FISHERY ASSESSMENT REPORT

TASMANIAN ROCK LOBSTER FISHERY

2005/06

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& Fisheries Institute
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This assessment of the giant crab fishery is produced by the Tasmanian Aquaculture and Fisheries Institute (TAFI) and uses input from the Crustacean Assessment Working Group (CAWG).

CAWG met on 30 October 2006 to consider the draft assessment report and provide input into the assessment. The Working Group participants were:

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Executive Summary

Current Stock Status

Relative to the stock's lowest point in 1993/94 there has been significant rebuilding in terms of exploitable biomass. This rebuilding has been so successful, with significant increases in catch rates and biomass, that none of the original performance measures (except area-based egg production) provide useful insights into the stock status and how it is performing over more recent years. The fishery performance measures are currently under formal review and consequently, for this year, more details are given in this assessment of model based performance measures in order to characterize the status of the resource.

The distribution of effort and catch (the fleet dynamics) continues to exhibit strong trends which appear to be related to a particular sequence of recruitment events. Effort peaked in 1992/1993 (2.07 million pot lifts), with current effort only 60.6% of that amount (1.25 million pot lifts). Current effort is 65.7% of a secondary peak of pre-quota effort in 1996/1997 (1.90 million pot lifts), and 78.7% of effort in 1998/1999, the first year of the quota management system (1.59 million pot lifts). The level of rebuilding is evident in the reduced amount of effort required to catch the TAC; this is especially significant given that there has also been a shift to more winter fishing, when catch rates are generally lower.

The geographical distribution of effort is changing with the amount of effort dropping significantly in assessment areas 2 to 6 and rising significantly in areas 1, 7, and 8 (dropping in the north and rising in the south). At the same time, catches are dropping or stable in the Northern four assessment areas and are rising in the Southern four areas. Combining these trends in effort and catch, catch rates are dropping or stable in the Northern four areas and rising in the southern four assessment areas. Consequently the stock is continuing to rebuild in the south while rebuilding appears to have slowed in the north.

The number of vessels reporting any catches of rock lobster in 2005/2006 is down to 224 from 344 in 1994/1995.

Model Based Performance Measures

The rock lobster stock assessment model is fitted to catches, catch rates, and, where available, length frequency of the catch data. The combination of length frequency data and catch rate data provide an insight into the underlying processes affecting stocks in different regions. For example, increases in catch rates combined with large numbers of relatively small lobsters in the catch indicate recent recruitment and rebuilding (observed in the southern four assessment areas). In contrast, stable or lowering catch rates combined with relatively few smaller lobster in the catch indicate relatively low recent recruitment and a decline in stock size brought about through a lack of recruitment (observed in the northern four assessment areas).

Legal biomass appears to be rising in all assessment areas, only very slightly in the northern areas but significantly in the southern areas. The increase in the south is related to relatively high recruitment.

The model attempts to explain the patterns visible in the various data streams by implying that recently, there has been below average recruitment in assessment areas 3, 4, and 5. On the other hand, there have recently been spikes of recruitment in areas 1, 7, and 8 and these have influenced catches, catch rates, mature biomass, and egg production.

Egg production over the whole State is stable but mature biomass has declined slightly in the last two to three years. Mature biomass can decline while exploitable biomass is rising because females can mature before they reach exploitable size classes, hence these two measures need not be correlated.

The average weight of landed lobsters continues to increase slightly in all areas. This may be due to the harvest rate dropping (the proportion of legal biomass removed by fishing) leaving more lobsters in the water for longer. Alternatively, it could also be due to there being low recruitment in some areas so that the only animals available are those that are growing bigger.

No new estimate of recreational catch is available since the 2004/2005 estimate of about 120t, but recreational licences have increased in numbers again.

For the last three years there have been very low puerulus catches on the East coast. This unusually low series suggests there may be a potential gap in the recruitment intensity that will only appear in a few years.

Implication of Future Harvest Strategies

All statements about the model projections assume that the fleet dynamics remain very similar to the present day fleet dynamics (including the proportion of recreational catch by assessment area). In addition, the projections assume that historical recruitment patterns will continue to occur. The fact that the model predicts low recruitment in the north and recent spikes of recruitment in the south suggests that the recruitment dynamics have taken on a particular pattern lately and may be poorly reflected by using the historical recruitment patterns. The significance of this for the risk assessment is that the use of historical recruitment dynamics, especially in the north of the State, may generate overly optimistic predictions about the future of the stock.

State-wide legal biomass projections suggest that with TACs between 1,475t and 1,600t (implying between 115.7t and 125.4t of recreational catch) rebuilding will continue. With a TAC of 1,523t, legal biomass has a >60% chance of increase over the next five years in all assessment areas. The areas with the lowest chance of stock rebuilding over the next five years are areas 3, 2, and 6, in that order. Area 6 is the most uncertain in the assessment and in the projections because of its history of discovery of new grounds, leading to highly variable recruitment dynamics. With a TAC of 1,600 tonnes the probability of stock rebuilding continuing becomes less than 50% in Area 3 and less than 60% in Areas 2 and 6.

Overall Conclusions

Stock rebuilding is continuing but the signs of poor recruitment (very low puerulus catches on the East coast for the last three years) suggest that stock rebuilding may slow, or even reverse, in the next few years.
So much stock rebuilding has occurred since the reference years (1994/1995) that the performance measures currently in place in the management plan are now uninformative when devising management advice.

The low recruitment levels in the northern areas combined with the low puerulus counts on the East coast both add uncertainty to the assessment and projections. Because of the uncertainty and the particular recruitment patterns recently exhibited by the stock, the potential rebuilding of the stock predicted by the model may be misleading (biased high). Because of this potential bias it would be prudent to be cautious when generating management advice.

Table 1. Formal performance measures for the Tasmania rock lobster fishery.

Performance measure	Trigger point		Status in 2005/06
Statewide commercial catch rates	<95% of reference year	✔	47% increase above reference year
Regional commercial catch rates	<75% of reference year	✔	>23% of reference year in all cases
Statewide legal-size stock biomass	<95% of reference year	✔	182% of reference year
Regional legal-sized biomass	<75% of reference year	✔	>154% in all areas
Regional biomass estimates from fisheries independent surveys.	Significant decline between years		Not available
Statewide egg production	< lowest year	✔	111% of lowest year
Regional egg production	<95% lowest year unless production >40% unfished state (no decline tolerated in Areas where production <10% unfished)	✔	>103% of lowest year in all areas
Total commercial catch	<95% TACC	✔	>99% TACC
Size of the fleet	<220 active vessels	✔	224
Recreational catch	>10%TACC	✔	Most recent estimate 2004/05: 7.8%

Table 2. DEH recommendations for Ecosystem Based Management (EBM) of the Tasmanian rock lobster fishery applicable to this assessment.

Recommendation	Status
Recommendation 4. DPIW to continue to monitor the situation with respect to the harvest of immature females in the northern part of the fishery to ensure any reductions in egg production or puerulus settlement are detected in a timely manner and develop a management response for implementation in the event that a major issue develops.	TAFI continues to monitor egg production in the north of the State. This is through model estimates of egg production based on commercial catch rates and research catch sampling. Regional importance of egg production sources has been investigated in a project on larval dispersal.
Recommendation 6. Stock assessment processes should incorporate, if not already done, a risk assessment into the ecological impact of the potential skew in sex ratio caused by a longer fishing season on males.	TAFI monitors sex ratios at a number of locations around the State. There is no evidence that ecological impacts are likely to be sex-linked *per se*, however, fishery impacts in terms of regional egg production continues to be monitored around the State. The evidence indicates that the longer fishing season for males has a smaller impact on sex ratios than differences in growth rate and the protection afforded through the different minimum size limit for the two sexes. This supports the current approach to monitoring of skew in sex ratio on a regional basis as per growth and egg production.
Recommendation 8. An analysis of measures to encourage the accuracy of by-product reporting should be conducted with a view to improving data collection, assessment and management responses.	An analysis of expected byproduct on the basis of catches in research pots versus reported bycatch suggested extensive under-reporting. This is being addressed through revised data collection.
Recommendation 9. Mechanisms should be developed to ensure better recording of by-catch in the fishery. A more formal assessment of the risks posed to by-catch species should be carried out before the next assessment.	At present, the fishery only formally records by-product or protected species interactions. Data on bycatch that is returned to the sea cannot be verified so this is collected through TAFI's research catch sampling program. A formal review of by-catch in the lobster fishery was conducted in 2006 in a combined workshop involving Victoria and South Australia.
Recommendation 10. A structured reporting and monitoring program into interactions with protected species should be developed as high priority.	Information on the frequency and type of interactions between protected species and the fishery are cited in this assessment report. This is the second year that this data has been collected following adoption of new reporting systems in 2004.

Recommendation 11. DPIW should establish a program monitoring fished and unfished areas in the fishery with a view to identifying changes in the wider marine environment that may be a result of the fishery.	Unfished areas have now been in existence for over a decade and have been surveyed regularly throughout this period. Statistically significant differences in the abundance and size-structure of unfished populations of rock lobster have developed over time. The abundance of some other species has also altered. Monitoring of these sites continues.

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1 Introduction

1.1 The modern fishery

The present commercial catch is taken from areas all around the State and involves the annual harvest of around 1.6 million animals. In the 2005/2006 season 224 licensed vessels reported catches of rock lobster. In addition, there were approximately 15,000 licensed recreational fishers (taking about 119 tonnes in 2004/2005). Commercial harvests have been controlled by a quota management system since March 1998, which has resulted in substantial stock rebuilding in all Areas. This rebuilding can be seen in the historical trends in the fishery (Figure 1).

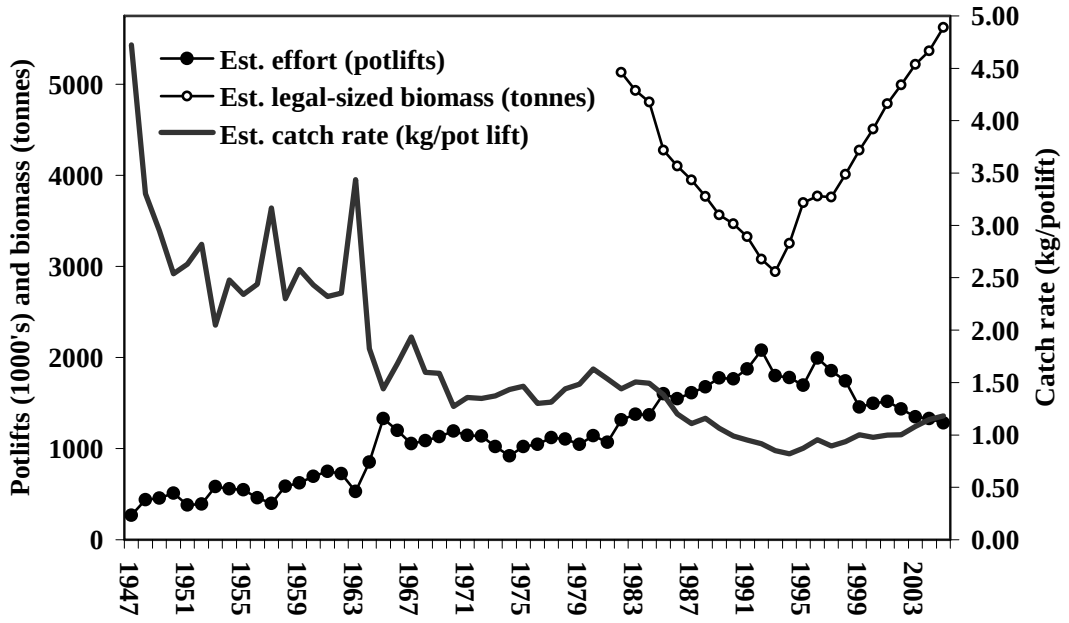

Figure 1. Historical trends in estimated fishing effort (pot-lifts), estimated catch-rate (kg/pot-lift) and estimated legal-sized biomass. Catch-rates after the 2nd world war and before the 1960s were much greater than those seen today. As fishing effort rose, catch-rates fell. Legal-sized biomass can only be estimated for later years commencing from a time when the resource was already fished down. The general trend in recent years exhibits a steady increase in legal biomass, with catch rates also recovering. This information is given in calendar years rather than quota years for ease of comparison with pre-1998 years.

Although biomass rebuilding has been substantial, catch-rates have picked up more slowly due to the dynamics of the fishery changing (such as time of year when catch is taken). This is because fishers are increasing their effort in locations and months when catch rates are lower, in order to supply lobsters to markets that fetch the highest prices.

Lobsters are harvested from all around the State with considerable variation in patterns of commercial fishing from region to region. Biological parameters also vary dramatically from region to region and both these sources of variation present major challenges for fishery management. An important step towards meeting these challenges is the use of a spatially explicit stock assessment model that considers eight different assessment Areas separately (Figure 2).

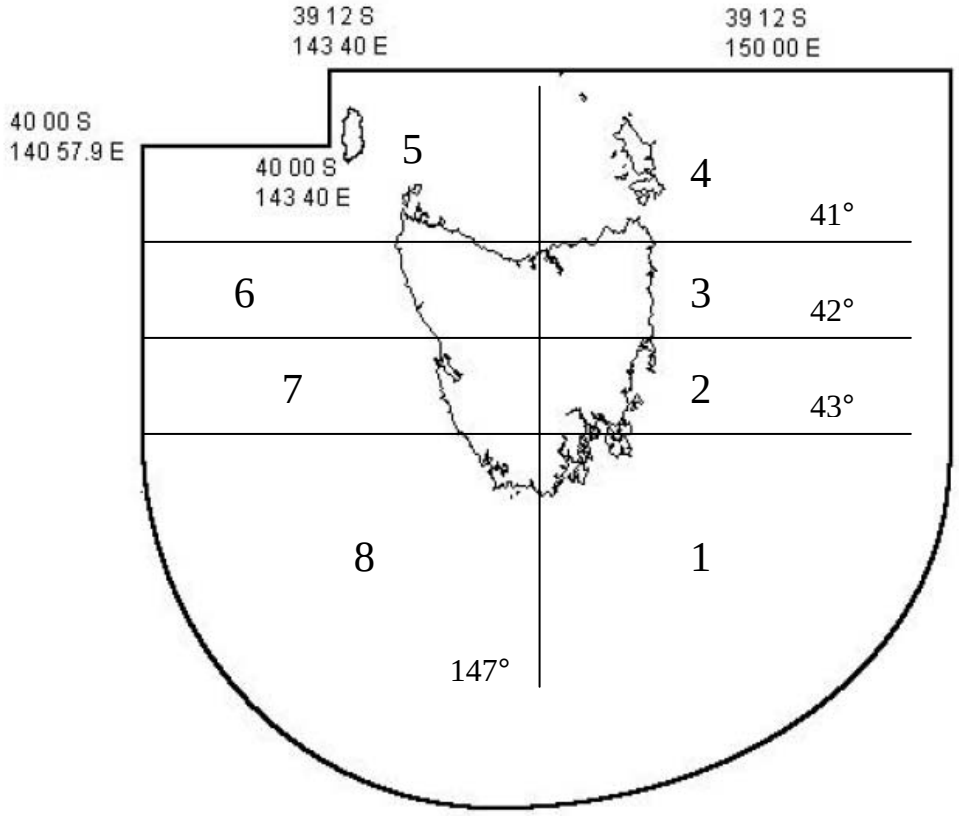

Figure 2. The boundaries of the eight Stock Assessment Areas and the area of State waters for the rock lobster fishery provided by the offshore constitutional settlement (OCS).

1.2 Economic and market status

While the commercial fishery for rock lobster is not the largest fishery in Tasmania by value of landed product, it is the major fishery contributing to employment in Tasmania. This economic benefit is well distributed around the State, where an estimated 1,350 Tasmanian jobs are reliant on the rock lobster fishery (EconSearch 2003). Details of the economic analysis of the commercial Tasmanian fishery by EconSearch (2003) were reported previously (Gardner *et al.*, 2004). At point of first sale, the present commercial catch is valued at $51 million (ABARE, 2004) or $184 million economic impact (Econ-Search 2003; including secondary economic impacts). About 63% of this catch is currently taken off the exposed West Coast.

Lobsters are largely sold into Asian markets although a marketing project is underway with the aim of expanding into markets in the USA.

In addition to the commercial fishery there is a significant recreational fishery. The main objective of management of the recreational sector is social benefit rather than economic, nevertheless, recreational lobster fishing also has an economic impact. The economic impact of all recreational fishing (lobsters, abalone, finfish etc), including secondary economic impacts, has been estimated at $50 million (Lyle *et al*., 2003).

2 Recent Developments

2.1 Management History of the Fishery

The implementation of the quota system in the commercial fishery in March 1998 resulted in an increased focus on profit rather than simply trying to maximize catch and revenue. Previous assessments have discussed the change in the dynamics of the fishing fleet since quota was introduced, the key observations being a shift in effort towards winter fishing and shallow water to maximise value. This has the potential to bias the stock assessment as it could lead to localized depletion in inshore regions while harvest rates in offshore stocks remain low due to the lower price of deep water, pale lobsters. At the present spatial scale implemented in the assessment model such local effects would not be accounted for except where catch rates were standardized by depth (which is now done for the data since 1994/95). Changes in the market have impacted on the economic yield of the commercial fishery in recent years. In particular, the price received from processors exporting into China has declined (in $Australian) due to changes in the exchange rate. Management of the recreational fishery has remained relatively stable with a daily catch limit of five lobsters. Licensing has been now been introduced for all methods of recreational lobster fishing and this provides information about levels of participation.

2.2 Developments in stock assessment analyses

2.2.1 Logbook changes

Commercial catch and effort logbooks are regularly reviewed to ensure effectiveness for assessment data collection. A recent significant change was the introduction of protected species interaction reporting. This assessment is the second to include a full year of data collection on protected species interactions, with results reported under "Ecosystem Interactions". A revised rock lobster log book design has been proposed for the 2006/2007 season, which includes a monthly reporting sheet for byproduct and threatened and protected species interactions.

2.2.2 Research catch sampling operations

The analyses in the assessment are based on a variety of data sources. Information about temporal changes in lobster stocks are mainly driven by commercial logbook data, research catch sampling surveys, and recreational surveys. The research surveys provide two main types of data for assessing temporal change in the resource; these are the size structure of lobster catches and independent estimates of harvest rates.

The options available for estimating harvest rate from research surveys were recently reviewed. Previously, attempts to use techniques based on the number or ratio of legal-sized lobsters in research catches (change-in-ratio and index-removal methods) had been made. However, with the introduction of quota, the extended season opening was continually compromising the effectiveness of these methods. Alternative methods to measure fishing mortality using tagging data were developed by Frusher and Hoenig (2001) and were seen as the best alternate option. The FRDC has funded a study to apply these models in Tasmania. This project started in August 2003 and is looking at

gaining estimates of harvest rate from broad regions of the fishery; this project will be reviewed in 2007 and decisions will be made either to implement the method more generally or develop alternative sampling schemes.

In the past, criticisms have been directed at a lack of sampling in certain regions of the fishery, at sampling in regions considered to be unrepresentative of the commercial fishery, and for using a research vessel that does not reflect a 'real' fishing operation. To obtain improved data from broader regions of the fishery, commercial vessels have been used to collect data since the 2004/05 fishing season. This has allowed us to increase our coverage of the State to include Areas 1, 4, 6 and 8 (Table 3; Fig. 3).

Table 3. Areas and depth ranges selected for the catch-sampling program in 2005/2006.

	Shallow	Deep
Area 1	0-30 m	35-60 m
Area 4	10-35 m	40-70 m
Area 6	40-70 m	100-150 m
Area 8	5-35 m	40-100 m

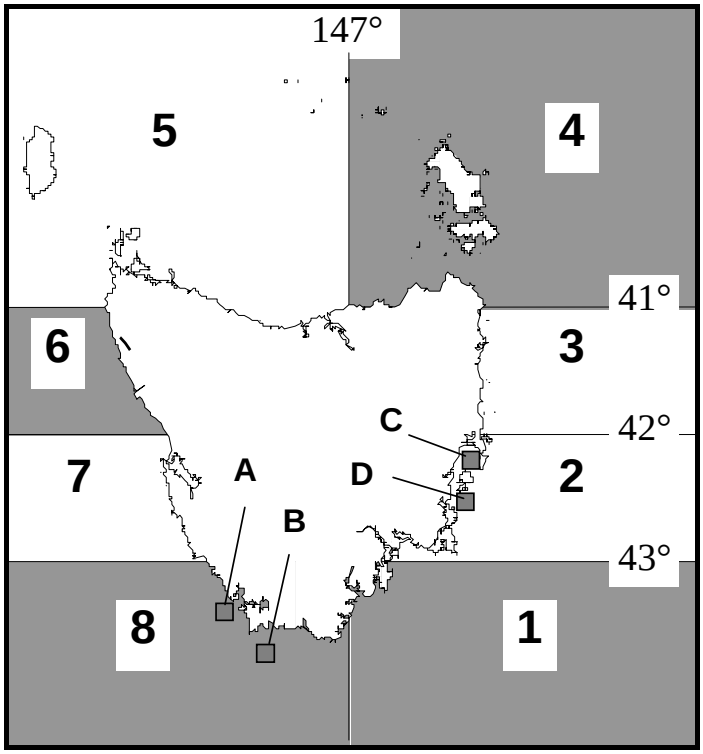

Figure 3. Fisheries-independent catch sampling coverage. Shaded areas represent Stock Assessment Areas covered by commercial vessels. Long-term survey sites sampled by research vessel (FRV Challenger) are indicated by black squares [A- Port Davey (2 sites), B – Maatsuyker Island (4 sites), C – Sandstone Bluff (3 sites) and D – Boy in Boat (1 site)].

Although catch sampling coverage of the State has increased, our ability to sample undersize lobsters has decreased due to the use of stick pots, rather than standard meshed research pots. These stick pots commonly used by commercial fishers have larger gaps, which reduces the retention of undersize lobsters. This issue relates to the trap selectivity and its effects, if significant, will need to be included in the assessment modelling. Trials are underway to standardise for this effect so that we can better account for selectivity in future assessments.

Annual sampling of research sites established on both the east and south coasts in 1992 (Figure 3) was undertaken in November 2006 using *FRV Challenger*. This long-term data set has already provided valuable insights into spatial and temporal changes in fisheries parameters such as size at maturity (Gardner *et al*, 2006).

2.2.3 Fisheries dependent data collection

Since 2004/2005, researchers from the Tasmanian Aquaculture and Fisheries Institute (TAFI) have been circulating electronic data loggers amongst the rock lobster and giant crab fleet to collect information about the size structure of the stocks.

The units consist of a set of digital Vernier callipers attached to a data logger, plus a small panel with buttons (Figure 4) for the selection of sex and presence / absence of eggs. They weigh less than one kilogram and are fully waterproof (IP 67) with a rechargeable power supply capable of lasting for up to 2500 entries and a total memory capable of holding in excess of 5000 individually timed and dated entries. The loggers are supplied to fishers so that they can measure a portion of their catch, which provides a low-cost method for collecting size-structure data. Data from these loggers are used in stock assessments and are a critical input in conjunction with catch and effort data from compulsory paper logbooks. The advantage of such a logger system over the conventional observer compiled data is that data is collected over a much wider area of the fishery and over the entire season. In addition, the system eliminates the use of paper and manual data entry, which can lead to errors.

TAFI currently has 12 of these units in circulation around Tasmania concentrating particularly in areas with lower levels of research catch sampling effort. After a fisher has collected data from several trips the logger is sent back to TAFI for downloading. TAFI then sends a report back to the fisher. The logger is then either sent back to the same fisher or circulated to a new crew who are interested in helping gather such data. The units can be used for either lobster or giant crab. Most fishers participating in the program are measuring a small number of animals each shot, say all lobsters from 3 or 4 pots. This quickly develops into a considerable dataset.

Figure 4. Measuring a lobster using an electronic data logger.

