Northern Zone
Rock Lobster (*Jasus edwardsii*)
Fishery 2009/10

Fishery Assessment Report to PIRSA Fisheries & Aquaculture

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This fishery assessment updates the 2008/09 report for the Northern Zone Rock Lobster Fishery (NZRLF) and is part of SARDI Aquatic Sciences ongoing assessment program for the fishery. The report provides a synopsis of information available and assesses the current status of the resource. The report also identifies both current and future research needs for the fishery.
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EXECUTIVE SUMMARY

1. This fishery assessment updates the 2008/09 report and assesses the current status of the Northern Zone Rock Lobster Fishery (NZRLF) against the performance indicators detailed in the Management Plan for the resource. It also provides information on a range of additional indices that are important to the fishery and identifies key areas of future research.

2. With the exception of marginal increases in 2005 and 2006, catch in the NZRLF has decreased annually over the last decade. In 2008, the catch was 403 tonnes, the lowest on record. This represents a 60% decrease in zonal catch since 1998 (1015.8 tonnes) and a 20% decrease since the introduction of the TACC system in 2003 (503.3 tonnes).

3. In 2009, the TACC was reduced from 470 to 310 tonnes. The total reported catch from logbook data was 310.2 tonnes, representing the first time that the TACC was fully taken in the history of the fishery.

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

5. In 2009, total effort decreased markedly in the NZRLF. Logbook data estimated that 350,838 potlifts were required to catch the 310 tonne TACC. This represents a 42% decrease from 2008 and is the lowest estimate on record.

6. Over the period 1999 to 2008, catch-per-unit-effort (CPUE; November to April inclusive) in the NZRLF decreased annually. The zonal estimate for 2008 was 0.68 kg/potlift, the lowest on record. This represents a 54% decrease since 1999 (1.49kg/potlift) and a 21% decrease since 2003 (0.86 kg/potlift). In 2009, the CPUE was 0.88 kg/potlift, reflecting a 29% increase from 2008.

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 have decreased markedly over the last two decades. Biomass in 2009 was ~1,600-1,700 tonnes, one of the lowest estimates on record. This represents a decrease of ~50% from 1998 (3,000–3,500 tonnes). Similar declines in egg production suggest that 2009 values represent only 9-16% of virgin egg production levels.
Despite the decline in status of the NZRLF over the last decade, there were some positive signs for the fishery in 2009. The increase in CPUE is likely to reflect observed spikes in puerulus settlement in 2005 and 2006. In the NZRLF, the period between settlement and pre-recruit (PRI) is ~3 years, with ~4 years between settlement and recruitment to the fishery. In 2008, PRI (based on voluntary catch sampling) increased to 0.62 undersized/potlift, one of the highest on record. This translated to increases in CPUE in 2009. The 2009 PRI estimate was 0.61 undersized/potlift, reflecting the high 2006 settlement. This suggests that increased levels of recruitment to the fishery will continue in 2010.

Increases in recruitment to the fishable biomass in 2009 were reflected in mean weights of landed lobster, with the estimate of 0.97 kg the lowest on record. In addition, the average number of days fished was 100, reflecting a 36% decrease from 2008 (156 days) and the lowest in the history of the fishery. Overall, this has resulted in exploitation levels decreasing to ~17–19%, which are also low in a historical context.

While recruitment in 2010 is expected to increase, it is important to highlight that puerulus settlement from 2007 to 2010 was below average for the fishery suggesting that recruitment to the fishery may be low from 2011 through to 2014. In particular, the 2010 settlement of 0.02 puerulus/collector, was the lowest on record since monitoring began. In response to such variations in recruitment to the NZRLF and the sporadic nature of puerulus settlement, careful consideration should be given as to how pulses of recruitment are protected. Specifically, in light of low recruitment predicted from 2011 to 2014, conservative TACCs must be applied to maintain biomass over this period.

The strong relationship in recent seasons between puerulus settlement and qR model recruitment was used to project future estimates of CPUE based on various TACC scenarios. Under the current TACC of 310 tonnes, the model suggested that CPUE will increase to ~1 kg potlift in 2010 and will be maintained at this level until 2013. However, based on low settlement in 2010, CPUE decreases to 0.94 kg/potlift in 2014. Under lower TACC scenarios tested (155-250 tonnes), CPUE increased from 2010 to 2013 before also decreasing in 2014. Overall, these results suggest that for sustained biomass rebuilding to occur in the NZRLF, TACCs below 310 tonnes may be required given projected recruitment trends.
1 GENERAL INTRODUCTION

1.1 Overview

This Fishery Assessment Report updates the 2008/09 report for the Northern Zone Rock Lobster Fishery (NZRLF) and is part of SARDI Aquatic Sciences ongoing assessment program for the fishery. The aims of the report are to provide a comprehensive synopsis of information available for the NZRLF and to assess the current status of the resource in relation to the performance indicators provided in the Management Plan (Sloan and Crosthwaite 2007).

The report is divided into eight sections. Section one is the General Introduction that: (i) outlines the aims and structure of the report; (ii) describes the environmental characteristics and history of the NZRLF; (iii) outlines the management arrangements 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 between the 1970/71 and 2009/10 fishing seasons. This section examines inter-annual and within-season trends in catch, effort and catch-per-unit-effort (CPUE) of both legal and undersized lobsters at zonal and regional spatial levels. Mean weight and length-frequency data are also analysed.

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

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

The sixth section uses information provided in sections two, three, four and five to assess the status of the fishery against the reference points defined in the NZRLF Management Plan (Sloan and Crosthwaite 2007).

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

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

1.2.1 Location and Size

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

1.2.2 Environmental Characteristics

Geology

Geologically, the NZRLF can be divided into two subregions. From Gulf St Vincent to the South Australia/Western Australia border, the marine substrate is comprised mainly of granite rocks (Lewis 1981). Reef communities and habitats for lobsters are confined to relatively small patches where basement granite projects through the overlying sands. Some additional areas of limestone reef occur off Elliston. The remainder of the NZRLF (i.e. from Gulf St Vincent to the Murray Mouth) is comprised of a metamorphosed basement with intrusions of igneous rocks, particularly granites. These produce peaked reefs that provide discrete localised habitats for lobsters, interspersed by large expanses of sand. Granite does not erode as easily as the limestone reefs in the Southern Zone Rock Lobster Fishery and thus lack the numerous ledges, crevices and undercuts which provide ideal habitats for lobsters.

Oceanography

The southern Australian continental shelf is storm-dominated with high (>2.5 m) modal deep-water wave heights. Winds are predominantly south-easterly during summer and north-westerly during winter (Middleton and Platov, 2003).

During summer, currents flow westward along the coast of the eastern Great Australian Bight and eastward over the shelf break (Herzfield and Tomczak 1997; Evans and Middleton 1998; Herzfield and Tomczak 1999). The Flinders Current (Bye 1972) flows from east to west along the continental slope, and is the source of cold, nutrient rich water that upwells onto the continental shelf from depths of around 600m (Figure 1-2). In summer the mean wind direction over the shelf from Robe to the head of the Great Australian Bight is favourable for upwelling. South-easterly winds transport warm surface water offshore and cold, nutrient rich water is upwelled from
below (Middleton and Platov 2003). The water layer above the thermocline is characterised by medium salinity (35.6 psu), low nutrient levels (NO$_3$ <0.1 ug/l) and high temperatures (18 to 19°C). Water below the thermocline has lower salinity (<35.5psu), higher nutrient levels (NO$_3$ >0.2 ug/l) and lower temperatures (~14°C). Sea surface temperatures during summer are lower near the coast (e.g. 14-15°C), especially along the western Eyre Peninsula and off the western tip of Kangaroo Island, and higher offshore (18-20°C) (Figure 1-2).

During winter, water over the continental shelf is vertically homogeneous, well mixed and characterised by low nutrient levels (NO$_3$ <0.25 ug/l), high salinities (> 36 ppt) and medium temperatures of ~17°C. Westerly, downwelling-favourable winds lead to the formation of an eastward coastal current along the shelf break from Cape Leeuwin to the east coast of Tasmania (Cirano and Middleton 2004). The presence of this coastal current suppresses the upwelling of water from the Flinders Current, which flows underneath the coastal current at a depth of around 600m, onto the shelf.

