonnes in 1998 to just 18 tonnes in 2010. Similarly, catch in MFA 28 has decreased by 72% from 218 tonnes in 1997 to 60 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 decreases in effort in many MFAs. For example, in MFA 28 effort has decreased by 61% from 137,090 potlifts in 2006 to 53,338 in 2010. Similarly, effort in MFA 39 decreased by 35% from 126,624 potlifts in 2004 to 82,365 potlifts in 2010. Notable decreases in effort were also observed in MFAs 15, 48 and 49.

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). From the late 1990s to 2008 CPUE has generally declined in most regions with the estimates in MFAs 7, 28, 39, 40, 48 and 49 the lowest on record in 2008. However, over the last two seasons CPUE has increased in almost all major MFAs. Most notable were the 2010 estimates in MFA 28 (1.12 kg/potlift), 39 (1.08 kg/potlift), 48 (1.05 kg/potlift) and 49 (1.09 kg/potlift) which reflected increases of 77%, 71%, 75% and 73%, respectively, from 2008 estimates.

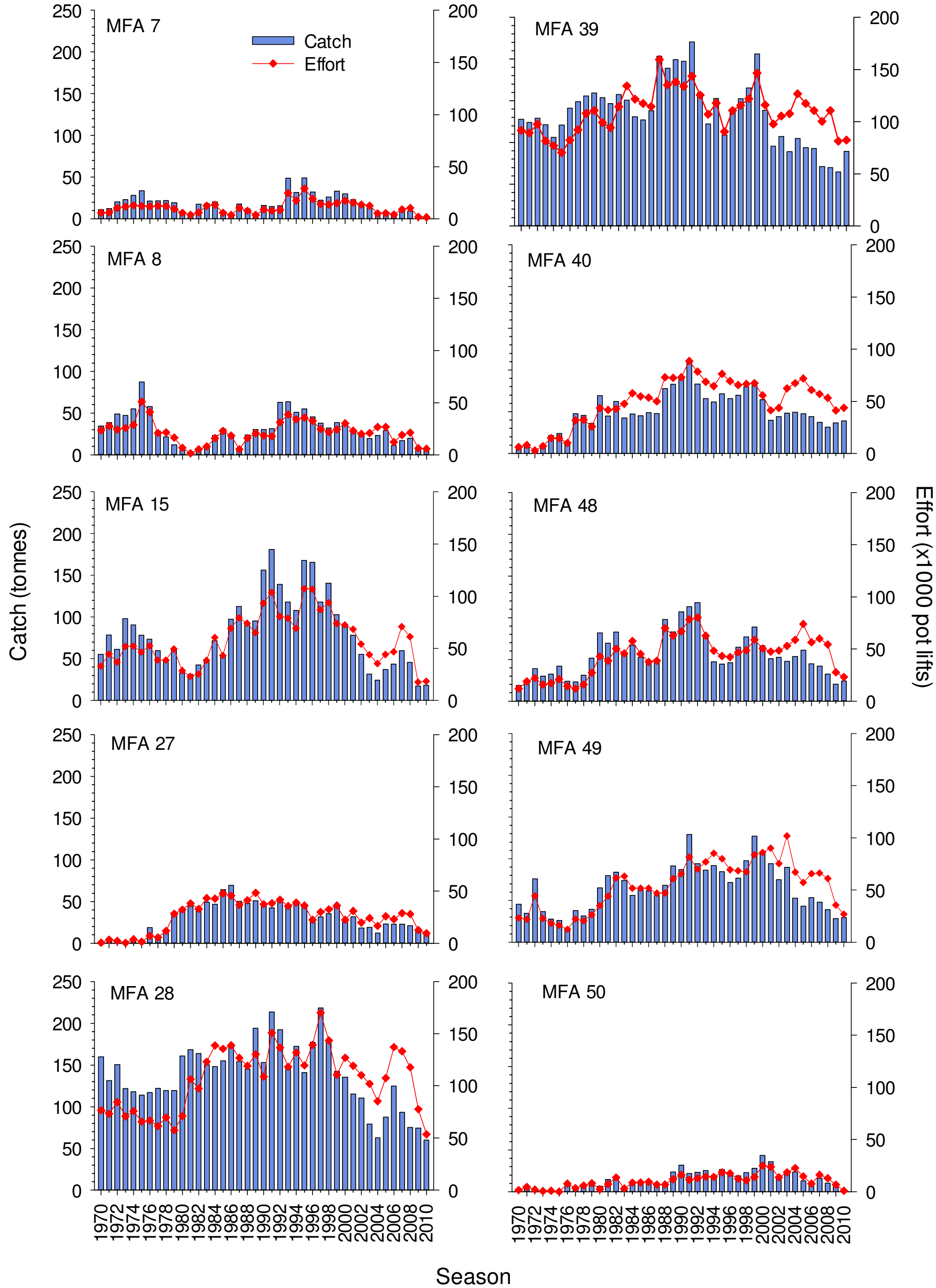

Figure 2-5 Inter-annual trends in catch and effort in the 10 main MFAs (from north-west to south-east) of the NZRLF for the fishing seasons between 1970 and 2010 (note: alternate seasonal ticks on X axis). Refer to Figure 1-1 for location of MFAs.

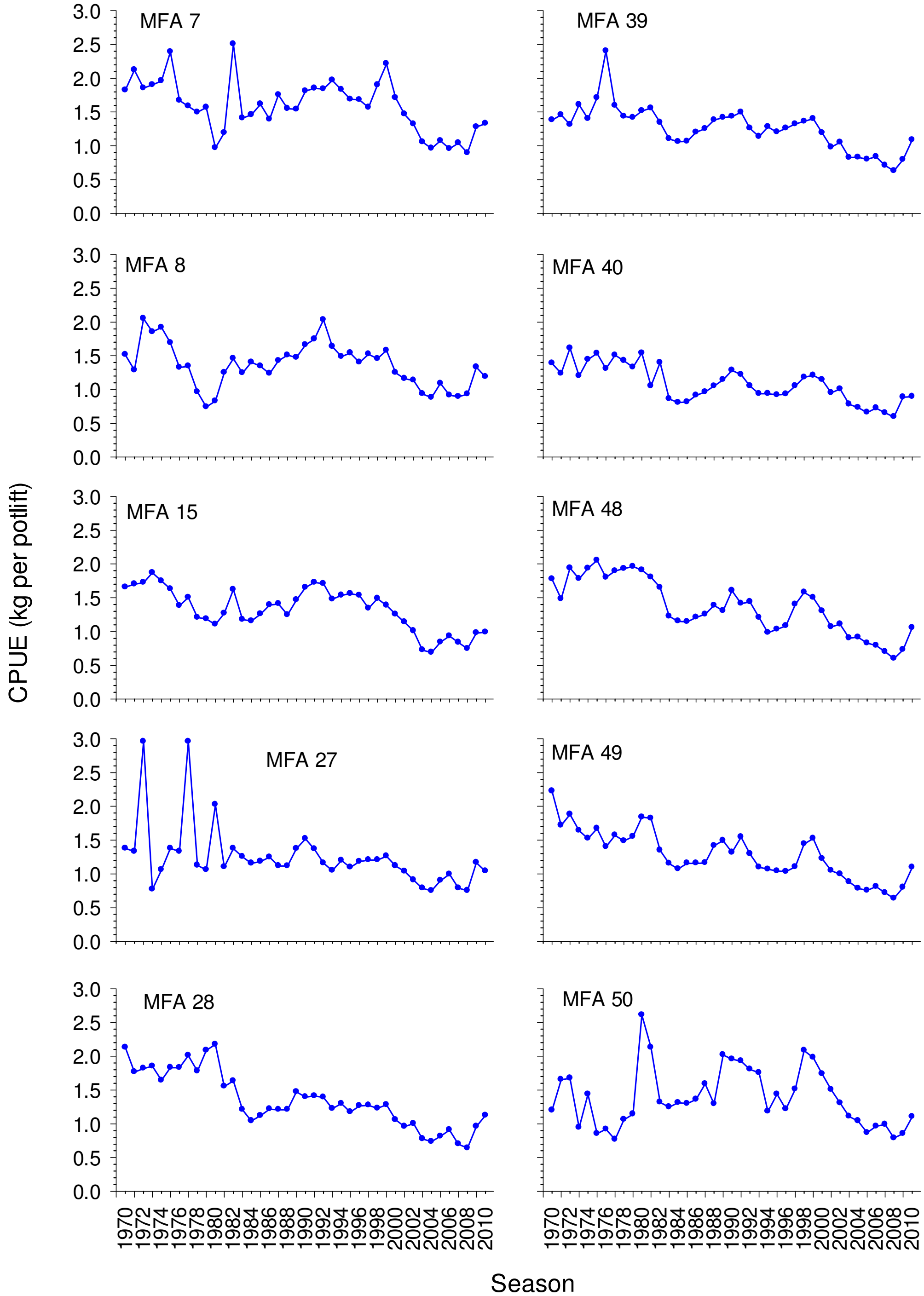

Figure 2-6 Inter-annual trends in CPUE of the 10 main MFAs (from north-west to south-east) of the NZRLF for the fishing seasons between 1970 and 2010 (note: alternate season ticks on x axis). Refer to Figure 1-1 for location of MFAs.

Table 2-2 Total catch taken from the 10 main MFAs in the NZRLF in 2010.

MFA	Catch (t)	% Total Catch
7	2.16	1
8	6.80	2
15	18.29	7
27	9.81	3
28	59.98	21
39	89.65	33
40	39.31	14
48	24.44	9
49	29.45	10
50	0.88	<1

2.3 Trends by Region

2.3.1 Catch

Regional catch trends in the NZRLF (refer to Figure 1-4) between 1970 and 2010 are presented in Figure 2-7. While up to 172 tonnes were taken in Region A in 1993, catches are now <50 tonnes with just 11.1 tonnes landed in 2010. The majority is taken in Regions B, C and D. In recent seasons, notable declines in catch have been observed in Regions B and D, reflecting the zonal trends presented in Figure 2-1. For example, the 2009 estimate in Region B of 123.0 tonnes is 73% lower than the catch of 453.3 tonnes in 1997. Similarly, catch in Region D has declined consistently on an annual basis over the last decade. The 2009 catch was 131.9 tonnes which is 67% lower than the 399.5 tonnes in 1999 from the same area. Catch in Region C has remained relatively constant over the last nine seasons at between 60-90 tonnes. In 2010, the catch was 11.14, 115.24, 67.24 and 119.10 tonnes in Regions A, B, C and D, respectively. These estimates are similar to those from 2009 in all regions.

2.3.2 Effort

Trends in effort generally reflect those in catch (Figure 2-7). Over the last two seasons effort decreased in all areas. In 2010, the estimates were 9,501, 100,005, 70,421 and 110,067 potlifts in Region A, B, C and D respectively. The 2010 estimates are the lowest on record in Regions A, B and D. Overall, the 2010 estimates represent a decrease of 75%, 59%, 28% and 49% in Regions A, B, C and D respectively from 2008 estimates.

2.3.3 CPUE

As with zonal trends in CPUE (Figure 2-5), there has been a general decrease in CPUE across the four Regions of the NZRLF over the last decade (Figure 2-8). With the exception of marginal increases in 2005 and 2006, catch rate in Region B decreased from 1.41 kg/potlift in 1999 to 0.69 kg/potlift in 2008. In Region C, CPUE decreased from 1.33 kg/potlift to 0.61 kg/potlift, while in Region D it decreased from 1.55 kg/potlift to 0.78 kg/potlift over the same period. Over the last two seasons, CPUE has increased in all Regions. In 2010, estimates were 1.16, 1.16, 0.95 and 1.08 kg/potlift, respectively, in Regions A, B, C and D. This represents an increase of 68%, 55% and 66% in Regions B, C and D, respectively, from 2008 estimates and reflects the highest catch rate since 2000 (1.21 kg/potlift) in Region B and the highest since 2002 in Regions C and D (1.00 and 1.08 kg/potlift, respectively).

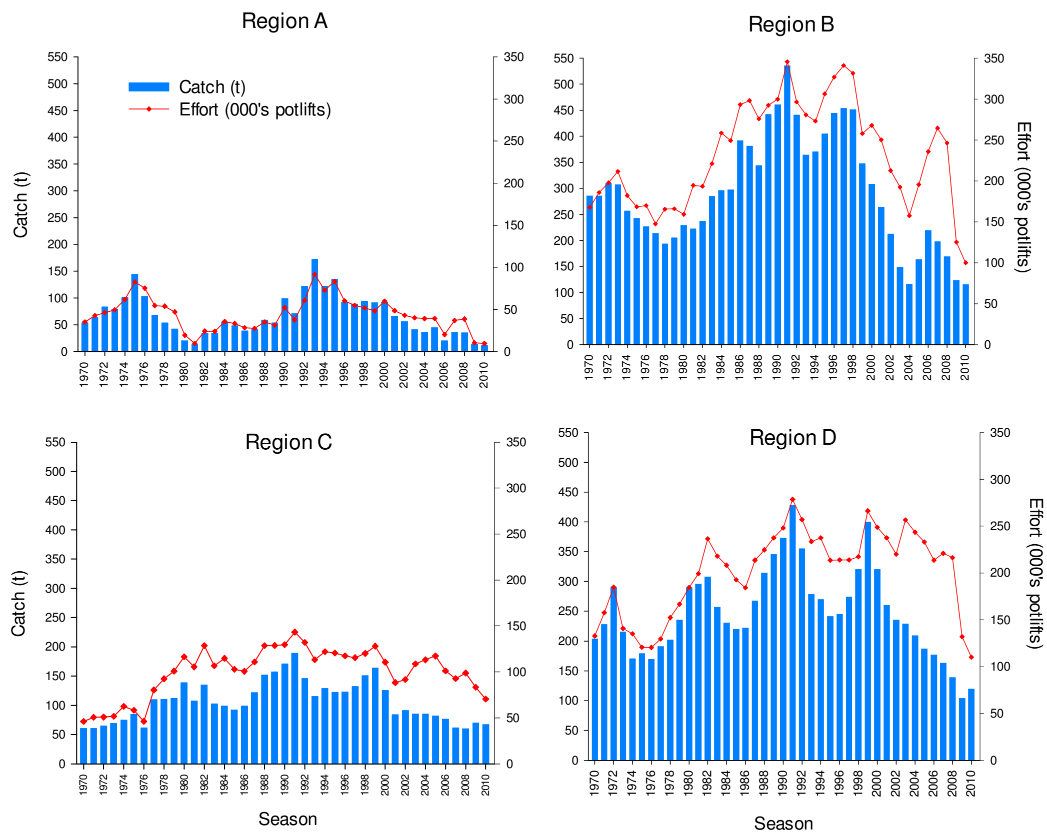

Figure 2-7 Catch and effort by region in the NZRLF from 1970-2010. Note that catch and effort from MFA 39 (Figure 1-1) has been apportioned 30:70 between Regions C and D.