2.2.4 Changes to the stock assessment model

The model projections that are required for the risk assessments use a description of the fleet dynamics to predict harvest rate in each assessment area. The observed fleet dynamics have begun to show some very strong trends that can lead to unrealistic predictions if these trends are projected forward using a statistical model (either the original one from 1997 or the new improved statistical model. To avoid this unrealistic behaviour, alternative fleet dynamics models were developed that attempted to average the fishing behaviour over the last few years. By constraining the time frame over which the fleet dynamics are characterized the projection of trends into implausible situations is avoided.

An additional development is the construction of a simple Excel front-end to facilitate running the model by members of the Crustacean Research Group. This will permit the exploration of alternative size limits in the eight different assessment areas. To complement the simplified front end a suite of routines in the statistical package *R* have been written which are used to plot up and tabulate the results of the model runs.

Technical documents describing these changes in detail are being prepared for distribution to interested stakeholders.

3 Fishery Assessment

3.1 Performance Measures

The management plan contains an array of different performance measures relating to:

- Commercial catch-rates
- Research catch-rates
- Estimated legal-sized biomass
- Egg production
- Abundance of undersized lobsters
- Total Catch
- Size of the active fleet, and
- Recreational catch

These performance measures are intended to provide a measure of the resource status across a board range of the properties of the Tasmanian rock lobster stock. The values for each of these performance measures are compared to standards, termed Limit Reference Points or trigger points, which have been defined for each of these measures. If these limits or triggers are breached then a management review is initiated to determine what action, if any, is required. Limit Reference Points define undesirable states for the fishery (see Appendix 5). Ideally, in addition to Limit Reference Points there would be Target Reference Points, which define the desirable state of the stocks and fishery. By default, at present, the targets for this fishery are any status greater or better than the Limit Reference Points. While not explicitly stated, there is a stock rebuilding strategy in place whose implicit objective is to increase the spawning stock biomass to something larger than that available when the stock was severely depleted in 1993/94. No target level has yet been set for the rebuilding strategy.

The current performance measures with their associated Limit Reference Points and triggers are under review but presently the Limits and triggers are often based on the 5-year period prior to the introduction of quota in March 1998 (which generally includes the lowest point for the stock in each of the eight assessment areas). For example, regional catch-rates for the current year are compared with those from the 5 years before quota; if the current catch-rate falls below the lowest value from those 5 years, then the trigger is activated (see Appendix 5). Many of these Limit Reference Points and trigger points were established at a time when the stock biomass was much lower than it is today. The standards against which the performance measures are evaluated are now being reviewed along with the management plan. Because of the stock rebuilding almost none of the performance measures currently used have any real value in characterizing the present stock status. Because of this reduced value, this year, only a rapid review will be made of the standard performance measures. However, in addition, a closer inspection of the rock lobster stock assessment model will be made with the stock status being summarized from an interpretation of the model outputs. This will provide an explicitly spatial description of the state of the resource.

Finally, although the criteria used for EPBC accreditation are also assessed in this report they do not constitute formal performance measures in the current management plan.

3.2 Catch

Catch in the Tasmanian lobster fishery occurs through a range of sectors / systems: commercial catch, recreational catch, research catch, commercial personal use provisions; non-quota well mortalities; indigenous catch; and illegal catch. Additional mortality occurs as a result of fishing through octopus mortality in traps and discard mortality. Data is available on the scale of each of these sources of fishing mortality except for indigenous and also illegal catch. The commercial sector accounts for the majority of catch with other sources trivial aside from recreational catch (Figure 5).

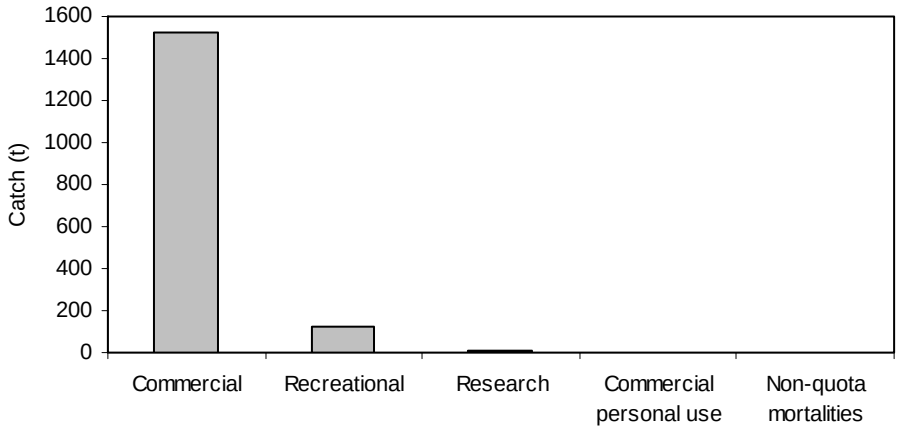

Figure 5. Different sources of fishing mortality in the Tasmanian rock lobster fishery.

3.2.1 Statewide Commercial Catch

Total commercial catch for 2005/06 taken through the quota management system was 1508.78 t, which is greater than 99% of the TACC of 1523 t (Figure 6).

3.2.2 Regional Commercial Catch

The total State-wide reported catch of rock lobster grew from about 1,500 t in 1970/71 to a maximum of 2,172 t in 1984/85, declining to 1,611 t in 1997/98. In 1998/99 a Total Allowable Catch (TAC) of 1,500 t was introduced, which was increased to 1523 t in 2002/03 (Figure 6). Total State-wide effort (as pot lifts) followed a similar trend but with a peak in effort in 1992/1993 and another in 1996/1997, with effort declining strongly since then. The stock assessment model is a size-based model modified from Punt & Kennedy (1997). The predicted legal sized biomass at the end of November each quota year has exhibited a strong decline in exploitable stock size from a peak in 1982/1983 to a minimum on 1993/1994. Following on from then the stock has rebuilt strongly, especially after the introduction of the quota management system in 1998/1998. The exploitation rate (as State-wide catch divided by the November exploitable biomass) follows a pattern similar to the distribution of effort but with changes brought about by changes in exploitable biomass (Figure 6).

The State-wide trends demonstrate the success of the rebuilding strategy introduced since the heavily depleted situation of the mid-1990s; first as input controls (for example November 1995 was closed to lobster fishing) and then as a conservative Total Allowable Catch (TAC) of 1,500t (now 1,523t). However, because of the regional differences in productivity interacting with the fleet dynamics, the rebuilding has not proceeded at an equal rate around the State.

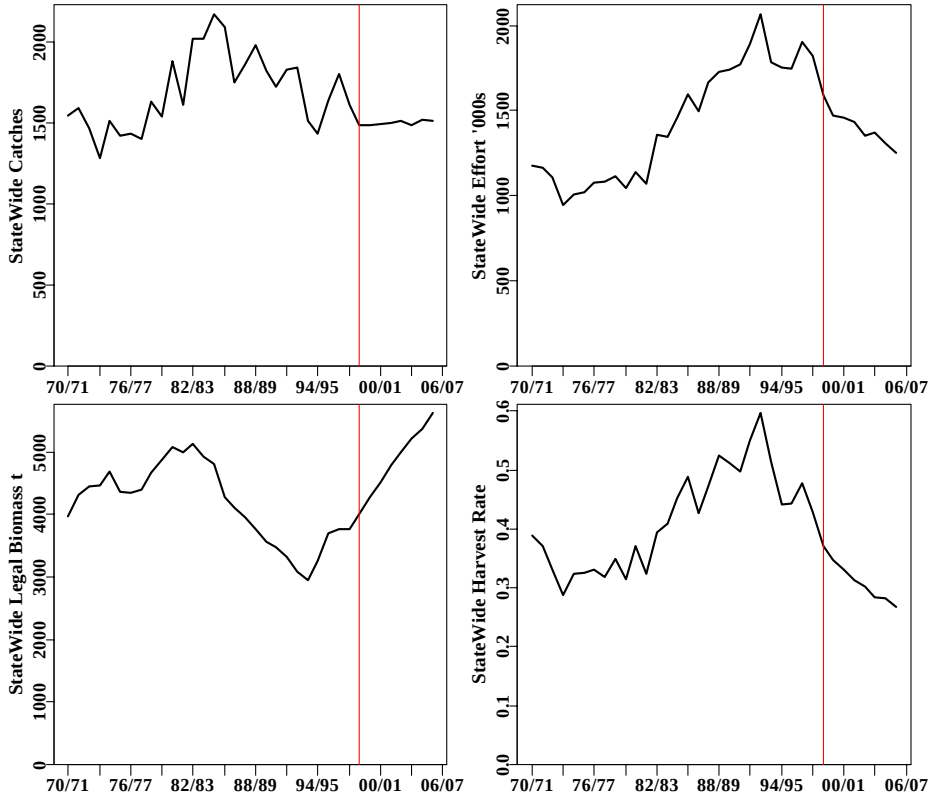

Figure 6. State-wide catches as tonnes, effort as thousands of pot lifts, legal biomass in November as tonnes, and the State-wide harvest rate approximated as the total catch versus the November legal biomass.

3.2.3 Non-Quota Commercial Catch

Non-quota commercial catch occurs in two ways: personal use provisions and well mortalities. Reporting of these additional sources of mortality was introduced in 2003/04. Reporting was introduced so that firm data could be collected on the scale of these activities, which are difficult to enforce. In particular, there was a perception that fishers could discard dead lobsters at sea to avoid having these deducted from their quota holding. This practice would lead to the under-estimation of commercial catch n the assessment process. The introduction of mandatory reporting of these discards without penalty provides a more objective basis for examining the scale of the problem.

Provisions for both personal use and reporting of well mortalities have been the subjects of philosophical debate, however, both practices are of a minute scale and have a trivial impact on the estimation of stock size (Figure 7).

Commercial fishers are allowed to retain up to five lobsters per trip for commercial use through personal use provisions. These lobsters are typically unhealthy when unloaded so that the fisher would receive a discounted price. Although these lobsters are not sold, and are thus not commercial, they are not considered to be recreational catch because they are taken outside the recreational permitting system. A total of 3200 lobsters were taken through this provision in 2005/06, which equates to around 14 lobsters per active vessel per year.

Well mortalities were also trivial in scale with only 779 lobsters landed but not deducted from commercial quota. This equates to less than 3.5 lobsters per active fishing vessel.

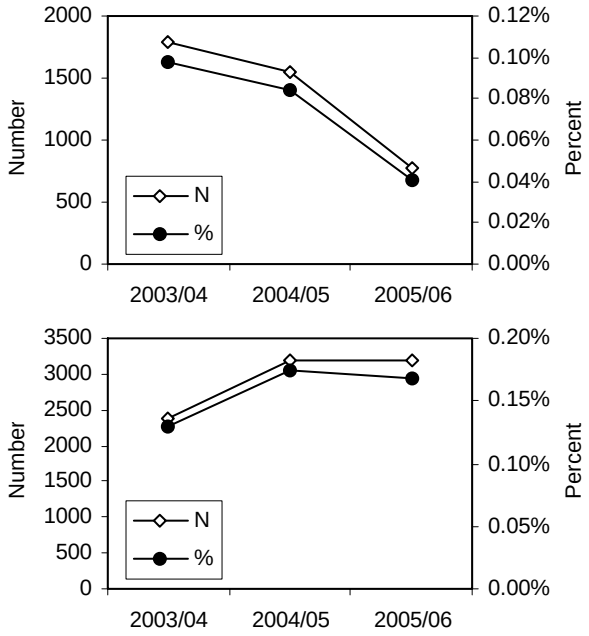

Figure 7. Trends in commercial catch outside the quota management system. Well mortalities that were not deducted off quota are show in the upper figure, lobsters retained for commercial use in the lower figure. Percentage values are the number of lobsters relative to the total harvest.

3.2.4 Research Catch

Research effort on the Tasmanian rock lobster resource is partially funded through the allocation of 1% of the quota for the support of research. The main use of this quota is as payment for vessel charter to conduct catch sampling research. A total of 14 tonnes were utilised in 2005/06.

3.2.5 Recreational Catch

The last recreational survey of rock lobster catches relates to the 2004/2005 fishing year. Since then the number of rock lobster recreational licenses has increased again but there are no new estimates of recreational catches by area. A summary of the surveys and other estimates that have been made (as they have been included in the stock assessment model) indicates that recreational catches rose steadily from 1992 until 2002/2003 after which they appear to have declined slightly (Table 4). The estimates of the proportion of the commercial catch taken by recreational fishers in each assessment area have also changed through time (Table 5).

Table 4. Estimated total weight of recreational catches by area and season.
The recreational surveys were usually conducted over a fishing year (November until October – with September and October assumed closed to recreational fishing). However, these figures have now been associated with given quota years. Spatial resolution of the surveys has increased through time.

Area	1996/1997	1997/1998	2000/2001	2002/2003	2004/2005
1	39.533	35.355	51.891	43.596	42.777
2	20.403	13.173	26.988	29.211	16.113
3				21.318	15.781
4	6.0075	4.813	19.57	13.506	7.343
5	10.381	8.058	6.272	17.595	17.437
6	13.361	8.271	22.084	11.866	8.225
7				5.497	7.889
8				5.937	3.791
Total	89.686	69.670	126.805	148.526	119.356

Table 5. Recreational catch as a percentage of commercial catch in each area for each survey.

Area	1996/1997	1997/1998	2000/2001	2002/2003	2004/2005
1	39.658	34.402	48.756	34.912	29.480
2	12.813	10.088	17.411	26.944	14.040
3	11.073	9.728	17.401	29.170	22.172
4	2.806	2.472	8.931	6.477	3.693
5	3.247	2.456	1.941	5.396	4.720
6	3.120	1.903	5.002	8.023	4.370
7	1.863	1.509	4.444	5.627	7.916
8	1.162	0.711	1.940	2.911	1.432
Start	Dec-96	Nov-97	Nov-00	Nov-02	Nov-04
Finish	Aug-97	May-98	Aug-01	Oct-03	Aug-05

3.3 Commercial Catch and Effort Analysis

Catch rate data from the commercial sector is presented in two parts.

First, ratio and geometric catch rate data are presented. These provide basic guidance on trends in catch rate. Both ratio and geometric catch rates are based solely on catch and effort data; they differ in the mathematical process used to calculate the value of catch rate.

The second method of presenting catch rate data is standardised catch rate. The process of standardisation accounts for many of the factors that alter catch rate aside from abundance of lobsters. The standardised catch rate data presented here show the trends in catch rate after removing the effects of month, boat, depth, day / night fishing, and ½ degree fishing block within the assessment area. This means that changing fishing practices, such as increasing effort in winter and shift of effort to shallow depths, should not bias trends in standardised catch rate data as they would ratio and geometric catch rates.

3.3.1 Ratio and geometric catch rates

Statewide commercial ratio catch rates for the 2005/06 quota year were higher than those recorded in the corresponding reference years and thus this trigger point has not been activated (Table 6). Interannular trends were similar for both ratio catch rates and geometric mean catch rates although were spatially variable both between areas and between fishing blocks within assessment areas (Table 7, Figure 12 and Figure 13).

The Statewide catch-rate has exhibited a sustained pattern of increase, which implies ongoing rebuilding of stocks (Figure 8). As catch is limited by quota, the improved catch rates have led to a decline in total effort so that in 2005/06 there was only 65% of the effort expended in 1996/97 (Figure 9, Table 8).

Table 6. Annual commercial catch-rates.
Negative values of change indicate a reduction. The reference year is defined as the year with lowest CPUE among 1993, 1994 and 1995.

		Commercial catch rates (kg/pot lift)			% change		Catch stats (March 2005-Feb. 2006)	
Area	Reference Year	Ref. Year	2004/05	2005/06	vs Ref.Year	vs 2004/05	Catch (t)	Effort (1000 pot lifts)
Statewide	1994	0.82	1.15	1.20	+47	+5	*1509	1253
1	1994	0.54	0.96	1.12	+106	+16	240	215
2	1994	0.54	0.96	0.96	+78	0	116	120
3	1994	0.43	0.74	0.69	+61	-7	62	90
4	1994	0.61	1.04	1.04	+70	0	153	146
5	1995	0.89	1.22	1.09	+23	-11	230	211
6	1995	1.23	1.64	1.72	+40	+5	159	93
7	1994	1.10	1.6	1.86	+69	+16	158	85
8	1993	0.77	1.25	1.34	+74	+7	391	293

* estimated catch from logbooks (where effort is also recorded) as compared to total (QMS) landed catch.

Despite the Statewide trend there were small declines in the ratio catch rates in Areas 3 and 5 (Table 6, Figure 10 and Figure 11). Apparent declines in ratio catch rates can be caused by factors unrelated to abundance. Standardised catch rates provide a better guide for these regional trends and are shown in the following section. The problem of seasonal change in effort leading to a bias of ratio catch rate data is partly overcome by examining monthly trends in catch rate (Figure 14). The seasonality trends indicate that catch rates in the northern four assessment areas are relatively stable while the southern four assessment areas all show increases in the average catch rate relative to the previous ten years.

Table 7. Annual geometric mean commercial catch-rates.

These are calculated only for those records with catch-rates > 0, with vessels present in the fishery for > 1 year, and with median annual catches > 1 tonnes. Negative values of change indicate a reduction. The reference quota year is defined as the quota year with the lowest CPUE among 1993/94, 1994/95 and 1995/96.

		Geometric Mean catch rates (kg/pot lift)			% change		Catch stats (March 2005-Feb. 2006)	
Area	Reference Year	Ref. Year	2004/05	2005/06	vs Ref.Year	vs 2004/05	Catch (t)	Effort (1000 pot lifts)
Statewide	1994/95	0.546	0.869	0.888	+62	+2	*1509	1253
1	1994/95	0.372	0.684	0.814	+119	+19	240	215
2	1994/95	0.405	0.753	0.782	+93	+4	116	120
3	1994/95	0.319	0.588	0.546	+71	-7	62	90
4	1994/95	0.470	0.839	0.815	+73	-3	153	146
5	1995/96	0.608	1.002	0.881	+45	-12	230	211
6	1995/96	0.931	1.341	1.356	+46	+1	159	93
7	1994/95	0.819	1.290	1.488	+82	+15	158	85
8	1994/95	0.567	0.907	0.973	+72	+7	391	293

* estimated catch from logbooks (where effort is also recorded) as compared to total (QMS) landed catch.

Table 8. Summary of statewide commercial catch and effort statistics.

1996/97 had the maximum level of effort since 1994/95 and other years are scaled to this peak. QYear is quota year (Mar 1st – Feb 28/29th). State CPUE is the total catch divided by the total pot lifts.

QYear	Catch	Pot Lifts	% of 96/97	State CPUE
1994/1995	1434.669	1752975	91.99	0.818
1995/1996	1636.899	1745920	91.62	0.938
1996/1997	1799.143	1905561	100.00	0.944
1997/1998	1611.474	1823317	95.68	0.884
1998/1999	1487.512	1592206	83.56	0.934
1999/2000	1485.585	1471364	77.21	1.010
2000/2001	1491.988	1455457	76.38	1.025
2001/2002	1498.338	1433289	75.22	1.045
2002/2003	1510.598	1350900	70.89	1.118
2003/2004	1482.723	1370621	71.93	1.082
2004/2005	1516.663	1309267	68.71	1.158
2005/2006	1508.782	1252846	65.75	1.204

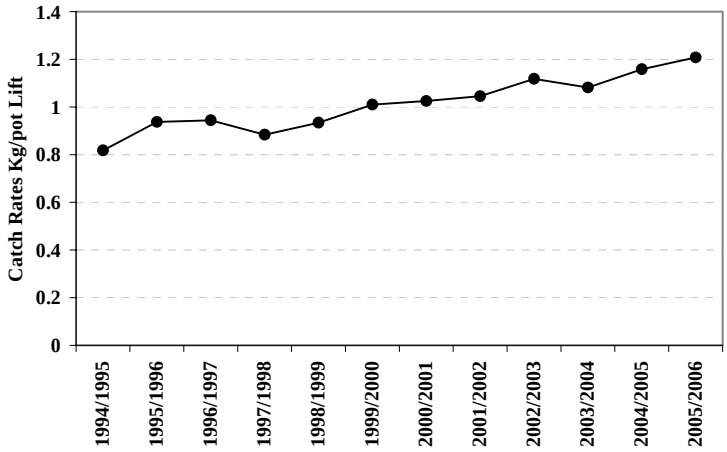

Figure 8. Change in State-wide ratio annual commercial catch rates since before the introduction of the quota system in 1998/99. The 1994/95 quota year was when catch rates (as sum of catch/sum of pot lifts) reached their lowest point statewide.

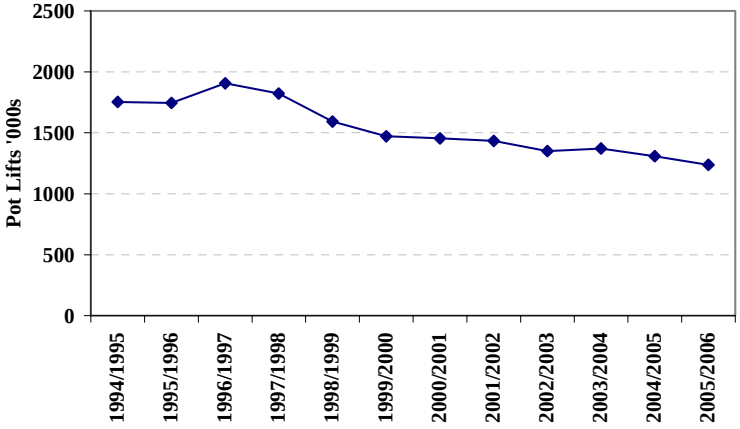

Figure 9. Change in State-wide commercial fishing effort as thousands of pot lifts since the 1994/95 quota year (quotas introduced in 1998/99).

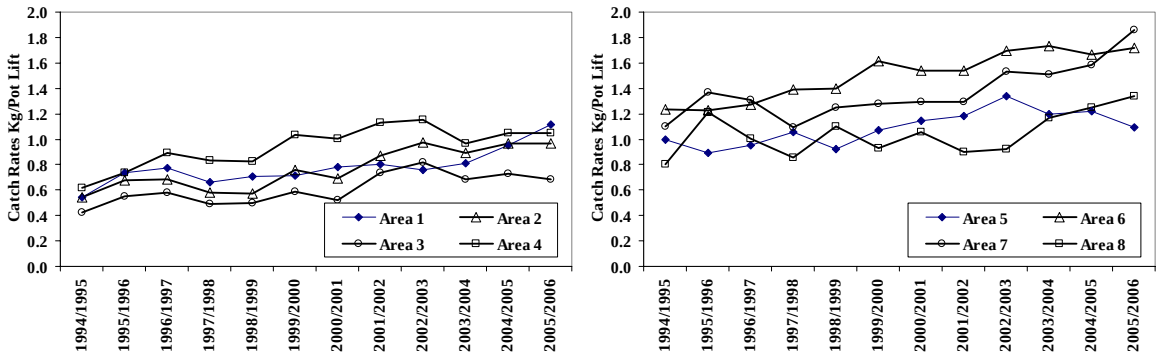

Figure 10. Change in ratio annual commercial catch-rates for quota years between 1994/95 and 2005/06 for assessment Areas on the east (left) and west coast (right). Data shown in this figure are expanded over a longer time series in Figure 11.

