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Tactical Research Fund: Assessing the feasibility of spatial management in the South Australian Northern Zone Rock Lobster (*Jasus edwardsii*) fishery

A. Linnane and R. McGarvey

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FRDC PROJECT NO. 2011/072

SARDI Aquatic Sciences
PO Box 120 Henley Beach SA 5022

July 2014

Final Report to the Fisheries Research and Development Corporation

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2011/072 Assessing the feasibility of spatial management in the South Australian Northern Zone Rock Lobster (*Jasus edwardsii*) fishery

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OBJECTIVES:

1. Attain estimates of lobster abundance in far-west and deep-water and regions of the South Australian Northern Zone rock lobster fishery.
2. Estimate size-of-maturity and length frequencies of these populations.
3. Estimate survival rates of these lobsters held on-board vessels and in processing plants.
4. Evaluate the economics of fishing outlying areas within the Northern Zone rock lobster fishery.

OUTCOMES ACHIEVED TO DATE

Two areas of the Northern Zone Rock Lobster Fishery of South Australia have low levels of commercial exploitation. These are the north-western coastal waters of the far-west and areas of deep-water (>90 m). A number of spatial management options are currently being considered for the fishery. Broadly, these options aim to encourage, through financial incentives, higher levels of exploitation in these outlying fishing areas. As a basis for spatial management discussions, this report provides fishery, biological and economic information to inform the cost/benefits of possible future options. Specifically, it details spatial time series of catch, effort, catch rate, and pre-recruit abundances across the key fishing regions of the Northern Zone. It also provides estimates for female size-of-maturity, and length frequency samples in both far-west and deep-water regions, which are compared spatially. Through two dedicated experimental fishing trips, a preliminary economic analysis of fishing both far-west and deep-water grounds was undertaken to support fishery and biological information. Overall, the report provides a comprehensive overview of fishing fleet dynamics within the Northern Zone Rock Lobster Fishery from 1970-2011. It highlights spatial variations in important biological characteristics and provides preliminary economic outputs for regional fishing including post-landing rock lobster survival rates. Based on the outcomes, the report discusses fishery, biological and economic factors that need to be considered should higher levels of exploitation be encouraged in either far-west or deep-water regions of the Northern Zone rock lobster fishery.

The Northern Zone rock lobster fishery of South Australia is extensive covering an area of approximately 207,000 km^2. As a result, number of spatial management options are currently being considered which focus on the far-west and deep-water regions of the fishery. Currently, levels of commercial exploitation in both these areas are low compared to eastern and inshore areas. For example, in the 2011/12 fishing season only 12 t (4%) of the 307 t total catch came from the far-west, while just 29 t (9%) came from >90 m depth.

Despite low levels of total catch, catch rates (kg of legal lobster/potlift) in both regions are high compared to eastern and inshore areas. In the far-west at least, this is influenced by a larger mean lobster size compared to eastern regions, presumable due to faster growth rates. While higher, catch rates trends from 1970-2011 in both far-west and deep-water regions are comparable to other regions in the fishery. In particular, catch rates in both areas declined simultaneously with eastern regions from 1999 to 2008 suggesting that the abundance of lobsters in the far-west and deep-water is driven by common recruitment patterns to the rest of the zone.

The far-west region is close to the western limit of *Jasus edwardsii* distribution within Australia with pre-recruit (undersized) abundances in this area the lowest in the zone suggesting that the region is recruitment limited. The size of maturity in far-west regions is substantially higher than the minimum legal size which again reflects faster growth rates. This is offset somewhat by the fact that few lobsters close to legal size are found within the commercial catch. However, if exploitation rates are increased in far-west regions, given that size limits are set in part to protect immature females, higher size limits may need to be considered under a spatial management regime. Alternatively, a male only fishery may be considered during specific months in line with management rules for *J. edwardsii* fisheries in Victoria and Tasmania. Data to estimate size of maturity in deep-water sites are limited in South Australia.

A preliminary bio-economic study, based on two experimental fishing trips, indicated that the costs of fishing both far-west and deep-water sites are substantially higher compared to other areas due namely to: a) higher fuel costs; and b) lower price for landed catch. Profitability from deep-water fishing was also impacted by high levels of lobster mortality. It is important to highlight that these results are based on experimental fishing trips and may differ from normal commercial fishing operations. In addition, it is worth noting that beach prices paid for lobsters vary monthly which impacts on profitability. The current study was based on prices paid during February only and as a result, the economic outcomes presented are a function of the price observed at that specific time. Future research should involve estimates based on prices paid across a range of time periods in order to investigate how temporal effects impact on rock lobster fishing profitability within South Australia.

Current biomass estimates for the fishery are non-spatial. A spatial management regime would presumably require annual setting of quotas, based on sustainable exploitation levels, for each sub-region. If sub-regions are to be considered, it is critical that spatial estimates of biomass are generated for the Northern Zone to ensure sustainable future exploitation levels for the resource. Finally, previous oceanographic modeling of puerulus larvae distribution suggests that the far-west may be a source of puerulus for more eastern regions of the Northern Zone which should be taken into account if exploitation levels in western regions are increased.

In summary, catch rates of rock lobsters from far-west and deep-water areas of this fishery are higher than other regions but this is likely to reflect larger individuals and faster growth rates rather than abundance. Opportunities to target these individuals at specific periods of high unit price may exist but requires further research, particularly if outside of the current fishing season. However, this strategy comes with some management challenges given that these areas are recruitment limited, have a higher size of maturity and may contribute disproportionately to larval supply in other regions of the fishery.

Keywords: rock lobster, *Jasus edwardsii*, spatial management, bio-economic, fleet dynamics, stock assessment

2 ACKNOWLEDGEMENTS

We thank Mr. Clint Ackland and crew of F/V *Miss Candice* and Mr. Richard Leech and crew of F/V *Peacekeeper* for undertaking the experimental fishing trips. Mr. Trent Gregory (Southern Ocean Rock Lobster Pty Ltd), Brendan Cappelluti and Steve Moriarty (Southern Waters Marine Products) assisted in post-harvest processing and provided economic data. Mr. Peter Hawthorne, Mr. Matthew Hoare and Ms. Kylie Howard collected and entered all fishery-dependent data. Finally, we acknowledge all Northern Zone Rock Lobster Fishery licence holders, skippers and crew who have participated in the voluntary catch sampling program over the years.

3 BACKGROUND

Southern rock lobster *Jasus edwardsii* are distributed around the southern mainland of Australia, Tasmania and New Zealand (Phillips 2006). They are primarily found in limestone reef systems or isolated granite formations that provide ideal rock lobster habitat in the form of protective crevices or ledges. In south-eastern Australia, the resource supports important regional fisheries across the States of South Australia, Victoria and Tasmania. The total annual catch across all States ranges from 3,500-4,000 tonnes with an estimated gross commercial value of ~AUS$200 million (Skirtun et al. 2013). Fishing methods have not changed markedly over time and generally consist of baited pots that are set individually, left overnight and hauled at first light.

The South Australian fishery is divided into two zones; Northern and Southern, which are further sub-divided into Marine Fishing Areas (MFAs) for statistical and management purposes that acknowledge known spatial differences in the biological characteristics of *J. edwardsii* (Figure 1). The Northern Zone Rock Lobster Fishery (NZRLF) is extensive, covering all South Australian marine waters between the mouth of the Murray River and the Western Australian border, an area of approximately 207,000 km^2. It is sub-divided into 53 MFAs, with most effort expended in MFAs 7, 8, 15, 27, 28, 39, 40, 48, 49 and 50.

The commercial NZRLF is a limited entry fishery with a total of 68 licences. Port Lincoln on the Eyre Peninsula is the base for the majority of the fleet (Figure 1). Regional geological features play an important role in the dynamics of the fishery. The NZRLF marine substrate is largely comprised of granite basement rock that projects through the overlying sands (Lewis 1981). As a result, with the exception of some aeolianite limestone reef located south of Kangaroo Island, rock lobster habitat is confined to discrete localised areas, interspersed by large expanses of sand. Based on these features, the region is commonly referred to as an “oasis” type fishery.

Management of the resource utilises both input and output control methods. The season extends from 1 November to 31 May 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 rock lobster. A Total Allowable Commercial Catch (TACC) is set annually and is divided proportionally between licence holders as individual transferable quotas (ITQs). Each licence holds one quota unit entitlement for each pot entitlement held. The daily catch of individual vessels is monitored through mandatory commercial logbooks and quota monitoring catch and disposal records. In the 2012/13 season, the TACC was 345 tonnes.

While a single TACC is set for the entire zone, the previous management plan (Sloan and Crosthwaite 2007) also focussed on assessing the fishery at the regional level, as well as the whole-of-fishery (zone) scale. The plan divided the zone into four regions i.e. “The West” (Region A), “Eyre Peninsula” (Region B), “Yorke Peninsula” (Region C) and “Kangaroo Island” (Region D) (Figure 1). The aims of regional assessment were to refine management to a finer spatial scale, as well as ensuring that greater precaution was factored into management arrangements. For example, regional assessment allowed known spatial variations in biological features such as growth rate (McGarvey et al. 1999) and size of maturity (Linnane et al. 2011) to be taken into consideration.

More recently, there have been further requests by both industry and management for improved spatial information in relation to the NZRLF. This centres on the changing dynamics of the fishing fleet, particularly in an area as extensive as the NZRLF, where under a TACC system fishers replace maximising catch volume with the need to maximise value per kilogram. Previous research undertaken in the Southern Zone fishery (Linnane and Crosthwaite 2009) indicated that rising fuel costs under a TACC system reduced the cost-benefit of travelling extended distances to take catch. In addition, market demands are now a clear driver of spatial dynamics across South-eastern Australia. Current overseas markets favour small (<1 kg), "red"-coloured lobsters that are primarily found inshore as opposed to larger "speckled" or "white" lobsters that are synonymous with offshore grounds (Chandrapavan et al. 2011). As a result, higher prices for red lobsters have driven effort into shallow water grounds and areas close to home ports, thus producing the unusual fisheries situation where fishers are avoiding high catch rate areas offshore in favour of lower catch rate areas inshore (Linnane and Crosthwaite 2009).

In response to these issues, a number of alternative spatial management strategies have been proposed for the NZRLF. This report aims to provide a discussion baseline for these proposals by detailing spatial trends in both commercial fishing effort and biological characteristics of rock lobster in the region. In addition, the report analyses survival rates of lobsters in outlying areas and provides a preliminary economic analysis in relation to associated costs of regional fishing. Specifically, this report focuses on the commercial fishing and biological characteristics of two regions within the NZRLF where commercial exploitation levels are currently low i.e. MFAs 7 and 8 in Region A (referred to as "far-west") and offshore grounds >90 m depth (referred to as "deep-water").

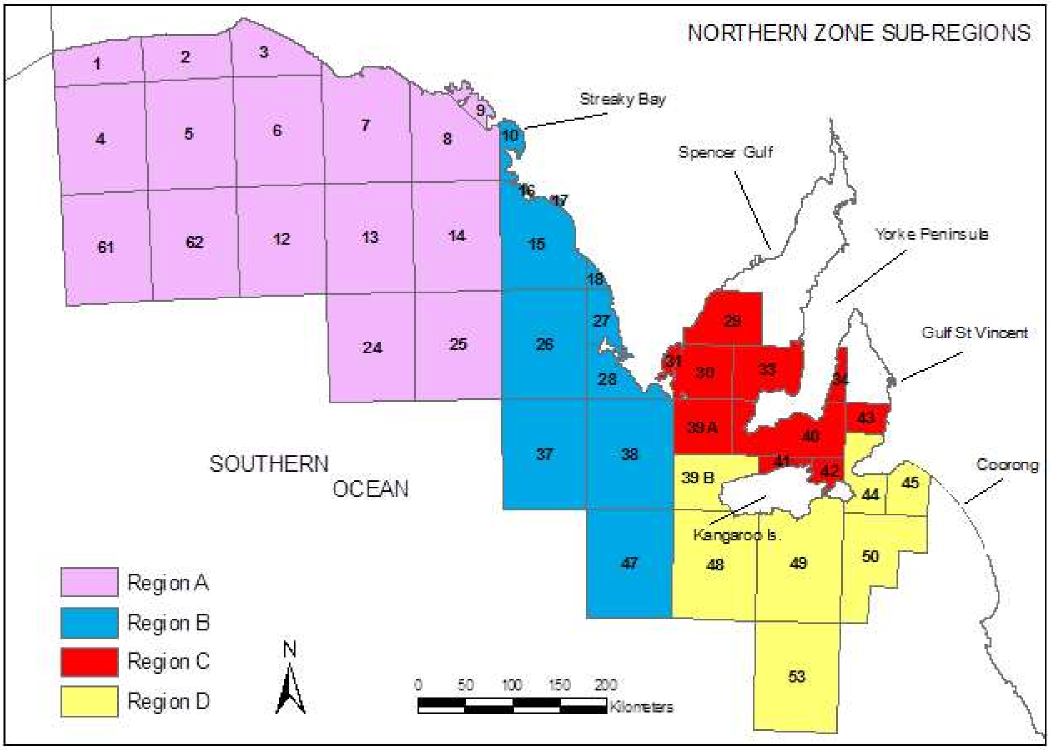

Figure 1 Key spatial management regions in the Northern Zone Rock Lobster Fishery.