1.2.3 Commercial Fishery

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

Commercial fishers predominantly harvest lobsters using steel-framed pots covered with wire mesh and incorporating a moulded plastic neck (Figure 1-3). Pots are generally set overnight and retrieved the following day. The catch is initially stored live in holding wells on boats and then transferred to live holding tanks at the numerous processing factories around the State.

1.2.4 Recreational Fishery

There is an important recreational fishery for lobsters in the SZRLF. Recreational fishers are allowed to use drop-nets, pots or SCUBA to take lobsters during the same season as commercial fishers. All recreational lobster pots must be registered.
The most recent report on recreational rock lobster fishers was undertaken during the 2007/08 South Australian Recreational Fishing Survey (Jones 2009). An estimated 106,483 (+/-54,423) lobster were caught by South Australians in 2007/08, with 47,875 (+/-20,331) of these harvested and 58,608 (+/-36,148) released, representing a release rate of 55%. Overall, total numbers caught decreased by 12% from previous surveys but release rates increased by 26%. The catch represents a total recreational harvest of ~60 tonnes, of which ~5 tonnes (8%) came from the NZRLF.

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

1.2.5 Illegal fishing

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

Figure 1-1 Marine Fishing Areas in the Northern and Southern Zones of the South Australian Rock Lobster Fishery.
Figure 1-2 Sea-surface temperatures over the continental shelf of South Australia during February 2008. An upwelling can be seen where cooler water (dark blue) has moved onto the inner continental shelf (source: CSIRO).

Figure 1-3 The most commonly used pot in the NZRLF.
1.3 Management of the Fishery

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

1.3.1 Management Milestones

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

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

<table>
<thead>
<tr>
<th>Date</th>
<th>Management milestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968</td>
<td>Limited entry declared</td>
</tr>
<tr>
<td>1985</td>
<td>10% pot reduction; max number of pots 65</td>
</tr>
<tr>
<td>1992</td>
<td>10% pot reduction; max number of pots 60</td>
</tr>
<tr>
<td>1993</td>
<td>1 week closure during season</td>
</tr>
<tr>
<td>1994</td>
<td>Minimum legal size (MLS) increased from 98.5 to 102 mm CL; further &quot;1 week&quot; closure</td>
</tr>
<tr>
<td>1995</td>
<td>Further &quot;1 week&quot; closure added</td>
</tr>
<tr>
<td>1997</td>
<td>Flexible closures introduced.</td>
</tr>
<tr>
<td></td>
<td>Management Plan for the fishery published (Zacharin 1997)</td>
</tr>
<tr>
<td>1999</td>
<td>Extra 3 days of fixed closure added</td>
</tr>
<tr>
<td>2000</td>
<td>MLS increased from 102 to 105 mm CL</td>
</tr>
<tr>
<td>2001</td>
<td>7% effort reduction</td>
</tr>
<tr>
<td>2002</td>
<td>8% effort reduction</td>
</tr>
<tr>
<td>2003</td>
<td>TACC implemented for the 2003 season at 625 tonnes; VMS introduced.</td>
</tr>
<tr>
<td>2004</td>
<td>TACC reduced to 520 tonnes. Vessel length and power restrictions removed.</td>
</tr>
<tr>
<td>2007</td>
<td>New Management Plan published (Sloan and Crosthwaite 2007)</td>
</tr>
<tr>
<td>2008</td>
<td>TACC reduced to 470 tonnes</td>
</tr>
<tr>
<td>2009</td>
<td>TACC reduced to 310 tonnes</td>
</tr>
</tbody>
</table>
1.3.2 Current Management Arrangements

Details of the management arrangements for 2009/10 are provided in Table 1-2. Currently, the commercial fishery is managed by a combination of input and output controls. The season extends from November 1st to May 31st of the following year. There is a minimum legal size of 105 mm carapace length, prohibition on the taking of berried females, and several sanctuaries where lobster fishing is prohibited. The dimensions of lobster pots, including mesh and escape gap size, are also regulated. Fishers may use up to 100 of the total number of pots endorsed on their licence at any one time to take lobster.

The TACC is set each year and is divided proportionally between licence holders as individual transferable quotas (ITQ’s). Each licence holds one quota unit entitlement for each pot entitlement held. If a pot entitlement is transferred, a quota unit must also be transferred at the same time to the same licence, and vice versa. The daily catch of individual boats is monitored via catch and disposal records. In 2009/10, the quota was 310 tonnes.

Table 1-2 Management arrangements for the South Australian Northern Zone Rock Lobster Fishery in 2009/10.

<table>
<thead>
<tr>
<th>Management tool</th>
<th>Current restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Allowable Commercial Catch</td>
<td>310 tonnes</td>
</tr>
<tr>
<td>Closed season</td>
<td>1 June to 31 October</td>
</tr>
<tr>
<td>Total number of pots</td>
<td>3,950</td>
</tr>
<tr>
<td>Minimum size limit</td>
<td>105 mm CL</td>
</tr>
<tr>
<td>Maximum number of pots/licence</td>
<td>100 pots</td>
</tr>
<tr>
<td>Minimum number of pots/licence</td>
<td>20 pots</td>
</tr>
<tr>
<td>Maximum quota unit holding</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Minimum quota unit holding</td>
<td>320 quota units</td>
</tr>
<tr>
<td>Spawning females</td>
<td>No retention</td>
</tr>
<tr>
<td>Maximum vessel length</td>
<td>None</td>
</tr>
<tr>
<td>Maximum vessel power</td>
<td>None</td>
</tr>
<tr>
<td>Closed areas</td>
<td>Gleeson Landing Reserve</td>
</tr>
<tr>
<td>Catch and effort data</td>
<td>Daily logbook submitted monthly</td>
</tr>
<tr>
<td>Catch and Disposal Records</td>
<td>Daily records submitted upon landing</td>
</tr>
<tr>
<td>Landing times</td>
<td>Landings permitted at any time during the season</td>
</tr>
<tr>
<td>Prior landing reports to PIRSA</td>
<td>1 hour before removing lobster from boat</td>
</tr>
<tr>
<td>Escape gaps</td>
<td>2 gaps per pot</td>
</tr>
<tr>
<td>Vessel Monitoring System (VMS)</td>
<td>Operational VMS units required on all vessels during the season</td>
</tr>
<tr>
<td>Bin tags</td>
<td>All bins must be sealed with a lid and an approved tag prior to lobster being unloaded from the vessel. Tags are sequentially numbered.</td>
</tr>
</tbody>
</table>
1.3.3 The Management Plan

Goals, Objectives and Strategies

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

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

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

The Management Plan 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 regions as defined under the Management Plan for the NZRLF.
1.3.5 Primary Biological Reference Points

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

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

Catch rate

LRPs for catch rate have been defined taking into account:

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

For the purposes of setting LRPs for catch rate, the year 2004 has been chosen as a starting point, as this represents a point when the fishery is considered to have been at its lowest point in both a biological and an economic sense. A LRP recovery trajectory has been developed for the whole fishery and for each region to allow for a gradual increase in the LRP over the recovery period.
Limit and target reference points have been established for both the fishery as a whole and each of the four regions, for the purposes of the TACC decision rules. Whilst the new Management Plan applies for a period of three years, the recovery trajectories relate to a twelve-year period. Details of zonal and regional LRPs and TRPs for catch rate are provided in Table 1-5.

**Pre-recruit index**

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

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

As set out in the decision rules of the Management Plan, the relevant measure for any particular year is the average of the most recent three years. For example, in calculating the PRI for 2009/10, the average of 2007/08, 2008/09 and 2009/10 will be used to determine whether PRI is considered to be above or below the reference levels. Zonal and regional LRPs for pre-recruit index are provided in Table 1-4.

<table>
<thead>
<tr>
<th>Region</th>
<th>Pre-recruit index (Pot sampling data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Zone</td>
<td>0.33</td>
</tr>
<tr>
<td>A</td>
<td>0.03</td>
</tr>
<tr>
<td>B</td>
<td>0.19</td>
</tr>
<tr>
<td>C</td>
<td>0.42</td>
</tr>
<tr>
<td>D</td>
<td>0.61</td>
</tr>
</tbody>
</table>
Table 1-5 Zonal and regional limit and target reference points for catch rate (kg/potlift) based on a 12-year recovery time period.