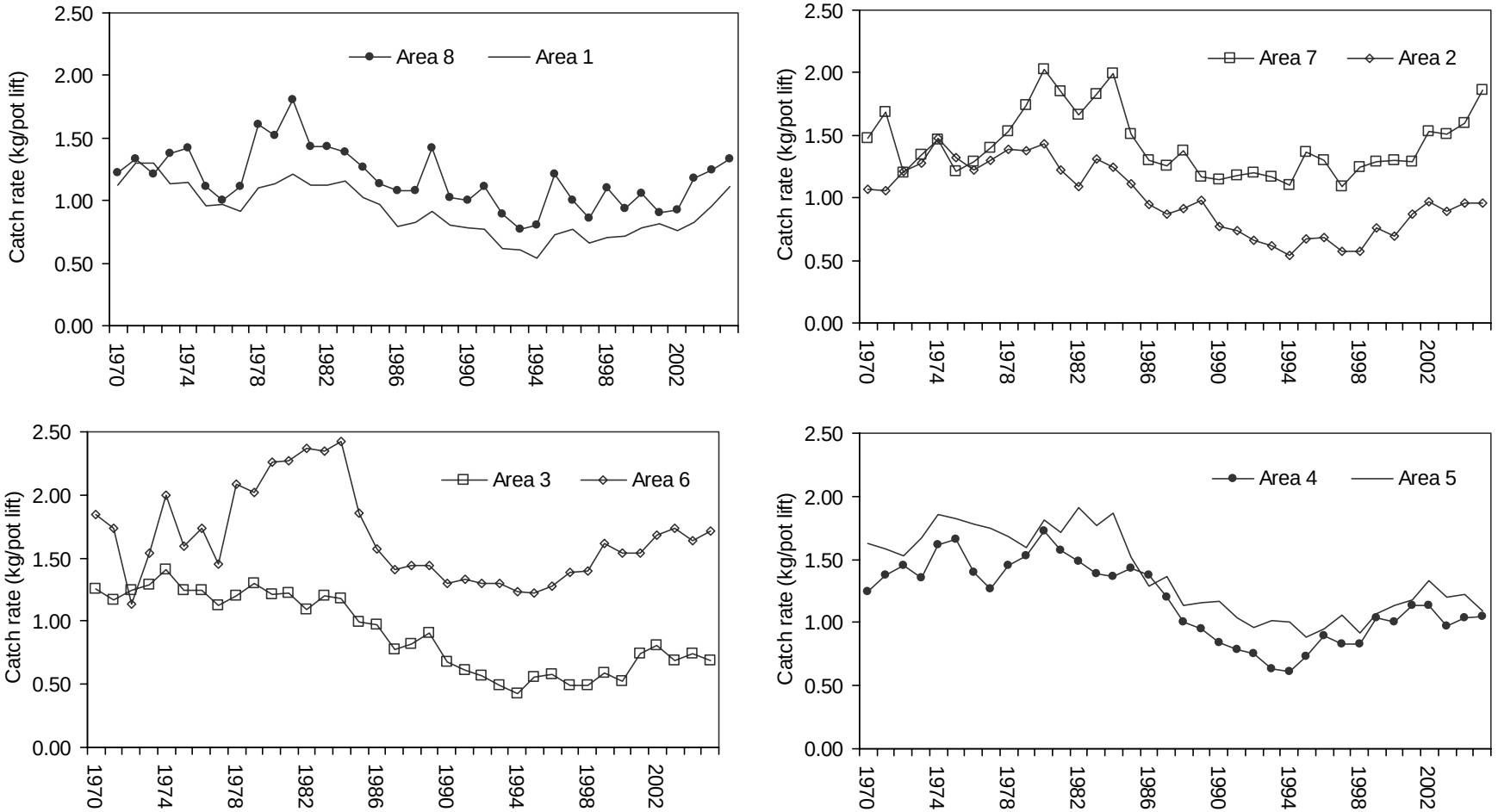

Figure 11. Regional ratio commercial catch rates since 1970. Data is presented on a quota year basis (i.e. March to February), so the last data point is for the period March 2005 to February 2006 inclusive.

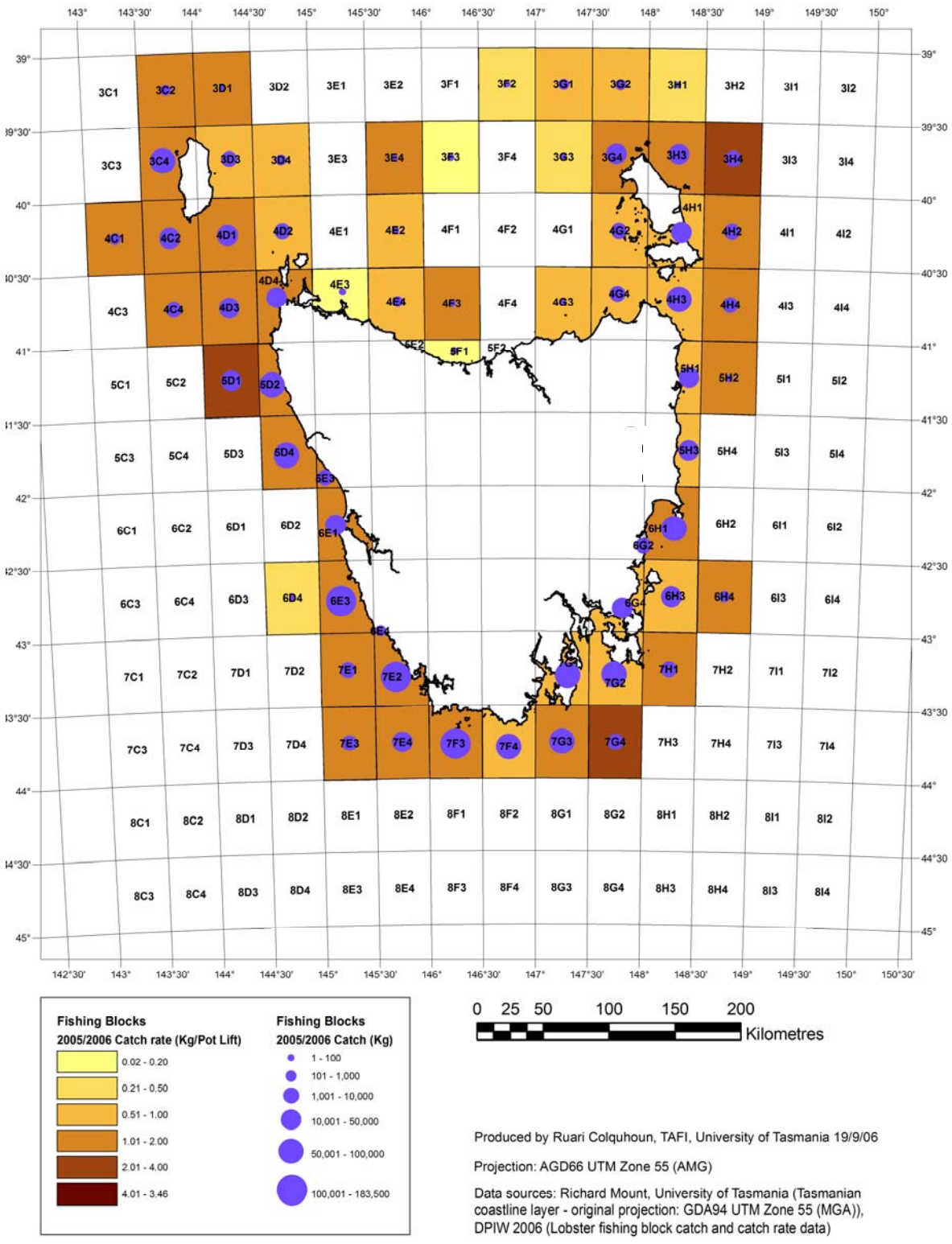

Figure 12. Ratio catch rates by fishing block. Total catch for the 2005/06 quota year is illustrated by the circles within each block. Note that spurious catch rates can occur where total catch is very low.

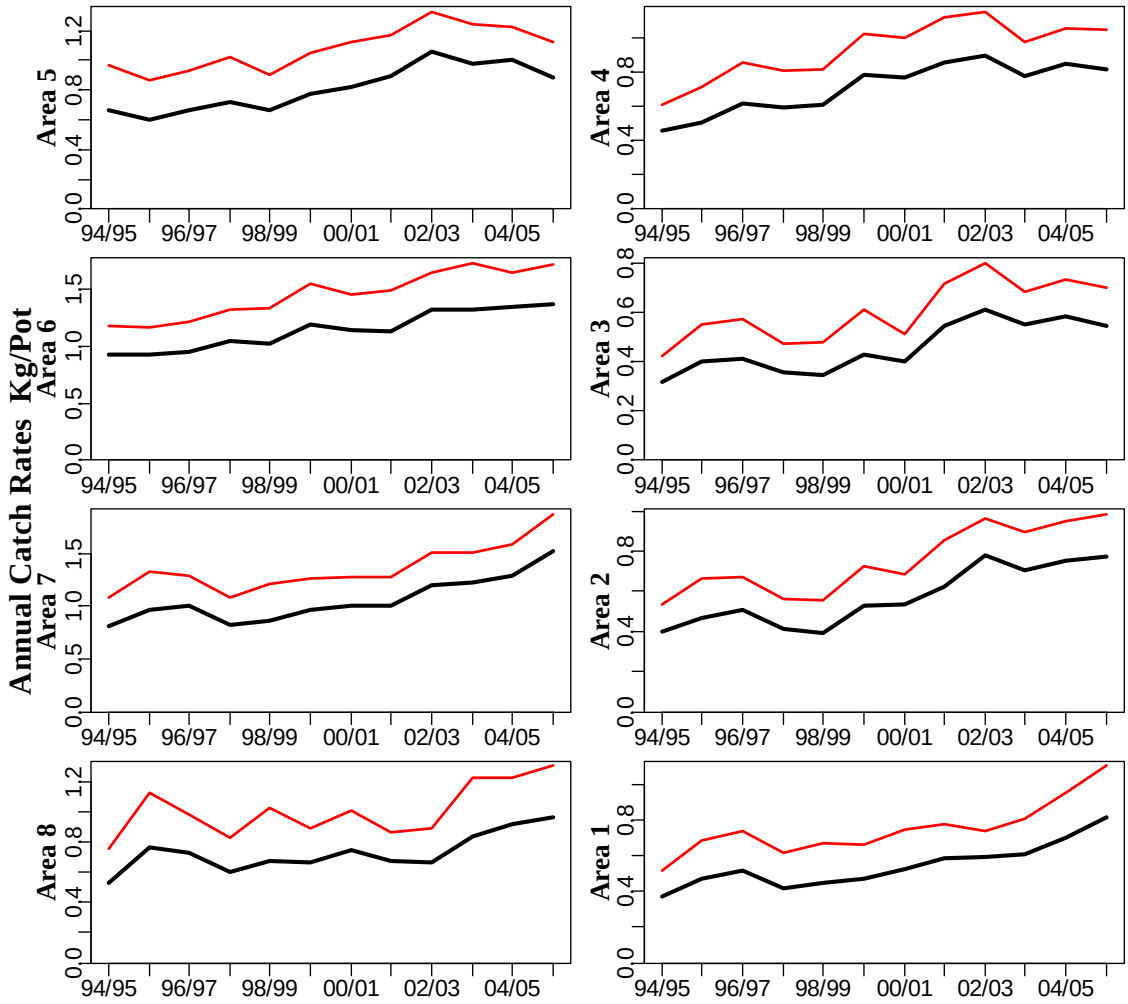

Figure 13. Comparison between geometric and ratio catch rates (kg/pot) for each year for each assessment area. The lower line in each case is the geometric mean catch rate while the upper is the arithmetic mean catch rate. This illustrates that the ratio catch rate tends to over-estimate the typical catch rate of the fleet, and also that trends are similar with the two approaches.

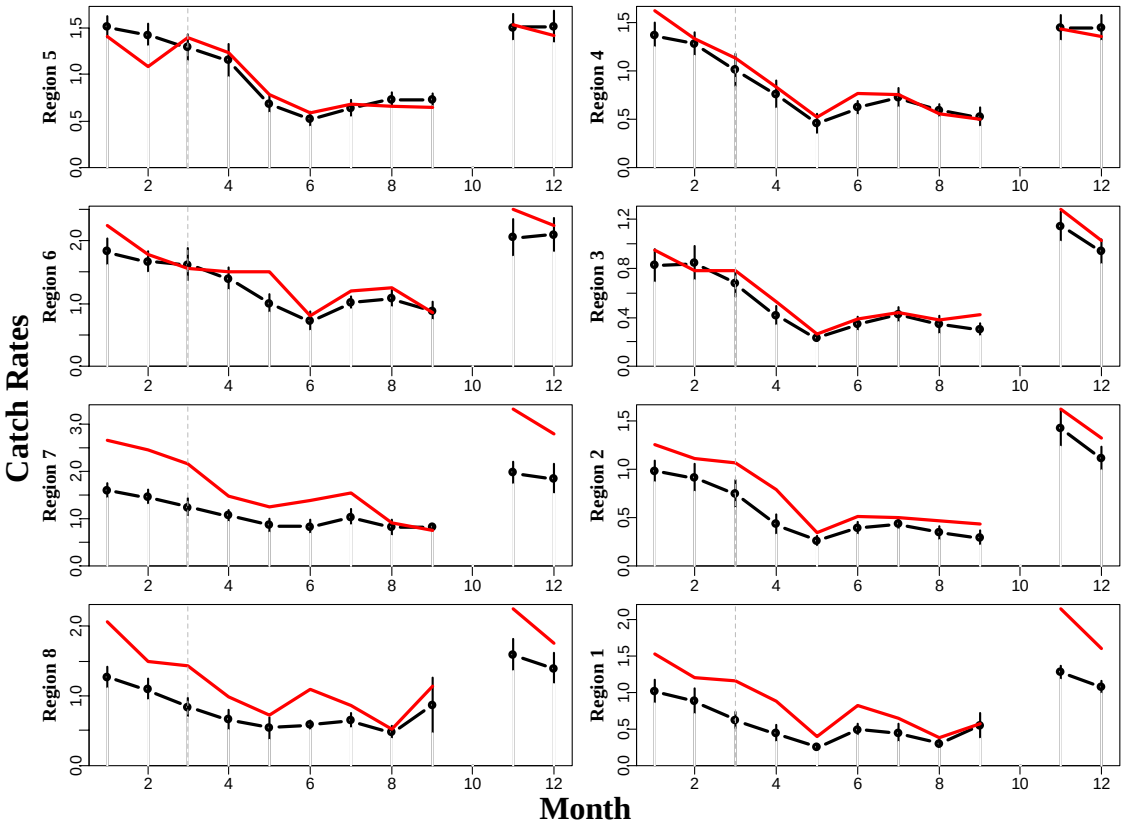

Figure 14. Change in ratio commercial catch rate (CPUE, kg/pot lift) between months for 2005/06 (the smooth line) and the mean of the previous ten quota years 1995/96 – 2004/05 (the line with dots and 95% confidence intervals). The vertical grey dashed line in each plot indicates the start of the quota season. The month of October is closed to fishing.

3.3.2 Standardised Catch Rates

Catch rates can alter in response to factors that have nothing to do with changes in the stock biomass. These include differences in the time of year, location, skipper, night vs day and depth. It is routine stock assessment practice to standardize commercial catch and effort data in an attempt to remove the influence of these factors. This process means that any variation left in the catch-rate data after standardization is more closely related to what is happening to the stock biomass. The method of standardising catch rate is described in detail in Appendix 1.

Optimal standardisations for each area were one of two forms. The first (termed "model 7") accounted for the effects of quota year, time of year (8 periods), boat ID, day/ night shot, depth, fishing block and an interaction between the time of year and depth. The second (termed "model 8") was equivalent except it included an interaction between the time of year and fishing block, rather than the time of year and depth.

The process of catch rate standardisation did not change the trends greatly from the geometric means (Figure 15 and Figure 13). As with other measures of catch rate, trends differ between Areas, with the southern Areas 1, 2, 7, and 8, all exhibiting continuing increases in standardized catch rates in the last quota year while the four northerly Areas, 3, 4, 5 and 6, continued with relatively stable catch rates or slightly declining catch rates (Figure 15). The standardisation process confirmed that there has been a sustained trend of declining catch rates in Area 5.

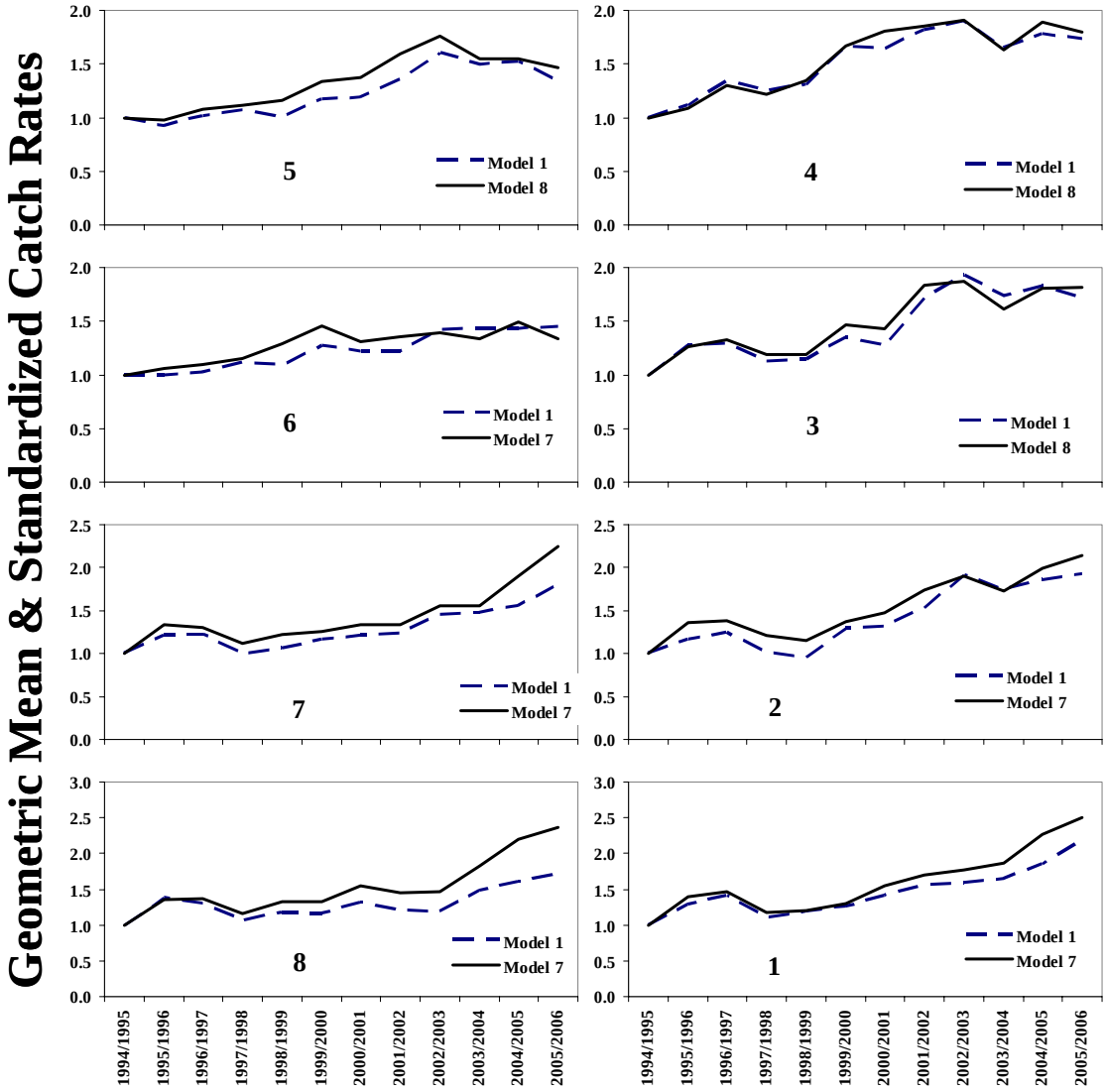

Figure 15. Geometric mean catch rates for each quota year compared with the optimal standardised catch rates for the eight assessment areas. Model 1 was the geometric mean in each case while the optimum statistical model was either Model 7 or Model 8 (see Appendix 1). Note that these catch rates are scaled against the first year (1994/95) and should not be read as kg per pot lift.

3.3.3 Trends in Commercial Catch and Effort

There has been a general trend of declining effort in the commercial sector over the last decade, which is reflected in a range of data. As noted in section 3.3.1, potlifts have declined by 65% over the past decade.

The number of records reported each quota year has also declined since 1998/1999 (Figure 16 and Table 9). This provides another measure of effort from potlifts, and is a better indication of a reduction in the days fished. In Areas 1, 8, and 7 there have been small increases over the last few years but in all other Areas the number of records has declined.

Table 9. Number of records from each quota year in each assessment area where catch was greater than zero.
The year with the maximum number of records is highlighted in bold.

QYear	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Total
94/95	5897	4457	4876	6955	**11339**	**5625**	3752	11464	54365
95/96	5882	**5394**	6177	7181	10203	5105	4406	9630	53978
96/97	**6327**	5393	**6243**	**7978**	9675	5164	**5070**	**12653**	**58503**
97/98	5947	5235	5561	7858	9801	4848	3819	12574	55643
98/99	4375	4144	4748	6459	8721	3924	2998	9201	44570
99/00	3978	3412	3687	5401	7034	4096	2312	8794	38714
00/01	3748	3418	3928	5964	6344	3982	1954	7661	36999
01/02	4021	3642	3068	5635	6141	3074	2072	7718	35371
02/03	4219	3672	3252	5219	6064	2720	1640	5657	32443
03/04	4283	3767	3227	4845	5879	2321	1646	5859	31827
04/05	4195	3613	2849	4176	5201	2622	1646	6133	30435
05/06	5018	3150	2199	3498	4478	1966	1765	6470	28544

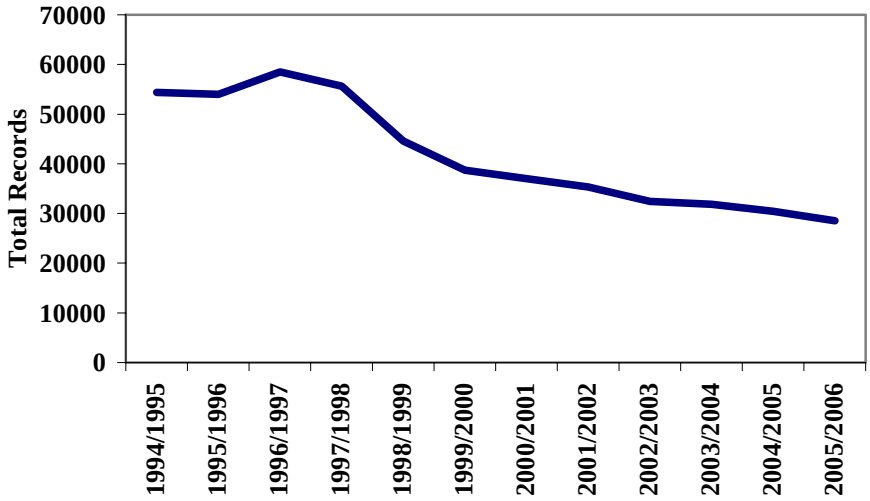

Figure 16. The total number of records across all assessment areas where catch rates are greater than zero. Only complete years are included.

The geographical patterns exhibited in the catch rates are consistent with the patterns in the distribution of catches and effort (Figure 17 and Figure 18). As would be expected, catch increased as catch rate rose because the fleet is mobile and fishers shifted effort to regions with better catch rates. Catch rate increased in Areas 1, 7, and 8 which led to an increase in effort and catch. Remaining areas had lower catch in response to lower catch rates. This pattern suggests a pulse of recruitment in southernmost assessment areas.