4 NEED

In order to allow for consideration of spatial management options in the NZRLF, there are a number of primary needs in relation to the fishery. These include the following:

1. To assess the level of stock abundance in regions outside the main fishery areas, in deep-water (>90 m) and the far-west (MFAs 7 and 8) regions of the fishery.
2. To assess the biological characteristics of rock lobsters taken in deep-water and the far-west, including maturity of females and length frequency.
3. To assess the survival and condition of rock lobsters during processing and transport.
4. To assess the economic feasibility of fishing in these areas.

5 OBJECTIVES

Based on the above needs, the objectives of this project were to:

1. Attain estimates of rock lobster abundance in far-west and deep-water regions of the South Australian Northern Zone Rock Lobster Fishery.
2. Estimate size-of-maturity and length frequencies of these populations.
3. Estimate mortality rates of rock lobsters held on-board vessels and in processing plants.
4. Evaluate the economics of fishing the above outlying areas within the Northern Zone Rock Lobster Fishery

6 METHODS

6.1 Spatial estimates of abundance

Mandatory logbooks have been in place in the NZRLF since 1970. All logbook data are fishery-dependent and provide information on: 1) number and weight of retained legal-sized (>105 mm carapace length; CL) lobsters reported at the end of each trip or as a daily estimate; 2) number of undersized lobsters; 3) MFA and depth range within which fishing took place and 4) number of pots set. These data were used to generate spatial estimates of catch and effort, catch per unit effort (CPUE) (kg/potlift), mean weight (kg) and pre-recruit indices (undersized/potlift) by regional, MFA and depth range spatial scales.

In addition to logbook data, survey estimates of undersized lobsters were also compared against spatial estimates obtained from an at-sea voluntary catch sampling program. Since 1991, participants are requested to count, measure (to nearest mm), sex and record the reproductive condition of lobsters from up to 3 research pots per fishing trip. The importance of the catch sampling program has increased in recent seasons with the mandatory introduction of escape gaps in all commercial pots in 2003. All escape gaps in catch sampling research pots are closed, thus providing a more accurate estimation of undersized than that provided by logbook data from pots where escape gaps are open.

Historical trends in catch and effort at both the regional and MFA spatial scales are derived from logbook data for the period from 1970 to 2011. At the MFA scale, estimates presented are for those MFAs in which most effort is expended (i.e. MFAs 7, 8, 15, 27, 28, 39, 40, 48, 49 and 50). Two targeted experimental fishing trips onboard commercial rock lobster vessels were also undertaken as part of this project. While the primary purpose of these surveys were to obtain economic data (see Section 6.4), historical logbook and catch sampling catch rates were also compared against survey derived indices. The first survey took place in the far-west in MFA 7 and 8 for a period of 9 days from 15 to 23 February 2012 (Refer to Figure 1). The second involved sampling a deep-water shelf site for 4 days from 8 to 12 March 2012 in depths >100 m in MFAs 37 and 38.

6.2 Length frequency and size of maturity

Length frequency data of both males and female lobsters were obtained from the catch sampling methods described above. In order to estimate female size of maturity, all female lobsters were pooled according to MFA of capture. A female rock lobster was categorised as "sexually mature" if it possessed either eggs or ovigerous setae (Wenner et al. 1974). The percentage of sexually mature female rock lobsters was plotted against carapace length in each 1 mm CL size class and then model parameters estimated, using the nonlinear least squares regression function in R (version 2.13.0), for the logistic equation:

$$P_m = \frac{1}{\left[1+e^{(-S.(L-L_{50}))}\right]}$$

where P_m is the percentage of mature females lobsters, L is the carapace length, L_{50} is the constant carapace length at which 50% of female lobsters are mature, and S is constant.

6.3 Lobster mortality

During each of the experimental fishing trips, the weight of all lobster mortalities onboard the fishing vessel was estimated. In addition, the weight of mortalities, as well as those individuals classified as "weak", and therefore unlikely to survive any transportation process, was also recorded through the storage, packing and ultimate shipping phases.

6.4 Preliminary economic analysis

The goal of the economic analysis was to compute a net profit/loss from the two experimental fishing surveys (far-west and deep-water). Profit equals revenues earned from fishing minus total fishing costs. Revenues were computed from the reported weight (kg) of lobsters landed in each weight grade times the price per kg paid for rock lobsters in each grade (which differ by rock lobster size or quality).

Costs were divided into two categories, fixed and variable. Fixed costs, which are attributed to expenditures that must be paid each year to operate the lobster fishing business, included license fees, insurance, interest, unpaid labour, legal and accounting fees, slip and mooring, travel, and office and administration Fixed costs were not available from data obtained in this study and were taken to be 45% of landed revenue as estimated in the latest EconSearch economic survey report for the fishery (EconSearch 2012). The variable costs of fishing were obtained from the skippers of the two experimental fishing trips. These were (1) fuel, (2) food for crew, (3) bait, (4) wages for skipper and (5) wages for deck hand.

7 RESULTS

7.1 Spatial estimates of abundance

7.1.1 Far-west

7.1.1.1 Legal sized catch and effort

Historical trends in catch and effort at both regional and MFA spatial scales are presented in Figure 2 and Figure 3. In general, the catch from Region A is considerably lower than that taken in other regions. For example, the long-term average catch in Region A is 65.1 t compared to 287.5 t, 104.7 t and 244.6 t in regions B, C and D respectively. The highest catch in Region A was recorded in 1993 at 172.2 t and as in other regions, catch has generally declined over the last decade. For example in 2000, the recorded catch in Region A was 92.2 t but by 2011 this had reduced to 11.7 t reflecting a decrease of 87%. Trends in effort have generally reflected those in catch. Specifically, effort in Region A has declined from 59,769 potlifts in 2000 to 8,303 potlifts in 2011, a decrease of 86%.

Catch and effort in Region A are largely dominated by two MFAs i.e. 7 and 8 (refer to Figure 1). Since 1999, catch in both areas has decreased considerably from 33.5 t to 3.1 t (91% decline) in MFA 7 and from 38.6 t to 7.2 t (81% decline) in MFA 8 (Figure 3). The 2011 catch estimates represent close to historical lows in both MFAs. Effort has declined at comparable levels to catch over the same period.

7.1.1.2 Legal sized catch per unit effort (CPUE)

Historically, catch rates in far-west regions have been generally higher than for areas further east (Figure 4 and Figure 5). For example up to 2000, the average CPUE in MFA 7 was 1.6 kg/potlift whereas CPUEs were generally <1.5 kg/potlift during this period in all other MFAs. Reflecting similar trends across all MFAs in the NZRLF, catch rates in MFAs 7 and 8 decreased from the late 1990s to 2008, before increasing over the last three seasons. Catch rates of both legal and undersized lobsters from the 9 day far-west survey undertaken across MFAs 7 and 8 are presented in Table 1. The legal size CPUE for the entire trip was 1.46 kg/potlift, which is comparable with the recent commercial catch rate derived from logbook data (1.41 kg/potlift in Region A; Figure 4; and 1.66 and 1.31 kg/potlift in MFAs 7 and 8, respectively, in 2011; Figure 5).

7.1.1.3 Mean Weight

Higher catch rates in far-west MFAs tend to reflect larger mean sizes in these areas (Figure 6). For example, the average mean weights in MFAs 7 and 8 from 1983 to 2011 were 1.67 kg and 1.55 kg, respectively. This compares to 0.94 kgs in both MFA 48 and 49 located in the eastern region of the zone. The higher mean weight in regions further west is likely to reflect spatial variation in growth. A study by McGarvey et al. (1999) indicated that some of the highest growth rates in the zone were in the far-west region most likely reflecting higher average water temperatures and lower density-dependent effects.

7.1.1.4 Undersized catch per unit effort (CPUE)

Pre-recruit estimates (undersized/potlift) from the 9 day far-west survey undertaken across MFAs 7 and 8 are presented in Table 1. Estimates were extremely low which is consistent with long-term trends as observed in both logbook (Figure 7) and catch sampling (Figure 8). Far-west regions have the lowest undersized CPUEs for the entire zone. For example, pre-recruit estimates in MFAs 7 and 8 rarely exceed 0.1 undersized/potlift compared to MFAs 48 and 49 in the eastern part of the fishery where catch rates are known to exceed 1 undersized/potlift in some years based on catch sampling data (Figure 8).

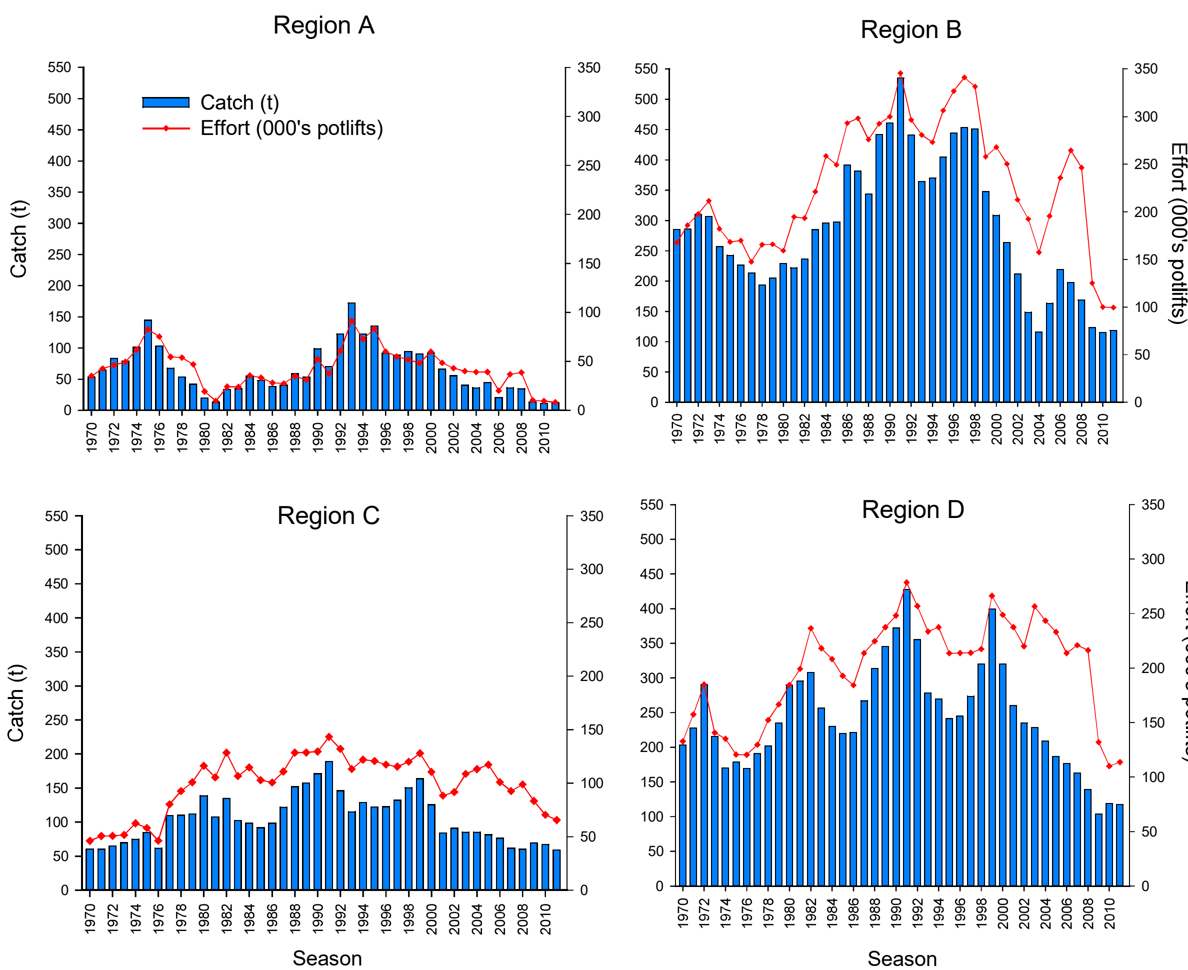

Figure 2 Inter-annual regional trends in catch and effort in the NZRLF from 1970-2011.