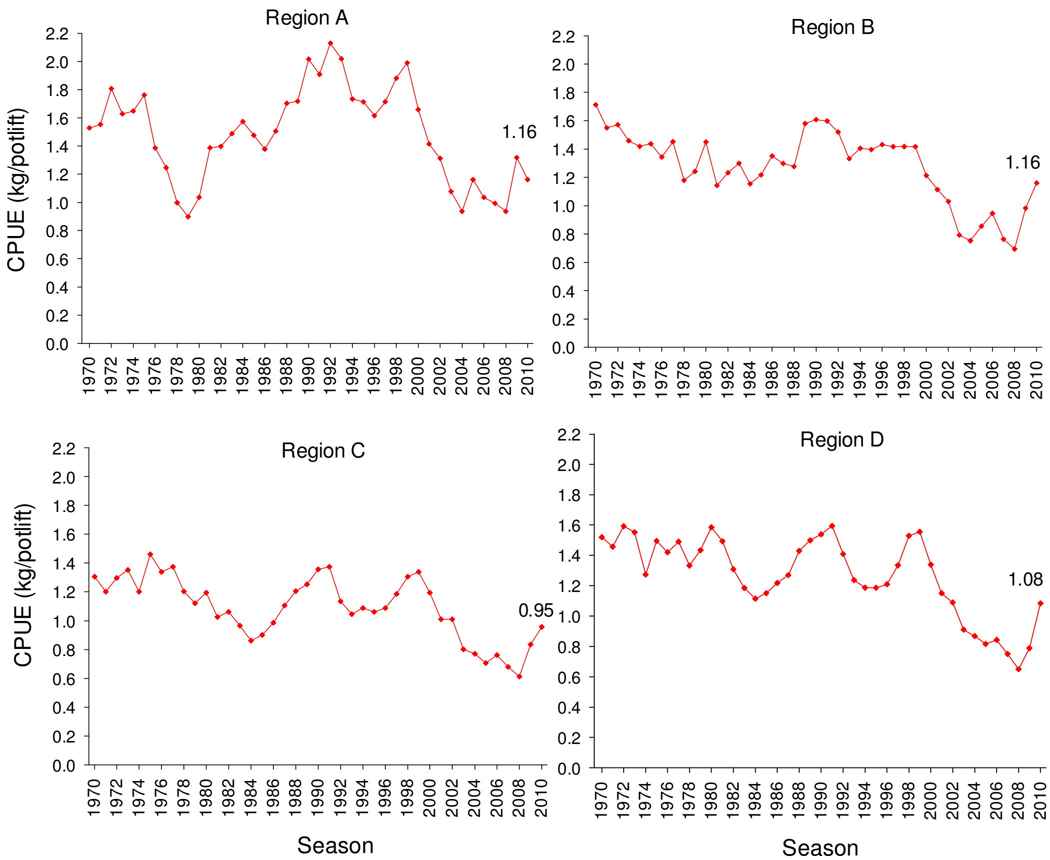

Figure 2-8 CPUE by region in the NZRLF from 1970-2010. Note that catch and effort from MFA 39 (Figure 1-1) has been apportioned 30:70 between Regions C and D to calculate catch rate.

2.4 Trends by Depth

2.4.1 Catch

Over the last six seasons, the majority (>80%) of the catch in the NZRLF has been taken at depths of <60 m (Figure 2-9). This trend continued in 2010 with 33% of catch taken from depths of 0-30 m and 57% taken from depths of 31-60 m. The deeper waters (61-90 m) contributed 9% to catch with only 1% coming from depths >90 m. For zonal estimates of catch by depth before 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 2-11). In 2010, 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 (up to 28% in MFA 49) was taken in deeper waters of >60 m depth. For estimates of catch by depth before 2001 in key MFAs, see Linnane et al. (2007).

2.4.2 CPUE

CPUE generally increases with depth in the NZRLF. Lowest catch rates tend to be in shallower depths of 0-30 m and 31-60 m while higher CPUEs are observed in waters >60 m (Figure 2-10). In 2010, in depths of <30 m, CPUE increased from 0.74 kg/potlift in November to 1.04 kg/potlift in January before decreasing over the next four months to 0.78 kg/potlift in May. Similar trends were observed at generally higher catch rates in the 31-60 m depth range. In 2010, the highest catch rates were recorded in the 61-90 m range with estimates of 1.81, 1.95 and 2.01 kg/potlift in November, January and March, respectively. Catch rates from depths >90 m are not provided due to limited data.

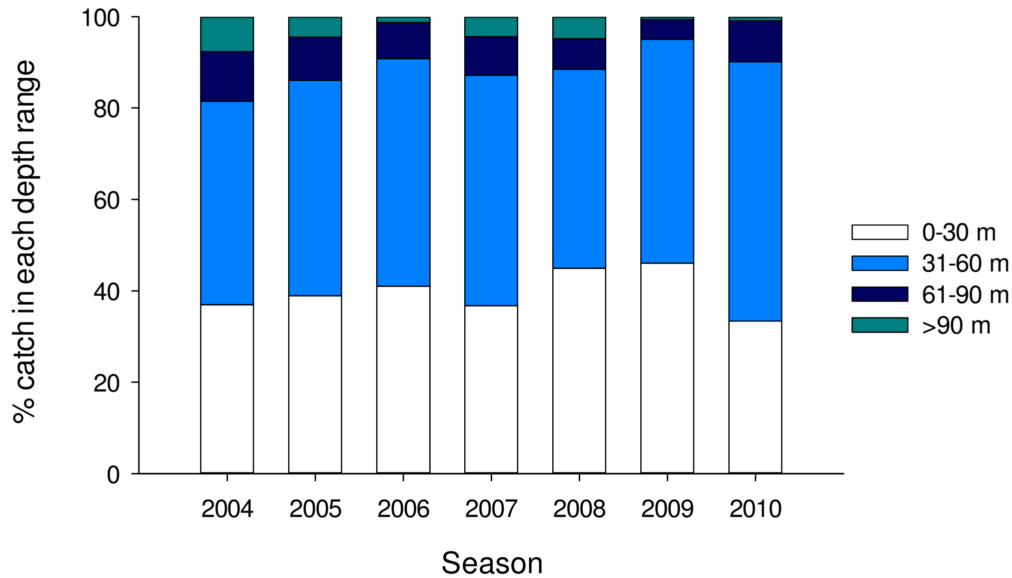

Figure 2-9 Percentage of the catch taken from four depth classes in the NZRLF from 2004-2010.

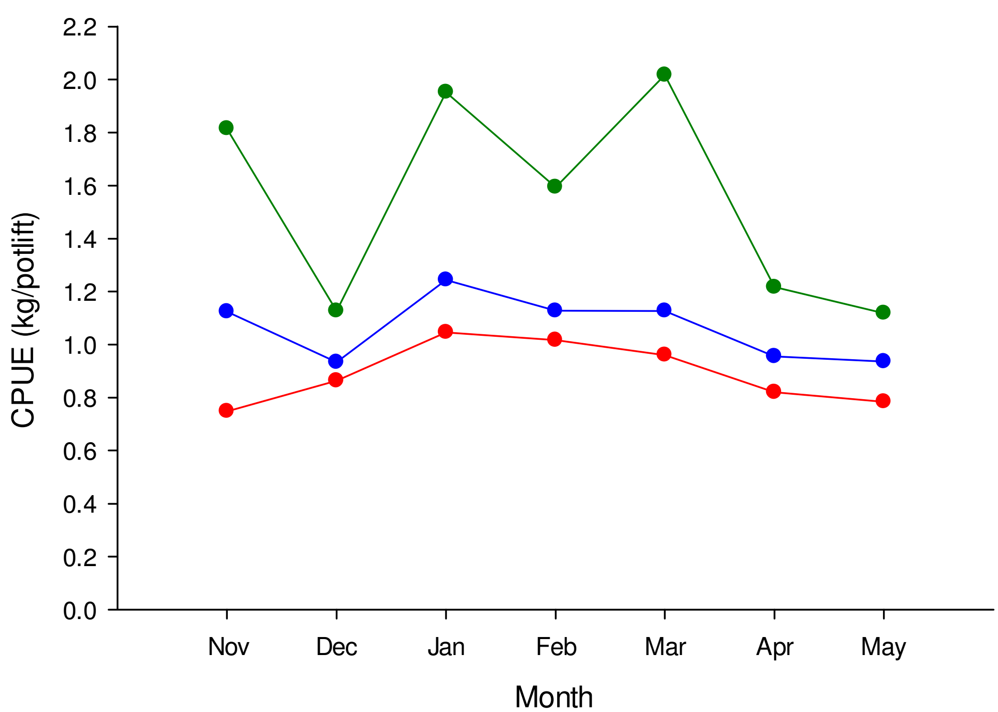

Figure 2-10 Monthly CPUE in three depth classes in the NZRLF during the 2010 fishing season.

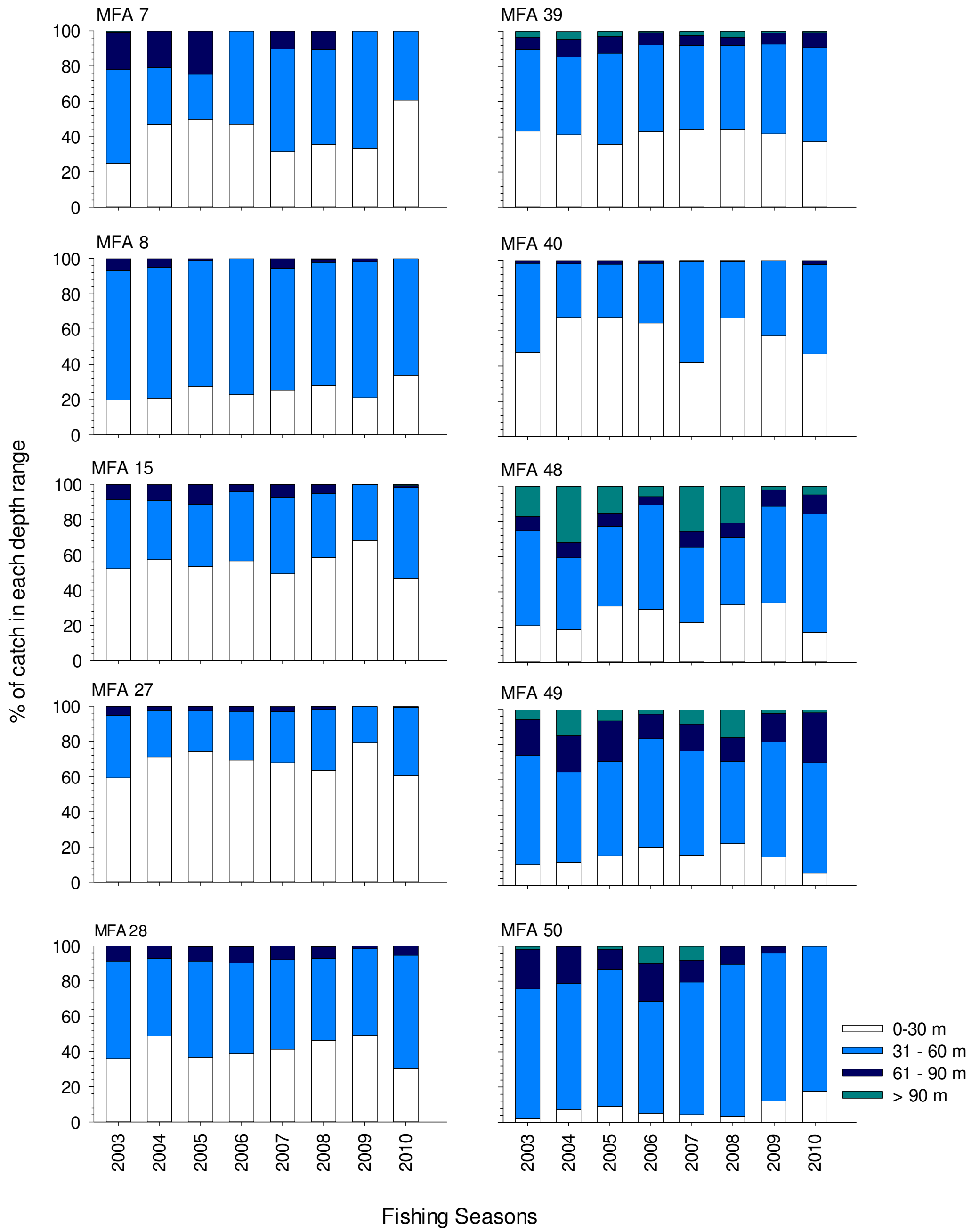

Figure 2-11 Percentage of the catch taken from four depth classes in the ten major MFAs of the NZRLF from 2003-2010. Refer to Figure 1-1 for location of MFAs.

2.5 Pre-recruit Index

2.5.1 Zonal trends

The pre-recruit index (PRI: Nov-Mar inclusive), based on logbook data is underestimated due to mandatory introduction of escape gaps in 2003. As part of the catch sampling protocol, fishers are allowed to close the escape gaps in up to three pots. From 2003 to 2009 both logbook and catch sampling data are highly correlated (R=0.75) (Figure 2-12). In the NZRLF, the estimated period between settlement and PRI is 3 years. As a result, the high PRIs in 2008 and 2009 are believed to reflect the high settlements in 2005 and 2006. In 2010, catch sampling and logbook data provided conflicting views in terms of future recruitment. Catch sampling estimated PRI was 0.67 undersized/potlift, the highest on record, while logbook PRI decreased by 19% from 0.26 undersized/potlift in 2009 to 0.21 undersized/potlift in 2010. It should be highlighted that catch sampling PRI in 2010 was based on about 3,500 potlifts (1.2% of total effort) the lowest on record, and as a result, estimates should be treated with some caution.

2.5.2 Within-season trends

In 2010, there were no clear trends in catch sampling derived PRI (Figure 2-13). PRI was highest in March at 0.99 undersized/potlift and lowest in May at 0.25 undersized/potlift. Logbook derived PRI had a seasonal high of 0.29 undersized/potlift in November before decreasing to 0.15 undersized/potlift in December (Figure 2-14). Over the next four months, PRI increased to 0.24 undersized/potlift in April before decreasing to a seasonal low of 0.06 undersized/potlift in May.

2.5.3 Trends by MFA

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 2-15 and Figure 2-16). Overall, based on data from the last 3-4 seasons both logbook and catch sampling data indicate that pre-recruit levels in the southern region part of the zone are at historically high levels but may be in decline in other areas. For example, based on catch sampling data PRI has generally increased in MFAs 39, 40, 48 and 49 from 2007 but has decreased over the last 1-2 seasons in MFAs 27 and 28 (Figure 2-15). Similarly, logbook data indicates that PRI has increased in MFAs 48 and 49 since 2008 but decreased in 2010 in MFA 27 and 28 (Figure 2-16).

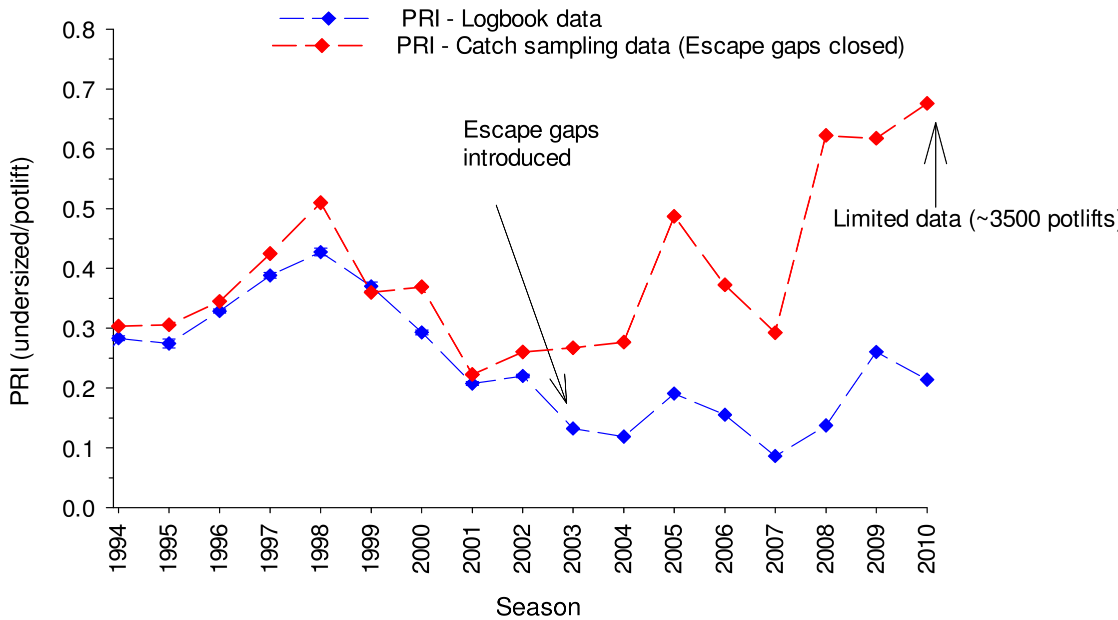

Figure 2-12 Comparison of inter-annual trends in pre-recruit index from logbook and voluntary catch sampling data from 1994-2010 (November-March inclusive).