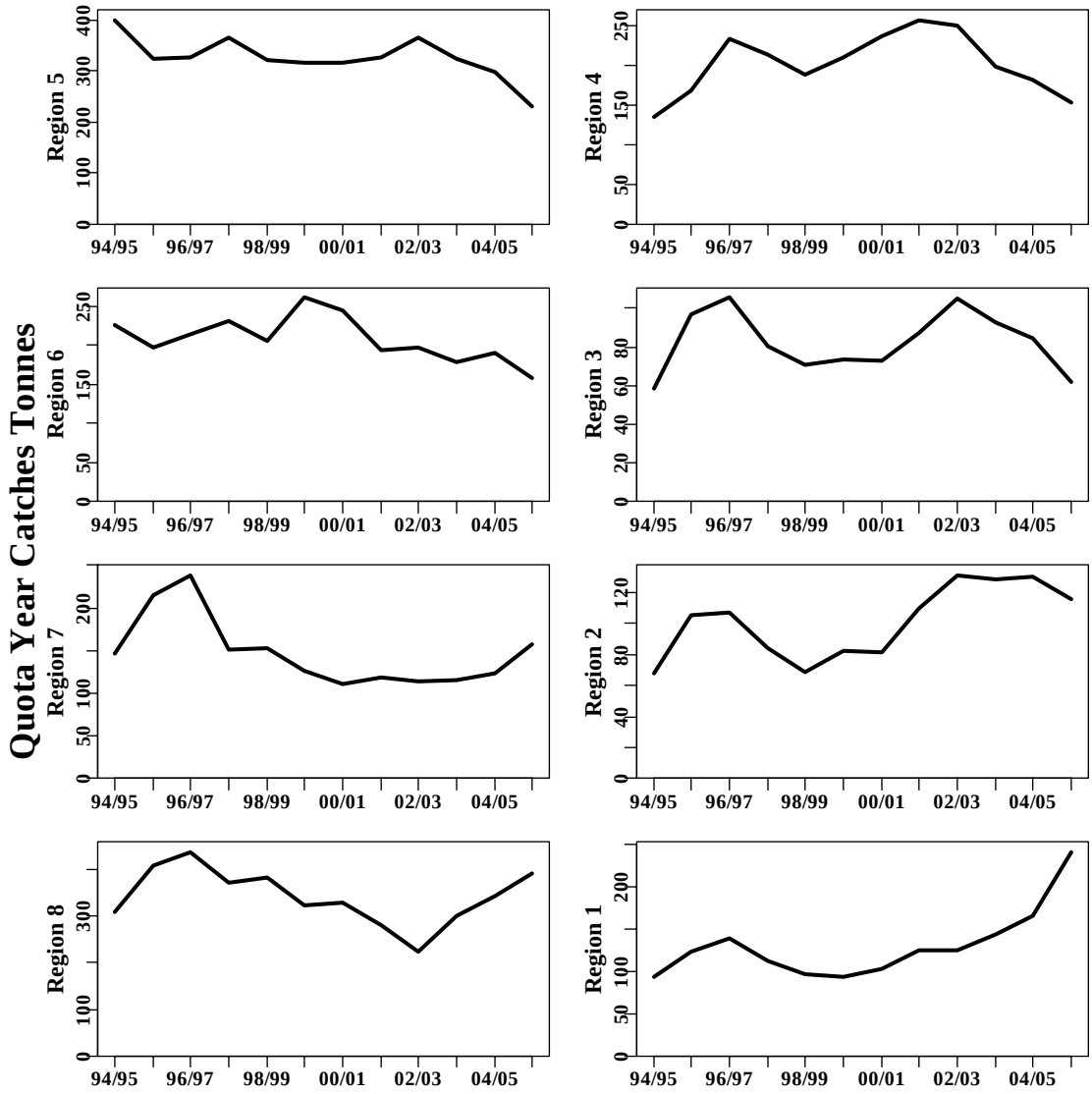

Figure 17. Total catch by quota year for the eight rock lobster assessment Areas. Note the y-axes have different scales.

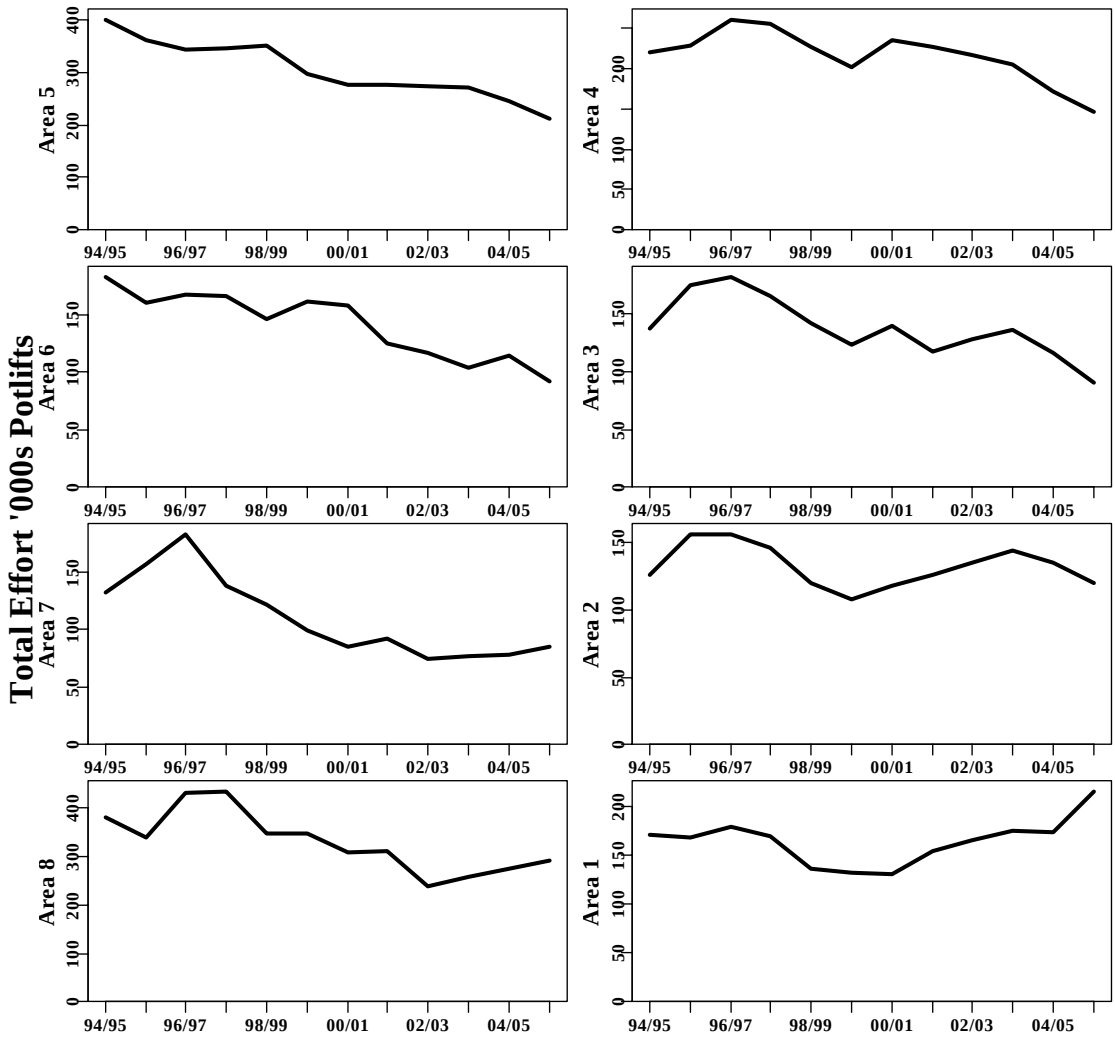

Figure 18. Annual total number of pot lifts as effort expressed in each assessment Area.

3.3.4 Trends in Depth of Fishing

Despite the relatively minor influence of depth category in the analysis of catch rate standardisation (see Appendix 1), depth clearly has an effect on catch rates as can be seen if catch rates are plotted against depth (Figure 19).

Catch rates are higher in deeper waters in Areas 4, 5, and 6 but an allocation of effort and catch to deeper waters only appears to occur in Areas 5 and 6 (Figure 19). In other areas there are slight trends in catch rates either up or down but the confidence intervals in the deeper areas are wide. When the depths are plotted as metres rather than fathoms more details are visible with Areas 1, 5, 6, and 8 exhibiting significant activity in the 50m depth category, which tends to be hidden when fathoms are used as a measure of depth (Figure 19 and Table 10). Whether this activity relates to specific middle depth reefs is unknown.

In Area 6 there have been some changes in fisher behaviour with respect to depth of operation through time (Figure 19). In all cases the number of records, the amount of effort (as pot lifts), and the amount of catch taken in 50 m or shallower has increased since the 1998/1999 quota year (the start of the quota system).

Prior to the introduction of the quota system there were signs of a shift to deeper water as catch rates and catches were higher out there. Since the introduction of quota management the trend has been towards maximizing the value of the catch rather than maximizing the catch. To achieve this new objective it is more profitable for fishers to fish in shallower waters and obtain the optimum size and colour of rock lobster desired by the markets.

Table 10. Number of records and proportion of records, effort, and catch from Area 6 in greater than 50 m and less than or equal to 50 m.

Qyear	# Records <=50M	# Records > 50M	Records %<=50M	Effort %<=50M	Catch %<=50M
1994/1995	3515	2134	0.6222	0.5595	0.4735
1995/1996	3500	1639	0.6811	0.6225	0.5719
1996/1997	3357	1848	0.6450	0.5855	0.5368
1997/1998	2770	2096	0.5693	0.5166	0.4443
1998/1999	2705	1232	0.6871	0.6467	0.5362
1999/2000	2601	1517	0.6316	0.5870	0.4689
2000/2001	2690	1298	0.6745	0.6268	0.4926
2001/2002	2242	835	0.7286	0.7001	0.5960
2002/2003	2027	695	0.7447	0.7211	0.6526
2003/2004	1981	500	0.7985	0.7769	0.6201
2004/2005	2000	655	0.7533	0.7358	0.6222
2005/2006	1532	450	0.7730	0.7733	0.7169

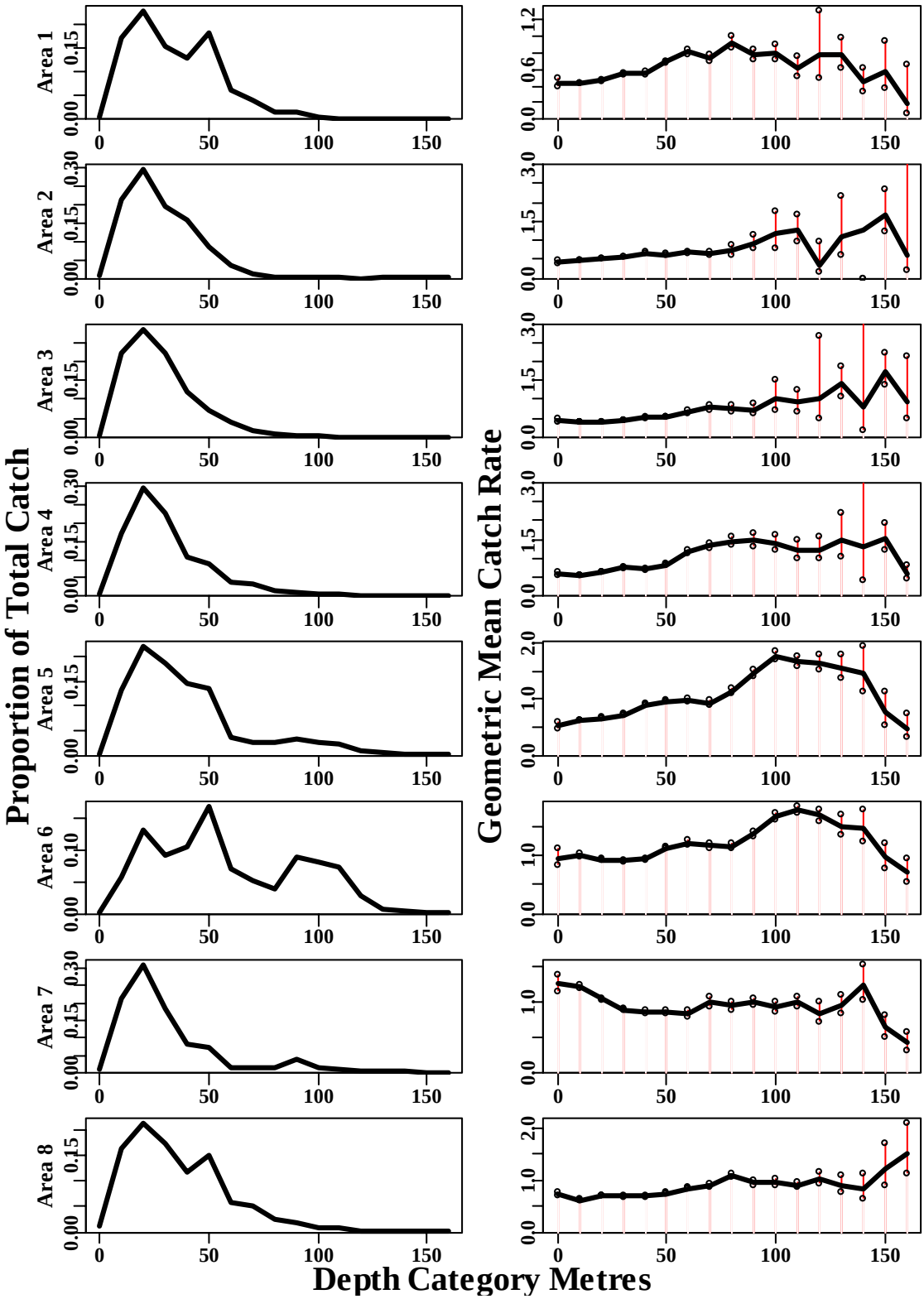

Figure 19. The proportion of the total catch and the geometric mean catch rate by depth category (10 metre steps) for each of the eight rock lobster stock assessment areas. In most Areas the catch rates in the deepest areas derive from very few data points, hence the wide 95% confidence intervals. Where the upper confidence bound is above 3.0 the graph is truncated to retain detail in the main body of the catch rate data. Data has been aggregated across all quota years from 1994/1995 to 2005/2006, but the patterns do not differ greatly between years, except in Area 6.

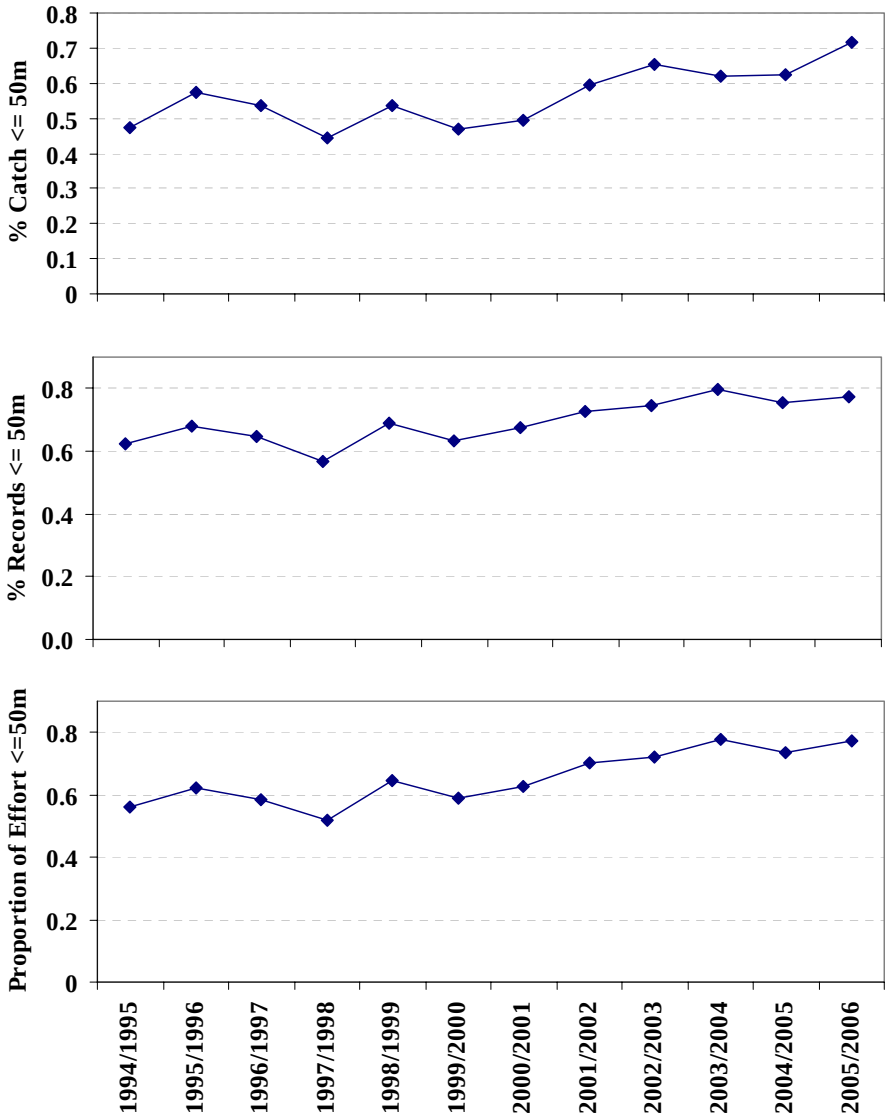

Figure 20. The proportion of effort (pot lifts), total catches, and number of records in Area 6 found in depth categories <= 50 m depth (*i.e.* <= 55 m).

3.3.5 Discussion

The behaviour of the rock lobster fleet continued to follow major trends, as depicted by the catch taken and effort applied in different assessment Areas. Catches in Areas 1, 7, and 8 continued to rise, especially in Areas 1 and 8. Catches in Area 8 were almost as high as they were in 1996/1997 whereas in Area 1 they were at their highest reported levels since before 1994/1995. In Area 2 the catches have been relatively stable over the last few years with a slight decline in the last quota year. In Areas 3, 4, 5, and 6, however, catches have continued to decline with catches in Areas 3, 4, and 5 declining relatively rapidly since 2002/2003.

These fleet dynamic changes were reflected in the catch rate indices. In Areas 1, 2, 7, and 8 the geometric mean catch rates continued to rise steeply, with the standardizations having the effect of increasing the gradients exhibited. In Areas 3, 4, 5, and 6, however, catch rates have been effectively static or declining since 2002/2003. The fleet appears to be reacting to better catch rates in the south of the State by shifting effort (and catch) south.

Although all areas have exhibited a marked improvement in catch rates since 1994/1995 the process of rebuilding appears to have stalled in the four northern assessment Areas.

It has been suggested that some high-grading of catch is occurring in parts of South Australia where very large lobsters are being returned to the water so that smaller but more valuable lobsters can be retained. This process has arisen because the lobster stocks there have recovered strongly. There are now suggestions that the same process may be occurring in parts of Tasmania, especially in Region 5, which could obscure trends in catch rates. The logbook is being redesigned to capture this information in future years.

3.3.6 Management Advice

Standardized catch rates in the southern four assessment areas remain high and this has led to a shift in effort to these areas. Catches in three of the southern areas have grown strongly (1, 7, and 8). This appears to be the result of a recruitment pulse, which implies that catch rates may drop in the future. Hence, the need for monitoring in the south remains very high.

In the northern four assessment areas, the standardized catch rates are remaining relatively stable or declining despite reduced catches in all areas. This lack of evidence for continued rebuilding in the northern four assessment Areas should perhaps be of concern. If the model predicts similar things are happening to the exploitable biomass then the concern should become real and would presumably be a reflection of relatively poor recruitment settlement in the northern Areas. Such a disparity in fishery performance between the north and the south would be likely to drive the continued radical change in fleet dynamics observable in the distribution of catches between the areas through time. If these trends continue then some form of explicit spatial management may become a necessity.

3.4 Research Catch Rates

Currently the coverage and number of observations available for characterizing catch rates from research sampling are marginal, leading to results that may not strictly be comparable from year to year. If the level of sampling can increase in the future then this performance measure may become valuable but presently it fails to provide useful information and is being omitted from the analysis.

3.5 Biomass

Estimates of legal sized biomass are produced for the start of the month of November because this reflects stocks prior to the opening of the fishing season. Estimates of legal sized biomass from the new rock lobster model continue to indicate relative stability of legal sized biomass in the four northerly assessment areas (3 – 6), whereas in the southerly assessment areas the legal size biomass continues to rise. With respect to the legal biomass present in November in 2004/05 all areas had increased in 2005/06 by a minimum of 1.2% in area 5 to a maximum of 10% in area 6 (Table 11; Figure 21).

All areas continue to show a marked increase in legal biomass relative to that estimated for the reference year. It is clear that there has been significant rebuilding, especially in areas 1 to 3. This increase appears to be associated with a recruitment pulse (Figure 22). The spikes in recruitment seen in areas 1, 7, and 8 in recent years relates directly to the success these areas are exhibiting now. Conversely, the low levels of recruitment in areas 3, 4, and 5 reflect the lowered catches and catch rates from those areas.

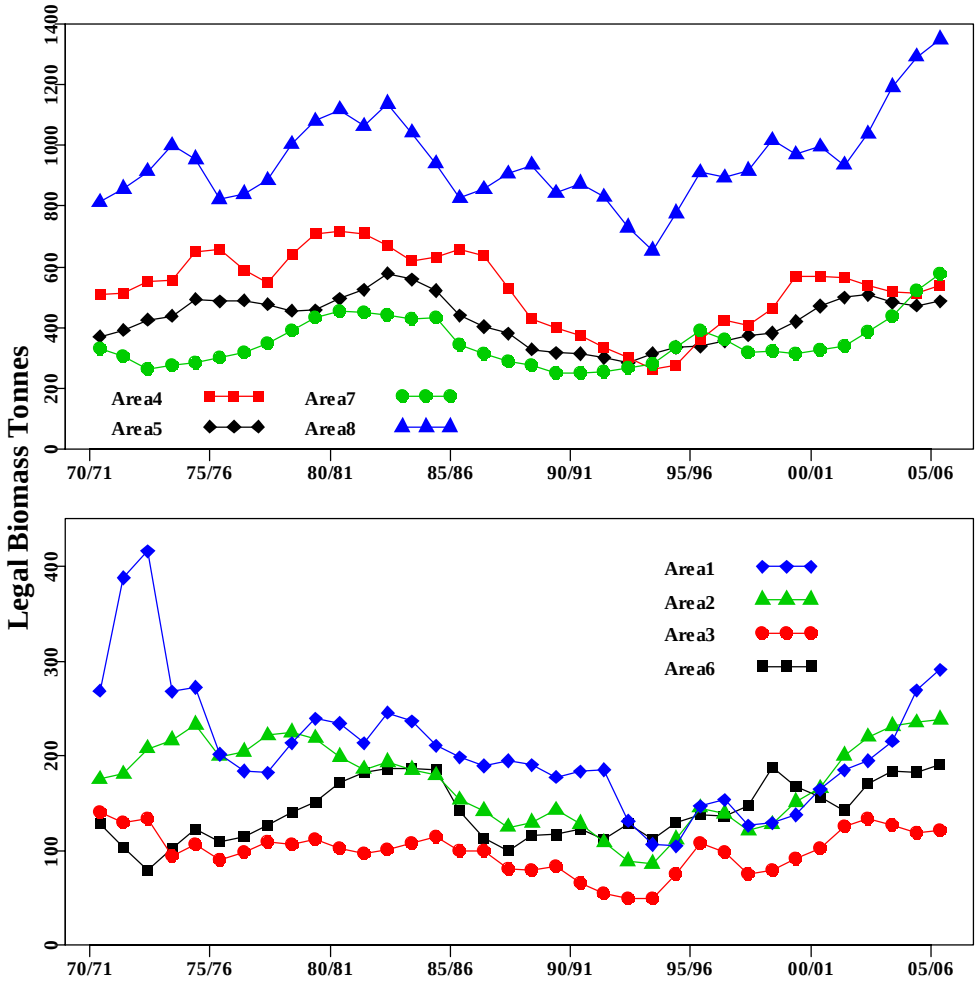

Figure 21. Legal-sized biomass estimates for the rock lobster fishery from 1970/71 to 2005/06. Note the plots have different vertical scales. Total legal-sized biomass in Areas with large amounts of reef such as Areas 5 and 8 is mainly a function of size of habitat. Note that for recent years the biomass has remained stable rather than rebuilding in areas 3, 4 and 5.