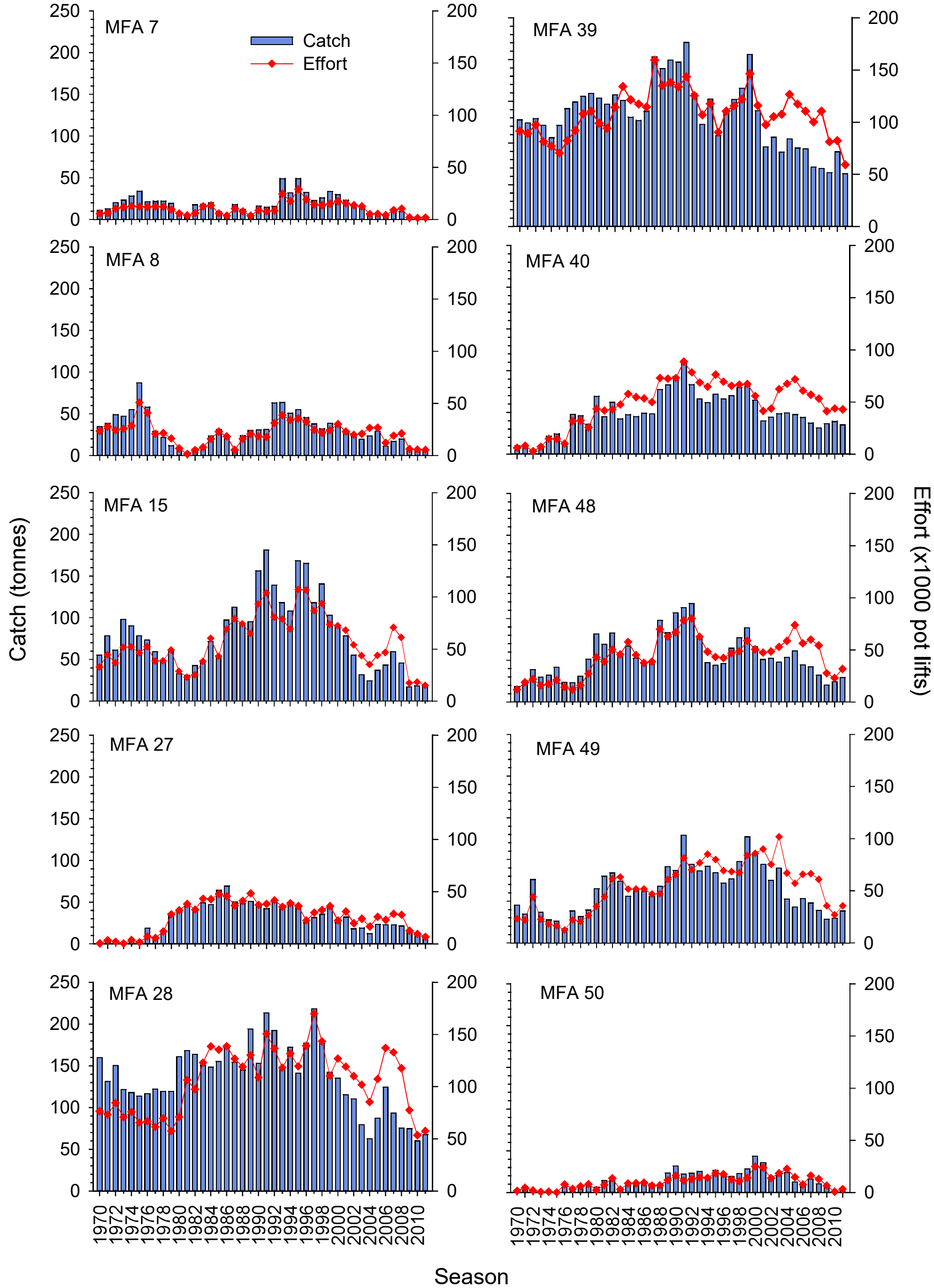

Figure 3 Inter-annual MFA trends in catch and effort in the NZRLF from 1970-2011.

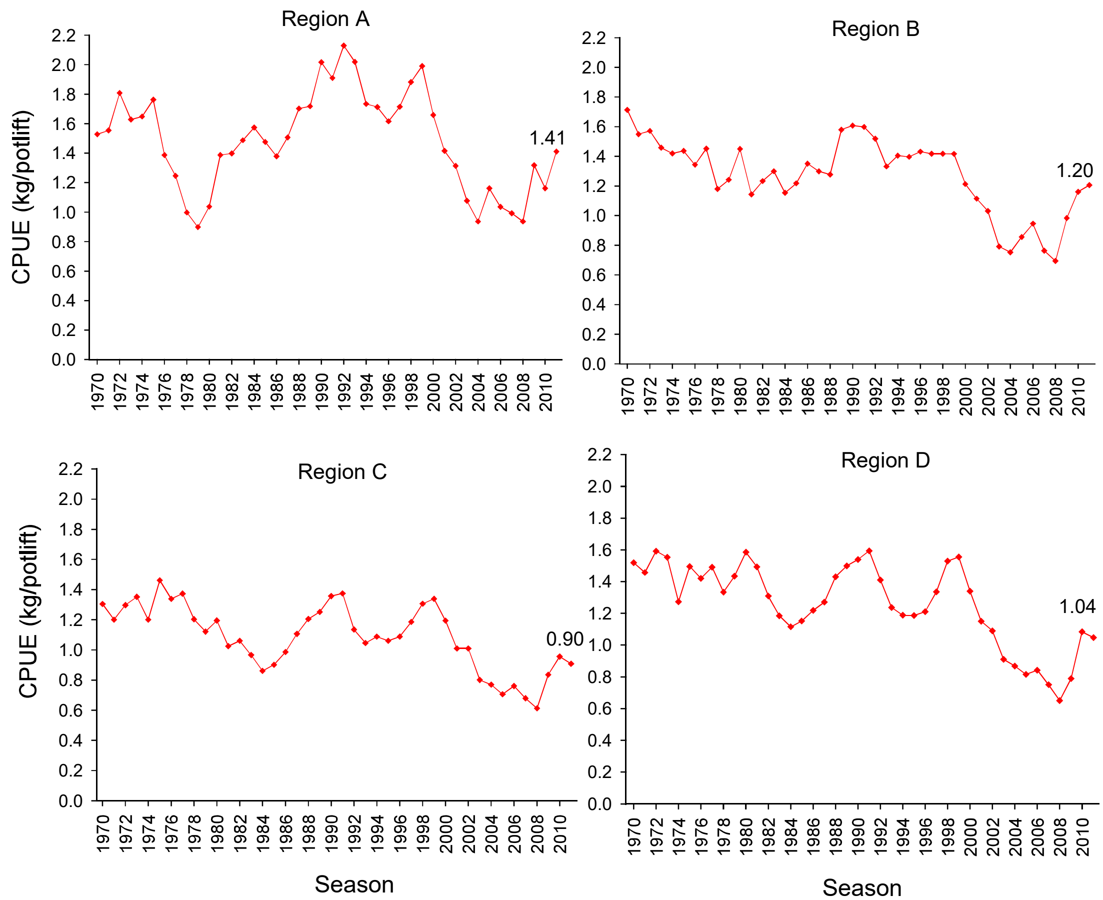

Figure 4 Inter-annual regional trends in catch per unit effort (CPUE) in the NZRLF from 1970-2011.

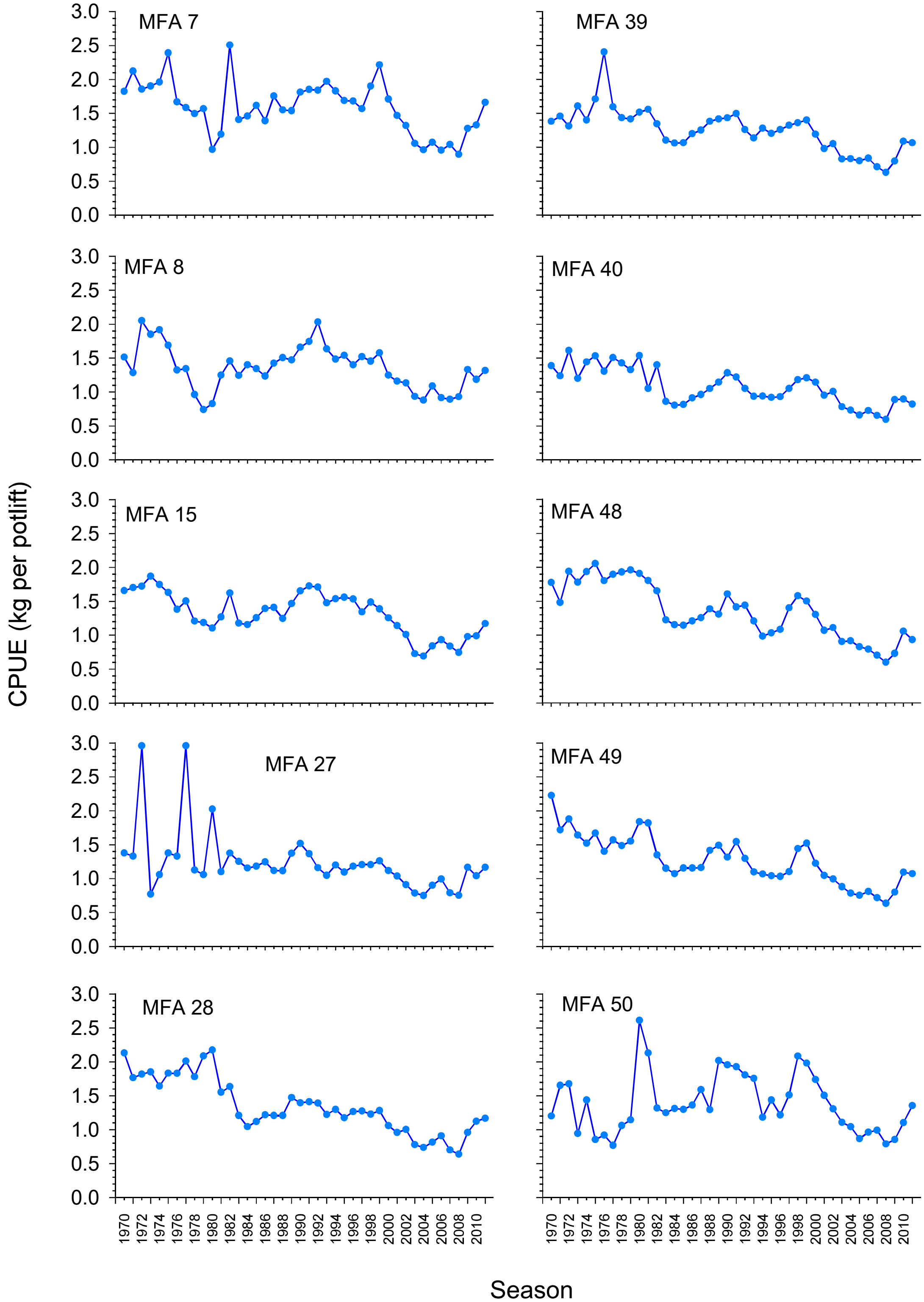

Figure 5 Inter-annual MFA trends in CPUE in the NZRLF from 1970-2011.

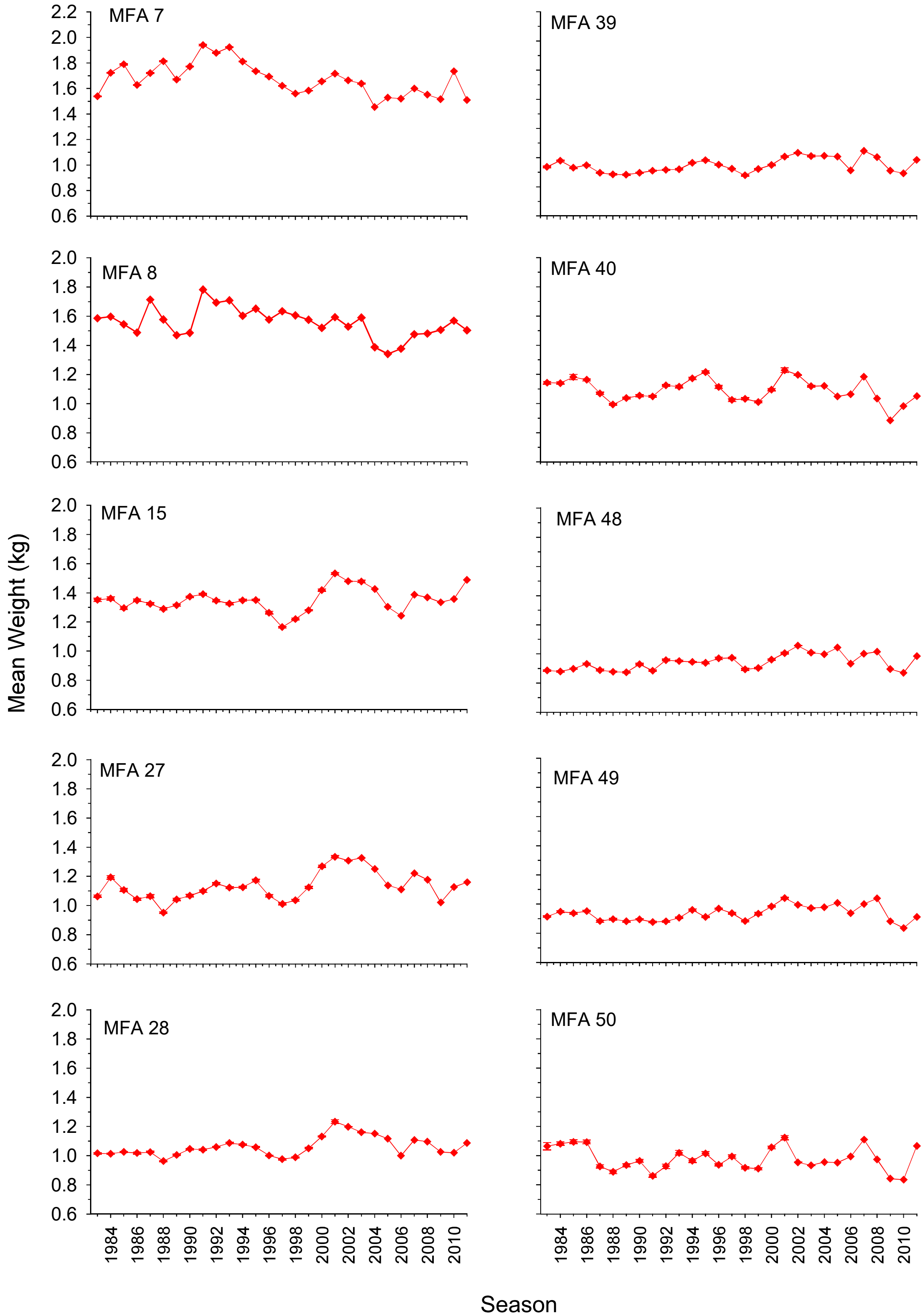

Figure 6 Inter-annual MFA trends in mean weight in the NZRLF from 1983-2011.