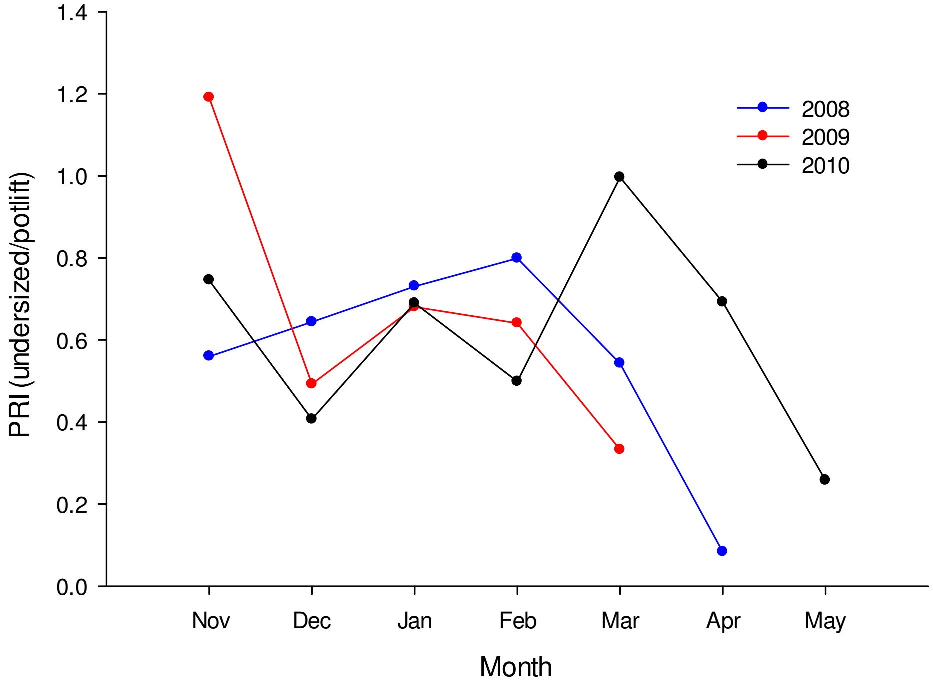

Figure 2-13 Within-season trends in catch sampling pre-recruit index (PRI) in the NZRLF from 2008–2010.

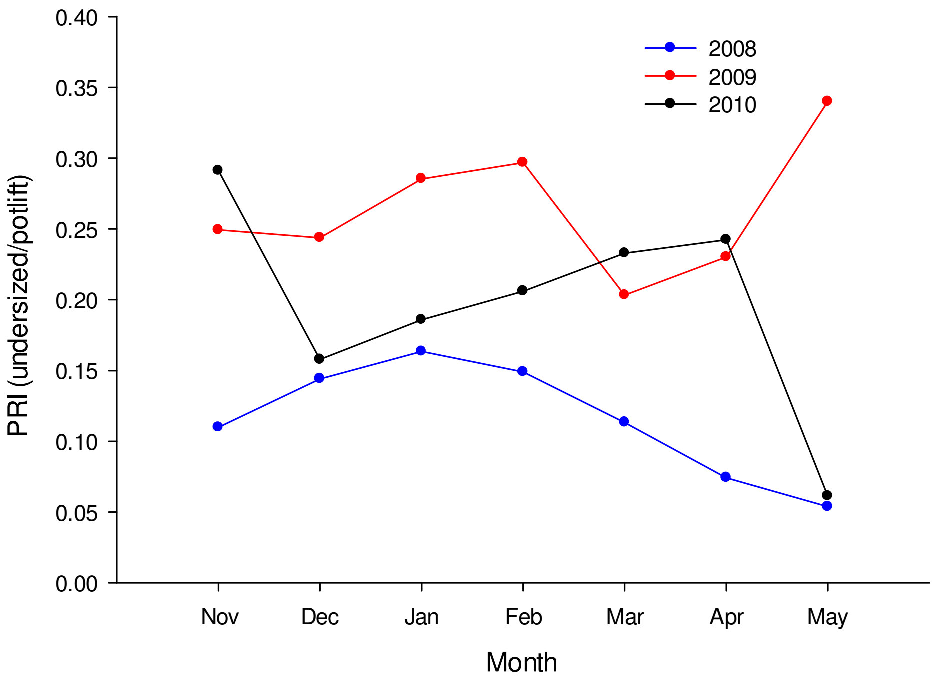

Figure 2-14 Within-season trends in logbook pre-recruit index (PRI) in the NZRLF from 2008–2010.

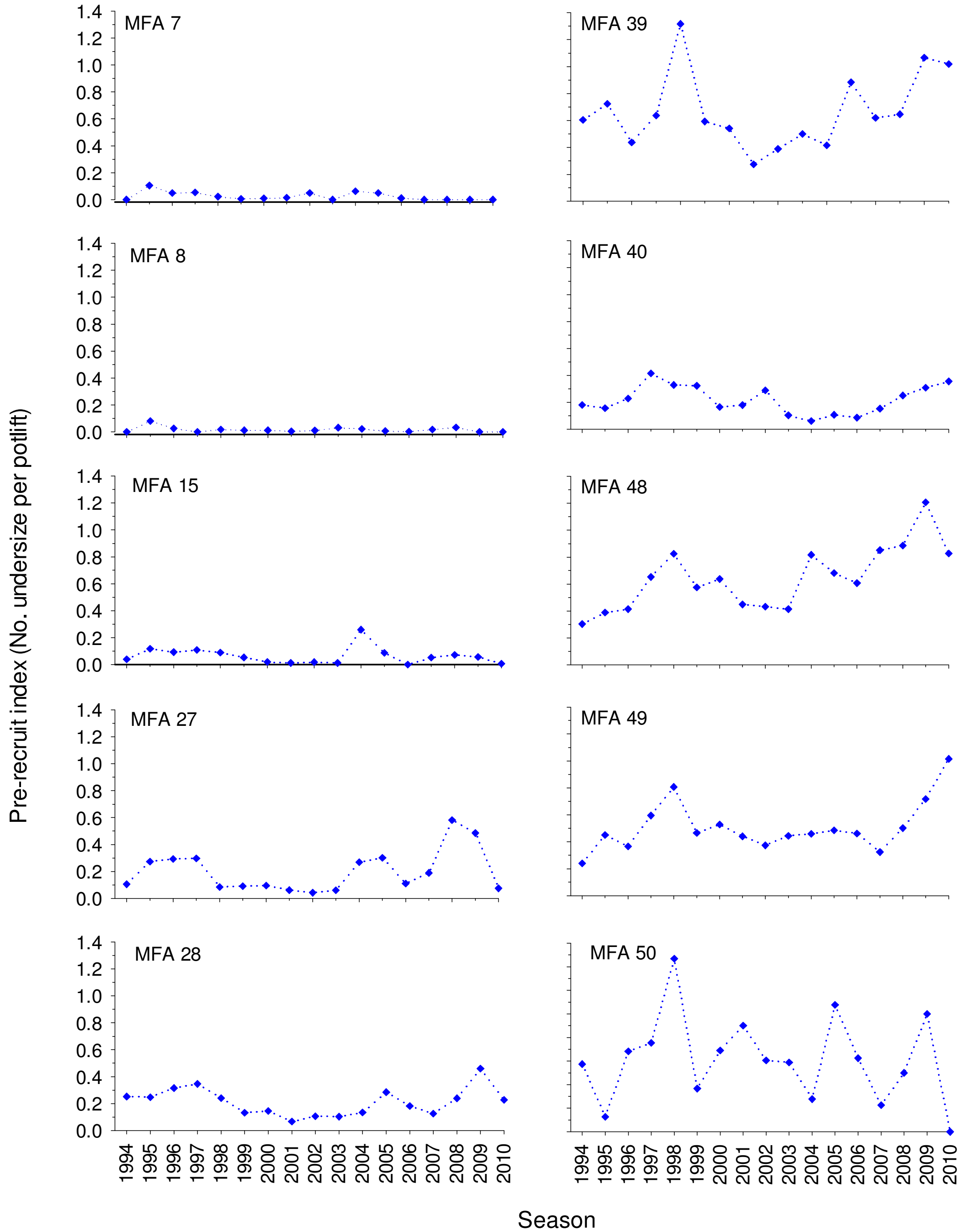

Figure 2-15 Pre-recruit index (catch sampling data) for MFAs in the NZRLF from 1994-2010 (Numerical order of MFAs is from north-west to south-east). Refer to Figure 1-1 for location of MFAs.

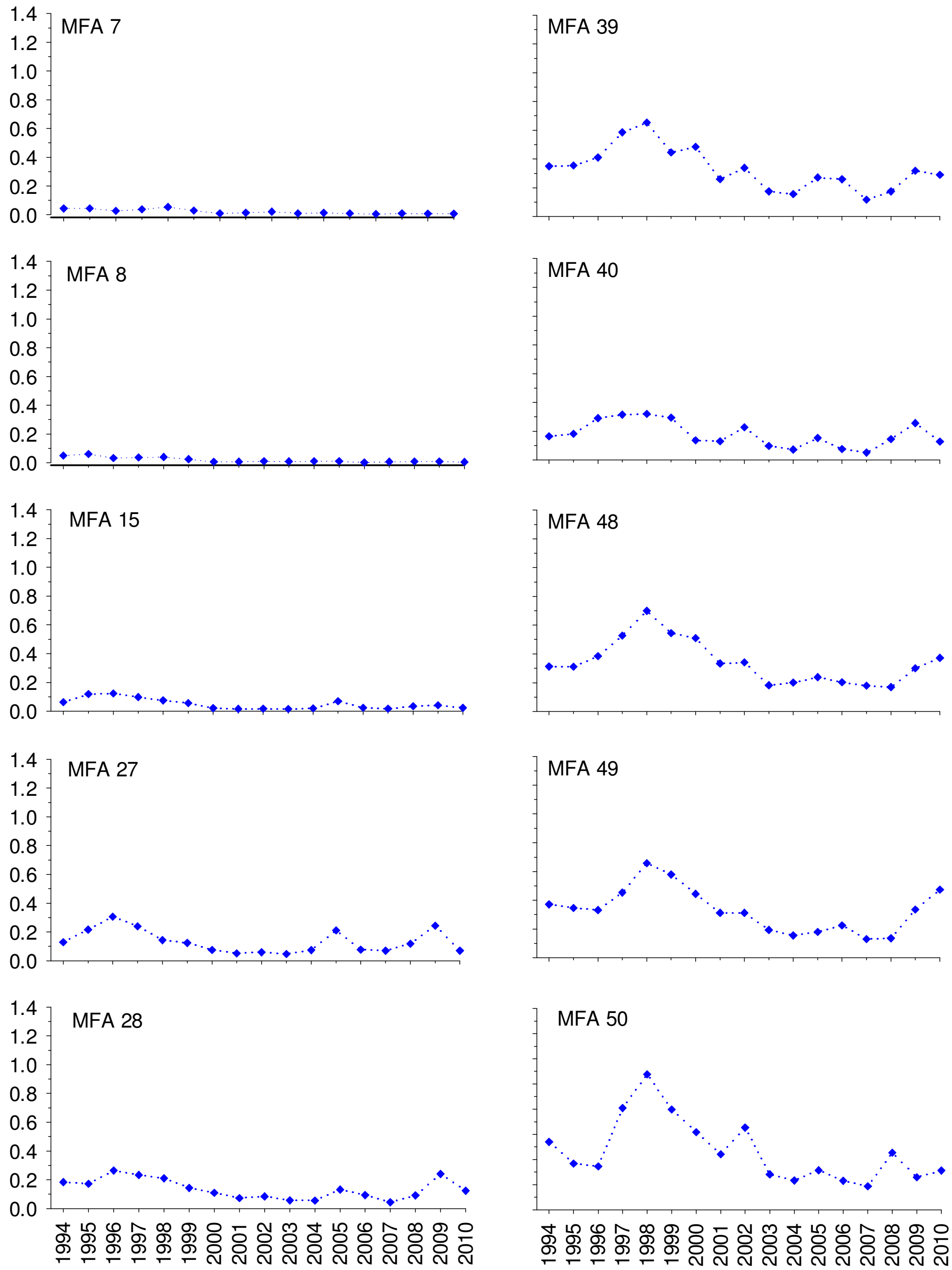

Figure 2-16 Pre-recruit index (logbook data) for MFAs in the NZRLF from 1994-2010 (Numerical order of MFAs is from north-west to south-east). Note: escape gaps introduced in 2003. Refer to Figure 1-1 for location of MFAs.

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 (Figure 2-17). 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. From 2001 to 2006 mean weights decreased from 1.21 to 1.00 kg. In 2007, mean weight increased to 1.13 kg before decreasing to 0.97 kg in both 2009 and 2010, reflecting two of the lowest mean weights on record. Mean weight estimates can be affected by the practice of high-grading where some larger lobsters are returned to the water due to low market value. Since 2000, total weight estimates of lobsters in the NZRLF have been <1 tonne. In 2010, it was 2.3 tonnes (<1% of total catch) however, it should be highlighted that since high-grading is recorded on a voluntary basis only, estimates are likely to be underestimated.

2.6.2 Within-season trends

Mean weight generally increases as the season progresses in the NZRLF (Figure 2-18). In 2010, mean monthly weight increased from 0.85 kg in November to 1.02 kg in January and remained at about 1 kg over the next three months before increasing to 1.17 kg in May.

2.6.3 Trends across key MFAs

Mean weights of lobsters are highest in MFAs located in the north of the NZRLF (e.g. MFA 7, 8, 15, 27), and lowest in MFAs located further south (e.g. MFA 48, 49, 50) (Figure 2-19). Between 1983 and 1998, mean weights were relatively stable in most MFAs but increased between 1998 and 2001, with the exception of MFA 8. From 2001 to 2006 mean weight generally decreased in most MFAs before increasing in 2007 and 2008 reflecting the zonal estimates over the same period (Figure 2-17). Over the last two seasons mean weight has decreased in most of the ten high catch MFAs with the 2010 estimates the lowest on record in MFAs 48, 49 and 50.

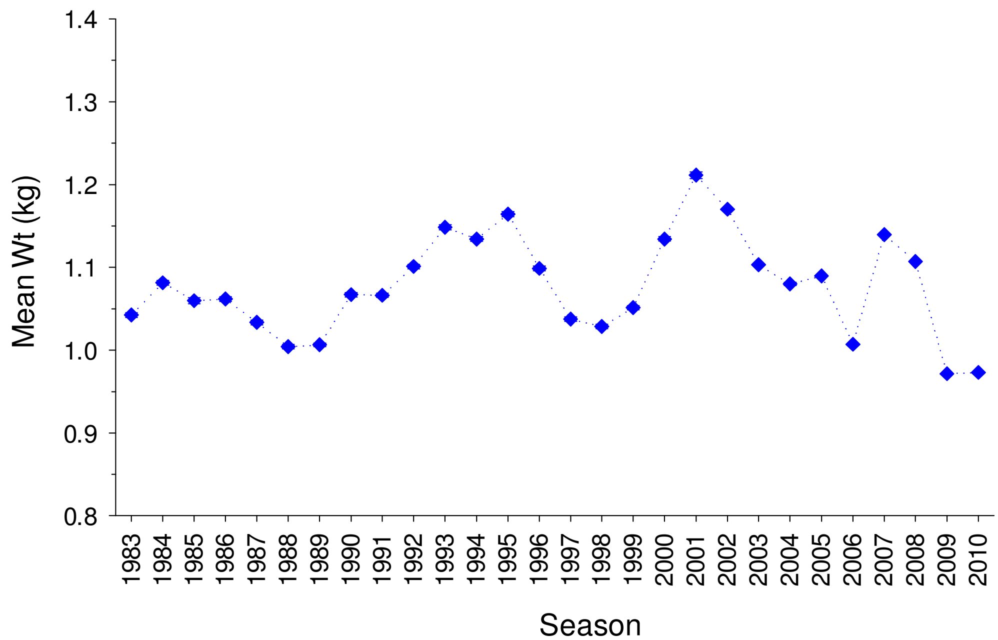

Figure 2-17 Inter-annual trends in the mean weight of lobsters in the NZRLF from 1983-2010.