Recruitment levels in the most recent years revert back to the average due to the fact that it takes several years for new recruits to enter the fishery. Hence, for recent yers there is no catch rate data to estimate recruitment. Each area has a different time-lag between recruits entering the stock and the animals growing into legal sizes. It takes the longest in Area 8 and the shortest time in Area 4. This is why the peak in recruitment in Area 8 occurred in 1997/1998 whereas it was in 2001/2001 in Area 1, and was spread over 1999/2000 and 2000/2001 in Area 7.

Table 11. Change in legal-sized biomass in November.

Area	Ref	Sized biomass estimate (tonnes)			% change in 2005	
	Year	Ref. Year	2004	2005	vs Ref. Year	vs 2004
Statewide	1993/94	2941	5366	5624	+82.5	+4.8
1	1993/94	161	335	351	+108.1	+4.7
2	1993/94	169	357	368	+111.2	+3.0
3	1993/94	94	207	217	+120.2	+4.6
4	1993/94	534	928	969	+73.8	+4.4
5	1993/94	603	931	942	+54.4	+1.2
6	1993/94	226	352	387	+55.8	+10.0
7	1993/94	397	767	841	+93.2	+9.6
8	1993/94	757	1489	1550	+96.7	+4.1

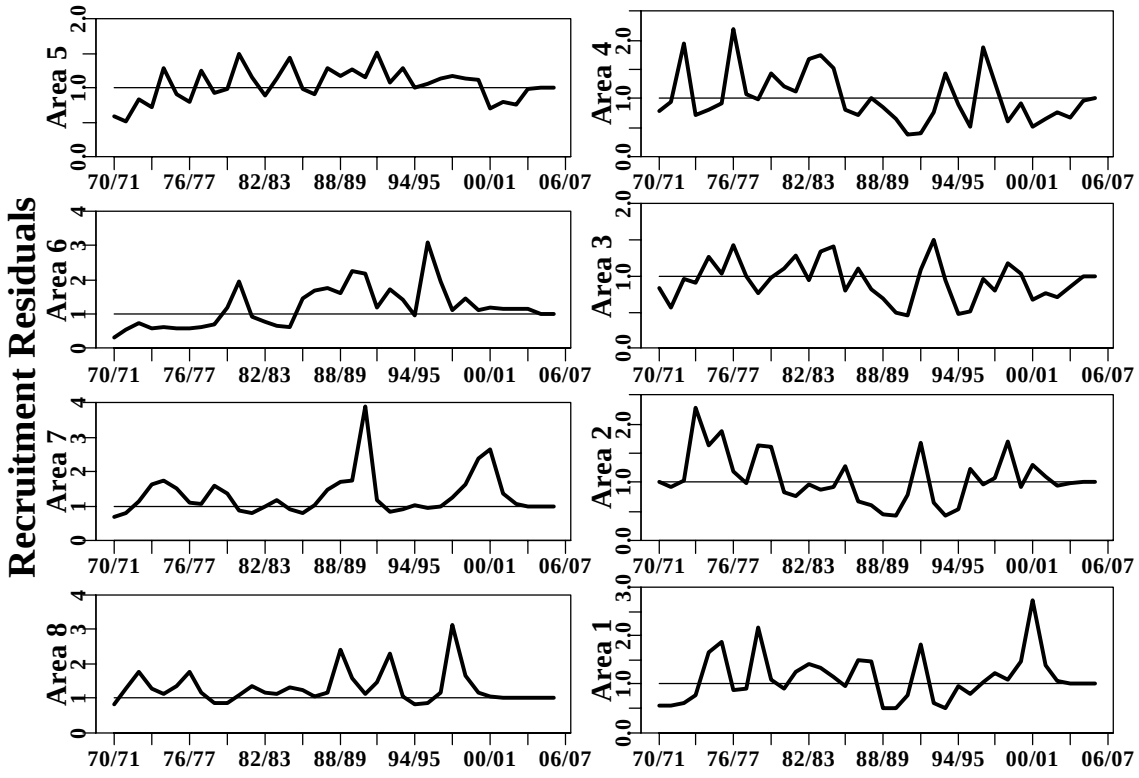

Figure 22. Recruitment residuals illustrating the relative recruitment strengths within each region through time. The absolute predicted recruitment levels are very different in the different assessment areas.

3.6 Egg production

Relative egg production has been stable for the last four years (Table 12 and Figure 23) although production declined in the 2005/06 year by about 1% (Table 12). Areas 5 and 6 declined the most in the past quota year, -3.2 and -5.5% respectively. This is more significant in Area 5 than Area 6 although both areas are producing less than 25% of virgin egg production.

Egg production remains most depleted in the four northern Areas (3, 4, 5, and 6). All northern Areas have improved levels of egg production relative to the reference years, by 30% or more, but this was typically off a very low base (Table 12). The overall improvement across the State is only about 11 % since 1993/94 because so much egg production is by sub-legal females in the south that are unaffected by changes in management (Table 12).

All four northern Areas remain below the threshold of 25% of virgin egg production, though for Areas 3, 4 and 6 this is only just below 25%. The target of a minimum of 25% is based upon observations and management targets in other lobster fisheries. Unfortunately, the exact level of egg production at which a stock is more likely to collapse is unknown until it collapses. Because it is unknown which areas contribute most significantly to the recruitment dynamics of the stock there remains concerns about the northern four areas remaining below 25% of virgin production.

The value of egg production as a guide for management is often debated by industry as there is uncertainty about the fate of larvae produced in different regions. This issue was addressed in an FRDC funded project that was completed in 2005/06. It showed that although larvae could self-recruit to most regions around Tasmania, the relative importance of areas differed. Eggs produced in the NW had lowest probability of contributing to stocks as they could be lost into the shallow waters of Bass Strait. Larval production from outside Tasmania was also important, especially that produced in SE South Australia.

There is also debate about the appropriate target level for egg production. The 25% target used in Tasmania is different to that used in Victoria (20%) and South Australia (no formal limit, but management consider the current level of ~12% to be acceptable).

Table 12. Statewide and regional egg production.
Virgin egg production is the estimated egg production prior to commercial exploitation, assuming average recruitment is the same as that from 1970 to the present. Relative egg production is a numerical (linear) index of egg production so that a relative egg production of 200 implies twice as many eggs are being produced compared to a relative egg production of 100. It is not a measure of the absolute number of eggs produced.

	Ref.	Relative Egg Production			% Change vs		% Virgin Prod.
Area	Year	Ref. Year	2004/05	2005/06	Ref. Year	2004/05	in 2005/06
Statewide	1993	1925	2136	2137	+11.0	+0.05	51.6
1	1994	203	238	238	+17.2	0.0	78.2
2	1992	101	151	151	+49.5	0.0	51.2
3	1992	48	68	69	+41.7	1.47	24.2
4	1993	112	167	170	+49.1	1.80	23.3
5	1992	71	137	135	+93.0	-1.46	14.4
6	1986	54	94	98	+74.1	4.26	22.7
7	1988	250	365	361	+46.0	-1.10	90.1
8	1994	991	1030	1016	+3.9	-1.36	106.22

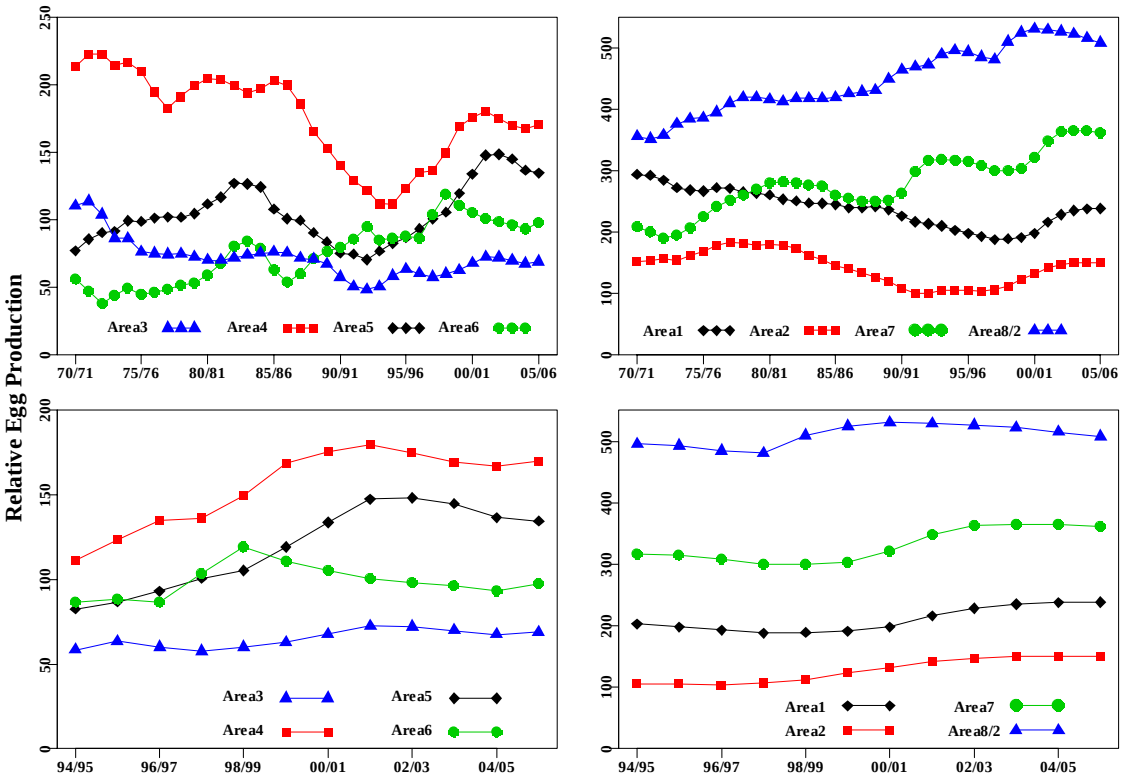

Figure 23. Relative egg production around Tasmania, northern Areas to the left, and southern Areas to the right. Area 8 was included by dividing each value by 2 to keep it on the same scale.

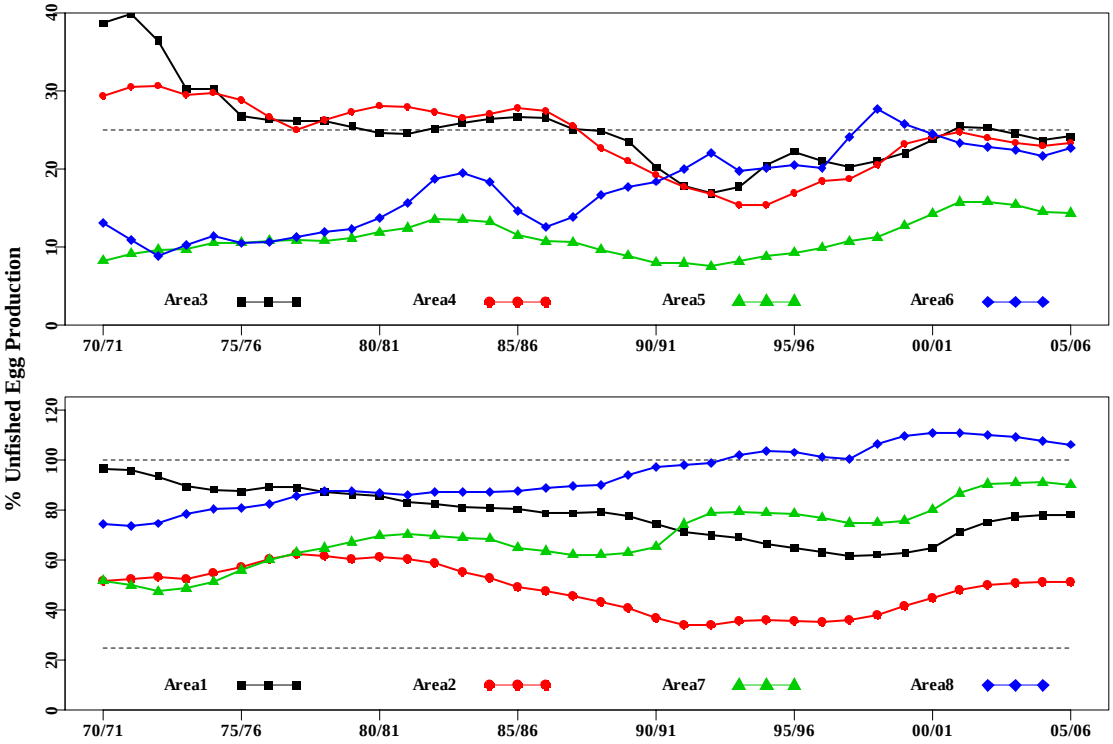

Figure 24. Percentage of virgin (unfished) egg production from eight Areas around Tasmania, southern Areas in the bottom panel, northern Areas in the top panel. The horizontal dashed line in each plot represents the management target of 25%, in the bottom panel 100% also indicated.

Although the mature biomass has been reducing Statewide for the last few years (Figure 25) the total egg production has increased very slightly. This is because the exact size distribution of females also influences exactly how many eggs are produced (Figure 26).

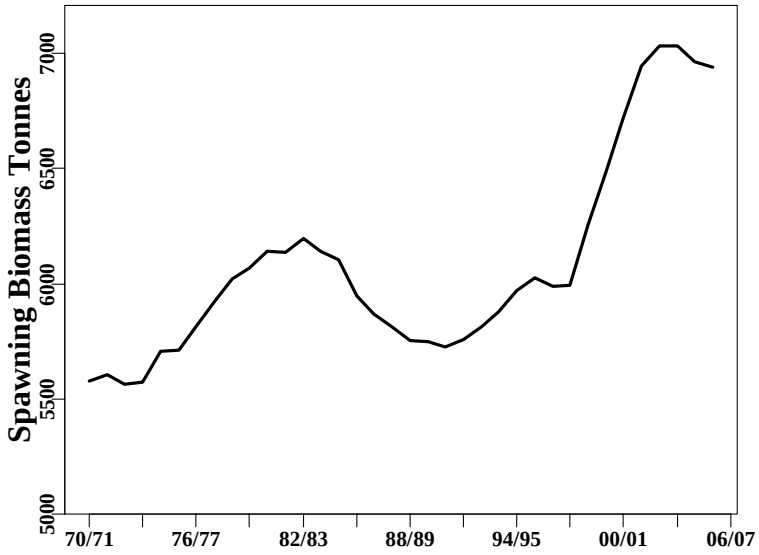

Figure 25. Total State-Wide female spawning biomass at the end of the October period.

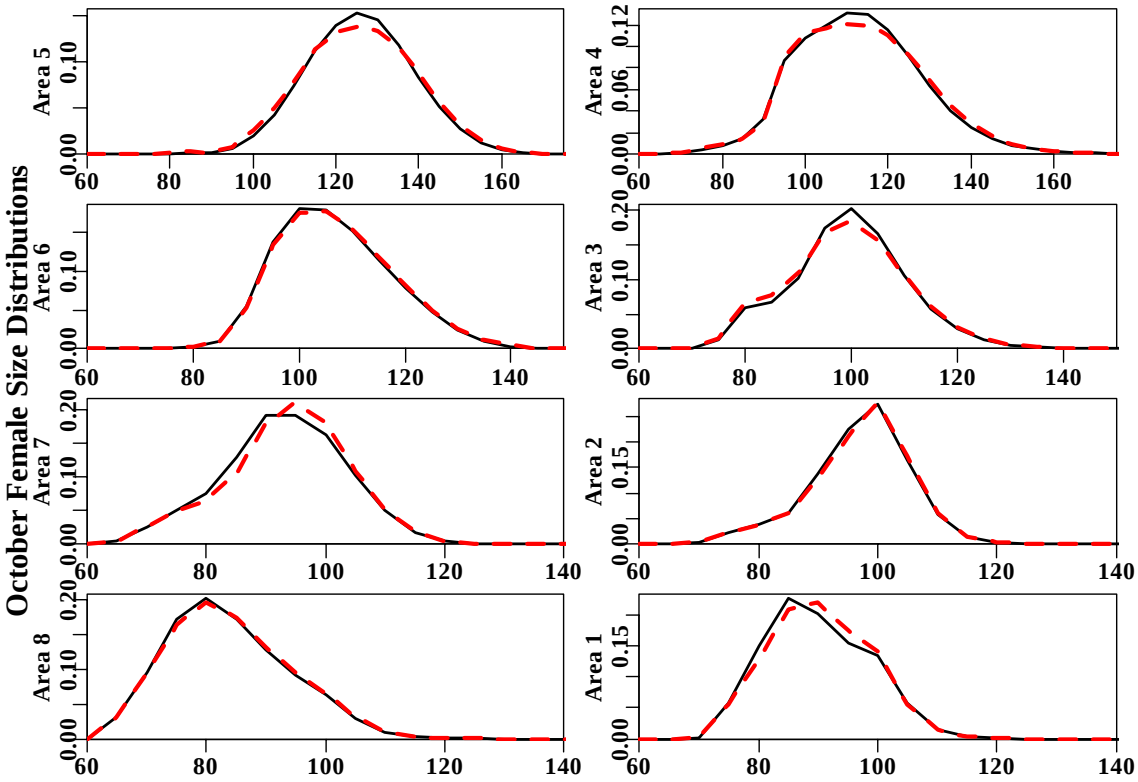

Figure 26. Female size distributions for 2004/2005 (fine solid line) and 2005/2006 (thicker dashed line). The balance between increases or decreased relative abundance and the fecundity at size is what changes the relative egg production.

3.7 Active Licenses

The number of active licences is assumed to be less than or equal to the number of active vessels (defined as those vessels reporting any catches of rock lobster). A Limit Reference Point of 220 active licences has been put into place and the number of vessels reporting any catches was 224 in 2005/2006 (Figure 27; Table 22).

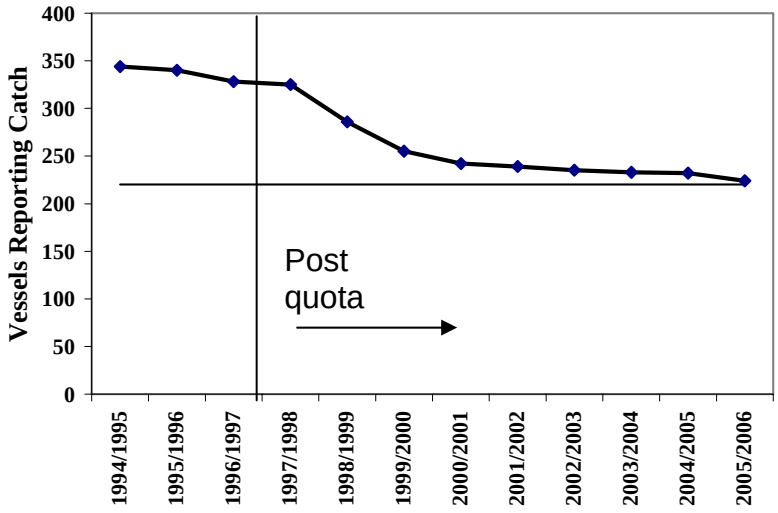

Figure 27. Number of vessels around the State reporting any rock lobster catch. The fine black line is the Limit Reference Point (220), the number reporting in 05/06 was 225.

Table 13. Number of active vessels reporting any catch of rock lobsters across the State.

Quota Year	Total
1994/1995	344
1995/1996	340
1996/1997	328
1997/1998	325
1998/1999	286
1999/2000	255
2000/2001	242
2001/2002	239
2002/2003	235
2003/2004	233
2004/2005	232
2005/2006	224

3.8 Mean Weight

The mean weight of lobsters in catches has slowly been increasing through time since minimum values occurred sometime between the mid-1990s and the late 1990s (Figure 28). This is a complex performance measure to interpret because a reduction could be due to both overfishing of larger lobsters or the influx of large numbers of recruits.

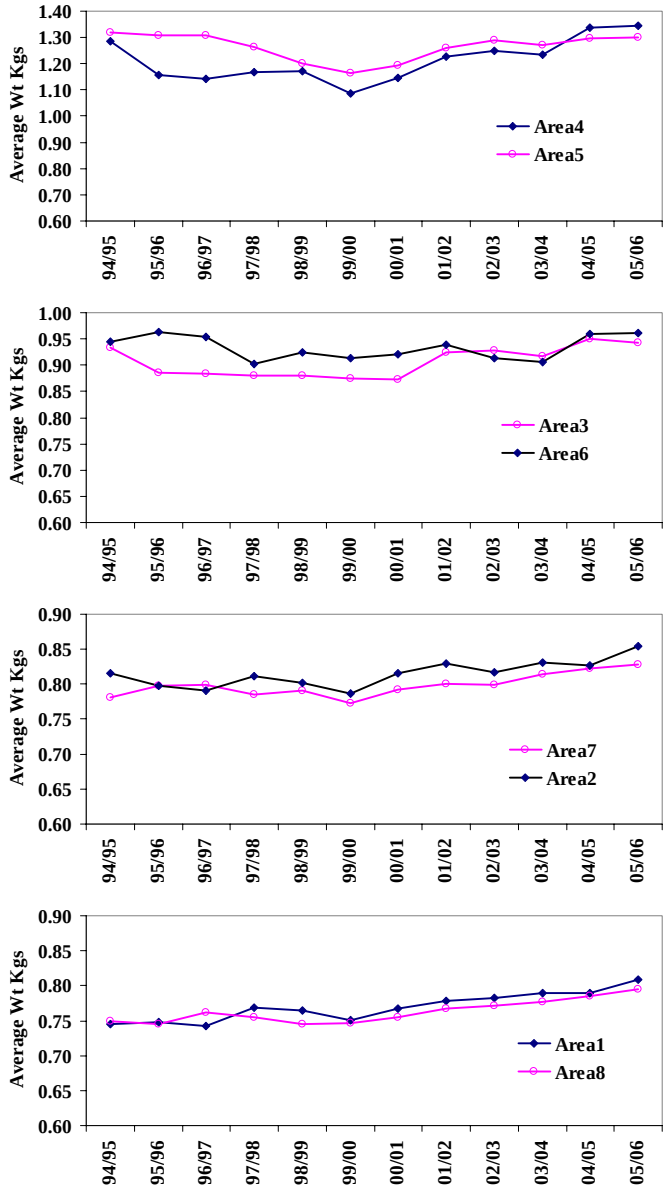

Figure 28. Average weight as kg, by each quota year and assessment area. Each latitudinal pair of assessment areas are illustrated on separate graphs. Since a minimum in each assessment areas during 1999/2000 there has been a slow increase in average weight in each area.

3.9 Recruitment monitoring

Settlement of puerulus is monitored at several sites around the Tasmanian coast as part of TAFI's pre-recruit monitoring program. Puerulus collectors are designed to mimic natural rocky reef with crevices that provide shelter for puerulus swimming in to shore from oceanic waters. These collectors have been deployed at Recherche Bay (Area 1), South Arm (Area 2), Bicheno (Area 3) and Flinders Island (Area 4). Several attempts have been made to establish sites on the west coast; however, all of these attempts have failed due to low catch rates.

The objectives of the puerulus monitoring project are to provide a measure of recruitment of juveniles into the population. This information has a number of potential benefits including early warning of large increases or declines in settlement, an improved basis for future projections of the assessment model, and contributing to an improved understanding of larval sources.

Catch rates of puerulus at east coast sites have been at record lows for the last three years (Figure 29 and Figure 30). This suggests that rebuilding on the east coast will slow and that trends in the fishery will be less positive than indicated in the risk assessment shown in Section 4.