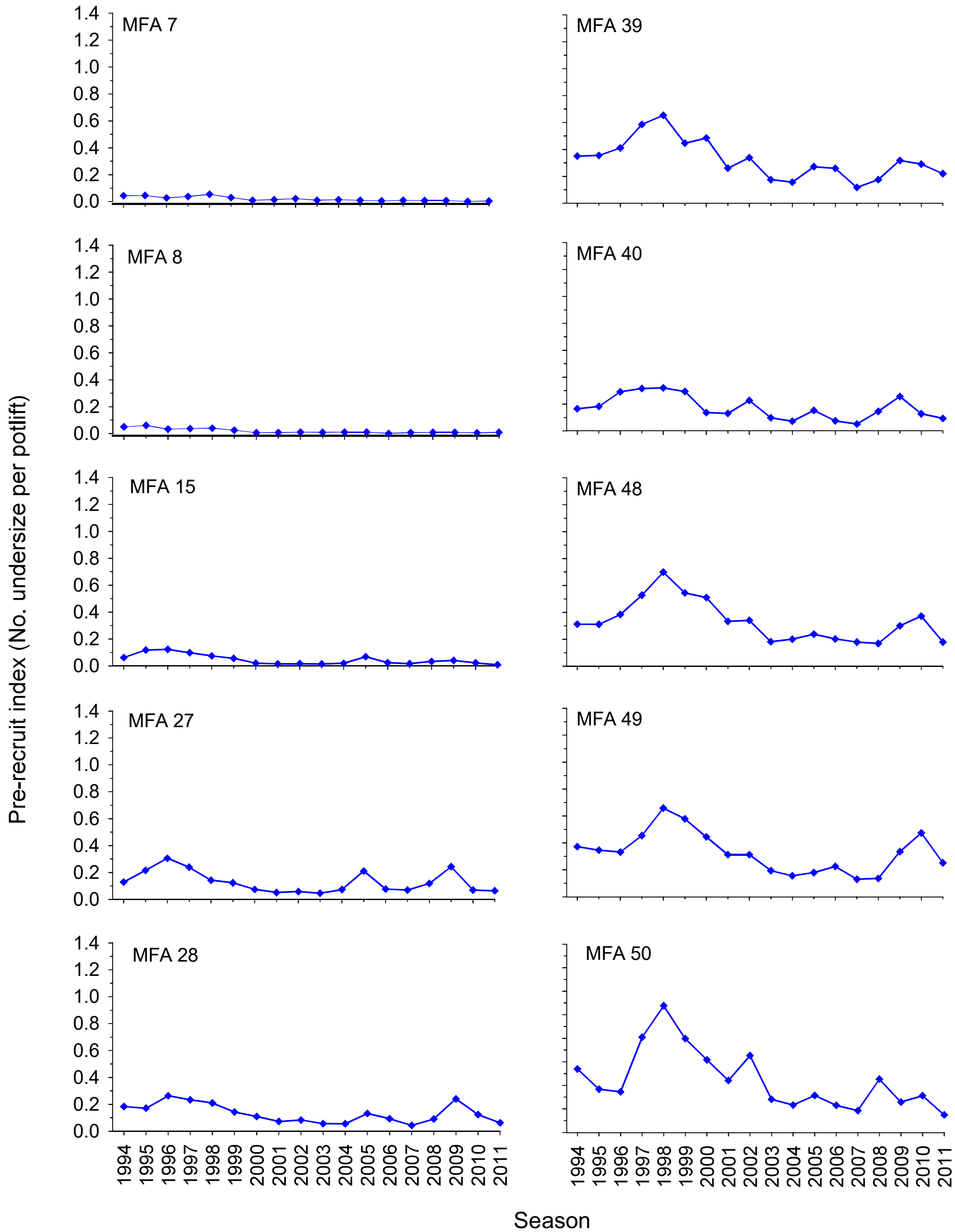

Figure 7 Inter-annual MFA trends in logbook derived pre-recruit indices in the NZRLF from 1994-2011.

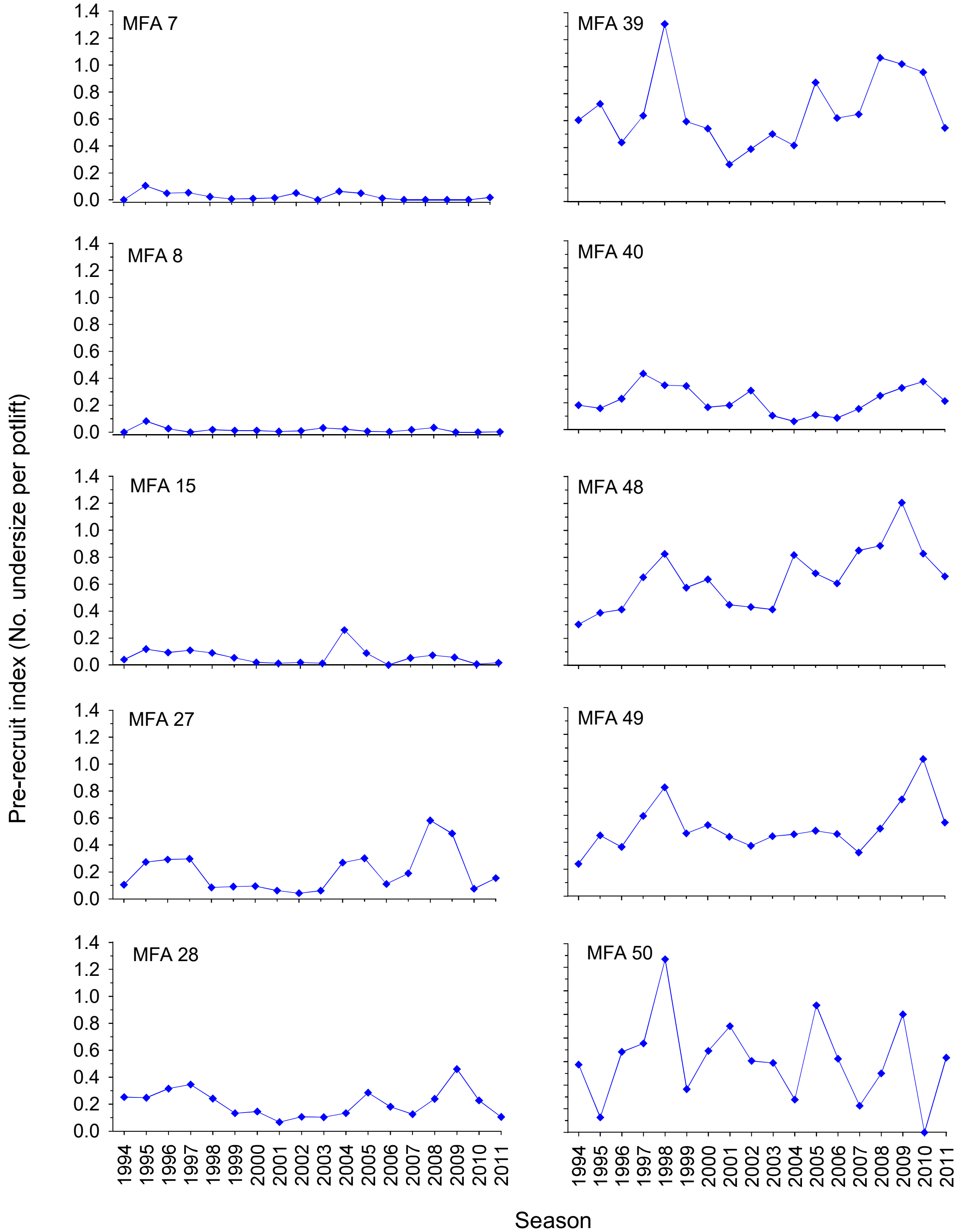

Figure 8 Inter-annual MFA trends in catch sampling derived pre-recruit indices in the NZRLF from 1994-2011.

Table 1 Catch, effort and catch per unit effort (CPUE) of both legal and undersized lobsters from dedicated survey trips to far-west and deep-water regions within the NZRLF.

Trip	Catch (kg or nr)	Effort (potlifts)	CPUE
Legal (far-west)	591	403	1.46 kg/potlift
Undersized (far-west)	3	403	0.01 undersized/potlift
Legal (deep-water)	510	200	2.55 kg/potlift
Undersized (deep-water)	14	200	0.07 undersized/potlift

7.1.2 Deep-water

7.1.2.1 Legal sized catch and effort

The percentage of catch taken in various depth categories both pre and post the introduction of a TACC in 2003 are presented in Figure 9 and Figure 10, respectively. Overall, regardless of time period, the majority of the catch (>80%) in the NZRLF has been taken from depths of <60 m. For example, over the last nine seasons 30-50% of the annual catch has come from 0-30 m while 40-60% was taken from 31-60 m (Figure 10). Less than 20% of catch was caught in depths of 61-90 m and >90 m with the exception being the 1970s and 1980s which indicates that 25-30% of catch came from these deeper depth ranges (Figure 9).

7.1.2.2 Legal sized catch per unit effort (CPUE)

With few exceptions, catch rates in the NZRLF increase with depth, being highest in >90 m and lowest in <30 m (Figure 11). Overall, catch rates are generally consistent from 1970–2011 with similar trends observed across all depth ranges. For example, catch rates in 0-30 m and 31-60 m declined from around 1.39 kg/potlift in 1999 to 0.66 kg/potlift in 2008, a decrease of 53%. Similarly, catch rates in 61-90 m declined from 1.77 to 0.76 kg/potlift over the same period, a decrease of 57%. Catch rates have increased across all depth ranges over the last few seasons with CPUE highest in the 61-90 m depth category.

7.1.2.3 Mean Weight

As with CPUE, trends in mean weight were generally consistent over time across all depth ranges (Figure 12). For example, mean weight increased in all depths from 1988 to 1995 before decreasing thereafter over the next 3-4 seasons. Similarly, mean weight subsequently increased in all depth ranges from 1998 to 2001 before generally decreasing to 2010. Over the last two decades, there is some evidence to suggest that mean weight was higher in the shallower depth ranges, particularly in the 0-30 m depth ranges, compared to other areas. During this period, highest estimates were recorded in 1993, 1995, 2001 and 2007 at around 1.2 kg.

7.1.2.4 Undersized catch per unit effort (CPUE)

With the exception of catch rates in depth >90 m, trends in logbook based pre-recruit indices are generally consistent by depth (Figure 13). For example, undersized catch rates increased in all depth ranges from 1983 to 1999/2000 before subsequently declining over the next 5-6 seasons. Pre-recruit indices have fluctuated in all depth ranges from 2005 to 2011. The exception to these trends were pre-recruit indices in depths >90 m which did not decline from the late 1990s. Indices generated at this depth should be viewed with caution, however, given the low volume of total catch taken from these areas in recent seasons (Figure 10).

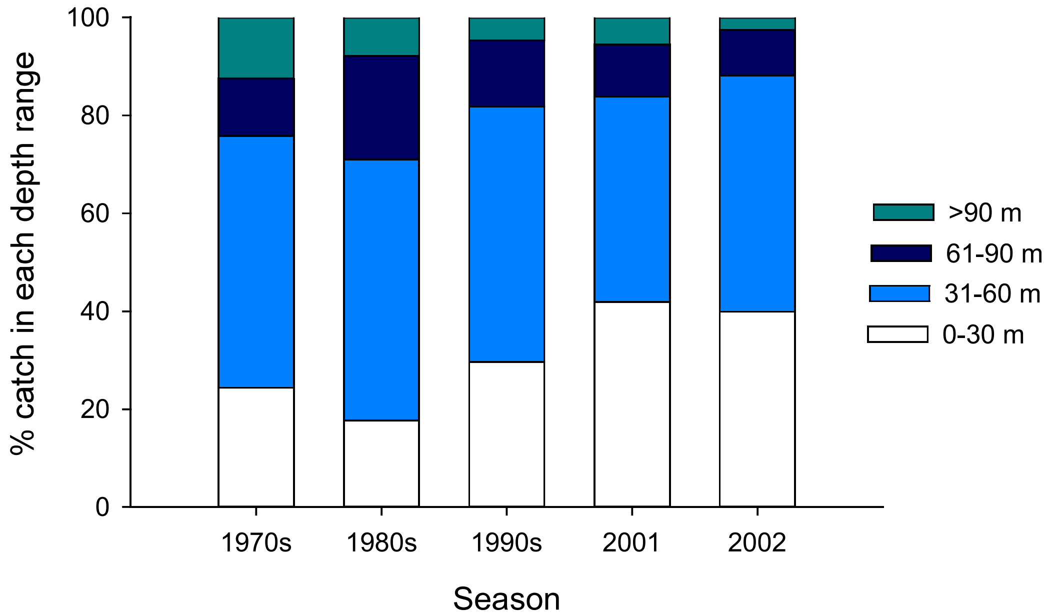

Figure 9 Percentage of the catch taken from four depth classes in the NZRLF over the past three decades as well as 2001 and 2002 fishing seasons.