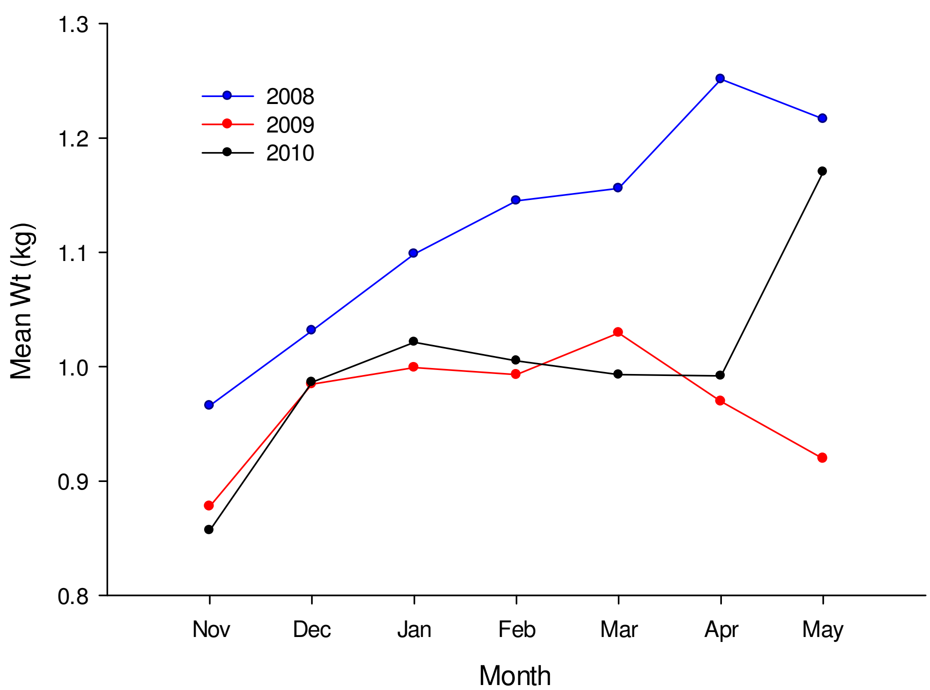

Figure 2-18 Within-season trends in the mean weight of lobsters in the NZRLF during the 2008, 2009 and 2010 seasons.

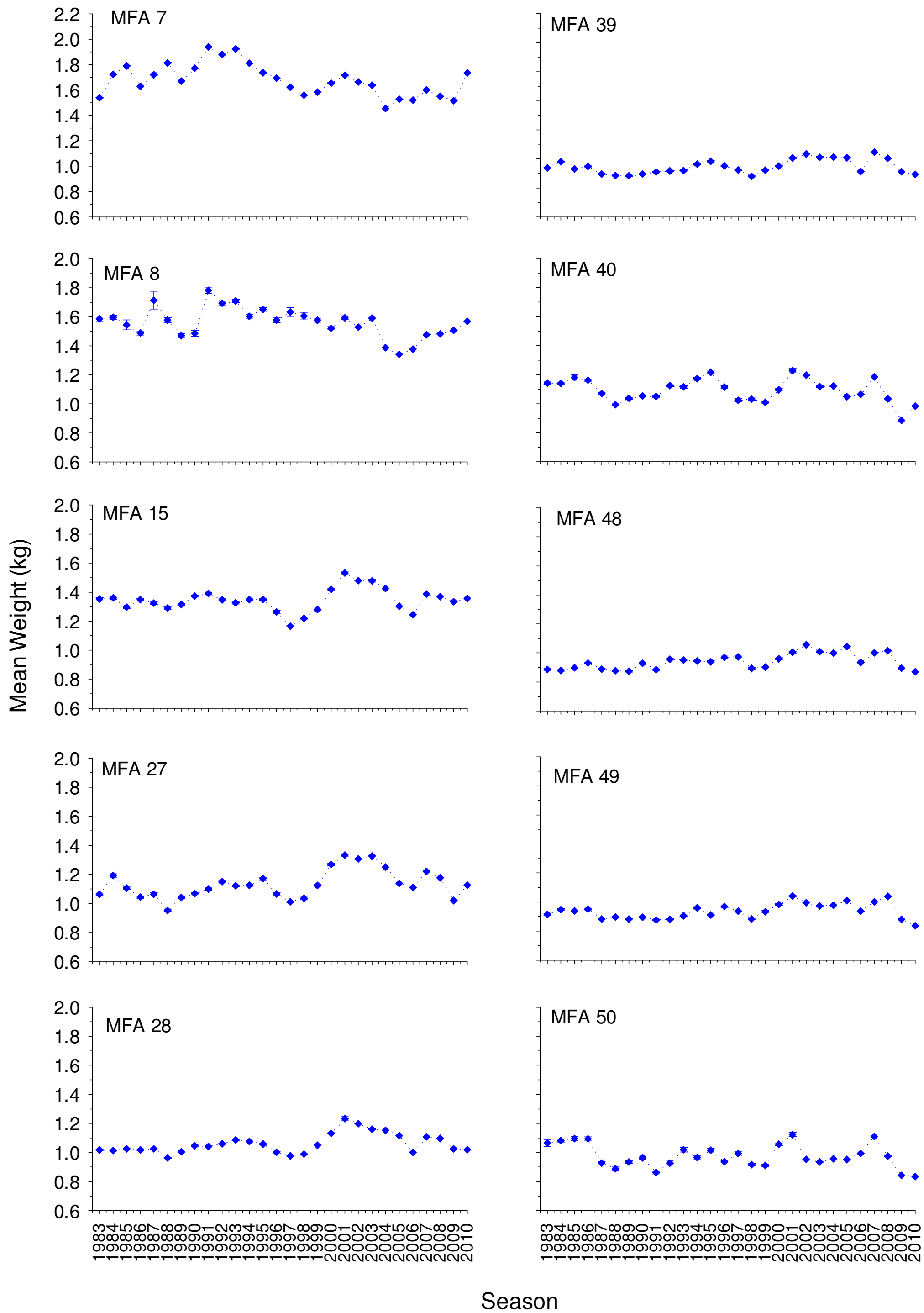

Figure 2-19 Inter-annual trends in the mean weights of lobsters for the main MFAs of the NZRLF from 1983-2010. Refer to Figure 1-1 for location of MFAs.

2.7 Length Frequency

Since 1991, up to 18,000 lobsters have been measured annually as part of the voluntary catch sampling program. The number measured is proportional to the level of participation in the program which has ranged between 20-40% over the last five seasons (Figure 1-8).

Male lobsters, which generally grow faster and reach larger sizes than females, range between 70 and 200 mm CL. In contrast, few females are larger than 150 mm CL. In 2010, a total of 6,279 lobsters were sampled (Figure 2-20). Of these, 52% were males and 48% females.

An analysis of length frequency distributions over the last three seasons indicates evidence of a recruitment pulse entering the fishery in both 2009 and 2010 (Figure 2-20) resulting from strong puerulus settlement (Figure 3-1) observed in 2005 and 2006 (given a four year period between settlement and recruitment). In 2008, 48% of all lobsters were represented by size classes below the MLS of 105 mm CL, reflecting the high PRI observed during that season (Figure 2-12). As these cohorts recruited into the fishery in 2009 and 2010, the frequency of sizes classes within the fishable biomass between 105 and 130 mm CL increased, reflecting the observed increased in legal size catch rate during these two seasons (Figure 2-2). For example, in 2008, 36% of lobsters fell between 105-130 mm CL. In 2009, it was 44% and in 2010, it increased to 51%.

In 2009 and 2010, the frequency of undersized lobsters within the 70-90 mm CL range decreased from 17% in 2008 to 10% in 2009 and 7% in 2010. This correlates with low levels of puerulus settlement observed in 2007 (Figure 3-1) given a three year period between settlement and pre-recruits. Overall, these data highlight the importance of length frequency data collated through the voluntary catch sampling program in providing information on recruitment trends within the fishery.

That withstanding, limitations associated with fishery dependent estimates of size should also 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 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 largely fishery dependent.

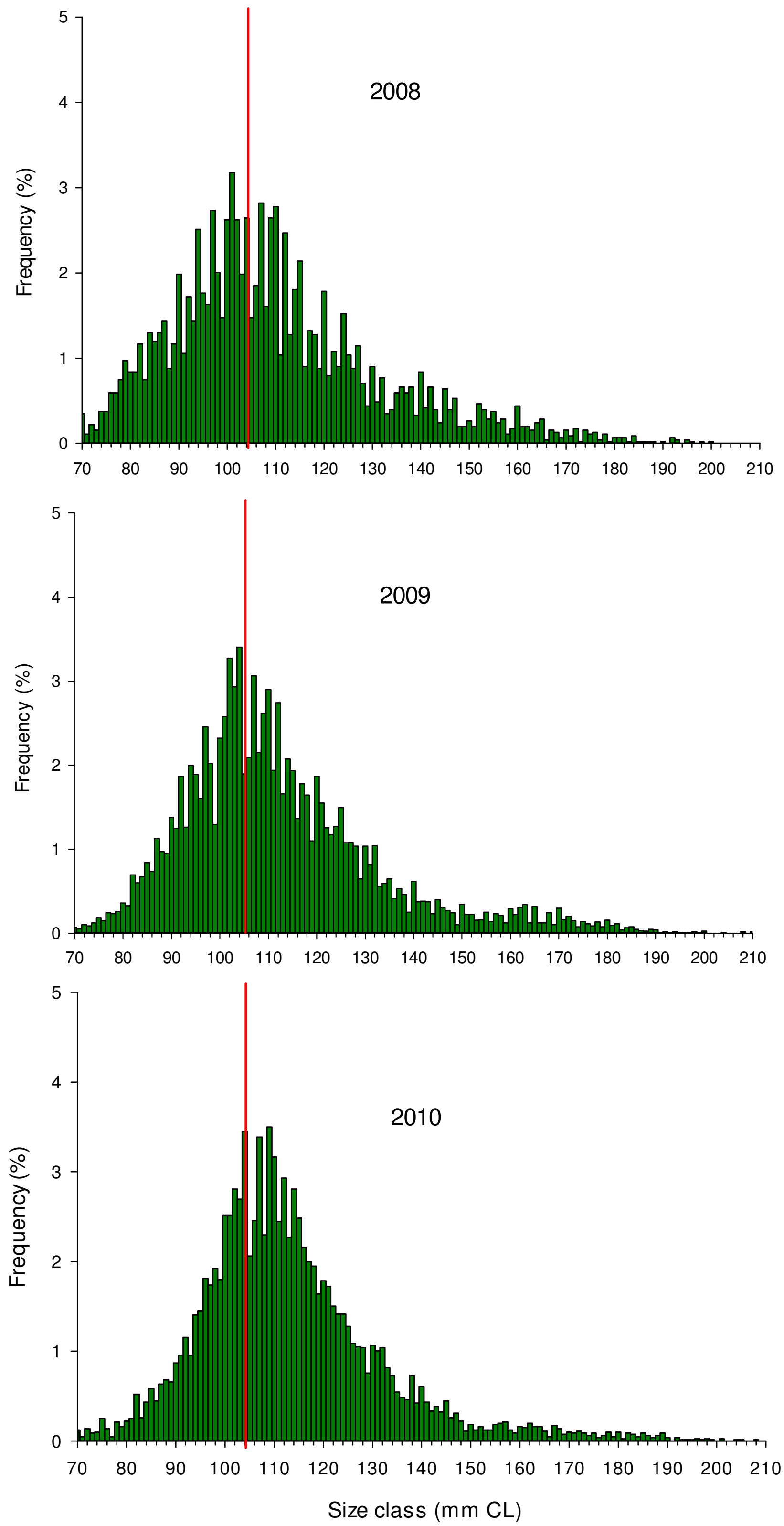

Figure 2-20 Length frequency distributions of male and female lobsters combined in the NZRLF from 2008-2010.

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 2-21) 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 2010, the index was 0.03 spawners/potlift representing the highest estimate on record since 2003. Overall, the data indicates a considerable decrease in the biomass of spawning lobsters in the NZRLF over the last decade.

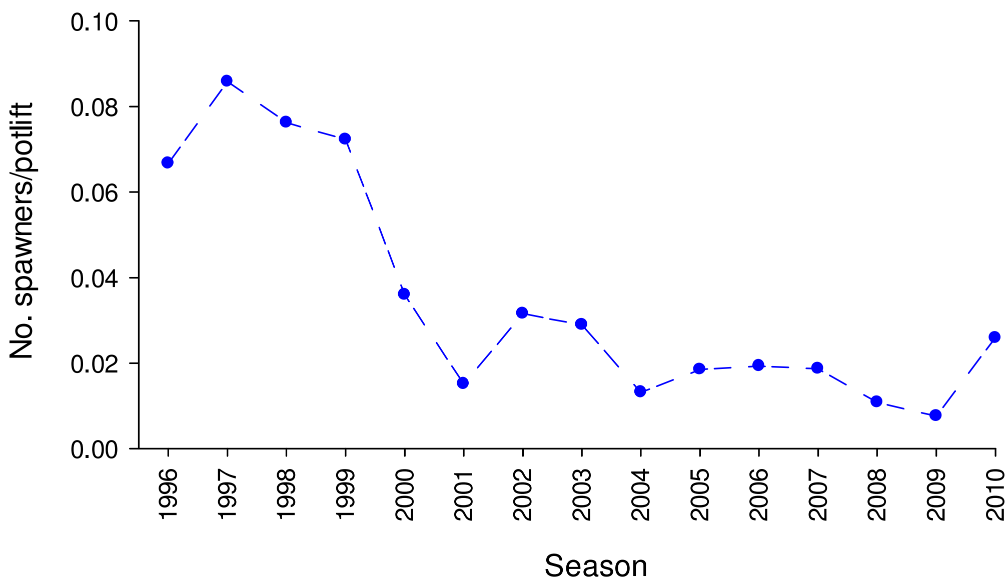

Figure 2-21 Inter-annual trends in the catch rate of spawning lobsters in the NZRLF between 1996 and 2010.

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 2-22). Between 1996 and 1999, estimates ranged between 0.07 and 0.09 dead/potlift before decreasing to ~0.04 dead/potlift in 2001. From 2001 to 2009 the index has not exceeded 0.05 dead/potlift. In 2010 it increased to 0.06 dead/potlift, the highest on record since 1999 (0.08 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.

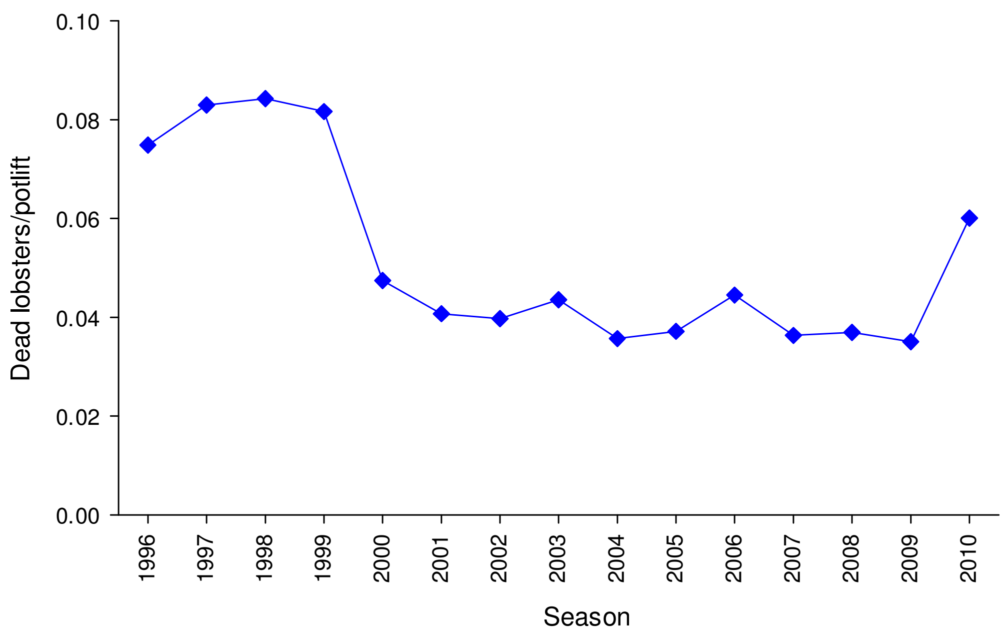

Figure 2-22 Inter-annual trends in the catch rates of dead lobsters in the NZRLF from 1996-2010.