<table>
<thead>
<tr>
<th>Rock Lobster Season</th>
<th>Year number</th>
<th>Whole Zone</th>
<th>Region A</th>
<th>Region B</th>
<th>Region C</th>
<th>Region D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Target</td>
<td>Limit</td>
<td>Target</td>
<td>Limit</td>
<td>Target</td>
</tr>
<tr>
<td>2004 (data)</td>
<td>0</td>
<td>0.82</td>
<td>0.82</td>
<td>0.94</td>
<td>0.94</td>
<td>0.75</td>
</tr>
<tr>
<td>2005</td>
<td>1</td>
<td>0.86</td>
<td>0.84</td>
<td>0.98</td>
<td>0.95</td>
<td>0.79</td>
</tr>
<tr>
<td>2006</td>
<td>2</td>
<td>0.89</td>
<td>0.85</td>
<td>1.02</td>
<td>0.97</td>
<td>0.83</td>
</tr>
<tr>
<td>2007</td>
<td>3</td>
<td>0.93</td>
<td>0.87</td>
<td>1.06</td>
<td>0.98</td>
<td>0.86</td>
</tr>
<tr>
<td>2008</td>
<td>4</td>
<td>0.96</td>
<td>0.88</td>
<td>1.09</td>
<td>0.99</td>
<td>0.90</td>
</tr>
<tr>
<td>2009</td>
<td>5</td>
<td>1.00</td>
<td>0.90</td>
<td>1.13</td>
<td>1.01</td>
<td>0.94</td>
</tr>
<tr>
<td>2010</td>
<td>6</td>
<td>1.04</td>
<td>0.91</td>
<td>1.17</td>
<td>1.02</td>
<td>0.98</td>
</tr>
<tr>
<td>2011</td>
<td>7</td>
<td>1.07</td>
<td>0.93</td>
<td>1.21</td>
<td>1.03</td>
<td>1.01</td>
</tr>
<tr>
<td>2012</td>
<td>8</td>
<td>1.11</td>
<td>0.94</td>
<td>1.25</td>
<td>1.05</td>
<td>1.05</td>
</tr>
<tr>
<td>2013</td>
<td>9</td>
<td>1.14</td>
<td>0.96</td>
<td>1.29</td>
<td>1.06</td>
<td>1.09</td>
</tr>
<tr>
<td>2014</td>
<td>10</td>
<td>1.18</td>
<td>0.97</td>
<td>1.32</td>
<td>1.07</td>
<td>1.13</td>
</tr>
<tr>
<td>2015</td>
<td>11</td>
<td>1.21</td>
<td>0.99</td>
<td>1.36</td>
<td>1.09</td>
<td>1.16</td>
</tr>
<tr>
<td>2016</td>
<td>12</td>
<td>1.25</td>
<td>1.00</td>
<td>1.40</td>
<td>1.10</td>
<td>1.20</td>
</tr>
</tbody>
</table>
1.3.6 Secondary Performance Indicators

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

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

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

1.4.1 Taxonomy and Distribution

For detailed information on all biological aspects of southern rock lobster *Jasus edwardsii* (Hutton 1875) biology, readers should refer to Phillips (2006). Southern rock lobster (Figure 1-5), are distributed around southern mainland Australia, Tasmania and New Zealand (Smith et al. 1980; Booth et al. 1990). In Australia, the northerly limits of distribution are Geraldton in Western Australia and Coffs Harbour in northern New South Wales. However, the bulk of the population can be found in South Australia, Victoria, and Tasmania where they occur in depths from 1 to 200 m (Brown and Phillips 1994). They are generally considered omnivores, but primarily carnivores of slow moving benthic invertebrate prey, in particular spiny urchin, crab and marine snail species (Fielder 1965; Johnston 2003; Hoare 2008).

![Figure 1-5 Southern rock lobster, *Jasus edwardsii*, in reef habitat.](image)

1.4.2 Stock Structure

Few genetic or morphological differences that may indicate sub-structuring have been found in the *Jasus edwardsii* population from southern mainland Australia, Tasmania and New Zealand (Smith et al. 1980; Booth et al. 1990; Brasher et al. 1991). Similarly, mitochondrial DNA analysis has failed to detect any sub-division of the population on a smaller scale and it is likely that there is some exchange of genetic material from lobsters from south-eastern Australia to New Zealand (Ovenden et al. 1992). The long larval phase and widespread occurrence of larvae
across the central and south Tasman Sea, in conjunction with known current flows, point to the likely transport of phyllosoma from south-eastern Australia to New Zealand, providing genetic mixing between the two populations (Booth et al. 1990).

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

1.4.3 Life History

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

The larvae hatch in early spring, pass through a brief (10-14 days) nauplius phase into a planktonic, leaf-like phase called phyllosoma. Phyllosoma have been found down to depths of 310 m, tens to hundreds of kilometres offshore from the New Zealand coast (Booth et al. 1991; Booth 1994; Booth et al. 1999; Booth et al. 2002). They develop through a series of 11 stages over 12-23 months before metamorphosing into the puerulus stage (Figure 1-6) near the continental shelf break (Booth et al. 1991; Bruce et al. 1999). A short-lived (ca. 3-4 weeks) non-feeding stage, the puerulus actively swims inshore to settle onto reef habitat in depths from 50 m to the intertidal zone (Booth et al. 1991; Phillips and McWilliam 2009).

There is substantial geographic variation in larval production. In New Zealand, it has been suggested that this may be due to variations in: (i) size at first maturity, (ii) breeding female abundance and/or (iii) egg production per recruit (Booth and Stewart 1992). Additionally, phyllosoma are thought to drift passively which, coupled with the long offshore larval period, means that oceanographic conditions, particularly currents and eddies, may play an important part in their dispersal (Booth and Stewart 1991; Chiswell and Booth 2005; Chiswell and Booth 2008; Phillips and McWilliam 2009).

Geographic patterns in the abundance of phyllosoma may also be consistent with those in puerulus settlement (Booth and Stewart 1991; Booth 1994). Correlations
between levels of settlement and juvenile abundance have been found at two sites in New Zealand (Breen and Booth 1989). In South Australia, it has been suggested that the strength of westerly winds, during late winter and early spring, may play a role in the inter-annual variation in recruitment to the NZRLF (McGarvey and Matthews 2001). In their study, both winds and recruitment were shown to exhibit a 10-12 year periodicity, with significant correlations between recruitment and westerly winds lagged by 5-7 years.

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

Figure 1-6 Newly settled southern rock lobster puerulus.
1.4.4 Growth and Size of Maturity

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

A tagging study undertaken between 1993 and 1996, which provided 16,000 recaptures demonstrated substantial variation in growth rates among locations in South Australia (McGarvey et al. 1999a) with a general trend of higher growth rates in the NZRLF compared to the SZRLF. Growth rates also varied throughout the life of individuals and the mean annual growth for lobsters at 100 mm carapace length (CL) ranged from 7-20 and 5-15 mm per year for males and females respectively. Along the South Australian coast from south-east to north-west growth rates tended to increase and were highest in areas of low lobster density and high water temperature. Growth rates were also related to depth and declined at the rate of 1 mm per year for each 20 m increase in depth (McGarvey et al. 1999a).

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

1.4.5 Movement

Movement patterns of Jasus edwardsii in South Australia were determined from 14,280 tag-recapture events from across the State between 1993 and 2003 (Linnane et al. 2005). In total, 68% of lobsters were recaptured within 1 km of their release site and 85% within 5 km. The proportion of lobsters moving >1 km in MFAs ranged from 13 to 51%. Movement rates were noticeably high in the SZRLF and at Gleesons Landing lobster sanctuary off the Yorke Peninsula in the NZRLF (refer to Figure 1-1), but patterns of movement differed spatially. In the SZRLF, lobsters moved distances of <20 km from inshore waters to nearby offshore reefs whereas off the Yorke Peninsula individuals moved distances >100 km from within the sanctuary to sites located on the north-western coast of Kangaroo Island and the southern end of Eyre Peninsula. Technological advances in acoustic tagging could help refine intermediate and fine scale movement patterns of lobsters, which conventional tag-recapture methods lack.
1.5 Stock Assessments: Sources of data

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

1.5.1 Catch and Effort Research Logbook

Licence holders complete a compulsory daily logbook that has been amended to accommodate changes in the fishery. During 1998, the logbook was modified to include specific details about giant crab (*Pseudocarcinus gigas*) fishing. In 2000/01, the logbook was amended so that the recording of numbers of undersize, spawning and dead lobsters, along with numbers of octopus became voluntary. Logbook returns are submitted monthly and are entered into the South Australian Rock Lobster (SARL) database. Fishery dependent statistics from logbook data are presented in Section 2 of this report. Details currently recorded in the daily logbook include:

1. the MFA within which the fishing took place
2. depth at which the pots were set
3. number of pots set
4. weight of retained legal-sized lobsters - reported at the end of each trip or as a daily estimated weight
5. landed number of legal-sized lobsters
6. number of undersized lobsters caught
7. number of dead lobsters caught
8. number of spawning lobsters caught
9. weight of octopus caught
10. number of octopus caught
11. number of giant crab pots
12. depth of giant crab pots
13. landed weight of giant crabs
14. landed number of giant crabs
15. marine scalefish retained
Validation of catch and effort logbook data in the NZRLF can be achieved by comparing them with the catch and disposal records (CDRs) used in the quota management system. Processor records are not used for validation as lobsters may be transported to processors outside of the zone in which the lobsters were landed.