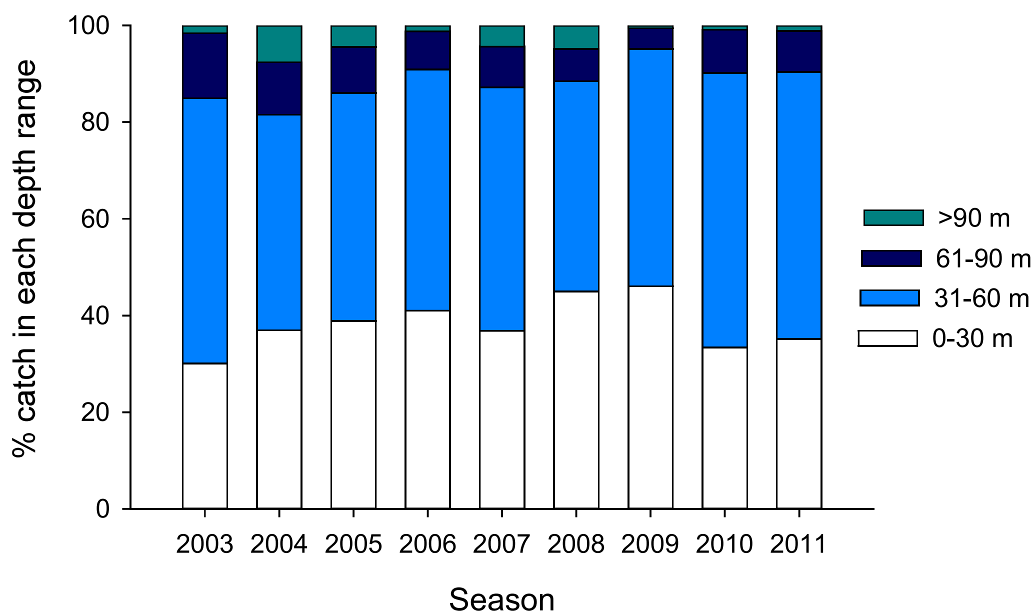

Figure 10 Percentage of the catch taken from four depth classes in the NZRLF from 2003-2011.

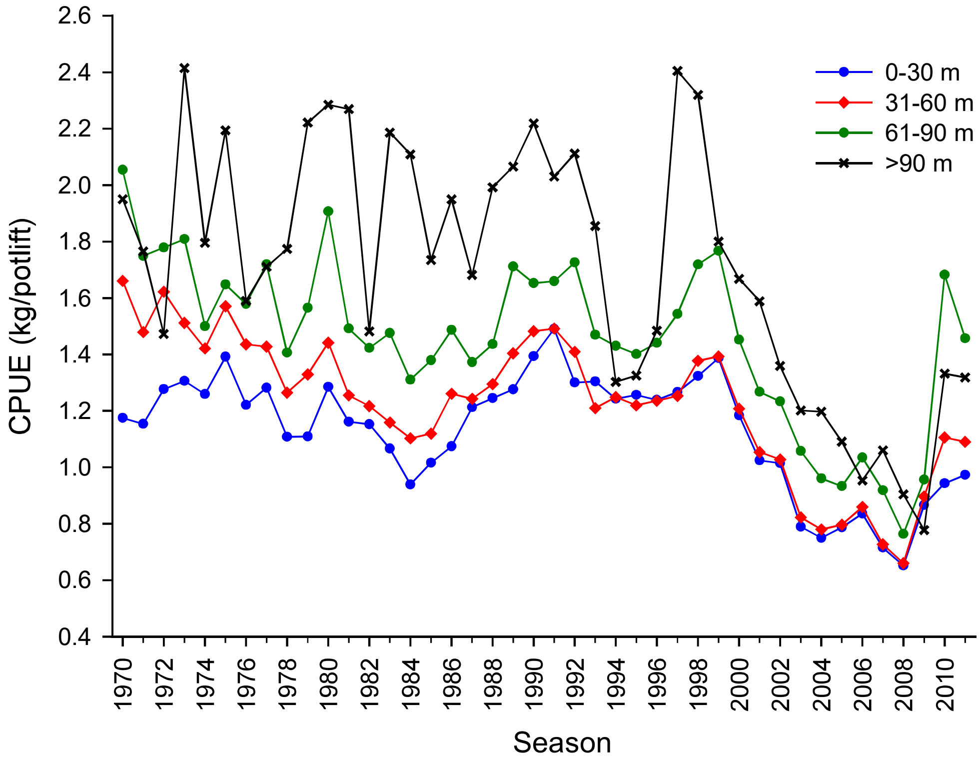

Figure 11 Catch per unit effort (CPUE) in four depth categories in the NZRLF from 1970–2011.

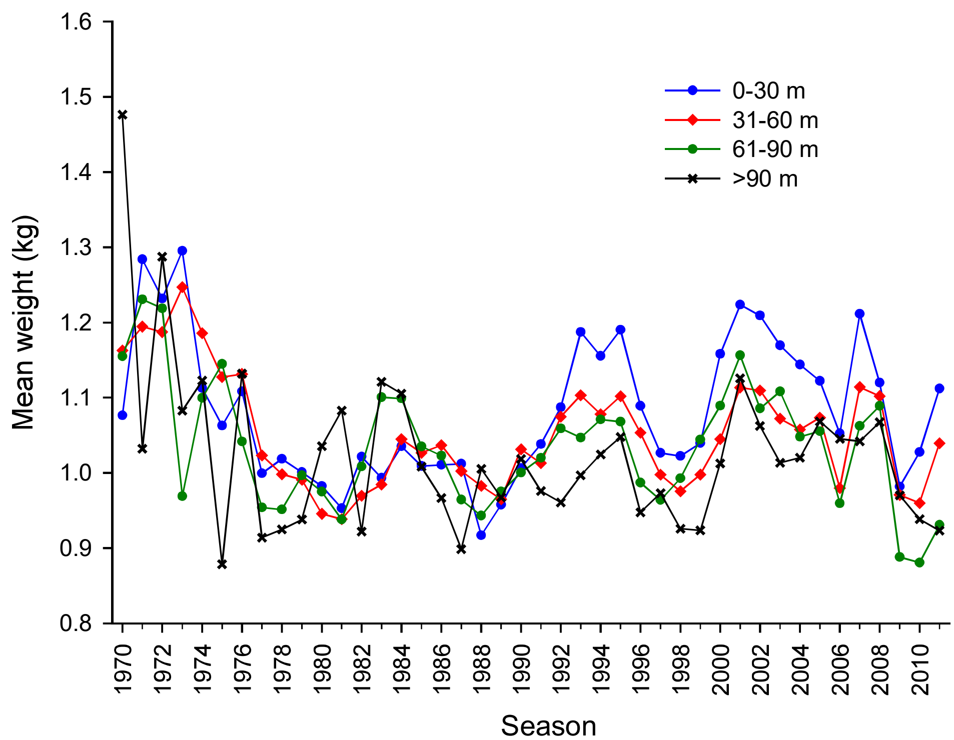

Figure 12 Mean weight in four depth categories in the NZRLF from 1970–2011.

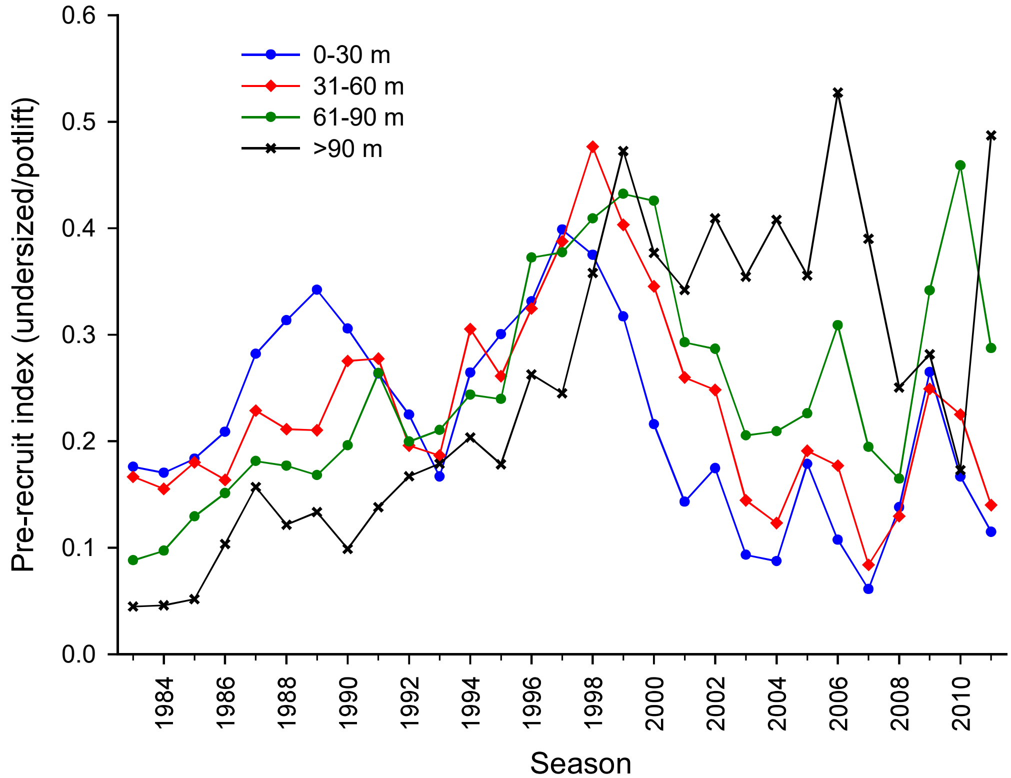

Figure 13 Pre-recruit index in four depth categories in the NZRLF from 1970–2011.

7.2 Length frequency and Size of Maturity

7.2.1 Far-west

7.2.1.1 Length Frequency

Length frequency data obtained through catch sampling showed a distinct spatial variation in the size distributions of lobsters across key MFAs within the NZRLF (Figure 14). Specifically, lobsters from the Far West regions of MFAs 7 and 8 were considerably larger than those sampled from areas further east confirming spatial estimates of mean weight (Figure 6). For example, approximately 65-70% of all rock lobsters measured in MFA 7 and 8 were 120-160 mm CL. This compares to areas further east in MFAs 39 and 49, where only 27-30% of lobsters are within this size range. In addition, lobsters >170 mm CL account for 13-16% of all animals in MFAs 7 and 8 compared to <4% in all other regions.

Length frequency data highlight the low abundance of lobsters below the minimum legal size (MLS) in far-west regions compared to other sites as also observed in spatial estimates of pre-recruits (Figure 7 and Figure 8). For example, <2% of all lobsters measured in MFAs 7 and 8 were below the MLS of 105 mm CL compared to estimates ranging from 17% in MFA 28 to 35% in MFA 39.

7.2.1.2 Size of Maturity (SOM)

The size at which 50% of female rock lobsters were sexually mature (L_{50}) varied spatially within the NZRLF (Figure 15 and Table 2). In general, SOM increases from east to west being highest in MFAs 7 and 8 and lowest in MFAs 48, 49 and 50 (with the exception of MFA 40). In relation to the MLS of 105 mm carapace length (CL), L_{50} estimates are close (+/- <1 mm CL) to 105 mm CL in MFAs 28, 49 and 50 indicating that the legal size is appropriate in these areas. Similarly, MFAs 15, 27, 39 and 48 all have L_{50} estimates below 110 mm CL. However, in MFAs 7 and 8, L_{50} estimates are substantially higher than 105 mm at 113.1 and 112.4 mm CL, respectively. MFA 40 has the highest L_{50} estimate at 118 mm CL.

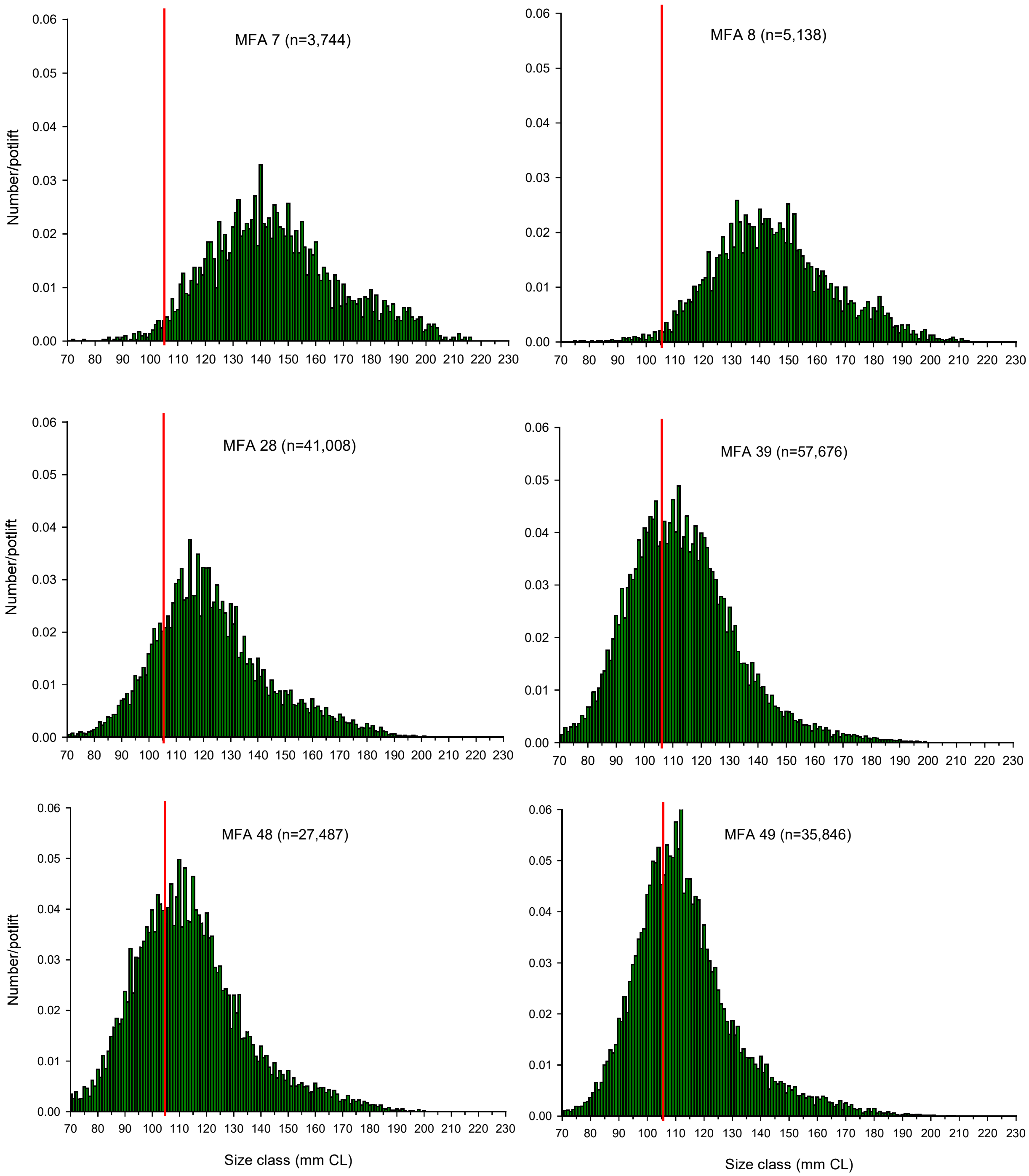

Figure 14 Size frequency distributions of lobsters from MFAs 7 and 8 compared with other regions in the NZRLF (refer to Figure 1 for location of MFAs). Red line represents minimum legal size of 105 mm CL.