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 2-23). Temporal trends indicate that the highest CPUE of 0.022 octopus/potlift was recorded in 1998. Over the next 11 seasons however, catch rates decreased and now rarely exceed 0.005 octopus/potlift. In 2010, 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 – 2010 (R^2 = 0.89; see Figure 2-22).

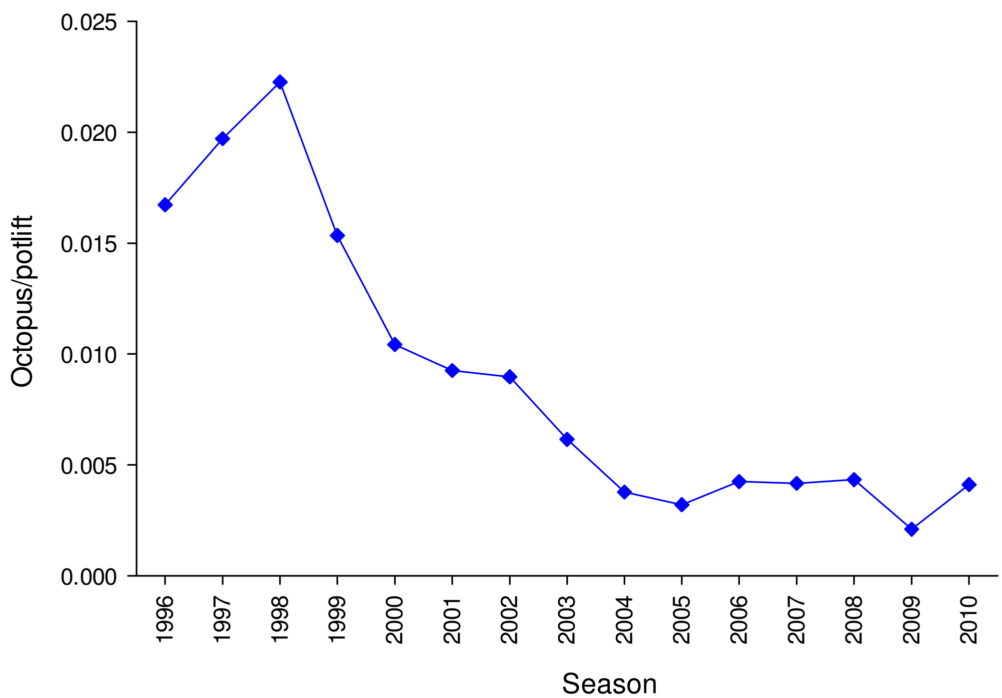

Figure 2-23 Inter-annual trends in catch rates of octopus in the NZRLF from 1996-2010.

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 about 184 days in the mid-late 1990s to 144 days in 2002 (Figure 2-24). 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. From 2002 to 2008, the estimate ranged from 152 to 162 days despite the fact that the fishery changed to output controls in the form of a TACC quota system in 2003. These data indicate that during this period, the TACC (introduced in 2003 at 625 tonnes and subsequently reduced to 470 tonnes in 2008) had minimal impact in constraining effort in the fishery highlighted by the fact that the 2008 estimate of 156 days fished was only 15% less than that recorded in 1997 (184 days), when the fishery was still managed under input controls. In 2009, the TACC was reduced to 310 tonnes which resulted in the average numbers of days fished decreasing to just 100 days. In 2010, it decreased further to 84 days, the lowest estimate on record.

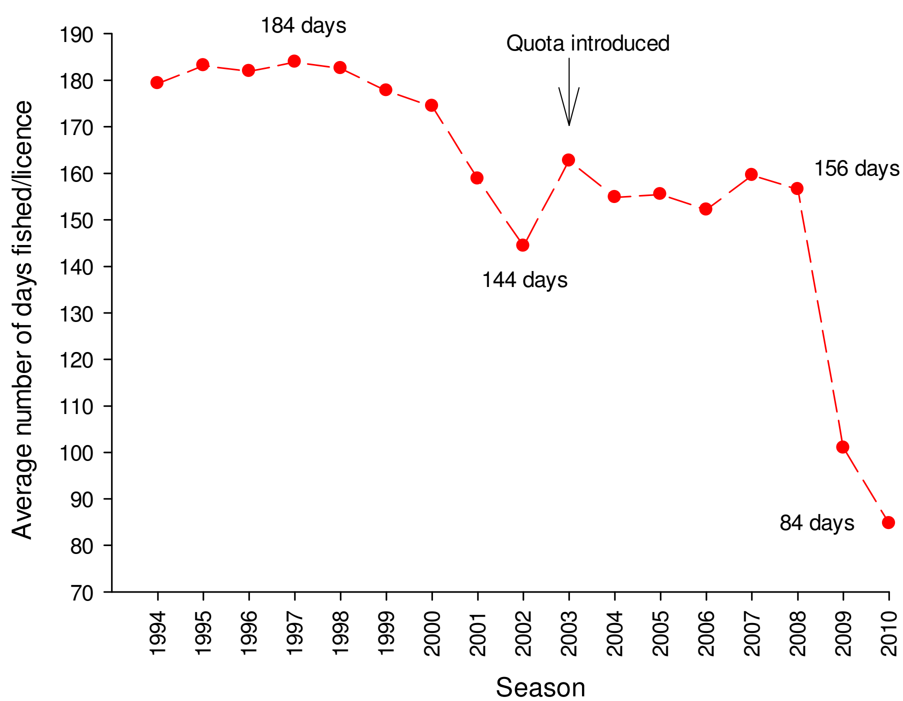

Figure 2-24 Inter-annual trends in the average number of days fished per licence in the NZRLF between the 1994 and 2010 fishing seasons.

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. From 1996 to 2001, the PSI remained relatively low (Figure 3-1). The period between settlement and recruitment to the fishery is about 4 years. 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. With the exception of 2009 (0.34 puerulus/collector), settlement was low over the next four seasons with the 2010 estimate of 0.02 puerulus/collector, the lowest on record. In 2011, it was 0.23 puerulus/collector, reflecting the fifth consecutive season that settlement was below average. Overall, these results highlight the variable nature of settlement in the NZRLF.

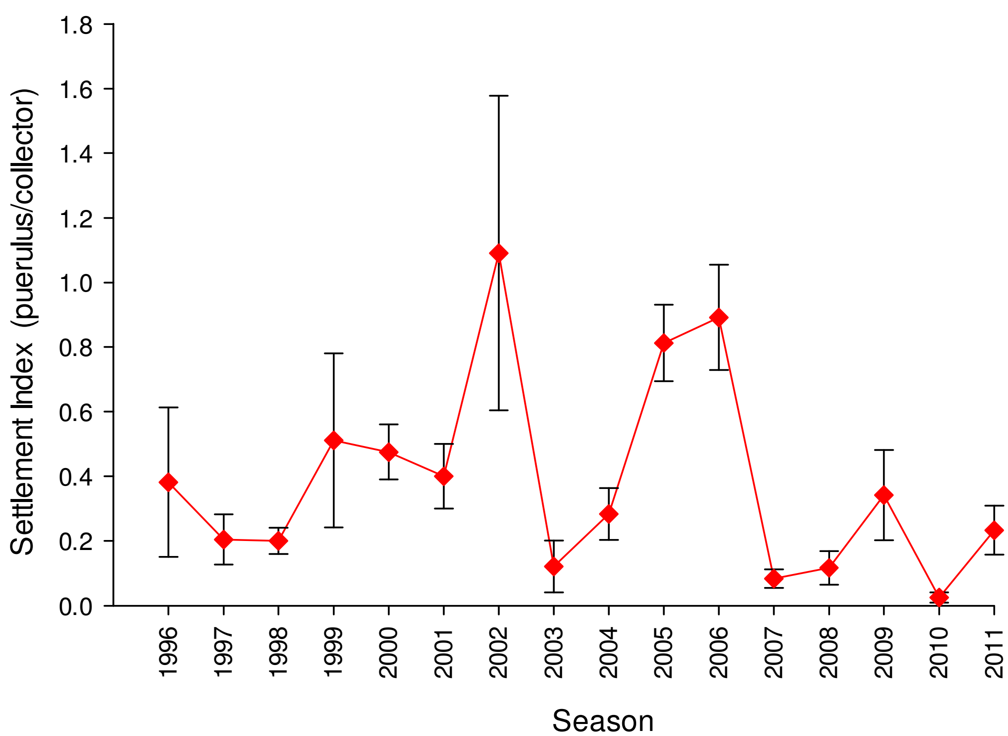

Figure 3-1 Puerulus settlement index (PSI; mean ± SE) in the NZRLF from 1996-2011.

3.1.1 Correlations with pre-recruit indices

Based on growth analyses from tagging studies, the estimated period from settlement to recruitment to the minimum legal size of 105 mm CL, is approximately four years (McGarvey et al. 1999a). The period from settlement to pre-recruitment is about three years. Lagged PSIs were correlated against PRIs from both catch sampling and logbook data over the period 1999 to 2010. *R* values were 0.37 over the complete time series for catch sampling PRI and PSI and 0.23 (from 2001 to 2010) between PSI and logbook PRI. Importantly, high PSIs in 2002, 2005 and 2006 were reflected by substantial increases in PRIs in both sampling methods in 2005, 2008 and 2009. For correlations between PRIs and model estimated recruitment from both the qR and LenMod models, see sections 4 and 5 of this report.

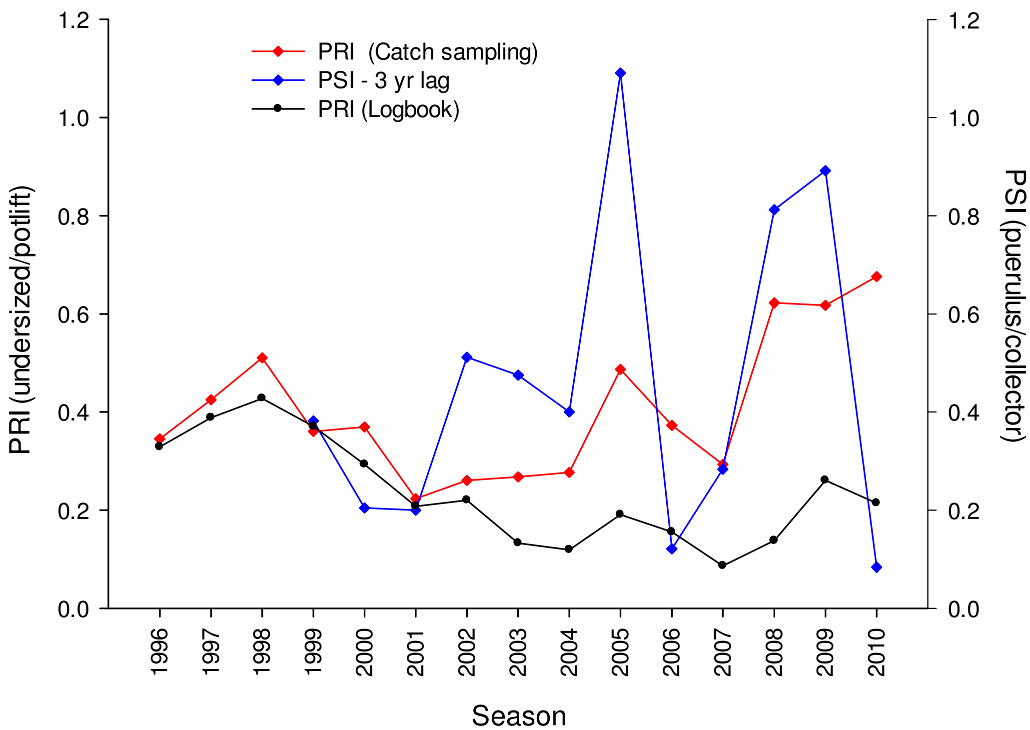

Figure 3-2 Correlations between NZRLF puerulus settlement index (PSI) lagged by 3 years with pre-recruit indices (PRI) from both catch sampling and logbook data.

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 notable changes to the model 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 and (iii) the incorporation of a 3% annual increase in effective effort over the period from 1983 to 2000.

This section of the report has two objectives; (i) to use the 2010 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 2010 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 model year are estimated as free parameters. The standard deviation of the two normal likelihood components is specified by a 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 significantly improves the accuracy and precision of stock assessment estimates.

The pre-recruit index, (PRI, measured as the catch rate of undersized lobsters), provides a direct measure of yearly recruitment that is independent of qR-inferred recruitment, the latter using only legally-sized, landed lobsters. PRI therefore provides a means of assessing the time trends in recruitment outputs from the qR model. The two pre-recruit indices (from catch sampling and logbooks) 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, and so ran from 1983-2000. 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 the 2008 season 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 2010 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 indicate a general decline in lobster biomass in the NZRLF over the last 30 seasons (Figure 4-3). For example, biomass in the early 1970s was estimated at ~5000 tonnes but by 2008 it had decreased by ~70% to 1,416 tonnes. In 2010, it was estimated to be 2,123 tonnes. This represents a 50% increase since 2008 (1,416 tonnes) and is the highest estimate on record since 2001 (2,199 tonnes).

Egg production

Due to decreasing biomass trends, egg production in the NZRLF has also declined since the inception of the fishery (Figure 4-4). In 2010, it was 253 billion eggs, an increase of 49 billion from 2009 (204 billion) and the second consecutive year that egg production has increased. Current levels equate to 20% of virgin egg production (Figure 4-5).

Exploitation rate

Exploitation levels increased substantially through the 1970s and 1990s, reaching a peak of 35% in 1999 (Figure 4-6). Since then, they have generally decreased and in 2010 were estimated at 15%. The 2010 figure represents a substantial decrease from 2008 (28%) and is the lowest since 1981 (12%) This decrease in exploitation rate reflects a corresponding decline in fishing effort indicating that current TACC levels are effectively constraining catch in the fishery.

Comparison of estimates of recruitment from qR model with PRI

Estimates from the qR model suggest that recruitment generally declined in the NZRLF from 1.5 million recruits in 1998 to ~0.4 million in 2008 (Figure 4-7). In 2009, the qR estimate of recruitment was 1.19 million representing the highest on record since 1999 (1.25 million). In 2010, the estimate was 0.95 million. When temporal trends in recruitment estimated by the qR model were compared against PRI estimates from both logbook and catch sampling from 1994-2010, the strongest correlation (R^2 = 0.86) was with logbook data (Figure 4-7). qR recruitment was poorly correlated with catch sampling estimates (R = 0.26).

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 with a general decline from 1970 through to 2008. However, over the last two seasons it has increased and in 2010 was estimated at 2,123 tonnes, the highest since 2001. Similar trends were observed in egg production with 2010 reflecting 20% of virgin estimates, the highest since 1999 (22%). The recent increase in biomass and egg production reflects high levels of recruitment in both 2009 and 2010 which has resulted in a considerable decrease in exploitation levels to 14%, the lowest since 1982 (15%).

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, the current version of the qR model for the NZRLF is exclusively reliant on fishery dependent data, namely catch in weight and number. As a result, 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.