1.5.2 Voluntary Catch Sampling

Since 1991, commercial fishers and researchers have collaborated in an at-sea pot-sampling program with the main aim of providing temporal and spatial data on pre-recruit indices, legal sized catch, length frequencies, female reproductive status, sex ratios and estimates of lobster mortality. During the life of this program there have been various levels of participation and changes to the sampling regime.

The program started with commercial fishers sampling from several (usually 3) pots each day, for the duration of the fishing season. During the 1995 season, sampling was reduced to one week per month over the period of the third quarter of the moon. In the following season, sampling was done as part of an FRDC project that aimed to determine the optimal sampling strategy required to produce quantifiable and minimum variances in the mean lengths and catch rates (McGarvey et al. 1999b; McGarvey and Pennington 2001). This study demonstrated that the optimal design should incorporate a high percentage of boats, with sampling done on as many days as possible from a small fraction of the pots from each boat. As a result, fishers are now encouraged to sample from up to three research pots per trip where the escape gaps are closed. They are supported by research staff who undertake trips to sea on commercial vessels to encourage more fishers to participate in the program and to demonstrate the methods to new participants.

Participation in the program is neither random nor systematic and can vary among areas. During a series of port meetings in 2009/10, the importance of participation in the catch sampling programme was emphasised by both SARDI personnel and industry representatives. In particular, it was highlighted that future management decisions for the fishery will rely heavily on pre-recruit indices that are directly estimated from voluntary catch sampling data. The participation level in 2009/10 represented only 22% of licence holders (Figure 1-7). Low participation in the program may bias catch rates and length frequencies. In addition, both current and future Management Plans for the fishery relies heavily on pre-recruit indices as determined from voluntary catch sampling. As a result, participation in the programme is strongly encouraged to ensure that future decisions for the fishery are
based on reliable and robust data. Results from the voluntary catch sampling program are presented in Section 2 of this report.

![Graph showing percentage of licence holders participating in the voluntary catch sampling program over the last 5 seasons.]

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

### 1.5.3 Puerulus Monitoring Program

Larval recruitment processes may be related to changes in breeding stock abundance and seasonal, annual and geographic variation in recruitment to the fishery (Booth et al. 2002; Booth and McKenzie 2009). Rates of puerulus and post-puerulus settlement have been monitored in the NZRLF since 1996. Four puerulus collector sites are located in the NZRLF at McLaren Point and Taylor Island (Port Lincoln) and Marion Bay and Stenhouse Bay (Yorke Peninsula). The annual Puerulus Settlement Index (PSI) is calculated as the mean monthly settlement on these collectors. Results from the puerulus monitoring program are presented in Section 3 of this report.
2 FISHERY DEPENDENT STATISTICS

2.1 Introduction

This section of the report summarises and analyses fishery statistics for the NZRLF for the period between 1 January 1970 and 31st May 2010. For ease of reference, figures and text in this section refer to the starting year of each season e.g. 2009 refers to the 2009/10 fishing season.

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

Estimates presented in this section are calculated from daily data and differ slightly from those based on season totals presented in other sections of this report. Daily data are used to describe the inter-annual and within-season patterns in catch (kg), effort (potlifts), catch-per-unit-effort (CPUE; kg/potlift) and mean weight (kg/lobster) both zonally and regionally. This section also presents statistics on indices such as pre-recruits and mean weights. Estimates of inter-annual variation in settlement rates of puerulus are compared with pre-recruit indices lagged by three years.

2.2 Catch, Effort and CPUE

2.2.1 Zonal trends

Catch

Total catch for the NZRLF remained relatively stable at around 600-700 tonnes during the 1970s and early 1980s (Figure 2-1). Within this period the highest catch recorded was 750 tonnes in 1972. The lowest was 560 tonnes in 1978.

The annual catch increased from 657 tonnes in 1985 to 1,221 tonnes in 1991. Between 1991 and the mid-1990s, catches declined to around 900 tonnes, before increasing again to over 1,000 tonnes in 1998 and 1999. Over the next 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. Overall, the 2008 figures represent a 60% decrease in catch since 1998 (1015.8 tonnes) and a 20% decrease since the introduction of 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.

**Effort**

Nominal fishing effort in the 1970s was ~450,000 potlifts per season (Figure 2-1). However, effort doubled from 411,939 potlifts in 1977 to 805,139 potlifts in 1991. From 1991, effort fell to ~720,000 potlifts per season during the mid-1990s before decreasing further to 570,689 potlifts in 2002. Over the next six seasons, effort ranged between 553-615,000 potlifts. Clearly, 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). However, in 2009, the recorded effort was just 350,838 potlifts. This represents a 42% decrease from 2008 and is the lowest 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 90s likely driven by advances in global positioning systems (GPS), advanced hydro-acoustic equipment and radar. However, the data on uptake and utilisation of such technological advances by individual licence holders are not available for the NZRLF thus complicating the issue of quantifying increases in fishing efficiency.

**CPUE**

CPUE in the early 1970s was over 1.40 kg/potlift (Figure 2-2). After the mid 1970s, it declined steadily to 1.1 kg/potlift 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 exceptions of marginal increases in 2005 and 2006, to 0.68 kg/potlift in 2008, the lowest on record. This represented a 54% decrease since 1999 (1.49kg/potlift) and a 21% decrease since the introduction of quota in 2003 (0.86 kg/potlift). In 2009, it was 0.88 kg/potlift, an increase of 29% from 2008 (0.68 kg/potlift).
Figure 2-1 Inter-annual trends in catch and effort in the South Australian Northern Zone rock lobster fishery between 1970 and 2009.

Figure 2-2 Inter-annual trends in CPUE in the South Australian Northern Zone rock lobster fishery for seasons between 1970 and 2009 (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 – 2009 (t = tonnes).

<table>
<thead>
<tr>
<th>Season</th>
<th>TACC (t)</th>
<th>Landed Catch (t)</th>
<th>Shortfall (t)</th>
<th>% TACC taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>625</td>
<td>503</td>
<td>122</td>
<td>80</td>
</tr>
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<td>2007</td>
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<tr>
<td>2008</td>
<td>470</td>
<td>403</td>
<td>67</td>
<td>86</td>
</tr>
<tr>
<td>2009</td>
<td>310</td>
<td>310</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

2.2.2 Within-season trends

*Catch and effort*

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

In 2009, trends in catch and effort reflected those from previous seasons (Linnane et al. 2009) (Figure 2-3). Approximately 87% (271.8 tonnes) of the total catch (310 tonnes) was taken from November to February inclusive. The highest catch was taken in January (83.90 tonnes) with the lowest taken in May (0.45 tonnes). Trends in effort reflected monthly trends in catch with the highest effort in January (83,943 potlifts) and lowest in May (609 potlifts).

*CPUE*

As with catch and effort, within-season CPUE is temporally consistent (Figure 2-4). CPUE generally increases for the first three to four months of the season before decreasing thereafter. In 2009, trends were similar to those from previous seasons. CPUE increased from 0.75 kg/potlift in November to 0.97 kg/potlift in January before decreasing to 0.75 kg/potlift in May.

It is important to note that the zonal increase in CPUE in 2009 (Figure 2-2) was observed across all months of the season (Figure 2-4). The most notable increase was in November for which the 2009 estimate of 0.75 kg/potlift was ~56% above that for 2008 (0.48 kg/potlift).
Figure 2-3 Within-season trends in catch and effort in the NZRLF during the 2009 fishing season.