Table 2 Parameters for logistic function ($P_m = 1/[1 + e^{(-S.(L - L_{50}))}]$) fitted data for each Marine Fishing Area (MFA) of the Northern Zone Rock Lobster Fishery.

MFA	n	S ±SE	L_{50} ±SE (mm CL)
7	1522	0.13 ±0.03	113.1 ±2.13
8	2055	0.11 ±0.01	112.4 ±0.87
15	4894	0.15 ±0.01	108.4 ±0.55
27	2665	0.16 ±0.02	106.8 ±0.97
28	14797	0.18 ±0.02	104.6 ±0.73
39	20386	0.08 ±0.03	109.9 ±4.57
40	4822	0.12 ±0.04	118.0 ±3.38
48	9096	0.15 ±0.01	107.2 ±0.28
49	13487	0.14 ±0.02	105.7 ±1.50
50	3037	0.16 ±0.01	105.1 ±0.26

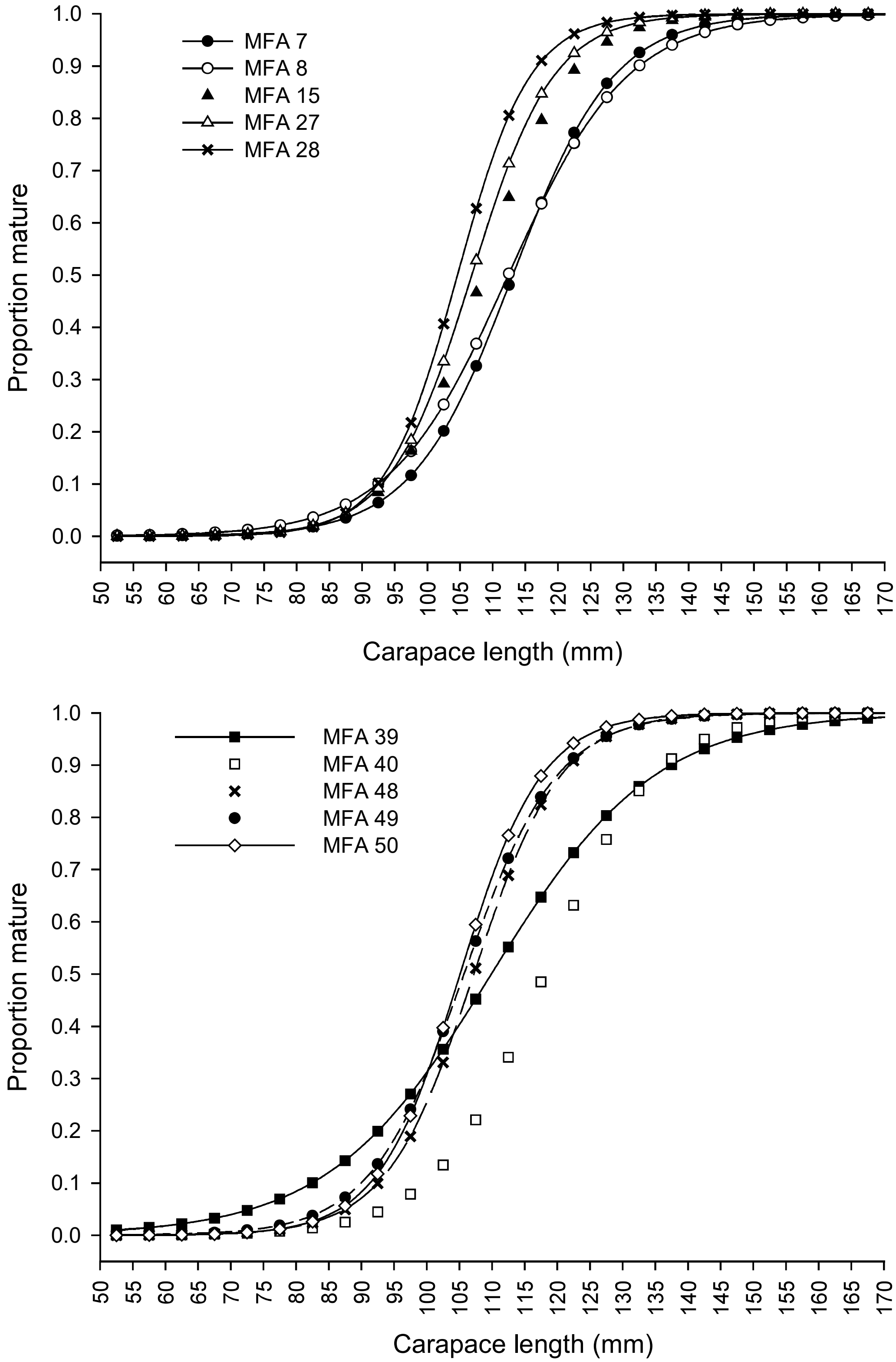

Figure 15 The logistic curves for the proportion of mature female rock lobsters as a function of carapace length sampled from the western (top) and eastern (bottom) Marine Fishing Areas (MFAs) of the Northern Zone rock lobster fishery.

7.2.2 Deep-water

7.2.2.1 Length Frequency

Length frequency distribution data of rock lobsters sampled from >90 m in MFA 37 and 38 are presented in Figure 16. Data are limited to just 1,549 individuals due to the low levels of catch taken at these depths (Figure 9 and Figure 10). Approximately, 85% of all rock lobsters sampled were within the 105 to 160 mm CL size range. Only 13% of all lobsters sampled were below the MLS of 105 mm CL. Rock lobsters >170 mm CL were negligible.

7.2.2.2 Size of Maturity (SOM)

Logistic curves for data >90 m depth could only be generated for MFA 38 due to limited data (Figure 17) with L_{50} estimates indicating that 50% of female lobsters were sexually mature at 104 mm CL which is just below the MLS of 105 mm CL. Overall, this estimate is similar to that observed in the central and eastern MFAs of 27, 28, 49 and 50 (Table 2).

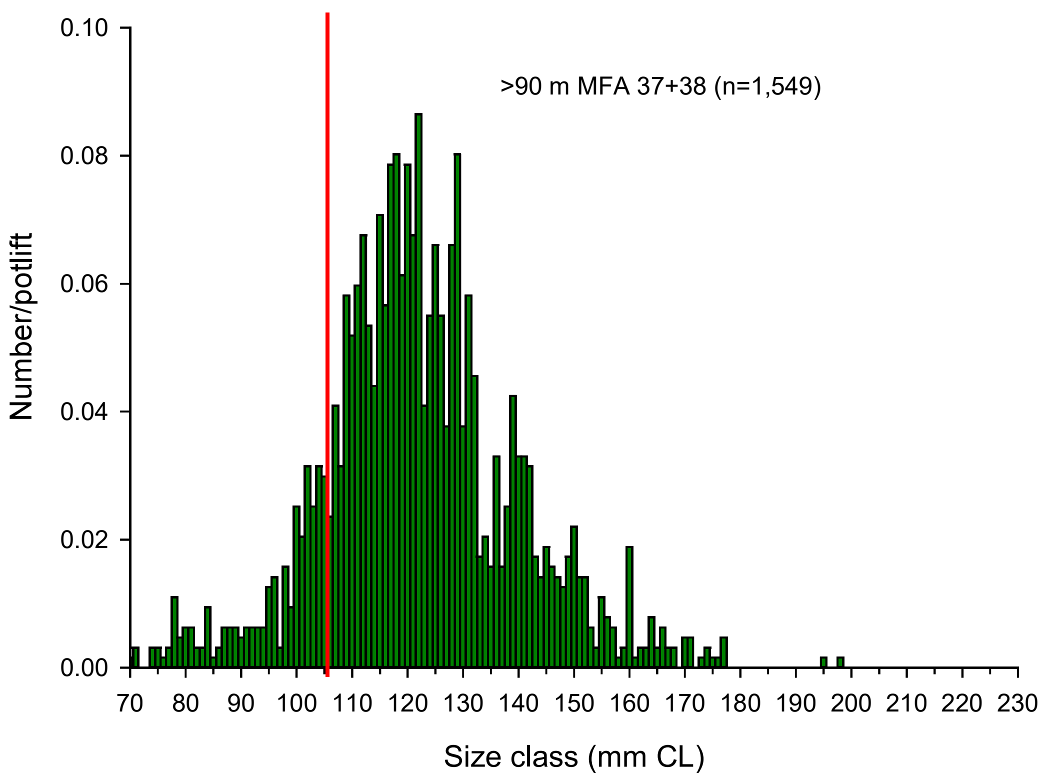

Figure 16 Size frequency distributions of lobsters sampled from deepwater sites (>90 m depth) in MFAs 37 and 38 in the NZRLF. Red line represents minimum legal size of 105 mm CL.

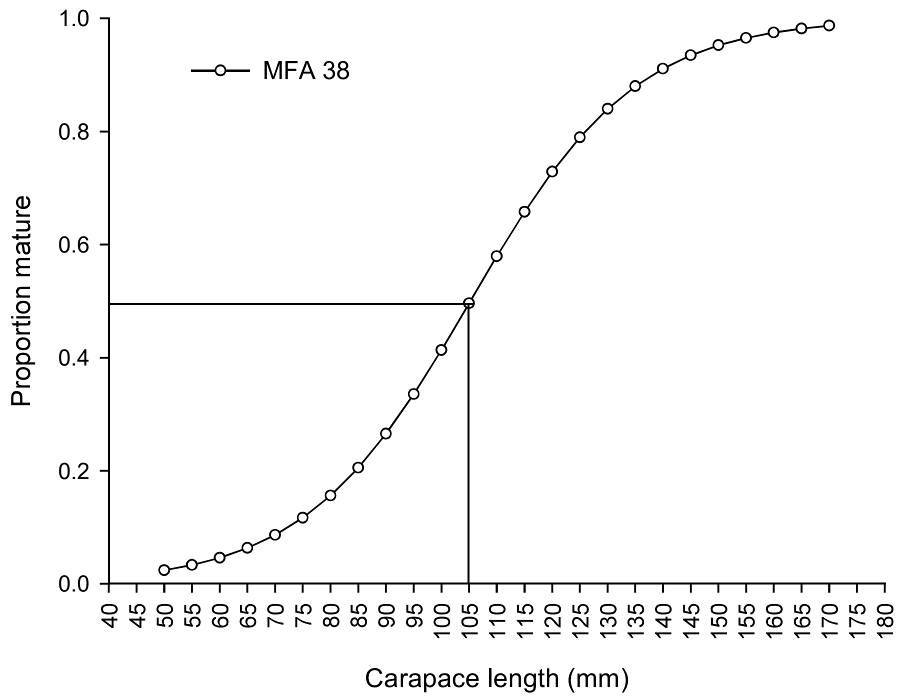

Figure 17 The logistic curves for the proportion of mature female rock lobsters as a function of carapace length sampled from >90m depth in MFA 38.

7.3 Lobster mortality

Estimates of mortalities (kg) from both the far-west and deep-water surveys are presented in Table 3. Mortalities from the far-west survey were minimal (1 kg) representing <1% of the total catch. In comparison, mortalities of lobsters from the deep-water survey were considerable. In total, through the storage, packing and shipping phases, 114.8 kg died or were deemed unlikely to survive shipping. This represented 23% of the total catch from the survey.

Table 3 Estimates of lobster mortality at various stages of processing from both fishery surveys in the NZRLF.

Trip	Stage	Estimated loss (kg)	Total Loss (kg)
Far-west	All stages	~1	**1**
Deep-water	Grading	52.5	
	Within storage tanks	13.8	
	Packing	19.5	
	During shipment	29	**114.8**

7.4 Preliminary economic study

The economic analysis is summarised in the five tables showing prices (Table 4), revenues (Table 5 and Table 6) costs and profits (Table 7 and Table 8). It is important to highlight that these results are based on experimental fishing trips and may differ from normal fishing operations.