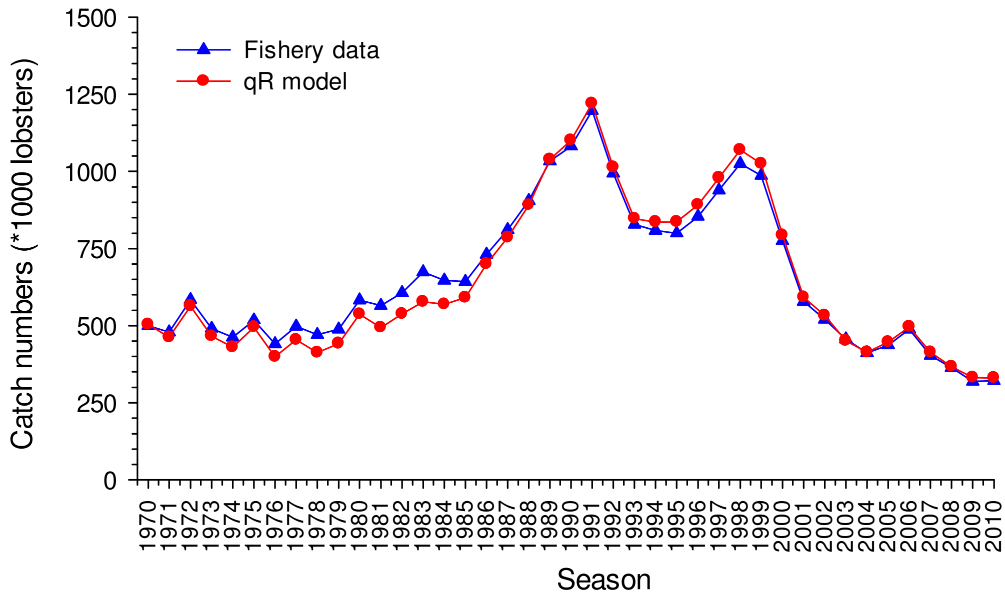

Figure 4-1 Fit of the qR model to catch in number (Cn) for the NZRLF, based on annual catch totals from the fishery and estimates provided by the 2010 version of the qR model.

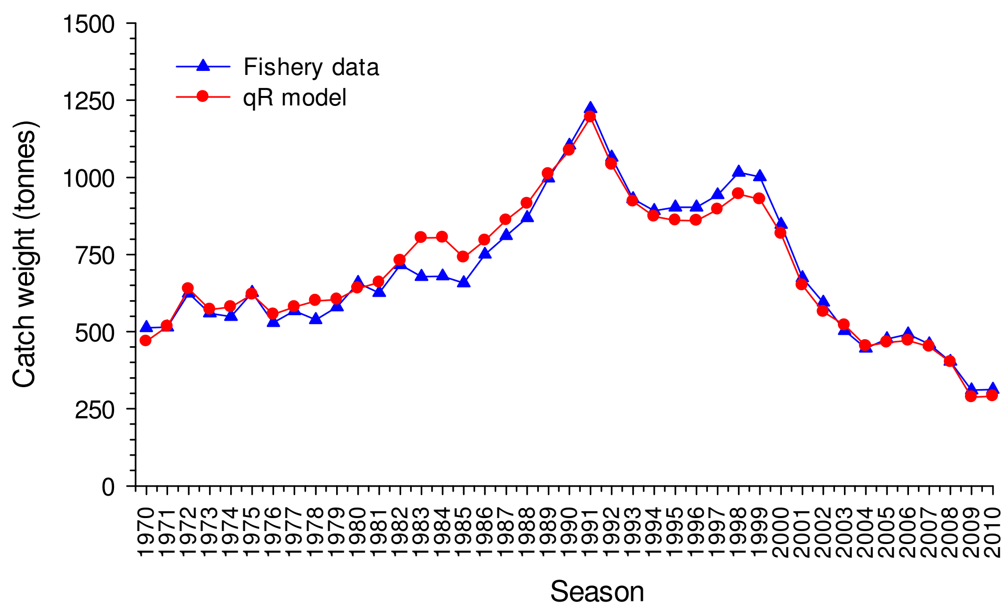

Figure 4-2 Fit of the qR model to catch in weight (Cw) for the NZRLF, based on annual catch totals from the fishery and estimates provided by the 2010 version of the qR model.

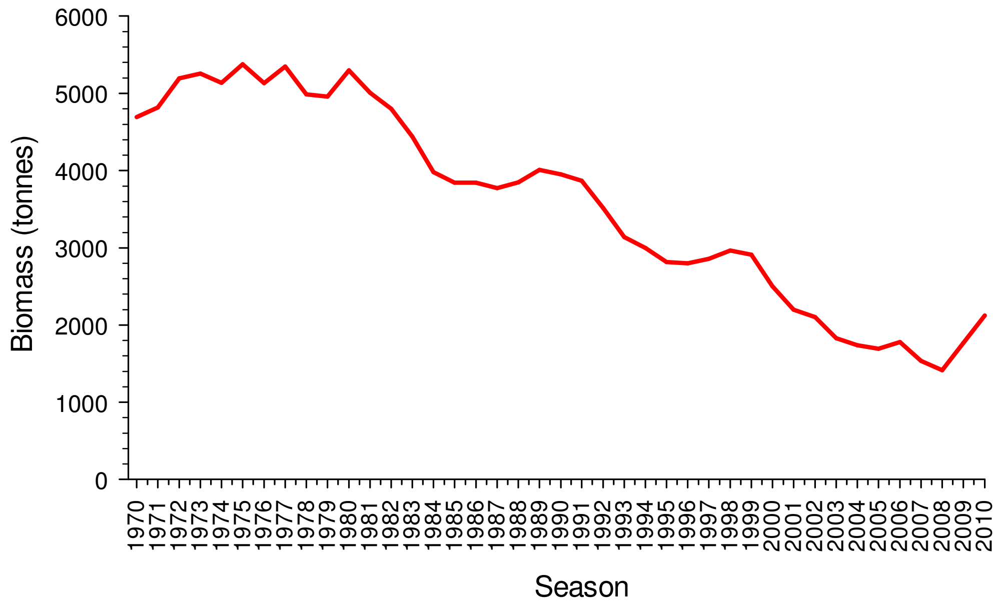

Figure 4-3 Estimates of biomass for the NZRLF provided by the 2010 qR model.

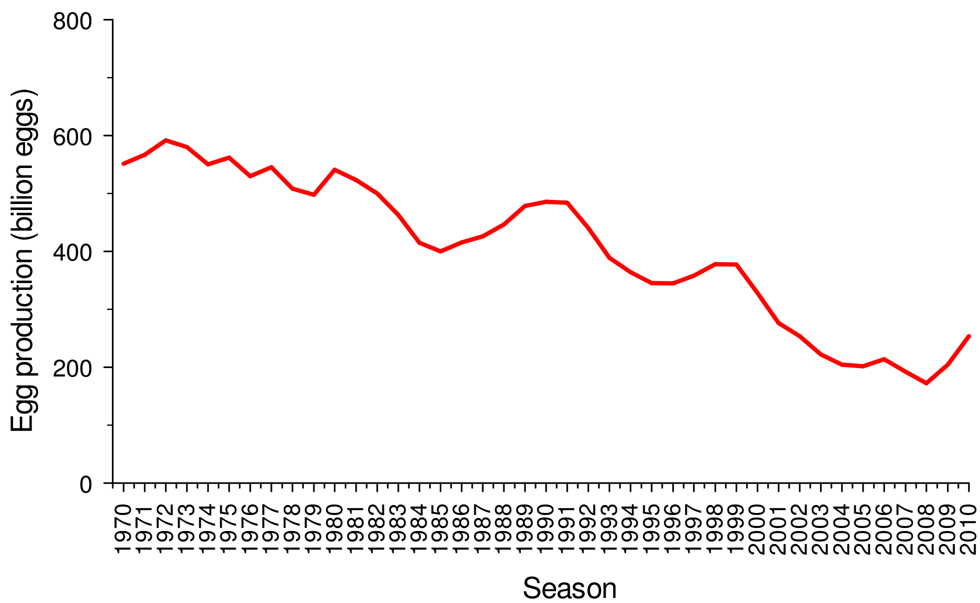

Figure 4-4 Estimates of egg production for the NZRLF provided by the 2010 qR model.

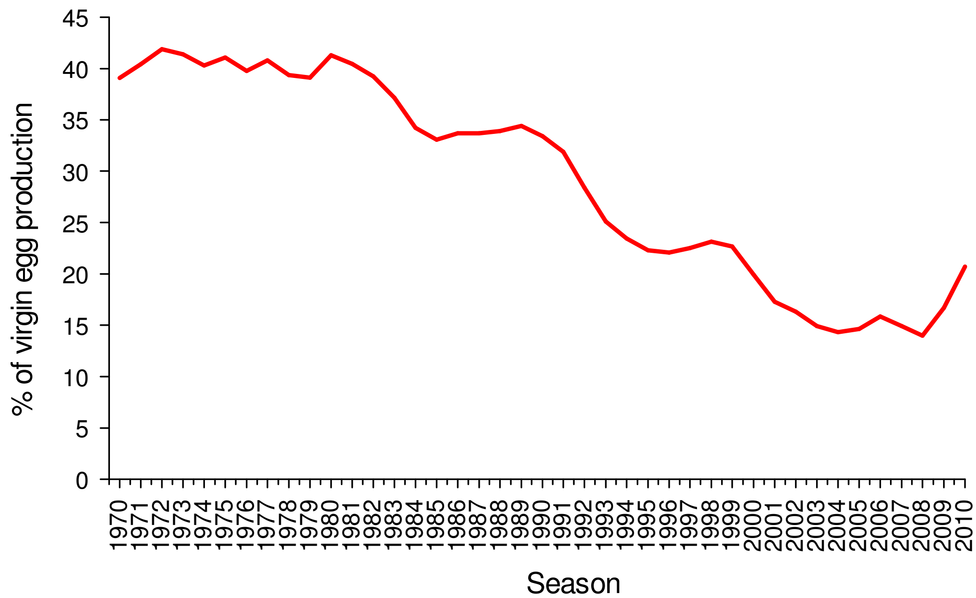

Figure 4-5 Estimates of % virgin egg production for the NZRLF from the 2010 qR model.

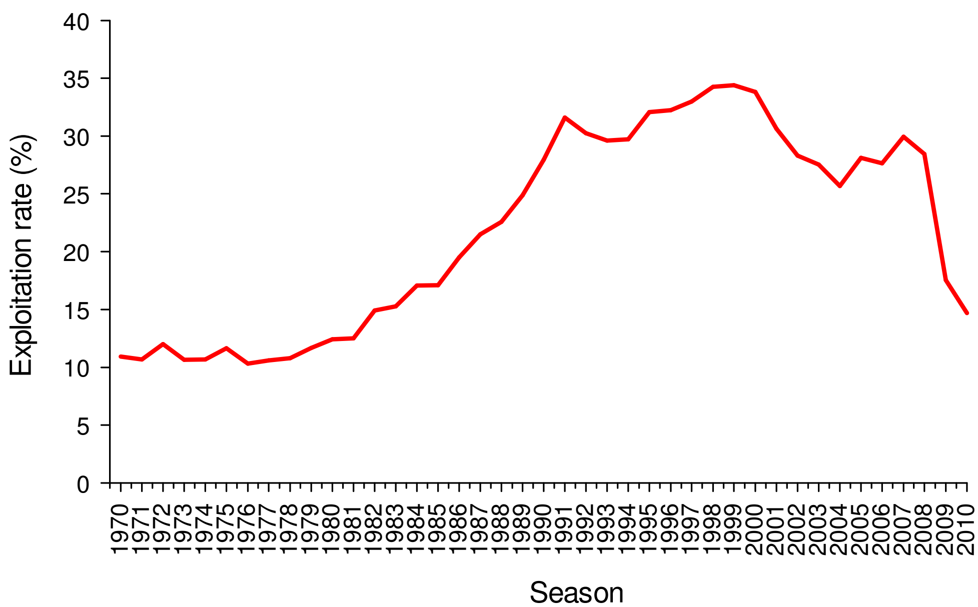

Figure 4-6 Estimates of exploitation rate for the NZRLF provided by the 2010 qR model.

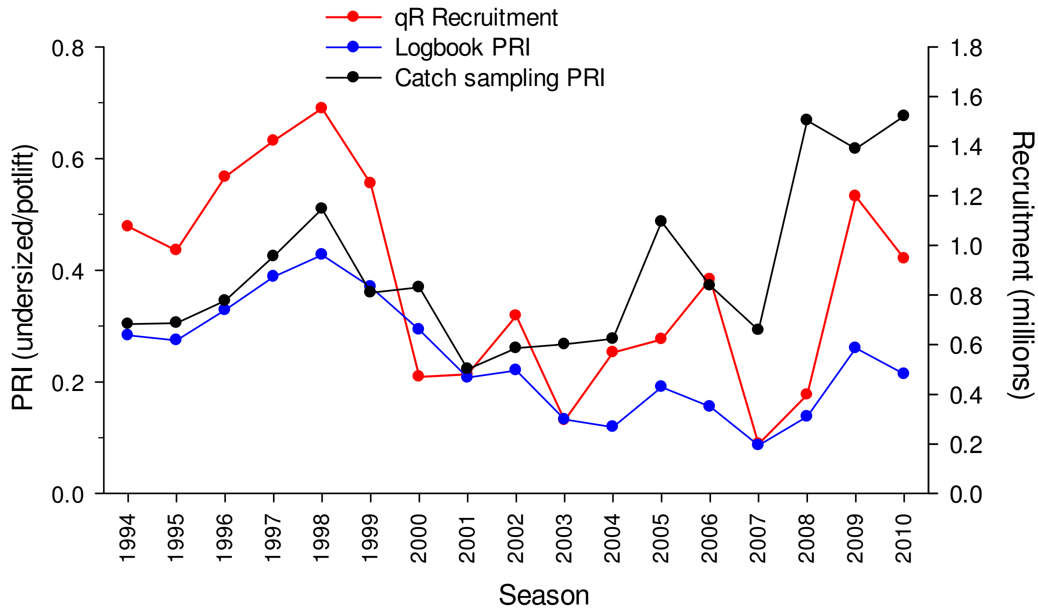

Figure 4-7 Estimates of annual recruitment for the NZRLF provided by the 2010 qR model and pre-recruit index (PRI) as undersize numbers per pot lift (Nov-Mar) obtained from both logbook and catch sampling data.

5 THE LENGTH STRUCTURED MODEL

5.1 Introduction

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

5.2 Methods

Details of the length structured model, with simulation testing of its performance, have been described in two peer-reviewed papers (Hobday and Punt 2001; Punt 2003). The code for the South Australian LenMod has been adapted from the Victorian version of the model (Hobday and Punt 2001; Punt 2003), 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 female 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 2010 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 1,248 tonnes, the lowest on record. However, over the last two seasons biomass has increased and in 2010 was estimated at 1,895 tonnes. This represents a 52% increase since 2008 and is the highest estimate on record since 2001 (1,933 tonnes).

Egg production

Similar to biomass, the long-term outputs from LenMod indicates that total egg production has decreased considerably in the NZRLF (Figure 5-5). In 2008, it was

149 billion eggs, the lowest on record. As with biomass, egg production has increased over the last two seasons and in 2010 was 188 billion, reflecting a 26% increase since 2008 and the highest estimate on record since 2003 (194 billion). Current estimates equate to 9.7% of virgin egg production (Figure 5-6).

Exploitation rate

LenMod estimates that exploitation rate increased from 24% in 1983 to 39% in 1999 (Figure 5-7). Over the next nine seasons it remained at between 30-40%. Over the last two seasons exploitation rates have decreased considerably from 32% in 2008 to 16.5% in 2010. Current exploitation rates are the lowest on record.

Estimates of recruitment and correlations with pre-recruit indices

Estimates from LenMod suggest that recruitment levels have generally decreased over the last ten seasons from 1998-2008 (Figure 5-8). However, over the last two seasons recruitment has increased and in 2010 was 0.83 million, the highest on record since 1999 (1.1 million). The temporal trends in recruitment estimated by LenMod were compared against trends in PRI as estimated from both logbook and catch sampling data over the period 1994-2010 (Figure 5-9). Trends in model recruitment were strongly correlated (R^2=0.94) with PRI from logbook data but were poorly correlated (R^2=0.13) with catch sampling based PRI.

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 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 currently non-spatial, meaning that each fishery zone is modelled as a single population.