Figure 2-4 Within-season trends in CPUE in the NZRLF for the 2009 fishing season.
2.2.3 Trends across key MFAs

**Catch**

Inter-annual catch and effort data for the 10 main MFAs (7, 8, 15, 27, 28, 39, 40, 48, 49 and 50) (refer to Figure 1-1 for location of MFAs) in the NZRLF from 1970 to 2009 are provided in Figure 2-5. Consistent with previous seasons, in 2008 ~90% of the catch came from these MFAs with 83% taken in MFAs 15, 27, 28, 39, 40, 48 and 49 (Table 2-2; Figure 2-7). In 2009, with the exception of MFA 40, catch decreased in all major MFAs which is likely to reflect the reduced TACC of 310 tonnes. 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 88% from 141 tonnes in 1998 to just 17 tonnes in 2009. Similarly, catch in MFA 28 has decreased by 66% from 218 tonnes in 1997 to 74 tonnes in 2008. Comparable decreases in catch over the same time periods are also evident in MFAs 39 and 49.

**Effort**

As in inter-annual patterns (Figure 2-1), effort across MFAs closely reflects trends in catch (Figure 2-5). Over the last five seasons there have been notable increases in effort in MFAs 15 and 28, while effort has generally decreased in MFAs 39 and 49. In 2009, there were substantial decreases in effort across all major MFAs. For example, effort in MFA 28 decreased by 34 % from 117,677 potlifts in 2008 to 77,509 potlifts in 2009. Similarly, effort in MFA 39 decreased by 26% from 110,673 potlifts in 2008 to 81,295 potlifts in 2009. Notable decreases in effort were also observed in MFAs 15, 39, 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). Since the late 1990's, the 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. In 2009 however, CPUE increased in all major MFAs. The most notably were in MFAs 7, 8, 27 and 40 which increased by 42, 43, 54 and 49% 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 2009 (note: alternate seasonal ticks on X axis).
Figure 2-6 Inter-annual trends in CPUE (± SE of the mean) of the 10 main MFAs (from north-west to south-east) of the NZRLF for the fishing seasons between 1970 and 2009 (note: alternate season ticks on x axis).
Table 2-2 Total catch taken from the 10 main MFAs in the NZRLF in 2009.

<table>
<thead>
<tr>
<th>MFA</th>
<th>Catch (t)</th>
<th>% Total Catch</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1</td>
</tr>
<tr>
<td>8</td>
<td>8.41</td>
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</tr>
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<td>39</td>
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<tr>
<td>49</td>
<td>28.51</td>
<td>10</td>
</tr>
<tr>
<td>50</td>
<td>5.71</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 2-7 Proportion of total catch taken from the 10 main MFAs in the NZRLF in 2009.
2.3 Trends by Region

2.3.1 Catch

Regional trends in catch in the NZRLF (refer to Figure 1-4) between 1970 and 2009 are presented in Figure 2-8. While up to 172 tonnes were taken in Region A in 1993, catches in this Region are now <50 tonnes with just 13.6 tonnes landed in 2009. The majority of the catch 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 from this Region 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 catch of 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 2009 it was 69.5 tonnes.

2.3.2 Effort

Trends in effort generally reflect trends in catch in all Regions (Figure 2-8). However, in 2009 there were notably decreases in effort in all regions. For example, effort in Region B decreased by 49% from 246,386 potlifts in 2008 to 125,197 potlifts in 2009. Similarly, effort in Region D has decreased by 39% from 216,284 potlifts in 2008 to 131,929 potlifts in 2009. Effort in Regions A and C also decreased in 2009.

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 since the late 1990s (Figure 2-9). 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. In 2009, catch rate increased in all Regions, with estimates of 1.31, 0.98, 0.83 and 0.78 kg/potlift in Regions A, B, C and D respectively.
Figure 2-8 Catch and effort by region in the NZRLF from 1970 to 2009. Note that catch and effort from MFA 39 (Figure 1-1) has been apportioned 30:70 between Regions C and D.
Figure 2-9 CPUE by region in the NZRLF from 1970 to 2009. 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 5 seasons, the majority (>80%) of the catch in the NZRLF has been taken at depths of <60 m (Figure 2-10). This trend continued in 2009 with 46% of catch taken from depths of 0-30 m and 49% taken from depths of 31-60 m. The deeper waters (61-90 m) contributed 4.5% to catch with only 0.5% coming from depths >90 m. For zonal estimates of catch by depth pre 2001, see Linnane et al. (2007).

Most of the main MFAs follow a similar pattern in catch by depth to that described for the entire fishery, with the majority of the catch coming from shallower depths of 0-30 and 31-60 m in recent seasons (Figure 2-12). In 2009, 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 (~11-18%) was taken in deeper waters of >60 m depth. For estimates of catch by depth pre 2001 in key MFAs, see Linnane et al. (2007).

2.4.2 CPUE

CPUE generally increases with depth in the NZRLF. Lowest catch rates tend to be in shallower depths of 0-30 and 31-60 m while higher CPUEs are observed in waters >60 m (Figure 2-11). In 2009, in depths of <30m, CPUE increased from 0.62 kg/potlift in November to 0.96 kg/potlift in January before decreasing over the next four months to a season low of 0.41 kg/potlift in May. Similar trends were observed at generally higher catch rates in the 31-60 depth range. In 2009, the highest catch rates were recorded in the 61-90 m range. CPUE increased from 0.86 kg/potlift in November to 1.25 kg/potlift in March before decreasing to 0.98 kg/potlift in May. Trends in CPUE by depth in 2009 were generally consistent with those observed in recent seasons within the NZRLF (Linnane et al. 2007).
Figure 2-10 Percentage of the catch taken from four depth classes in the NZRLF from 2003-2009.

Figure 2-11 Mean monthly CPUE (+/− SE) in four depth classes in the NZRLF during the 2009 fishing season.
Figure 2-12 Percentage of the catch taken from four depth classes in the 10 major MFAs of the NZRLF from 2003 - 2009.
2.5 Pre-recruit Index

2.5.1 Zonal trends

The introduction of escape gaps in 2003 means that data used to calculate a pre-recruit index (PRI - number of undersized/pot lift) is dependent on catch sampling, where the escape gaps from up to 3 pots are closed. However, it should be highlighted that participation levels in 2009 were just 22% (Figure 1-7). As a result, estimates of PRI should be viewed with caution.

PRI increased over the period of 1994 to 1998, peaking at 0.51 undersize/potlift before decreasing to 0.22 undersized/potlift in 2001 (Figure 2-13). Over the next four seasons, PRI increased to 0.49 undersized/potlift in 2005 before decreasing to 0.29 undersized/potlift in 2007. PRI estimates in 2008 and 2009 were two of the highest on record at 0.62 and 0.61 undersized/potlift respectively. This presumably reflects high puerulus indices observed in 2005 (Figure 3-1), given ~3 years between settlement and PRI. Trends in logbook PRI generally compare with those from catch sampling but at lower levels, reflecting the effects of escape gaps (Figure 2-14).

2.5.2 Within-season trends

In 2009, PRI decreased from 1.19 undersized/potlift in November to 0.33 undersized/potlift in March (Figure 2-15). Since the majority of undersized are caught between November and March, these months are exclusively used to calculate annual indices.

2.5.3 Trends by Region

In 2009, the regional trends in PRI (Figure 2-16) reflected those zonally (Figure 2-13). Estimates for 2009 were 0.06, 0.41, 0.61 and 0.98 undersized/potlift in Regions A, B, C and D, respectively. Note that given the low participation level in the program in 2009 (Figure 1-7), regional estimates of PRI should be viewed with caution.

2.5.4 Trends across key MFAs

The PRI is generally low in MFAs 7, 8, 15, 27 and 28 and high in the more southern MFAs of 39, 40, 48, 49 and 50 (Figure 2-17). In southern MFAs, PRI increased
between 1996 and 1998 before decreasing thereafter. In 2009, PRI increased in MFAs 28, 40, 48, 49 and 50 but decreased in MFAs 8, 15, 27 and 39.

Figure 2-13 Inter-annual trends in pre-recruit index in the NZRLF from 1994 to 2009 as calculated using voluntary catch sampling data (November-March inclusive).

Figure 2-14 Comparison of inter-annual trends in pre-recruit index from logbook and voluntary catch sampling data from 1994 to 2009 (November-March inclusive).
Figure 2-15 Within season trends in pre-recruit index in the NZRLF for the 2007, 2008 and 2009 fishing seasons as estimated from voluntary catch sampling data.