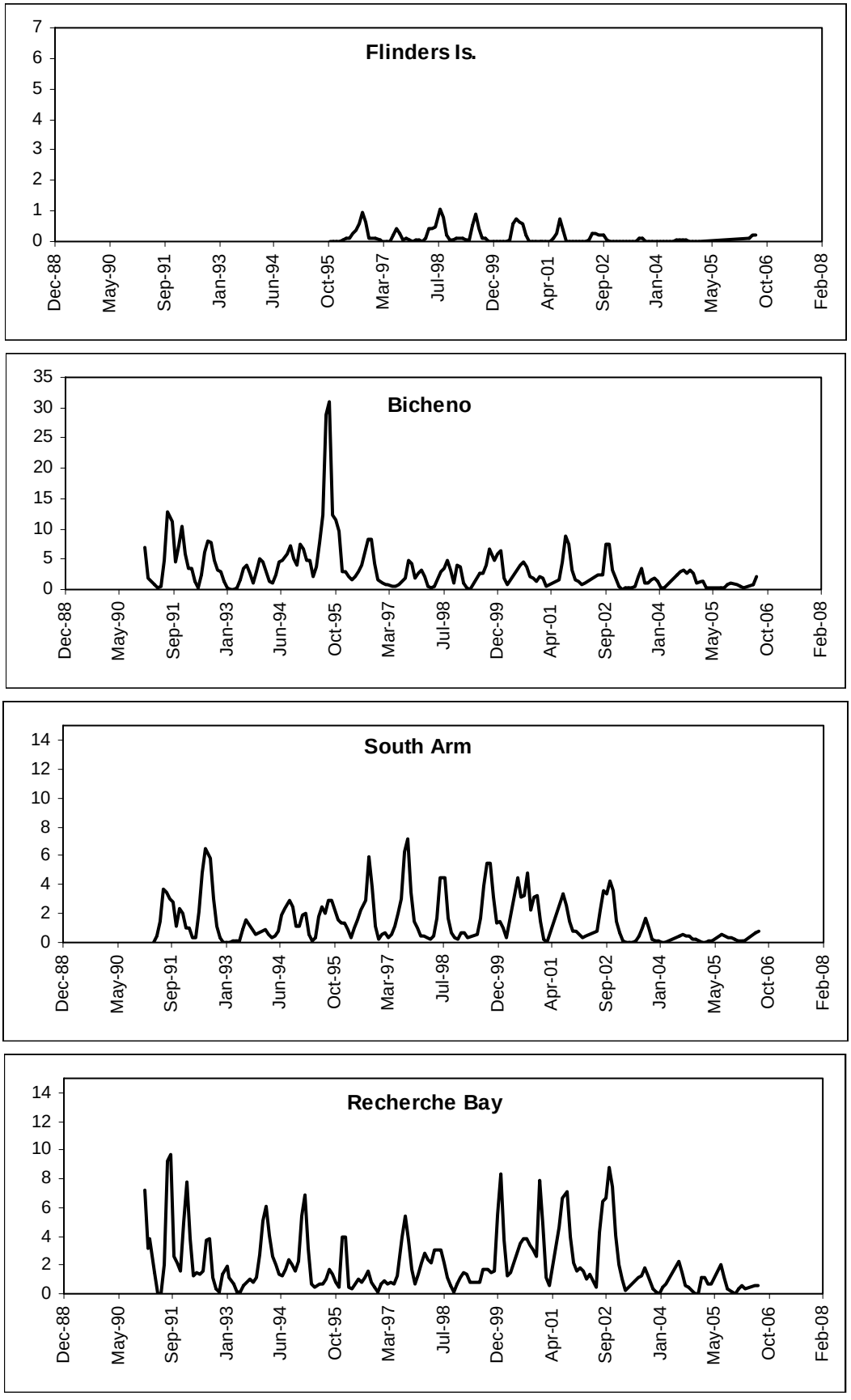

Figure 29. Puerulus catches from long term monitoring sites. Values are the 2-month rolling average of average catch rate of puerulus per collector per site.

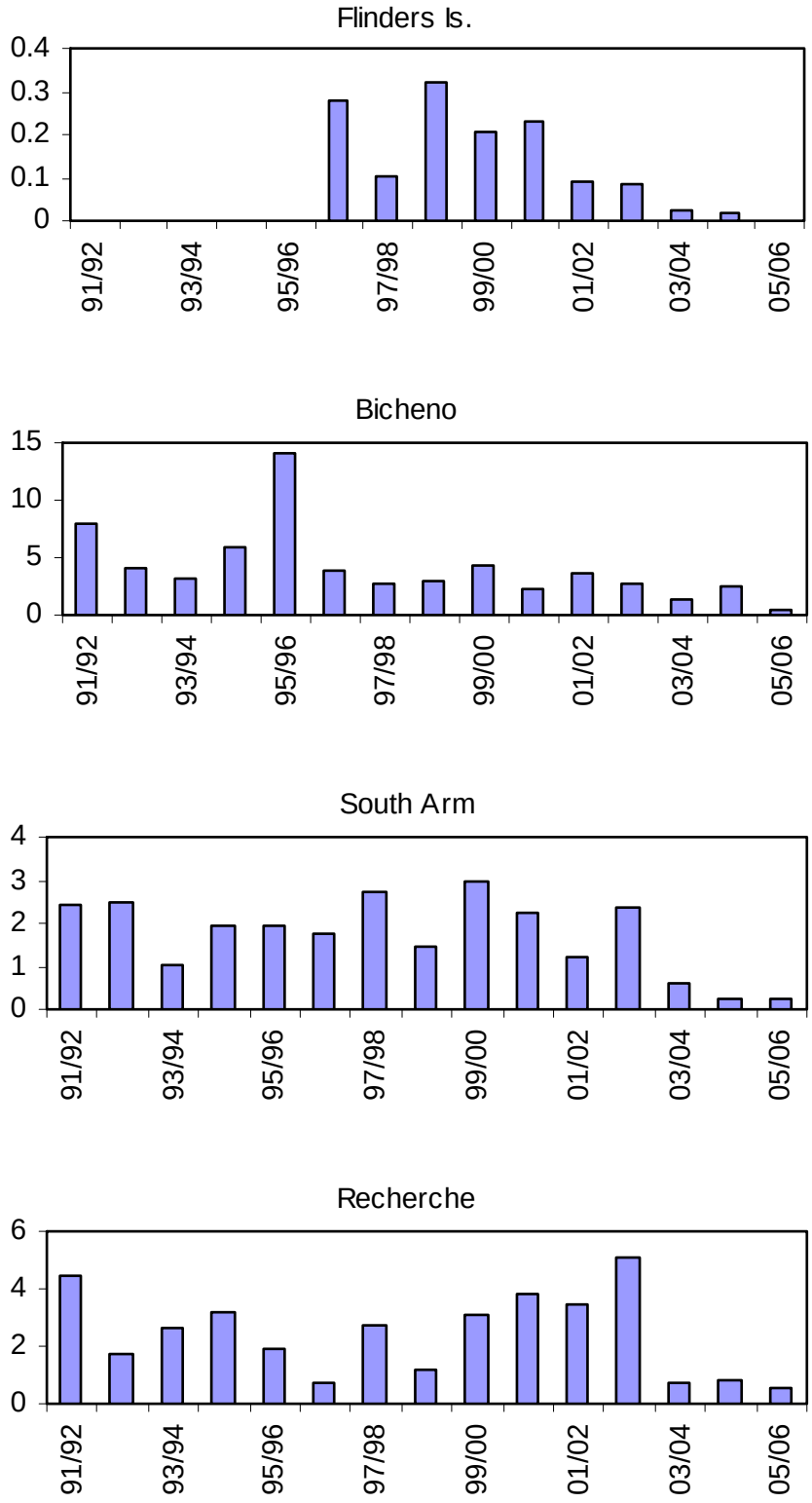

Figure 30. Yearly average puerulus catch rates for east coast sites. Catch rates are for the high catch period July to February only. Note that settlement has been at record lows for the last three years for each site.

4 Risk Assessments

4.1 Biomass

Risk assessment of the fishery is conducted by first producing a randomised recruitment series based on previous observed recruitment levels. The stock is then forward projected under different TAC arrangements. If this process is repeated many times it becomes possible to ask about what proportion of the projections indicate that the legal biomass in 2010/11 will be greater than or equal to the legal biomass in 2005/06, given a particular TAC. If the result is 50% or less this suggests that the chance of continued stock rebuilding is equal to or less than the chance of the stock declining (Table 14).

Table 14. Probability of the legal sized biomass in 2010/2011 being greater than the legal biomass available in 2005/06 with a TAC at the current level of 1523 t.

Assessment Area	Probability of $B_{2010/11} > B_{2005/06}$ (%)
Area1	86.8
Area2	66.0
Area3	63.6
Area4	92.8
Area5	79.2
Area6	59.6
Area7	100.0
Area8	96.8

The modelling process also needs to consider how the catch will be distributed around the State. The current strong trends in the fleet dynamics are being driven by singular recruitment events in the south combined with a lack of recruitment in the north, but the projections rely on average recruitment patterns and do not necessarily reflect the particular pattern presently seen (Figure 22). Whether future recruitment really will reflect the average behaviour exhibited over the last decades will only be known after it has happened. However, the puerulus sampling project has failed to find significant numbers of puerulus on the east coast for at least the last 3 to 4 years. This means that the projections may well be overly optimistic.

Statewide legal biomass appears likely to continue to rebuild over the next five years (Figure 31). However, this need not be the case in every assessment area (Figure 31 and Figure 32). Note that in the projections for the individual assessment areas the 90% percentile confidence intervals tend to be wider reflecting the greater uncertainty when only single areas are considered. In many cases the lower bound includes the possibility of the stock becoming smaller rather than larger.

The model outputs suggests that in all assessment areas the chance of the stock in 2010/11 being greater in size than the 2005/06 quota year is always greater than ~60% (Table 14), with some areas exhibiting much higher chances, especially areas 4, 7 and 8. The areas with lowest probability of rebuilding are areas 6, 2 and 3. Part of the reason for the lower value in area 6 is that recruitment variability in that area is greater than elsewhere. This is a result of the expansion of the fishing grounds into deeper water in the mid-1980s. The model interpreted this as a simple increase in stock size and could only account for this by increasing the apparent recruitment levels. While Table 14 suggests that there is a high likelihood of stock rebuilding in all areas with the current management strategy, it is important to note that the model outputs have historically erred towards more positive predictions.

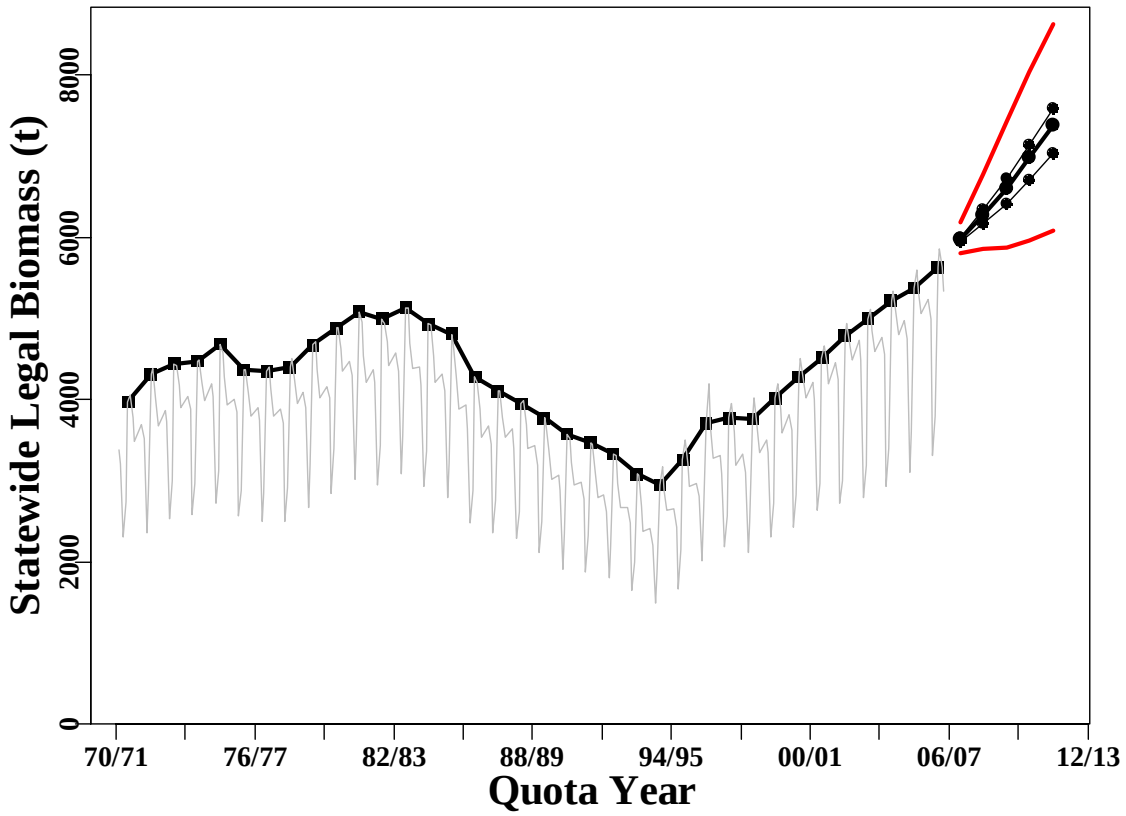

Figure 31. The State-wide legal biomass in tonnes at the end of November from 1970/1971 to the present and projected forward five years until 2010/2011. The outer projection lines are the upper and lower 90% percentile confidence bounds on stock size (from TACS of 1,475 t and 1,600 to respectively. The central thick line is the expected median legal biomass with the current TAC of 1,523t, while the finer lines either side relate to TACs of 1,475 t (upper) and 1,600 t (lower). The fine grey line relates to Legal Biomass throughout each quota year.

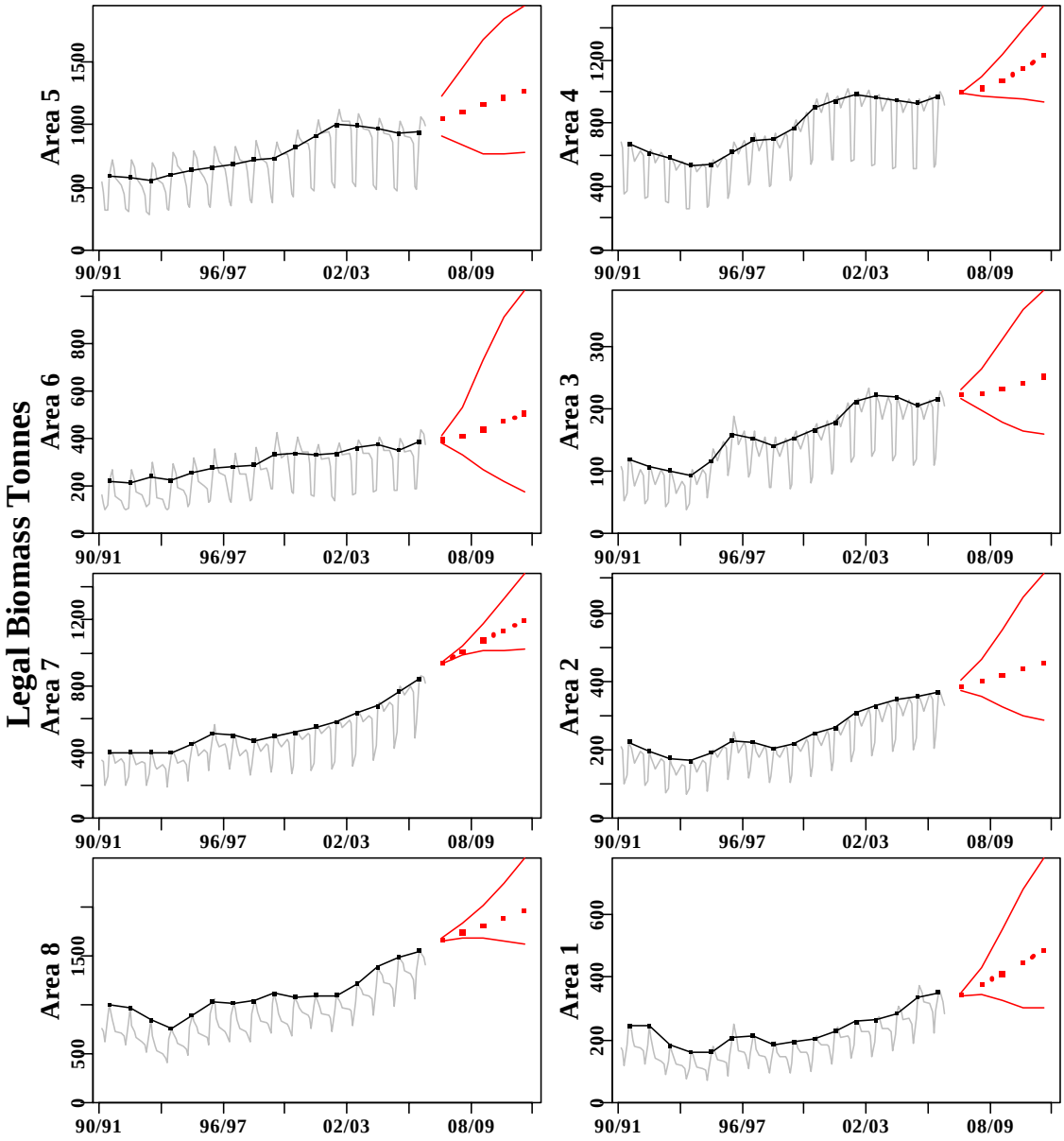

Figure 32. Risk assessment projections of legal biomass of Tasmanian rock lobster for the more recent quota years and all assessment areas. The points in the historical portion represent the November legal biomass. The projected points represent the median predicted legal biomass and the fine lines surrounding these are the 90% percentile bounds on predicted legal biomass given a TACC of 1,523 t. The fine grey line represents the exploitable legal biomass in all eight periods of each quota year.

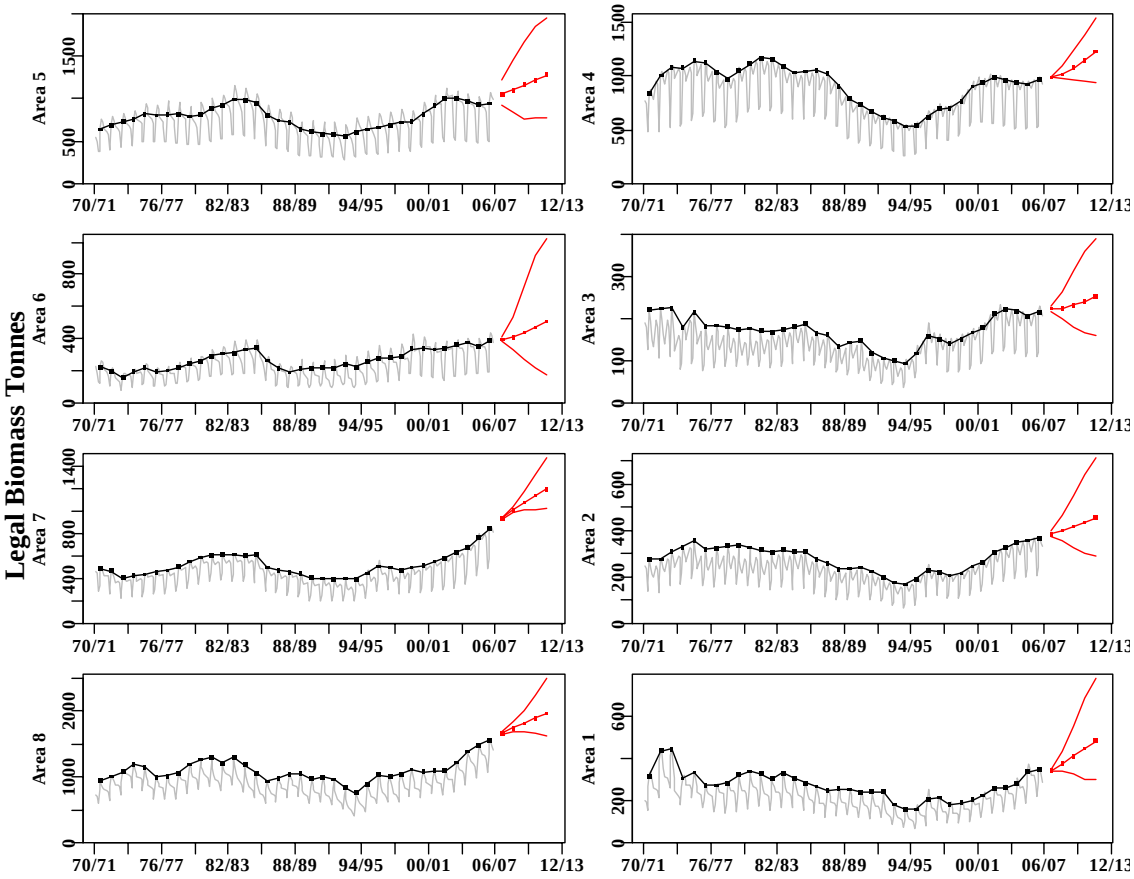

Figure 33. Legal Biomass at the end of November each quota year combined with five years of projection under a TAC of 1,523 t. This repeats information shown in Figure 32 but over a longer time series.

Table 15. Estimated probability (%) that the legal biomass at the end of November in 2010/2011 will greater than the legal biomass at the end of November in 2005/2006 under different conditions of Total Allowable Catch (TAC).

The fleet dynamics are assumed to be the average behaviour of the fleet in the last four years. Values less than 60% are bolded.

Area	TAC 1475	TAC 1500	TAC 1523	TAC 1550	TAC 1600
1	89.6	87.6	86.8	83.2	79.2
2	72.0	70.4	66.0	64.8	**59.6**
3	70.8	66.8	63.6	**57.6**	**48.0**
4	95.2	94.4	92.8	91.6	89.2
5	86.8	83.2	79.2	76.0	69.6
6	63.2	62.0	**59.6**	**57.6**	**53.2**
7	100.0	100.0	100.0	100.0	100.0
8	98.0	97.2	96.8	95.6	92.4

5 Ecosystem Based Management

5.1 Protected Species Interactions

This is the second year for which protected species reporting was available through the commercial logbooks. Reporting for other sectors is more ad-hoc and no interactions with protected species have been reported from other sectors in the lobster fishery over the assessment period. The number of reported interactions increased slightly from the previous year (263 vs 237, Figure 34).

Unfortunately the quality of protected species data has declined. In 2004/05, 26% of fishers who reported an interaction provided details of the species and nature of interaction. In 2005/06 only 19% of records included any information on the interaction.

On the occasions when a detail of the interaction was recorded, they always involved seals. In half of these interactions (25 of 49) it appeared that the seal was not harmed.

No interactions with protected bird, reptile or fish species were reported in commercial logbooks. This appears to be a function of reporting as a small number of pied cormorants have been killed in pots recorded in research sampling each year for the last decade (averaging 0.9 per annum from research trapping).