The LenMod outputs estimate that biomass in the NZRLF has decreased considerably over the last two decades. In 2008, it was estimated to be 1,248 tonnes, the lowest in the time series. This represented a 63% decline in biomass since 1990 (3,393 tonnes). Trends in egg production compare with those in legal sized biomass.

The 2008 estimate of 149 billion eggs was also the lowest on record which equated to 7.7% of the virgin level.

In 2009, the TACC in the NZRLF was decreased from 470 to 310 tonnes. Over the next two seasons, recruitment into the fishery increased as evidenced from both model estimates and fishery dependent pre-recruit estimates. As a result, legal sized biomass and egg production levels within the fishery increased substantially over this period. Biomass has increased by 52% while egg production levels have risen by 26%. Overall, decreases in catch combined with increases in biomass have resulted in a considerable decrease in exploitation levels to 16.5%, the lowest in the history of the fishery.

The temporal trends in recruitment predicted by LenMod were compared against trends in PRI as estimated from both logbook and catch sampling data over the period 1994-2010. While correlations with logbook PRI were strong, those with catch sampling data were poor. 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.

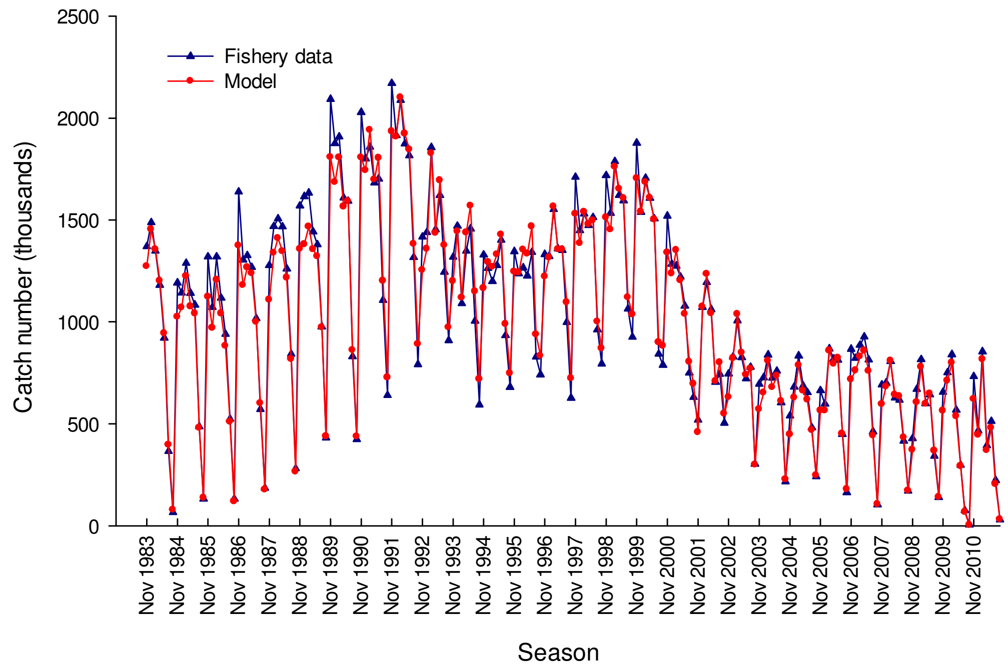

Figure 5-1 Fit of the LenMod model to monthly catch in numbers (Cn) for the NZRLF, based on annual catch totals from the fishery and estimates provided by the 2010 version of the model.

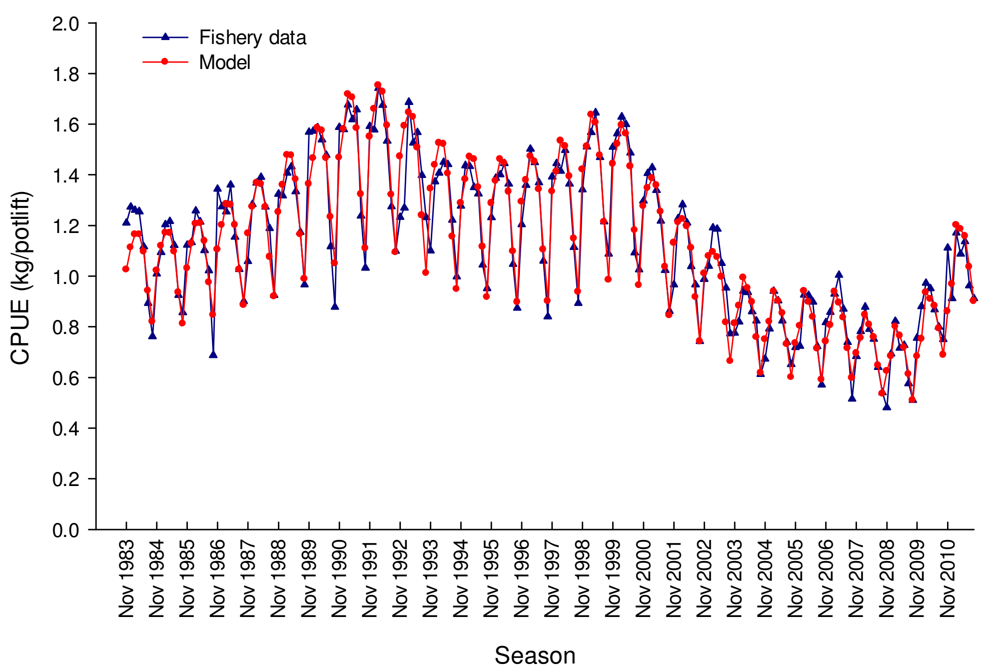

Figure 5-2 Fit of the LenMod model to monthly catch rate for the NZRLF, based on annual estimates from the fishery and those provided by the 2010 version of the model.

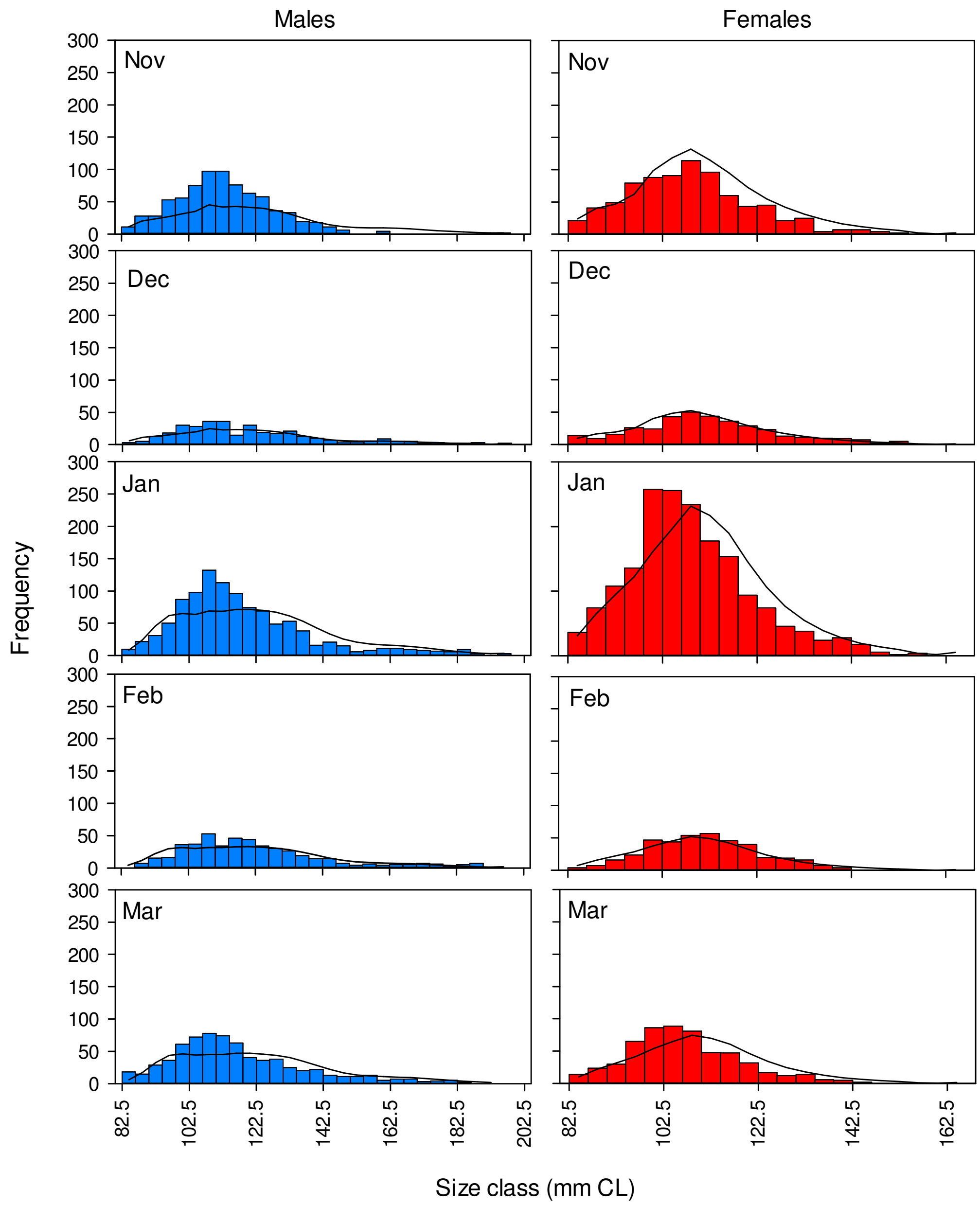

Figure 5-3 Sample of model fit (black line) to commercial length frequency data (blue bars) taken from the 2010 season in the NZRLF.

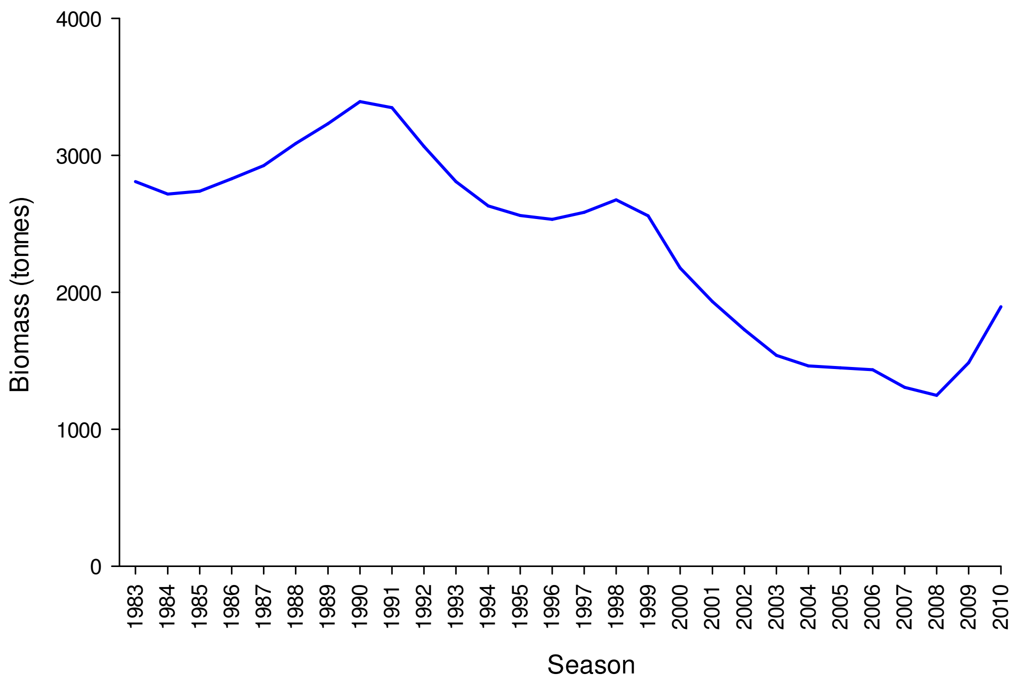

Figure 5-4 Estimates of biomass provided by the 2010 LenMod model.

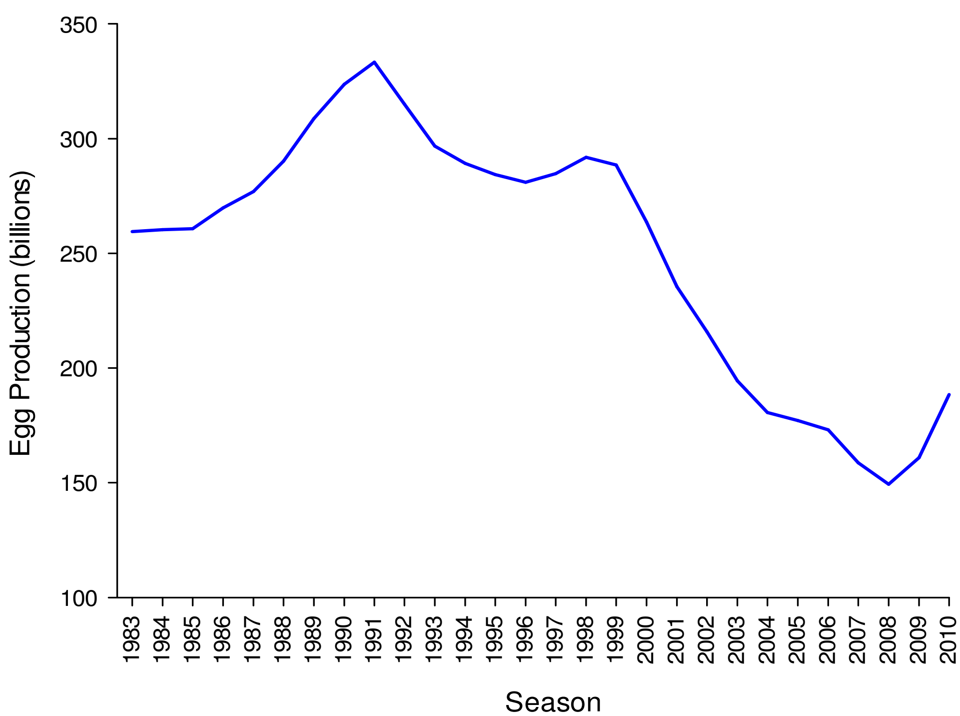

Figure 5-5 Estimates of egg production provided by the 2010 LenMod model.

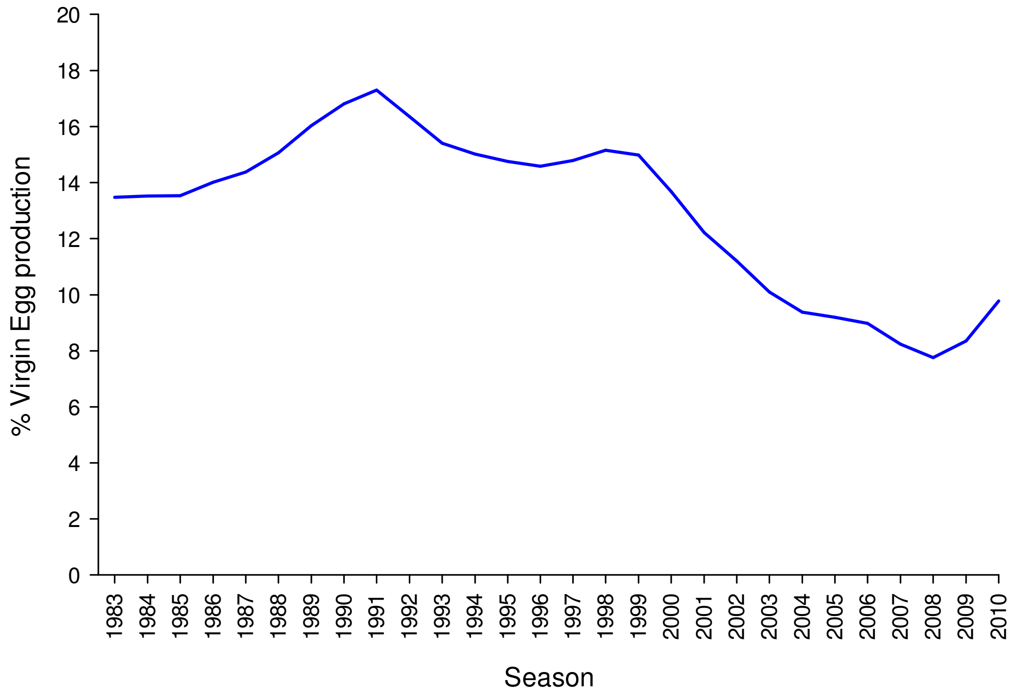

Figure 5-6 Estimates of percent of virgin egg production provided by the 2010 LenMod model.