Both experimental fishing trips lost money when all variable and fixed costs were accounted for. Most of the costs reported fell within the range of those estimated by EconSearch (2012) for the Northern Zone fishery overall. One exception was fuel costs which were higher for both the deep-water and far-west trips due to the increased steaming distances to these fishing grounds. Specifically, fuel costs were 20% (deep-water) and 32% (far-west) of gross landings revenue, compared to the more typical 9-15% as indicated by EconSearch reports over the last few years (Table 7 and Table 8).

Besides higher fuel costs, a second principal difference for economic outcomes in the two experimental trips, compared with more typical fishing grounds in the Northern Zone, was the lower price received for lobsters from both areas. Far-west lobsters brought a lower price due to their larger average size (Figure 18). Specifically, 45% of lobsters by weight from the far-west trip were above the 2 kg ‘price split’ above which lowers prices are paid by South Australian processors due to lower demand for larger lobsters from Chinese buyers. A price of $53 per kg was paid for lobsters below the price split, and $45 above (Table 4).

For deep-water rock lobsters, the average price was again much lower than normal for two reasons: (1) 31% of lobsters by weight from the deep-water site were above the 2 kg “price split” (Figure 18); and (2) a lower price overall was paid for these individuals. Specifically, prices for deep-water lobsters were substantially lower than far-west lobsters in the same size grades (Table 4), presumably reflecting lower quality of lobsters from deep-water and thus a lower expected export price.

For the deep-water trip, lobster mortalities played an additional role in reducing economic return with a 23% loss by number during post-harvest (Table 3) reducing final export revenues accordingly. Losses included 29 kg of lobsters (about 6% of the total harvested) which were shipped live but arrived dead in China. All of these mortalities occurred subsequent to landing and therefore were not discounted from the landings revenues paid as beach price (Table 6). As a result, the estimated profit to the fisher from the deep-water trip (Table 8) would have been more reduced if the subsequent mortalities were taken into account. Presumably, all financial losses were absorbed by the processor who purchased these particular lobsters.

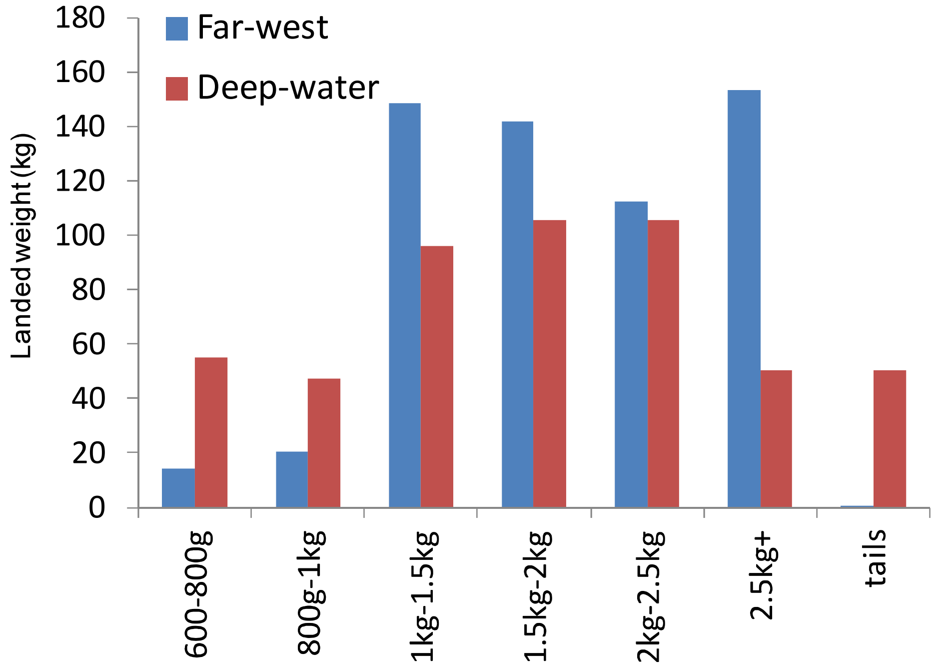

Figure 18 Lobster landings (kg) by weight grade for the two experimental fishing trips.

Table 4 Prices paid for landed lobsters from the two experimental fishing trips: deep-water compared with far-west.

Size Grade	Far-west Price ($ per kg)	Deep-water Price ($ per kg)	% difference
600-800g	53	37	-30%
800g-1kg	53	37	-30%
1kg-1.5kg	53	37	-30%
1.5kg-2kg	53	30	-43%
2kg-2.5kg	45	25	-44%
2.5kg+	45	25	-44%
tails	40	25	-38%

Table 5 Revenue for landed lobsters from the far-west trip, broken down by market size grade.

Size Grade	Landings (kg)	Price ($ per kg)	Gross revenue ($)
600-800g	14.1	53	747.30
800g-1kg	20.3	53	1,075.90
1kg-1.5kg	148.7	53	7,881.10
1.5kg-2kg	141.8	53	7,515.40
2kg-2.5kg	112.2	45	5,049
2.5kg+	153.4	45	6,903
tails	0.7	40	28
TOTALS	591.2	49.8	**$29,199.70**

Table 6 Revenue for landed lobsters from the deep-water trip, broken down by market size grade.

Size Grade	Landings (kg)	Price ($ per kg)	Gross revenue ($)
600g-1.5kg	198.4	37	7,340.80
1.5kg-2kg	105.6	30	3,168
2kg+	155.7	25	3,892.50
2nds	50.5	25	1,262.50
TOTALS	510.2	30.7 = avg	**$15,663.80**

Table 7 Economic summary information for the far-west trip.

	$	% gross revenue	EconSearch Range (2007-09)
Costs			
fuel (GST excl)	9,376	**32%**	9-15%
Ceduna pick-up truck costs	504.19	2%	
Food for crew (@$100/day x 10 days)	1,000	3%	3-4%
bait	1,080	4%	1-5%
TOTAL operating COSTS:	11,960	41%	
Wage costs			
skipper @23% of gross value of landings	6,716	23%	
deckie @14%	4,088	14%	
TOTAL wage COSTS:	10,804	37%	
Fixed Costs (taken from EconSearch report):		45%	
Net profit			
OPERATING PROFIT (before fixed costs) =	6,436	22%	
Actual Profit (including fixed costs)		**-23%**	

Table 8 Economic summary information for the deep-water trip.

	$	% gross revenue	EconSearch Range (2007-09)
Operating Costs			
fuel (GST excl)	3,129	**20%**	9-15%
Food for crew (@$100/day x 10 days)	400	3%	3-4%
bait	480	3%	1-5%
TOTAL operating COSTS:	4,009	26%	
Wage costs			
skipper @23% of gross value of landings	3,603	23%	23%
deckie @14%	2,193	14%	14%
TOTAL wage COSTS:	5,796	37%	37%
Fixed Costs (taken from EconSearch report):		45%	
Net profit			
OPERATING PROFIT (before fixed costs) =	5,859	37%	
Actual Profit (including fixed costs)		**-8%**	

8 DISCUSSION

Spatial estimates of stock abundance

This report provides a spatial breakdown of catch by region in the Northern Zone Rock Lobster Fishery and specifically focuses on comparing abundance estimates in both far-west and deep-water areas with those from other regions in the fishery.

Overall, commercial catches from the far-west are low compared to regions further east with the majority taken in two MFAs (i.e. MFA 7 and 8). Spatial analyses show that catch in Region A, which incorporates the far-west region, increased considerably during the 1980s reaching an historical high of 172 tonnes in 1993. While difficult to quantify, it is likely that substantial improvements in effective effort and fishing power during the 1980s were major contributors to increases in catch within the far-west area during this period (Linnane et al. 2010). The most significant technological development in the Northern Zone fishery was the uptake of Global Positioning System (GPS) technology, which by the mid-1990s had become fully operational on almost all Australian commercial fishing vessels (Baelde 2001). In particular, GPS facilitated the accurate location of fishing grounds and positioning of gear and combined with greater fleet mobility, provided opportunities for vast spatial expansion. Over time, fishers were also able to locate and fish more discrete or isolated rock lobster grounds, as well as return to these specific sites on a regular basis. In addition, the introduction of larger vessels with increased engine power, permitted operators to travel greater distances. As a result, in the 1980s and 1990s, levels of exploitation increased in fishing grounds not traditionally targeted such as the far-west region of the zone. That spatial expansion was occurring in the Northern Zone during this time was highlighted by Linnane et al. (2010) who showed that the average number of MFAs fished per license holder increased considerably during the 1980s and 1990s.

After increases through the 1980s, catch from 1990 to 2000 remained relatively stable in the far-west at approximately 100 tonnes per season. However, from 2000 to 2011 catch decreased considerably from 92 to 12 tonnes. It is important to highlight that the declines in catch in Region A were correlated with comparable declines in other regions within the Northern Zone during the same period. In particular, annual catches in Regions B (Eyre Peninsula) and D (Kangaroo Island) also decreased from the late 1990s to 2011.

Despite being a low catch area, the far-west region has historically had some of the highest catch rates in the Northern Zone. In particular, CPUE increased from 1.0 kg/potlift in 1980 to 2.1 kg/potlift in 1992, which is the highest regional catch rate estimate recorded in the fishery. CPUE in the far-west remained above 1.5 kg/potlift through to 2000 before decreasing to a historical low of 0.94 kg/potlift in 2008 in line with comparative catch rate decreases in other regions within the Northern Zone during the same period.

The impact of spatial expansion on catch rates within the far-west region is important. In particular, catch rate trends in the far-west from 1980 to 2000 reflect the effect of on-going spatial expansion. During this period, CPUE was relatively stable, fluctuating between 1.1 kg/potlift and 1.5 kg/potlift, while the average number of MFAs fished per licence increased (Linnane et al. 2010). It is now widely accepted that overall reductions in nominal CPUE within eastern and inshore regions of the fishery were masked by compensating catches in virgin grounds as the fishing fleet expanded westwards into far-west and deep-water. This, in turn, led to ‘‘hyperstability’’ in CPUE estimates (Hilborn and Walters 1992) where expanded search effort, facilitated by technological advances such as GPS and larger fishing platforms, allowed fishers to serially locate and target areas of high rock lobster abundance, thus maintaining high catch rates. As a result, high historical catch rates in the far-west region of the NZRLF were, in part, due to spatial expansion, rather than high lobster abundance. The vulnerability of the Northern Zone to hyperstability is further enhanced by the geological features of the region which limit lobster abundance to isolated discontinuous granite outposts as opposed to the more continuous limestone reefs founds in other parts of the State fishery.

High catch rates in the far-west are also influenced by mean size. Average mean weight of legal sized lobsters landed in MFAs 7 and 8 are consistently above 1.5 kg, the highest in the Northern Zone. This is further evidenced by length frequency information from catch sampling which shows that a considerable proportion of lobsters landed in the far-west are above 150 mm CL, as opposed to eastern regions where catches above this size are minimal. As a result, high catch rates in terms of kg/potlift in the far-west tend to be driven by larger size individuals in the catch rather than a higher abundance of overall lobsters.

The catch rate of undersized lobsters in the far-west MFAs 7 and 8 is the lowest in the Northern Zone as evidenced by pre-recruit estimates from both logbook and catch sampling data. The Northern Zone itself is close to the western extremity of *J. edwardsii* distribution across south-eastern Australia and tends to experience lower levels of puerulus settlement compared with other regions (Linnane et al. 2013). Overall, this indicates that recruitment levels, particularly in the far-west, are low compared to both the Northern Zone itself and to other *J. edwardsii* fisheries. The low abundance of undersized lobsters implies that the far-west is a relatively low recruitment region.

Regarding the deep-water regions, low levels of catch from depths >90 m make interpretation of these data in relation to spatial management difficult. Since the inception of the fishery in the 1970s, <10% of total catch has come from this depth range with approximately 80-90% coming from <60 m. This suggests that despite increases in effective effort within the fishery that promoted spatial expansion across MFAs, the fleet has primarily remained inshore. Current market demand for *J. edwardii* is a key factor for retaining the commercial catch within shallow grounds. Overseas markets in China favour small (<1 kg), "red"-coloured lobsters that are primarily found inshore as opposed to larger "speckled" or "white" lobsters that are synonymous with offshore grounds (Chandrapavan et al. 2011). As a result, higher prices for red lobsters have driven effort into shallow water grounds, evidenced by the fact that approximately 80% of the 3,000 tonnes annual TACC is taken at <60 m depth across south-eastern Australia (Linnane and Crosthwaite 2009).

The targeting of high value rock lobsters has produced an unusual fisheries situation where fishers avoid high catch rate areas offshore in favour of lower catch rate areas inshore. This was highlighted in the current study where catch rates were shown to be consistently higher in offshore grounds >60 m compared to inshore sites, yet most of the annual catch was taken inshore. In addition to economic factors, fishers in South Australia regularly state that lifestyle choice, under the quota system, affects their spatial distribution of effort. Specifically, fishers prefer to fish closer to home ports rather than spend extended periods of time at sea (Chandrapavan et al. 2011). Therefore, fishers will forgo maximising volume of catch and instead seek to promote value per kilogram, with the added incentive of shorter fishing days.