Figure 2-16 Pre-recruit index (PRI number of undersized/potlift) by region in the NZRLF from 1994 to 2009. Note that PRI from MFA 39 (Figure 1-1) has been apportioned 30:70 between Regions C and D.
Figure 2-17 Mean pre-recruit index (catch sampling data) for MFAs in the NZRLF from 1994 to 2009 (Numerical order of MFAs is from north-west to south-east). Refer to Figure 1-1 for location of MFAs.
2.6 Mean Weights

2.6.1 Zonal trends

The pattern of rise and fall in mean size reflects long-term patterns of recruitment, with low mean weights resulting from influxes of small lobsters into the fishable biomass and high mean weights resulting from several consecutive years of low recruitment. From 1983 to 2008, the mean weight of lobsters taken in the NZRLF has fluctuated between 1.00 and 1.21 kg (Figure 2-18). Low mean weight was recorded in 1988 and 1989 with peaks in 1984 (1.08 kg) and 1995 (1.16 kg), with that of 1.21 kg for the 2001 season being the highest recorded for the fishery. Over the next five seasons, mean weight decreased, declining to 1.0 kg in 2006. In 2007, mean weight increased to 1.13 kg before decreasing to 0.97 kg in 2009, the lowest mean weight on record. From 1998 to 2001 the gradual increase in lobster mean weight probably reflects the effects of the increases in minimum legal size from 98.5 mm to 102 mm in 1994 and from 102 mm to 105 mm in 2001.

2.6.2 Within-season trends

Since the 1970s, there has been a consistent trend of increasing mean weight as the fishing season progresses indicating that smaller lobsters are caught early in the season (November to January) compared to those between February to May (Figure 2-19). In 2009, mean monthly weight increased from 0.87 kg in November to 1.02 kg in March before decreasing over the next two months to 0.91 kg in May.

2.6.3 Trends across key MFA’s

Mean weights of lobsters are highest in MFAs located in the north of the NZRLF (e.g. MFAs 7, 8, 15, 27), and lowest in MFAs located further south (e.g. 48, 49, 50) (Figure 2-20). Between 1983 and 1998, mean weights were relatively stable in most MFAs but increased between 1998 and 2001, except in MFA 8. Since 2001, mean weight has generally decreased in most MFAs reflecting the zonal estimates of mean weights over the same period (Figure 2-18). However, in 2007, mean weight increased in all regions. In 2008 and 2009, with the exception of MFA 8, mean weight generally decreased in all major MFAs in the NZRLF.
Figure 2-18 Inter-annual trends in the mean weight of lobsters in the NZRLF for the fishing seasons between 1983 and 2009.

Figure 2-19 Within-season trends in the mean weight of lobsters in the NZRLF during the 2007, 2008 and 2009 seasons.
Figure 2-20  Inter-annual trends in the mean weights of lobsters for the main MFAs of the NZRLF for the fishing seasons between 1983 and 2009.
2.7 Length Frequency

Since 1991, between 3,200 and 18,000 male lobsters and between 3,200 and 15,500 female lobsters, have been measured annually (refer to Linnane et al., 2006 for previous length outputs) as part of the voluntary catch sampling programme. The number of lobsters measured is proportional to the level of participation in the programme which has ranged between 20-40% over the last five seasons (Figure 1-7).

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 2009, a total of 12,825 lobsters were sampled (Figure 2-21). Of these, 50% were males and 50% females. An analysis of length frequency distributions over the last three seasons indicates evidence of a strong recruitment pulse entering the fishery in 2009 (Figure 2-21). In 2007, only 17% of all lobsters were represented by size classes below the MLS of 105 mm CL, reflecting the low pre-recruit index observed during that season (Figure 2-13). However in 2008, the frequency of these size classes increased to 33% in line with one of the highest PRIs in the history of the fishery. As these cohorts recruited into the fishery in 2009, 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 the 2009 season (Figure 2-2). In 2009, 25% of lobsters were below the MLS. Overall, these data highlight the importance of length frequency data collated through the voluntary catch sampling programme 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 2-21 Length frequency distributions of male and female lobsters combined in the NZRLF from 2007-2009.
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 2-22) 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 2009, the estimate was 0.007 spawners/potlift, representing an 91% decrease in catch rate since 1997 (0.08 spawners/potlift). Overall, the findings suggest a considerable decrease in the biomass of spawning lobsters in the NZRLF over the last decade.

Figure 2-22 Inter-annual trends in the catch rate of spawning lobsters in the NZRLF between 1996 and 2009.
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 2-23). Between 1996 and 1999, estimates ranged between 0.07 and 0.09 dead/potlift before decreasing to ~0.04 dead/potlift in 2001. Since then, the index has not exceeded 0.05 dead/potlift and in 2009 was ~0.03 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 2-23 Inter-annual trends in the catch rates of dead lobsters in the NZRLF from 1996 to 2009.](image-url)
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 2-24). Temporal trends indicate that the highest CPUE of 0.022 octopus/potlift was record in 1998. Over the next 11 seasons however, catch rates decreased and now rarely exceed 0.005 octopus/potlift. In 2009, the estimate was 0.002 octopus/potlift, the lowest on record Temporal trends in octopus catch rate are strongly correlated with those observed for dead lobsters over the time period of 1996 – 2009 (R² = 0.94; see Figure 2-23).

Figure 2-24 Inter-annual trends in catch rates of octopus in the NZRLF from 1996 to 2009.
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 ~184 days in the mid-late 1990s to 144 days in 2002 (Figure 2-25). 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. In 2008 it was 156 days. In 2003, the fishery changed to output controls in the form of a TACC quota system. However, 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. This is 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, the lowest estimate on record.

Figure 2-25 Inter-annual trends in the average number of days fished per licence in the NZRLF between the 1994 and 2009 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). In 2002, the highest PSI on record of 1.09 puerulus/collector was observed. However, PSI decreased again in 2003 and 2004, with the 2003 estimate of 0.12 puerulus/collector one of the lowest settlements on record. High settlement was observed in 2005 and 2006, with the estimates of 0.81 and 0.89 puerulus/collector the highest since 2002. However, in 2007 and 2008, two of the lowest settlements on record were recorded with estimates of 0.08 and 0.11 puerulus/collector, respectively before a marginal increase in settlement in 2009 at 0.34 puerulus/collector. In 2010, the PSI estimate was 0.02 puerulus/collector, the lowest estimate on record. The period between settlement and recruitment to the fishery in the NZRLF is believed to be ~4 years. Overall, these results highlight the variable nature of settlement in the fishery.

Figure 3-1 Puerulus settlement index (PSI; mean +/- SE) in the NZRLF from 1996 to 2010.
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 (iii) the incorporation of a 3% annual increase in effective effort over the time period of 1983 to 2000.

This section of the report has two objectives; (i) to use the 2009 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 2009 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 ($C_w$, kg) and catch in number ($C_n$, 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 ($C_n=qEN$) 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, $C_w$ and $C_n$.

Stock assessment models (e.g. delay-difference and biomass dynamic) that fit to catch and effort data normally have available only catch in weight ($C_w$), and rely on $C_wPUE$ 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 $C_{wPUE}$ as a relative measure of change in abundance and mean weight as a measure of change in size structure. McGarvey et al. (2005) demonstrated using simulated data that adding catch in number dramatically improves the accuracy and precision of stock assessment estimates.

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.

Finally, the qR model, in combination with PSI, was used to project how the fishery might evolve under several selected TACC scenarios, including the current TACC of 310 tonnes. These tested TACC scenarios run over 5 years from 2010 to 2014 inclusive.
4.3 Outputs

Goodness of fit

Estimates of catch in number and weight from the 2009 version of the qR model fitted closely with measures of $C_n$ and $C_w$ obtained from catch logbook data for the NZRLF (Figure 4-1 and Figure 4-2).

Biomass

Outputs from the qR model suggest that the biomass in the NZRLF has decreased considerably over the last 20-30 years (Figure 4-3). In 2009, it was estimated to be 1,751 tonnes, an increase of 344 tonnes from 2008 (1,407 tonnes), yet still one of the lowest estimates on record. Note that these outputs are based on average yearly biomass and therefore are lower than those presented in Linnane et al., (2009) for which start-of-year biomass was used. The 2009 value represents a 67% decline in biomass from that estimated in 1980 (5,378 tonnes) and a 40% decrease since the most recent biomass peak in 1998 (2,949 tonnes).