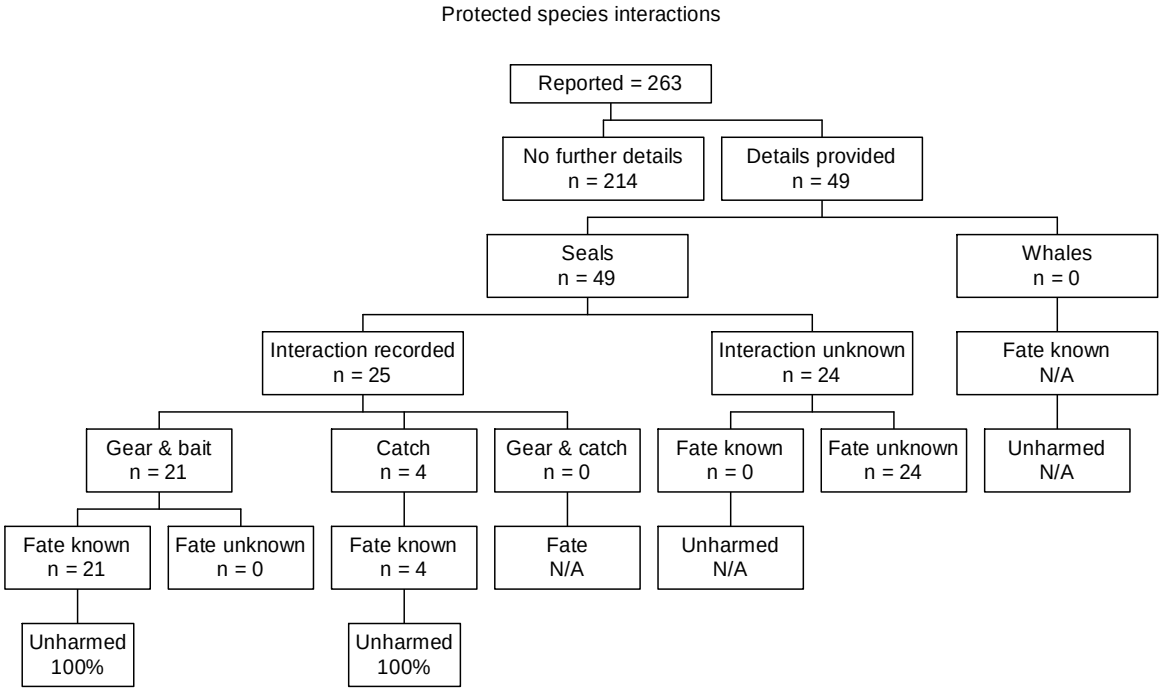

Figure 34. Schematic of reported interactions between commercial fishers and protected species.

Although current records of protected species interaction are of little value, an attempt is being made to improve the reporting in a revised logbook. A factor contributing to the poor quality of this data is uncertainty about what needs to be recorded. There is uncertainty about taxa covered; for example, in 2005/06 many fishers recorded events where seals ate discarded bait, yet none recorded the same interaction with seabirds. Likewise there is uncertainly about the type of interaction that needs to be recorded – does this include consuming discarded bait, removing bait from traps, or only entanglement in traps?

5.2 By-catch Survey Results

By-catch in research lobster traps have been recorded in Tasmania as part of annual catch sampling trips since 1992. These records provide valuable information on spatial diversity and trends associated with by-catch levels. Bycatch trends have been reported each year. In this report a summary is presented from a research project that investigated trends at three long term research sites. The research is reported more fully elsewhere (report available from TAFI).

By-catch abundances from 4867 lobster traps set at two east coast sites and one south west coast during October-November 1992-2000 and 2001-2004 were investigated in a study of inter annual trends (Figure 35). A total of 36919 by-catch individuals were recorded (Table 16). For the analysis by-catch was grouped in size classes and species contribution to classes calculated.

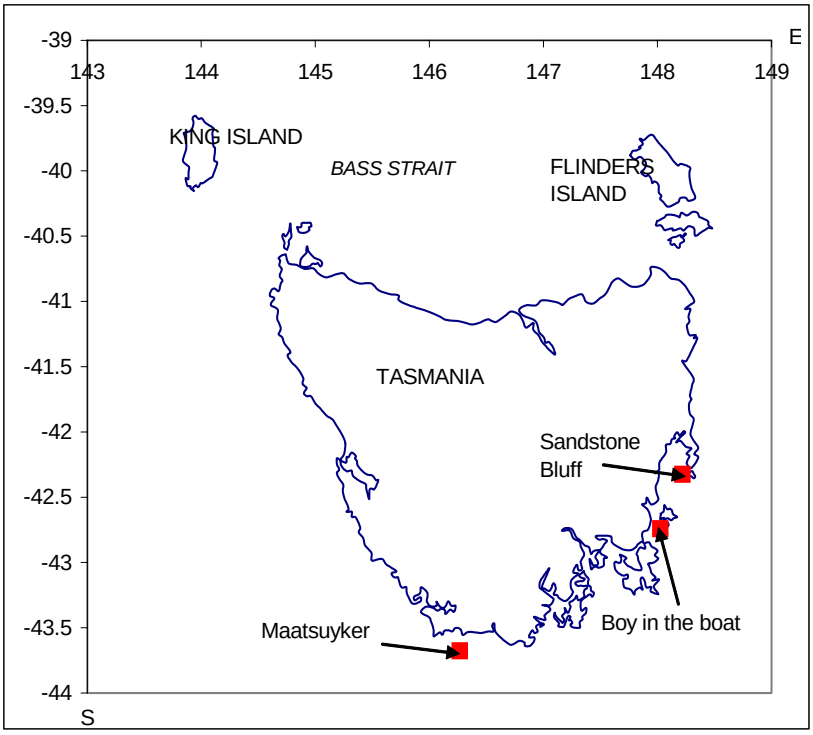

Figure 35. Sites included in the bycatch analysis study conducted in 2005/06: Maatsuyker, Boy in the boat and Sandstone Bluff.

The study indicated both temporal and spatial differences in type and amount of by-catch. Spatial differences were the result of habitat and depth differences. Temporal differences were a result of trap catchability and abundance changes due to recruitment and selectivity (Figure 36). To investigate lobster catch sampling as a possible monitoring tool for species found as by-catch, abundance trends of four species (Barber Perch, Blue-throat Wrasse, Purple Wrasse and Rosy Wrasse) in lobster traps were compared with abundance trends from dive surveys. Trends were only apparent for Purple Wrasse.

Table 16. Numbers caught and percent contribution for by-catch species at the three sites over the entire sampling period.

Site	Sandstone Bluff		Boy in the Boat		Maatsuyker		Total	
Species	Number caught	Percent contribution	Number caught	Percent contribution	Number caught	Percent contribution	Number caught	Percent contribution
Hermit Crab	**21036**	78.00%	**6416**	73.49%	**808**	66.18%	**28260**	76.55%
Rough Rock Crab	**2979**	11.05%	**1067**	12.22%	**81**	6.63%	**4127**	11.18%
Rosy Wrasse	**471**	1.75%	**181**	2.07%	**23**	1.88%	**675**	1.83%
Degen's Leatherjacket	**557**	2.07%	**27**	0.31%			**584**	1.58%
Barber Perch	**446**	1.65%	**78**	0.89%	**9**	0.74%	**533**	1.44%
Southern Conger Eel	**272**	1.01%	**144**	1.65%	**51**	4.18%	**467**	1.26%
Red Gurnard Perch	**375**	1.39%	**38**	0.44%	**10**	0.82%	**423**	1.15%
Blue Throat Wrasse	**182**	0.67%	**182**	2.08%			**364**	0.99%
Purple Wrasse	**14**	0.05%	**232**	2.66%			**246**	0.67%
Draughtboard shark	**89**	0.33%	**32**	0.37%	**116**	9.50%	**237**	0.64%
Brown-striped Leatherjacket	**151**	0.56%	**63**	0.72%			**214**	0.58%
Octopus	**108**	0.40%	**50**	0.57%	**46**	3.77%	**204**	0.55%
Rock Cod	**80**	0.30%	**45**	0.52%	**37**	3.03%	**162**	0.44%
Cleft Fronted Shore Crab	**13**	0.05%	**81**	0.93%			**94**	0.25%
Morwong	**62**	0.23%	**14**	0.16%	**1**	0.08%	**77**	0.21%
Toothbrush Leatherjacket	**50**	0.19%	**20**	0.23%			**70**	0.19%
Velvet Leatherjacket	**35**	0.13%	**16**	0.18%	**1**	0.08%	**52**	0.14%
Butterfly Perch	**35**	0.13%	**4**	0.05%	**1**	0.08%	**40**	0.11%
Senator Wrasse	**1**	<0.005%	**29**	0.33%			**30**	0.08%
Spider Crab	**1**	<0.005%			**18**	1.47%	**19**	0.05%
Giant Tasmanian Crab	**2**	0.01%	**1**	0.01%	**8**	0.66%	**11**	0.03%
Catshark	**1**	<0.005%	**1**	0.01%	**6**	0.49%	**8**	0.02%
Mosaic Leatherjacket	**3**	0.01%	**5**	0.06%			**8**	0.02%
Crab unidentified	**3**	0.01%					**3**	0.01%
Sponge Crab					**3**	0.25%	**3**	0.01%
Rosy Perch			**2**	0.02%			**2**	0.01%
Gummy Shark					**1**	0.08%	**1**	<0.005%
Ling					**1**	0.08%	**1**	<0.005%
Pie Crust Crab			**1**	0.01%			**1**	<0.005%
Port Jackson shark	**1**	<0.005%					**1**	<0.005%
Rock Ling			**1**	0.01%			**1**	<0.005%
Southern Cardinal Fish	**1**	<0.005%					**1**	<0.005%
Total	**26968**		**8730**		**1221**		**36919**	

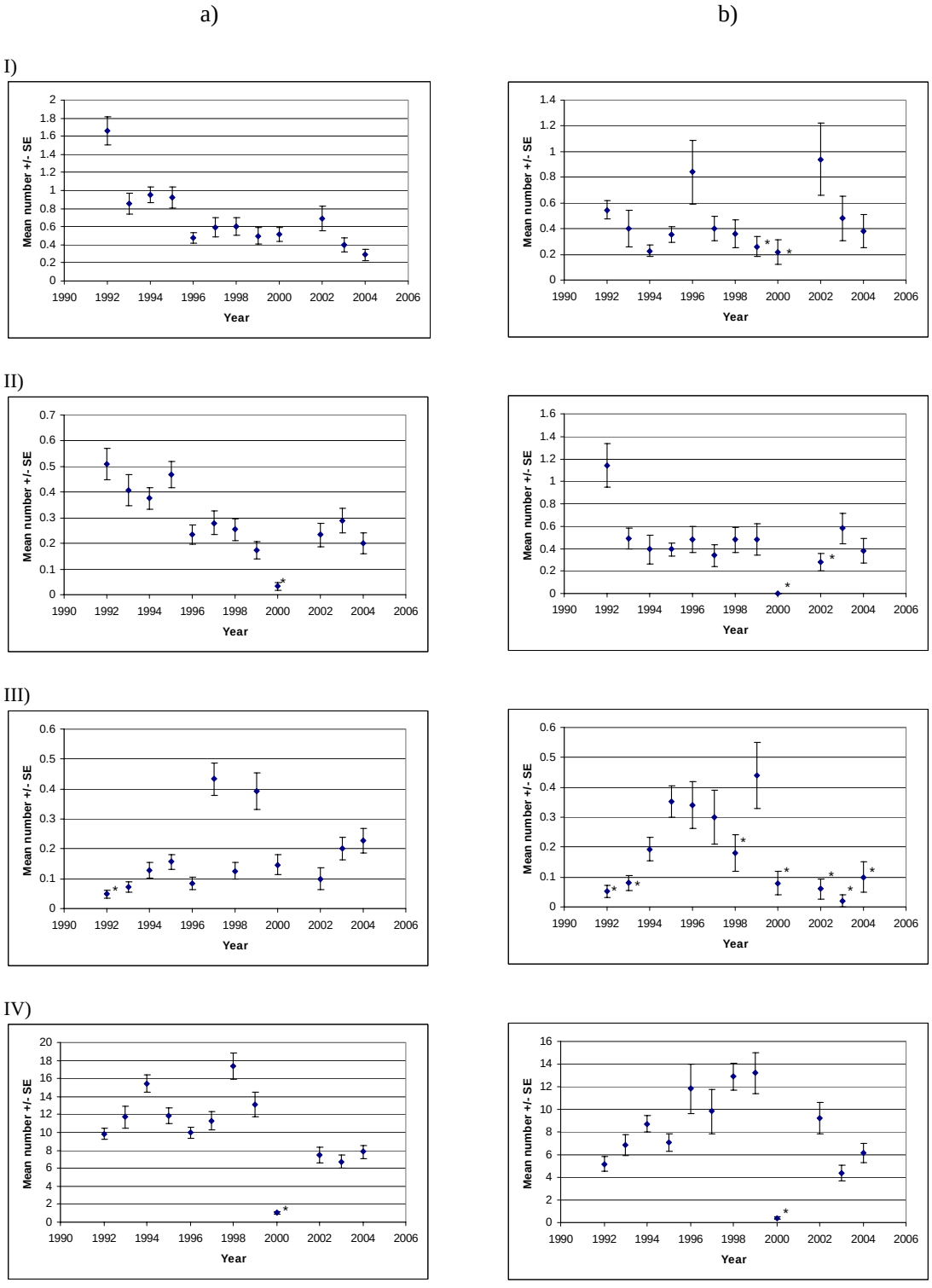

Figure 36. Mean catch rate (#/trap lift) +/- SE of I) Small fish, II) Medium fish, III) Large fish and, IV) Small crabs at Sandstone Bluff (a) and Boy in the Boat (b) from 1992-2000 and 2002-2004. * for catch <15 (Small, Medium and Large), < 200 (Small crabs).

5.3 Byproduct

Seventeen taxa were reported as byproduct from rock lobster pots, although this under states the number of species with several grouped under categories such as leatherjackets and wrasse. All reported byproduct was of a trivial volume, the largest being octopus, which averages around 2.5 t per annum (Table 17).

An analysis of byproduct captured in research pots versus that reported by the fishery demonstrates that under-reporting occurs on a large scale, especially for animals used as bait. For example, research sampling indicates that around 100 t of blue throat wrasse are likely to be captured by fishers, yet only 240 kg are reported on average each year as by-product (around 1 kg per vessel per annum).

There appears to be two sources to this problem. First, many fishers believe that catch only needs to be recorded if it's sold. Secondly, the recording of byproduct in a separate general fish logbook complicates data recording for fishers. Both these problems are being addressed by altering the rock lobster log book to include bycatch, with specific mention of the use of byproduct as bait.

Table 17. Estimated bycatch and byproduct relative to reported byproduct.
Bycatch data was obtained from research catch sampling. This was scaled up to estimated annual commercial catch on the basis of pot lifts. While there was no account of spatial differences between research and commercial data, the results demonstrate under-reporting of byproduct. This relates to the use of bycatch as bait and is being addressed through a combined log book.

	Research RL trap bycatch		Estimated commercial RL trap bycatch	Reported retained catch (t) (Ave. 2000-2005)	
Species	**Total**	**Average per pot**	**Catch N (1000s)**	**Lobster gear**	**All gear**
LOBSTERS			1681	1520.00	1520.00
Hermit Crab	28260	5.8065	7964	0.00	0.00
Rough Rock Crab	4127	0.8480	1163	0.05	0.08
Rosy Wrasse	675	0.1387	190	0.00	0.00
Degen's Leatherjacket	584	0.1200	**165**	**0.20***	**14.10***
Barber Perch	533	0.1095	150	0.00	0.00
Southern Conger Eel	467	0.0960	**132**	**0.39**	**0.56**
Red Gurnard Perch	423	0.0869	**119**	**0.06**	**5.18**
Blue Throat Wrasse	364	0.0748	**103**	**0.24**	**56.51**
Purple Wrasse	246	0.0505	**69**	**0.18**	**29.43**
Draughtboard shark	237	0.0487	67	0.00	0.85
Brown-striped Leather-jacket	214	0.0440	**60**	**-**	**-**
Octopus	204	0.0419	**57**	**2.25**	**59.58**
Rock Cod	162	0.0333	**46**	**0.15***	**2.56***
Cleft Fronted Shore Crab	94	0.0193	26	0.11	0.18
Morwong*	77	0.0158	**22**	**0.12**	**60.01**
Toothbrush Leatherjacket	70	0.0144	**20**	**-**	**-**
Velvet Leatherjacket	52	0.0107	15	-	-
Butterfly Perch	40	0.0082	11	0.00	0.00
Senator Wrasse	30	0.0062	8	-	-
Spider Crab	19	0.0039	5	0.00	0.00
Giant Crab	11	0.0023	3	0.49	0.49
Catshark	8	0.0016	2	0.00	0.00
Mosaic Leatherjacket	8	0.0016	2	-	-
Crab unidentified	3	0.0006	1	-	-
Sponge Crab	3	0.0006	1	0.00	0.00
Rosy Perch	2	0.0004	1	0.01	1.71
Gummy Shark	1	0.0002	0	0.04	21.16
Ling	1	0.0002	0	0.04	0.24
Pie Crust Crab	1	0.0002	0	0.00	0.00
Port Jackson shark	1	0.0002	0	0.00	0.08
Rock Ling	1	0.0002	0	0.10	0.55
Southern Cardinal Fish	1	0.0002	0	0.00	0.00
Trumpeter (striped)				0.34	31.70
Barracouta				0.16	65.07
Stargazer				0.08	0.12
Sand crab				0.02	0.02
Warehou (blue)				0.02	45.45
Trumpeter (bastard)				0.01	19.12
Short finned eel				0.01	0.01
Sand flathead				0.01	11.81
Total	**36919**	**7.6**	**11082**	**5.08**	

* unspecified species

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7 Appendix 1. Standardized Catch Rate Series

7.1 Introduction

The behaviour and composition of the Tasmanian fishing fleet has altered significantly through time and this has had effects on catch rate data. For example, there is now far more effort in relatively shallow water in Area 6, and perhaps in Area 7 as fishers pursue higher valued, deeper red lobsters. This pattern has had an impact upon nominal catch rates, making them look lower than if all depths were fished evenly. These changes in the fleet has important implications in assessing stock biomass and might lead to the conclusion that the stock status is less positive than it is in reality or conversely it may obscure a negative trend.

Many factors are likely to have an impact on observed catch rates that have nothing to do with changes in the stock biomass. These factors would include the precise location where fishing occurred, who was doing the fishing, whether they were fishing at night or at day, and, of course, the depth of fishing. It is standard stock assessment practice to standardize commercial catch and effort data in an attempt to remove the influence of such factors as location, depth, vessel, and night/day. These attempts make the assumption that any variation left in the catch-rate data after standardization will be more closely related to what is happening to the stock biomass.

As Kimura (1981, p211) states: “Since the 1950s it has been recognized that fishing power generally differs among vessels, and if c.p.u.e. is to be proportional to abundance, effort measurements must be standardized.” The most commonly used method of standardization is to include the various factors thought to effect catch rates into a general linear model and to include year as a factor, in this way the parameters derived for each year become the indices of relative abundance (Klaer 1994; Vignaux 1992).

Detailed catch and effort data with associated vessel, depth, and location information is only available for a full year from 1994 onwards so it was decided to provide a standardization of this 12 year period to see if it were possible to detect and reduce the effect of, at least, depth of fishing on catch-rates.

7.2 Methods

The General Linear Models fitted to the available data were all conducted using SAS version 9.1.1. The analysis was conducted to provide standardized catch rates for what would have been each quota year of the fishery, that is, each quota year was treated as a separate parameter estimate. The factors available for analysis included period (eight separate periods in each quota year; Table 7), vessel distinguishing mark, 10 metre depth-categories, half-degree statistical block, and the day/night flag. By including QYear as a dummy variable into the statistical model the parameter estimates for each QYear constitute the indices of relative abundance. When these are examined they should provide a cleaner representation of the status of the rock lobster stock through time. This year the analysis of catch rates was restricted to vessels that had been fishing for more than one year since 1994/1995 and who had had a median annual catch of greater than one tonne. If a vessel has only been fishing for a single year it cannot be successfully compared with other years and only adds statistical noise. This combined

with a median catch of one tonne is a first attempt to focus on vessels taken to be targeting rock lobster.

It should be noted that the output from a GLM does not guarantee that a relation exists between stock size and standardized catch per unit effort. It is possible that factors not included in the GLM (through no other information being available) may continue to obscure any effects of changes in stock biomass.

It is possible to define the so-called 'full model' for the set of factors being considered. This would include all of the factors and the entire set of interaction terms possible between them. It would be difficult to provide a real interpretation for some of the interaction terms possible and their value in describing the data is marginal. In fact, it is not valid in a fixed factor analysis to include interaction terms with the QYear terms as this would distort and alter the meaning of the individual QYear parameter estimates. For example, if we were to consider the catch rate trends across the whole fishery, but the trends differed between Areas, this would be tantamount to claiming that there was a significant interaction between the QYear terms and Area. To avoid this potential problem we proceed by conducting a separate analysis for each assessment Area.

A further complication arises because there is no doubt that the more terms or parameters used in a statistical model the more likely we are to describe a larger proportion of the variation in the available data. But just adding more and more parameters to a model is not necessarily an improvement when there can be correlations among them. To illustrate the point with an extremity, we could obtain a perfect fit to the data simply by having the same number of parameters as we had data points. What is required is a compromise between the variability of the data described by the statistical model and the model's complexity.

One way of selecting such a compromise, which is becoming more accepted as such a criterion, is the use of the Akaike's Information Criterion (AIC). In our own case, after log-transformation, the statistical residuals of the statistical model are normal and additive. The AIC is usually based around a maximum likelihood framework but, in the special case of a least squares estimation with normally distributed additive errors, the AIC can be expressed as:

$$\mathrm{AIC} = n.\mathrm{Ln}\left(\frac{\mathrm{SSE}}{n}\right) + 2p \qquad (0.1)$$

where where SSE is the sum of the squared residuals, n is the total number of observations, and p is the number of parameters (Burnham & Anderson, 1989). A second definition is:

$$\mathrm{AIC2} = \mathrm{Ln}\left(SSE\right) + \frac{2p}{n} \qquad (0.2)$$

In addition, the adjusted R^2, gives a better estimate of total variability described by the statistical model (Neter *et al*, 1996) than the simple R^2, with n-p degrees of freedom, where SSTO (total sum or squared residuals), with n-1 degrees of freedom, is the SSE plus the variation due to the statistical model:

$$R^2 = 1 - \frac{SSE}{SSTO} \quad R_A^2 = 1 - \frac{\frac{SSE}{n-p}}{\frac{SSTO}{n-1}} = 1 - \left(\frac{n-1}{n-p}\right)\left(\frac{SSE}{SSTO}\right) \tag{0.3}$$

"This adjusted coefficient of multiple determination may actually become smaller when another X variable is introduced into the model; because any increase in SSE may be more than offset by the loss of a degree of freedom in the denominator *n-p*" (Neter *et al*, 1996, p. 231).

In fact, there are so many data point available that almost every statistical factor proves statistically significant. However, by plotting the QYear parameters for each statistical model the convergence to a stable outcome can be confirmed graphically.

Table 18. The duration of each of the 8 periods within each quota year.
This is used instead of simple months to eliminate as many zero catch and effort months as possible.

Period	Months
1	March
2	April
3	May, June, July
4	August, September, October
5	November
6	December
7	January
8	February

Table 19. Definitions of the eight difference statistical models used in the standardization of the rock lobster catch rates for 1994/1995 to 2005/2006.
Cst was a constant, Qyear was quota year, Period was the 8 periods in each Qyear, BoatDM was vessel distinguishing mark, DayNight was whether a shot was overnight or during the day, DepCat was a series of 10 metre depth categories, Block was statistical block.

Model 1	Ln(CE) = Cst + Qyear
Model 2	Ln(CE) = Cst + Qyear + Period
Model 3	Ln(CE) = Cst + Qyear + Period + BoatDM
Model 4	Ln(CE) = Cst + Qyear + Period + BoatDM + DayNight
Model 5	Ln(CE) = Cst + Qyear + Period + BoatDM + DayNight + DepCat
Model 6	Ln(CE) = Cst + Qyear + Period + BoatDM + DayNight + DepCat + Block
Model 7	Ln(CE) = Cst + Qyear + Period + BoatDM + DayNight + DepCat + Block + Period*DepCat
Model 8	Ln(CE) = Cst + Qyear + Period + BoatDM + DayNight + DepCat + Block + Period*Block

7.3 Results

Where the contribution of the Period*Block factor was negative (Areas 1, 2, 6, 7, and 8) Model 7 was optimal, elsewhere (Areas 3, 4, and 5) Model 8 was optimal. The various factors described different amounts of variation in the catch rate data in different Areas (Table 9). The seasonality of the fishery is so marked that the factor *Period* accounted for most of the variation described by the statistical models in every Region except Region 6 where the vessel doing the fishing was most important. In Regions 1, 2, and 3 *Period* accounted for over 65% of all variation described while *Vessel* accounted for about 15% (Table 9). In Regions 4 and 5, *Period* accounted for between 43 and 51%, but only about 37 to 42 % in Region 6 and 7. *Vessel* accounted for between 13 and 27% except in Region 6 where it was 45.2%. In half the areas the *daynight* factor described more variation than the *depthcategory* factor, in the other areas the reverse occurred. In Region 7, *daynight* was as influential as *Vessel* (Table 9). These results are very similar to those obtained by a similar analysis last year.