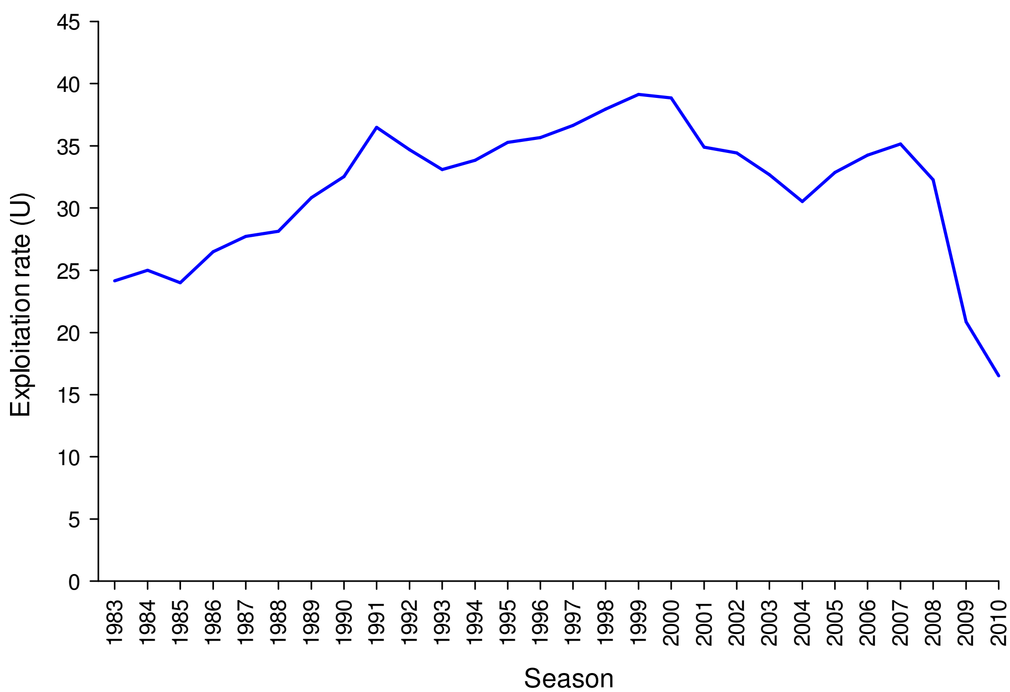

Figure 5-7 Estimates of exploitation rates provided by the 2010 LenMod model.

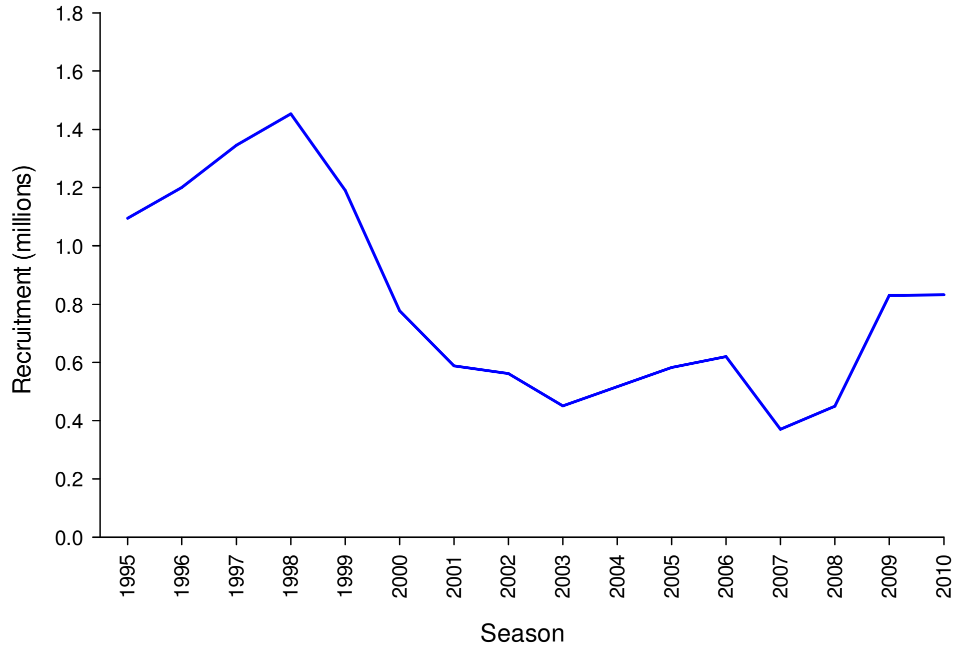

Figure 5-8 Estimates of recruitment obtained from the 2010 LenMod model.

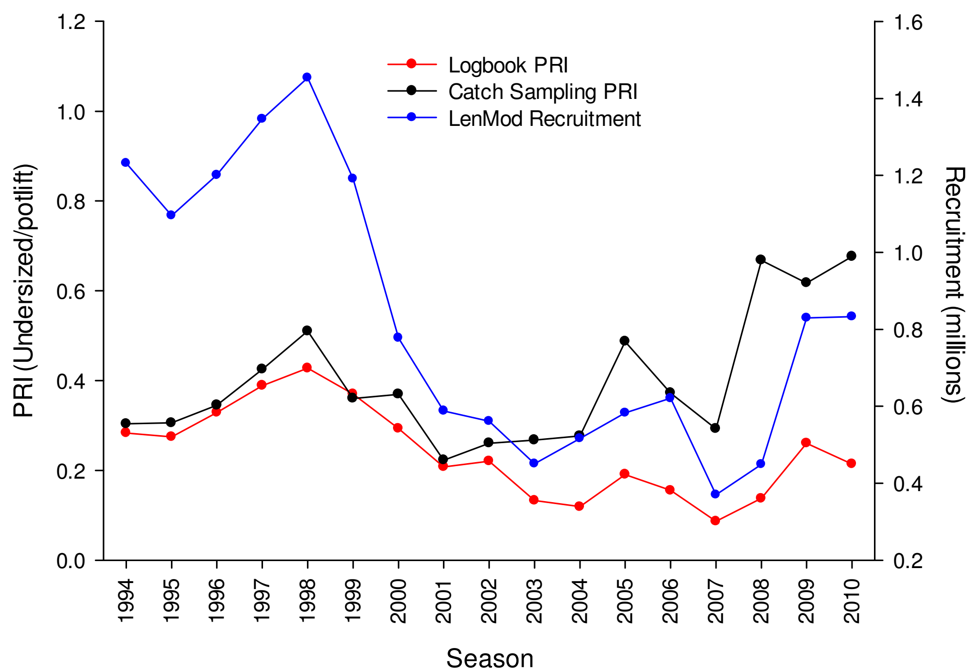

Figure 5-9 Estimates of annual recruitment for the NZRLF provided by the 2010 LenMod model and pre-recruit index (PRI) as undersize numbers per potlift (Nov-Mar) obtained from both logbook and catch sampling data.

6 PERFORMANCE INDICATORS

In 2011, the Harvest Strategy for the NZRLF was reviewed. During the review process, based on the fishery data to date, it was agreed that the TACC for the NZRLF would be retained at 310 tonnes for the 2011/12 season. The new harvest strategy details specific reference points for both the primary biological performance indicator of CPUE and the secondary indicator of PRI (see Section 1.3.4) which will be used to provide a TACC recommendation for the 2012/13 season.

7 GENERAL DISCUSSION

7.1 Information available for 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. 2010). 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 NZRLF 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

Data presented in this report highlights a major decline in the status of the NZRLF over the period from 1999 to 2008. 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 estimate represents a decrease of 60% from 1998 (1,015 tonnes) and a 20% decrease since 2003 (503 tonnes) when the TACC system was introduced. While catch had 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 just 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 reflects corresponding declines in commercial CPUE over the same period. The 2008 zonal estimate of 0.68 kg/potlift was the lowest on record. With the exception of 2005 and 2006, catch rate decreased over nine successive seasons. The 2008 estimate represents a 54% decrease since 1999 (1.49 kg/potlift) and a 21% decrease since the introduction of quota in 2003 (0.86 kg/potlift).

The zonal trends in fishery performance were 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.

Model outputs confirm fishery dependent data in relation to the decline in the status of the NZRLF resource. 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 about 1,300-1,400 tonnes, the lowest estimate on record. This represents a decrease in biomass of about 60% from that estimated in 1990 (3,300–3,900 tonnes). Similar declines in egg production were observed, with 2008 values representing about 9-14% of virgin.

Historically, TACCs were not set at levels that constrained catch, which was inconsistent with the aim of stock rebuilding defined in the Management Plan. From 2003 to 2008, the TACC was never fully 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 represented the sixth successive season in which the TACC had not been landed within the fishery. As a result, with low levels of recruitment to the fishery, biomass continued to decline which in turn was translated into poor fishery performance as reflected by the long-term decrease in both zonal and regional catch rates from 1999 to 2008.

In 2009, the TACC was reduced from 470 to 310 tonnes. This represented the first time that a TACC had been set at a level below the previous years catch (402.7 tonnes in 2008). This decision was largely based on evidence which suggested that a recruitment pulse was about to enter the fishery in 2009. Given the status of the fishery, there was a clear need to constrain the catch in order to protect this pulse and attempt to rebuild the biomass. The scientific data underpinning this advice came from puerulus, undersized and length frequency data. Puerulus settlement in the NZRLF was high 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. As a result, the high pre-recruit index (PRI) observed in both catch sampling and logbook data in 2008 was interpreted as reflecting the high settlement of 2005, which would enter the fishery in 2009. In addition, the length frequency data in 2008 showed a strong cohort of size classes just below the MLS. This cohort was predicted to enter the fishery the following season. Similarly, the high levels of settlement in 2006 were expected to translate into high pre-recruit levels in 2009 with recruitment into the fishery continuing in 2010.

Data presented in this report confirms that recruitment into the NZRLF increased in both 2009 and 2010. The 2010 zonal catch rate was 1.07 kg/potlift, reflecting a 57% increase from 2008 (0.68 kg/potlift). This estimate reflects a substantial decline in fishing effort over the last two seasons. The 2010 estimate of 289,925 potlifts represents a 52% decrease from 2008 (600,347 potlifts) and the lowest effort estimate on record. That the increase in CPUE is the result of new recruits is confirmed by mean weight and length frequency data. The 2010 mean weight was 0.97 kg, the lowest on record while size classes just above the MLS were strongly represented in length frequency data attained through the voluntary catch sampling program.

In summary, the increase in biomass and subsequent catch rate estimates over the last two seasons are a positive sign for the NZRLF and are a strong indication that stock rebuilding is starting to occur within the resource. However, despite recent increases, it is important to highlight that puerulus settlement from 2007 to 2011 was below average, suggesting that recruitment to the fishery will most likely be reduced from 2011 to 2015. As a result, commercial catch rates will require close monitoring over the coming seasons to ensure that biomass levels remain sustainable over what is likely to be an extended period of low recruitment to the fishery.

7.3 Implications for Management

The Management Plan for the NZRLF is currently under review by PIRSA Fisheries and Aquaculture. During the harvest strategy development it was agreed that the TACC would remain at 310 tonnes for the 2011 season.

7.4 Future Research Priorities

In 2010, only 23% of licence holders provided catch sampling data, one of the lowest participation rates on record. These data are critical to the spatial assessment of size distributions, pre-recruit indices and reproductive condition of females. In addition, under the newly devised harvest strategy, the pre-recruit index will be estimated based on data from this program as the secondary indicator for the fishery. As a result, increased participation in the program should be considered as an immediate research priority.

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

8 BIBLIOGRAPHY

Addison, J.T. (1995) Influence of behavioural interactions on lobster distribution and abundance as inferred from pot-caught samples. ICES Marine Science Symposium, Moncton, 199, 294-300.

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

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

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

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

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

Booth, J.D. and McKenzie, A. (2009) Strong relationships between levels of puerulus settlement and recruited stock abundance in the red rock lobster (Jasus edwardsii) in New Zealand. Fisheries Research 95: 161-168.

Brasher, D.J., Ovenden, J.R. and White, R.W.G. (1991) Mitochondrial DNA variation and phylogenetic relationships of Jasus spp. (Decapoda: Palinuridae). Journal of Zoology 227: 1-16.

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

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

Brock, D.J., and Ward, T.M., 2004. Maori octopus (Octopus maorum) bycatch and southern rock lobster (Jasus edwardsii) mortality in the South Australian rock lobster fishery. Fisheries Bulletin 102, 430–440.

Brock, D.J., Hawthorne, P.J., Ward, T.M. and Linnane, A.J. (2007) Two monitoring methods that assess species composition and spatio-temporal trends in by-catch from an important temperate rock lobster (Jasus edwardsii) fishery. Marine and Freshwater Research 58: 273-285.

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

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

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

Bye, J.A.T. (1972) Ocean circulation south of South Australia. Antarctic Oceanography 2. The Australian New-Zealand Sector. American Geophysical Union, Washington DC, pp. 95-100, 19.

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

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

Cirano, M. and J.F. Middleton (2004) Aspects of the mean wintertime circulation along Australia's southern shelves: Numerical studies. Journal of Physical Oceanography 34: 668-685.

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

Evans, S.R. and Middleton, J.F. (1998) A regional model of shelf circulation near Bass Strait: a new upwelling mechanism. Journal of Physical Oceanography 28: 1439-57.

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

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

Gardner, C.; Frusher, S. D.; Buxton, C.; Haddon, M. (2003) Movements of southern rock lobster, Jasus edwardsii, in Tasmania, Australia. Bulletin of Marine Science 73: 653–671.

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

Herzfield, M. and Tomczak, M. (1997) Numerical modelling of sea surface temperature and circulation in the Great Australian Bight. Progress in Oceanography 39: 29-78.

Herzfield, M. and Tomczak, M. (1999) Bottom-driven upwelling generated by eastern intensification in closed and semi-closed basins with a sloping bottom. Marine and Freshwater Research 50: 613-27.

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

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

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

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

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

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

Linnane, A., McGarvey, R. and Feenstra, J. (2007) Northern zone rock lobster (*Jasus edwardsii*) fishery 2005/06. Final stock assessment report to PIRSA Fisheries. SARDI Aquatic Sciences publication No. F2007/000320-1.

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

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

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

Linnane, A, Penny, S, Hoare, M. and Hawthorne, P. (2011). Assessing the effectiveness of size limits and escape gaps as management tools in a commercial rock lobster (*Jasus edwardsii*) fishery. Fisheries Research 111: 1–7.

MacDiarmid, A.B. (1988) Experimental confirmation of external fertilisation in the southern temperate rock lobster *Jasus edwardsii* (Hutton) (Decapoda:Palinuridae). Journal of Experimental Marine Biology and Ecology 120(3): 277-85.

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

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

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

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

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

McGarvey, R. and Matthews, J.M. (2001) Incorporating numbers harvested in dynamic estimation of yearly recruitment: onshore wind in interannual variation of South Australian rock lobster (Jasus edwardsii). Journal of the International Council for the Exploration of the Sea 58(5): 1092-99.

McGarvey, R. and Pennington, M. (2001) Designing and evaluating length-frequency surveys for trap fisheries with application to the southern rock lobster. Canadian Journal of Fisheries and Aquatic Sciences 58(2): 254-61.

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

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

Middleton, J.J. and Byre, J.T. (2007): A review of the shelf-slope circulation along Australia's southern shelves: Cape Leeuwin to Portland. Journal of Physical Oceanography 75: 1-41.

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

Ovenden, J.R., Brasher, D.J. and White, R.W.G. (1992) Mitochondrial DNA analyses of red rock lobster, *Jasus edwardsii*, supports and apparent absence of population subdivision throughout Australasia. Marine Biology 112(2): 319-26.

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

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

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

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

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

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

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

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

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