Egg production

Similar to biomass, the qR model indicates that total egg production has decreased considerably in the NZRLF (Figure 4-4). In 2009, it was 202 billion eggs, which equates to 16% of virgin egg production (Figure 4-5). The 2009 value represents a 63% decrease in egg production from that estimated in 1980 (546 billion) and a 46% decrease since the most recent peak in 1998 (376 billion).

Exploitation rate

Exploitation levels increased substantially through the 70’s 80’s and 90’s, reaching a peak of 35% in 1999 (Figure 4-6). Since then, they have generally decreased and in 2009 were estimated at 17%. The 2009 figure represents a substantial decrease from 2008 (28%) and is the lowest since 1985. This decrease in exploitation rate reflects a corresponding decline in fishing effort indicating that for the first time, the TACC constrained exploitation in the NZRLF in 2009.
Comparison of estimates of recruitment from qR model with PRI and PSI

Estimates from the qR model suggest that recruitment generally declined in the NZRLF from 1998 to 2008 (Figure 4-7). In 2009, the qR estimate of recruitment was 1.17 million representing a substantial increase from 2008 (0.39 million) and the highest on record since 1999 (1.25 million). Temporal trends in recruitment estimated by the qR model were compared against trends in puerulus settlement index (PSI) as well as estimates of pre-recruit index (PRI) from both logbook and catch sampling data over the period 1994-2009 (Figure 4-8). The best correlation ($R^2 = 0.68$) between qR recruitment and PSI was obtained using a 4-year lag between settlement and recruitment. Correlations between qR recruitment and PRI, from catch sampling and logbook data, were $R^2 = 0.25$ and $R^2 = 0.87$, respectively. There was no correlation between PRI and PSI under a range of time lags.

**Future projections of CPUE**

There was relatively good agreement of yearly puerulus settlement rates (PSI) qR model-estimated recruitment to legal size four years later, most notably from 2004 to 2009 (Figure 4-9). Forward projections of CPUE under four possible TACC scenarios are presented in Figure 4-10. Under the current TACC of 310 tonnes, CPUE increases to 1.03 kg/potlift in 2011 and remains at ~1 kg/potlift for the next three seasons before declining to 0.94 kg/potlift in 2014. If the TACC is reduced from 310 to 250 tonnes in 2011, CPUE increases to 1.11 kg/potlift in 2013 before decreasing to 1.06 kg/potlift in 2014. Under lower TACC scenarios, CPUE increases to higher levels from 2010-2014. For example, TACCs of 155 tonnes in 2011 and 2012 results in CPUE increasing to 1.2 kg/potlift in 2013, before decreasing to 1.12 kg/potlift in 2014. Overall, future qR projections suggest that due to the historically low settlement in 2007, 2008 and 2010 (Figure 3-1), which are predicted to impact the fishery from 2011 to 2014, TACCs below 310 tonnes may be required to ensure sustained rebuilding in the fishery.

**4.4 qR Model Discussion**

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

The qR model outputs estimate that biomass in the NZRLF has decreased considerably since the inception of the fishery. In 2009, it was 1,751 tonnes one of the lowest in the history of the fishery and a 67% decline from that estimated in 1980. Egg production in the NZRLF has also decreased with the 2009 estimates of 202 billion eggs equating to just 16% of virgin. Despite these historically low levels, there were some positive signs for the fishery in 2009. The 2009 recruitment estimate of 1.17 million is one of highest on record which resulted in a considerable decrease in exploitation levels to just 17% which is the lowest on record since 1985.

There is relatively close agreement between qR model yearly recruitment trends and pre-recruit estimates from logbook (R$^2 = 0.87$). The relatively strong correlation between PSI and qR recruitment to the fishery after 4 years (R$^2 = 0.68$) was used to assess the effectiveness of future harvest strategies. Under the current TACC of 310 tonnes, the qR model predicts that CPUE will increase to ~1 kg/potlift in the short-term before decreasing in 2014. Given the historically low settlements observed in 2007, 2008 and 2010, the model suggests that TACCs below 310 tonnes may be required to ensure sustained rebuilding in the fishery over the period 2010-2014.

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. Future development of the model will benefit from the inclusion of fishery independent data by a) providing a spatial component to the fishery assessment and b) allowing assessment of the overall resource rather than just areas fished.
Figure 4-1 Fit of the qR model to catch in number (Cn) for the NZRLF, based on annual catch totals from the fishery and estimates provided by the 2009 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 2009 version of the qR model.
Figure 4-3 Estimates of biomass for the NZRLF provided by the 2009 qR model.

Figure 4-4 Estimates of egg production for the NZRLF provided by the 2009 qR model.
Figure 4-5 Estimates of % virgin egg production for the NZRLF, from the 2009 qR model.

Figure 4-6 Estimates of exploitation rate for the NZRLF provided by the 2009 qR model.
Figure 4-7 Estimates of annual recruitment for the NZRLF provided by the 2009 qR model.

Figure 4-8 Estimates of annual recruitment provided by the 2009 qR model, pre-recruit index (PRI) as undersize numbers per pot lift (Nov-Mar) obtained from both pot sampling and logbook data and puerulus settlement index (PSI) lagged by 4 years.
Figure 4-9 Comparison of puerulus settlement index (PSI, lagged forward 4 years; and qR model-estimated recruitment. Puerulus estimates from 2010-2014 were used to forecast recruitment in model projections.

Figure 4-10 Historical CPUE and forward projections under four TACC scenarios for 2010-2014 NZRL seasons.
5 THE LENGTH STRUCTURED MODEL

5.1 Introduction

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

5.2 Methods

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

LenMod infers change and absolute levels of stock abundance principally from three data sources: (1) CPUE (see Section 2.2) to which biomass is assumed to vary in direct proportion, (2) catches in both weight and numbers (see Section 2.6), which supply a highly precise (100% sample) measure of mean weight of lobsters in the catch, and (3) length-frequency data (see Section 2.7), interpreted in combination with the length-transition matrices to yield estimates of mortality rate and absolute biomass. Data sources (2) and (3) both provide LenMod with information on size of lobsters in the catch.
Growth is modelled using length-transition matrices which specify the proportion of lobsters in each length category that grow into larger length classes during each summer and autumn moulting period. Growth matrices were estimated for each combination of sex and moulting season. The length-transition matrices for the NZRLF were estimated from the extensive tag-recovery data. The length-transition estimation method of McGarvey and Feenstra (2001) was applied which permits more flexible growth curves to be inferred by modelling the parameters predicting mean and variance of observed tag-recovery growth increments as polynomial functions of (starting) carapace length. This method has also been adopted for use in Tasmania and Victoria. Growth rates of 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 $C_n$ 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 2009 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 2009, it was estimated to be 1,628 tonnes, an increase of 303 tonnes from 2008 (1,325 tonnes). The 2009 value remains one of the lowest on record and represents a 52% decline in biomass from that estimated in 1990 (3,426 tonnes).

Egg production

Similar to biomass, LenMod indicates that total egg production has decreased considerably in the NZRLF (Figure 5-5). In 2009, it was 178 billion eggs, which equates to 9.2% of virgin egg production (Figure 5-6). The 2009 value represents a 48% decline in egg production from that estimated in 1991 (345 billion).
Exploitation rate

LenMod estimates that exploitation rate increased from 25% in 1983 to 40% in 1999 (Figure 5-7). Over the next nine seasons it remained at between 30-40%. In 2009, exploitation rate decreased to 19%, which represents the lowest estimate on record.

Comparison of estimates of recruitment from LenMod with PRI and PSI

Estimates from LenMod suggest that recruitment levels have generally decreased over the last ten seasons from 1998-2008 (Figure 5-8). In 2009, the LenMod estimate of recruitment was 0.91 million representing a substantial increase from 2008 (0.45 million) and the highest on record since 1999 (1.19 million). The temporal trends in recruitment estimated by LenMod were compared against trends in puerulus settlement index (PSI) as well as pre-recruit index (PRI) estimates from both logbook and catch sampling data over the period 1994-2009 (Figure 5-9). Correlations between LenMod recruitment and PSI were moderate ($R^2=0.50$) using a 4-year lag. Correlations between LenMod recruitment and PRI as estimated from catch sampling and logbook data were $R^2=0.14$ and $R^2=0.93$ respectively. There was no correlation between PRI from logbook data and PSI under a range of time lags.