The trends in the unstandardized catch rates (both the geometric mean and arithmetic mean catch rates (Fig. 13), were similar to those exhibited by the standardized catch rates. The arithmetic mean closely followed the geometric mean catch rates in all assessment Areas.

Table 20. Contribution to total adjusted R^2 for each model for each assessment area. The models are described by adding each term down the left-hand size. QYear is quota year, DayNight is whether a shot was made during daylight hours or night, DepthCat were a set of 10 m depth categories, and block was the statistical block within each area, Period was one of the 8 assessment periods in each quota year. The bottom half of the table are the R^2 values converted to percent of the total.

	Area1	**Area2**	**Area3**	**Area4**	**Area5**	**Area6**	**Area7**	**Area8**
Qyear	5.49	8.43	5.82	6.16	4.19	3.05	3.83	2.75
Period	33.35	38.58	32.32	18.25	20.27	14.19	16.71	23.33
Vessel	8.04	7.40	7.64	11.37	10.50	17.16	8.36	11.21
DayNight	0.31	2.42	0.41	2.47	1.99	1.51	8.63	0.41
DepthCat	1.15	0.38	0.54	2.55	1.78	1.15	1.72	0.97
Block	0.67	0.19	0.03	0.86	0.49	0.34	0.02	3.42
Period*Depth	0.46	0.15	0.18	0.27	0.21	0.56	0.62	0.82
Period*Block	-0.12	-0.10	0.12	0.24	0.45	-0.29	-0.29	-0.54
Total R2	49.46	57.55	46.89	41.90	39.66	37.97	39.89	42.90
Qyear	11.09	14.64	12.41	14.69	10.55	8.03	9.59	6.41
Period	67.43	67.03	68.94	43.55	51.10	37.38	41.88	54.37
Vessel	16.25	12.87	16.30	27.14	26.46	45.19	20.96	26.14
DayNight	0.62	4.21	0.88	5.89	5.02	3.99	21.64	0.96
DepthCat	2.32	0.65	1.14	6.09	4.50	3.02	4.30	2.27
Block	1.35	0.33	0.07	2.05	1.23	0.91	0.06	7.96
Period*Depth	0.94	0.27				1.48	1.56	1.90
Period*Block			0.26	0.58	1.13			

Table 21. Geometric mean catch rates along with the optimal statistical model for each assessment area.

The different models are described in Table 19. In the four northern areas (3, 4, 5, and 6) the standardization produces only relatively minor effects and catch rates are relatively flat. However. in the southern Areas all areas exhibit continued increases in catch rates with the standardization leading to larger increases than observed in the original geometric mean catch rates.

Qyear	Area1 Model1	Area1 Model7	Area2 Model1	Area2 Model7	Area3 Model1	Area3 Model8	Area4 Model1	Area4 Model8
94/95	1	1	1	1	1	1	1	1
95/96	1.2894	1.4019	1.1596	1.3640	1.2774	1.2633	1.1110	1.0881
96/97	1.4159	1.4597	1.2498	1.3852	1.2934	1.3251	1.3433	1.2999
97/98	1.1105	1.1706	1.0155	1.2126	1.1276	1.1888	1.2548	1.2194
98/99	1.1910	1.2000	0.9619	1.1536	1.1407	1.1932	1.3105	1.3490
99/00	1.2620	1.2931	1.2958	1.3680	1.3423	1.4624	1.6662	1.6673
00/01	1.4141	1.5484	1.3168	1.4750	1.2714	1.4272	1.6372	1.8039
01/02	1.5673	1.7026	1.5377	1.7392	1.7178	1.8341	1.8175	1.8568
02/03	1.5958	1.7715	1.9168	1.9051	1.9231	1.8688	1.8998	1.9035
03/04	1.6419	1.8655	1.7421	1.7272	1.7358	1.6096	1.6478	1.6313
04/05	1.8458	2.2633	1.8549	1.9953	1.8289	1.8039	1.7795	1.8895
05/06	2.1887	2.5057	1.9296	2.1418	1.7127	1.8111	1.7297	1.7959

	Area5 Model1	Area5 Model8	Area6 Model1	Area6 Model7	Area7 Model1	Area7 Model7	Area8 Model1	Area8 Model7
94/95	1	1	1	1	1	1	1	1
95/96	0.9248	0.9742	0.9985	1.0569	1.2094	1.3379	1.3762	1.3611
96/97	1.0134	1.0737	1.0271	1.0960	1.2173	1.3063	1.2930	1.3703
97/98	1.0711	1.1119	1.1197	1.1556	0.9881	1.1142	1.0680	1.1675
98/99	1.0037	1.1640	1.0842	1.2922	1.0611	1.2185	1.1779	1.3309
99/00	1.1659	1.3328	1.2709	1.4517	1.1603	1.2522	1.1666	1.3304
00/01	1.1909	1.3753	1.2141	1.3110	1.2124	1.3313	1.3157	1.5457
01/02	1.3560	1.5932	1.2122	1.3508	1.2371	1.3407	1.1984	1.4531
02/03	1.6020	1.7583	1.4192	1.3883	1.4530	1.5586	1.1833	1.4711
03/04	1.4927	1.5456	1.4279	1.3355	1.4740	1.5605	1.4769	1.8181
04/05	1.5246	1.5493	1.4265	1.4917	1.5558	1.9031	1.6042	2.1938
05/06	1.3386	1.4698	1.4446	1.3400	1.8005	2.2417	1.7184	2.3578

8 Appendix 2: Historical overview

The following section is based largely on a synopsis of the history of the fishery compiled by Tony Harrison (http://members.trump.net.au/ahvem/Fisheries/Lobster/Crayfishery.html).

Tasmania's rock lobster resource is distributed around the coast although fewer animals are found along the central north coast bordering Bass Strait due to limited opportunity for recruitment.

Aborigines fished lobsters around the State and a small indigenous harvest continues, mainly in the northeast. The resource has been harvested commercially since European settlement with fishing effort initially focused on the East Coast. Accounts of historical catches provide insight into the abundance of lobsters in conditions with very low fishing pressure. When James Kelly called at Port Davey in 1815 he traded swans he had shot for crayfish; the local Aborigines quickly collected 3 tons (at least 1000 lobsters) by hand from the waters edge. In 1905, James Rattenbury caught 480 lobsters from the *Rachel Thompson* in six hours using only 6 "cray" rings in Wineglass Bay.

The commercial and recreational fisheries initially proceeded without records but the need for management of the fishery was recognised nonetheless. The first Act for the protection of Rock Lobster was passed by Parliament in 1885. This Act prohibited the possession of soft-shelled "crayfish" and egg-carrying females and introduced a minimum legal-size of 10 inches. This size limit is essentially equivalent to that used today and remains one of the main management constraints.

Some commercial catch information was collected in the late 1880's with around 60,000 lobsters a year landed into Hobart. This remains around the average annual commercial harvest from shallow waters in the SE of the State today (average of 39 tonnes in <10 fathoms for the period 2000-2003, Area 1; although it should be noted that now the recreational catch could match the commercial harvest).

In 1888 fisheries matters were placed under the control and management of a single Fisheries Board comprising 23 commissioners. Much of their time was spent debating the merits of different gear types.

Hemispherical cane pots (based on pots used for taking clawed lobsters in Cornwall, England) were used in Victoria while in Tasmania a baited hoop ("cray" ring) was the traditional (and preferred) method of catching rock lobsters. The two methods led to two quite different commercial fishing industries; one using larger, more robust boats that could operate pots and the other using smaller boats sufficient for operation of "cray" rings. These two fleets came into contact and conflict during periods around the moult when lobsters were too soft for freight to Victoria. Pots were subsequently banned in Tasmania in November 1902, later amended to latitudes south of 39° 31′ S in February 1904 and subsequently south of 40°38′S (*i.e.* north of St Marys) in July 1904. The Fishing Board ratified this ban in November 1905.

In response to further pressure from northern commercial fishers, a Parliamentary enquiry conducted by Joseph Lyons considered that pots were not destructive and recom-

mended that pots be legalised. However, it wasn't until 1925 that pots were finally legalised as part of a new fisheries bill that placed responsibility for the management of sea fisheries with a newly appointed Sea Fisheries Board. The centrepiece of this new bill was the allocation of varying numbers of pots to commercial vessels depending on their size. For example, a limit of 30 pots was adopted for larger vessels with proportionately fewer pots allowed for smaller vessels. Inevitably, the use of pots led to dramatic increases in commercial catch due to greater efficiency, halted fleetingly by reduced market demand during the depression years (1930s) and the Second World War. Markets have adapted to change in technology throughout the development of the fishery.

The adoption of diesel engines during the Second World War meant that more product could be shipped to mainland Australia, which led to expanded markets. Soon after this, the development of refrigeration enabled a rapid expansion into the American frozen tail market. Most of the commercial catch is now transported live into Asia, the world's premium market for lobsters. The increased value of lobsters that has resulted from the development of these markets along with growing recognition of rock lobster as a preferred seafood is considered to be a motivating factor for the steadily increasing recreational effort.

The annual commercial catch reached its historical maximum in 1984 at 2250 tonnes, prior to falling to a recent historical low of 1440 tonnes in 1994, a reduction of 400 tonnes from the 1992 year.

Concerns about declining future catches led to a shift away from a commercial fishery managed by input controls (*i.e.* number of pots and licences etc.) to one managed through control of fishery outputs (or total catch limits). This resulted in the adoption of an individual quota system in March 1998 for the commercial fishery.

9 Appendix 3: Management

Management regulations were first introduced in 1885 and included a minimum legal size, and a prohibition on taking soft shelled (recently moulted) lobsters or berried female lobsters. These input controls still play a role in management of the resource although soft-shelled lobsters are now largely protected by a seasonal closure.

Since the inception of catch records in the 1880's, the reported annual catch steadily increased in the commercial rock lobster fishery to a high in 1984 of over 2,250 tonnes. During this period of growth in catches, concerns were expressed about overfishing in the commercial fishery, which resulted in changes in regulations. The most important changes were the legislation of design of pots in 1926, introduction of closed seasons to limit the harvest of soft-shelled lobsters in 1947, the restriction of the number of licenses in 1966, and a ceiling on the number of pots in the fishery set at 10,993 in 1972.
From the record high catch of 1984, the reported annual catch declined to a low of 1,440 tonnes in 1994 reflecting a decline in the available biomass. In recognition of the declining trend in biomass, an individual transferable quota (ITQ) management system was introduced for the commercial fishery in March 1998 following an industry ballot to decide whether to accept the system.

Management of the commercial fishery has remained relatively stable since the introduction of quota. Quota was initially set at 1503 tonnes for the 1998/99 fishing season. After three years of successive improvements in biomass, the quota was increased to 1523 tonnes for the 2001/02 fishing season. As catch is now constrained by quota, seasonal controls in the fishery have been relaxed. Lengths of seasonal closures have varied since their introduction in 1926 but complete closure of September and October was in place from 1963 to 1998. In 1998, the first 2 weeks of September were opened, to provide fishers with flexibility to take hard-shell lobsters that command a high price or fish for the lower priced soft new-shell lobsters that have a higher catchability after their moult. Timing of the September closure has changed regularly since 1998 with complete access in 2000. There remained some concern about fishing in September due to negative impacts on markets.

Management of the recreational fishery has proceeded in parallel with that for the commercial fishery. A rock lobster license is required to take lobsters recreationally or to deploy gear. Many regulations are shared by both sectors, such as size limits, closed seasons, and pot specifications. Key differences included the ability of recreational fishers to harvest lobsters by diving, a cap on the daily bag limit of 5 lobsters, and the absence of an output control mechanism.

10 Appendix 4: Previous Assessments

This report is the tenth assessment report since regular reporting commenced in the 1995 calendar year (Table 22). This report uses data available up until 28th February 2005. It includes data for the first seven years since ITQ implementation.

Table 22. Previous Tasmanian rock lobster fishery assessment reports.

Assessment Report No.	Last month of data used	Reference
1	December 1995	Frusher, 1997a
2	December 1996	Frusher, 1997b
3	February 1998	Frusher and Gardner, 1999
4	February 1999	Gardner, 1999
5	February 2000	Gardner, Frusher and Eaton, 2001
6	February 2001	Gardner, Frusher, Eaton, Haddon and Mackinnon, 2002
7	February 2002	Frusher, Gardner, Mackinnon and Haddon, 2003
8	February 2003	Gardner, Mackinnon, Haddon and Frusher, 2004
9	February 2004	Gardner, Hirst and Haddon, 2005

11 Appendix 5: Management Objectives and Strategies

There are eight policy objectives in the current rock lobster fishery policy document (Anon, 1997). Although this document remains current, the introduction of the *Environment Protection and Biodiversity Conservation Act 1999* and the subsequent assessment of the fishery for export exemption under Parts 13 & 13A of the *Act*, has meant that these objectives are now interpreted, for the purposes of managing the fishery, under an overriding policy of ecologically sustainable development. The strategies adopted to achieve the existing objectives remain the management tools that are currently utilised.

To provide for ecologically sustainable development, the management objectives have recently been expanded and modified and will shortly be released for public comment as part of a new policy document. In line with the draft objectives, a number of changes to the management strategies are also proposed in the new policy document.
The proposed policy objectives listed in the draft plan are:

- The fishery shall be conducted at catch levels that maintain ecologically viable stock levels at an agreed point or range and within acceptable levels of probability.
- Where the fishery assessment suggests that the fish stock is below defined reference points, then the fishery will be managed to promote recovery to ecologically viable levels within a nominated timeframe.
- An appropriate compliance strategy that minimises the opportunity for illegal activity through monitoring, compliance and enforcement measures that are supported and aided by industry.
- Optimise the economic value of the fishery within the constraints of objective 1.
- Recover a financial contribution from both commercial and recreational rock lobster fishers to contribute to the real costs of management, compliance and research.
- Ensure that the rock lobster fishing fleet continues to provide employment and an economic return to Tasmanian coastal communities.
- The fishery is conducted in a manner, which minimises the effect on by-catch or by-product species.
- The fishery is conducted in a manner, which minimises mortality of, or injuries to, endangered threatened or protected species and avoids or minimises impacts on threatened ecological communities.
- The fishery is conducted in a manner that minimises the impact of fishing operations on the ecosystem generally.
- Maintain a fishery that is conducted in an orderly manner recognising different participants need to access shared fishing grounds.
- Provide reasonable recreational access to the fishery.
- Provide access to the fishery for Aboriginal people to undertake cultural activities.
- To promote and maintain handling and processing practices that attempt to ensure the highest quality rock lobster product.

12 Appendix 6: Present Performance Indicators and Trigger Point Strategies

12.1 Performance Indicators

The performance indicators for the Tasmanian rock lobster fishery are identified in the rock lobster fishery policy document (Anon, 1997).

12.1.1 Catch per unit effort (CPUE)

Catch per unit of effort (or catch-rate) is commonly used as an index of abundance. For the purpose of the Management Plan, CPUE is defined as the kilograms of lobster caught per pot lift and will be calculated separately from both commercial catch returns and independent research surveys.

12.1.2 Biomass

- While CPUE can provide a relative index of abundance, it does not provide an actual estimate of biomass. For the purpose of the Management Plan, biomass will be defined as the estimated tonnage of legal-sized lobster on the bottom at a stated point in time. Changes in the biomass are important because this will affect the catch-rate, productivity, sustainable harvest level and egg production of the fishery.

- Biomass will be estimated by two different techniques. The first will be a length structured, spatially explicit, stock assessment model of the rock lobster fishery and the second method will be through independent research surveys in selected regions of the fishery. While these two techniques are different, the stock assessment model incorporates research data, which implies that the two sources of biomass estimates are not completely independent.

12.1.3 Egg production

- Maintenance of sufficient levels of egg production is crucial to prevent declining recruitment and eventual recruitment failure of the fishery. Unfortunately there is a high degree of uncertainty in terms of both the level of egg production required and whether there are certain regions, which are most important as the source of future recruitment. In light of this uncertainty, it is important to apply a precautionary approach and to ensure that both global and regional egg production does not fall below the lowest levels that have been experienced in the past.

- Both global and regional egg production will be estimated through the previously mentioned stock assessment model of the rock lobster fishery. For the purpose of this Management Plan, the term Egg_{low} will refer to the value of the lowest level of annual egg production experienced between 1970 and 1995 on a global or regional basis (depending on context). The Egg_{low} value will be used as a limit reference point against which egg production in future years will be compared.

12.1.4 Relative abundance of undersized lobster

- CPUE, Biomass and Egg production reflect the performance of the fishery over the preceding fishing season. In contrast, a measure of the undersized component of the resource can give an indication of expected future harvests. This would allow for adjustments to catch levels to be made prior to problems being reflected in the fishery. For the purpose of the Management Plan, undersized lobster will be defined as the kilograms of lobster caught per pot lift in specified length classes. The size of the length classes will reflect the annual growth increments needed to grow into the fishery, taking into account the different regional growth rates.

- The relative abundance of undersized lobster will be estimated from independent and fishery dependent research surveys in selected regions of the fishery.

12.1.5 The total annual commercial catch

- The total annual commercial catch may fall below the TACC for a number of reasons, that must be accounted for before any action is taken. The total commercial catch will be monitored against the TACC for the fishery. The reference point is currently set at 95% of the TACC, dropping below this will trigger a fishery review.

12.1.6 The size of the commercial rock lobster fishing fleet

- As the restructuring process occurs, following the introduction of the quota system, it is likely that the number of active commercial licenses and vessels operating in the rock lobster fishery will decline. It is important to monitor this decline to assess possible social and economic impacts on the coastal communities where commercial rock lobster fishing is an important industry.

12.1.7 The recreational catch

- The recreational catch will be monitored through the continuation of recreational surveys. The recreational catch is not limited directly. While this is of little concern as the catch appears to have fallen over the past ten years, it is important to monitor the catch and to take corrective action if it increases above what it may have been in the past. In the last 10 years the recreational catch has ranged from 5% and 11% of the commercial catch.

12.2 Trigger Points

The trigger points for the Tasmanian rock lobster fishery are listed in the rock lobster fishery policy document (Anon, 1997).

12.2.1 Catch per unit effort (CPUE)

- Annual CPUE from commercial catch returns falls below 95% of the CPUE for the reference year with the lowest catch-rate (i.e. 1993, 1994, or 1995). For the first year of the Management Plan only, catch-rate will be permitted to fall to 90% of that

in the reference year with the lowest catch-rate. The analysis to assess this trigger point must standardise CPUE to take account of possible biases caused by changing fishing patterns on at least a monthly and regional basis.

- Annual CPUE from commercial catch returns for any Area falls below 75% of the CPUE for the reference year with the lowest catch-rate for that region, unless at least three other years for the same Area between 1970 and 1995 had a lower catch-rate. The analysis to assess this trigger point must standardise CPUE to take account of possible biases caused by changing fishing patterns on at least a depth stratified and monthly basis. This analysis should also take into account any other mitigating factors that might artificially affect regional catch-rates.

- CPUE from research surveys in available regions declines significantly from matching surveys (location and month) from that of the reference year with the lowest matching survey catch-rate. The analysis of this trigger point should consider mitigating factors such as variations in catchability due to weather or variation in moult timing or seasonal influences.

12.2.2 Legal-sized biomass

- The estimate of global (Statewide) legal-sized biomass from the stock assessment model falls below 95% of that estimated for the reference year with the lowest biomass.

- The legal-sized biomass estimate from the stock assessment model for any Area falls below 75% of that estimated for the reference year with the lowest biomass in the related region.

- Legal-sized biomass estimates from research surveys in available regions declines significantly from one survey year to the next (technique being developed). Biomass specific research surveys will not commence till the 1997/98 season, hence it is not possible to use a past reference year in the trigger point. An exception to this trigger can be invoked if the stock assessment model or other models can adequately demonstrate that the decline in biomass seen through research surveys results in a biomass that remains higher than that which existed in the reference years.

12.2.3 Egg production

- The estimate of global (Statewide) egg production falls below that of Egg_{low}. An exception to this can be invoked if the estimated egg production is within 5% of Egg_{low} provided that the reduction is restricted to Areas with egg production levels which exceed 40% of that of the estimated unfished (virgin) stock.

- Any regional estimates of egg production falls to less than 95% of the related egg_{low} unless the affected Areas have egg production levels which exceed 40% of that of the estimated unfished stock.

- For Areas in which the estimated value of Egg_{low} is less than 10% of that of the estimated unfished stock, no reduction in egg production below that of Egg_{low} is permissible.

12.2.4 Relative abundance of undersized lobster

- Annual CPUE of undersized lobster in the pre-recruit size class falls below 95% of that estimated for the reference years already mentioned, for the same sampling Area and sampling period. The analysis of this trigger point should consider mitigating factors such as variations in catchability due to weather or variations in moult timing.[1]

12.2.5 The total annual catch

- The total annual commercial catch falls below 95% of the TACC for any year. The analysis will consider the reasons for the actual catch falling below the TACC, these may include weather factors, quota availability factors or market factors.

12.2.6 The size of the commercial rock lobster fleet

- The number of commercial licenses operating in the fishery falls below 220. The analysis will consider factors that have caused the number of licenses to fall to this level. Action may be taken to ensure there is no further decline in the number of licenses if it is considered necessary by the industry or the Government.

12.2.7 The recreational catch

- The recreational catch exceeds 10% of the TACC in a year there will be a review of the recreational management arrangements.

[1] The Tasmanian rock lobster stock assessment working group considered this trigger point to be of questionable value, given the large annual variation in natural recruitment. It was suggested that future management plans incorporate a trigger based on trends in relative abundance of undersize lobsters over periods of several years.

13 Appendix 7: Summary of Rules

Table 23. Summary of rules for the Tasmanian Rock Lobster Fishery.

COMMERCIAL	
Management zone	one management zone for the State
Limited entry	314 licenses
Limited seasons	Males: season open from 15 November 2006 to 30 September 2007 inclusive. Females: season open from 15 November 2006 to 30 April 2007 inclusive.
Limits of pots on vessels	minimum of 15 pots, maximum of 50 pots
Quota	Total allowable catch of 1523 tonnes
Restrictions on pot size	maximum size of 1250 mm x 1250 mm x 750 mm.
Escape gaps	one escape gap at least 57 mm high and 400 mm wide and not more than 150 mm from the inside lower edge of the pot, or two escape gaps at least 57 mm high and 200 mm wide and not more than 150 mm from the inside lower edge of the pot
Minimum size limits	105 mm CL for females, 110 mm CL for males
Berried females	taking of berried females prohibited

RECREATIONAL	
License requirements	rock lobster potting licence - 1 recreational pot per person,rock lob
Daily limit	5 per recreational license holder
Limited seasons	Males: Saturday 4 November 2006 to 31 August 2007 inclusive. Females: Saturday 4 November 2006 to 30 April 2007 inclusive.
Restrictions on gear	Pots as per commercial fishers, rings no more than 1 m in diameter, capture by glove only when diving.
Escape gaps	as per commercial fishers
Minimum size limits	as per commercial fishers
Berried females	as per commercial fishers
Sale or barter of lobsters	prohibited
Marking	All recreational lobsters must be tail clipped within 5 minutes of landing. No tail-clipped lobsters to be sold.