Finally, another key factor driving spatial dynamics by depth appears to be quality of catch. Despite improvements in live export practices, there is a widely held perception within the industry that lobsters from deeper water have higher mortality rates during out-of-water transport to overseas markets. The results from the current study support this belief with 23% of the total catch from the offshore survey recorded as having died or deemed unlikely to survive overseas shipping due to poor condition. Under a range of simulated packing trials, Hawthorne (2009) also found significantly higher mortalities in lobsters caught from offshore grounds and hypothesized when hauling from depth at high speed sudden decompression may cause dissolved gases to come out of solution, primarily in the haemolymph, causing damage to internal organs and thus contributing to post-harvest mortality. It is important to state that the mortality rates observed are from a single study, nonetheless, the results do highlight the potential risk of occasional high mortality events in individuals taken from deep-water areas. Furthermore, if exploitation rates in deep-water areas were to increase in the future, it would be critical to ensure, from a sustainability perspective, that accurate estimates of mortalities could be taken into account in total fishing mortality.

Biological considerations

In addition to recruitment levels from outlying Northern Zone areas, there are a number of other biological characteristics that require consideration when assessing spatial management options within this fishery. Size of maturity (SOM) in females is known to vary spatially within the Northern Zone (Linnane et al. 2011). In general, SOM is highest in areas further west and decreases eastwards. This was highlighted in the current study where SOM in MFAs 7 and 8 was >110 mm CL compared to approximately 105 mm CL in eastern regions such as Kangaroo Island. It is widely accepted that these spatial variations reflect known regional differences in temperature which ultimately impacts on growth rates. Specifically, the eastern region of South Australia, where SOM is lowest, experiences an annual coldwater upwelling event known as the Bonney upwelling (Schahinger 1987). During summer the predominant south-easterly winds result in an upwelling of nutrient-rich, cold water (11–12 $^{\circ}$C) which intrudes onto the continental shelf. This cold-water upwelling tends to be confined to eastern regions and only occasionally impacts western parts of the Northern Zone (McClatchie et al. 2006). The resulting temperature gradient impacts growth rates of *J. edwardsii* across the State with growth higher in warmer western regions and lower in cooler eastern areas (McGarvey et al. 1999).

It is generally accepted that the purpose of a MLS in lobster fisheries is to allow individuals to reproduce at least once before reaching their exploitable size (Chubb 2000). The current MLS for lobsters in the Northern Zone is 105 mm CL. Based on SOMs of >110 mm CL in MFAs 7 and 8, this suggests that the current MLS may not be appropriate for females in far-west regions. It is worth noting however, that based on length frequencies of the commercial catch, few lobsters in the far-west are caught close to the MLS. In fact, the majority of lobsters in MFAs 7 and 8 are caught between the 130-160 mm CL size ranges, indicating that despite a higher SOM, female lobsters are still afforded some protection by the MLS within this region. Nonetheless, if exploitation rates are increased in far-west regions, given that size limits are set in part to protect immature females, higher size limits may need to be considered under a spatial management regime. Alternatively, a male only fishery may be considered during specific months in line with management rules for *J. edwardsii* fisheries in Victoria (Vic DPI 2009) and Tasmania (Rock Lobster Rules 2011).

Limited data from deep-water sites makes interpretation of biological characteristic difficult. Based on the catch sampling data to date, SOM estimates from deep-water in MFA 38 were similar to eastern regions of the fishery at 105 mm CL. Again, the length frequency data suggests that female lobsters are afforded some protection as the majority of lobsters in the catch ranged from 110-130 mm CL. Working in the Southern Zone fishery of South Australia, Linnane et al. (2009) found that SOM in deep-water females was considerably lower than inshore sites and attributed these differences to lower growth rates driven by differences in water temperature and spatial densities. However, despite catch rate data indicating that densities of lobsters are also higher in deep-water Northern Zone locations, there was no evidence to suggest that this impacted on female SOM.

A final biological consideration when assessing the feasibility of spatial management in the Northern Zone is sources and sinks of puerulus larvae. Using a combination of biological and hydrodynamic modelling, Bruce et al. (2007) simulated the planktonic early life history of *J. edwardsii* and concluded that larval transport had a net west to east movement pattern across the south Australian coast. The study also predicted that the only significant levels of recruitment to the Northern Zone occur from Western Australia or locally. Recruitment from areas of higher spawning abundance such as the Southern Zone fishery or Tasmania only occurred infrequently in years when oceanographic conditions for an east-west movement of puerulus were favourable. This finding has implications in terms of future spatial management proposals within the Northern Zone. Specifically, if, as the hydrodynamic modeling suggests, the far-west region of the Northern Zone is a source of puerulus larvae which ultimately settle into eastern regions of the fishery, then consideration needs to be given to potential impacts of increasing exploitation levels within far-west regions.

Preliminary economic study

Three principal economic factors influence the profitability of fishing in the far-west and deep-water areas compared to more eastern Northern Zone regions such as grounds off the Eyre and Yorke Peninsulas and Kangaroo Island: (1) fuel costs are higher for fishing in the far-west and deep-water grounds due to greater distances from port; (2) lobsters from far-west and deep-water regions attract a lower price as exported seafood product; and (3) additional costs associated with steaming farther distances to fishing grounds which mainly include higher depreciation associated with higher levels of vessel and engine wear and tear.

In relation to deep-water fishing, the high mortalities reflect additional losses to egg production from the stock for modest or no economic return. In addition, the lower product quality of deep-water lobsters results in a much lower price (30-44% lower depending on size grade) received for these individuals compared with far-west lobsters of comparable size grade. Overall, higher fuel costs, combined with a lower price, meant that both experimental fishing trips in the current study were non-profitable. While the results presented are based on experimental fishing trips and may differ from normal commercial fishing operations, they highlight that the economic feasibility of fishing regional areas within the Northern Zone needs to be taken into consideration in any future spatial management discussions. In addition, it is worth noting that beach prices paid for lobsters vary monthly which impacts on profitability. The current study was based on prices paid during February only and as a result, the economic outcomes presented are a function of the price observed at that specific time. Future research should involve estimates based on prices paid across a range of time periods in order to investigate how temporal effects impact on rock lobster fishing profitability within South Australia. Other costs not included, but which should be considered in relation to spatial management, include the possibility of higher compliance, quota monitoring and research costs associated with spatial assessment of the resource.

9 BENEFITS

The commercial Northern Zone Rock Lobster Fishery of South Australia is the primary beneficiary sector of this research. This research will be used to inform resource managers of fishery, biological and economic factors that need to be considered in relation to the spatial management of the Northern Zone rock lobster resource.

10 FURTHER DEVELOPMENTS

The information provided in this report will be used as a basis for future spatial management discussions in relation to the South Australian Northern Zone Rock Lobster Fishery. Specifically, the report will be presented to the South Australian Management Advisory Committee Research Sub-Committee for consideration in relation to any future research proposals pertaining to spatial management options for the fishery.

11 PLANNED OUTCOMES

The outputs from this project related directly to the planned outcomes as follows:

1) The estimation of indices of relative abundance.

Catch rate as an indicator of relative abundance was estimated at various spatial scales across the Northern Zone Rock Lobster Fishery for both undersized and legal-sized lobster. The proportion of the annual catch taken at various spatial scales by region and depth were also provided.

2) Identification of biological characteristics from outlying populations, i.e. size-at-maturity, length, colour, sex.

Biological characteristics such as size of maturity, length frequencies and annual mean weight were estimated in both far-west and deep-water fisheries of the Northern Zone.

3) Estimates of net economic return from fishing such regions.

An economic analysis was used to compute a net profit/loss from two experimental fishing surveys in both far-west and deep-water regions of the fishery.

4) An assessment of survival rates of lobsters taken in deep-water and the far-west during different transport/storage phases.

The level of lobster mortalities from deep-water and far-west fishing, as estimated from dedicated surveys, were provided as part of the economic analysis of fishing these specific regions in the fishery.

5) An assessment on the feasibility of implementing spatial management in the Northern Zone Rock Lobster Fishery.

Based on the outcomes, the report discusses fishery, biological and economic factors that need to be considered should higher levels of exploitation be encouraged in either far-west or deep-water regions of the Northern Zone Rock Lobster Fishery.

12 CONCLUSIONS

1) Historical levels of overall catch from both far-west and deep-water areas are low compared to eastern and inshore regions of the fishery. In the 2011/12 fishing season only 12 t (4%) of the 307 t total catch came from the far-west region, while 29 t (9%) came from >90 m depth. Highest catch periods in far-west regions are more likely to reflect spatial expansion of the fishery, as a result of increasing effecting effort, rather than an increase in stock productivity.

2) While commercial catch rates are highest in both far-west and deep-water areas, in the far-west at least, this is due to larger mean size as opposed to a higher level of stock abundance. In addition, despite low levels of overall catch, catch rates in both far-west and deep-water regions declined simultaneously in line with all other regions of the fishery from 1999 to 2008. This suggests that the abundance in these regions is driven by common factors to the rest of the population.

3) Due to faster growth rates, the size of maturity in far-west regions is substantially higher than the minimum legal size. This is offset somewhat by the fact that few lobsters close to legal size are found within the commercial catch. However, given that size limits are set in part to protect immature females higher size limits may need to be considered if new sub-regions are created.

4) Low abundance of undersized lobsters in far-west regions indicates that the region is recruitment limited thus highlighting that the area is close to the western limit of *J. edwardsii* distribution within south-eastern Australia. Previous research would suggest that the region may well be a source of puerulus larvae for more eastern regions of the Northern Zone fishery.

5) A preliminary bio-economic study, based on two experimental fishing trips indicated that the cost of fishing both far-west and deep-water sites is substantially higher compared to

other areas due namely to a) higher fuel costs and b) lower price for landed catch. Profitability from deep-water fishing was also impacted by high levels of lobster mortality. It is important to highlight that results are based on experimental fishing trips in February only and may differ from normal on-going fishing operations. Future research may wish to consider catch composition and price estimates in other months including those outside of the current fishing seasons.

6) Current biomass estimates for the fishery are non-spatial. A spatial management regime would likely require annual setting of quotas, based on sustainable exploitation levels, for each sub-region. If management sub-regions are to be considered, it is critical that spatial estimates of biomass are generated for the NZRLF to ensure sustainable future exploitation levels for the resource. These would presumably incur additional management and research costs.

7) In summary, catch rates of lobsters from far-west and deep-water areas of this fishery are higher than other regions but this is likely to reflect larger individuals and faster growth rates rather than abundance. Opportunities to target these individuals at specific periods of high unit price may exist but requires further research, particularly if outside of the current fishing season. However, this strategy comes with some management challenges given that these areas are recruit limited, have a higher size of maturity and may contribute disproportionately to larval supply in other regions of the fishery.

13 REFERENCES

Baelde, P. 2001. Fishers' description of changes in fishing gear and fishing practices in the Australian South East Trawl Fishery. Marine and Freshwater Research 52: 411–7.

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

Chandrapavan, A., Gardner, C., Green, B.S., Linnane, A. and Hobday, D. 2011. Improving marketability through translocation: a lobster case study from southern Australia. ICES Journal of Marine Science, 68: 1842–1851.

Chubb, C.F. 2000. Reproductive biology: issues for management. In: Phillips, B.F., Kittaka, J. (Eds.), Spiny Lobsters: Fisheries and Culture. Blackwell Science Publishing, Victoria, pp. 245–275.

EconSearch 2012. Economic Indicators for the South Australian Northern Zone Rock Lobster Fishery, 2010/11. A report prepared for Primary Industries and Regions South Australia, 64 pp.

Fisheries (Rock Lobster) Rules 2011. S.R. 2011, No. 92. http://www.thelaw.tas.gov.au/

Hawthorne, P. 2009. Effects of deep water hauling and translocation from deep water to shallow water inshore reefs on the physiological condition of southern rock lobster (Jasus edwardsii). Honours thesis submitted to Flinders University, 33 pp.

Hilborn R and Walters C.J. 1992. Quantitative fisheries stock Assessment: choice, dynamics and uncertainty. New York: Chapman and Hall.

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

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

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

Linnane A, Sloan, S., McGarvey R. and Ward T. 2010. Impacts of unconstrained effort: Lessons from a rock lobster (Jasus edwardsii) fishery decline in the northern zone management region of South Australia. Marine Policy 34: 844 50.

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

Linnane A., McGarvey, R., Hoare, M. and Hawthorne, P. 2013. The importance of conserving recruitment pulses in rock lobster (Jasus edwardsii) fisheries where puerulus settlement is low or highly sporadic, Marine Biology Research 9: 97-103.

McClatchie, S., Middleton, J.F. and Ward, T.M. 2006. Water mass and alongshore variation in upwelling intensity in the eastern Great Australian Bight. Journal of Geophysical Research 3: 1–13.

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

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

Schahinger, R.B. 1987. Structure of coastal upwelling events observed off the south- 440 east coast of South Australia during February 1983–April 1984. Australian Journal of Marine and Freshwater Research 38: 439–459.

Skirtun, M, Sahlqvist, P. and Vieira, S. 2013. Australian fisheries statistics 2012, FRDC project 2010/208. ABARES, Canberra.

Sloan, S. and Crosthwaite, K. 2007. Management plan for the South Australian Northern Zone rock lobster fishery. The South Australian Fishery Management Series. PIRSA Paper no. 51, Adelaide, Australia, 82 pp.

VicDPI. 2009. Victorian Rock Lobster Fishery Management Plan. Fisheries Victoria. Management Report Series No. 70. Department of Primary Industries. Fisheries Victoria. 85pp.

Wenner, A.M., Fusaro, C. and Oaten, A. 1974. Size at onset of sexual maturity and growth rate in crustacean populations. Canadian Journal of Zoology 52: 1095–1106.

Appendix 1: Intellectual property

No intellectual property has arisen from this research.

Appendix 2: Staff List

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Richard McGarvey (SARDI Aquatic Sciences)

Peter Hawthorne (SARDI Aquatic Sciences)

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