5.4 Model Discussion

Details of the length structured model including simulation testing of its performance have been described in two peer-reviewed papers (Hobday and Punt 2001; Punt 2003). The LenMod outputs estimate that biomass in the NZRLF has decreased considerably since the inception of the fishery. In 2009, it was estimated to be 1,628 tonnes, one of the lowest in the time series. This represents a 52% decline in biomass since 1990. Trends in egg production compare with those in legal sized biomass. The 2009 estimate of 178 billion eggs is also one of the lowest on record and currently equates to only 9.2% of the virgin level. Despite these historically low levels, as with the qR outputs, there were some positive signs for the fishery in 2009. The 2009 LenMod recruitment estimate of 0.91 million is the highest on record since 1999 which resulted in a considerable decrease in exploitation levels to just 19%, the lowest in the history of the fishery.

The temporal trends in recruitment predicted by LenMod were compared against trends in puerulus settlement index (PSI) as well as pre-recruit index (PRI) estimates from both logbook and catch sampling data over the period 1994-2009. While correlations between LenMod recruitment and PSI were moderate ($R^2 = 0.50$ using a
4-year lag), they were strongly correlated with PRI based on logbook estimated data ($R^2 = 0.93$). Given the mandatory introduction of escape gaps in the NZRLF, this result is surprising as it could be expected that PRI from logbook data would be underestimated. PRI from catch sampling data however is estimated from pots where the escape gaps are closed. Nonetheless, given that similar results were observed in qR outputs and the importance of catch sampling estimated PRI in the current Management Plan, the robustness of this indicator needs to be closely monitored in future seasons.

The current version of LenMod, like the qR model, utilises fishery dependent data, namely CPUE and catch by weight and number. As a result, similar features to the qR model exist, namely, that trends in biomass (Figure 5-4) are informed by trends in legal-sized catch rate (Figure 2-2). The Northern Zone model outputs are currently non-spatial, meaning that each fishery zone is modelled as a single population.

In this most recent 2009 version of LenMod, the reported rates of discarding in relation to spawners, dead and high grading have been more accurately accounted for. A new FRDC project titled “Sustainability of rock lobster resource in south-eastern Australia in a changing environment: implications for assessment and management” will start in 2010. This project will focus on environmental influences on catchability and recruitment which could lead to refined measures of catch rate in the length-based model, as well as potentially permit insight into recent negative recruitment trends.
Figure 5-1 Fit of the LenMod model to monthly catch in numbers (Cn) for the NZRLF, based on annual catch totals from the fishery and estimates provided by the 2009 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 2009 version of the model.
Figure 5-3 Sample of model fit (black line) to commercial length frequency data (blue bars) taken from the 2009 season in the NZRLF.
Figure 5-4 Estimates of biomass provided by the 2009 LenMod model.

Figure 5-5 Estimates of egg production provided by the 2009 LenMod model.
Figure 5-6 Estimates of percent of virgin egg production provided by the 2009 LenMod model.

Figure 5-7 Estimates of exploitation rates provided by the 2009 LenMod model.
Figure 5-8 Estimates of recruitment obtained from the 2009 LenMod model.

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

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

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

6.1 Zonal Catch rate

In 2009, the zonal estimate of 0.88 kg/potlift was marginally below the limit reference trajectory (the 2009 trajectory point is 0.90 kg/potlift) of 1.00 kg/potlift over 12 years (Figure 6-1) as per the Management Plan for the resource (Sloan and Crosthwaite 2007).

6.2 Regional Catch rate

In 2009, regional CPUE was above the target reference points in Regions A and B (Figure 6-2). It was above the limit reference point in Region C but below it in Region D.

6.3 Zonal Pre-recruit Index

In 2009, the zonal 3-year average PRI (2007-2009) was 0.51, which is above the long-term LRP for the NZRLF (Figure 6-3).

6.4 Regional Pre-recruit Index

In 2009, the regional 3-year average PRI (2007-2009) was above the long-term limit reference points in Region B, C and D (Figure 6-4).
Figure 6-1 Zonal limit and target reference points for CPUE in the NZRLF including current estimates from the 2009 season.

Figure 6-2 Regional limit and target reference points for CPUE in the NZRLF including current estimates from the 2009 season.
**Figure 6-3.** Zonal pre-recruit indices (PRI) (1994-2009) with Limit Reference Point (LRP) and current 3-year average (2007-2009).

**Figure 6-4 Regional pre-recruit indices (PRI) (1994-2009) with Limit Reference Points (LRPs) and current 3-year average (2007-2009).**
7 GENERAL DISCUSSION

7.1 Information available for the fishery

Stock assessment of the NZRLF is aided by documentation on the history of the management of the fishery in the Management Plan and recent stock assessments and status reports (e.g. Sloan and Crosthwaite 2007; Linnane et al. 2009). The Management Plan also describes the management arrangements in place at the time of this assessment and the biological reference points used for assessing the fishery.

Comprehensive catch and effort data have been collected since 1970. Data collected since 1983, however, provide more reliable information on effort. Voluntary catch sampling data have been collected since 1991 and provide information on length frequency, pre-recruit indices and reproductive condition of females. Data from 1994 onwards are more robust due to low levels of participation in the early years of the program. Fishery stock assessments are also aided by trends in puerulus settlement data from four 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 trend 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 (1.49kg/potlift) and a 21% decrease since the introduction of quota in 2003 (0.86 kg/potlift).
The zonal trends in fishery performance are reflected in all of the major fishing regions of the NZRLF. In 2008, >90% of the catch was taken in Regions B, C and D (refer to Figure 1-4). The 2008 catch figures of 60 and 138.9 tonnes in Regions C and D respectively were the lowest on record, while the catch of 168.7 tonnes in Region B was the fourth lowest. These trends represent consistent declines in catch of 51%, 63% and 65% in Regions B, C, and D respectively since 1999.

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

The reason for the decrease in fishery performance is clear. TACCs have not been set at levels that constrained catch, which is inconsistent with the aim of stock rebuilding defined in the Management Plan. 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, 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.

Data presented in this report confirms that recruitment into the NZRLF increased in 2009. The zonal catch rate was 0.88 kg/potlift, a 29% increase from 2008 (0.68 kg/potlift). This estimate reflects a substantial decline in fishing effort during the season. The 2009 estimate of 350,838 potlifts represents 42% decrease from 2008 and is the lowest estimate on record. That the increase in CPUE is the result of new recruits is confirmed by mean weight and length frequency data. The 2009 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.

Clearly, increased recruitment levels in 2009 are a positive sign for the fishery. In addition, recruitment to the fishable biomass should continue in 2010 based on the 2006 settlement levels and high PRI estimates observed in 2009. However, while recruitment in 2010 is expected to increase, settlement in 2007 and 2008 was low suggesting that recruitment to the fishery 2011 and 2012 will be poor. It should also be highlighted that settlement in 2010 was the lowest on record, indicating that recruitment in 2014 will also be low. Therefore, as stated in previous reports, given the level of variation in recruitment to the NZRLF and the sporadic nature of puerulus settlement, careful consideration should be given as to how pulses of recruitment are protected. Specifically, given the period of low recruitment predicted from 2011 to 2014, conservative TACCs must be applied to maintain a sustainable biomass over this period.

7.3 Implications for Management

The Management Plan for the NZRLF is currently being reviewed by PIRSA Fisheries. The previous Management Plan (Sloan and Crosthwaite 2007) required that both legal-sized catch rate and pre-recruit index performance indicators must trigger before a management response is taken. In 2009, catch rate triggered, but PRI (based on a three year average) was above the limit reference point defined in the Management Plan.
The strong relationship in recent seasons between puerulus settlement and qR model recruitment was used to project future estimates of CPUE based on various TACC scenarios. Under the current TACC of 310 tonnes, the model suggested that CPUE will increase to ~1 kg/potlift in 2010 and will be maintained at this level until 2013. However, based on low settlement in 2010, CPUE decreases to 0.94 kg/potlift in 2014. Under more conservative TACC scenarios ranging from 155-250 tonnes, CPUE is maintained above the 2010 predicted level of 1.03 kg/potlift before decreasing in 2014. Overall, these results suggest that for sustained biomass rebuilding to occur in the NZRLF, TACCs below 310 tonnes may be required given projected recruitment trends.

7.4 Future Research Priorities

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

Finally, given the importance of voluntary catch sampling to estimates of future recruitment to the fishery, it is imperative that increased participation in the program is encouraged for the 2010 season.
8 BIBLIOGRAPHY


